REMEDIAL INVESTIGATION REPORT
WEST OSBORN COMPLEX
WEST OSBORN ROAD, PHOENIX, ARIZONA

Prepared for

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A.A.C.	Arizona Administrative Code
AEC	Applied Environmental Consultants
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
A.R.S.	Arizona Revised Statutes
ASTM	American Society for Testing and Materials
AWQS	Aquifer Water Quality Standards
BCC	Brown and Caldwell Corporation
bgs	below ground surface
BTEX	benzene, ethylbenzene, toluene, xylenes (total)
˚C	degrees Celsius
CLP	Contract Laboratory Program
COP	City of Phoenix
1,1-DCE	1,1-Dichloroethylene or 1,1-Dichloroethene
DO	dissolved oxygen
Earth Tech	The Earth Technology Corporation
f_{oc}	fraction of organic carbon
ft/d	feet per day
EPA	Environmental Protection Agency
GPL	Groundwater Protection Level
GWG	The GeoWest Group, Inc.
GZA	GZA GeoEnvironmental Group
gpm	gallons per minute
Kd	distribution coefficient
K_{oc}	organic carbon partition coefficient
LAU	Lower Alluvial Unit
Layke	Layke, Inc.
lbs/day	pounds per day
LSGS	Lower sand and gravel subunit
LUST	leaking underground storage tank
MAU	Middle Alluvial Unit
MCL	Maximum Contaminant Level
MDL	method detection limit
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mL	milliliter
mg/L	milligrams per liter
NFA	no further action
PA	preliminary assessment
PCE	tetrachloroethylene or tetrachloroethene
PID	photoionization detector
PSC	Preliminary Site Characterization
PVC	polyvinyl chloride

RCRA	Resource Conservation and Recovery Act
Rd	retardation factor
Redox	oxygen-reduction potential
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
SDWA	Safe Drinking Water Act
SRL	Soil Remediation Level
SRP	Salt River Project
SRV	Salt River Valley
SI	site inspection
SVE	soil vapor extraction
TCA	1,1,1-Trichloroethane
TCE	trichloroethylene or trichloroethene
TCLP	Toxicity Characterization Leaching Process
TDS	Total Dissolved Solids
UAU	Upper Alluvial Unit
UIC	United Industrial Corporation
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
USCS	Unified Soil Classification System
UST	underground storage tank
VOC	volatile organic compound
WCP	West Central Phoenix
WESTON	Weston Solutions, Inc. (formerly Roy F. Weston, Inc.)
WGA	West Grand Avenue
WMI	Waste Management, Inc.
WOC	West Osborn Complex
WQARF	Water Quality Assurance Revolving Fund
WSRV	West Salt River Valley

United Industrial Corporation (UIC) has conducted a remedial investigation (RI) at the former West Osborn Complex (WOC) in accordance with Consent Decree No. CV-93-0950-PHX-RCB. This report, which has been prepared by GeoTrans, Inc. on behalf of UIC, presents the results of this work conducted from January 1996 through January 2004.

The WOC consists of about 15 acres that are presently subdivided into three parcels: East, Middle, and West. It has industrial park zoning, and 51 percent of the area within a radius of about 0.75 miles has industrial zoning. Beginning in 1957, the WOC was used by different owners to manufacture electronic components. Solvents, including trichloroethene (TCE), were used in the manufacturing processes. When the WOC was first developed, there was no municipal sewer service, and on-site systems, consisting of septic tanks and seepage pits, were used for wastewater disposal.

The WOC was previously investigated before UIC conducted this RI. The Middle Parcel was investigated in 1987 by Lansdale Semiconductor, Inc. and in 1992 by Components Incorporated. During the 1992 investigation, soil samples were collected and five on-site monitor wells were constructed. The West Parcel was investigated in 1991 by May Industries, Inc. Other investigations included the collection of soil and soil-gas samples at each of the three parcels by the Arizona Department of Environmental Quality (ADEQ) and an aerial photographic analysis by the United States Environmental Protection Agency (U.S. EPA) in 1989.

According to work completed in 1987 by Lansdale Semiconductor, Inc. the on-site irrigation well was reported by the Arizona Department of Health Services as first being sampled for volatile organic compounds (VOCs) in 1984. It was next sampled for VOCs by Lansdale Semiconductor, Inc. in 1987.

For the RI soil investigation, samples were collected at test trenches, test pits, angle borings, and vertical borings pursuant to a Work Plan that was developed with the ADEQ, approved by the ADEQ, and incorporated into the Consent Decree. VOCs were detected in 33 of 240 soil samples (13.8 percent). Of the VOCs that were detected, TCE occurred most frequently, and the highest concentrations were detected in septic tank contents, which were excavated along with the septic tanks and disposed of off-site. In soil samples from borings, concentrations of VOCs were lower. No VOCs were detected below septic tanks, and VOCs were only detected in the shallowest samples collected at seepage pits. To address residual VOC contamination in the vadose zone soils, a soil vapor extraction (SVE) system was installed and operated from August 1999 through October 2002. Confirmation soil sampling in 2003 demonstrated that the SVE system had successfully remediated the onsite soils above the water table to below non-residential Soil Remediation Levels (SRLs) and Groundwater Protection Levels (GPLs). The abandonment of the WOC Irrigation Well in July 2004 will further remove any mechanism for continued vertical transport of VOCs.

Heavy metals were also measured in septic tank contents and soil samples from beneath tanks and from soil borings completed down to the water table. Except for septic tank contents, which were disposed off-site, and in stained soil that was directly adjacent to one septic tank, concentrations of all metals, except arsenic, were lower than ADEQ's soil remediation standards. Arsenic concentrations were greater than soil remediation standards in some samples, but were within the range of site background concentrations and within the normal range of concentrations in Arizona alluvial soils.

For the RI groundwater investigation, the saturated portion of the alluvial material at the WOC were characterized. These soils have been previously subdivided into three major units. The Upper Alluvial Unit is 300 to 350 feet thick and contains two main water-bearing zones that are separated by fine-grained soils: (1) a shallow, coarser-grained zone near the water table at a depth of about 100 feet below ground surface (bgs), and (2) a deeper, 50-foot thick, sand and gravel subunit. The Middle Alluvial Unit directly underlies the lower sand and gravel subunit and is predominantly clay. The Lower Alluvial Unit occurs at a depth of more than 800 feet bgs. Because no groundwater impacts were ever observed and no mechanism for transport of TCE identified, only limited investigation was conducted on the Lower Alluvial Unit.

Twenty-nine monitor wells were installed specifically for this RI, 24 of them by UIC. They were completed at the water table (shallow wells), in the lower sand and gravel subunit (LSGS wells), and in the Middle Alluvial Unit (deep wells). Depths of wells ranged from 108 to 820 feet bgs, and screened intervals were 40 feet long. Aquifer tests were conducted at seven of the wells, and the highest transmissivities (14,000 square feet per day [ft^2/day]) were measured in the LSGS subunit.

Water level measurements were initiated in November 1996. During the course of the RI water levels were measured in the 29 RI wells and up to 15 additional wells. At the start of the RI, the water table was mounded beneath the Grand Canal due to seepage through the canal bed, and the direction of the horizontal groundwater gradient at the water table was south-southeast. The canal was lined in January 1998, seepage through the canal bed has stopped and water table elevations at the site have declined by over 30 feet since that time.

Through January 2004, 15 rounds of quarterly groundwater samples have been collected for analysis of VOCs. TCE has been detected most frequently and in highest concentrations and is considered the principal contaminant of concern (COC) at the site. Based on historical water quality data and the January 2004 sampling round, tetrachloroethene (PCE) is the only other COC. At the start of the RI, the highest concentrations of TCE, up to 600 micrograms per liter (µg/L), were measured in shallow on-site monitor wells. Concentrations decreased downgradient (south) and off-site. Concentrations were lower in intermediate wells, and no VOCs have ever been detected in deep wells. After the canal was lined and the water table mound dissipated, concentrations of VOCs in on-site shallow wells decreased considerably. Concentrations in the shallow well furthest down-gradient also have steadily decreased.

One objective of the RI was to identify the extent of soil and groundwater contamination. The extent of VOCs in the soil has been defined and the remediation of soil completed. In groundwater, VOCs occur in areas hydraulically down-gradient from the WOC in the shallow water-table aquifer and in the confined lower sand and gravel subunit of the Upper Alluvial Aquifer. Further migration in the shallow aquifer is limited by the lining of the canal, which effectively cuts off the source of water to the shallow water table system, the lowering of the water table into low permeability sediments, and the greatly decreased hydraulic gradient. Since pumping of the SRP well 9.5E-7.5N was stopped in 1999, the extent and magnitude of VOCs in the LSGS wells have been defined.

Based on the soil and groundwater characterizations completed, and the successful soil remediation removing any additional source of VOCs to the shallow aquifer, the nature and extent of contamination has been successfully defined and characterized for the purpose of proceeding with the Feasibility Study.

1.0 INTRODUCTION

1.1 PURPOSE

This report presents the results of the Remedial Investigation (RI) that has been conducted at the West Osborn Complex (WOC) in Phoenix, Arizona (Figure 1-1). This report has been prepared in accordance with the Consent Decree[1] between the State of Arizona, the Arizona Department of Environmental Quality (ADEQ), and United Industrial Corporation (UIC). The activities described in this report were conducted over the time period January 1996 through January 2004.

The RI has been carried out in accordance with the January 29, 1996 Work Plan (HSI GeoTrans, Inc., 1996), which was incorporated into the Consent Decree. According to this Work Plan, the objectives of the RI are to:

- Measure the nature and extent of residual soil contamination attributable to activities at the WOC;
- Identify possible sources of groundwater contamination;
- Characterize subsurface geologic and hydrogeologic conditions;
- Evaluate the nature and extent of groundwater contamination;
- Implement a remedial system to provide rapid contaminant mass reduction in soil and to reduce further groundwater contamination; and,
- Evaluate the impact of the Grand Canal on aquifer recharge and groundwater flow.

Additional groundwater monitoring and well installation were completed to define the extent of groundwater contamination, and a soil vapor extraction (SVE) remediation system was installed that successfully removed on-site vadose zone contamination.

1.2 SCOPE OF WORK

The scope of work for the RI at the WOC has included the activities listed below. In accordance with the January 29, 1996 Work Plan, some of these activities were conducted in two phases:

- Historical records search;
- On-site soil investigation consisting of sampling from test trenches, test pits and soil borings;
- Excavation and disposal of septic tanks and their contents;

[1]Consent Decree No. CV-93-0950-PHX-RCB

- Groundwater investigation consisting of the installation of 28 monitor wells, sampling and measurement[2] of more than 35 wells, and hydraulic testing of seven wells;

- Surveying and sampling of the Grand Canal;

- Installation and operation of an on-site SVE system and successful remediation of soils impacted by volatile organic compounds (VOCs); and,

- Completion of a depth-specific sampling in select shallow wells using passive diffusive bag samplers.

In accordance with the January 29, 1996 Work Plan, one intermediate report was prepared during the RI, *Field Report and Aquifer Testing Proposal, Phase I Remedial Investigation/Feasibility Study, West Osborn Complex Facility, Phoenix, Arizona* (HSI GeoTrans, 1997a). An August 20, 1997 Work Plan, *West Osborn Complex Work Plan* (HSI GeoTrans, 1997b), was also prepared. It was approved by the ADEQ prior to conducting Phase II activities. Numerous other data summaries or quarterly progress reports were also prepared and submitted to ADEQ over the 1996 to 2004 time period and will be referenced in this document. A complete listing of reports is provided with the references in Section 7.

1.3 PREVIOUS WORK

The WOC has been the subject of several investigations prior to 1996. These include:

- Site inspections conducted by the ADEQ (1989a,b,c,) and an aerial photographic analysis by the United States Environmental Protection Agency (U.S. EPA) (1989);

- On-site soil and groundwater investigations that were undertaken by present and former property owners (Woodward-Clyde Consultants [WCC], 1987; Applied Environmental Consultants, 1991; GeoWest, 1991; Brown and Caldwell Consultants [BCC], 1992); and,

- Regional groundwater investigations completed by the ADEQ (The Earth Technology Corporation [Earth Tech], 1989; Earth Tech, 1994; Earth Tech, 1996).

These and other reference documents are listed in Section 7.

[2] Measurement of water-levels.

2.0 PHYSICAL SETTING

2.1 SITE DESCRIPTION

The WOC is located within the S1/2 of the SE1/4 of the NE1/4 quarter of Section 27, Township 2 North, Range 2 East of the Gila and Salt River Baseline and Meridian. It is bounded by the Grand Canal on the north, Osborn Road on the south, 35th Avenue on the east, and the extension of 37th Avenue on the west (Figure 1-1). The WOC is approximately 15 acres in size and consists of three parcels: the East Parcel, Middle Parcel, and West Parcel. Figure 2-1 shows each of the three parcels and the locations of existing buildings, monitor wells, and other pertinent features.

West Parcel - The West Parcel is approximately 8 acres in size. It contains six buildings and an asphalt parking lot. Two of the six buildings are industrial buildings, and four are multi-tenant office buildings. Until 2000 May Industries, Inc., a precision machine shop, occupied an industrial building and about 2.6 acres of land at the northwest portion of the West Parcel. The other industrial building, located at the northeast corner of the parcel, is occupied by Metal Joining, an affiliate of May Industries, Inc. The parcel transferred ownership to Elm Properties, LLC in February 2000 (see Section 2.2).

Middle Parcel - The Middle Parcel is approximately 3.9 acres in size and is partially enclosed with a chain-link fence. Structures on the Middle Parcel include a large main building and a smaller storage shed located north of the main building. There are unpaved dirt areas at the south and east sides of the main building. The remaining exterior areas are paved, primarily with asphalt. A mattress and furniture liquidation business, Capital Liquidation, has been the main tenant at the Middle Parcel since approximately 1992. An unused water-supply well, the WOC Irrigation well[3] (also referred to as the Pincus Well), is located in the northwest part of the Middle Parcel.

East Parcel - The East Parcel is approximately 3.2 acres in size and is completely enclosed by a chain-link fence. One multi-tenant commercial/industrial building is located on the parcel. The driveways and parking areas are paved with asphalt. Formerly, the main tenant at the West Parcel was Western Dynex Corporation. Until September 2002 the main tenant was a machine shop owned by Mr. Eugene Perri. Since September 2002 the property has been owned by Seven Angels, LLC.

2.2 SITE HISTORY

Like most of the central part of the Phoenix metropolitan area, the WOC was once used for agricultural purposes and was irrigated with water from the Grand Canal. Irrigation on the parcel commenced in 1889 (Hurley v. Abbott et. al., 1910).

The history of development at the WOC was previously summarized by BCC (1992), the U.S. EPA (1989), and WCC (1987). Information provided in these references is included below.

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[3] This well was designated the WOC Irrigation Well based on its observed use for landscape irrigation in 1987, when environmental investigation was undertaken by Woodward-Clyde Consultants.

In about 1957, the first building was constructed on what is now the East Parcel. A second building was added north of the first one between 1961 and 1964, and the two buildings were eventually connected with additions. Buildings on what is now the Middle Parcel were constructed between 1958 and 1961, and the West Parcel was not developed until after 1980.

2.2.1 Site Ownership and Use

From 1957 to 1965, the WOC was owned by six different entities (Table 2-1). According to the ADEQ, all were involved in the manufacturing of electronic components, their manufacturing processes were similar, and each used TCE as a solvent (ADEQ, 1989a,b,c).

The ADEQ evaluated manufacturing processes and solvent usage by conducting interviews with employees and former employees. ADEQ also obtained purchase records for solvents and disposal records for wastes, and asked former and present owners and tenants to fill out hazardous waste questionnaires. The results of these activities are summarized in the ADEQ's site investigation reports (ADEQ, 1989a,b,c).

Components Inc. acquired the WOC in 1965, and it subdivided the WOC in 1971 into the East, Middle, and West Parcels. Beginning in October 27, 1976, Components Inc. started to sell its interest in the WOC. The subsequent ownership of the three parcels was discussed in Section 2.1 and is presented in Table 2-2.

After the subdivision and sale, the WOC continued to be used for electronics manufacturing and assembly. Lansdale Semiconductor leased the Middle Parcel from approximately 1976 through 1987 for the manufacture of transistors. Western Dynex Corporation, for which Mr. Eugene Perri was president, assembled computer disk drives on the East Parcel.[4] According to the ADEQ, both of these facilities used solvents: TCE at Lansdale, and TCE and TCA at Western Dynex. May Industries began operations at the West Parcel in about 1980 and used TCA, along with other chemicals.

2.2.2 Wastewater Disposal Systems

Septic Tanks and Seepage Pits

Septic tanks and seepage pits were used for on-site wastewater disposal since the WOC was first constructed until at least 1966, when the properties were connected to the municipal sewer system. Since 1989, these systems and other potential source areas have been the subject of several investigations. The on-site wastewater disposal systems were eventually excavated in 1996 during the RI, as required by the Consent Decree. Disposal systems that were identified are described in Section 4.0.

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[4]Western Dynex began operations at the property in 1978 and was still present in 1989, when the ADEQ conducted its preliminary assessment. It is not currently in business at the East Parcel.

According to Maricopa County Environmental Services Department records, six septic tanks and ten seepage pits were permitted at the WOC. Copies of the records were obtained from the ADEQ. They are summarized on Table 2-3.

GeoTrans found five septic tanks and 17 seepage pits during the WOC soil investigation (Section 4.0). However, there are inconsistencies between the permitted tanks and the actual tanks identified during the RI. These inconsistencies cannot be completely resolved.

Buildings at the WOC were connected to the municipal sewer system in 1966, but septic systems may have been in use until a later date. According to Mr. Jim Connell, Manager of the City of Phoenix (COP) Industrial Waste Control in the 1960s, the connection to the sewer system does not necessarily mean that all industrial waste began to be discharged to the municipal sewer (ADEQ, 1989c).

Other Drainage Features

In addition to the septic systems and sewer lines, other drainage features have been identified at the WOC. BCC (1992) and WCC (1987) described many of these features and this information is presented below.

A pipe that apparently discharged to the Grand Canal was formerly present on the Middle Parcel. This pipe was investigated during this RI, and additional information is presented in Section 4.0.

Drywells were also reported by BCC (1992) and WCC (1987). Formerly, there was one drywell in a loading dock at the north side of the building on the Middle Parcel, and there was also a reported drywell on the east side of the East Parcel. GeoTrans could not independently confirm the existence of these drywells during the RI. The loading dock has been filled in and repaved, and there is no drywell evident on the East Parcel.

A concrete chamber with the characteristics of an oil/water separator is located south of the southwest corner of main building on the Middle Parcel. The function of the separator is not known. It is presently filled with dirt, and no discharge line has been located. Soil samples were collected near this feature during the RI, and additional information is presented in Section 4.0

2.2.3 Irrigation Well

It is unclear when the WOC Irrigation Well on the Middle Parcel was constructed, and no driller's log is available.[5] The WOC Irrigation Well was video-logged in 1992 by the ADEQ. The record of the video log is summarized below:

Well Depth:	581 feet
Well Diameter:	12 inches (0 to 390 feet) 8 inches (390 to 581 feet)

[5] In some documents, 1947 construction data has been incorrectly reported, probably because a duplicate copy of a log for SRP Well 9.5E-7.7N was in the ADWR's registration file for the WOC Irrigation Well. SRP 9.5E-7.7N was drilled in 1947.

Casing Perforations:	237 to 390 (possible, but uncertain) 395 to 581 feet (some open slots)

The WOC Irrigation Well is scheduled for abandonment in July 2004.

2.3 HYDROGEOLOGIC SETTING

The WOC is located in the West Salt River Valley, a broad, level, alluvial valley in the Basin and Range physiographic province of Central Arizona. The valley is filled with a layered mixture of unconsolidated sand, gravel, silt, and clay, also referred to as basin-fill, that have been derived from erosion of surrounding bedrock uplands. The total depth of basin-fill at the site is unknown, but is estimated at more than 1,500 feet based on information provided in Brown and Pool (1989).

2.3.1 Classification of Basin Fill

Over the past 20 or more years, a three-part hydrostratigraphic subdivision of the Salt River Valley basin fill was developed in formative works by Arizona's main water-resource agencies: the U.S. Bureau of Reclamation (USBR), the U.S. Geological Survey (USGS), and the Arizona Department of Water Resources (ADWR). However, each agency adopted slightly different nomenclature, and the USGS used an altogether different approach to subdividing the alluvial units. As a result, there are now three separate classification systems in general use.

The differences between the classification systems are explained below, and a correlation chart is presented as Table 2-4.

U.S. Bureau of Reclamation

In its 1976 evaluation of the geology and groundwater resources of the Central Arizona Project (CAP) area, the USBR developed the first practical classification system for the Salt River Valley basin fill. On the basis of dominant lithology identified in test holes, electric logs, and cuttings from water wells, the USBR proposed three major hydrostratigraphic units: the Upper Alluvial Unit, the Middle Fine-Grained Unit, and the Lower Conglomerate Unit (Table 2-4). These subdivisions were widely adopted and are still in common use.

U.S. Geological Survey

About 10 years after the CAP reports were released, the USGS published the first of its two regional basin studies of the Salt River Valley. The East Basin study was released in 1986, (Laney and Hahn, 1986), and the West Basin study was published in 1989 (Brown and Pool, 1989). In these, the USGS defined three basin fill units on the basis of hydrogeologic properties: the upper unit, the middle unit, and the lower unit (Table 2-4).

The names that the USGS selected were similar to those that were used by the USBR, but the correlations create confusion. The USGS's upper and middle units are equivalent to only the USBR's Upper Alluvial Unit, whereas the USGS's lower unit includes both the USBR's Middle Fine-Grained Unit and the USBR's Lower Conglomerate Unit. The USGS subdivided its lower unit into upper and lower parts, which correlate with the Middle Fine-Grained and Lower Conglomerate Units of the USBR.

Arizona Department of Water Resources

In 1993, the ADWR released the results of its modeling study of the Salt River Valley (Corkhill et. al. 1993). For modeling purposes, the ADWR defined three hydrogeologic units that are generally correlative with the hydrostratigraphic units of the USBR: the Upper Alluvial Unit (UAU), the Middle Alluvial Unit (MAU), and the Lower Alluvial Unit (LAU) (Table 2-4). The ADWR stated that it believed that its hydrogeologic units could be recognized in most of the modeled area and differed from the definitions of the USBR mainly in nomenclature (e.g., LAU rather than Lower Conglomerate Unit). However, the ADWR also stated that differences between the ADWR and the USGS classification systems concerned definition of units as well as nomenclature.

For this report, the ADWR's hydrostratigraphic nomenclature has been used. Because of its correlation with the USBR's original classification scheme, the ADWR's system is arguably more widely accepted and understood than the USGS's system.

The main complication introduced with the ADWR's stratigraphic nomenclature system is that the suffixes for the wells that were drilled during the WOC RI are somewhat misleading. The wells that were drilled at the WOC were denominated with the suffixes S, M, and L,[6] but no wells at the WOC were completed in the LAU. The L-series wells were completed in the MAU and the M-series wells were completed in the deepest part of the UAU. Therefore, the S-, M-, and L-series wells will be referred to as simply the shallow, intermediate, and deep wells.

The characteristics of the hydrostratigraphic units of the basin fill are summarized in the subsequent section, using the ADWR's nomenclature and descriptions (Corkhill et. al. 1993).

2.3.2 Description of Hydrostratigraphic Units

The basin-fill alluvial units are described in ascending order below.

Lower Alluvial Unit

The LAU consists mainly of conglomerate and gravel near the margins of the Salt River Valley (SRV). It grades into mudstone, gypsiferous and anhydritic mudstone, and anhydrite in the central areas of the basins. In portions of the Western Salt River Valley (WSRV) it also contains some interbedded lava flows.

Due to the absence of wells installed to the necessary depth, the thickness, lithologic and hydrogeologic characteristics of the LAU at the WOC are not well-known. Based on the regional, basin-wide maps of the USGS (Brown and Pool, 1989) and the ADWR (Corkhill et. al, 1993), the projected depth to the top of the Unit is as much as 1,000 feet below ground surface, and it may be as much as 1,600 feet thick.

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[6] In accordance with the Work Plan (HSI GeoTrans, 1996).

The closest site-specific data for the LAU is from a 950-foot deep production well that was drilled for Crystal Bottled Water in 1974. According to the Maricopa County Assessors Office the current (and historic) owner of this well is the Sparklets Drinking Water Corporation. According to ADEQ this well is now owned by Danone Waters of North America (Danone). It is believed that Danone purchased Sparklets/Crystal but has not changed the name on the deed. This well is about 0.75 mile southeast of the WOC, and the top of the LAU may have been reached at a depth of 912 feet (Figure 2-2). The well was perforated between 905 and 930 feet, and a sand and gravel unit in the interval from 912 to 935 feet is apparently responsible for all of the well yield.

Although it is completed in a coarse-grained layer, the yield of the well is low. During an aquifer test that was conducted immediately after drilling was completed, the well produced 25 gallons per minute (gpm) with 380 feet of drawdown.[7]

Middle Alluvial Unit

The MAU in the Salt River Basin is generally characterized as a fine-grained unit consisting of clay, silt, mudstone, and gypsiferous mudstone, with some interbedded sand and gravel. Near the Basin margins, coarser-grained sediments predominate, and the unit is indistinguishable from the overlying UAU or the underlying LAU. At the WOC, the fine-grained facies of the MAU is well-developed, and it is a distinctive hydrostratigraphic unit.

The ADWR's regional maps show that the top of the MAU occurs at a depth of about 300 feet at the WOC and it is about 650 feet thick. This correlates with conditions encountered in on-site wells. At MW-4L, which was drilled on the Middle Parcel adjacent to the WOC Irrigation Well (Figure 2-1), the top of a thick clay and silty clay unit, correlating with the MAU, was encountered at a depth of 287 feet. Logs of cuttings, drive samples, and geophysical logs (Appendix F) show that the unit is predominantly fine-grained and that it extends to a depth of at least 822 feet, the maximum depth drilled.

At offsite wells MW-7L and MW-6L, the characteristics of the MAU are similar to those observed at MW-4L. At MW-7L, the top of the MAU was encountered at a depth of 296 feet, similar to MW-4L. However, at MW-6L it was encountered at 360 feet. Drill cuttings, relatively undisturbed drive samples, and geophysical logs at both wells show that the unit is predominantly clay (Appendix F).

Thin, coarse-grained zones capable of producing small quantities of water are present in the MAU. At MW-7L, a sand and gravel unit interbedded with clay or silty clay, was encountered at a depth of 756 to 792 feet, and a similar unit was encountered near the bottom of MW-4L. Both wells were screened in this zone, and during aquifer testing, MW-7L sustained a pumping rate of 7 gallons per minute (gpm), with 25 feet of drawdown. MW-4L was not tested. However, a similar coarse-grained unit was not encountered at MW-6L, and a screened zone at the approximate same depth yielded less than 2 gpm during aquifer testing.

Upper Alluvial Unit

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[7] The record for this test was obtained from the former well owners, McKesson Water Products Company. The driller's log is on file at the ADWR.

The UAU is the uppermost basin fill unit in the SRV and, where saturated in the WSRV, is the most prolific water producer. It is composed mainly of silt, sand, and gravel, but local, usually relatively thin clay layers can be present. Within the WSRV, the unit is predominantly gravel and sand with some thick zones of cobbles near the present channels of the Salt River and regions north and south of the present-day channel, where the ancestral channel was located. Near the WOC, the UAU is much finer-grained than approximately 1.5 miles to the south, closer to the Salt River channel.

According to the ADWR, the UAU is typically 300 to 400 feet thick in the West Salt River Basin. At the WOC, the regional ADWR maps show that the UAU is slightly more than 300 feet thick (Corkhill et. al., 1993).

The UAU has been encountered in all of the previous wells that have been drilled in the West Central Phoenix WQARF Study Area. Most of these have been shallow, water-table wells and have only penetrated the top approximately one-half of the Unit. However, the entire thickness was drilled at several locations for the WOC RI, and at most of these, three or four subunits of the UAU can be recognized. The general lithology of the subunits, and thicknesses are listed on Table 2-5. This summary is based on the stratigraphy at on-site soil borings and MW-4L, but the subunits are generally similar at other on-site monitor wells and many off-site wells.

The lower sand and gravel subunit is the most significant water-bearing zone in the vicinity of the WOC. Its distinctive geophysical signature is present on most of the well logs (Appendix F), and shows relatively good continuity between all wells that were drilled to a sufficient depth. Aquifer tests show that it also has the capacity to transmit large quantities of water (Section 5.0). It was the target zone for the M-series wells that were drilled for the RI.

3.0 PREVIOUS WORK

The WOC was the subject of previous soil and groundwater investigations prior to the work by UIC, described here. These previous investigations are summarized below.

3.1 PREVIOUS SOIL INVESTIGATIONS

1987 Investigation by WCC

In 1987, WCC completed a preliminary site investigation for Lansdale Semiconductor, Inc. on the Middle Parcel of the WOC (Figure 2-1).[8] WCC collected 10 soil samples at the Lansdale facility, and analyzed them for VOCs.

WCC detected TCE in two shallow soil samples. One sample was collected at a depth of 4 to 6 inches below the surface of the pavement in the area adjacent to the east side of the small metal storage building that is behind the main building (Figure 2-1). The TCE concentration was 2,050 micrograms per kilogram (µg/kg). In the second sample, the concentration of TCE was 285 µg/kg. It was collected at a depth of 13 to 18.5 inches below the floor surface in the former deionized water (DI) room. According to the ADEQ (1989c), this room contained a drain that was believed to have been connected to an on-site septic tank until 1982, when it was capped by a Lansdale employee. GeoTrans was not able to confirm the existence of the drain.

1989 Inspections by ADEQ

In 1989, the ADEQ conducted site inspections of all three WOC parcels (ADEQ, 1989a,b,c) . They were conducted after the results of preliminary assessments (also conducted in 1989) recommended further investigations. This recommendation was largely based on conclusions regarding historic TCE usage. Soil-gas surveys were conducted in conjunction with drilling operations as part of the site investigations. A total of 39 soil-gas samples were collected at depths ranging from 18 to 65 feet below ground surface (bgs). Ten samples were collected on the East Parcel, 16 samples were collected on the Middle Parcel, and 13 samples were collected on the West Parcel. The concentrations of TCE ranged from 0.4 micrograms per liter (µg/L) to 1,100 µg/L, with the highest concentrations being detected on the Middle Parcel.

The ADEQ also collected seven soil samples. Two samples were collected from each of the East and Middle parcels, and three samples were collected from the West Parcel. Sample depths ranged from 2 to 25.5 feet bgs. TCE was not detected in any of the soil samples.

[8]Lansdale has since sold the Middle Parcel. A history of ownership is presented in Section 2.2.

1991 Investigation by Applied Environmental Consultants

In 1991, Applied Environmental Consultants completed a Phase I RI/FS on the West Parcel of the WOC on behalf of May Industries.[9] The investigation was performed to identify contaminants in soil. A total of nine soil borings were drilled to depths of 30 to 83 feet bgs, with 50 soil samples analyzed by the laboratory. TCE was not detected in any of the samples. 1,1,1-trichloroethane (TCA) was detected in one sample at a concentration of 0.011 milligrams per kilogram (mg/kg).

1991 and 1992 Investigation by BCC

Prior to the work completed by UIC, the most recent soil investigation at the WOC was conducted by BCC on behalf of Components Incorporated. Between July 1991 and April 1992, BCC conducted a preliminary site characterization (PSC) that included a geophysical survey and a subsurface soil investigation. The geophysical survey, although inconclusive, identified a number of drain, sewer, and abandoned lines. However, not all lines were identifiable, and the locations of septic lines, tanks, and seepage pits could not be verified.

The results of the geophysical survey were used to select locations for the subsurface soil investigation. A total of 36 soil borings were drilled to depths of 5 to 72 feet bgs, with 82 soil samples selected for analysis. TCE was detected in four samples at concentrations ranging from 6.2 to 20 μg/kg. Fifty-eight soil samples were analyzed for total RCRA metals. Arsenic and selenium were not detected in any samples, barium and chromium were detected in all samples in concentrations substantially below their respective Arizona Non-Residential Soil Remediation Levels (NR-SRLs), and lead, mercury, silver and cadmium were detected in 16 of the samples tested for metals also in very low levels. The locations of these soil borings are shown in Figure 3-1, and the analytical results are shown in Table 3-1; the corresponding laboratory reports are available in ADEQ files.

3.2 PREVIOUS GROUNDWATER INVESTIGATIONS

WOC Irrigation Well

Based on information in WCC (1987) it was reported that the WOC Irrigation Well was initially sampled for analysis of VOCs by the ADHS in 1984. It was subsequently sampled in 1987 by the ADEQ (ADEQ, 1989c) and by WCC during its soil investigation for Lansdale (WCC, 1987). A total of six groundwater samples from the well were analyzed between 1984 and 1987. The concentrations of TCE ranged from 260 to 340 μg/L. TCE concentrations in groundwater were reported from the 1984 sampling by ADHS, ranging from 260 to 340 μg/L (WCC, 1987).

In 1991, Earth Tech conducted depth-specific sampling on the WOC Irrigation Well. It was sampled during two events; one involved static conditions and the other involved pumping conditions. During the static event, samples were collected from depths of 120, 250, 385, 386, and 575 feet bgs. The concentrations of TCE were 23.0, 57.0, 60.0, 90.0, and 77.0 μg/L, respectively. During pumping, samples were collected from depths of 240, 345, 378, 379, and 480 feet bgs. The

[9] The work was carried out by The GeoWest Group, Inc. as a subcontractor to Applied Environmental Consultants.

concentrations of TCE were 16.0, 21.0, 32.0, 31.0, and 40.0 μg/L, respectively. Neither set of results is considered informative regarding the vertical extent or vertical distribution of groundwater contamination.

BCC also sampled the WOC Irrigation Well on March 20, 1992 as part of its PSC. The well was purged for a duration of 3 hours and 19 minutes at 100 gpm using a 25-horsepower submersible pump set at a depth of 450 feet bgs. Groundwater samples were collected for analysis of VOCs using EPA Method 601 and for Primary and Secondary Safe Drinking Water Act (SDWA) compounds. The SDWA compounds were collected from the pump discharge, which would indicate that they were composite samples being composed predominantly of the most productive portions of the vertical portion of the aquifer intersected by the well perforations. The VOC sample was collected using a bailer but no details were provided on exactly when, e.g., during pumping, immediately after pumping, etc., the sample was collected or where in the water column the bailer was lowered to. A TCE concentration of 17μg/L was measured. PCE and 1,1-DCE were both non-detect (<1.0 μg/L). Results of interest for inorganics and metals are as follows: Total Dissolved Solids [TDS] (500 mg/L), Nitrate as Nitrogen (2.25 mg/L), Arsenic (0.009 mg/L), Total Chromium (<0.010 mg/L) and mercury (<0.0002 mg/L).

On-Site Monitoring Wells

While conducting the PSC in 1991 and 1992, BCC installed five shallow monitor wells at the WOC. Wells MW-1S, MW-2S, and MW-3S were installed in August 1991, and MW-4S and MW-5S were completed in February 1992. Locations are shown on Figure 2-2, and general construction data are summarized on Table 3-2. The wells were completed to depths of about 30 feet below the top of the saturated zone, with total depths ranging from 100 feet at MW-3S to 135 feet at MW-5S.

Prior to the work undertaken by UIC for this RI, the samples from the five WOC monitor wells and the WOC Irrigation Well were the only on-site water quality data that were available for the WOC. The monitor wells were measured and sampled twice by BCC between August 1991 and April 1992. The WOC Irrigation Well was also sampled during the same period. On February 5 and 6, 1996, the five monitor wells were re-sampled by the ADEQ's contractor, Earth Tech. A summary of TCE results from these investigations is listed in Table 3-3, along with the earlier results from the WOC Irrigation Well.

Aquifer Testing

Aquifer testing has been carried out during previous investigations at the WOC. In 1992, as part of its PSC, BCC conducted pumping tests and slug tests on the shallow monitor wells (MW-1S through MW-5S) they had installed. BCC also conducted a pump test at the WOC Irrigation Well. At monitor wells, the rates of test pumping ranged from 3.5 to 6.5 gallons per minute (gpm). The WOC Irrigation Well was test-pumped at a rate of 100 gpm.

Transmissivity values ranging from 200 to 540 square feet per day (ft^2/day) for the tests at MW-3S, MW-4S, and MW-5S and values of 800 and 2600 ft^2/day for slug tests at MW-1S and MW-2S were reported by BCC. Using an average saturated thickness of 25 feet results in a hydraulic conductivity value of approximately 8 to 22 feet per day (ft/day) for the monitor well pumping tests. The slug tests results are considered suspect. A transmissivity value of 50 ft^2/day was reported for the WOC Irrigation Well.[10]

[10] BCC may have made an error in calculating the transmissivity of the WOC Irrigation Well. GeoTrans recalculated the transmissivity using the specific capacity method cited in the PSC (specific capacity times 2,000), and derived a transmissivity value of 240 ft^2/day.

4.0 SOIL INVESTIGATION

4.1 APPROACH

The soil investigation for this RI was conducted in two phases. In Phase I, completed over the time period from July to November, 1996, potential sources of soil contamination at the WOC were identified and characterized. During Phase II, completed over the time period from October, 1997 to December, 1997, the extent of contamination at potential sources was evaluated more completely. Phase II was conducted with the approval of the ADEQ and in general accordance with the January 29, 1996 Work Plan.

The ADEQ provided oversight during the Phase I and Phase II soil investigations. Its oversight contractors, GZA GeoEnvironmental, Inc. (GZA) and Roy F. Weston, Inc. (Weston), observed field procedures and collected split samples for analysis at some sample locations. In addition, in July 1999, Weston collected 17 near-surface soil samples at the Site (from depths from 6 to 12 inches bgs, labeled WOC RA-01 through WOC RA-14) in support of their Baseline Human Health Risk Assessment. The sampling locations are shown in Figure 3-1. The collected samples were analyzed for VOCs and total RCA metals; and three of the 17 samples were also analyzed for chromium-6 (Cr^{+6}). The analytical results for these soil samples are included in Table 4-2.

Phase I Soil Investigation

Specific activities conducted during the Phase I soil investigation included the following:

- Excavation and sampling test trenches and test pits for the purpose of locating and characterizing waste disposal systems such as septic tanks, tile lines, and seepage pits;
- Removing contaminated septic tanks as a source control measure; and
- Drilling soil borings in potential source areas to measure the vertical extent of contamination.

Phase II Soil Investigation

During the Phase II soil investigation, the following activities were carried out:

- Further delineation of the horizontal and vertical extent of VOCs in soil at the potential source areas; and,
- Evaluation of potential releases from piping that had not been investigated during Phase I.

4.2 PROCEDURES

Sampling and Analysis Procedures

Sampling and analysis activities completed during the Phase I and II soil investigations were conducted in general conformance with the procedures outlined in the RI/FS Work Plan, the Phase II Work Plan, and the attachments to the RI/FS Work Plan: the Sampling and Analysis Plan (SAP), the Quality Assurance Project Plan (QAPP), and the Health and Safety Plan (HASP).[11] All samples collected for VOC analysis were extracted in the field using the ADEQ's methanol extraction procedure.

Some minor modifications to procedures were agreed to by GeoTrans and the ADEQ prior to commencing field work. These modifications included adjusting the locations of selected test trenches, test pits, and soil borings to more closely achieve the objectives of the investigation. Locations of some soil boring locations were also moved slightly to avoid underground utilities.

Figure 4-1 shows the final locations of septic tanks, seepage pits, test trenches, test pits, exposed piping, and soil borings based on field observations, measurements, and surveys. Figures 4-2 through 4-8 present details of the investigated areas.[12] Analytical results are summarized in Tables 4-1 through 4-4. Laboratory results are attached as Appendix C.

4.3 SAMPLING LOCATIONS

4.3.1 Phase I Soil Investigation

Test Trenches

A total of four test trenches were excavated at the WOC (Figure 4-1). Test trenches TT-1 and TT-3 were excavated on the Middle Parcel, test trench TT-2 was excavated on the West and Middle Parcels, and test trench TT-4 was excavated on the East Parcel. Locations of the composite samples from the test trenches are shown on Figure 4-1.

Most samples from test trenches were collected as 10-point composites from every 50 cubic yards of excavated soil. A total of 221 sub-samples were collected. These were used by the laboratory to prepare 28 composite samples for analysis of VOCs and total RCRA metals. An additional nine discrete samples were collected from test trenches as grab samples. Analytical results from test trenches are presented in Table 4-2. Lithologic logs of soils exposed in the walls of the trenches are included in Appendix B.

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[11] See Section 7 for reference list.

[12] These figures also show the results of analyses of selected VOCs. Except for one soil sample, results of metals are not shown. In all but one sample of soil, concentrations of heavy metals were less than the ADEQ's soil remediation levels (SRLs). Heavy metals were measured in some samples of septic tank contents in concentrations greater than SRLs, but these contents were excavated and disposed of.

Septic Tanks

Five septic tanks were identified during the excavation of the test trenches. Septic tanks ST-1 and ST-3 were located on the Middle Parcel, septic tank ST-2 was located on the West Parcel, and septic tanks ST-4 and ST-5 were located on the East Parcel. Locations of the septic tanks are shown on the site map on Figure 4-1 and in the detailed maps on Figures 4-2 through 4-5.

Samples were collected from septic tank contents and from soils below the septic tanks.[13] A total of eight samples of septic tank contents were collected and analyzed for total VOCs, total RCRA metals, Toxicity Leaching Characteristic Procedure (TCLP) VOCs, and TCLP RCRA metals. Four soil samples (one from beneath each septic tank) were collected from the soils below the septic tanks. Analytical results are presented in Tables 4-1 and 4-2.

Characteristics of the septic tanks are summarized below. These characteristics are based on observations made as the septic tanks were uncovered and excavated for removal. Septic tanks were uncovered with a trackhoe during test trenching.

Septic Tank ST-1

Septic tank ST-1 (Figure 4-2) was a pre-cast, concrete tank with lateral dimensions of 12 feet by 4.5 feet. Its interior vertical dimension was 4.5 feet, and the top was buried about 4 feet bgs. The tank had rounded ends, and its long axis was aligned at an azimuth of about 330 degrees. There were two cleanout or vent openings in the lid. Two pipes were uncovered in the wall of the septic tank excavation, but their connections to the tank were unclear.

The tank was uncovered and the lid was removed on July 24, 1996. The contents of the tank consisted of aggregate base course (ABC, which is a graded mixture of sand and gravel) and dried sludge. Two samples were collected from the top and bottom of the tank contents (TT1-SEP and ST1-SL-8). The tank contents were removed on October 30 and 31, 1996, and the tank was removed on November 1, 1996. Soil sample ST1-BASE was collected from native soil underlying the former location of the tank at a depth of 10 feet bgs.

Septic Tank ST-2

Septic tank ST-2 (Figure 4-3) was a pre-cast, concrete tank with lateral dimensions of 12 feet by 4.5 feet. Its interior vertical dimension was 4.5 feet, and the top of the tank was buried about 4 feet bgs. The tank had rounded ends, and the long axis was oriented east-west. It was directly adjacent to the south wall of a building on the West Parcel. Five, black, 2-inch ABS pipes entered the east side of the tank. This piping originated on the Middle Parcel. No other inlets or outlets were observed. However, the close proximity of the tank to the building precluded excavation and inspection on the north side of the tank.

Septic Tank ST-2 did not have a lid, and the contents consisted of ABC and dried sludge. On July 19 and 23, 1996, two samples were collected from the near-surface and deeper tank contents (ST2-

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[13] Samples from below the septic tanks were collected after the contents and the tank structures had been excavated and removed.

SL and ST2-SL-10, respectively). The tank contents were removed on October 30 and 31, 1996, and the tank was removed on November 1, 1996. Soil sample ST2-BASE was collected from native soil underlying the former location of the tank at a depth of 10 feet.

Septic Tank ST-3

Septic tank ST-3 (Figure 4-4) was a cast-in-place, concrete tank that had two chambers separated by a baffle. It had lateral dimensions of 15 feet by 6 feet and had an interior vertical dimension of about 7 feet. The tank had squared-off corners, and the long axis was oriented east-west. The top, which was buried about 5 feet bgs, was constructed with reinforced concrete and had two manhole openings for access.[14] An inlet was located on the west end of the tank, and an outlet pipe that led to seepage pits was present on the east end of the tank.

On August 19, 1996, the contents of septic tank ST-3 were sampled. An auger drill was used to drill through the reinforced concrete lid. One hole was drilled into each chamber, and sample ST3-SL-10 was collected from the dried sludge in the west chamber. A sludge sample was not recovered from the east chamber. The layer of dried sediment of the floor of the east chamber was too thin to sample.

The tank contents were removed on October 29, 1996, and the tank was removed on November 1, 1996. Soil sample ST3-BASE was collected from native soil underlying the former location of the tank at a depth of 12 feet.

Septic Tank ST-4

Septic tank ST-4 (Figure 4-5) was a cast-in-place, concrete tank with lateral dimensions of 33 feet by 8 feet. Its vertical dimension varied from 5 feet on the west end to 4 feet on the east end. The top was about 3 feet bgs. The tank had squared-off ends, and the long axis was oriented east-west. Possible remnants of a concrete lid were present when the tank was excavated, but most of the top of the tank was open. An inlet was located on the west end of the tank, and three outlet pipes that were connected to seepage pits were located on the east end. The inside of the tank contained stained and colored sediment and dried sludge.

On July 25, 1996, the remnants of the tank lid were removed, and two samples of the tank contents were collected (ST4-SL-1 and ST4-SS-1). Sample ST4-SL-1 was collected from the contents inside the tank, and sample ST4-SS-1 was collected from a small portion of the tank contents that were excavated and placed in a 55-gallon drum for more complete examination and characterization.

The contents of septic tank ST-4 were completely removed on October 30 and 31, 1996. In accordance with the Phase I Work Plan, the tank itself was not removed because VOCs were not detected in the samples of the tank contents. Since the tank was not removed, native soil below the tank was not sampled.

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[14]The manholes were not identified during the initial excavation, but they were discovered later during tank closure.

Septic Tank ST-5

Septic tank ST-5 (Figure 4-5) was a pre-cast, concrete tank with lateral dimensions of 6 feet by 5.5 feet. Its interior vertical dimension was about 6 feet. The tank had rounded ends, the long axis was oriented east-west, and the concrete lid was about 2 ft bgs. No inlets or outlets were observed on the walls of the tank. The inside of the tank contained ABC and dried sludge.

On August 14, 1996, the tank lid was removed, and the tank contents were sampled (ST5-SL). The tank contents were completely removed on October 30 and 31, 1996, and the tank was removed on November 1, 1996. Soil sample ST5-BASE was collected from native soil underlying the former location of the tank at a depth of 8 feet.

Seepage Pits

A total of 17 seepage pits were identified at the WOC (Figure 4-1): ten near septic tanks ST-4 and ST-5 on the East Parcel (Figure 4-5) and seven near septic tank ST-3 on the Middle Parcel (Figure 4-4). A circular distribution box was also encountered on the Middle Parcel (Figure 4-4).

The seepage pits were constructed with concrete tops and were lined with red brick. However, the lower part of the liner in at least one seepage pit on the East Parcel was constructed of concrete block. Typically, the tops of the seepage pits were at a depth of approximately 7 feet bgs, and the total depths were 15 to 24 feet bgs. The brick liners were approximately 4 feet in diameter.

At some seepage pits, gravel backfill had been placed below and on the outside of the brick lining, but at others, the annular space between the brick and the wall of the hole had apparently been backfilled with soil. When the seepage pits were first uncovered, the interior chambers were all open to some degree.

With one exception, soils were dry at all the seepage pits. At seepage pit ST4-SP-10, the interior of the seepage pit was wet, and some water was present. This seepage pit was located at the edge of a roof, and the ground surface near the seepage pit was depressed.[15] Therefore, the pit collected storm runoff.

Piping connecting individual seepage pits and septic tanks consisted of either vitrified clay pipe (VCP), "Orangeburg" pipe (pipe composed of compressed asphalt-impregnated felt), or black plastic ABS pipe. No perforated pipe or leach pipe was encountered.

The distribution chamber at septic tank ST-3 was approximately 3 feet deep and had a diameter of 4 feet. The walls were constructed of concrete, and the bottom was open. There were five pipe openings in the circular outer wall. The piping connections are shown schematically on Figure 4-4.

Seepage pits were not anticipated when the Work Plan was prepared. After they were identified, GeoTrans and the ADEQ jointly developed an approach to evaluating possible releases. First, a soil boring was drilled through the base of each seepage pit, and one sample of native soil was collected

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[15]The ground surface was leveled after sampling was completed.

at each seepage pit for analysis of RCRA metals and VOCs. These samples were collected immediately below any gravel backfill, and sample depths ranged from 20 to 55 feet bgs. Results of analyses of these initial evaluation samples (Table 4-2) were used to select seepage pits for deeper drilling and additional investigation. This procedure could not be implemented at seepage pit ST4-SP-10. It was located underneath a parking canopy, and access was restricted. Therefore, the seepage pit was sampled by hand. A sample of sludge was collected with a hand auger at a depth of 10 feet bgs. A thin layer of water was present on top of the sludge, and it was sampled with a disposable bailer.

After the analytical results from the initial evaluation samples were available, locations were selected for additional drilling. One deep boring was advanced to within about five feet of the water table at each of three seepage pits on the East Parcel: ST4-SP4, ST4-SP7, and ST4-SP8. Two deep borings were also drilled on the Middle Parcel: one at seepage pit ST3-SP1 and one at the distribution chamber (DBOX).

Samples at these borings were collected at 10-foot intervals, beginning at the first 5-foot increment below the initial evaluation, and they were analyzed for VOCs and RCRA metals. Analytical results are presented in Table 4-2, and the locations of the borings are shown on Figures 4-4 and 4-5.[16]

Test Pits

A total of 12 test pits were excavated at the WOC (Figure 4-1), two more than were specified in the RI Work Plan. Six test pits were located on the Middle Parcel, and the other six were located on the East Parcel. The two additional test pits (TP-3A and TP-3B) were excavated to more completely investigate piping that had been identified in the vicinity of test pits TP-3 and TP-5.

Soil samples from test pits were collected in general conformance with the Work Plan. At most test pits, three grab samples were collected from native soil (one from the base and one from each of two sidewalls), and a composite sample was prepared using five subsamples from the soil stockpile.[17] Each sample was analyzed for VOCs and total RCRA metals. Analytical results are presented in Table 4-2, and lithologic logs of test pits are presented in Appendix B.

Soil Borings

In addition to the soil borings drilled at the seepage pits, seven soil borings were drilled at locations that were originally identified in the RI/FS Work Plan. Locations are shown on Figure 4-1. Two angle borings were drilled on the West Parcel (AB-1 and AB-2), two angle and two vertical borings were drilled on the Middle Parcel (AB-3, AB-4, BH-1 and BH-2), and one vertical boring was drilled on the East Parcel (BH-3). Each angle boring was advanced to a total vertical depth of 53 to 63 feet, and most vertical borings were drilled to a depth of 5 feet above the estimated position of the water table. Some borings were terminated at a shallower depth due to drilling conditions.

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[16]The deeper borings were drilled at the same location as the initial borings. The initial boring numbering scheme was retained.

[17]Grab samples from test pit walls generally have suffixes of E, W, N, or S. The grab samples from the floor have depth designations only. At some shallow test pits, where the soil stockpile was small, the stockpile sample was a grab sample.

Soil samples at the auger borings were collected and analyzed for VOCs and total RCRA metals in conformance with the RI/FS Work Plan. Analytical results are presented in Table 4-2, and lithologic logs are included in Appendix B.

Hand Auger Sampling

On September 23, 1996, samples were collected inside the building on the Middle Parcel at locations HA-1 and HA-2 (Figure 4-1). The concrete floor was cored with a diamond bit, and samples were collected from approximate depths of 0.65 and 4.35 feet bgs using a hand auger and a drive sampler.

Two samples were collected at each of the two locations, and they were analyzed for VOCs and total RCRA metals. Analytical results are presented in Table 4-2.

Dye Test

On September 23, 1996, a dye test was conducted at the May Industries facility on the West Parcel to evaluate possible releases from a "trench drain" inside the production area. In the RI/FS Work Plan, an angle boring was originally proposed for this evaluation. However, due to space limitations, drilling was not feasible. Therefore, with the approval of the ADEQ, the dye test was conducted instead. Test results showed that the drain was connected to the sewer system, and the ADEQ did not require the angle boring.

4.3.2 Phase II Soil Investigation

Soil Borings

During Phase II, soil borings were drilled at three locations to more completely identify the extent of VOCs on the Middle Parcel:

- Seepage Pit ST3-SP1;
- Soil Boring BH-1; and,
- Soil Boring BH-2.

Three borings were drilled at each location, for a total of nine borings. The locations are shown on the site map (Figure 4-1) and on the detailed maps (Figures 4-6 and 4-7).

Locations for the Phase II borings were selected based on the results from the Phase I investigation and approved by the ADEQ. At all of these Phase II locations, VOCs had been detected in Phase I samples from soil borings. Earlier investigations by WCC, BCC, and the ADEQ were also a factor in selecting the area near soil boring BH-1 for additional investigation. Near BH-1, VOCs had been detected in soil-gas samples and shallow soil samples that had been collected during these earlier investigations using a hand auger.

The Phase II borings were advanced to a total vertical depth of 50 to 85 feet. In general, the soil borings were evenly spaced and located about 20 feet from the Phase I borings.

A total of 84 soil samples were collected and analyzed for VOCs from the Phase II borings. In accordance with the Phase II Work Plan, samples collected from the soil borings were not analyzed for heavy metals. Analytical results are presented in Table 4-2, and lithologic logs are included in Appendix B.

Pipe Investigation

A soil investigation was also conducted by GeoTrans at the location of two pipes on the Middle Parcel in conformance with the Phase II Work Plan, as amended. One of these pipes appeared to terminate at a concrete headwall on the south bank of the Grand Canal. It was traced from a point just inside the property line[18] to a point near the northwest corner of the main building on the Middle Parcel. A second, shorter pipe, was identified that was next to and parallel to the first pipe for part of its route. The second pipe extended from the on-site irrigation well to the main building. The locations of the pipes are shown on Figure 4-8.

The pipe that appeared to terminate at the canal may have been permitted by the SRP. On January 9, 1964, the SRP issued a permit to Research Chemicals to discharge water to the Grand Canal at a location that was near the 35th Avenue bridge over the Grand Canal. However, the observed location of the pipe does not match the permitted location; the observed location is about 750 feet west.

Where the pipes were uncovered, they were nearly identical in appearance. They had an off-white color and were constructed of transite cement. The outside diameters were approximately five inches, and the inside diameters were approximately four inches. They were buried 3.3 to 3.5 feet bgs.

A “plumber’s snake”, consisting of a flexible coiled cable with a radio transmitter on the distal end, was used to trace the paths of the pipes, beginning at the property line near the canal headwall. As the location of the pipes were traced, the overlying asphalt pavement was marked at 20 to 30-foot increments. Both pipes were traced to a point below a fenced enclosure located near the northwest corner of the main building.

The pipes could not be traced beyond the fenced enclosure. A pipe fitting or other obstruction prevented the “snake” from advancing. At the limit of its advance, the transmitter on the end of the “snake” was inside the fenced enclosure and about 1.5 feet from the outside wall of the main building under a concrete slab. A cooling tower, a water softener, and water treatment piping were located inside the fenced enclosure. Based on its appearance, the equipment was deteriorated and had been out of service for several years. A connection between the equipment and the piping was not visible.

Shallow excavations (Excavation Areas 1 through 5) were excavated to expose the piping (Figure 4-8). Four of the excavations, Excavation Area 1, 3, 4, and 5, were completed at the locations of pipe joints. In conformance with the Phase II Work Plan as amended, soil samples WW-1 through

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[18] The pipe that was uncovered inside the property line, south of the canal, is believed to be connected to the pipe that terminates at the canal headwall due to its alignment and position. However, access to excavate on the canal right-of-way was not obtained.

WW-4 were collected from underneath the pipe joints at the four locations. These samples were analyzed for VOCs and for total RCRA metals.

When the east pipe broke during the excavation of Excavation Area 2, water drained from the pipe. At the request of the ADEQ, GeoTrans also collected a sample of water during the pipe investigation. The water sample, which was collected from water standing in the excavation, was labeled PT-2L and was analyzed for VOCs.[19]

Analytical results from the GeoTrans pipe investigation are presented in Tables 4-1 and 4-2. Locations of samples are shown on Figure 4-8.

On January 12, 1998, SRP Field Services Crew excavated a concrete headwall located on the south bank of the Grand Canal, at 36th Avenue, north of Osborn Road. The headwall was removed as part of a mile-long dry-out and canal-lining project (between 35th Avenue and 37th Avenue). Upon exposure, approximately 15 lineal feet of a 4-inch transite asbestos pipe were found encased within the headwall. The drainpipe was located about 4 feet below the ground surface. The headwall was removed with a backhoe, but the excavation was limited to the headwall area and did not extend far enough to establish a link with the drainpipe investigated by GeoTrans. Prior to excavation and removal of the headwall, SRP Laboratory and Field Services Crew collected split samples of soil from beneath the drainpipe, and sludge and water from the drainpipe itself.

SRP collected soil samples from a depth of 2 feet below the drainpipe, using a hand auger. The soil samples did not show any stains, odor or other visible indications and/or appearance of contamination. Field-screening of soil samples with organic vapor analyzer was not conducted, based on screening conducted by Weston in the vicinity of that sampling location that did not detect any vapors in soil, sludge, or liquid samples.

Sludge samples were collected by SRP from the drainpipe, approximately every 5 feet to a total length of about 30 feet, where there was auger refusal that was attributed to the drainpipe being plugged or connected to a valve that probably controlled pipeline drainage into the canal. When sludge was pulled out from the pipe, water drained out at an approximate rate of 0.67 gallons per minute into plastic buckets. SRP collected water samples from the bucket.

The SRP analytical results are shown in Tables 4-1 and 4-2; corresponding laboratory reports are available in the ADEQ files.

4.4 RESULTS

4.4.1 Soil Characteristics

Soils that were encountered during the soil investigation were fairly uniform and consisted of silt, sandy silt, silty sand, and some sand. Some coarser-grained materials and caliche (calcium carbonate cement) were observed in deeper soil borings. Some gravel with a diameter that ranged

[19] The sample was collected by transferring aliquots of water from the excavation into two VOA vials using a clean 4-ounce laboratory-supplied glass jar. The sample was not collected directly from the pipe because the shallow excavation quickly filled with water when the pipe broke, submerging the end of the pipe.

from 0.2 to 3 inches was observed in soil boreholes, trenches, and test pits. The approximate diameter of gravel observed in seepage pits was two inches. Cobbles were encountered during the drilling of the boring at seepage pit ST4-SP-6.

Most soils were brown in color and were dry to moist. Typically, shallow soils in test trenches and test pits were dry. Increased moisture content was observed in soil borings near septic tanks, seepage pits, and beneath asphalt pavement. Some soils in the excavations near septic tanks ST-1, ST-2, ST-4 and ST-5 were stained.

Borings that were drilled for the soil investigation had a maximum depth of 90 feet, and in this interval, soils had some characteristics that were consistent. In general, the upper 40 to 50 feet of soils are finer-grained and contain a higher proportion of silty clay and silty sand than deeper soils, where more sand and gravel are present. However, in this upper 90-foot interval, individual soil layers could not be correlated over lateral distances of more than about 100 feet. In some instances, soil layers could not be correlated between borings as close as 20 feet. A summary of typical soil lithology based on soil borings is presented below, and additional detail is described in the boring logs in Appendix B.

Depth (ft bgs)	**Description**
0-40	Silty clay near surface; sandy silt and silty sand; brown;
40-55	Silty sand and sand; traces of gravel, some caliche; brown; and,
55-90	Sand and silt; weak to moderate cementation in places, gravel, some caliche; brown.

4.4.2 Phase I Analytical Results

Volatile Organic Compounds

A total of 168 original samples[20] from the Phase I soil investigation were analyzed for VOCs, with VOCs detected in 13 of the samples (7.7 percent). The following compounds were detected: trichloroethylene (TCE), tetrachloroethylene (PCE), and 1,1,2-trichloroethane (1,1,2-TCA). The Phase I soil investigation results are summarized in Table 4-1 and Table 4-2, and shown on Figures 4-2 through 4-5.

In the 13 samples in which VOCs were detected, TCE occurred most frequently and in the highest concentrations. TCE was measured in 12 of the samples of soil and septic tank contents at concentrations that ranged from 50 to 85,000 μg/kg. It was also detected at a concentration of 28 μg/L in the water sample that was collected from seepage pit ST4-SP10.

[20] Excluding duplicates and excluding samples that were re-analyzed using the toxicity characteristic leaching procedure (TCLP) after they were analyzed for total VOCs.

The other VOCs detected included PCE in five samples at concentrations ranging from 66 to 550 μg/kg, and 1,1,2-TCA in one sample at a concentration of 98 μg/kg.

The highest concentrations of TCE were measured in samples of septic tank contents. A sample of septic tank ST-3 contents contained 85,000 μg/kg of TCE. This sample was also analyzed for TCLP VOCs. Measured concentrations of TCE and PCE in the TCLP extract were 9.4 and 0.27 milligrams per liter (mg/L), respectively. Low levels of TCE were also detected in grab samples of septic tank contents from ST-1 and ST-2. No VOCs were detected in soil samples collected from excavations in native soils beneath the septic tanks after the septic tanks had been removed. Although soil gas samples did indicate the presence of VOCs around the septic tanks, the absence of TCE in soil samples suggests that large magnitude releases did not occur.

PCE was detected in samples collected from septic tank contents at ST-1 at concentrations of 66 and 92 μg/kg. And, except for the occurrence in the TCLP extract from ST-3, PCE was not detected in any other samples of septic tank contents.[21]

VOCs were detected in some samples that were collected from borings at seepage pits. TCE and PCE were detected in a sample collected from directly beneath the distribution box (ST3-DBOX) at concentrations of 2,700 and 550 μg/kg, respectively. However, no VOCs were detected in soil samples collected from a deep boring advanced in the same location. TCE was also detected in a soil sample collected from a boring at seepage pit ST3-SP-1 at a depth of 35 feet bgs, and PCE was detected in the 40-foot sample. The concentrations were 7,300 and 66 μg/kg, respectively.

VOCs were also detected in soil samples collected from borings BH-1 and BH-2. The concentrations of TCE collected from boring BH-1 at depths of 20, 40, and 70 feet bgs were 160, 61, and 920 μg/kg, respectively (Figure 4-6). The concentration of TCE was 50 μg/kg at a depth of 70 feet bgs in borehole BH-2 (Figure 4-7).

Metals

Wastewater Disposal Systems. All RCRA metals were detected in samples of waste (sludge, solids, etc.) from wastewater disposal systems in low concentrations. The following are the highest total concentrations of RCRA metals detected in sludge: 180 mg/kg silver, 19 mg/kg arsenic, 210 mg/kg barium, 0.78 mg/kg cadmium, 390 mg/kg chromium, 5,000 mg/kg mercury, 270 mg/kg lead, and 1.1 mg/kg selenium. A wastewater sample from Seepage Pit ST4 was found to contain only very low levels of arsenic, barium, cadmium, chromium, lead and selenium. Based on the TCLP results for all RCRA metals, the removed sludge and concrete were characterized as non-hazardous waste. The corresponding results are shown in Table 4-1.

Soil. A total of 154 soil samples collected from soil borings during Phase I at depths ranging from 0.65 to 90 feet bgs were analyzed for total RCRA metals. The corresponding analytical results are summarized in Table 4-2. Four or more heavy metals were detected in all of the Phase I soil samples. Silver, cadmium and selenium were detected in only few samples, and arsenic, barium, chromium and lead were detected in most samples. Except for arsenic, all metals were detected in concentrations substantially below their respective Arizona Residential Soil Remediation Levels (R-

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[21] PCE was not detected prior to TCLP extraction. However, for total VOC analysis, the sample had an elevated detection limit.

SRLs) and Non-Residential Soil Remediation Levels (NR-SRLs) as well as Groundwater Protection Levels (GPLs). Only at three locations, arsenic concentrations of 11 mg/kg, 12 mg/kg, and 16 mg/kg were slightly above the SRLs of 10 mg/kg, but still well below the GPL of 290 mg/kg.

4.4.3 Phase II Analytical Results

Volatile Organic Compounds

In the Phase II soil investigation, a total of 72 original soil samples[22] were analyzed for VOCs, and VOCs were detected in 20 samples (28 percent). Analytical results are presented on Table 4-2, and they are also summarized on Figures 4-6 through 4-8.

Three VOCs were detected in Phase II soil samples: TCE, PCE, and 1,1-dichloroethylene (1,1-DCE). TCE was detected in the most samples (20) and in the highest concentrations. PCE and 1,1-DCE were detected in one Phase II sample, a water sample that was collected during the pipe investigation.

Of the 20 samples in which TCE was detected, 18 were collected from borings drilled in the vicinity of BH-1. The other two samples were collected from borings drilled in the vicinity of BH-2. The concentrations of TCE in samples collected from the three borings near BH-1 ranged from 15 to 510 µg/kg. The concentrations of TCE in four of these samples were below the laboratory detection limit of 50 µg/kg, and the laboratory estimated these concentrations at the request of GeoTrans.

TCE was also detected in two samples collected from soil boring BH-2-103, which was drilled in the vicinity of BH-2. The concentrations of TCE in samples collected at depths of 70 and 80 feet bgs, were 33 and 9.9 µg/kg. These concentrations are below the laboratory detection limit and were estimated by the laboratory at the request of GeoTrans.

Pipe Investigation

TCE was detected in three samples collected by GeoTrans from trenches that were excavated during the pipe investigation: WW-2, WW-3, and WW-4. The concentrations ranged from 57 to 61 µg/kg.

TCE, PCE, and 1, 1-DCE were also detected in sample PT-2L at concentrations of 52, 6.0, and 3.2 µg/l. This sample was collected from water that had pooled in the shallow test trench. Therefore, soil was a possible source of VOCs. To test this hypothesis, HSI GeoTrans conducted a simple bench test. On December 29, 1997, an additional shallow soil sample, PH-101-2.5, was collected from a depth of 2.5 feet in the vicinity of sample PT-2L using a posthole digger. A portion of this soil sample was analyzed for VOCs, and a water sample, PH-101-H20, was prepared by mixing distilled water with the remainder of the soil sample at an approximate ratio of 1:1. After allowing an approximately 15-minute contact time,[23] the water sample was decanted from the mixture for VOC analysis.

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[22]Excluding duplicates, the water sample from the pipe, and bench-test samples from the pipe investigation.

[23]This is the estimated contact time of the water from the pipe with soil in the test trench prior to collecting the sample PT-2L.

TCE was detected in the soil sample PH-101-2.5 at a concentration of 47 μg/kg, which is only slightly less than the concentrations in other shallow soil samples that were collected during the pipe investigation. TCE and PCE were detected in water sample PH-101-H20 at concentrations of 5.3 and 1.4 μg/L, respectively, showing that soil could have been a source of some TCE in sample PT-2L.

The soil collected by SRP from beneath the pipe, and sludge and water samples collected by SRP from the pipe itself did not contain any VOCs in concentrations above their respective detection limits.

Metals

In Phase II, the only samples that were analyzed for metals were the samples from the pipe investigation by GeoTrans. The following metals were detected: arsenic, barium, cadmium, chromium, and lead (Table 4-2). All metals were detected in concentrations below their respective SRLs and GPLs. The only exception is arsenic, which was detected at two locations in concentrations of 11 mg/kg and 12 mg/kg, which is above the SRLs of 10 kg/kg, but well below the GPL of 290 mg/kg.

4.4.4 Post-Phase II Soil Sampling

In 1999, 17 near-surface soil samples collected by Weston were analyzed for VOCs and total RCRA metals; three of the 17 samples were also analyzed for Cr^{+6} content. VOC were not detected in any of the collected samples. Cadmium, mercury, and silver were not detected in any of the samples, and Cr^{+6} was not detected in any of the three samples analyzed. Selenium was detected in one sample only in a concentration slightly above its detection limit. Barium, total chromium and lead were detected in concentrations well below their respective R-SRLs and NR-SRLs. Arsenic was detected in 15 out of 17 samples in concentrations below the SRLs of 10 mg/kg; in two samples, arsenic was detected in concentrations of 11 mg/kg and 120 mg/kg, thus above the SRLs. It should be noted that the sample containing the anomalously high concentration of 120 mg/kg arsenic was collected east of Building #2. Additional samples collected in that area either did not contain any arsenic in concentrations above the laboratory detection limit or arsenic was detected in concentrations below the SRLs.

4.4.5 Quality Assurance/Quality Control Samples

During Phase I and Phase II soil investigation, quality control/quality assurance (QA/QC) samples were collected consisting of field blanks, equipment rinsate blanks, trip blanks, and site-specific matrix spike/matrix spike duplicate (MS/MSD) samples.[24] All QA/QC was conducted following the protocols defined in the RI/FS WorkPlan and its attachments.

A total of 34 field and rinsate blanks were collected during the combined soil investigation. No VOCs were detected in the field blanks. Low levels of total trihalomethanes, an artifact of disinfection by chlorination, were the only VOCs that were detected in rinsate blanks.[25] No heavy

[24]The laboratory also prepared and analyzed laboratory method blanks, and laboratory control samples.

[25]Trihalomethanes are common in bottled water supplies in the Phoenix area. Bottled-water suppliers wash reusable 5-gallon plastic water bottles and disinfect them with a chlorine solution. Chlorine reacts with either the bottle or with residual detergent to create chloroform, bromodichloromethane, and dibromochloromethane. Trihalomethanes are also present in the

metals were detected in any of the rinsate blanks. In addition, 22 trip blanks were analyzed for VOCs. No VOCs were detected in any of the trip blanks.

Laboratory duplicates and method blanks were collected, prepared, and analyzed. Twelve samples were collected in triplicate to provide MS/MSD samples for the laboratory. Results of laboratory QA/QC analyses indicate acceptable control of laboratory procedures.

4.5 NATURE AND EXTENT OF SOIL CONTAMINATION

The results of the extensive soil sampling and analyses detailed in Section 3.1, 4.3 and 4.4 indicate that the soil contamination at the WOC was due to VOCs. Except for a few samples with arsenic concentrations slightly above the SRLs (but still well below the GPLs), heavy metals were not detected in soil in concentrations greater than SRLs and/or GPLs.

4.5.1 Distribution Trends of Metals in Soil

A total of 257 soil samples collected from soil borings at all three parcels were analyzed for total RCRA metals. These soil borings were collected to depths up to 90 feet bgs. All RCRA metals, were detected in concentrations well below their respective NR-SRLs, R-SRLs and GPLs. The only exception is arsenic, which exceeded the SRLs of 10 mg/kg in a total of eight samples; two near-surface samples (11 and 120 mg/kg[26]), two test pit grab samples (12 and 13 mg/kg), two samples from underneath pipes (11 mg/kg and 12 mg/kg), one deep boring sample (12 mg/kg), and one test trench sample (12 mg/kg). All these concentrations are however, below the GPL of 290 mg/kg. The following is a summary of the highest total concentrations of each RCRA metal detected in soil:

- Silver: 51 mg/kg at 35 feet bgs from Seepage Pit boring (R-SRL 380 mg/kg, NR-SRL 8,500 mg/kg, GPL not established);
- Arsenic: 12 mg/kg at 6 to12 inches bgs east of Building #2 (R- and NR-SRL 10 mg/kg, GPL 280 mg/kg) (Note: the detected concentration of 120 mg/kg, detected by Weston during post-Phase II sampling for risk assessment purposes is considered anomalously high - see Section 7.0);
- Barium: 170 mg/kg at 20 feet bgs from Angle boring AB-1 located west of Test Trench-1 (R-SRL 5,300, NR-SRL 110,000 mg/kg, GPL 12,000 mg/kg);
- Cadmium: 2.7 mg/kg at 50 feet bgs from Seepage Pit 8 boring (R-SRL 38 mg/kg, NR-SRL 850 mg/kg, GPL 29 mg/kg);
- Chromium: 200 mg/kg in sample ST1-Base located at 10 feet bgs from base of Septic Tank 1 excavation (R-SRL 2,100 mg/kg, NR-SRL 4,500 mg/kg, GPL 590 mg/kg);
- Mercury: 2.2 mg/kg at 10 feet bgs from base of Septic Tank 1 excavation (R-SRL 6.5 mg/kg as methyl mercury, NR-SRL 68 mg/kg as methyl mercury, GPL 512 m/kg);
- Lead: 120 mg/kg at a depth of 35 feet bgs from Seepage Pit 1 boring; and,

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municipal water systems.

[26]This sample is considered anomalous and is not considered as part of the distribution trend.

- Selenium: 16 mg/kg at a depth of 40 feet bgs from boring BH-2 located directly south of the oil/water separator.

The above results of extensive soil sampling activities at the WOC by BCC and GeoTrans showed concentrations of total RCRA metals that are too low to be indicative of any source areas that would impact the groundwater beneath the Site.

The results of the extensive soil sampling and analyses detailed in Sections 3.1, 4.3 and 4.4 indicate that metals contamination in soil is not an issue at the WOC. Heavy metals were not detected in soil in concentrations greater than SRLs or GPLs. With the exception of two samples (TT1-SS1 and ST1-Base) from native soils directly beneath former wastewater disposal system with slightly elevated concentrations of Total Cr, 100 mg/kg and 200 mg/kg respectively, native soil samples and soil at depth in soil borings were at or less than reasonably estimated background concentrations for all metals.

4.5.2 Distribution of VOCs

VOCs were only detected in soil samples collected from the Middle Parcel at the WOC, and only one potential source area was clearly identified: the septic tank system ST-3, which is on the south side of the Middle Parcel (Figures 4-1 and 4-4). VOCs were detected in lower concentrations in two other septic tanks residue, ST-1 and ST-2, but no VOCs were detected in the angled soil borings completed adjacent to the tanks, AB-1 and AB-3, and AB-2 and AB-4, respectively. Low concentrations of TCE were also detected in the northwest corner of the Middle Parcel associated with the pipe investigation (see Section 4.4.3 and Figure 4-8).

At septic tank ST-3, TCE and PCE were detected in the septic tank contents, in a shallow (3-foot) soil sample collected at the septic tank distribution box, and in the shallowest soil samples (35- and 40-feet bgs) from seepage pit ST3-SP1. VOCs were detected in only the shallowest soil samples, in apparent association with the highest concentrations of organic matter (the sample of septic tank contents at ST-3 consisted of dried sludge). VOCs were not present in any of the deeper soils that were sampled in Phase II borings in the vicinity of septic tank ST-3 (Figure 4-7).

Based on the soil samples collected from boreholes BH-1, BH-1-101, BH-1-102, BH-1-103 drilled in the northern portion of the Middle Parcel VOCs were present in soils at other locations on the Middle Parcel, but the distribution is inconsistent with a surface source. This conclusion is based on the vertical and lateral distribution of TCE in the boreholes and the relationship of the TCE to soil properties. In all of these borings except BH-1-103 the highest concentrations of TCE were measured in the moist, finer-grained soil close to the water table, at depths of 70 to 90 feet bgs. In shallower soil, concentrations were about one order of magnitude lower (Figure 4-6).

The nearly uniform concentration of TCE in many of the shallow soil samples in the north part of the Middle Parcel is also inconsistent with a surface disposal source. In four out of the five samples that were collected during the pipe investigation, TCE was measured at concentrations that varied from only 52 to 61 µg/kg over a length of more than 100 feet (Figure 4-8). These concentrations were similar to the concentrations that were measured in the shallow samples from borings BH1-101 and BH1-103 immediately to the east of the pipe investigation. In 9 out of 10 samples that were collected in the 10- to

30-foot interval in the northern portion of the Middle Parcel, TCE was detected at an average concentration was 67 µg/kg (Figure 4-6).

It is believed that volatilization and subsequent vapor transport from a shallow groundwater source is a more likely explanation for the observed lateral and vertical distribution of TCE concentrations from soil in the north part of the Middle Parcel. A shallow groundwater source with soil vapor transport is also consistent with the higher concentration of TCE in the deeper soil samples, and the similarity of concentrations in shallow soil samples.

The recent changes in the concentrations of TCE in groundwater at the Middle Parcel also support the concept that TCE in the shallowest part of the saturated zone and in the capillary zone is the main source of the TCE that has been measured in monitor wells. When the Grand Canal was lined (January 1998), groundwater levels at the Middle Parcel immediately declined, and at the same time, concentrations of TCE in monitor wells declined. At MW-4S, the TCE concentration decreased from more than 100 µg/L to less than 10 µg/L from November 1997 to February 1998 while the depth to groundwater increased from 91 feet to 101 feet over the same time period. TCE that was formerly in the shallow groundwater and in the capillary zone was now trapped in the vadose zone. Because no continuing sources of TCE to groundwater are present, concentrations in the on-site shallow monitor wells decreased as groundwater levels decline and a portion of the dissolved TCE in the groundwater is sorbed onto vadose zone soils.

4.5.3 Fate and Transport of VOCs in the Vadose Zone

The fate of VOCs in the vadose zone at the WOC includes the following:

- Sorption on soil particles, where the VOCs may become relatively immobile and resistant to degradation;
- Dissolution in soil water and migration to the water table, where the VOCs become incorporated into groundwater; and,
- Volatilization in soil gas, with subsequent migration to the water table or to the atmosphere.

Volatilization is a potential transport mechanism for VOCs in the vadose zone, and there is evidence that soil-vapor transport is responsible for the observed occurrence of TCE in low concentrations in the vadose zone on the north part of the Middle Parcel. The observed lateral and vertical distribution of TCE in shallow soil is consistent with a soil-vapor source.

Dissolution into soil water and migration to groundwater is the final fate and transport mechanism for VOCs in soil at the WOC. Based on the observed relationship between water levels and TCE concentrations in on-site wells, this mechanism is responsible for observed groundwater contamination. However, when the Grand Canal was lined, the only local source of groundwater recharge was eliminated, greatly reducing the future significance of this mechanism. Because of the very high evapotranspiration rate in the Phoenix area, there is virtually no infiltration from precipitation other than in major washes or stormwater retention/detention basins.

4.6 MANAGEMENT OF INVESTIGATION-DERIVED WASTE

Investigation-derived wastes generated during the soil investigation included septic tank contents, concrete septic tanks, and cuttings from soil borings. All waste materials were handled according to the guidelines established in the RI/FS Work Plan and attachments.

Septic Tank Contents

Sludge samples were collected from the septic tanks and analyzed for total VOCs, TCLP VOCs, total RCRA metals, and TCLP RCRA metals. Analytical results are presented in Table 4-1. The contents of septic tanks ST-1, ST-2, ST-4, and ST-5 were profiled as non-hazardous septic tank fill material. Approximately 52 tons of material was disposed at Waste Management, Inc.'s (WMI) Butterfield Station Landfill. With the exception of septic tank ST-3, the contents of the septic tanks were handled as a non-hazardous waste.

Septic tank ST-3 exceeded RCRA TCLP standard for TCE and was disposed of as a hazardous waste. Approximately four cubic yards of hazardous material was disposed of at Chemical Waste Management's (CWM) Trade Waste Incinerator near Sauget, Illinois. Manifests and documentation of disposal are included in Appendix G.

Concrete Septic Tanks

Most excavated concrete septic tanks were profiled for disposal using the results of each tank's respective contents. Two samples of the concrete were collected from each chamber of septic tank ST-3 for additional testing. These samples were collected as broken pieces of concrete, stored for three days on dry ice, and then shattered and pulverized with a hammer. The samples were analyzed for VOCs and RCRA metals. A third sample from the remains of the concrete distribution chamber was prepared in the same manner.

Analytical results of the concrete samples indicated that the septic tank concrete could be disposed of as non-hazardous waste. Except for septic tank ST-4, which was not removed, septic tank concrete was disposed at WMI's Butterfield Station Landfill. Analytical results are presented in Table 4.1. Copies of profiles and waybills are included in Appendix G.

Soil Cuttings

Soil cuttings generated from soil boring activities were stored in 55-gallon, steel drums. Analytical results of soil samples collected during the soil boring program indicated that the cuttings could be disposed of as non-hazardous waste. However, soil samples collected from three boring locations, BH-1, ST3-SP1, and VB-BOX, contained VOC concentrations that exceeded RCRA regulatory limits (after allowing for a 20X dilution). In order to profile the soil from these three locations, three composite samples were collected from the drums containing soil from each location. Analytical results of the composite samples indicated that the soil cuttings could be disposed as non-hazardous waste. The analytical report is included in Appendix G.

4.7 EARLY RESPONSE ACTION

Soil vapor extraction (SVE) was conducted as an Early Response Action (ERA) at the WOC to remove the contamination in the source area. The SVE operation activities are discussed in Section 6.

5.0 GROUNDWATER INVESTIGATION

5.1 APPROACH

The groundwater investigation at the WOC under the direction of UIC has included the drilling and installation of 24 monitor wells and the sampling and monitoring of over 35 monitor wells. Additional activities have included geophysical logging associated with the drilling, and hydraulic testing. The results from these activities have been used to identify the vertical and horizontal distribution of VOCs in groundwater, characterize the lithology of soils, and measure the hydraulic properties of the saturated zone.

RI monitor wells were installed by UIC in multiple phases, which occurred from July 1996 through May 2003. In 1996, the original 10 monitor wells, MW-6S, MW-7S, MW-2M, MW-3M, MW-4M, MW-6M, MW-7M, MW-4L, MW-6L and MW-7L, were constructed at locations that were designated in the Consent Decree and Work Plan. During October to December 1997, nine additional wells, MW-100S, MW-101S, MW-102S, MW-103S, MW-104S, MW-102M, MW-105M, MW-106M and MW-13M, were constructed at locations that were selected with the approval of the ADEQ. Since December 1997, five additional monitor wells, including MW-201S, MW-107M, MW-108M, MW-109M and MW-110M were installed as part of defining the lateral extent of the TCE impacts to the shallow or regional aquifer.

As previously mentioned, BCC had installed five shallow monitor wells, MW-1S, MW-2S, MW-3S, MW-4S and MW-5S, prior to UIC's work. Including these five wells, a total of 29 wells have been used to investigate and monitor potential contaminant impacts to the groundwater. Depths of the 29 RI monitor wells range from 103 to 810 feet bgs, and they monitor three different levels in the saturated zone: shallow, LSGS, and deep (S, M, and L suffixes, respectively). Well construction data are summarized on Table 5-1. Records of drilling, well construction, lithologic logging, and geophysical logging are included in Appendix F. All of the monitor wells installed by UIC are shown on Figure 2-2.

Two of the wells, MW-100S and MW-101S, were installed as recovery wells. These were constructed as shallow wells, completed to a depth of approximately 140 feet bgs. Because they are located immediately adjacent to MW-5S (Figure 2-1), they were not incorporated into the groundwater monitoring program. Although limited sampling of them has since occurred, the wells have never been utilized as recovery wells.

During much of the RI, the monitor wells have been sampled quarterly and water levels have been measured monthly.[27] The monitoring program has included the following wells: (1) the 29 wells listed above, (2) various wells that were drilled by the ADEQ as part of its WCP-WQARF groundwater monitoring program, and 3) the WOC Irrigation Well. WCP wells sampled include WCP-3, WCP-4, WCP-8, WCP-10, WCP-11, WCP-12, WCP-13, WCP-14 and WCP-15. Most of the WCP wells were sampled numerous times during the 1996 to 1999 time frame. Sampling of

[27] Water levels have generally been measured at maximum intervals of one month. During early 1998, immediately after the Grand Canal had been lined, water levels in some wells were measured at an increased frequency.

some was discontinued, because they were on the north side of the Grand Canal, and therefore up-gradient, while sampling of others was discontinued because, similar to WOC shallow wells, they went dry after the lining of the Grand Canal. Construction data for these additional wells are summarized on Table 5-2, and locations are shown on Figure 2-2.

In accordance with the Consent Decree, GeoTrans also completed aquifer tests. A total of six, short-term, constant-rate discharge tests were conducted at the three MW-6 wells (MW-6S, MW-6M and MW-6L) and the three MW-7 wells (MW-7S, MW-7M and MW-7L). A 24-hour, constant-rate, test was conducted at MW-5S, an on-site well that was constructed by BCC. Pumping rates for these aquifer tests varied from 1.5 to 76 gpm.

The procedures for constructing, sampling, and testing the monitor wells are explained in the following sections.

5.2 PROCEDURES

5.2.1 Well Drilling and Construction

All of the RI monitor wells installed by UIC were drilled by Stewart Brothers Drilling Company using a mud-rotary drilling system. Wells were drilled in accordance with the procedures outlined in the Consent Decree and in accordance with the regulations of the ADWR.

At each well location, a 6-inch pilot hole was drilled for lithologic characterization and geophysical logging. At all pilot holes, soil lithology was characterized using samples of drill cuttings. At MW-7, soil lithology was also characterized using relatively undisturbed soil samples that were collected at 25-foot intervals using a split-barrel drive sampler. All soil samples were screened with a flame ionization detector (FID) for the presence of VOCs. None were detected in any of the soil samples.

The total depths of the pilot holes were selected on the basis of the planned well completion depths, the lithology observed during drilling, and the lithologic characteristics of nearby wells. Where only shallow wells were constructed, pilot holes were 155 to 180 feet deep. At locations where deep wells were constructed, pilot holes were more than 800 feet deep.[28]

After the pilot holes were drilled, they were logged by Southwest Geophysical Surveys typically using natural gamma, neutron, caliper, resistivity, single-point resistance, and self-potential downhole geophysical tools. Wells MW-108M, MW-109M and MW-110M were also logged using the Guard Log which is a focused resistivity log. Lithologic logs, geophysical logs, well completion logs, and well construction diagrams for all of the RI wells are included in Appendix A. Construction procedures are described below.

[28]Pilot holes were drilled at five locations where only LSGS and not deep wells were installed. Depths ranged from 325 feet at MW-106 to 450 feet at MW-102M.

S-Series Wells

S-series wells are shallow water-table monitor wells that were constructed with 4-inch (nominal) casing and screen in a 10-inch borehole. Well screen extends from approximately 10 feet above the water table to 30 feet below the water table. At locations where no M- or L-series well was constructed, the S-series wells were completed after the pilot hole was geophysically logged and reamed. At other locations, the S-series well was constructed in a new borehole.

Two types of casings and screens were used. For Phase I, wells were constructed with low carbon steel (LCS) blank casing and stainless steel (SS) wire-wrap screen, with a 0.040-inch slot aperture. Phase II monitor wells were completed with Schedule 40, plastic PVC casing and screen. PVC screen has a 0.020-inch slot aperture.

Annular materials were placed with a tremie pipe. Silica sand was placed to a depth of approximately 5 feet above the top of the screen, approximately 5 feet of bentonite was placed on top of the sand pack, and the annulus of the hole was grouted to within approximately 1.5 feet of the surface. Wells were completed in a traffic-rated, tamper-resistant well vault.

Recovery wells MW-100S and MW-101S were constructed similar to S-series monitor wells with some exceptions. Casing and screen are 5-inch (nominal), Schedule 80 PVC, and a 10-foot long section of blank casing was installed below the well screen as a sediment sump.

M-Series Wells

All M-series wells were completed with 40 feet of screen in the LSGS subunit of the UAU. The depth to this aquifer was picked from lithologic logs and geophysical logs. Figure 5-1 shows the typical and distinctive geophysical signature of the LSGS subunit.

M-series wells were constructed with two casing strings. An 8-inch diameter, intermediate string of blank LCS casing was seated in a 12-inch borehole about 20 feet above the top of the LSGS subunit. After it was grouted in place, a 7.875-inch bit was used to advance a borehole to the base of the LSGS subunit. A 4-inch (nominal) string of casing and screen[29] was set from the bottom of the hole to the ground surface. Annular materials were placed by tremie pipe, an at-grade vault was set, and the annulus between the casing strings was sealed with a cement grout.

L-Series Wells

Three L-series wells, MW-4L, MW-6L, and MW-7L, were installed to an approximate depth of 800 feet during the initial phase of the groundwater investigation in accordance with the Consent Decree and the Work Plan. No additional L-series wells were installed.

L-series wells were also constructed with two casing strings. An 8-inch (nominal), LCS casing string was cemented into a 12-inch borehole at a depth of about 20 to 25 feet below the base of the LSGS subunit. A 7/8-inch borehole was drilled to total depth, and 4-inch (nominal) LCS casing and

[29]LCS casing and SS 0.040-inch slot screen were used for Phase I. PVC casing and PVC 0.020-inch slot screen were used for Phase II.

0.04-inch slot SS screen were installed from the bottom of the hole to ground surface. Annular materials were placed by tremie pipe, the annulus between the casing strings was sealed with a cement plug, and an at-grade vault was set.

5.2.2 Monitor Well Development and Pump Installation

Monitor wells were developed in accordance with the Consent Decree and Work Plan. Phase I monitor wells were developed using a submersible pump, a bailer, and air lift. Initially a submersible pump and bailer were used; however, due to low yields and relatively great depths of some Phase I wells, the method was inefficient. Eventually, all the Phase I wells were developed by air lifting. Dual-tube air lift systems were used at deep and LSGS wells, and shallow wells were developed using a single air line. Phase I monitor wells were developed until purge water was clear and more than 2,500 gallons of water had been purged from each well.

Phase II monitor wells were developed in two stages. The well driller initially bailed drilling mud from the well after the sand pack was placed, but prior to the placement of the bentonite seal and/or grout. After the drill was demobilized, the wells were re-developed by a pumping contractor with a submersible pump. The pump was raised and lowered in the well, surging and purging the well simultaneously. Phase II monitor wells were developed until the purge water was relatively clear and more than 1,500 gallons of water had been pumped from each well.

At LSGS and deep wells, dedicated sampling pumps were installed after development was completed. Sampling pumps are 0.5-horsepower (hp) SS submersible pumps that are installed on steel drop pipe at a depth of approximately 5 feet above the screened section of each well.

To reduce the volume of water that must be purged prior to sampling, packers were installed approximately 3 to 10 feet above the pumps in the LSGS (M) and deep (L) wells. Packers are inflated with nitrogen prior to each purging and sampling event, and they are deflated between sampling events to eliminate unnecessary strain and to allow accurate measurement of water levels. During sampling, water levels above the packers are monitored to verify that packers are not leaking.

At wells with packers (see Table 5-1), check valves in pumps were perforated or removed to minimize problems with air-locking. Original pump motors at some LSGS and deep wells were also replaced with more rugged motors after the initial sampling event.

5.2.3 Management of Investigation-Derived Waste

Investigation-derived waste (IDW) that was produced during the groundwater investigation included drill cuttings, drilling mud, purge water, and development water. Each was managed differently.

Drill cuttings were contained in end-dump semi-trailers and in roll-off bins at the drill site. As each trailer or bin was filled, a sample was collected and analyzed for VOCs and RCRA metals. As results became available,[30] cuttings were transported off-site. They were either disposed of as unregulated fill dirt at CalMat's 16th Street Landfill or were mixed with road base by Diversified

[30]No VOCs were ever detected in samples of drill cuttings or drilling mud. Concentrations of RCRA metals were always less than RCRA standards and SRLs.

Environmental for use in various road construction projects. All disposal procedures were approved by the ADEQ.

Purge and development water was contained in 20,000-gallon Baker tanks at the well construction staging area at the Middle Parcel.[31] When a tank was full, a water sample was collected and analyzed for VOCs and other analytes that are required by the City of Phoenix (COP) for approval for discharge into the sanitary sewer system. VOCs were detected in low concentrations in a few samples, but concentrations were always lower than the COP limits for direct discharge. Manhole entry permits were obtained from the COP for each batch of water as it was produced. With the approval of the ADEQ, water was discharged to a manhole on the West Parcel.

As drilling mud was generated, it was stored at the Middle Parcel in a Baker tank. Water was decanted and sampled in accordance with the requirements of the COP. After approval for disposal was obtained, the water was disposed of in the COP sanitary sewer under a manhole entry permit. Mud solids were transferred from the Baker tank to a lined and bermed drying area. After it dried, it was analyzed for VOCs and RCRA metals and, with the approval of the ADEQ, it was disposed of as unregulated fill dirt.

No IDW was hazardous waste. Laboratory results for IDW analyses, manhole entry permits, and related IDW documentation are included in Appendix F.

5.2.4 Water Sampling and Water-Level Measurements

As of February 2004, GeoTrans has completed 15 rounds of groundwater monitoring and sampling at the WOC. Five sampling rounds were completed in 1996 and 1997 prior to the lining of the Grand Canal. In addition, the Grand Canal was sampled three times over the period from 1996 to 1997 time period at the upstream and the downstream boundaries of the WOC.

In accordance with the Consent Decree, all groundwater samples have been analyzed for VOCs using U.S. EPA Method 601/602. The first round of samples, which were collected in November 1996 from the MW-1 through MW-7 series of wells were also analyzed for selected inorganic compounds including nitrate, ferrous iron, sulfate, sulfide, chloride, and indicator parameters including dissolved oxygen, alkalinity, total organic carbon, pH, and oxidation-reduction potential. Additional rounds of most of these parameters were also collected in June 2001, September 2003 and January 2004. The initial rounds were largely sampled in support of potential water treatment designs, the latter rounds were for the analysis of natural attenuation or biodegradation. All of the inorganic chemistry and indicator parameter results are provided in Appendix J (Tables J-1 and J-3).

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[31] Water trailers, water trucks, and poly tanks were used for interim water storage at well sites and for transporting water to the Baker tanks.

Groundwater Sampling and Measurements

Monitor wells were measured and sampled in accordance with the procedures outlined in the Consent Decree and the Work Plans. These procedures are summarized below. Additional detail is provided in the Work Plan (HSI GeoTrans, 1996).

At all wells, water levels were measured and recorded prior to purging. The depth to water was measured from a surveyed point on the north side of the casing or sounding tube. If it was not known, the depth of the well was also measured, and the height of the water column was used to calculate the single casing purge volume.[32]

LSGS wells were purged using a dedicated 3-inch submersible sampling pump that was powered by a portable electric generator.

Shallow wells have been purged using either a 2-inch variable frequency, submersible pump or 3-inch disposable bailer. Wells were purged until field parameters (pH, conductivity, temperature, and turbidity) stabilized and/or until a minimum of three well volumes was removed. Purge water was collected in a mobile 500-gallon water wagon and then transferred to either a 20,000-gallon Baker tank or smaller-capacity polyethylene tanks for storage at the Middle Parcel prior to sampling and disposal into the COP sanitary sewer system.

After purging the LSGS wells, samples were collected at the well head from the pump discharge line. For S-series wells, after purging, samples were collected using disposable bailers in accordance with the Consent Decree and Work Plan, except at the three ADEQ wells, WCP-10, WCP-11 and WCP-13, that were initially purged and sampled with dedicated pumps. For VOC analysis, samples were collected in two, 40-milliliter (ml), VOA vials. Duplicate samples were collected for evaluating laboratory QA/QC procedures in accordance with the Consent Decree and Work Plan. For the first round of samples, samples from MW-1S, MW-2S, MW-3S MW-4S, MW-5S, MW-6S and MW-7S were also collected in 500-ml and 1-liter glass and polyethylene bottles for analysis of select inorganic compounds (see Appendix J, Table J-1). All sample bottles were supplied by the laboratory.

After each sampling event, the pump and discharge tubing were decontaminated. The pump decontamination procedure was as follows: the pumps were submerged in a 55-gallon drum containing a solution of laboratory detergent (Alconox) and tap water. After the pump was run for 15 minutes, the assembly was placed in a second drum containing tap water. In the second drum, sufficient water was pumped to completely purge several rinse volumes. In accordance with the Consent Decree and Work Plan, rinse blanks and field blanks were collected for evaluating field decontamination QA/QC procedures.

Surface Water Sampling

In May 1996, November 1996, and November 1997, samples were collected from the Grand Canal. SW-1 was collected upstream (east) of the WOC property, and SW-2 was collected on the downstream (west) side. The samples were collected from the canal using a disposable bailer.

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[32] At wells equipped with packers, the purge volume is fixed and is the volume of water between the packer and the bottom of the well.

5.2.5 Laboratory Procedures

Del Mar Analytical (Del Mar) and Precision Analytical Laboratories analyzed all samples collected during the RI. Whenever possible, samples were delivered to the laboratory at the end of each day of sampling. Otherwise, samples were stored in GeoTrans' sample refrigerator for delivery the next business day.

For Phases I and II, Del Mar analyzed the collected samples for VOCs using EPA Method 601/602. During the first sampling round, water samples were also analyzed for the inorganics and indicators listed in Table 5-3.

5.2.6 Aquifer Testing Procedures

As stated in Section 5.1, seven constant-discharge aquifer tests were conducted during the groundwater investigation in accordance with the Consent Decree and Work Plan. Six tests were conducted at each of the three monitor wells at the MW-6 and MW-7 clusters. A comprehensive description of testing procedures and results at these wells was reported in *Field Report and Aquifer Testing Proposal, Phase I Remedial Investigation/Feasibility Study, West Osborn Complex Facility, Phoenix, Arizona* (HSI GeoTrans, 1997a) previously submitted to ADEQ. The seventh test was conducted at BCC monitor well MW-5S.

Tests were conducted with electric submersible pumps, discharge was measured with a flowmeter, and water levels during testing and recovery were measured both manually and electronically. Pumping rates were selected to attempt to achieve at least several feet of drawdown without dewatering the well or the aquifer. Selected pumping rates for the constant-discharge tests are listed in Table 5-4.

Water that was produced during testing was disposed of to the COP sanitary sewer. At MW-6 and MW-7, water was temporarily contained at the well site in a water wagon. The filled water wagon was pumped into a 20,000-gallon Baker tank at the Middle Parcel. At the end of testing, the water in the Baker tank was sampled for disposal approval from the COP, and was subsequently discharged under a manhole entry permit to the sanitary sewer system. Water produced during testing at MW-5S was discharged directly to the COP sanitary sewer under a manhole entry permit.

Aquifer test data were analyzed with the assistance of commercial software: AQTESOLV™ (Duffield and Rumbaugh, 1989) and the Well Hydraulics Interpretation Package, or WHIP™ (Hydro Geo Chem, 1987). The Cooper-Jacob straight-line method (Cooper and Jacob, 1946), Kruseman and De Ridder's correction for reduction in saturated thickness for unconfined aquifers (Kruseman and De Ridder, 1979), Theis method (Theis, 1935), and Theis recovery methods (Theis, 1935) were used to analyze the data. Time-drawdown graphs are presented in Appendices D and E.

5.2.7 Surveying

Wells were surveyed by Landmark Engineering and Surveying, Inc., a registered land surveyor, to measure the elevation with respect to mean sea level. Elevations were based on a City of Phoenix benchmark. The horizontal positions of wells were measured with respect to nearby physical features.

The Grand Canal was surveyed in January 1997 by staff from GeoTrans. About one year after the survey was completed, the SRP lined the canal with gunite, which changed its configuration. The results of the survey are presented in Appendix I.

5.3 AQUIFER HYDRAULIC PROPERTIES

The transmissivity of the saturated zone at the WOC is highly variable. Values derived from the aquifer tests range from 3 to 14,000 ft^2/day. These results are summarized on Table 5-5, and drawdown data are presented in Appendices D and E. Results are discussed in the following sections.

5.3.1 Shallow Water-Table Aquifer

Average transmissivity values for the shallow water-table aquifer at the WOC range from 350 ft^2/day at MW-7S to 7,500 ft^2/day at MW-6S. At MW-7S, recovery data are considered more representative than drawdown data. At MW-5S and -6S, drawdown and recovery data are considered approximately equally representative.

Results from the tests at MW-7S and MW-6S are reasonable and correlate with the lithologic characteristics of the screened intervals. Lithologic and geophysical logs show that MW-6S is screened across a coarser-grained part of the UAU than MW-7S. The results from MW-7S are similar to results obtained from BCC's tests at on-site wells.

Results from MW-5S are considered to be under-representative, even though the test at MW-5S was the longest of any that were conducted at the WOC (24 hours). The yield of the MW-5S well is low compared to observed yields at nearby wells, MW-100S and MW-101S. When MW-100S and MW-101S were developed after drilling, they could be pumped at rates of more than 10 gpm with only small drawdown. However, MW-5S could not sustain a pumping rate of 10 gpm during a pretest, and the aquifer test was eventually conducted at 6 gpm. A possible explanation is that a portion of the fine-grained material present at the well screen depths was not completely removed during the well development process.

Based on the transmissivity range of 350 to 7,500 ft^2/day and a saturated thickness of 10 feet at MW-7S and 35 feet at MW-6S, hydraulic conductivities in the water table aquifer range from 35 to 210 ft/day. Based on borehole lithologic logs these estimates are believed to be high for the shallow saturated zone in it's entirety. However, they may be representative of select sand zones intersected by the wells.

5.3.2 LSGS Subunit

Average transmissivity values in the LSGS subunit are 11,500 ft^2/day for MW-7M and 14,000 ft^2/day for well MW-6M. At MW-6M, because of well inefficiencies during pumping, recovery data are considered to be more reliable and yield higher transmissivity values than the drawdown data. At MW-7M, manual drawdown and electronic recovery data give similar results and are considered equally reliable. However, the drawdown data from the pressure transducer at MW-7M are difficult to interpret due to unexplained fluctuations, and results are not considered representative.

Based on saturated thicknesses of 30 feet at MW-7M and 40 feet at MW-6M, the hydraulic conductivity of the LSGS subunit would be estimated at approximately 350 to 380 ft/day. Actual values are likely slightly lower as leakage from the fine-grain material both above and below the well screen probably lowered the measured drawdown slightly.

Transmissivity estimates from tests at MW-7M and -6M are very similar to the average transmissivity values derived by the ADWR for two separate groundwater flow modeling efforts. In its 1982, two-dimensional Salt River Valley groundwater model (Long et. al., 1982), the ADWR calculated that the average transmissivity for the one-square mile section that includes the WOC (Section 27, T2N, R2E) at 10,700 ft^2/day (80,000 gpd/ft). In its three-dimensional model (Corell and Corkhill, 1993), the ADWR used a hydraulic conductivity of 40 ft/day[33] for the UAU in Section 27. Based on the ADWR's initial average saturated thickness of about 275 feet for the UAU, the associated transmissivity is 11,000 ft^2/day (275 ft x 40 ft/day). Even though data interpretation in small diameter monitor wells tested at low pumping rates for relatively short time periods needs to be done carefully and the results used with caution, the consistency reflected in the various estimates provided above adds confidence in the results

5.3.3 Middle Alluvial Unit

Transmissivity values for tests at MW-6L and MW-7L are 3 ft^2/day and 80 ft^2/day, respectively. Because of the low rates of pumping, well inefficiencies due to turbulent, near-well flow were likely small, and results from drawdown and recovery phases of the tests were similar at both wells.

The transmissivities for both wells are low, and both wells have very low yields. The screened formation is considered an aquitard. Although a small response was observed on the resistivity log, no recognizable coarse-grained material was observed in the formation samples. At MW-7L, the screen was set in a unit that had a recognizable resistivity signature. Formation samples contained fine gravel.

Because both of these wells are screened for 40 feet within a 300- to 500-foot thick layer composed of relatively undifferentiated clayey silt and silty clay, it is difficult to derive a hydraulic conductivity estimate from the transmissivity values. However, based on the test results and the lithology, an estimated overall hydraulic conductivity of < 1.0 ft/day is considered a reasonable estimate.

5.4 GROUNDWATER FLOW

At the WOC site, groundwater flow direction and volumetric flux is a function of the hydraulic conductivity and hydraulic gradient. The hydraulic gradient is in turn a function of groundwater system inputs (recharge) and outputs (pumping). Hydraulic conductivity estimates were derived in

[33] The ADWR's hydraulic conductivity estimate is lower than the estimate derived by GeoTrans, but the ADWR's estimate is presented as an average value over the entire thickness of a 275-foot thick aquifer. In the vicinity of the WOC, the UAU contains thick fine-grained intervals that yield only small quantities of water to wells. In a well that is screened over the lower few hundred feet of the UAU and the upper few hundred feet of the MAU (which is how many of the production wells are constructed), most of the yield will be derived from the relatively thin lower sand and gravel subunit of the UAU.

the preceding section. In this section, the results of water-level measurements are used to calculate the value and direction of the gradient and estimate the rate and direction of flow.

Complete results of water-level elevation measurements for the RI groundwater investigation at the WOC are presented in Table 5-6. During the 1996 through 2003 time period significant changes have been observed in the depth to groundwater, the direction of the horizontal gradient, and the values of the vertical and horizontal gradients. When it was unlined, seepage from the Grand Canal had major impacts on and essentially controlled the groundwater gradient as measured in the shallow (S-series) wells. Likewise, pumping from the SRP well 9.5E-7.7N had major impacts on the groundwater gradient and flow direction in the LSGS intersected by the M-series wells. Water level elevation maps for three discrete time periods have been prepared to visually present the dynamic water level systems. Figure 5-2 through Figure 5-4 present shallow groundwater elevations and flow direction for November 1997, June 2003, and January 2004, respectively. Groundwater elevation contours have been presented for all of the maps, however, it should be noted that due to the presence of different well construction depths, the high likelihood that the shallow monitor wells may intersect different zones of saturation, and the limited number of data points available, the groundwater contours for the shallow groundwater system need to taken with caution. Despite the loss of data points due to the declining water levels an analysis of these figures displays the relatively consistent shallow groundwater flow direction at the same time the water level elevation and gradient away from the canal were decreasing. Figures 5-5 through Figure 5-7 present LSGS groundwater elevations and flow direction for November 1997, June 2003 and January 2004, respectively. Groundwater contours are also presented for the June 2003 and January 2004 maps when sufficient data was available to reliably develop equal elevation contours. An additional groundwater elevation map (Figure 5-8) was prepared for June 1997, a time during which the SRP well 9.5E-7.7N was known to have pumped. This data displays the large effect that pumping from the SRP well 9.5W, 7.7N has on the LSGS water levels.

As is evident in the previous discussion, most of the hydrogeologic changes that have been observed during the RI are directly related to the SRP water delivery system, which includes both the Grand Canal, Well 9.5E-7.7N, and other nearby wells (Figure 2-2). The canal system was constructed in the early 1900s, and all of the present features were in place by 1950, before the WOC was first developed. Table 5-7 presents the annual pumping by the SRP well up through 1999 when, at the request of ADEQ, SRP agreed to discontinue pumping. As is evident in Table 5-7, prior to 1991, the SRP well 9.5E-7.7N routinely pumped a considerable volume of water.

5.4.1 Vertical Gradients and Flow Rates

There are large vertical groundwater gradients at the WOC. The highest groundwater levels are measured in the shallow and deep wells, and the lowest water levels are measured in the intermediate depth LSGS wells. An example is presented in Figure 5-9 where water level elevations are approximately 15 to 20 feet higher in MW-6S than MW-6M and almost 40 feet higher in MW-6L than MW-6M.[34] An analysis of the hydrograph for this well cluster indicates that there is at least

[34]At the outset of the RI in late 1996, water levels were the highest in shallow wells close to the Grand Canal (MW-3S, WCP-12, and WCP-13). The water levels were about 80 feet bgs, which was 30 to 40 feet higher than the water level in the LSGS wells. Since the canal was lined in January 1998, these three wells have gone dry.

minimal hydraulic communication between the shallow, LSGS and deep wells. In particular, the set of data collected during the March 1997 through December 1997 time period reveals a direct correlation between large water level changes in the LSGS (MW-6M), likely due to regional pumping, with much smaller and slightly lagged in time responses in the shallow (MW-6S) and deep (MW-6L) monitor wells.

The lower water levels in the LSGS subunit are likely due to regional groundwater pumping as water has been withdrawn at a rate faster than it can be replenished. As a result, the aquifer has been depressurized, and groundwater moves vertically into the unit from both above and below. At the start of the RI, and under non-pumping conditions, the downward vertical gradients from the water table aquifer to the LSGS subunit ranged from 0.05 to 0.18 feet per feet (ft/ft). Upward vertical gradients to the lower sand and gravel subunit ranged from 0.03 to 0.09 ft/ft.

Vertical groundwater seepage velocities into the lower sand and gravel subunit from the shallow water-table aquifer can be estimated using the following relationship:

$$V_s = \frac{K_v \cdot \nabla h}{n_e \cdot B_a}$$

where:

K_v = the vertical hydraulic conductivity (estimated at 1/10 of the horizontal conductivity),
∇h = the difference in hydraulic head across the aquitard;
B_a = the aquitard thickness; and,
n_e = the effective porosity.

At the on-site MW-4 well cluster, a sandy clay aquitard approximately 100 feet thick separates the water table aquifer from the lower sand and gravel subunit. Based on a vertical hydraulic conductivity of 0.01 ft/day, an effective porosity of 0.20, and a ∇h of 20 feet (from July 98 data) between MW-4S and MW-4M, the downward seepage velocity is approximately 0.01 ft/day. The upward seepage velocity based on data from the deep well, MW-4L, and using a ∇h of 35 feet (from July 98 data) is approximately 0.0035 to 0.035 ft/day, assuming a vertical hydraulic conductivity of 0.001 to 0.01 ft/day.

5.4.2 Horizontal Gradients and Flow Rates

Although some amount of hydraulic communication appears to be present between the saturated material intersected by the shallow and LSGS wells the connection appears to be so poor that the two zones behave very differently in response to most aquifer stresses (e.g., canal recharge or regional pumping). Therefore, as presented in Section 5.4 water level elevation measurements from LSGS and shallow wells have been evaluated separately (Figures 5-2 through 5-8). Measurements from shallow wells have been used to calculate the direction of the horizontal component of the groundwater gradient at the water table, and measurements from LSGS wells have been used to evaluate the direction of the gradient in the LSGS subunit.[35]

At the outset of the RI, in November 1996, the direction of the gradient in the shallow water-table aquifer was south-southeast. The value of the hydraulic gradient was highest, about 0.05 ft/ft, close to the Grand Canal and decreased to about 0.008 ft/ft southeast of the site. This overall pattern remained relatively constant until January 1998, when the canal was lined. In June 2003, the last quarter with sufficient data to estimate the hydraulic gradient, it had further decreased to approximately 0.001 to 0.002 ft/ft to the south.

At the LSGS wells, horizontal gradients have been consistently south-southwest, with the exception of June 1997, when the SRP well was pumping (Figure 5-8). On-site, the value of the horizontal gradient has ranged from about 0.005 to 0.01 ft/ft. Southwest of the site, between MW-107M and MW-110M the gradient is about 0.002 ft/ft. Although a poor hydraulic connection between the water table system and the LSGS appears to exist, no changes in the gradient in the LSGS that were obviously attributable to canal lining have been observed. This supports a poor hydraulic connection, and subsequent low vertical flux, between the water table and the LSGS subunit.

Horizontal groundwater seepage velocities in the saturated zone can be estimated using the following relationship:

$$V_s = \frac{K_h \cdot i}{n_e}$$

where:

K_h = the vertical hydraulic conductivity;

i = the horizontal hydraulic gradient; and,

n_e = the effective porosity (estimated at 0.2).

Prior to canal lining, the estimated horizontal seepage velocities in the shallow water-table aquifer ranged from about 4 to 13 ft/day. In the lower sand and gravel subunit, the estimated range of horizontal seepage velocities is 2 to 14 ft/day.

5.4.3 Effects of Canal Leakage and Lining on Groundwater Flow

Prior to January 1998, and for the first five rounds of quarterly groundwater monitoring, the Grand Canal was unlined at the WOC. The upstream lining stopped at 35th Avenue, near the upstream property boundary. Seepage from the canal created a water-table mound, and in the shallowest part of the saturated zone, there was a groundwater divide beneath the canal. At the WOC, the direction of the horizontal groundwater gradient at the water table was southeast, away from the mound. On

[35] Below the LSGS subunit, the direction of the gradient is uncertain as there are only three L-series wells, and there is no demonstrated hydraulic continuity between their completion zones. However, no contaminants have ever been detected in L-series wells.

the north side of the canal, the direction of the gradient was apparently northeast, although only wells closest to the canal were monitored during this period.[36]

In January 1998, during the annual north-side canal dry-up, the Salt River Project placed a gunite lining in the Grand Canal from 35th Avenue to 43rd Avenue. There was a immediate effect on the water levels in the shallow wells. By February 1998, the mound beneath the canal had dissipated, and water levels in wells closest to the canal had dropped by several feet. By May 1998, the effects were more noticeable. The water table was much flatter, and it had a relatively uninterrupted south to southeast gradient that extended from wells north of the canal to wells south of the WOC.[37] The value of the gradient in May was approximately 0.01 ft/ft at the site and 0.003 ft/ft southeast of the site. The corresponding horizontal seepage velocities are about 1 to 3 ft/day. Figures 5-10 through 5-38 present water level hydrographs for all monitor wells installed for this project. Figures 5-10 through 5-20 present hydrographs of wells greatly affected by the lining of the Grand Canal. Water levels were at their highest during the 1997 irrigation season, when the Grand Canal was at a bank-full stage. In October 1997, groundwater levels began to decline as irrigation deliveries were curtailed, and when the canal was dried up in December 1997 for lining, the rate of decline increased, at least for wells near the canal. Water levels continued to decline in all of the shallow wells throughout the 1998 to present time period. The decline was relatively steep in the shallow wells closest to the canal. Shallow wells further south, such as MW-102S (Figure 5-17) and MW-103S (Figure 5-18) display a more smoothly declining water table. The furthest south shallow well, MW-201S (Figure 5-20), indicates that a steady decline continues to occur. Flow patterns in the water table aquifer will continue to adjust as the flow system reaches a new equilibrium condition without the influence of recharge from the canal.

5.4.4 Effects of Pumping on Groundwater Flow

Wells completed in the LSGS subunit did not appear to be influenced by canal lining, however, a decreased vertical gradient between the shallow part of the system and the LSGS portion would be expected to have decreased the downward flux of groundwater to some degree. Pumping from the SRP Well 9.5E-7.7N does have a profound influence on LSGS water levels. The SRP well was pumping on June 4, 1997, during a water-level measurement round, and as shown on Figure 5-8, a pumping cone of depression developed in the LSGS subunit. The direction of the horizontal groundwater gradient was radial, toward the well, and at the WOC, it shifted from southwest to west-northwest. The value of the gradient was 0.006 to 0.007 ft/ft, and the estimated seepage velocity was 10 to 14 ft/day.

The effect of pumping at the SRP well is also shown on Figures 5-24 through 5-31, which presents hydrographs for LSGS wells. During the June 1997 measurement round, water levels in all of the LSGS wells were 15 to as much as 30 feet lower than in previous and following measurement rounds.[38]

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[36]In accordance with the Consent Decree and Work Plan.

[37]At the request of the ADEQ, six wells north of the canal, WCP-1, -2, -5, -6, -7, and -9, were incorporated into the water-level measurement network in March 1998. These wells were not sampled.

[38]The well was pumped prior to June 4, 1997, which was probably at least partly responsible for the earlier fluctuations. However, June 4, 1997 was the only time that RI water level measurements were made at the same time that the well was pumping. According to the SRP, the well was turned on a few days prior to June 4, 1997.

5.4.5 Groundwater Flow Summary

The direction and rates of groundwater flow at the WOC were formerly a function of:

- The depth of saturation of interest (shallow water-table zone vs. the LSGS subunit);
- Hydraulic conductivity;
- The proximity to the canal, especially in the shallow water-table aquifer;
- Timing of canal lining; and,
- Pumping in the SRP Well 9.5E-7.7N.

With both the canal recharge and SRP well shut-off, the direction and rates of groundwater flow in both the shallow and LSGS saturated zones are now almost entirely determined by aquifer transmissivity (hydraulic conductivity x saturated thickness). The net effects of these influences are summarized in matrix format in Table 5-8.

5.5 NATURE AND EXTENT OF GROUNDWATER CONTAMINATION

A complete record of groundwater quality monitoring for VOCs at the WOC is provided in Table 5-9, and results of inorganic analyses are provided in Table 5-10. Results of VOC analyses for three sampling events (November 1997, June 2003 and January 2004) are presented graphically on Figures 5-2 through 5-4 for the shallow wells and on Figures 5-5 through 5-7 for the LSGS wells. The November 1997 sampling event was selected because it represents a period before the canal was lined. The June 2003 and January 2004 sampling events were selected to display a more recent and the most current snapshot of water quality conditions, respectively. Based on these results, TCE and PCE are considered the COCs for this Site. Results and observations from groundwater quality monitoring are discussed below.

5.5.1 Distribution of VOCs

VOCs have been detected in both on-site an off-site shallow and LSGS wells and are discussed in greater detail below. No VOCs have been detected in the deep (L-series) wells and these will not be discussed further.

5.5.1.1 TCE and PCE

In the approximately 15 rounds of groundwater quality monitoring completed as part of this RI, TCE has been detected most frequently. The highest concentration that has been measured in WOC monitoring wells was 600 µg/L at the on-site well MW-4S during the May 1997 sampling round. Concentrations in on-site shallow wells MW-4S and MW-5S decreased from 1996 until the two wells went dry in August 2001 and May 2003, respectively (Figure 5-13 and 5-14). Concentrations in off-site shallow wells MW-102S and MW-104S have increased whereas off-site well MW-201S have gradually decreased (Figures 5-17, 5-19 and 5-20). In June 2003 concentrations of TCE exceeded the AWQS of 5 µg/L in on-site shallow well MW-100S (70 µg/L) and in off-site shallow wells MW-102S (120 µg/L), MW-104S (190 µg/L) and MW-201S (39 µg/L). In January 2004, TCE concentrations decreased but remained above the AWQS in MW-100S (47 µg/L) and MW-201S (27 µg/L). The remaining shallow wells could not be measured due to declining water levels and the wells being dry.

The highest concentration of PCE, 34 µg/L, was measured at MW-4M in June 2003. The only shallow well it is presently detected in is on-site well MW-100S, however low levels (generally <5 µg/L) have been observed in shallow wells MW-4S, MW-5S, MW-102S, and MW-104S since 1997. Concentrations of PCE did not exceed the AWQS of 5 µg/L in any of the shallow wells sampled during either the June 2003 or January 2004 sampling events.

Dissolved concentrations of PCE is presently detected in LSGS wells MW-2M, MW-3M, MW-4M, MW-7M, MW-105M, and MW-106M. In June 2003, concentrations of PCE greater than 5 µg/L were measured in LSGS wells MW-2M (11 µg/L), MW-3M (7.6 µg/L), MW-4M (34 µg/L), MW-7M (20 µg/L) and MW-105M (7.5 µg/L). In January 2004, concentrations of PCE greater than 5 µg/L were measured in LSGS wells MW-2M (11 µg/L), MW-3M (9.6 µg/L), MW-4M (27 µg/L), MW-7M (20 µg/L) and MW-105M (8.9 µg/L). Its presence in MW-3M and MW-106M, outside of the lateral extent of TCE, and its high concentration in MW-4M suggests an offsite, up-gradient (northeast) source of PCE. Concentrations of PCE in LSGS wells have been increasing in wells MW-2M, MW-3M, MW-4M, MW-7M, and MW-106M since 1999. This is thought to reflect a change in LSGS groundwater flow conditions since the SRP well 9.5E-7.7N was shut down in 1999.

5.5.1.2 Other VOCs

Of the other VOCs, only 1,1-DCE has been detected in concentrations greater than the AWQS.[39] The highest concentration of 1,1-DCE, 86 µg/L, was detected at MW-5S in November 1996.

In the shallow wells, 1,1-DCE occurs both in on-site wells (MW-1S, MW-4S and MW-5S) and off-site wells to the south (MW-102S, MW-103S, MW-104S and MW-201S). In the LSGS wells, 1,1-DCE occurs mainly on-site in MW-2M, MW-3M and MW-4M.

1,1-DCE - In June 2003, concentrations of 1,1-DCE greater than the AWQS of 7 µg/L were measured in shallow wells MW-100S (7.7 µg/L), MW-102S (12 µg/L) and MW-104S (9.4 µg/L). January 2004 concentrations of 1,1-DCE did not exceed the AWQS in any of the shallow wells sampled.

Concentrations of 1,1-DCE greater than 7 µg/L were not measured in any of the LSGS wells sampled in both June 2003 and January 2004.

5.5.2 Effects of Canal Leakage and Lining on VOC Distribution

During the period from 1996 through 1998, the highest concentrations of TCE in the shallow wells were measured at on-site wells, and concentrations decreased off-site to the south (Table 5-9 and Figures 5-2, 5-13, 5-14, and 5-17). After the Grand Canal was lined and the elevation of the water table decreased, the distribution of TCE changed. Concentrations of TCE in on-site wells in the area of the former water-table mound have decreased while concentrations offsite to the south have risen slightly (Table 5-9 and Figures 5-3, 5-4, 5-17 and 5-19). In June 2003, the highest concentration of TCE was measured in off-site well MW-104S (190 µg/L).

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[39] Other VOCs have been detected infrequently and always in concentrations less than AWQS in groundwater samples. Benzene was detected in three samples, all from WCP-12. Chloroform and bromodichloroethylene were detected in eight and four samples, respectively. Toluene, cis-1,2-DCE, and trichlorofluourmethane have been detected in one sample each. Trace levels of VOCs have also been measured in some blanks.

In the LSGS wells, the highest concentrations of TCE have consistently occurred in wells MW-2M, MW-105M and MW-107M, which are located along a down-gradient flowline from the site. Concentrations at other LSGS wells with a history of TCE impacts have remained relatively stable. Based on these trends, concentrations of TCE in the LSGS wells have not shown a response to the lining of the canal.

5.5.3 Current Extent of VOCs

The extent of VOC contamination in the portion of the aquifer defined by the LSGS subunit has been defined to the north-northwest (MW-106M), south (MW-102M), southwest (MW-6M), and west (MW-108M, MW-109M and MW-110M) (Figure 5-7). The estimated 5 µg/L concentration contours for both TCE and PCE are also shown on Figure 5-7. Due to the "well-behaved" nature of the plume resulting from the absence of pumping in the area and the apparent geologic homogeneity of the LSGS subunit, this definition of the plume is expected to continue. However, as stated in Section 5.5.1.1 it is believed that the PCE may originate from an up-gradient source.

Through both historical and current data, the extent of VOC contamination site in the water-table aquifer originating from the WOC has been defined to the north (MW-3S), east (MW-1S), and west (MW-2S). To the south, the lateral extent of VOC contamination has not been defined. However, due to the lining of the canal, the completion of the on-site SVE remediation, and the water table declining down into low permeability material, the shallow zone VOC plume is believed to be reaching a state of stagnation. An estimated 5 µg/L TCE concentration contour is presented on Figure 5-4.

5.5.4 Metals

Due to the general absence of impacts to native soils by metals identified in the work conducted by BCC and for the Phase I and II soil investigations only limited analysis of groundwater samples for metals were conducted. The first analysis was conducted by BCC on the WOC Irrigation Well. Completed on March 20, 1992 as part of its PSC, BCC purged the Irrigation Well for a duration of 3 hours and 19 minutes at 100 gpm using a 25-horsepower submersible pump set at a depth of 450 feet bgs. Groundwater samples were collected for analysis of VOCs using EPA Method 601 and for Primary and Secondary Safe Drinking Water Act (SDWA) compounds, including total metals . The SDWA compounds were collected from the pump discharge. Results of the metals analysis are as follows (all concentrations in mg/L): Arsenic (0.009), Barium (0.046), Cadmium (<0.005), Total Chromium (<0.010), Copper (0.088), Iron (0.186), Lead (0.017), Mercury (<0.0002), Magnesium (8.6), Manganese (<0.010), Selenium (<0.005), Sodium (162), and Zinc (0.444).

In June 2003 groundwater from onsite well MW-100S, which is screened from 87 to 137 feet bgs, was sampled and analyzed for total chromium and Cr^{6+} in June 2003. The results were non-detect for both compounds. Being screened across the existing groundwater table and located at the hydraulically down-gradient extent of the property, the absence of total chromium and Cr^{6+} suggests that chromium impacts to shallow groundwater have not occurred at the WOC.

5.5.5 Inorganics and Indicators

Inorganic compounds and indicator parameters have also been measured as part of the groundwater monitoring and sampling activities. In addition to evaluating for possible groundwater impacts by inorganic contaminants, these analyses were conducted either to address potential water treatment questions or as part of quantifying biodegradation activity. The results of all inorganic compound analyses or laboratory measured indicator parameters are presented on Table 5-10 and Appendix J, Table J-2. The results of inorganic analyses conducted on samples collected from the WOC Irrigation Well in March 1992 are as follows (all concentrations in mg/L): carbonate (<1), bicarbonate as $CaCO_3$ (108), hydroxide (<1), total alkalinity as $CaCO_3$ (108), chloride (180), fluoride (1.88), nitrate as nitrogen (2.25),sulfate (61) and TDS (500). The results presented in Table 5-10 are summarized below.

TDS concentrations in the samples were variable and ranged from 400 to 1400 mg/L. Lowest values were recorded at shallow wells (MW-1S, WCP-4, WCP-12), and at a deep well (MW-7L). The highest values were also recorded at other shallow wells (WCP-8, MW-7S) and an LSGS well (MW-6M). The two canal samples had equal TDS values, 610 mg/L.

The concentrations of other inorganic ions and alkalinity (which is an indirect measurement of bicarbonate in most samples) were also variable. Chloride concentrations ranged from 47 to 470 mg/L, sulfate from 20 to 190 mg/L, and alkalinity from 76 to 500 mg/L.

Ammonia was detected in only two samples, and cyanide was not detected in any samples. Concentrations of total organic carbon were low; the highest concentrations, 6.3 mg/L, were measured in samples from the Grand Canal. Concentrations of total suspended solids (TSS) ranged from 7 to 1400 mg/L. The highest values were measured in samples from the deepest wells, where well yields are lowest and fine-grained sediment could not be completely removed during development.

The inorganic results are consistent with a hydrogeologic system that has had a complex history of recharge and a variable direction of groundwater flow. With the possible exception of WCP-8, a well that has abnormally high concentrations of TDS and chloride, the results do not indicate inorganics contamination. WCP-8 is a well that is on the north side of the Grand Canal and is more than 500 feet northeast of the WOC.

5.6 FATE AND TRANSPORT OF GROUNDWATER CONTAMINANTS

As described in Section 4.5.2, other than septic tank ST-3, no obvious source of TCE to groundwater was identified at the WOC. Although TCE was identified in the contents of three septic tanks it was only found in native soils beneath septic tank ST-3 and from shallow soil beneath seepage pit ST3-SP1 near septic tank ST-3. The highest TCE concentrations in soil have been measured in the shallow water table aquifer and in the capillary zone above this aquifer. Dissolved TCE has migrated offsite in the shallow water table aquifer from this source. Currently, based on the results of the SVE confirmation borings, there is not a continuing on-site source of VOCs to the shallow groundwater. A finite mass of dissolved phase TCE has migrated off-site with the shallow groundwater flow, but this migration will continue to decrease with the declining water table due to sorption of dissolved phase TCE onto soil grains and the decreasing rate of advective flow as the water table declines into lower permeability material. Figures 5-10 through 5-20 illustrate the relationship between declining shallow groundwater system water levels and decreasing groundwater concentrations of TCE.

The presence of groundwater concentrations of TCE in the LSGS, which is located at depths ranging from approximately 110 to 210 feet below the bottom of the shallow groundwater system monitor wells suggests that the source to the LSGS is the on-site Pincus Well. Although this hypothesis has not been confirmed, the lack of hydraulic communication between the shallow groundwater system and the LSGS, described previously, supports the hypothesis. This potential source will be removed when the well is abandoned in July 2004. Previous sampling of the Pincus well, described in Section 3.2, did not identify groundwater concentrations of PCE. This observation supports an up-gradient, off-site source for the PCE observed in the LSGS.

5.6.1 Advection of TCE

The predominant transport mechanism for TCE and other VOCs at the WOC is advection. In the past, when canal leakage dominated groundwater flow rate and direction in the shallow aquifer, TCE was transported in the water table aquifer in a south-southeast direction at an estimated rate of 4 to 13 ft/day. Current rates of advective flow cannot be estimated due to the continuing decline of the water table into poorly characterized aquifer/aquitard material.

In the LSGS subunit, TCE and groundwater flow southwest at a rate of approximately 2 to 14 ft/day. When the SRP well was pumping, advection in the LSGS subunit was toward the northwest with an estimated seepage velocity of approximately 10 to 14 ft/day.

5.6.2 Sorption of VOCs

TCE, PCE, and 1,1-DCE are all hydrophobic chemicals that readily sorb to the organic fraction of the soil matrix, and because of low solubility, they also sorb to any solid surface to a moderate extent. Sorption retards the rate of transport by advection and serves to disperse a plume that has a discontinuous or variable source by temporarily storing contaminants in the solid phase, potentially releasing them to groundwater in the future. Based on the relatively low organic carbon content of the aquifer materials at the WOC,[40] sorption to organic material is expected to play only a relatively minor role in the retardation of contaminant transport, however, sorption to the clay fraction of soil also occurs. Although documented to occur, the magnitude of this type of sorption has not quantified at the WOC.

5.6.3 Receptors

At some sites of contaminant releases, there are potential receptors of contaminants in groundwater. These are groundwater users supplied by wells that are down-gradient from releases and withdraw water from the contaminated portion of the aquifer. At the WOC, VOC impacts, in particular TCE, has been identified in two separate aquifer zones, each with distinct hydrogeologic properties and a different gradient.

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[40] Selected soil samples from Phase II borings were analyzed for total organic carbon. None was measured at a detection limit of 5,000 ppm. Results are included in Appendix C.

Shallow Water Table Aquifer - The shallowest aquifer is the water-table aquifer. It presently occurs at a depth of approximately 135 feet bgs. The direction of the groundwater gradient is generally south (Figures 5-2 through 5-4).

Down-gradient[41] (south) from the WOC, there are no production wells intersecting the shallow water table aquifer within a distance of more than one mile, and there are no exposure pathways to contaminated groundwater. In 1989, the ADEQ inventoried registered production wells in the WCP WQARF Study Area (Earth Tech, 1989). The Sparkletts well (now owned by Danone Waters of North America), located near 33rd Avenue and Earll Street (Figure 2-2) is the closest production well southeast of the WOC, but it is not completed in the shallow aquifer. It is 950 feet deep, and its yield is derived from a short-screened zone in the interval from 905 to 930 feet (Section 2.3.2). No TCE or any other VOCs have been detected at this well.

The next closest production well located down-gradient (south or southeast) of the WOC in the shallow water table aquifer is an unused COP production well, Well 68. It is located near 37th Avenue and Encanto Boulevard, 1 mile south of the WOC. A review of ADWR records did not identify any well construction information for this well. According to ADWR the well has not been pumped since 1986 when approximately 125 acre-feet of pumpage was reported. In groundwater samples collected in 1985 no TCE was detected.

LSGS - The LSGS subunit is the second aquifer zone at the WOC where impacts from VOCs are identified. It occurs at the base of the UAU, at a depth of about 245 to 285 feet bgs in the northern part of the site and at a depth of approximately 320 to 360 feet bgs in the south and western portions of the site. The direction of the groundwater gradient in the LSGS is southwest, as long as the SRP Well 9.5E-7.7N is not pumping. When LSGS water levels were measured with this well pumping, the gradient was northwest, directly toward the well (Figure 5-8). The next closest SRP production well is 8.5E-7.5N, located approximately 6,000 feet west of the Middle Parcel.

The SRP monitors its wells for VOCs during its annual groundwater sampling program. Because neither well is currently used, the most recent round of sampling for these wells was conducted in February 1999 (per Greg Elliot, SRP Hydrologist, June 2004). In February 1999, well 9.5E-7.7N had 2.2 µg/L of TCE and 3.3 µg/L of PCE detected. 1,1-DCE was <0.5 µg/L. Well 8.5E-7.5N was <0.5 µg/L for all three compounds. The complete list of VOC analytical results for the two wells, as provided by SRP, are provided in Table 5-11. Based on this information, although VOCs are detected in the closest SRP well, the concentrations are all below the respective AWQS. Additionally, flow in the Grand Canal is many times greater than the well discharge, and a large dilution factor would apply. With designated uses of domestic water source, agricultural irrigation and agricultural livestock watering, the AWQS of 5 µg/L applies for TCE and PCE in the Grand Canal (Arizona Administrative Code, Title 18, Section 11, Appendix A, Table 1).

Two other production wells in the down-gradient (SW) direction are COP wells 70 and 71, drilled in 1955 and 1957, respectively, and located approximately 2,500 from the Middle Parcel (Figure 2-2). COP 70 is reportedly 701 feet deep with the perforated interval(s) unknown with a former pumping capacity of 600 gpm. COP 71 is 545 feet deep, perforated from 260 to 441 feet bgs, and

[41] This refers to the shallow water table aquifer and not the LSGS. In the LSGS, down-gradient is southwest.

with a former pumping capacity of 800 gpm. According to ADWR records, neither well has been pumped since 1984 when annual pumping records were required to be submitted to ADWR.

Because none of the down-gradient production wells are being pumped there are currently no exposure pathways to groundwater in the LSGS subunit.

5.7 NATURAL ATTENUATION EVALUATION

Natural attenuation refers to the processes that can reduce the mass, toxicity, mobility, volume or contaminant concentration in the groundwater system as a result of biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, and/or transformation. Natural attenuation processes affect the fate and transport of chlorinated solvents in all hydrologic systems. When these processes are shown to be capable of attaining site-specific remediation objectives in a time period that is reasonable compared to other alternatives, they may be selected alone or in combination with other more active remedies as the preferred remedial alternative. Natural attenuation mechanisms can be classified as either destructive or nondestructive. Biodegradation is the most important destructive attenuation mechanism. Nondestructive attenuation mechanisms include sorption, dispersion, dilution from recharge, and volatilization.

5.7.1 Shallow Aquifer

Within the shallow saturated system, the current definition and general lack of further plume migration has been attained through the successful remediation of the on-site soils and the rapid decline in water levels within the shallow saturated system, which has resulted in much of the residual TCE within the shallow plume being sorbed on the fine-grained soil and/or being volatilized within the vadose zone. The remaining aqueous phase TCE within the shallow aquifer system is within fine-grained soils with no aquifer stresses, i.e., recharge or pumping, to provide a mechanism for further migration.

5.7.2 LSGS Aquifer

The decrease in contaminant concentrations observed within the LSGS unit, and the current plume definition, is the result of attenuation mechanisms such as sorption, dilution, volatilization, dispersion, and/or abiotic degradation. Although chlorinated hydrocarbon concentrations are generally decreasing, preliminary natural attenuation screening for this site suggests that anaerobic (reductive dechlorination) biodegradation is not the primary cause. The results of this screening is presented in Appendix J.

6.0 INTERIM REMEDIAL ACTION

In accordance with the Remedial Investigation/Feasibility Study (RI/FS) Work Plan, an interim remedial action, soil vapor extraction (SVE), was conducted to meet the short-term remedial action objective specified in the RI/FS work plan: mass reduction of contaminants in the vadose zone before they reach the groundwater. The SVE system was installed in June 1999 and operated from August 4, 1999 through October 21, 2002. A total of approximately 447 pounds of VOCs were extracted from the subsurface and treated. The system was shut down on October 21, 2002, after the short-term mass removal of VOCs has been achieved.

6.1 SVE System Installation and Start-up Monitoring

The interim remedial action SVE system at the WOC Middle Parcel was installed in June 1999. The SVE system consisted of three (3) pairs of nested SVE wells, underground conveyance piping, a conventional extraction blower package, and vapor-phase granular activated carbon (GAC) treatment vessels. The general layout of the system is shown on Figure 6-1. The system was designed to remove residual trichloroethene (TCE) from the shallow and deep vadose zone in an area where wastewater discharges from former septic tanks and seepage pits occurred. The nested SVE wells were installed in the vicinity of the storage shed near the northwest (SVE-1 nest), southeast (SVE-2 nest), and south (SVE-3 nest) sides of the storage shed. Each nest consisted of two 2-inch PVC wells installed in the same borehole, but screened through different depths. The shallow SVE wells and deep SVE wells at each location were screened from approximately 10 to 40 feet deep, and approximately 65 to 110 feet deep, respectively. Each SVE well is equipped with a 2-inch butterfly flow control valve and a monitoring port to allow measurement of the applied well vacuum and for collecting samples of extraction vapor. Street-rated, flush-to-grade vaults were installed over the SVE wells.

A 7.5-horsepower SVE extraction blower and related mechanical equipment were installed in a fenced equipment compound at the northwest end of the Middle Parcel. Two GAC vessels, each containing 400 pounds of coconut shell GAC, were used to abate VOC emissions. The GAC vessels were connected in series with a dual plumbing manifold that was used to facilitate change-out of spent GAC, and switching the positions of the primary and secondary GAC vessels.

Initial periodic testing of the SVE remediation system at the WOC began on August 4, 1999. Official start-up occurred the following day, on August 5, 1999.

6.2 SVE System Operation and Monitoring

The interim SVE system was operated from August 5, 1999 to October 21, 2002. During this operating period, a total of 25 influent and 25 effluent vapor samples were collected and analyzed by U.S. EPA Method TO-15. Analytical results indicate that the vast majority of contaminant mass in the extracted vapor were TCE, with trace amounts of PCE and 1,1-DCE.

The interim SVE remediation system at the WOC has been successful at remediating significantly more contamination than had originally been anticipated. Table 6-1 and Figure 6-2 present SVE system performance data with respect to the cumulative VOC mass removal over time. Using average SVE flow rates, average analytical results, and system operation time, GeoTrans has calculated that approximately 449 pounds of VOCs have been removed from the subsurface since start-up of the SVE system on August 4, 1999, through October 21, 2002. The SVE system operated for approximately 706 days over this period. System downtime has resulted from equipment repairs/maintenance, periodic power outages, and intentional shut-down periods for response tests and "pulse-mode" operations. Using a density of approximately 12 pounds per gallon for TCE, the 449 pounds of total remediated VOCs represents approximately 37.41 gallons of liquid TCE solvent.

6.3 SVE System Shut-down

On behalf of UIC, GeoTrans submitted a technical letter on September 11, 2001 to ADEQ, requesting ADEQ's approval to permanently shut-down the SVE system operation. Consequently, confirmatory drilling/sampling was conducted in September 2002. The results showed that no detectable VOCs were present in 39 subsurface samples collected from the SVE remediation zone. Based on these results, the justification specified in GeoTrans' September 11, 2001 letter has been deem satisfied, and the SVE system was shut down on October 21, 2002.

The activities and the analytical results associated with the confirmatory soil drilling and sampling were all contained in the GeoTrans' report entitled *Confirmatory Drilling/Soil Sampling Results for Shut-Down of Interim SVE Remediation System, Middle Parcel, West Osborn Complex*, submitted on January 23, 2004.

7.0 BASELINE HUMAN HEALTH RISK ASSESSMENT

In February 2000, Weston prepared a Baseline Human Health Risk Assessment (BHHRA) for the Site (Weston, 1999). The site was divided into the following exposure areas that were evaluated separately:

- On-Site surface soils sampled during post-Phase II soil investigation;
- Four on-Site soil areas that were subject to the Phase II soil investigation by GeoTrans; and,
- Five groundwater exposure areas.

The no-action alternative was evaluated based on Site soil and groundwater use and off-Site groundwater use in the downgradient residential neighborhood. The following six exposure pathway scenarios were evaluated:

- Exposure to on-Site surface soils:
  - Current on-Site trespassers; and,
  - Current on-Site industrial/commercial workers;
- Exposure to groundwater:
  - Current residents of downgradient neighborhoods living above contaminated groundwater.
- Exposure to on-Site soil:
  - Future residents;
  - Future industrial/commercial workers; and,
  - Current on-Site construction workers.

Intakes and risks were calculated under reasonable maximum exposure (RME) and central tendency (CT). The following is a summary of the RME results:

- Current On-Site Trespassers:
  - *Total Carcinogenic Risk*: 1.7E-06, thus on the lower regulatory risk range set by EPA and the State of Arizona of 1E-06 to 1E-04; arsenic accounted for approximately 99% of the total cancer risk
  - Total Hazard Indices (HIs): <1, thus below the benchmark of concern.

- Current On-Site Industrial/Commercial Worker:
  - *Total Carcinogenic Risk*: 8.9E-06, thus on the lower regulatory risk range of 1E-06 to 1E-04; arsenic accounted for approximately 99% of the total cancer risk
  - *Total Hazard Indices (HIs)*: <1, thus below the benchmark of concern.

- Current/Future Off-Site Child and Adult Residents:
  - *Total Carcinogenic Risk*: 1.8E-4 (above the regulatory risk range of 1E-06 to 1E-04; majority of risk (51 percent) due to inhalation of VOCs during noningestion groundwater use, and groundwater ingestion (approximately 47 percent); 1,1-DCE accounted for about 80 percent of the risk;
  - *Total HIs*: 4.1 for child and 2.8 for adult, thus above the benchmark of 1; TCE and chloroform accounted for approximately 94 percent of the total HI.

- Future On-Site Child and Adult Residents:
  - On-Site Soil:
    - *Total Carcinogenic Risk*: 1.4E-07 to 1.8E-05, depending on the location; based on arsenic and/or TCE;
    - *Total HIs*: <1.
  - Groundwater:
    - *Total Carcinogenic Risk*: 3.5E-04; majority of risk (51 percent) due to inhalation of VOCs during noningestion groundwater use, and groundwater ingestion (approximately 47 percent);1,1-DCE accounted for about 75 percent of the risk;
    - *Total HIs*: 7.2 for child and 4.8 for adult; TCE accounted for about 94 percent of the total His.

- Future On-Site Industrial/Commercial Worker:
  - On-Site Soil:
    - *Total Carcinogenic Risk*: greater than 1E-06 but lower than 1E-05; arsenic accounted for most of the risk;
    - *Total HIs*: <1.
  - Groundwater:
    - Total Carcinogenic Risk: 4.4E-05, thus within the regulatory range; the majority of the risk (approximately 88 percent) was due to groundwater ingestion; 1,1-DCE accounted for approximately 76 percent of the risk;
    - *Total HIs:* <1.

- Future On-Site Construction Worker:
  - *Total Carcinogenic Risk*: Less than 1E-06, thus below the regulatory risk range;
  - *Total HIs*: <1.0.

In summary, the BHHRA calculations indicated TCE, arsenic, and/or 1,1-DCE to be the primary chemical of potential concern resulting in the following:

- Receptors that are not exposed to total carcinogenic risks above the lower limit of the regulatory risks range of 1E-06 to 1E-04 and to total hazard index below 1, the benchmark of concern, are as follows:
  - On-Site trespassers; and,
  - Future on-Site construction workers.

- Receptors that are exposed to total carcinogenic risks within the regulatory range of 1E-06 to 1E-04 and to total hazard index below 1, the benchmark of concern, are as follows:
  - On-Site Soil: Future on-Site child and adult residents; and,
  - On-Site Soil and Groundwater: Future on-Site industrial/commercial workers.

- Receptors that are exposed to total carcinogenic risks above the regulatory range of 1E-06 to 1E-04 and to total hazard index above 1, the benchmark of concern, are as follows:
  - Groundwater: Future on-site child and adult residents; and,
  - On-Site Soil and Groundwater: Future on-Site industrial/commercial workers.

Weston also calculated Preliminary Remediation Goals for those scenarios where the total cancer risk exceeded 1E-06 or the total hazard index exceeded 1.

Because no direct domestic or municipal use of groundwater is currently occurring, and no future use is planned without treatment, the groundwater exposure pathway is not complete for on-or off-Site receptors. For this reason, the risks identified in this assessment may be over-estimated for groundwater exposure at the WOC and surrounding areas.

Similarly, risk assessment calculations for exposure to arsenic in soils at the WOC are based upon soil samples which include one anomalously high concentration of 120 mg/kg. This may also result in an overestimated risk from arsenic in soils at the WOC.

8.0 CONCLUSIONS

Extensive soil and groundwater investigations have occurred at the WOC Site starting 1987 with detailed work being completed first by BCC on behalf of Components, Inc. in 1991 and 1992 and then by GeoTrans on behalf of UIC from 1996 through 2004. During that time approximately 240 soil samples were collected on-site and analyzed for VOCs and/or metals, 29 monitor well have been installed and sampled, and an ERA utilizing three SVE well clusters was installed and operated for approximately 26 months. Although various metals were identified in contents from on-site waste disposal facilities and adjacent soil samples, an analysis of this data indicates that metals are not an on-site soil problem. Additionally, although only very limited metals analysis in groundwater samples were completed, the absence of detectable concentrations in these samples combined with the soil sample results leads to a conclusion that metal impacts to groundwater are not a concern at the WOC Site. Based on this work, it has been shown that the primary Site COC is TCE with PCE also currently being a COC in the LSGS.

The SVE system was shown to successfully remediate the vadose zone VOCs making TCE impacts to the shallow water table aquifer and TCE and PCE impacts to the LSGS as the primary targets of the RI. Through a phased series of drilling and well installations the extent of groundwater concentrations of TCE, and subsequently PCE, have been defined in the LSGS. The decrease in contaminant concentrations observed within the LSGS unit, and the current plume definition, is the result of attenuation mechanisms such as sorption, dilution, volatilization, dispersion, and/or abiotic degradation. Based on the present LSGS plume definition and the information on aquifer hydraulics known regarding the advective flow of groundwater and potential plume migration, sufficient information is available for the purpose of proceeding with the FS.

The extent of groundwater concentrations of TCE in the shallow water table aquifer are not entirely defined due to a combination of factors. These include the large southerly groundwater gradient present prior to the lining of the Grand Canal in December 1998, resulting in rapid movement to the south, the rapid decline of shallow groundwater levels since the lining of the canal, and the presence of additional sources of VOCs to the east of the WOC site. However, the rapidly declining water levels in conjunction with the fine-grained nature of the shallow water table system soils is believed to have greatly slowed the further migration of the TCE-impacted groundwater.

Within the shallow water table aquifer the current definition and general lack of further plume migration has been attained through the successful remediation of the on-site soils and the rapid decline in water levels within the shallow saturated system. This is believed to have resulted in much of the residual TCE within the shallow plume being sorbed on the fine-grained soil and/or being volatilized within the vadose zone. The remaining aqueous phase TCE within the shallow aquifer system is within fine-grained soils with no aquifer stresses, i.e., recharge or pumping, to provide a mechanism for further migration. Based on this information, sufficient information is available for the purpose of proceeding with the FS on the shallow aquifer system.

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