FINAL REMEDIAL INVESTIGATION REPORT FOR SHANNON ROAD/EL CAMINO DEL CERRO WQARF SITE TUCSON, ARIZONA

Prepared by ADEQ and URS

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EXECUTIVE SUMMARY

Background

ADEQ placed the El Camino del Cerro (ECDC) site on the WQARF Priority List in May 1995. Evaluation of analytical data indicated that volatile organic compounds (VOCs) were leaching into regional groundwater from the former ECDC Landfill. The landfill encompasses approximately 19 acres north of El Camino del Cerro Road along the Santa Cruz River, west of Interstate 10 in northwest Tucson. The landfill was operated by Pima County from 1973 to 1977 at the location of a former gravel pit. Dumping was allowed 24 hours per day with no documentation of disposal.

In August 1998, the site was evaluated using the newly established WQARF Eligibility and Evaluation Form. The evaluation resulted in a score of 71 out of a possible 120 and the site was officially placed on the WQARF Registry. The ECDC WQARF Site was historically divided into two primary areas: north-northeast of the I-10 freeway (the former ADEQ ECDC WQARF Site) and the Pima County response area southwest of I-10, which includes the ECDC Landfill (Figure 1). The landfill area is described as north of El Camino del Cerro Road, east of the Santa Cruz River, south of Curtis Road, and west of I-10.

Tetrachloroethene (PCE) had been detected in March 1993 in the Tucson Water supply well Z-006 on the west side of Shannon Road just south of Rillito Creek (Figure 2). In 1994, PCE and trichloroethene (TCE) were detected in Metropolitan Domestic Water District's South Shannon supply well on the west side of Shannon Road just north of Rillito Creek. In 1996, ADEQ began a preliminary investigation to determine if this area, referred to as Shannon Road-Rillito Creek (SRRC), qualified for the WQARF program. The site was evaluated using the Eligibility and Evaluation Form, resulting in a score of 53 out of a possible 120. In April 1999, the site was placed on the WQARF Registry. The approximate location of this site is shown in Figure 1.

Numerous facilities have been evaluated as potential sources of groundwater contamination at the both the ECDC WQARF site and the SRRC WQARF Site. Evaluation of available data eventually indicated that there existed a single groundwater plume rather than two distinct plumes. Therefore, the sites were administratively combined into the one SR/ECDC WQARF Site (the Site) in the fall of 2004. Figure 3 depicts the simplified conceptual site model.

Figure 4 shows the historical groundwater plume, depicting the approximate area of groundwater associated with the Site in which a contaminant of concern has been detected, at any point in time, at a concentration greater than a regulatory standard. A brief description of historic activities and the corresponding dates is provided in Table 1. Well locations in the Site vicinity are provided in Figure 2 and well construction information for wells discussed in this RI is summarized in Table 2.

Hydrogeology

Soil underlying the Site generally consists of sandy gravels to silty gravels, with some areas of sand, gravel, and clays, consistent with the Ft. Lowell Formation of the Tucson Basin. The regional aquifer appears to have significant communication across the various depths as little to no hydraulic head difference is detected at wells with multiple screened depths to approximately 400 ft bgs. The depth to groundwater within the Site as of the April-May 2013 monitoring event was approximately 155-160 feet below ground surface (ft bgs). Perched groundwater does not appear to be a factor at this site.

Water levels in the area have been declining steadily since the late 1940's at a rate of approximately 1.5 ft per year (ft/yr). Thus, water levels were likely more than 50 ft higher during landfill operation. Given the documented depth-to-waste of approximately 85 ft bgs, waste was likely deposited in relative close proximity to the groundwater surface (Figure 3).

For the purpose of discussing and evaluating the vertical extent of groundwater impacts at the Site, the regional aquifer has been divided into the following three depth zones:

- **Shallow-zone wells** are screened across the uppermost portion of the regional aquifer, with the depth to the bottom of the screens ranging from approximately 100 to 200 feet (ft) below ground surface (bgs);
- **Medium-zone wells** have submerged screens typically in the upper part of regional aquifer, with screen intervals ranging from approximately 200 to 280 ft bgs; and
- **Deep-zone wells** have submerged screens in the regional aquifer, with the depths ranging from approximately 280 to 400 ft bgs.

The direction of the groundwater hydraulic gradient in the vicinity of the Site has been historically variable and appears to be locally influenced by flooding events and regional groundwater pumping. Groundwater flow in the area is currently affected by pumping from Metro Water's South Shannon and DeConcini wells, though other production wells have influenced groundwater flow in the past. Significant infiltration events have occurred in the past, though infrequently, in the form of wide-spread flooding. These events can cause short-term changes in the direction of the hydraulic gradient.

The determination of the general direction of the groundwater flow is likely complicated by complex hydrogeologic features present due to the Site's location near the confluence of two major drainage channels of the Tucson Basin. Characteristics of these features can be difficult to identify given the limited lithologic data points available. Therefore, the determination of the general groundwater flow direction considers multiple lines of evidence including: measured hydraulic gradient, the effects of pumping, historical contaminant concentration data, and information on potential source areas collected during extensive field investigations. In general, groundwater at the site appears to flow in a direction to the north-northeast across the Site.

Contaminant Fate and Transport

A COC, as defined by Arizona Administrative Code R18-16-401, "means a hazardous substance that results from a release and that has been identified by the Department as the subject of remedial action at a site." COCs are those contaminants that have been detected with some consistency in groundwater, soil or soil gas at concentrations above regulatory or risk-based concentrations. COCs at the Site include the VOCs PCE, TCE, 1,1-dichloroethene (DCE), cis-1,2-DCE and vinyl chloride. For the purposes of this RI, a contaminant of potential concern (COPC) is a chemical that may have been used or disposed of at a facility, is detected in environmental media at a site in concentrations below regulatory standards, or is detected inconsistently (spatially or temporally) above a regulatory standard. COPCs at the Site include 1,1,1-trichloroethane (TCA), 1,4-dioxane, 1,1-dichloroethane (DCA), Freon 11, Freon 12, chromium, lead, benzene-toluene-ethylbenzene-xylenes (BTEX), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and nitrate plus nitrite. The COCs have been monitored in groundwater regularly since at least 1992. The COPCs have been monitored in groundwater intermittently since that time.

Given the arid environment and generally low moisture content of soils at the Site, VOCs migrate readily from contaminated soils to soil gas via evaporation and volatilization. The high vapor pressures of these compounds allow them to move easily from the liquid to vapor phase. At the landfill, COCs are part of the landfill gas mixture along with methane and carbon dioxide generated due to the degradation of waste. As organic wastes in the landfill degrade, landfill gas is generated resulting in increasing gas pressure within the landfill. As gas pressure within the landfill increases, landfill gas will migrate radially out of the waste impacting soil vapor adjacent to the landfill and groundwater underlying the landfill. VOCs are transported from the gas phase into the saturated zone at the capillary fringe as the landfill gas constituents partition into groundwater.

Contaminants may also have reached groundwater as a result of large infiltration events such as heavy rainfalls or floods. In these cases, water infiltrating from the surface may transfer contaminants present in the soil or soil gas to groundwater. Large infiltration events have occurred periodically at the Site. Water that infiltrates through the landfill cover can continue to percolate through the waste and eventually to groundwater resulting in leachate-like impacts to groundwater. Additionally, heavy rainfall or flood events have been shown to cause a temporary rise in water levels. Rising water may submerge contaminated soil and soil gas and thus further increase the mass transfer of contaminants into the groundwater.

Biotransformation of chlorinated ethenes can occur in the presence of water under anaerobic conditions. These conditions are often present at landfills as methane-producing organisms consume oxygen. Sequential reductive dehalogenation of PCE produces the breakdown products TCE and then cis- and trans-1,2-DCE. Under some conditions, this sequential dehalogenation may continue, resulting in the production vinyl chloride and, finally, ethene. The reduction of chlorinated ethenes to ethene gas has been observed at the ECDC Landfill.

Concentration time-series graphs indicate that the plume migrated from its source near the ECDC landfill to the north-northeast and beneath the I-10 freeway. This is generally consistent with the direction of groundwater flow in this area. It is likely that areas of high concentration observed in the area of the I-10 corridor (a commercial area adjacent to the I-10 freeway) in the first years of groundwater sampling had migrated from beneath the landfill prior to the time of initial sampling.

The mechanisms controlling contaminant transport at the Site have likely led to the irregular distribution of contaminants over both space and time. As described above, the mass transfer of contaminants to groundwater may have periodically increased following large infiltration events. Additionally, chemical containers disposed of in the ECDC Landfill may have degraded at different rates causing contaminant releases at various times throughout the history of the Site. The migration of these contaminants in groundwater following such events likely explains isolated areas of higher concentration observed downgradient of the ECDC Landfill.

As the plume progresses north and east of the I-10 freeway, it moves deeper within the regional aquifer. Several collocated medium- and shallow-zone wells confirm that contamination exists primarily in the shallow zone upgradient of well SRC-W38. Downgradient of this area, contamination exists primarily in the medium zone of the aquifer. PCE was detected in the South Shannon well as early as 1994 despite the fact that VOCs were not detected in some monitor wells located upgradient of the Shannon well, but screened in the shallow zone. This was likely due to the fact that contamination had migrated below the shallow-zone well network in place at the time. None of the available data indicate an additional source has existed in the vicinity of the South Shannon well. The conceptualization of plume movement is depicted in Figure 3. Based on COC concentration trends, it appears that the groundwater plume at the Site has been generally well-defined and is not expanding.

Freon 12 and to a lesser extent Freon 11 have been detected in groundwater throughout the plume. While the concentrations are not high enough to be considered Site COCs, the locations of detectable concentrations provides insight into the nature and source of the contaminant plume. Both Freon 11 and 12 are primarily used as propellants and refrigerants and are commonly detected in landfill gas. Freons in groundwater at the Site have been detected at approximately the same frequency as PCE and TCE, but at roughly an order of magnitude less in concentration. The difference in groundwater concentrations of PCE and TCE versus Freons may be attributable to the higher volatility of Freons relative to chlorinated ethenes, which causes Freons to preferentially remain in the vapor phase. The co-occurrence of Freon at wells with significant PCE and TCE across the site and at different depths within the aquifer is an indication that there is a common source area of the PCE, TCE and Freon. Similar to PCE and TCE, Freons are typically persistent in the environment and are not readily degradable and are therefore reliable tracer compounds for evaluating potential sources of groundwater impacts.

Groundwater samples collected in April 2013 were analyzed for 1,4-dioxane, a compound recognized as an emerging contaminant. No regulatory standard currently exists for this compound. 1,4-Dioxane was detected in each of the sampled wells at the Site. The highest concentrations appear to be correlated with areas of highest PCE and TCE contamination, suggesting they likely have a common source. The large area of 1,4-dioxane detection is likely a result of the hydrophilic properties of the compound, which allow it to move readily with groundwater. However, additional sampling events are warranted to further assess spatial and temporal trends of 1,4-dioxane in groundwater at the Site.

PCE has generally occurred at slightly elevated concentrations relative to TCE in groundwater throughout the plume. More recently, however, TCE concentrations in some areas have been higher than PCE concentrations. PCE/TCE ratio plots are included in Appendix T. In the center of the plume the data generally show a relatively constant PCE/TCE ratio along the length of the plume. In this area, PCE is generally detected at a concentration higher than two times the TCE concentrations. The PCE/TCE ratio does not appear to be significantly different between the shallow or medium aquifer but occurs within the discussed ranges throughout both depths. Current and historical PCE/TCE ratios in the center of the plume do not appear to be significantly different over time in downgradient wells compared to upgradient wells. Therefore, these PCE/TCE ratios provide no indication that a significant source of PCE or TCE exists downgradient of the ECDC landfill.

Along the eastern edge of the plume, PCE/TCE ratios appear to exhibit different behavior. Wells at and immediately downgradient of the landfill in the area of the I-10 corridor show ratios that are historically near two but have dropped below one in recent years. This change in ratios occurs concurrent with an increase in PCE breakdown products detected both in the groundwater and soil gas along the southeastern edge of the landfill. Therefore, it appears that the change in the PCE/TCE rations is attributable to biodegradation of PCE into TCE and other associated breakdown products due to localized anaerobic conditions in the vicinity of the ECDC landfill. PCE degradation compounds then appear to have migrated downgradient beneath the I-10 corridor.

Well SRC-W41S, located on the E.C. Winter Oil Service (E.C. Winter) property, and well SRC-W40 northeast of this property have exhibited relatively constant PCE/TCE ratios near one since their installation in the mid-2000's. These ratios appear slightly lower than expected when compared to historical ratios in upgradient wells and accounting for the approximate rate of groundwater flow in the area. Given the lack of PCE and TCE biodegradation products and the generally aerobic conditions in the vicinity of the E.C. Winter property, the PCE/TCE ratios may be indicative of a minor source of TCE in this area.

The South Shannon well pumps a significant volume of water throughout the year. Aquifer testing and capture-zone modeling in 2005 suggested that this well likely has the capacity to sufficiently capture the plume (URS, 2005). Groundwater monitoring results from wells surrounding the South Shannon well (SRC-W31S, M, and D; SRC-W35S and M; and SRC-52M) indicate the South Shannon well provides hydraulic containment of the VOC plume and prevents it from migrating farther north. Engineering improvements were completed at the South Shannon well in 2013 to increase pumping capacity and maintain hydraulic containment of the plume.

Site-Specific Source Investigations

Investigations conducted at the ECDC Landfill as part of a remedial investigation completed in 1997 indicate that the landfill area is a source of contamination at the Site. As presented above, groundwater data are generally consistent with this conclusion. Though groundwater data do not definitively indicate another significant source at the Site, several potential source areas in the Site vicinity have been identified through historical research and environmental investigations. These areas include: the I-10 corridor properties, the former E.C. Winter Oil Service facility, the former AMRI Oil facility, the parcel that Acacia Gardens Mobile Home Park currently occupies, Curtis Landfill, and the south bank of Rillito Creek. Extensive site-specific investigations conducted at these facilities over many years have yielded no indication of impacts to groundwater from these properties with the exception of the former E.C. Winter facility. TCE concentrations in soil gas beneath the E.C. Winter property indicate there may have been an impact to groundwater, though groundwater in this area is likely also impacted by contamination originating from the landfill area. The results of early response actions and recent sampling results described in Section 4.3 indicate the former E.C. Winter property does not likely represent an ongoing threat to groundwater quality in the area.

Remedial Actions

Potential contaminants likely remain in the ECDC Landfill. However, Pima County has installed and maintained a native soil cover ranging in thickness from approximately 5 to 20 ft to reduce exposure of contaminants and improve drainage away from the landfill. Pima County installed a landfill gas collection system in 1996 and a soil vapor extraction system in 2001. The extraction of soil gas was discontinued in 2004. Pima County has also installed a groundwater pump and treat system that operated from 2009 to 2011 and was modified and restarted in 2014. These remedial actions have begun to decrease the groundwater COC concentrations at the ECDC Landfill and the contaminant mass emanating from the ECDC Landfill area, though higher concentration areas persist downgradient (Figures 5-8).

In addition to the numerous investigations that have been conducted outside of the landfill property, several remedial actions have been implemented in an effort to reduce the risk of human exposure to contaminants and the potential for contaminants to migrate to groundwater. Contaminated soil was excavated at several properties in the I-10 corridor, and at the former AMRI Oil and E.C. Winter properties. A soil vapor extraction system was constructed at the E.C. Winter property that removed several pounds of VOCs. These removal actions have minimized the potential for human exposure to soils contaminated above relevant regulatory standards.

Alternate drinking water sources have been secured to replace supplies produced by a number of wells in the Site vicinity. These include several wells in the vicinity of the ECDC Landfill and in the I-10 corridor, City of Tucson wells Z-004 and Z-006, and the well serving the Acacia Gardens Mobile Home Park. The only known contaminated drinking water well currently in-service is the South Shannon well. A wellhead treatment system was installed on the South Shannon well in 1997 to treat for chlorinated VOCs. The system was upgraded in 2006. A Health Risk Assessment conducted by Arizona Department of Health Services (ADHS) in 2014 indicated that 1,4-dioxane, for which the current treatment system is ineffective, poses a “very low” risk to human health given the exceedingly low concentrations detected at the site.

Conclusions

The evidence collected during extensive investigations at the Site indicates that the primary source of groundwater contamination at the Site is the ECDC Landfill. Based on the examination of multiple lines of evidence, there is no indication that another significant source of contamination exists outside of the ECDC Landfill. Due to numerous ERAs and other actions conducted at the Site, there is currently no known immediate threat to human health. The complete Final RI report text describes, in detail, the information used to draw these conclusions.

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LIST OF ACRONYMS AND ABBREVIATIONS

ac-ft/yr	acre-feet per year
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
ADOT	Arizona Department of Transportation
ADWR	Arizona Department of Water Resources
AST	Above-ground Storage Tank
ASTDR	Agency for Toxic Substances and Disease Registry
AWQS	Aquifer Water Quality Standard
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
ECDC	El Camino del Cerro
cfs	cubic feet per second
COC	contaminant of concern
COPC	contaminant of potential concern
DCE	dichloroethene
DCA	dichloroethane
DNAPLs	dense nonaqueous phase liquids
ECDC	El Camino del Cerro
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
ERA	Early Response Action
ESA	Environmental Site Assessment
ESI	Expanded Site Inspection
°F	degrees Fahrenheit
FS	Feasibility Study
ft	feet
ft/day	feet per day
ft/yr	feet per year
gpd/ft^2	gallons per day per square foot
GPL	Groundwater Protection Level
HGL	HydroGeoLogic
I-10	Interstate 10
LESP	Landfill Environmental Studies Program
LOU	Landfill Operable Unit
MCL	Maximum Contaminant Level
Metro Water	Metropolitan Domestic Water Improvement District
amsl	above mean sea level
mg/kg	milligram per kilogram

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

mg/L	milligram per liter
µg/L	micrograms per liter
NCGH	North Casa Grande Highway
PA/SI	preliminary assessment/site inspection
PAH	polyaromatic hydrocarbons
PCB	polychlorinated biphenyls
PCE	tetrachloroethene
PCSWM	Pima County Solid Waste Management
ppbv	parts per billion by volume
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
SAISC	Southern Arizona Insurance Service Center, Inc.
SI	Site Inspection
SPLP	synthetic precipitation leaching procedure
SR/ECDC	Shannon Road/El Camino del Cerro
SRL	soil remediation level
SRRC	Shannon Road-Rillito Creek
SVE	soil vapor extraction
TCA	trichloroethane
TCE	trichloroethene
TPH	total petroleum hydrocarbon
URS	URS Corporation
USGS	United States Geological Survey
UST	Underground Storage Tank
VOCs	volatile organic compounds
WQARF	Water Quality Assurance Revolving Fund
WRCC	Western Regional Climate Center
XRF	X-ray fluorescence

1.0 INTRODUCTION

The Draft Remedial Investigation (RI) report for the Shannon Road/El Camino del Cerro (SR/ECDC) Water Quality Assurance Revolving Fund (WQARF) Site was prepared by URS Corporation (URS) on behalf of the Arizona Department of Environmental Quality (ADEQ). URS prepared the Draft RI report under the Arizona Superfund Response Action Contract guidelines outlined in the Scope of Work. ADEQ revised the Draft RI in response to comments received during the 60-day public comment period. This Final RI report presents the findings of investigative activities performed from January 2001 through June 2013 by URS. Summaries of previous investigations conducted by other consultants under contract with ADEQ and Pima County are also included.

In January 2001, ADEQ contracted with URS to conduct the RI and Feasibility Study (RI/FS) for the El Camino del Cerro (ECDC) WQARF site. Beginning in February 2001, URS reviewed and evaluated existing information obtained from previous regional and site-specific investigations, published reports, the Arizona Department of Water Resources (ADWR), and Pima County Solid Waste Management (PCSWM) to identify data gaps. In February 2003, URS was contracted by ADEQ for RI/FS work at the Shannon Road-Rillito Creek (SRRC) WQARF site. In the fall of 2004, the ECDC and SRRC WQARF sites were combined into one Site, the SR/ECDC Site (the Site). The Site is located in northwest Tucson, Arizona (Figure 1).

1.1 OBJECTIVES AND SCOPE OF THE REMEDIAL INVESTIGATION

The objectives were as follows:

- Establish the nature and extent of contamination and the potential sources,
- Identify current and potential impacts to public health, welfare, and the environment,
- Identify current and reasonably foreseeable uses of land and waters of the state,
- Develop remedial objectives for the site, and
- Obtain and evaluate any other information necessary for identification and comparison of alternative remedial actions.

The RI was conducted to assess the following factors:

1. Physical characteristics of the Site, including surface features, soils, geology, hydrogeology, meteorology, and ecology;
2. The extent and general characteristics of the hazardous substances released, including physical state, concentration, toxicity, and mobility;
3. The extent and degree of the source(s) of the release;
4. Current and reasonably foreseeable exposure routes and impacts for the hazardous

substances released, such as inhalation, ingestion and dermal contact; and

5. Other factors, such as sensitive populations, that pertain to the characterization of the Site or support the analysis of potential remedies.

1.2 REPORT ORGANIZATION

The Final RI report is structured as follows:

- Section 2.0, Site Overview, presents the Site location, description, and brief history.
- Section 3.0, Physical Characteristics, describes the meteorology, topography, current or reasonably foreseeable land use, present and future groundwater use, site hydrogeology, and surface water hydrology.
- Section 4.0, Investigations and Remedial Activities, presents a summary of the investigations and Early Response Actions (ERAs) conducted at the El Camino del Cerro Landfill, and the Site on behalf of both Pima County and ADEQ. Additionally, the distributions, trends and extent of contamination in the soils and regional groundwater and potential source areas are provided.
- Section 5.0, Groundwater Investigations and Contaminant Concentration Trends, presents a summary of groundwater monitor well installation and historical contaminant concentration trends.
- Section 6.0, Contaminant Fate and Transport, presents the factors affecting the fate and migration of contaminants of concern (COCs) in the environment, including chemical characteristics and physical properties, transport processes, chemical and biological transformation, and routes of migration.
- Section 7.0, Conceptual Site Model, presents the interpretation of all data collected during the course of the RI.
- Section 8.0, Conclusions and Data Gaps, summarizes the major findings of the Final RI.

2.0 SITE OVERVIEW

The current SR/ECDC WQARF Site has multiple stakeholders including ADEQ, Pima County, Tucson Water, and Metropolitan Domestic Water Improvement District (Metro Water). Figure 4 shows the historical groundwater plume, depicting the approximate area of groundwater associated with the Site in which a contaminant of concern has been detected, at any point in time, at a concentration greater than a regulatory standard. A brief description of historic activities and the corresponding dates is provided in Table 1. Well locations in the Site vicinity are provided in Figure 2 and the well construction information for the wells discussed in this RI is summarized in Table 2.

2.1 EL CAMINO DEL CERRO LANDFILL

ADEQ placed the ECDC site on the WQARF Priority List in May 1995. Evaluation of analytical data indicated that volatile organic compounds (VOCs) were leaching into regional groundwater from the former ECDC Landfill. In August 1998, the site was evaluated using the newly established WQARF Eligibility and Evaluation Form. The evaluation resulted in a score of 71 out of a possible 120 and the site was officially placed on the WQARF Registry.

The ECDC WQARF Site was historically divided into two primary areas: north-northeast of the I-10 freeway (the former ADEQ ECDC WQARF Site), and the Pima County response area southwest of I-10, which includes the ECDC Landfill (Figure 1). The landfill area is described as north of El Camino del Cerro Road, east of the Santa Cruz River, south of Curtis Road, and west of I-10.

The ECDC Landfill consists of approximately 19 acres and was owned and operated by Pima County between 1973 and 1977. Analytical data from monitor wells documented a VOC groundwater plume migrating from the ECDC Landfill to the north-northeast. Numerous investigations and remedial actions have been performed by Pima County at the ECDC Landfill and include:

- Soil-gas surveys on the landfill and adjacent properties;
- Drilling and construction of landfill gas monitor wells on the perimeter of the landfill;
- Characterization of the soils and landfill materials;
- Completion of a Landfill Gas Extraction Pilot Test and Landfill Gas Collection System;
- Construction of a groundwater monitor well network (Figure 2);
- Regular groundwater monitoring and water level measurements;
- Evaluation of the lateral and vertical extent of contamination; and
- Pilot study implementation followed by operations of a groundwater treatment system at the ECDC Landfill.

The findings of the RI suggest that the ECDC Landfill area is the primary source of contamination in the Site vicinity. In support of these findings, numerous other potential sources have been investigated. These investigations and their results are described in Section 4.0.

2.2 SHANNON ROAD-RILLITO CREEK

Tetrachloroethene (PCE) had been detected in March 1993 in the Tucson Water supply well Z-006 on the west side of Shannon Road just south of Rillito Creek. In September 1994, PCE, TCE, and cis-1,2-dichloroethene (cis-1,2-DCE) were detected in the Acacia Gardens Mobile Home Park (Acacia) water supply well (Figure 2). Pima County connected the mobile home park to the Tucson Water distribution system in 1995. The Acacia well was abandoned in 2001. Also in 1994, PCE and trichloroethene (TCE) were detected in Metropolitan Domestic Water District's South Shannon supply well on the west side of Shannon Road just north of Rillito Creek. Metro Water completed the installation of a wellhead treatment system in 1997 to remove VOCs. The system initially used air-stripping to remove VOCs from the water and later transitioned to direct liquid-phase carbon absorption. The South Shannon well is currently used to provide drinking water to the Metro Water service area.

ADEQ began a preliminary investigation in 1996 to determine if this area, referred to as Shannon Road-Rillito Creek (SRRC), qualified for the WQARF program. The site was evaluated using the Eligibility and Evaluation Form, resulting in a score of 53 out of a possible 120. In April 1999, the site was placed on the WQARF Registry. The approximate location of the former SRRC site is shown in Figure 1.

2.3 SR/ECDC WQARF SITE

The investigations detailed in this RI included characterization of the nature and extent of groundwater contamination in the SR/ECDC area, evaluation of aquifer characteristics, early response actions (ERAs), soil-gas investigations, and characterization of the composition of the landfill gas. Evaluation of available data indicated that there is a single groundwater plume rather than two distinct plumes. Therefore, the sites were administratively combined into the one SR/ECDC WQARF Site in the fall of 2004.

This Final RI report presents activities conducted at the Site through 2014 including groundwater sampling and installations of new monitor wells in April and May 2013. These events are discussed further in Section 5.0 and in Appendix D. However, the most recent groundwater quality data from the ECDC Landfill area made available to URS for inclusion in this report is from 2012. These data are included in Figures 5 and 7.

The contaminants of concern (COCs) identified within the SR/ECDC WQARF site include PCE, TCE, 1,1-dichloroethene (DCE), cis-1,2-DCE and vinyl chloride. A COC, as defined by Arizona

Administrative Code R18-16-401, “means a hazardous substance that results from a release and that has been identified by the Department as the subject of remedial action at a site.” COCs are those contaminants that have been detected with some consistency in groundwater, soil, or soil gas at concentrations above regulatory or risk-based levels. For the purposes of this RI, a contaminant of potential concern (COPC) is a chemical that may have been used or disposed of at a facility, is detected in environmental media at the Site at concentrations below regulatory standards, or is detected inconsistently (spatially or temporally) above a regulatory standard. COPCs at the Site are 1,1,1-trichloroethane (TCA), 1,4-dioxane, 1,1-dichloroethane (DCA), Freon 11, Freon 12, chromium, lead, benzene-toluene-ethylbenzene-xylenes (BTEX), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and nitrate plus nitrite.

3.0 PHYSICAL CHARACTERISTICS

Section 3.0 presents the physical characteristics of the Site, including meteorology, topography, current or reasonably foreseeable land use, present and future groundwater use, Site hydrogeology, and surface water hydrology.

3.1 METEOROLOGY

The climate of the Tucson area is typical of the arid southwestern desert. According to data from the Western Regional Climate Center (WRCC), temperatures reported from the University of Arizona range from average summer maximum highs in July of 101.3 degrees Fahrenheit (°F) to average winter minimum lows in December of 40.0 °F (WRCC, 2012). Temperatures reached a record high of 117 °F in Tucson in June 1990 and a record low of 6 °F in January 1913. Tucson has an annual average of 85 percent sunshine (National Weather Service, 2012). Average monthly evapotranspiration rates range from 2.58 inches in December to 9.06 inches in July (WRCC, 2008). Precipitation tends to be extremely variable, with average annual precipitation ranging from approximately 30 inches in the mountains surrounding the Tucson Basin to an average annual precipitation of 10 to 12 inches on the valley floor (WRCC, 2008).

More than one-third of the annual precipitation occurs during the months of July and August when moisture-bearing winds move into Arizona from the Gulf of Mexico. Summer rains occur in the form of thunderstorms, which can produce short, intense downpours, strong winds, lightning strikes, and flash floods. Tropical systems from the eastern Pacific Ocean can affect the area in the summer and fall months. Several large-scale flooding events have been associated with these systems including historic events in 1977 and 1983. Winter storm systems from November through March typically originate over the Pacific Ocean.

Surface winds in the Tucson Basin are typically light, with wind velocity and direction influenced by the surrounding mountains and local terrain. The winds tend to be from the southeast during the night and early morning hours and from the northwest during the day. Winds from the southwest and southeast tend to have the highest velocities. Occasional dust storms may occur in areas where the surface soils are exposed.

3.2 TOPOGRAPHY

The city of Tucson lies within the Tucson Basin, a broad northwest trending alluvial valley within the Basin and Range Physiographic Province encompassing approximately 1,000 square miles. Valley floor elevations range from 2,000 ft above mean sea level (amsl) at the very northwestern edge of the basin to approximately 3,500 ft amsl at the southeastern boundary. The surrounding mountains range from 3,000 ft to over 9,000 ft amsl. Ground surface elevations within the Site range from approximately 2,074 to 2,087 ft amsl (URS, 2012a).

3.3 CURRENT OR REASONABLY FORESEEABLE LAND AND WATER USE

The Site occupies an area of approximately 356 acres. Approximately 240 acres are located in Pima County and are zoned as Industrial Multiple Use. Approximately 116 acres are located within City of Tucson limits and are Rural Suburban Homestead, Industrial and Multiple Use. The Land and Water Use Study for the SR/ECDC area is presented in Appendix A.

The foreseeable changes to land regulated by Pima County include allowing residential uses in the strip between I-10 and North Highway Drive, regulating development along Rillito Creek, and allowing light and general industry north of Rillito Creek. Between Rillito Creek and the I-10/North Highway strip, the Pima County Comprehensive Plan allows for a wider variety of residential, business, and industrial uses. Pima County considers the land in the vicinity of the Site as an area for potential future growth. The City of Tucson is not planning to change any of its land uses in the Site vicinity.

The SR/ECDC area lies within the Tucson Active Management Area and encompasses approximately 110 ADWR registered wells. Tucson Water owns two inactive groundwater extraction wells in the Site vicinity. Metro Water currently uses groundwater to supply potable drinking water to its customers. These uses are expected to continue into the foreseeable future. The Pima County Regional Wastewater Reclamation Department currently uses groundwater to supply irrigation and industrial water on a standby/emergency basis. The responses to the Land and Water Use Study Questionnaire are provided in Appendix A.

The Site is located just east of the Santa Cruz River and extends north of Rillito Creek. These streams are the major surface drainages in the Tucson Basin. There is a discharge flow during most of the year on the Santa Cruz River from the Roger Road Wastewater Reclamation Facility located approximately one mile upstream of the Site. There are no known uses of surface water within the Site.

3.4 SITE HYDROGEOLOGY

This section describes the regional hydrogeology and the Site-specific geologic and hydrologic conditions including results from aquifer testing performed by Metro Water. In addition, surface water hydrology is addressed including discharge data related to recharge of the regional aquifer.

3.4.1 Hydrogeologic Units

A generalized geologic cross section is shown in Figure 9. Given the relatively sparse data collected by different geologists from monitor wells across a large area and over a long time period, it is difficult to draw specific conclusions regarding geologic patterns at the site. However, historical research in the Tucson basin has provided a general overview of broad hydrogeologic units present in the basin.

Recent Alluvium

The Quaternary age recent alluvium includes modern floodplain, stream channel, and terrace deposits, and consists of unconsolidated coarse-grained sand and gravel with a small percentage of silt and clay. The Site is near the confluence of the Santa Cruz River and Rillito Creek and is underlain by recent alluvium. Geologic cross sections based on drillers' logs indicate that the thickness of the recent alluvium ranges from approximately 50 to 90 ft (CH2M Hill et al., 1987). Results of gravity measurements by Montgomery (1971) indicate that specific yield of recent alluvium sediments may range from 0.11 to 0.41 with an average of approximately 0.27.

Fort Lowell Formation

The Fort Lowell Formation unconformably overlies the Tinaja beds. The Quaternary age Fort Lowell Formation consists of unconsolidated to weakly consolidated heterogeneous deposits of interbedded clayey silts, sandy silts, sands, and gravels. At the Site, the Fort Lowell Formation is estimated to be approximately 80 ft thick, and relative silt and clay content is estimated to be approximately 20 to 40 percent (CH2M Hill et al., 1987). Based on review of drilling logs, the Fort Lowell Formation and the upper Tinaja beds form the most productive part of the aquifer, because these units are generally coarser-grained and less consolidated than underlying units.

Because aquifer sediments were deposited in braided channel alluvial environments, buried paleochannels containing coarser-grained sediments may have formed. The paleochannels may be actual channels or small and discontinuous braided channels that may be close together and able to form higher permeability preferential pathways for groundwater flow within the aquifer.

Tinaja Beds

The Tertiary age Tinaja Formation unconformably overlies the Pantano Formation, and is generally subdivided into the upper, middle, and lower Tinaja beds. The Tinaja Formation formed in a closed basin environment and contains evaporitic deposits in the middle and lower beds.

The upper Tinaja beds consist of unconsolidated to weakly consolidated heterogeneous deposits of interbedded clayey silts, sandy silts, sands, and gravels. At many locations, grain size is coarse and similar to the Fort Lowell Formation. At the SR/ECDC Site on the west side of the Santa Cruz Fault, the upper Tinaja beds are estimated to be approximately 150 ft thick. On the east side of the Santa Cruz Fault, the upper Tinaja beds are estimated to be approximately 650 ft thick. Relative silt and clay content is estimated to be approximately 20 to 60 percent at the SR/ECDC Site (CH2M Hill et al., 1987).

The middle Tinaja beds consist of moderate to well consolidated gypsiferous and anhydritic clayey silt and mudstone, and locally include reddish cemented sands and gravels. The middle Tinaja beds are generally absent on upthrown fault blocks along the basin margins and are likely not present on the southwest side of the Santa Cruz Fault. Thickness of the middle Tinaja beds at the SR/ECDC Site is unknown. Maximum thickness of the middle Tinaja beds in the Tucson Basin is believed to be more than 2,000 feet (Anderson, 1987).

The lower Tinaja beds consist of well-consolidated clayey silt, mudstone, sand, gravel, and moderately lithified conglomerate. The lower Tinaja beds are more consolidated and cemented than the upper and middle beds. Reported thickness of the lower Tinaja beds is about 1,500 feet.

Pantano Formation

The Tertiary age Pantano Formation unconformably overlies the basement complex and consists of gypsiferous mudstone, sandstone, and conglomerate. In places, it includes megabreccias, tuff beds, and volcanic flows. The formation is weakly to strongly cemented with calcium carbonate (Davidson, 1973). Wells in the Tucson Basin have penetrated as much as 1,700 ft of Pantano Formation.

Basement Complex

The basement complex includes igneous, metamorphic, and well-lithified sedimentary rocks. The permeability and porosity of the basement complex is low, and these rocks yield only small amounts of groundwater from fractures to wells and springs. The rocks of the basement complex are considered to form the basal confining unit for the Tucson Basin groundwater reservoir.

3.4.2 Geomorphology

The Tucson Basin lies in the Basin and Range Lowlands Hydrogeologic Province of southern Arizona, which is characterized by alluvial valleys and basins separated by isolated mountain ranges. The Tucson Basin is formed by a tectonically-depressed trough filled with several thousand feet of sediments eroded from the surrounding mountain blocks. The Santa Catalina Mountains and the Rincon Mountains form the northern and eastern boundaries, respectively, and consist primarily of metamorphic and igneous rocks. The igneous and sedimentary Santa Rita Mountains form the southern boundary, and the volcanic and sedimentary Tucson Mountains bound the basin to the west (Anderson, 1987).

The Santa Cruz Fault is a high-angle, normal fault that trends southeast to northwest through the Site vicinity. Well logs suggest that the Santa Cruz Fault displaces the middle and lower Tinaja beds and the Pantano Formation; however, there is no indication that the Santa Cruz Fault displaces the upper Tinaja beds or the Fort Lowell Formation. Anderson (1987) stated that the fault may influence flow in the lower regional aquifer, but that groundwater in the upper aquifer was not likely to be affected. A second, unnamed fault trends southwest to northeast through the Site vicinity.

3.4.3 Groundwater

Groundwater withdrawal and recharge are considered to have a major effect on the groundwater flow regime in the Tucson Basin. Sources of groundwater withdrawal include groundwater pumping and groundwater underflow to adjacent basins. Sources of groundwater recharge include infiltration from the Santa Cruz River and tributaries, irrigation return flow, and surface water impoundments.

Regional groundwater at the Site occurs in the Fort Lowell Formation at an average depth of approximately 155-160 ft bgs. The regional water level in the Tucson Basin has declined in response to pumping. In the vicinity of the SR/ECDC Site, the decline in water levels during the period from 1947 to 1985 is estimated to be approximately 50 to 75 ft (CH2M Hill et al., 1987). Groundwater levels continued to decrease at an average rate of approximately 1.4 ft/yr from 1986-2013. For the purpose of discussing and evaluating the vertical extent of groundwater impacts at the Site, the regional aquifer has been divided into the following three depth zones:

- **Shallow-zone wells** are screened across the uppermost portion of the regional aquifer, with the depth to the bottom of the screens ranging from approximately 100 to 200 feet (ft) below ground surface (bgs);
- **Medium-zone wells** have submerged screens typically in the upper part of regional aquifer, with screen intervals ranging from approximately 200 to 280 ft bgs; and
- **Deep-zone wells** have submerged screens in the regional aquifer, with the depths ranging from approximately 280 to 400 ft bgs.

Groundwater elevation contours measured during the first half of 2012 are presented in Figure 10. Groundwater elevation data from shallow, medium, and deep screened wells are displayed on Figure 10 because significant vertical gradients have not historically been observed in wells at the Site. Groundwater elevation data indicate that the direction of hydraulic gradient is generally towards north-northeast but historically varies due to groundwater pumping and short-term large-scale infiltration events. The hydraulic gradient varies from approximately 0.002 along the western edge of the Site to approximately 0.01 north of the Rillito Creek, near the South Shannon well as measured using the groundwater elevation contours in Figure 10. Groundwater levels, direction of groundwater flow, and hydraulic gradient have been observed to vary considerably over time (Malcolm Pirnie, 1998). Appendix E contains groundwater elevation maps from 1988 to 2012. The determination of the general direction of the groundwater flow may be further complicated by complex hydrogeologic features present due to the Site's location near the confluence of two major drainage channels of the Tucson Basin. Characteristics of these features can be difficult to identify given the limited lithologic data points available. Therefore, the determination of the general groundwater flow direction considers multiple lines of evidence including measured hydraulic gradient, the effects of pumping, historical contaminant concentration data and information on potential source areas collected during extensive field investigations. In general, groundwater at the site appears to flow in a direction to the north-northeast across the Site.

Tucson Water has two inactive production wells (Z-004 and Z-006) in the Site vicinity (Figure 2). Metro Water has seven active production wells (South Shannon, DeConcini, Wildwood, Estes, Moore, Lattimore-N and Lattimore-S) north of Rillito Creek near South Shannon Road. The number and location of wells, the rates for individual wells, and the duration and schedule of pumping have changed over time. Historically, pumping regimens and recharge events have combined to influence the direction of groundwater flow and gradient.

During storm runoff recharge events, groundwater mounding occurs at the water table along stream channels and the direction of groundwater flow may temporarily shift toward a direction nearly perpendicular to the stream channel in localized areas. During the spring of 1993, the groundwater flow direction reversed from northerly to southerly flow in the vicinity of the eastern boundary of the ECDC Landfill (Appendix E). Recharge occurring along stream channels in response to storm runoff events has been shown to be highly variable (Malcolm Pirnie, 1997).

At the Site, recharge from ephemeral flow may occur along Rillito Creek and the Santa Cruz River depending on the distribution of precipitation and streamflow. From 1904 to 1975, annual peak flow in Rillito Creek ranged from 297 to 70,660 acre-ft per year (ac-ft/yr) and the average annual peak flow was 11,660 ac-ft/yr. From 1906 to 1980, annual peak flow in the Santa Cruz River ranged from 976 to 58,840 ac-ft/yr and the average annual peak flow was 16,450 ac-ft/yr. In addition to storm water runoff, the Santa Cruz River receives discharge from the Roger Road Wastewater Reclamation Facility (Malcolm Pirnie, 1997).

The Roger Road Wastewater Reclamation Facility discharges to the Santa Cruz River upstream from the ECDC Landfill. This discharge increases the fine sediments lining the Santa Cruz River reducing the infiltration capacity of the river channel in the vicinity of the discharge. However, infiltration capacity of the area river beds is believed to increase following the scouring effects of storm water runoff events which remove silt and other fine sediment.

According to the City of Tucson, about 8,700 ac-ft/year of the effluent produced at the Roger Road Wastewater Reclamation Facility is reclaimed for irrigation of 30 school grounds, 25 parks, and 13 golf facilities, as well as other uses. Because peak effluent production occurs in the winter months and peak demand for effluent as irrigation occurs May through October, the city stores effluent underground. The Sweetwater Recharge Facility is located approximately one mile upgradient of the ECDC Landfill and consists of basins constructed on the west and east sides of the Santa Cruz River to recharge and filter effluent. During the summer months, water is recovered, chlorinated, and placed in the reclaimed water distribution system to supplement production.

3.4.4 Aquifer Parameters

In order to assess plume migration and hydraulic containment systems, estimates of aquifer parameters have been established. The porosity of the Fort Lowell Formation was estimated by Davidson (1973) from geophysical logs obtained at four wells to range from 26 to 34 percent; the average was 30 percent. Average specific yield is approximately 15 percent. Hydraulic conductivity, estimated from pumping tests at Tucson Water wells about 1 to 2 miles west of the Site, ranges from 200 to 500 gpd/ft^2. Results of a pumping test at well CW-1 in the northeastern corner of the ECDC Landfill indicated a hydraulic conductivity of about 900 gpd/ft^2 and a specific yield of about 0.05 (Malcolm Pirnie, 1998). The ratio of vertical to horizontal hydraulic conductivity computed from aquifer tests for units similar to the Fort Lowell Formation commonly ranges from 1:10 to 1:100, indicating that vertical hydraulic conductivity of the Fort Lowell Formation at the Site may be in the range of 1.2 to 20 gpd/ft^2.

In February 2004, an aquifer test was performed on Metro Water's South Shannon well (URS, 2005a). The South Shannon well is screened from 90 to 501 ft bgs. Analysis of the aquifer tests indicates a transmissivity of 53,000 gallons per day per foot, average storativity of 0.00066, average specific yield of 0.017, and an average ratio of vertical hydraulic conductivity to horizontal conductivity of 1:32. Aquifer testing was also conducted using the South Shannon well, the Acacia Gardens well, and Tucson Water's well Z-006. Aquifer transmissivity was calculated to be between approximately 37,000 and 82,000 gallons per day per foot (Kleinfelder, 2002b).

Porosity of the upper Tinaja beds was estimated by Davidson (1973) from geophysical logs obtained at four wells to range from 24 to 35 percent. Horizontal and vertical hydraulic conductivities of the upper Tinaja beds were estimated from the results of a 72-hour aquifer test at the Tucson Water Demonstration Recharge site on the west bank of the Santa Cruz River approximately 1 mile south from the SR/ECDC Site. Horizontal hydraulic conductivity ranged from 110 to 480 gpd/ft^2; the average was approximately 300 gpd/ft^2. Vertical hydraulic conductivity ranged from 2 to 17 gpd/ft^2; average was approximately 7 gpd/ft^2. The ratio of vertical to horizontal hydraulic conductivity was approximately 1:40 (CH2M Hill, 1986).

3.5 SURFACE WATER HYDROLOGY

The majority of the Site lies between the Rillito Creek and Santa Cruz River (Figure 1). The Santa

Cruz River and Rillito Creek are the major surface drainage ways in the Tucson Basin.

3.5.1 Rillito Creek

Rillito Creek is the largest tributary to the Santa Cruz River and drains approximately 900 square miles (Hoffmann et al., 2002). The Rillito Creek originates at the confluence of Pantano and Tanque Verde washes and flows approximately 12 miles northwest to its confluence with the Santa Cruz River. Rillito Creek is an ephemeral stream that flows only in response to precipitation events and snowmelt from the Santa Catalina Mountains to the north and the Rincon Mountains to the east. Storm related flows can persist from a few hours to a few days. Similar to the Santa Cruz River, monthly and annual peak discharges from the Rillito Creek vary significantly. Table 3 presents a summary of the United States Geological Survey (USGS) monthly mean discharge data between 1995 and 2012 from a gauging station just upstream of the SR/ECDC Site at the intersection of La Cholla Boulevard and Rillito Creek. The discharge rate is measured in cubic ft per second (cfs). The mean monthly discharge rates over this 18-year period range from 0.0 cfs in May to 51 cfs during July. The mean peak monthly discharge rate occurred in July 2006 with a discharge rate of 509 cfs; the mean peak daily discharge was 39,000 cfs on July 31, 2006 (USGS, 2013).

In 2002, the USGS in cooperation with the ADWR conducted research on the characteristics of the stream channel and basin fill deposits beneath a 12-mile section of Rillito Creek to improve understanding of recharge processes beneath ephemeral streams (Hoffmann et al., 2002). The lower reach of the study area encompasses a portion of the Site. It was determined that the Rillito Creek deposits range in thickness from 15 to 40 ft, generally consisting of sands and gravels. The underlying basin fill deposits were also identified as mostly sands and gravels; however, with a slightly higher percentage of silt and clay. Porosity values for the stream channel and basin fill deposits were similar with average porosity of 31 and 34 percent, respectively. Saturated vertical hydraulic conductivity of the stream channel deposits was an order of magnitude greater than basin fill deposits. The equivalent hydraulic conductivity of stream channel deposits averaged 4 ft per day (ft/day) and the basin fill deposits averaged 0.61 ft/day.

3.5.2 Santa Cruz River

The Santa Cruz River drains a 13,790 square-mile watershed in southern Arizona and northern Mexico and flows north through Tucson along the western edge of the Site. Davidson (1973) reported that the Santa Cruz River averaged from 320 to 330 days per year without natural flow. Natural stream flows are typically based on seasonal precipitation with summer flows characterized by high peak discharges and short durations reflecting summer monsoons, and winter flows characterized by lower peak discharges and longer durations. Perennial flow in the Santa Cruz River is present downstream of the Roger Road Wastewater Reclamation Plant because of treated effluent releases. According to the 2011 Effluent Generation Report, prepared by Pima County Regional Wastewater Reclamation Department, the reclamation facility discharged 22,985 acre-ft to the Santa Cruz River under the authorization of an Arizona Pollutant Discharge Elimination System permit. An additional 11,273 acre-ft of effluent was discharged to the City of Tucson Sweetwater Recharge Facility.

Table 3 presents a summary of the USGS monthly mean discharge data from a gauging station on the Santa Cruz River near Congress Street. The discharge rates are measured in cfs between 1996 and 2011. The mean monthly discharge rates over this 16-year period range from 0.14 cfs in May to 55 cfs during July. The peak monthly mean discharge rate occurred in August 2005 with a discharge rate of 253 cfs; the peak daily mean discharge rate for all historical data was 52,700 cfs, on October 2, 1983 (USGS, 2013).

4.0 INVESTIGATIONS AND REMEDIAL ACTIVITIES

The following section discusses the investigations, ERAs, and remedial activities at various properties throughout the Site. A chronology of selected Site activities is presented in Table 1.

URS conducted a records search in 2002 to assess properties in the area based on historical occupants, operations, and activities. This study area encompassed an area approximately bounded by Sunset Road on the north, Emerald Avenue on the east, Ruthrauff Road on the south and I-10 on the west. The results indicated that 13 of the 22 properties within this area may have used solvents or reportedly had VOC detections in soil samples. Sites identified with potential to impact groundwater quality according to operational history and available analytical data included the ECDC Landfill area, former AMRI Oil (Wrecksperts/Western Stucco/Western Trailer), former E.C Winter, and several properties within the I-10 corridor area Figures 11 and 12 (URS, 2002e).

The RI field activities provided further information to evaluate the sources, nature, and extent of contamination in soils and groundwater (URS, 2002a). The activities have characterized hydrogeologic conditions, evaluated the factors that influence fate and transport, and assessed the risks to human health and the environment.

The following sub-sections discuss individually the properties identified as having potential to impact groundwater quality and the associated investigations and remedial activities that have been conducted at each of the properties. Monitoring activities associated with groundwater are primarily discussed in Section 5.0.

4.1 EL CAMINO DEL CERRO LANDFILL AREA

The ECDC Landfill area is comprised of properties to the south and west of I-10. These properties include the ECDC Landfill and the Drake/Lee's Auto property. These properties are being discussed together for simplicity, as many investigations were conducted on both properties.

The ECDC Landfill occupies approximately 19 acres along the east bank of the Santa Cruz River just north of El Camino del Cerro Road (Figures 11 and 12). Aerial photography indicates this location was used as a sand and gravel pit from as early as 1967. A January 7, 1971, aerial photograph shows that a gravel pit covered the north half and southwest quarter of the property. The gravel processing plant was located in the southeast corner of the property. There was a pond in the north half of the gravel pit and four ponds in the gravel processing areas. A drainage ravine that entered the property from the east had been disrupted by the gravel processing area. (HGL, 2014)

The Pima County Department of Sanitation operated El Camino del Cerro Landfill, which was permitted to receive garbage and trash. The landfill received approximately 330 tons of garbage and trash per day. According to a 1977 Pima County memorandum, the county's standard operating procedure for landfills in the 1960s and 1970s was to maintain an employee presence on site for 9 hours a day. However, landfills were open 24 hours a day, which led to "uncontrolled scavenging and dumping". Interviews conducted to date by HydroGeoLogic (HGL), which are considered privileged at this time in the investigation, indicate that the landfill was used as a "wildcat" dump before it was used as a landfill (HGL, 2014).

The landfill had an approximate depth of 80 feet below ground surface (bgs) and operated on a 24-hour basis from 1973 through 1977 (HGL, 2014). The landfill was closed in October 1977 after being inundated by flooding from the Santa Cruz River (Brown and Caldwell, 2011a). Specifically, the area that was flooded in 1977 was in approximately the southern third of the property. The landfill contains an estimated 582,000 tons of buried debris. No records or manifests were kept regarding the types and quantities of waste disposed of on site or the names of the companies that hauled the waste to the landfill for disposal (HGL, 2014).

In 1982, Pima County began a Landfill Environmental Studies Program (LESP) to determine the environmental effects of active and closed landfills, including the ECDC Landfill. The LESP was originally managed by the Pima County Office of Capital Development, a division of the Pima County Wastewater Management Department. The Pima County Solid Waste Management Division was responsible for the daily operation of all public solid waste disposal facilities in the unincorporated areas of Pima County when the LESP began. The project was undertaken by the Pima County Office of Capital Development to allow the Solid Waste Management Division staff to operate the active County landfills. The Pima County Office of Capital Development completed two phases and initiated the third phase of the LESP, conducted by Malcolm Pirnie. The monitoring program at the landfill area included soil-gas surveys and soil sampling, installation of monitor wells and soil vapor extraction wells, and the installation of lysimeters and neutron access probes to aid in monitoring soil moisture over time.

In 1990, as part of the LESP Phase 3, water levels were collected and evaluation of the data confirmed that during periods of high surface water flow in the Santa Cruz River, infiltration from the river would enter the ECDC Landfill. In July 1994, Pima County Department of Transportation and Flood Control District extended soil cement bank protection from approximately 20 ft to 40 ft below the top of the river bank (Malcolm Pirnie, 1997).

Lee's Auto, an automobile salvage/wrecking yard, was located on the Drake property, adjacent to the east of the ECDC Landfill (Figures 11 and 12). Historical aerial photographs show that the Drake property contained an automobile storage area as early as 1958. However, the former Lee's

Auto is thought to have operated on the Drake property only from 1964 through 1985; prior to 1964 Lee's Auto was located on another property on North Oracle Road in Tucson (HGL, 2014). According to aerial photographs, an ephemeral tributary that had historically drained the watershed east of the property was diverted around the auto salvage yard. This tributary flows in the direction of the ECDC Landfill property. The aerial photographs also show that during operations at Lee's Auto, no fencing or other constraints existed to prohibit access to the ECDC Landfill property (HGL, 2014). In 1995, Pima County purchased a 200 ft strip of the Drake property adjoining the eastern edge of the landfill as part of an interim remedial measure (Malcolm Pirnie, 1998).

4.1.1 Early Response Actions and Investigations

Soil

In 1986, as part of the LESP Phase 2, geology in the vicinity of the ECDC Landfill was characterized through evaluation of the existing lithologic data. It was determined that shallow alluvium at the ECDC Landfill was relatively coarse-grained from the surface to a depth of approximately 40 ft bgs. Finer-grained sediments extended from approximately 40 ft bgs to an approximate depth of 175 ft bgs. From 175 ft bgs to 200 ft bgs, the sediments transitioned to a coarser grain material. The total porosity of native soil samples ranged from 29.2 to 44 percent bulk volume.

In 1989, Pima County placed native soil over the ECDC Landfill. The cover material, with thickness ranging from approximately 5 to 20 ft, was graded to improve drainage away from the landfill, eliminate ponding, and reduce infiltration into landfill materials (Malcolm Pirnie, 1997).

LESP Phase 3 drilling activities began in 1994 to install five shallow and five deep landfill gas monitor wells around the perimeter of the ECDC Landfill (Figure 13). Geologic logs from soil borings demonstrated that the depth of landfill materials ranged from 30 ft bgs near the perimeters of the landfill to approximately 85 ft bgs in the central and western portions of the landfill.

VOCs were not detected in 78 soil samples collected from depths between 10 ft bgs and 90 ft bgs in the native soils surrounding the ECDC Landfill. However, analysis of soil samples collected from landfill materials near the eastern perimeter of the ECDC Landfill, at depths of 30 ft bgs and 70 ft bgs, detected 1,2-dichlorobenzene, 1,4-dichlorobenzene, ethylbenzene, and xylenes at concentrations ranging from 0.011 milligrams per kilogram (mg/kg) to 0.16 mg/kg.

Soil-Gas Studies Adjacent to the ECDC Landfill

From 1984 through 1992, the following five soil-gas studies were performed on properties adjacent to the ECDC Landfill:

- Harding Lawson Associates: LESP Phase·2, Areal Survey, June 1984.
- Harding Lawson Associates: LESP Phase 2, Areal Survey, March 1986.
- Tracer Research Corporation: Shallow Soil Gas Investigation, September 1990.
- Hydro Geo Chem, Inc.: Soil Gas Survey of 3200 El Camino del Cerro, October 1991.
- Tracer Research Corporation: Shallow Soil Gas Investigation - Drake Property, August 1992.

Harding Lawson Associates performed the first soil-gas survey in June 1984 to provide preliminary information of the areal distribution of VOCs in soils 5 to 7 ft bgs around the landfill. Sample locations were spaced approximately 200 ft apart in areas primarily to the north and south of the ECDC Landfill, with four sampling locations on the Drake/Lee's Auto property. All samples were analyzed for PCE and TCE and less than half of the samples were also analyzed for 1,1,1-TCA and Freon 113. Concentrations of PCE, TCE, 1,1,1-TCA, and Freon 113 were detected, although concentrations of 1,1,1-TCA and Freon 113 were relatively low compared with concentrations of PCE and TCE. The highest PCE concentration reported was 946 parts per billion by volume (ppbv) at a location on the southeast border of the ECDC Landfill, and the highest concentration of TCE was 1,492 ppbv on the south border of the ECDC Landfill (Appendix Q, Figure 1). PCE and TCE were also detected in the areas along the northern border of the ECDC Landfill, at concentrations ranging from 103 to 739 ppbv for PCE, and <0.4 to 559 ppbv for TCE (Malcolm Pirnie, 1996a).

Harding Lawson Associates performed a second soil-gas survey in March 1986 on the east side of the ECDC Landfill, primarily on the property to the north of Drake/Lee's Auto, with four sampling locations extending along the southeast border of the landfill. The 1986 soil-gas survey measured concentrations of PCE, TCE, 1,1,1-TCA, and methane in samples at depths that ranged from 3 to 5 ft bgs, depending on location. The survey provided confirmation of the presence of PCE, TCE, and 1,1,1-TCA around the ECDC Landfill. Similar to results reported from the earlier 1984 soil-gas survey, in 1986 the highest concentrations of VOCs were present in soil-gas samples near the southeast corner of the ECDC Landfill boundary, at 296 ppbv for PCE and 186 ppbv for TCE (Appendix Q, Figure 2). The highest off-Site methane concentrations were reported for samples coinciding primarily with the high PCE/TCE detections. Methane concentrations in soil gas appeared to rapidly decrease with increasing distances from the landfill (Malcolm Pirnie, 1996a).

The purpose of the September 1990 Tracer Research Shallow Soil Gas Investigation was to delineate the extent of VOC contamination in soil gas from sampling locations north and northeast of the ECDC Landfill, including the I-10 Corridor (Section 4.4). The target analytes were PCE, TCE, 1,1,1-TCA, and benzene, toluene, ethylbenzene, and total xylenes (BTEX). During this investigation samples were collected from approximately 6 ft bgs from numerous properties. The results indicated that PCE had the widest distribution among the target compounds analyzed. PCE was detected in all but two soil-gas samples with the highest recorded at 591 ppbv in the I-10 Corridor area (Appendix Q, Figure 3). Additional details regarding the results from the vicinity of the I-10 Corridor area are provided in Section 4.4. PCE was detected at 30 ppbv in locations along the north and southeast boundaries of the landfill. TCE was detected in less frequently in the soil-gas samples than PCE. Consistent with PCE, the highest concentration of TCE (112 ppbv) was detected in samples collected on the southeast corner of the ECDC Landfill. 1,1,1-TCA was detected in soil-gas samples at low concentrations (<0.006 to 7.3 ppbv) with no discernable pattern. In addition to chlorinated compounds and BTEX, Tracer Research Corporation analyzed samples for total hydrocarbons. The BTEX compounds were not detected in any of the soil-gas samples collected during this investigation. However, one soil-gas sample on the northern boundary of the ECDC Landfill had a reported a total hydrocarbon concentration of 20,000 μg/L (which is equivalent to approximately 32,000,000 ppbv, assuming an average molecular weight of 150 g/mol for total hydrocarbons) (Malcolm Pirnie, 1996a).

Hydro Geo Chem, Inc. performed a soil-gas investigation of the Drake/Lee's Auto property (Figures 11 and 12) immediately east of the ECDC Landfill in 1991. Soil-gas samples were collected from 5 ft bgs in most locations, and from 5 and 15 ft bgs in two locations along the southeast boundary of the ECDC Landfill. The chlorinated hydrocarbons analyzed at each location were PCE, TCE, 1,1,1-TCA, and 1,1-DCE. BTEX, total hydrocarbons, and methane were also target compounds for this investigation. As observed in previous soil-gas sampling, PCE had the greatest number of detections in soil-gas samples among the chlorinated compounds. PCE was primarily detected near the southeastern boundary of the ECDC Landfill, extending 200 to 400 ft east into the Drake property, with the highest detection of PCE (581 ppbv) located approximately 200 ft east of the eastern boundary of the southern portion of the landfill (Appendix Q, Figure 4). TCE had a similar areal distribution to PCE, with the maximum concentration of 468 ppbv in the same location as the highest PCE detection. In addition, 1,1-DCE was detected in soil-gas samples from some of these locations. BTEX compounds were also detected in soil-gas samples from the Drake property and all soil-gas samples had detections for total hydrocarbons. Methane concentrations in gas samples ranged from 5 to 67,000 μg/L (equivalent to approximately 7500 – 100,500,000 ppbv) with a distribution correlated with the distribution pattern of PCE and TCE (Malcolm Pirnie, 1996a).

A further field investigation of VOC contamination in soil gas at the Drake/Lee's Auto property was performed by Tracer Research Corporation in 1992. This investigation included collecting soil-gas samples at 34 sample locations from approximately 3 to 19 ft bgs. The majority of the 34 sample locations were sampled only at one depth (10 – 13 ft bgs), with three locations sampled at two depths (approximately 5 and 10 ft bgs), and a fourth location sampled at three depths (6.5, 13, and 19 ft bgs). The four multi-level sampling locations were spaced along the eastern edge of the ECDC Landfill. Soil-gas samples were evaluated for the presence of PCE, TCE, 1,1,1-TCA, cis-1,2-DCE, 1,1-DCE, vinyl chloride, and methane with detectable concentrations of each compound detected. The sampling locations and PCE and TCE results from the approximately 13 ft bgs samples are presented in Figure 5 of Appendix Q. A summary of the results of this investigation is presented on Figure 6 of Appendix Q. The highest PCE concentration was 1,034 ppbv, detected at 12 ft bgs in the same general location as the highest concentrations observed in previous studies – that is, approximately 200 ft to the east of the southern portion of the eastern boundary of the ECDC Landfill. The PCE distribution was also similar to previous soil-gas surveys, with concentrations ranging from 0.9 to 738 bbpv along the eastern boundary of the landfill, and extending 200 - 400 ft to the east into the Drake property. TCE and 1,1,1-TCA had lower detection frequencies than PCE, but similar areal distributions. TCE concentrations ranged from 0.4 to 373 ppbv with the maximum concentration of 746 ppbv detected in the sample collected from 19 ft bgs adjacent to the eastern boundary of the landfill. 1,1,1-TCA was detected at concentrations ranging from 0.09 to 0.4 ppbv with a maximum concentration of 165 ppbv detected in the sample collected from 6 ft bgs on the southeast corner of the landfill,. Detections of cis-1,2-DCE and 1,1-DCE also occurred primarily in the area next to the southeast corner of the ECDC Landfill. Vinyl chloride was detected in high concentrations in samples from the same areas with high concentrations of PCE, TCE, and 1,1,1-TCA. The maximum concentration of vinyl chloride detected was 82,320 ppbv in a sample collected near the southeast corner of the landfill from 5 ft bgs. BTEX compounds were not detected in most of the soil-gas samples collected from the Drake Property during this investigation. However, total hydrocarbons was reported from locations across the entire site with the highest detection of 74 μg/L (approximately 11,800 ppbv). Methane concentrations of 110,000 μg/L (approximately 165,000,000 ppbv) were detected in samples collected at 12 and 13 ft bgs from locations nearest to the landfill. Generally, chemical concentrations in soil gas increased with increasing sample depths; however, these results varied among sampling locations (Malcolm Pirnie, 1996a).

In summary, chlorinated solvents were the target compounds for each of the surveys performed in the vicinity of the ECDC Landfill. Soil-gas samples were collected from relatively shallow depths of less than 20 feet. Concentrations of PCE, TCE, and 1,1,1-TCA were detected in soil-gas samples from each investigation between 1984 and 1992. PCE consistently had the widest distribution and some of the highest concentrations among the chlorinated VOCs, with the exception of vinyl chloride in 1992. Additionally, concentrations of PCE were consistently elevated along the southeastern boundary of the landfill and extending from that boundary approximately 200 – 400 ft east into the Drake property (Malcolm Pirnie, 1996a).

Soil-Gas Studies at the ECDC Landfill

Studies of VOCs in soil gas within the boundaries of the ECDC Landfill were conducted as part of the LESP Phase 2 and Phase 3 investigations.

Harding Lawson Associates performed an investigation at the ECDC Landfill as part of the broader soil-gas survey conducted in 1986. The purpose of this investigation was to determine the distribution of VOCs in the northern half of the landfill (Harding Lawson Associates, 1986). Samples were collected from 5 and 7 ft bgs. PCE was detected in all the samples and TCE in all but one of the samples collected at the ECDC Landfill. The highest reported concentration of PCE is 443 ppbv detected in two samples; one collected along the northern end of the western boundary of the landfill and the other collected from the center of the landfill. TCE was detected at a maximum of 373 ppbv in a sample collected from the center of the northern half of the landfill. 1,1,1-TCA was detected in four samples, ranging from 0.1 to 73 ppbv. These detections were located on the eastern and western boundaries of the landfill. Methane was detected in all but one sample, in concentrations ranging from 6,000 to 370,000 ppbv. Other VOC data from this study were not available. None of these sampling locations were near the area of highest chlorinated solvent detections external to the landfill (i.e. near the southeastern corner of the landfill).

In 1992, Tracer Research Corporation performed a survey that focused on methane at the ECDC Landfill. Methane was primarily distributed around the boundary of the landfill. The western and southern boundaries had consistently high concentrations and localized areas of high concentration were identified along the eastern and northern boundaries of the ECDC Landfill (Malcolm Pirnie, 1997).

In 1994 and 1995, Pima County initiated an ERA to remove VOCs from the soil gas at the landfill. In preparation, soil-gas samples were taken from five shallow (GS-1 – GS-5) and five deep (GD-1 – GD-5) soil vapor monitor wells located within the landfill (Figure 13). In addition, three shallow groundwater monitor wells that were installed in 1988 were converted to soil vapor monitor wells (P-1, P-2, and P-3; Figure 13) and sampled. The maximum concentration of PCE (2,100 ppbv), TCE (350 ppbv), and cis-1,2-DCE (1,600 ppbv) were in detected in samples collected from deep (70 ft bgs) well GD-5. In samples collected from other wells PCE ranged from <1 – 940 ppbv, TCE ranged from <0.1 – 190 ppbv, and DCE ranged from <0.2 – 330 ppbv. Most PCE and TCE detections were from samples collected along the eastern and northern boundaries of the landfill. Cis-1,2-DCE was detected in each of the wells sampled except GD-1. Vinyl chloride had the highest concentrations detected of all the chlorinated ethenes. This result is not unexpected given the reductive conditions within and underlying landfills. Vinyl chloride was detected in samples collected from each of the wells at concentrations ranging from 93 –5,600 ppbv with the maximum concentration detected in shallow (40 ft bgs) well GS-4 (Malcolm Pirnie, 1995a). 1,1,1-TCA was only detected in GS-3 and GS-4 at 90 and 110 ppbv. Concentrations of 1,1,1-TCA breakdown products 1,1-DCA and chloroethane were detected in both shallow and deep wells at concentrations ranging from 13 – 450 ppbv. Summaries of the landfill gas monitoring results are presented in Figures 7 and 8 in Appendix Q. Further details of ECDC Landfill Operating Unit soil-gas characterization for this ERA can be found in Malcolm Pirnie, 1995a and 1997.

In 1995, the ERA landfill gas extraction pilot test was implemented after the installation of additional landfill vapor monitor wells (LFGP-1 through LFGP-7) and landfill gas extraction wells (GW-1 and GW-2) (Figure 13). The concentrations of PCE, TCE, cis-1,2-DCE, vinyl chloride, and 1,1-DCA detected in landfill monitor wells prior to the pilot test in 1995 are included in the Pima County Landfill Feasibility Study (Appendix Q, Figure 9). The highest concentrations detected during the pilot test were 7,100 ppbv for PCE (LFGP-1, 60 ft bgs), 1,400 ppbv for TCE (LFGP-7, 75 ft bgs), 5,600 ppbv for cis-1,2-DCE (GD-5), and 20,000 ppbv for vinyl chloride (LFGP-4, 60 ft bgs) (Malcolm Pirnie, 1995b, 1997).

The pilot test was performed to estimate the rate of landfill gas generation within the ECDC Landfill and to provide data for the design of an active landfill gas extraction and treatment system (Malcolm Pirnie, 1997, Malcolm Pirnie, 1998). The landfill gas extraction pilot test was completed in three phases. During Phase I, gas was extracted from perimeter monitor and extraction wells. Phase II consisted of continuous extraction of landfill gas from wells for 10 days. Phase III was to provide long-term data on methane generation, condensate generation, VOC extraction, potential well spacing, and well construction. During the 10 day pilot test, PCE was detected in the landfill-gas effluent at concentrations ranging from 8,800 to 17,000 ppbv, TCE from 2,000 to 5,500 ppbv, cis-1,2-DCE from 8,900 to 16,000 ppbv, and vinyl chloride from <3,300 to 18,000 ppbv (Appendix Q, Figure 10). The concentrations of all constituents remained relatively constant over the ten day pilot test.

In 1996, Pima County completed the installation of the landfill gas collection system (LGCS) that consisted of extraction wells installed along the eastern perimeter of the landfill and a conveyance network installed in the waste and in the vadose zone below the waste. The LGCS was then equipped with a flare. In the first few months of operation the landfill did not generate enough methane to support the flare. Pima County modified the system in July 1999 by disconnecting the flare and installing a biofilter system. Between 20 and 40 pounds of VOCs were removed each week while this system was operating.

In 2001, Hydro Geo Chem performed a series of studies on the effectiveness of the LGCS. Based on this investigation Pima County installed a soil vapor extraction (SVE) system to extract additional landfill gases. The SVE system consisted of passive extraction wells along the perimeter and in the interior of the landfill although none of the wells extended below the refuse. In 2004, Pima County shut down the LGCS due to ineffective mass removal and allowed the landfill soil gas to return to equilibrium.

In 2005, BAS & Associates evaluated the LGCS and determined that concentrations of contaminants were pervasive throughout the ECDC Landfill. The contaminants included methane, PCE, TCE, cis-1,2 DCE, and vinyl chloride. Six of the nine landfill gas wells sampled had methane concentrations over 40 percent and positive pressures before purging. The positive pressures are indicative of gas migration out of the landfill. In addition, it was determined that concentrations of other contaminants (PCE, TCE, cis-1,2 DCE, and vinyl chloride) were detected in the vadose zone under the ECDC Landfill. BAS & Associates reported that vadose-zone concentrations ranged from non-detect to 8.8 µg/L (BAS, 2005).

4.1.2 Interpretation of Data

Multiple soil-gas surveys indicate that prior to, during, and after remedial activities at the ECDC Landfill, chlorinated solvents including PCE, TCE, cis-1,2-DCE, vinyl chloride, and 1,1,1-TCA have been detected in soil gas in the landfill area. Chlorinated solvents detected outside the landfill perimeter are associated with areas of high methane concentrations. Because the ECDC Landfill is the only known source for these methane concentrations, the detected chlorinated solvents and methane appear to have propagated from the landfill due to the positive pressure caused by the production of methane gas. Chlorinated solvent gasses have likely moved through the subsurface due to a combination of this landfill gas pressure and diffusive and advective flow outside of the landfill.

In 1997, Pima County conducted an RI as part of the LESP Phase 3 (Malcolm Pirnie, 1997) that came to similar conclusions. In addition, this report suggests that concentrations of chlorinated ethenes in deep landfill gas were high enough to represent possible equilibrium with groundwater concentrations, and that high gas transmissivities exist in the ECDC Landfill Area for horizontal migration in landfill materials and shallow soils. The landfill gas to groundwater pathway likely represents a route of chemical contamination in the vicinity of the ECDC Landfill.

The east and southeast portions of the ECDC Landfill area historically had the highest concentrations of chlorinated solvents in soil gas. The southern area of the landfill -was reportedly flooded in 1977 (Malcolm Pirnie, 1998) resulting in saturated waste and likely contributing to the direct advective transport of chlorinated solvents to groundwater. Water inundation may also have provided optimal conditions for reductive dechlorination, causing later transport of the more reduced constituents to the groundwater through landfill gas.

4.2 5280 AND 5348 NORTH HIGHWAY DRIVE (AMRI OIL, ET AL)

The AMRI Oil facility operated from 1950 to 1969 and was located at the current addresses of 5280 North Highway Drive and 5348 North Highway Drive (Figures 11 and 12). Approximately 5 acres of the southern portion of the former AMRI Oil property occupied the northern half of 5280 North Highway Drive (Figure 12). Approximately 3 acres of the northern portion of the former AMRI Oil property occupied 5348 North Highway Drive (Western Stucco and Western Trailer Park) (Figure 12). Review of historic aerial photographs reveals the presence of ASTs, potential surface impoundments, and trenches at AMRI Oil. Historic AMRI Oil operations included recycling of waste oil, a process which reportedly involved running oil through clay to purify it (ADEQ, 1995). Arizona Wrecksperts (Wrecksperts) took ownership of 5280 North Highway Drive in 1985. Since that time, the property has been used as a construction yard, auto salvage, and storage facility. A residential structure was present and formerly occupied by a family with children.

In 1992, the property first came to the attention of Pima County as a potential environmental concern. The Wrecksperts property owner reported that heavy equipment was sinking into soft soils and a tar- like substance was exuding from the subsurface. The property was identified as a potential hazardous waste site and entered into the Comprehensive Environmental Response, Compensation, and Liability Act system in August 1993. The site was recommended for a Preliminary Assessment/Site Investigation (PA/SI) resulting from concerns regarding chemical disposal at the site. In January 1995, ADEQ conducted a Site Inspection (SI) of the Wrecksperts (AMRI et al) property, which included the collection of soil, soil-gas, waste-oil sludge, and groundwater samples. A summary of the activities for Wrecksperts from June 1995 to August 2007 is included as Table 4.

4.2.1 Early Response Actions and Investigations

Soil

Soil samples were collected from nine locations at the former AMRI Oil facility in January 1995 and submitted for analysis of metals and VOCs (Appendix Q, Figure 11). Samples at each location were collected either near the surface (primarily 0-2 ft bgs), deeper in the subsurface (10-13 ft bgs), or at both depths. Total lead concentrations ranged from <50 to 36,800 mg/kg. Lead exceeded the residential soil remediation level (SRL) in near surface samples from the waste oil trench, the surface impoundment area, and the area southeast of the residence. Three samples from the waste oil trench exceeded the non-residential SRL for lead (ADEQ, 1995).

During this investigation, the analytical results for soil samples indicated that PCE and toluene were detected in the near surface sample from within the former surface impoundment near the north-central portion of the property (WRK #5A; Appendix Q, Figure 11). PCE and toluene concentrations in this sample were 0.077 mg/kg and 0.023 mg/kg, respectively. This was the only soil sample in which a VOCs was detected above the laboratory method detection limit.

According to the PA/SI report, the U.S. Environmental Protection Agency (EPA) Region 9 Emergency Response Team visited the property in April 1995 because of concerns associated with arsenic, barium, cadmium, lead, zinc, and aroclor polychlorinated biphenyls (PCBs) detected in the soil. At the EPA's recommendation, five additional near surface locations (WRK #23-27) were sampled by ADEQ in June 1995 to further assess the oil delivery ditch and soils around the residence. The samples were analyzed for total metals and VOCs (ADEQ, 1995). Elevated concentrations of metals in the surface soils adjacent to the residence (Figure 14) were detected. Chloroform was the only VOC detected, with a measured concentration of 0.12 mg/kg in sample WRK #27 and 0.11 mg/kg in its duplicate. A summary of the analytical results from June 1995 to August 2007 are presented in Table 4.

During June 1995, the Pima County Health Department visited the property to collect blood samples from the children who were residing at the property. Evaluation of the results indicated the children's blood-lead levels ranged from 6.3 to 17.4 micrograms per deciliter (Pima County Health Department, 1996). The Centers for Disease Control and Prevention has defined an elevated blood lead level as above 10 micrograms per deciliter.

The EPA Region 9 Emergency Response Team re-visited the property in August 1995 to collect additional surface soil data in the vicinity of the residence. A total of 19 locations in and around the residence were assessed using X-ray fluorescence (XRF) (ADEQ, 1995). The detection of blood lead concentrations above 10 micrograms per deciliter resulted in the allocation of WQARF funds for an early response soil removal action at the Wrecksperts property. ADEQ determined that hazardous substances, including lead and waste oil sludge, were present in surface soils and trenches on the property at concentrations considered to be a health concern. ADEQ prepared a scope of work to remove the contaminated soils and waste sludge, as well as plug and abandon an unused well on the property (ADEQ, 1995).

In 1996, ADEQ conducted an Expanded Site Inspection (ESI) which included the collection of samples from the north half of the Wrecksperts property to further characterize the extent of contamination. Soil samples were analyzed for total petroleum hydrocarbon (TPH), PCBs, VOCs, and lead. Soil samples collected from beneath the trench did not contain detectable concentrations of VOCs. The detection limit for most VOCs in this analysis was 0.05 mg/kg (ADEQ, 1997).

Soils were excavated at the property from February to April 1996 (SWCA, 2006). Figure 14 shows the lateral extent and approximate depth of excavation. As documented in the Growth Resources Inc. (Growth) site remediation report, approximately 2,610 cubic yards of lead contaminated soil were excavated from the area around the residence (Growth, 1997a). Approximately 1,430 cubic yards of waste-oil impacted soils and 150 cubic yards of PCB-contaminated soils were excavated from the delivery ditch. In addition, approximately 231 cubic yards of soils were excavated from the waste oil trench area. Excavated areas were restored to the approximate pre-existing grades with 7,317 tons of clean backfill soil.

On May 22, 1996, Growth subcontractor Saguaro Environmental mobilized personnel and equipment to the Wrecksperts property to abandon the unused well in order to eliminate a potential conduit from contaminated surface water runoff. The well was first identified by ADEQ in 1987 and was first observed in 1995 during a site inspection. The well was located adjacent to the northeast side of the main building identified in Figure 14. The well was reportedly drilled to 125 ft bgs; however, a soil bottom was encountered at 102 ft bgs. According to the 1995 PA/SI report, the well may have collapsed or filled with sediment. During the abandonment, the steel well casing was perforated with four 3-inch perforations spaced every foot for the upper 20 ft. The borehole was then pressure grouted with neat cement, and the top foot was filled with concrete (Growth, 1997a).

During the remedial operations at Wrecksperts, concerns arose from the owner and residents of Western Trailer Park that contamination may have migrated onto the property (Figure 12) from historic operations at the former AMRI facility, or from fugitive dust created during the excavation and soil removal activities. To address these concerns, ADEQ personnel conducted a lead survey in May 1996 of surface soil around the southern row of Western Trailer Park trailers situated immediately north of the eastern half of the Wrecksperts property. Field personnel used XRF as a screening tool and collected samples for laboratory analysis (Figure 15). The screening and sampling results indicated that elevated concentrations of lead were present in the southeastern corner of the Western Trailer Park site, and in the alley to the east of the property (ADEQ, 1997). According to the ADEQ ESI report, Pima County personnel collected one subsurface soil sample in 1996 from a depth of 6 inches in the eastern most lot of the Western Stucco/Western Trailer Park property. The results for this sample indicated a total lead concentration of 2,840 mg/kg.

The depth and location of the lead contamination as determined from screening and sampling was variable and appeared to be isolated to the upper 2 ft of soil in the southeast corner lot of the Western Trailer Park site. Lead-contaminated soils may have also existed on the adjacent Wrecksperts property; however, access to the property had not been granted and testing could not occur. The contamination found in the southeastern corner of the Western Trailer Park property was adjacent to residential trailers.

During the 1996 Wrecksperts ESI, it was reported that approximately 0.6 acres of residual lead-contaminated soils remained after the 1996 excavation. It was also determined that areas in the former “delivery trench” continued to exceed the EPA Region 9 Preliminary Remediation Goal for PCB of 0.11 mg/kg. This was concluded based on the follow-up sampling conducted subsequent to the backfill of the excavated areas (ADEQ, 1997).

In February 2001, surface soil samples were collected from eight locations in the southeastern corner of the Western Stucco/Western Trailer Park property (Figure 16) (URS, 2003a). ADEQ requested the sampling event to further define the extent of contamination identified during the 1996 ESI effort. Based on the results of the 2001 sampling event, it was determined that a removal action would be necessary to reduce exposure risks to the Western Trailer Park occupants. At the request of ADEQ, URS returned to the site in February 2003 to further assess the extent of contamination along the southern Western Stucco/Western Trailer Park property boundary (URS, 2003b). The original intent was to conduct sampling on both the Western Stucco/Western Trailer Park and Wrecksperts properties, however, the property owner did not grant access to the Wrecksperts property. Eighteen soil samples were collected to assess the extent of lead contamination along the southern boundary of the Western Stucco/Western Trailer Park property and concentrations of lead above the residential SRL of 400 mg/kg were detected at two of the sampling locations.

In April 2002, URS advanced two borings on the Western Stucco/Western Trailer Park property to approximately 130 ft bgs, just below the static water table (URS, 2002g). These borings, B-6 and B-7, were located north of the former waste oil trench (Figure 14; Appendix Q, Figure 12). Soil and soil-gas samples were collected at depths of 30, 60, 90, 120, and 128 ft bgs from each boring using a sealed-screen sampling device. Soil and soil-gas samples were analyzed for VOCs using EPA Method 8260. No VOCs were detected above the method detection limit in any of the soil samples collected. Groundwater samples were collected using a similar sealed-screen device. TCE, detected at a concentration of 2.0 μg/L in boring B-7, was the only Site COC detected. Results of soil-gas analysis are described in detail in the “Soil Gas” sub-section below.

In October 2006, URS constructed three nested soil-gas wells, SV-1, SV-2, and SV-3, on the Wrecksperts parcel (Figure 17). Four individual soil-gas wells were nested and completed within each of the three boreholes. The screens were set at depths of approximately 30, 50, 70, and 90 ft bgs in each well. During drilling, discrete soil samples were collected and submitted for VOC analysis. Soil samples were collected at the depth of each screened interval, for a total of 12 soil samples from the three borings. One additional soil sample and duplicate were collected from stained soils observed at 4 ft bgs in the boring for soil-gas well SV-1. In the soil sample collected from SV-1 at 4 ft bgs PCE and 1,3,5-trimethylbenzene were detected at concentrations of 0.320 mg/kg and 0.240 mg/kg, respectively. This sample also contained 680 mg/kg of lead and was noted to have visible hydrocarbon staining. Analysis of four samples and the duplicate sample from SV3 detected 1,3,5-trimethylbenzene at concentrations ranging from 0.059 to 0.200 mg/kg. No other analytes were detected in the soil samples (URS, 2007b). Six polyaromatic hydrocarbon (PAH) compounds were detected in various samples, however, no concentrations exceeded the SRLs (URS, 2007c). The detections are summarized in Table 4.

URS conducted shallow soil removal at the former AMRI property in 2007. The soil removal included a portion along the southern boundary of the Western Trailer Park property (Figure 17), within the former AMRI property. A total of 1,378 tons of lead-impacted soil was excavated and disposed off-site (URS, 2007a). During excavation activities, field personnel screened the surficial soil using a hand held XRF as initial confirmation that remaining soils were below remediation standards. A comparison of XRF and laboratory results shows that the XRF data were consistently conservative; resulting in excavation of soils to levels significantly below the residential soil remediation level of 400 mg/kg for lead (URS, 2007a). Approximately 353 tons of soil was excavated from the 5238 N. Highway Drive property and 76 tons of soil was excavated from the 5230 N. Highway Drive property.

In August 2007, ten soil borings were drilled to depths ranging from 11 to 30 ft bgs and soil samples were collected approximately every 5 ft in the area of the former oil pits. The objective of this was to evaluate potential impacts associated with the three rectangular historic oil pits that were operated by AMRI as part of their oil reclamation operations. These pits were located in the north-central portion of the former AMRI oil facility (Figure 17) (URS, 2007c). During this event, 40 soil samples were collected and retained for laboratory analysis of polycyclic aromatic hydrocarbons (PAHs), VOCs, and metals. The investigation identified the presence of 15 VOCs including PCE and TCE, six PAHs, lead, and arsenic in the subsurface soils. Soil samples submitted for laboratory analysis showed a PCE concentration of 3.5 mg/kg in boring WS-SB4 at 5 ft bgs which exceeded the residential SRL of 0.51 mg/kg. The nonresidential SRL was not exceeded. This soil sample also contained a lead concentration of 450 mg/kg which was in excess of the residential SRL. Minor concentrations of VOCs below SRLs were reported in samples from soil borings at 5, 10, 15, 20, and 25 ft bgs. Six PAH compounds were detected in soil samples collected at 5, 10, 15, 20 and 25 ft bgs, however concentrations of PAHs did not exceeded SRLs (URS, 2007c). The results of the August 2007 soil investigation are summarized in Table 4 and VOC results included on Figure 14 of Appendix Q.

During the 2007 event, two soil samples were selected and submitted for PCB analysis because of visual staining. Concentrations of PCBs (aroclors) were not detected above the laboratory reporting limits of 0.050 and 0.10 mg/kg in the samples submitted for laboratory analysis. In samples collected from boring WS-SB7 at 5 ft bgs and boring WS-SB2 at 10 ft bgs, arsenic was detected at 11.0 and 13.0 mg/kg, respectively. These concentrations exceed the residential SRL. Three soil samples from visibly stained intervals were submitted for toxicity characteristic leaching procedure (TCLP) and synthetic precipitation leaching procedure (SPLP) lead analysis. In WS-SB4 at 5 ft bgs, SPLP lead was reported at 1.1 milligram per liter (mg/L). The remaining SPLP sample results were below the laboratory reporting limit (URS, 2007c).

Soil Gas

In January 1995, soil gas was analyzed from ten samples collected at approximately 8.5 ft bgs or 14.5 ft bgs throughout the Wrecksperts property. The locations of the soil-gas samples correlate to the locations of soil samples depicted in Figure 11 of Appendix Q, with the exception of samples WRK #4SV and #5SV for which collocated soil samples were not collected. PCE and benzene were detected above the method detection limits in two samples. PCE was detected in the soil-gas sample collected from the surface impoundment (WRK #5A-SV) at a concentration of 2.5 μg/L, or approximately 370 ppbv. Benzene was detected in one sample collected from the trench (WRK #2SV) at a concentration of 58 μg/L, or approximately 18,000 ppbv (ADEQ, 1995).

In April 1996, Pima County subcontracted with Hydro Geo Chem to collect soil-gas samples at the Wrecksperts facility (formerly AMRI Oil). Hydro Geo Chem sampled eight locations along the northern and eastern property boundary. Of 23 soil-gas samples collected, PCE was detected in just one sample at a concentration of 4.2 μg/L or approximately 600 ppbv. (Hydro Geo Chem, 1996).

During November 2001, ADEQ conducted a passive soil-gas survey at the Western Stucco/Western Trailer Park property. The objective of the soil-gas survey was to identify and delineate potential sources of groundwater and soil contamination at the property (Figure 18). Passive soil-gas sorbers were installed to a maximum depth of 3 ft bgs. Samples were analyzed for several VOCs and semi-volatile organic compounds (SVOCs). TCE was not detected above the detection limit in any samples. PCE was the analyte with the highest detected mass of 2.08 μg and was detected in 32 of the 124 samples. This includes 14 samples with detectable masses that were less than the method reporting limit. Two distinct areas were identified with detectable concentrations of PCE; around the main office building on the Western Stucco parcel and along the eastern half of the Western Stucco parcel. The observed PCE masses were highest in the vicinity of the main building on the Western Stucco parcel. PCE was detected in most of the sample locations along the eastern portion of the Western Stucco parcel, but at lower concentrations than around the main building (URS, 2002b). Maps showing the analytical results from the 2001 soil-gas survey are included in Appendix F.

BTEX constituents were the most frequently detected analytes in the November 2001 survey.

BTEX constituents were detected in 56 of the 124 soil-gas samples. This includes six samples with detectable masses that were less than the method reporting limits (Appendix F).

Evaluation of the results from the November 2001 soil-gas survey also indicated that three isolated areas contained detectable relative masses of PAH constituents including naphthalene, 2-methyl naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, and pyrene. PAHs were detected in 17 of the 124 soil-gas samples including five samples with results less than the method reporting limits for the individual analytes (Appendix F).

As described above, in April 2002 soil-gas samples were collected during the advancement of two borings just north of the former waste oil trench (Figure 14; Appendix Q, Figure 12). Soil-gas samples were collected using a sealed-screen sampling device at depths of 30, 60, 90, and 120 ft bgs in each boring. A summary of the results are presented in Figure 13 of Appendix Q. PCE was the only Site COC detected. All concentrations of PCE were less than 15 ppbv (URS, 2002g).

In March 2003, nested groundwater monitor well CDC-W32 was installed on the Western Stucco property. Soil-gas samples were collected from 30, 60, 90, and 120 ft bgs during the boring installation. The highest soil-gas detections were as follows: benzene at a concentration of 110 ppbv at 90 ft bgs, PCE at a concentration of 24 ppbv at 60 ft bgs, and TCE at a concentration of 50 ppbv at 60 ft bgs (Appendix Q, Figure 15). Details of the soil and soil-gas sampling and the well installation are reported in the *Vapor Monitoring Report 1st and 2nd Quarter, 2003 1st Quarter 2004, El Camino del Cerro WQARF Site* (URS, 2004a) and the *Monitor Well Installation Report for Well Sites W- 30 through W-35 and W-37, Shannon Road-Rillito Creek & El Camino del Cerro WQARF Sites* (URS, 2004b). The detections of VOCs in soil-gas samples collected from the CDC-W32 boring led to the recommendation to do additional deep soil-gas sampling at Wrecksperts to further assess the elevated concentrations of COCs.

In June 2006, URS conducted a passive soil-gas and geophysical survey on the Wrecksperts property to identify potential hydrocarbons in the subsurface (URS, 2006c). The objectives of the survey were to identify and delineate potential sources of contamination at the property. Soil-gas samples were collected from approximately 3 ft bgs from fifty-five locations. The mass distributions of PCE, TCE, and PAHs are presented in Appendix G. The pattern of PAHs correlates to areas of high vehicle traffic at Western Stucco and in the vicinity of the southwestern portion of the Western Trailer Park parcel. Therefore, concentrations of PAHs appear to be attributable to vehicle emissions. Elevated concentrations of PCE and TCE appeared to be associated with the former waste oil trenches and pits at the former AMRI facility depicted in Figure 17.

As described previously, the detections of VOCs in soil gas at CDC-W32 and the results of the June 2006 passive soil-gas survey indicated additional investigation of deep soil and soil gas were warranted in the area of the historic oil pits, immediately upgradient of well CDC-W32. In October 2006, URS constructed three nested soil vapor wells, SV-1, SV-2, and SV-3 each with foot-long screened intervals at approximately 30, 50, 70, and 90 ft bgs (Figure 17) (URS, 2007b). Numerous compounds associated with waste oil were detected, including PCE and TCE, in the soil-gas samples collected from SV-1, SV-2, and SV-3. The maximum concentration of PCE was 220 ppbv in SV-1 at approximately 30 ft bgs. The maximum concentration of TCE was 53.0 ppbv in SV-2 at 33 ft bgs. Concentrations of PCE and TCE generally decreased with depth. Sampling results are reported in Figure 16 of Appendix Q.

The maximum concentration of PCE (220 ppbv) detected in the October 2006 soil-gas survey was detected in the sample collected from the shallowest interval (30 ft bgs) of SV-1. Based on the Henry's Law constant for PCE of 18 atm·L/mol, the expected equilibrium concentration in groundwater would be approximately 2 μg/L (example calculations are included in Appendix U). This value is significantly lower than concentrations detected in groundwater beneath the site (64 μg/L in well SRC-W32S in April 2006). Additionally, equilibrium conditions are not expected under most field conditions and concentrations of PCE were observed to decrease with depth. Therefore this calculation likely over-estimates the concentration that would be expected in groundwater given the observed concentrations in soil gas above the water table. Thus, it appears that although PCE was detected in deep soil-gas samples, the concentrations do not appear to be indicative of a significant source of groundwater contamination.

SV-1, SV-2, and SV-4 were sampled again in February 2007. During this sampling event, PCE and TCE were detected in each of the four sampling intervals in each of the three wells (Appendix Q, Figure 17). Concentrations were generally consistent with those detected following well installation. Consistent with the October 2006 sampling event, soil-gas concentrations did not appear to increase with depth. Concentrations of both PCE and TCE were less than 65 ppbv at depths greater than 73 ft bgs (URS, 2007e). If groundwater concentrations were at equilibrium with these soil-gas concentrations, PCE and TCE concentrations in groundwater, calculated using the respective Henry's Law constants, would be less than 1 μg/L.

4.2.2 Interpretation of Data

The release of PCBs, lead, and chlorinated VOCs to the environment at the former AMRI Oil facility, likely associated with waste oil recycling operations, has been confirmed by numerous investigations at the site. Chlorinated VOC contamination in soils has been detected infrequently. PCE is the only Site COC that has been detected in soil above the laboratory detection limit at this property. Soil excavations were conducted in 1997 and 2007 to remove lead and PCB-contaminated soil from across the site. These excavations removed soil from areas that correlate with the highest VOC contamination observed during soil-gas sampling.

Property-wide passive soil-gas surveys were conducted at both the Wrecksperts and Western Stucco/Western Trailer Park properties. These investigations identified areas of PCE and TCE contamination associated primarily with historic oil pits and trenches. The results of active soil and soil-gas investigations conducted in 2006 and 2007 indicate PCE and TCE concentrations at the site are relatively minor and generally attenuate significantly with depth. Soil-gas samples collected during the installation of monitor well SRC-W32 just north of the historic oil pits were generally consistent with concentrations attenuating with depth. Because possible source areas identified during the passive soil-gas survey on the Western Stucco/Western Trailer Park property had lower relative mass detections than those in the area of the historic oil pits, it is unlikely that this contamination represents a risk to groundwater.

Given the infrequent VOC detections in soil and the relatively low concentrations of chlorinated-VOCs in soil gas, there does not appear to have been release of PCE or TCE that was substantial enough to significantly impact groundwater at this facility. Groundwater concentrations beneath the site are significantly higher than equilibrium concentrations calculated based on measured soil-gas concentrations in deep soils, just above the water table. Therefore, it is possible that these minor deep soil-vapor concentrations were caused by mass transfer of contaminants from the groundwater plume. Thus, the available data from numerous and extensive investigations do not indicate that the VOC contamination at the former AMRI Oil property impacted groundwater. Based on the available data, it appears excavations of the former pits and trenches on site have likely mitigated any current and future risk to human health or to groundwater beneath the site due to releases from the for AMRI Oil operations.

4.3 E.C. WINTER PROPERTY

The property formerly occupied by the E.C. Winter facility is located at 3100 West Curtis Road (Figure 11). The property was operated as a waste oil recycling facility from 1962 to 1974. Waste oil was stored in a surface impoundment at the north end of the property. The impoundment was reported to be 6 ft deep with a concrete bottom; however, it was later determined that a concrete bottom did not exist. In addition to being stored onsite, waste oil was applied to dirt roads in the area and on the ground at the property for dust control. Waste oil operations were discontinued in 1974 and the surface impoundment was abandoned by backfilling in the mid-1980s. The northern portion of the property, in the area of the former waste oil pit, has been occupied by two private mobile homes since the mid-1980s.

4.3.1 Early Response Actions and Investigations

Soil and Groundwater

In March 1997, the results of soil sampling and analysis conducted at the former E.C. Winter property indicated that lead exceeded the residential SRL in two samples. Based on the results it was determined that lead-contamination was located in the upper 18 inches of soil within the northern portion of the E.C Winter property and along two adjacent properties (5230 and 5238 N. Highway Drive) (ADEQ, 1998). Several VOCs were also detected in soil samples, primarily in sample WOC-3 at a depth of 11-12 ft bgs where PCE, TCE, and 1,1,1-TCA were detected at concentrations of 0.66 mg/kg, 0.28, and 0.45 mg/kg respectively. The concentrations are below the respective Groundwater Protection Levels (GPL) of 1.0, 0.61, and 1.0 mg/kg. Analytical results are included in Appendix H.

In 2001, the initial investigation for an ERA included surface and subsurface soil sampling to delineate the nature and extent of lead, TPH, and chlorinated solvent impacts. Concentrations of lead exceeded the residential SRL in five surface samples and one shallow subsurface sample collected within 30 ft of the two manufactured homes and on the adjacent property immediately to the west. Two soil borings were advanced to evaluate potential impacts in deeper subsurface soil. TPH was detected at concentrations that exceeded the residential SRL in effect at that time in samples collected at 10 and 25 ft bgs. However, currently there are not SRLs for TPH. TCE was detected at 53 mg/kg in soil boring #2 at 10 ft bgs, exceeding the residential SRL. TCE exceeded the GPL in this boring at depths of 10 and 25 ft. Lead exceeded the residential and non-residential SRLs (400 mg/kg and 800 mg/kg, respectively) at several locations. Appendix I contains a figure illustrating the sample locations and summary of analytical results. Although it had been reported that there was a concrete bottom at 6 ft bgs within the surface impoundment, URS advanced a soil boring to 30 ft bgs within the footprint of the surface impoundment and no concrete was encountered (URS, 2001a).

During a January 2001 site visit, a previously undocumented well on the property was discovered (Appendix Q, Figure 18). Because of concern that the well could provide a conduit for the migration of contaminants to groundwater the well was abandoned in June 2001 in accordance with ADWR requirements. Based on video obtained during investigation of the well, the total depth was approximately 110 ft bgs. Water was not encountered during the abandonment process. However, because the well had remained open for an unknown period of time, the soil at the bottom of the well was analyzed for SVOCs and VOCs. There were no detectable concentrations of SVOCs or VOCs in soil samples collected from the bottom of the well (URS, 2001b).

In October 2001, a soil removal action was conducted at the former E.C. Winter site (URS, 2002c). The objective for the removal was to remove soil containing COCs at concentrations that could pose a potential risk to human health and the environment and to reduce the potential for hydrocarbons to impact groundwater beneath the site. Approximately 1,202 tons of lead-contaminated soil were excavated from the northern portion of the E.C. Winter property and portions of the adjoining 5230 and 5238 North Highway Drive properties (Figure 19).

Approximately 2,236 tons of TPH-impacted soil was also excavated from the former impoundment area during the October 2001 soil removal action (Figure 19). The excavation in the former impoundment area extended to approximately 15 to 20 ft bgs. Following excavation and confirmatory sampling, a bioventing system was installed before the area was backfilled. A slotted PVC pipe was placed in the center of the excavation with a vent pipe leading to the surface at the eastern edge. The system allowed oxygen to circulate to areas within the excavation. All areas of excavation were backfilled with clean material and top soil to the original grade (URS, 2002c).

In early April 2002, five soil borings were advanced to further delineate the vertical and lateral extent of residual contamination beneath the former oil impoundment area (Figure 19) (URS, 2002f). Boring B-1 was advanced to approximately 375 ft bgs using rotasonic drilling methods, while borings B-2 through B-5 were advanced to approximately 130 ft bgs using hollow stem auger drilling methods. Soil sub-samples were collected for lab analysis from the rotasonic cores in boring B-1 where PID readings were increased over the normal background readings. Samples from borings B-2 through B-5 were collected using a sealed-screen sampler advanced ahead of a hollow-stem auger. These samples were collected at 30, 60, 90, and 120 ft bgs in each boring. No VOCs were detected in sub-surface soil samples from borings B-1 through B-5 (URS, 2002f). Grab groundwater samples were collected from B-1, B-3, B-4, and B-5. PCE exceeded the Aquifer Water Quality Standard (AWQS) in samples from three of the four borings and TCE concentrations exceeded the AWQS in samples from each of the four borings (Appendix Q, Figure 19). PCE concentrations ranged from 1.4-23 μg/L and TCE concentrations ranged from 15-27 μg/L (URS, 2002f). Borings B-2 and B-5 were completed as SVE wells and B-1, B-3 and B-4 were abandoned. Discussion of soil-gas samples collected from these borings is provided in the following sub-section.

Soil Gas

In July 1995, as part of the Phase 3 LESP, Tracer Research Corporation performed a shallow soil-gas survey. Samples were collected from twenty-three locations in the vicinity of Curtis Road and Highway Drive including ten sampling points adjacent to the former E.C. Winter site. Soil-gas samples were also collected from locations within a county easement near several businesses that may have used hazardous materials such as solvents. Sample depths ranged from 5.0 to 6.5 ft bgs. The highest concentrations of PCE (2,224 ppbv), TCE (737 ppbv), and 1,1,1-TCA (560 ppbv) were detected in samples collected in the northeast corner of the E.C. Winter property (Tracer, 1995). This soil-gas sampling was conducted prior to the soil removal that took place in 2001. For the location of the samples and a summary of the results see Appendix J.

During the March 1997 sampling event described previously, soil-gas samples were collected from four locations at approximately 8.5 ft bgs (ADEQ, 1998). TCE was detected in each of the four samples at concentrations ranging from 3.7 to 81 μg/L (approximately 700 and 15,000 ppbv). PCE was detected in two of four samples at concentrations of 2.9 and 13 μg/L (approximately 400 ppbv and 2000 ppbv). 1,1,1-TCA was detected in one sample at a concentration of 35 μg/L (approximately 5000 ppbv). Sample locations and analytical results are provided in Appendix H.

Five soil-gas monitor wells (SR-84-101, SR-84-201, SR-84-301, CY-101, and TR-101) screened at discrete intervals at 20, 40, 60, and 75 ft bgs were installed by Growth Resources, Inc., in the ECDC study area in May 1997 (Appendix Q, Figure 21) (Growth, 1997b). The wells were installed in areas of known groundwater contamination. Five rounds of soil-gas sampling were conducted between from 1997-1998 (Appendix Q, Figures 22-24) (Growth, 1997b; Fluor Daniel, 1998). These wells were sampled again during the second and third quarters of 2001 (Appendix Q, Figures 25-26) (URS, 2001c,d). Well TR-101 was located on the former E.C. Winter property approximately 20 ft west of the northernmost manufactured home. TCE concentrations in this well were relatively constant with depth at approximately 5000-7000 ppbv in 1997 and 1998. Concentrations remained relatively consistent though slightly lower during subsequent sampling in 2001. Concentrations of TCE were significantly elevated in TR-101 compared to concentrations in the other wells. Concentrations of PCE in TR-101 were also fairly consistent with depth but an order of magnitude lower. Other chlorinated VOCs were detected, including 1,1-DCA and 1,1,1-TCA, though not consistently nor at concentrations as high as TCE and PCE.

As described previously, soil-gas samples were collected during the drilling of four deep soil borings on the property in April 2002 (Figure 19) (URS, 2002f). Soil-gas samples were collected in each well at depths of 30, 60, 90, and 120 ft bgs (Appendix Q, Figure 20). The maximum TCE concentration detected was 3,500 ppbv at 60 ft bgs in boring B-4. The maximum TCE concentration in soil-gas samples collected from 120 ft bgs, approximately 10 ft above the water table at that time, was 900 ppbv in the sample collected from boring B-3 (Appendix Q, Figure 20). Given the average TCE groundwater concentration of 23 μg/L detected in grab groundwater samples collected from these borings and a Henry's Law coefficient of 11 atm·L/mol, the calculated equilibrium soil-gas concentration would be approximately 1900 ppbv (example calculations are provided in Appendix U). Other VOCs, including PCE, 1,1,1-TCA, 1,1-DCA, and 1,1-DCE were detected but were generally low or non-detect at depth.

Based on the results of soil-gas analyses during the investigation of the deep soils, URS installed multiple completion vapor extraction wells in two of the borings for the purposes of conducting a SVE pilot test. Boring B-2, northeast of the former waste oil pit, was completed with screened sections from 30 to 40 ft and from 80 to 90 ft bgs, and boring B-5, near the center of the former waste oil pit, was completed with screened sections from 30 to 40 ft and from 60 to 70 ft bgs. A horizontal screen, installed during the October 2001 investigation in the backfill of the TPH impacted soil excavation, was also used for the pilot test (URS, 2002f).

The SVE pilot test included both extraction and injection testing. The SVE pilot test was conducted to determine flow rates, pressures, and contaminant concentrations in extracted soil gas. An injection test was performed to evaluate subsurface oxygen concentrations during injection and to monitor oxygen uptake rates after oxygen had been introduced into the subsurface. A summary of the SVE pilot test analytical results is provided in Appendix K. The following COCs were detected in soil-gas samples collected from SVE wells B2 and B5 at the conclusion of the SVE pilot test (URS, 2006a):

- TCE concentrations were highest in the extracted gas sample collected from Well SVE B-5 (60 to 70 ft depth) at 2,400 ppbv.
- PCE concentrations were highest in the extracted gas samples collected from Wells SVE B-2 and SVE B-5 (both at the 30 to 40 ft depth), both at 1,100 ppbv.

Based on results of the pilot testing, SVE was determined to be a feasible alternative for remediation of VOCs in the vadose zone beneath the E.C. Winter property. The SVE wells were monitored for VOCs between spring 2002 and fall 2005. The concentration of PCE ranged from 4 to 1,800 ppbv, and TCE ranged from 44 to 4,100 ppbv (URS, 2006a). The results of soil-gas sampling in these wells are presented in Figure 29 of Appendix Q. Because residual VOC concentrations below the excavation area had not decreased significantly in the years immediately following excavation, an SVE system was constructed at the former E.C. Winter Property.

The SVE system was constructed in June 2006 and consisted of five extraction wells (two nested wells and the horizontal vent pipe installed in the bottom of the excavation). The system was operated in a cyclical manner (12 hours on and 12 hours off) during three separate periods. The initial start-up was on June 26, 2006, however, the system only operated for approximately 25 hours because of failure of an overload switch on the control panel. The system was repaired and restarted on July 10, 2006 and ran until January 31, 2007. Samples were collected throughout the operation of the system. The inlet concentrations of PCE ranged from 20.31 to 236.42 ppbv and TCE concentrations ranged from 64.07 to 384.44 ppbv. The system was restarted on September 11, 2007, and operated until January 30, 2008. During the second operational period the inlet concentrations of PCE ranged from 1.74 to 216.11 ppbv and TCE concentrations ranged from

23.8 to 166.59 ppbv. During operation, the system removed approximately 0.85 pounds of PCE and 4 pounds of TCE from the subsurface (URS, 2008a).

4.3.2 Interpretation of Data

The release of lead and chlorinated VOCs to the environment at the former E.C. Winter property has been confirmed by numerous investigations at the property. TCE, in particular, has been detected in soils at levels exceeding the GPL, the residential SRL, and at concentrations as high as 15,000 ppbv in soil-gas samples.

Soil-gas sampling conducted between 1997 and 2002 in five nested vapor wells indicated that TCE soil-gas concentrations at the former E.C. Winter property were significantly higher than many other areas of the Site, even in locations with similar TCE concentrations in groundwater. The concentrations of TCE in soil gas at the former E.C. Winter property indicate that TCE in soil gas had migrated to at least 75 ft bgs, the deepest sampling point in the study.

During the investigation of deep soils in 2002, elevated soil-gas concentrations were detected at a depth of 120 ft bgs, less than ten feet above the water table. These concentrations were less than the equilibrium concentration calculated based on measured groundwater concentrations. Therefore, it is possible that mass transfer has occurred from the groundwater plume to soil gas. However, the inconsistent detections of TCE on the property at this depth, despite a relatively uniform distribution of TCE in groundwater, indicate that concentrations of TCE in deep soil gas may be attributable to another source. Additionally, TCE was not detected in soil gas at 120 ft bgs in well W32 near the former AMRI oil facility despite TCE concentrations in groundwater that were generally consistent with those at the former E.C. Winter property, further indicating that deep soil-gas TCE concentrations at the former E.C. Winter property may not be attributable to mass transfer from the groundwater plume.

Though deep soil-gas data indicate TCE may have migrated to the water table from overlying soil gas, deep soil-gas concentrations are below levels expected to have produced the observed groundwater concentrations. Additionally, contaminants such as PCE and 1,2-DCE that are detected in the groundwater at the E.C. Winter property were not detected at significant concentrations in deep soil-gas samples collected near the water table. Therefore, the deep soil-gas and groundwater data indicate that although TCE in soil gas may have contributed to groundwater contamination, the primary source of groundwater contamination beneath the former E.C. Winter property is located upgradient. Furthermore, ERAs implemented at the E.C. Winter property, including soil excavation and soil vapor extraction, have largely removed the VOC mass in the vadose zone and minimized any potential remaining threat to groundwater quality in this area.

4.4 I-10 CORRIDOR

Historical research of the properties along the I-10 corridor indicated that specific operations demonstrated the use of fuels, waste oil, grease pits, and the presence of both above-ground storage tanks (ASTs) and underground storage tanks (USTs) that may have adversely impacted soil and/or groundwater. In 1986, the LESP Phase 2 activities for the I-10 corridor focused on properties that were determined to be potential contributors to impacted groundwater. This determination was based on operational history and the site-specific analytical data that were available at the time. The details of each site are documented in the *Final Report Historical Research, El Camino Del Cerro WQARF Site, URS, 2002* (URS, 2002e).

Because of the concerns associated with groundwater impacts beneath these properties, Pima County purchased eight privately owned water supply wells along the I-10 corridor in 1989 to prevent potential human exposure to VOC-impacted groundwater. The owners of the wells were connected to the public water supply system to replace their well water. The wells purchased were located at Cardinal Castings, Kaylor Trailer (later Carson Trailer), Cowtown Boots (property formally belonging to Kaylor Trailer), Sunset Plaza, Arizona Truck Service (AZ Truck), Quality Truck, Jenks Café, and National Truck (Figures 2 and 12). The wells were then incorporated into the regular ECDC study area groundwater monitoring network (Malcolm Pirnie, 1997).

Environmental investigations of properties along the east side of I-10 between Sunset and Ruthrauff roads were conducted by the Arizona Department of Transportation (ADOT) between 1998 and 2000. These properties were proposed by ADOT for right-of-way acquisition in the construction of a new I-10 frontage road system. Based on the results of a Pre-Initial Site Assessment submitted in July 1997, parcels within the proposed I-10 right-of-way area were identified that may have been adversely impacted soil and/or groundwater and which therefore, warranted additional investigation to assess the potential for contamination (Environmental Research Associates, 1997). Of the 31 parcels evaluated during the Pre-Initial Site Assessment, 20 were recommended for Phase I Environmental Site Assessments (ESAs). Based on the findings of the Phase I ESAs, Phase II ESAs were recommended for 18 of the parcels. The results of the Phase II ESAs indicated two parcels required remediation prior to commencement of ADOT construction activities; National Truck Stop and Tire Industries. On these two parcels, ADOT's contractor was responsible for removal and off-site disposal of TPH-contaminated soils. Following excavation of TPH impacted soil, construction was completed on the ADOT frontage road improvement project in 2002.

4.4.1 Early Response Actions and Investigations

Soil

In 1986, the LESP Phase 2 activities for I-10 focused on Tire Industries at 5050 North Casa

Grande Highway (NCGH) as a potential contributor of COCs to impacted groundwater. Based on historical data at Tire Industries, the soils were impacted by petroleum hydrocarbons from former USTs and possible fuel pump areas. In September 2000, a 650-gallon waste oil UST was removed and petroleum hydrocarbons were detected in soil at a concentration of 55,000 mg/kg at the maximum depth investigated of 25 ft bgs. This investigation focused on the sump and grease trap in the truck wash area. Cis-1,2-DCE was detected at a concentration of 7,700 mg/kg in a sludge sample collected from the grease trap. However, VOCs were not detected in surface soil samples collected from a suspected release area. Soil sampling during this investigation was limited and samples were not collected in the service pit or shop floor drains and sampling for VOCs in deep soils was also not conducted. Details of specific sites are listed in the *Final Report – Historical Research, ECDC WQARF Site* (URS 2002e). Tire Industries was reportedly further remediated by ADOT during the I-10 expansion project.

Soil samples collected during the 1995 site assessment and cleanup activities at the Industrial Radiator property at 4998 NCGH (Figure 12) contained lead concentrations as high as 23,100 mg/kg in samples collected 0 to 6 inches bgs and 860 mg/kg in samples collected from 6 to 12 inches bgs. Lead was the only COC for this property. Soil and soil-gas surveys conducted during the site assessment found no detectable concentrations of VOCs or hydrocarbons present in site soils. This site was not further addressed under the ERA due to the lack of human exposure risk at the site. It remains on the WQARF Preliminary Investigation (PI) list as a separate site from the SR/ECDC WQARF Site (ADEQ, 1999).

Previous environmental investigations indicated undocumented water wells and USTs on the properties adjacent to NCGH. Other records indicate the presence of unregistered USTs with no documentation of closure. Therefore, in August 2001, the following properties were included in a geophysical survey conducted to assess properties for improperly abandoned subsurface features which could act as conduits or source areas:

- 4870 NCGH: Mantis Development
- 4950 NCGH: Cummings Plumbing
- 4966 NCGH: National Truck Stop
- 4998 NCGH: Industrial Radiator Service
- 5000 NCGH: Jenk’s Cafe
- 5050 NCGH: Tire Industries

The geophysical survey occurred following the demolition and removal of surface features on the properties within the southern portion of the survey area.

The results of the geophysical survey identified one subsurface feature adjacent to the northern side of the former Tire Industries building. The Tire Industries property reportedly had USTs removed from the vicinity of the geophysical anomaly; however the results from the geophysical output indicated the presence of a metallic object. URS interpreted this anomaly to potentially be a previously unidentified UST (URS, 2002d). The magnetometer gradient field plots for the northern and southern portion of the geophysical survey area are presented in Appendix L. This property was reportedly later remediated by ADOT during the I-10 expansion project.

A limited surface and shallow subsurface soil investigation was conducted by Aplomado Environmental, LLC on the former I-10 Surplus (former Cardinal Casting) property as part of a LESP Phase I ESA in 2006. The investigation selected multiple distinct surface stained soils that appeared to be associated with the release of petroleum products and other atypical stains of varying colors that were from unidentified sources. The samples were assessed for PCE, BTEX, PAHs, and RCRA metals. The petroleum stained surface and shallow subsurface soil samples were determined to have maximum concentrations of BTEX constituents as high as 29,000 mg/kg and the atypical stains to have maximum arsenic and lead concentrations of 2,000 mg/kg and 22,000 mg/kg, respectively.

Soil Gas

A soil-gas survey was performed in 1990 by Tracer Research Corporation as part of the ECDC Study Area RI (Tracer Research, 1990). The purpose of the soil-gas investigation was to delineate the extent of VOC contamination in soil gas at locations north and northeast of the ECDC Landfill. The 1990 survey collected 31 soil-gas samples from approximately 6 ft bgs, primarily from an area along the I-10 frontage road, extending from the former Jenk's Café to the former Cardinal Casting (I-10 Surplus) properties (sample locations and concentrations can be seen in Figure 3 of Appendix Q). PCE was detected at a maximum concentration of 591 ppbv next to the Kaylor Trailer/Cowtown Boots property line, approximately 200 ft north of the former Arizona Truck Service site. The maximum PCE concentration detected in the remaining soil-gas samples was 30 ppbv detected in two samples collected near the northern boundary of the ECDC Landfill. In 1993, a Site Investigation (SI) of the Cardinal Castings property did not detected chlorinated solvents above the 1 ppbv detection limit in soil gas collected from 3 to 12 ft bgs (ADEQ, 1993).

In 1995, a Tracer Research Corporation shallow soil-gas survey measured PCE, TCE, total 1,2-DCE, vinyl chloride, and 1,1,1-TCA in samples collected from 6 ft bgs in locations extending down an easement adjacent to the E.C. Winter property, Curtis Street, and Highway Drive. Seven of the sampling locations along Highway Drive were in the proximity of Carson (Kaylor) Trailer and Cowtown Boots. Results for each of the analytes did not exceed 5 ppbv in any of the sampling locations on Highway Drive (TRC, 1995). Figure 30 of Appendix Q presents a summary of the PCE and TCE results along Highway Drive; for information about the other sampling locations, please see Section 4.3 and Appendix J.

During July, October, and November of 2001, URS conducted a passive soil-gas survey (URS, 2002d). The intent of the passive soil-gas survey was to reduce site characterization costs by identifying areas with suspected contamination, thereby minimizing the number of soil borings and monitoring wells required to delineate the extent of contamination.

Eleven properties were included in the soil-gas survey as follows:

- My Antiques Trading Post,
- Quality Truck Parts/AZ Fleet Specialists,
- Arizona Truck Service/Northwest Auto Repair,
- Accurate Auto Body,
- Cowtown Boots,
- Carson Trailer (former Kaylor Trailer),
- Southwest Glassware,
- Sunset Plaza Industrial Park,
- Delron Mechanical,
- I-10 Surplus (former Cardinal Casting), and
- Ayles Trust.

The locations of parcels in the survey area are shown in Figure 12. The survey was performed in two phases to accommodate ADOT construction activities. GORE-SORBER® screening modules were placed at approximately 3 ft bgs for 14 days. The results of the passive soil-gas survey indicated the presence of PCE, BTEX, and PAHs (Appendix L). PCE was detected in 115 of 267 soil-gas samples collected. The highest PCE mass in the I-10 corridor area was found on the north side of the I-10 Surplus (former Cardinal Castings) site building. The I-10 Surplus property was later investigated in 2006 during a LESP Phase I ESA for soil contamination, as described in the "Soil" section above. BTEX was detected in 102 of the 264 samples. The highest concentrations of BTEX were reported on the west side of the former Tire Industries site southwest of the fueling area canopy. As discussed previously, the Tire Industries property was remediated by ADOT. PAHs were detected in 56 of the 264 soil-gas samples submitted. The highest PAH concentration was reported on the east side of the Industrial Radiator site (URS, 2002d), which as discussed above, remains on the WQARF PI list.

Multi-depth, active soil-gas monitoring was carried out in various sampling events from 1997 to 2003 (Appendix Q, Figures 21-28). Soil-gas samples were collected from 20, 40, 60, and 75 ft bgs in vapor monitor wells located near Carson (Kaylor) Trailer (SR84-101), Accurate Auto

Body/Arizona Truck Service (SR84-201), and Quality Truck (SR84-301) (see well locations in Figure 21 of Appendix Q). In addition, a vapor monitor well located hydraulically upgradient from the I-10 corridor properties (CY-101) was sampled at the same depths from 1997 to 2001. In SR84-301, concentrations of PCE and TCE remained below 11 ppbv for all depths, with an average concentration of 2.4 ppbv for PCE and 1.7 ppbv for TCE. Cis-1,2-DCE and VC have not been detected in soil-gas samples collected from SR84-301 (Appendix Q, Figures 22-28). These data indicate that there were no impacts to groundwater from the Quality Truck area of the I-10 corridor. Soil-gas samples collected from vapor monitor wells SR84-101, SR84-201 and CY-101 contained similar concentrations of PCE and TCE, with concentrations generally low at 20 ft bgs and increasing with depth. Cis-1,2-DCE and VC were only occasionally detected at the 75 ft depth in SR82-101 and CY-101 in concentrations ranging from 5 – 10 ppbv. As concentrations near the ground surface were low, concentrations increased with depth, and were generally of similar magnitude between the SR84 wells and the CY-101 well, which is not located near any suspected release area, it does not appear that releases at the I-10 corridor properties near the SR84 wells impacted groundwater. Concentrations observed in SR84-101, SR84-201, and CY-101 may be attributable to residual contamination remaining from historically high groundwater concentrations in the area before water levels dropped.

Active soil-gas sampling of the SR84 monitor wells was conducted again in 2007, along with three soil-gas monitor wells located on the former AMRI Oil property, but results did not differ greatly from previous sampling results (URS, 2007e). Detailed sample results are presented on Figure 17 of Appendix Q.

4.4.2 Interpretation of Data

The elevated relative mass of PCE, BTEX, and PAHs observed on the I-10 Corridor properties appear to be attributable to historical vehicle maintenance activities, former ASTs, and former USTs which appear to have resulted in isolated minor releases to soil. The 2002 soil-gas survey indicated elevated soil-gas concentrations of PCE, BTEX and PAHs for two locations in the I-10 corridor and recommended further soil investigations in the vadose zone for the area of I-10 Surplus (Cardinal Castings). Soil remediation was carried out in 2006, but because historical PCE concentrations in groundwater in the Cardinal Castings well have been low (<0.5 – 1.2 historically and <0.5 since 1993; see “Groundwater” section below), it does not appear that the VOCs detected in soil have significantly impacted groundwater in this area.

Active soil-gas monitoring data from 1997 until 2003, and again in 2007 indicate that groundwater does not appear to have been impacted by any releases to soil that may have occurred in the regions of Quality Truck, Accurate Auto Body, Arizona Truck Service, Carson Trailer, or Cowtown Boots. Therefore, the available data do not indicate that soil contamination at the properties along the I-10 Corridor impacted groundwater.

4.5 ADDITIONAL INVESTIGATIONS

Several investigations have been conducted in an effort to determine whether any additional sources to the groundwater plume may exist at the SR/ECDC Site. The following sub-sections describe these investigations.

4.5.1 Pima County Flood Control District Properties

In 2002, a passive soil-gas survey was completed in two phases at Pima County Flood Control District properties along the south bank of Rillito Creek (Figure 11) (Kleinfelder, 2002a). The first phase included the installation of 62 soil-gas monitoring locations on March 14, 2002 and the second phase included installation of 80 monitoring locations on May 22, 2002 (Appendix Q, Figures 31-33). At each location GORE-SORBER® screening modules were placed at a depth of approximately 2-3 ft bgs and were retrieved after approximately two weeks. PCE was the only COC detected and masses were less than 0.18 μg. It was concluded the discontinuous spatial distribution of PCE in soil gas and the low magnitude of detected masses were unlikely to be indicative of any potential contaminant sources in the area.

4.5.2 Acacia Gardens

A total of 26 locations on the Acacia Gardens Property and 14 locations on the Southern Arizona Insurance Service Center, Inc., (SAISC) property (Figure 11) were selected for soil-gas monitoring in three 100 foot transects across these properties in November 2001 (Appendix Q, Figures 31 and 34). At each location GORE-SORBER® screening modules were placed at a depth of approximately 2-3 ft bgs and were retrieved after approximately two weeks. Masses of PCE, TCE and trichloromethane were detected above laboratory detection limits in samples from collected from 7 of the 40 locations. It was concluded that detected masses were not of sufficient magnitude to reflect the presence of a source of VOC contamination below the Acacia Gardens and SAISC properties (Kleinfelder, 2002a).

4.5.3 Curtis Landfill

A 1992 report by EMCON identified PCE in soil gas at the former Tucson Sand & Soil property (Curtis Landfill), northwest of La Cholla Boulevard and Curtis Road, at a maximum concentration of approximately 58 ppbv (Smith and Cetwinski, 1992). No VOCs or other contaminants associated with landfill leachate were detected in groundwater in an onsite well (EMCON, 1992).

In July 2001, a total of 210 locations were selected for passive soil-gas monitoring in a 100-foot grid on the Curtis Landfill property (Appendix Q, Figures 31 and 35). At each location GORE-SORBER® screening modules were placed at a depth of approximately 2-3 ft bgs and were retrieved after approximately two weeks. PCE was detected at 13 of these locations; TCE and 1,1,1-TCA were each detected at a single location. The area with the most detections of PCE was along Curtis Road. Kleinfelder concluded that masses detected were not of sufficient magnitude to reflect the presence of a source of groundwater VOC contamination below the Tucson Sand Property (Kleinfelder, 2001). During a Phase II Soil Site Investigation, Kleinfelder reported there to be no VOCs or TPH detected in the site soils (Kleinfelder, 2002c).

In 2012, URS and ADEQ sampled the onsite well (former Tucson Sand) and 5 downgradient private wells for VOCs (Appendix Q, Figure 36). Concentrations of Site COCs in each well were below their respective laboratory method detection limits (URS, 2012b).

The soil, soil-gas and groundwater data indicate that there is no impact to groundwater in the vicinity of the property designated as Curtis Landfill.

4.5.4 Flux Box Sampling

In January and February 2003, a non-property specific soil-gas investigation was conducted. URS installed flux boxes to monitor soil-gas migration in the shallow soil at the I-10 Corridor, Former E.C. Winter, and Former Western Trailer Park locations (Figure 20). The collected samples were analyzed for VOCs using EPA Method TO-15. The primary constituents detected in soil gas were benzene, chloroform, PCE, and TCE (URS, 2004a). However, ADEQ no longer considers flux box sampling to be an accepted vapor investigation methodology.

5.0 GROUNDWATER INVESTIGATIONS AND CONTAMINANT CONCENTRATION TRENDS

This section presents a summary of the historical groundwater investigations conducted at the Site. Monitor well locations are shown in Figure 2. Well numbers are used to denote locations on the map. Many of the well locations have multiple screened intervals. An “S,” “M,” or “D” following the well number is used for well/sample identification to indicate the shallow, medium, or deep screened interval of the well or the interval from which a sample was collected. However, this designation is not consistent amongst all wells; for example, SRC-W29 M and D are both in regions considered to be in the deep zone. Monitor well construction diagrams and soil boring logs are provided in Appendix N.

Groundwater sampling in wells associated with the Site was conducted primarily by Pima County and its contractors until 2001. In February 2001, URS initiated a monitoring program for the collection of groundwater samples from wells at the SR/ECDC Site. Since this time, 29 sampling events have been conducted at the Site in accordance with the schedule presented in Table 5. The analytical suite for each of the monitoring events consistently included VOCs. Other analytes such as metals, alkalinity, and cations and anions have been analyzed periodically. These analytes were included in some quarterly monitoring events to evaluate potential changes in general water chemistry. Summary tables for PCE, TCE, 1,1-DCE cis-1,2-DCE, and vinyl chloride are included as Tables 6 through 10. Summary tables for these constituents prior to February 2001 are provided in Appendix R.

Well installation activities and groundwater monitoring results are presented in the following sub-sections. To be concise, PCE concentrations are used in most cases to discuss contaminant trends because PCE is the primary contaminant detected at the Site. TCE has generally exhibited distribution and trends similar to PCE but has been detected at lower concentrations. The COCs cis-1,2-DCE and vinyl chloride generally exhibit distribution and trends in groundwater similar to PCE and TCE and appear to be attributable to the degradation of PCE and TCE. Water quality results are presented primarily as general contaminant trends; for detailed groundwater monitoring results, the reader is referred to Tables 6-10 as well as appendices R, O, P and S. Historical contaminant distribution figures are provided in Appendix M.

5.1 Contaminant Characterization 1987-1994

Well Installation

From 1987 until 1994, groundwater characterization was primarily focused near the CDC Landfill and available private wells in the I-10 corridor area. Three shallow monitor wells (P-1, P-2, and P-3) and ten regional aquifer monitor wells (CDC-10 through CDC-W19) were installed between

January 1988 and February 1994 as part of the Phase 3 LESP (Figures 2 and 13). P-1, P-2, and P-3 were installed in January 1988 to determine the presence of perched groundwater at the ECDC Landfill. Groundwater was not present in the shallow monitor wells at volumes sufficient for sampling immediately after installation and was not detected during regular groundwater level monitoring events until January 1993, after a prolonged storm resulted in greater than normal runoff in the Santa Cruz River (Groundwater Resources Consultants, 1988). Because shallow groundwater is not normally found near the landfill, the shallow monitor wells were converted to vapor-phase monitor wells in late August 1994 (Malcolm Pirnie, 1997).

Regional monitor wells CDC-W10, CDC-W11, CDC-W12, CDC-W13, and CDC-W15D were constructed during July and August 1988. Locations of the monitor wells were selected based upon the apparent direction of groundwater flow, as determined from historical data and depth to water measurements completed during a well inventory conducted in May 1987. Wells CDC-W10 through CDC-W13 were constructed with screens from 93 to 168 ft bgs to provide groundwater samples from the uppermost portion of the aquifer. Well CDC-W15D was completed at a depth of 338 ft bgs adjacent to monitor well CDC-W5 along the CDC Landfill eastern boundary to evaluate the vertical distribution of VOCs in the aquifer (Malcolm Pirnie, 1996a). Monitor wells CDC-W14 and CDC-W16 were installed hydraulically downgradient (northeast of the landfill) in November 1989. The wells were constructed with screens from 107-170 ft bgs. Three additional monitor wells (CDC-W17, CDC-W18, and CDC-W19) were constructed in February 1994. CDC-W17 was located between CDC-W14 and CDC-W16 to provide information on the continuity between the two areas of contamination previously characterized. CDC-W18 was approximately 400 ft east of the southeastern boundary of the ECDC Landfill to provide information on the potential eastward migration of VOCs in groundwater from the landfill. CDC- W19 was installed along the northern boundary of the ECDC Landfill to provide a monitoring point at the assumed boundary of the VOC plume at that time (Malcolm Pirnie, 1996a). A summary of groundwater monitor well construction specifications is presented in Table 2.

Pima County purchased eight privately-owned water supply wells on the eastern side of I-10 in 1989. The wells were purchased to prevent potential human exposure to VOC-impacted groundwater. The wells purchased were Cardinal Castings, Kaylor Trailer, Cowtown, Sunset Plaza, AZ Truck, Quality Truck, Jenk’s Café and National Truck (Figure 2). These purchases were made after Pima County supplied the residents with bottled water and extended the public water utility service to many of the businesses. Pima County has used these wells for water level and water quality monitoring purposes.

Existing pumps and appurtenant equipment were removed from the private wells in March 1993. Seven of the wells were videologged following removal of the pumps to decide what action was appropriate for each of the wells. The AZ Truck well was not videologged because of restricted well access. In June and July 1994, the wells at Cardinal Casting, Kaylor Trailer, Quality Truck, Jenks Café, and National Truck were equipped with 1½ horsepower pumps, new 1½-inch diameter column pipes, and new 1-inch diameter water level sounding pipes to incorporate them into the regular ECDC study area groundwater monitoring network. The Sunset Plaza and AZ Truck wells were converted to piezometers, and the Cowtown well was abandoned due to degraded casing and the location of the well in relation to the business entrance.

Groundwater Monitoring

During this time period, groundwater sampling was conducted on either an annual or quarterly frequency. PCE and TCE were detected in the area of the ECDC Landfill (primarily in wells CDC-W5 and CDC-W14) and near the I-10 corridor (e.g. Kaylor Trailer, Cowtown, AZ Truck, and Quality Truck). PCE concentrations in CDC-W14, located southwest of I-10, were as high as 230 µg/L but had decreased to 16 µg/L by the end of 1994. PCE concentrations in CDC-W5, located adjacent to the landfill, remained relatively constant, fluctuating between 32.4 and 79 µg/L. In the I-10 corridor area, the highest PCE concentrations detected were approximately 450 µg/L from 1988-89 in the Cowtown and Kaylor Trailer wells. These concentrations had decreased to approximately 200 µg/L by 1994.

The Tanner well and monitor well CDC-W15D, both located near the ECDC Landfill, are screened in the deep zone of the aquifer. Site COC's were not detected in well CDC-W15D during this time period. PCE concentrations in the Tanner were approximately 1-5 µg/L.

At this time, no monitor wells existed in the shallow portion of the aquifer northeast of I-10, outside of the I-10 corridor. However, in the early 1990's, PCE was detected in Tucson Water production wells Z-004 and Z-006, at maximum concentrations of 1.5 µg/L and 3.5 µg/L respectively. These wells have long screens that extend across a large portion of the aquifer. Both Z-004 and Z-006 were subsequently taken out of service. Similarly, PCE was detected at Metro Water's South Shannon well, also screened across a large portion of the aquifer. PCE was first detected in this well in 1994 at a maximum concentration of 3.9 µg/L. A wellhead treatment system was installed at this well in 1997.

In September 1994, VOCs were detected in the Acacia Gardens Mobile Home Park (Acacia Gardens) water supply well, another long-screen production well northeast of the former ECDC WQARF Site. The VOCs detected included PCE, TCE, and cis-1,2-DCE. In 1995, Acacia Gardens was connected to the Tucson Water distribution system to ensure the residents had safe drinking water (PCSWM, 1995). Tucson Water supplied water to Acacia Gardens until the owners installed a wellhead treatment system in July 1997 that was operated until December 2000. This well was abandoned in 2001 by perforating the top 20 ft of casing and adding neat Portland cement from the bottom of the casing (400 ft bgs) to the ground surface (ADWR, 2001). The mobile home park currently is supplied water from the City of Tucson (ADEQ, 2012). The detection of VOCs in production wells in this area prompted the listing of the SRRC site on the WQARF registry in 1999.

5.2 Contaminant Characterization 1994-2002

Well Installation

During the span of approximately 1994-2002, the well network expanded northeast of I-10. Three wells (CDC-W20, CDC-W21, and CDC-W22) were constructed in November 1994. Water quality data from these wells indicated that VOCs extended northeast of I-10, beyond the area previously delineated. Five additional monitor wells (CDC-W23, CDC-W24, CDC-W25, CDC-W26, and CDC-W27) were installed in July 1995 to further evaluate the lateral extents of VOC-impacted groundwater. Monitor well CDC-W28D was installed in October 1995 to evaluate the presence of VOCs in the deep groundwater near existing monitor well CDC-W20 which, at the time, had the highest reported VOC concentrations northeast of I-10.

Groundwater Monitoring

As of 1996, evaluation of existing data from monitor wells CDC-W20 through CDC-W27 indicated that the downgradient boundary of the VOC plume was approximately 700 ft north of CDC-W24. VOCs were not detected in well CDC-W27, CDC-W25, or the Smith well during this time period and have never been detected in these wells. Thus, these wells appeared to define the downgradient edge of the plume associated with the former ECDC WQARF Site. The upgradient boundary of the VOC plume extended to the ECDC Landfill to the south.

The existing monitor wells provided an understanding of the horizontal extent of VOC contamination in the upper regional aquifer, but little data existed regarding the vertical extent of contamination. With few exceptions, the monitor wells were screened from approximately 95 to 170 ft bgs, limiting characterization of the VOC distribution to only the upper portion of the aquifer.

During this time period, PCE concentrations in well CDC-W24 increased from 10 µg/L initially and remained between approximately 100-200 µg/L from 1997-2002. January 1998 was the first sampling event in which CDC-W24 contained water with the highest PCE concentrations for the sampling event, with a concentration of 160 µg/L. Prior to that time, the highest PCE concentrations at the site had been detected in wells near the landfill or in the vicinity of the I-10 corridor.

PCE concentrations in the vicinity of the I-10 corridor generally decreased during this time. PCE concentrations in the Kaylor Trailer well continued to decrease though this well was last sampled in 1996. Well CDC-W20, installed in 1994, decreased steadily from 150 µg/L to approximately 30 µg/L in 2002. Wells in the vicinity of the landfill exhibited variable PCE concentration trends but concentrations in the area generally remained between approximately 10-100 µg/L during this time period.

The Cardinal Casting well was abandoned in December 2001 by ADOT subsequent to property acquisition in support of the expansion of the I-10 frontage road. Beginning in the first quarter of 2001, water levels in the Kaylor Trailer well had declined to the point that the well could no longer be sampled. In November 2001, field personnel attempted rehabilitation, but were not successful. The Kaylor Trailer well was abandoned in April 2003.

Water supply wells with deeper and longer screen intervals (Acacia Gardens, Z-006, and South Shannon) were beyond the northern edge of the plume, as defined by wells screened in the shallow portion of the aquifer, yet continued to contain detectable concentrations of PCE and TCE. The Acacia Gardens well and Z-006 are located only 160 ft north of well CDC-W25, a shallow-zone well with no detectable concentrations of VOCs. This indicated that the vertical, and hence downgradient horizontal, extent of the plume may not have been fully characterized.

In 2001, a series of geophysical measurements, flow testing, and groundwater sampling were conducted on the Acacia Gardens, Z-006, and South Shannon production wells (Kleinfelder, 2002b). A cross-hole pumping test was performed using the Acacia Gardens and Z-006 wells. For the cross-hole test, well Z-006 was used as the pumping well and the Acacia Gardens well used as the monitoring point. The primary goals of the investigation were to:

1) Identify the vertical extent of chlorinated VOC; and
2) Collect information to assist in the interpretation of the hydrogeologic conditions controlling the migration of the contaminants

The results of geophysical measurements and flow testing indicated the presence of a vertical gradient in the boreholes. Multi-level sampling results showed the highest contamination within each borehole was present between 225 and 325 ft with a lack of contaminants in the shallow portion of the aquifer. At or just below the depth of highest contamination, the interpretation of the geophysical logs indicated the tip of a finer-grained unit suggesting that the vertical migration of contaminants may be impeded below this point. The results of the investigation indicated a need for better vertical characterization of the aquifer.

5.3 Contaminant Characterization 2002-2014

Well Installation

Since 2002, a number of wells have been installed at various depths in the aquifer in an effort to better delineate the vertical extent of contamination (Table 11). Monitor wells installed by URS since this time include 18 wells in the shallow zone, 14 wells in the medium zone, and 7 wells in the deep zone (URS, 2005b; 2006b; 2007d; 2008b). SRC-W51S and SRC-W52M were installed in April 2013 to provide greater horizontal delineation of the plume. Appendix D includes details on the 2013 Site activities. Monitor well locations are shown in Figure 2. Well numbers are used to denote locations on the map. Many of the well locations have multiple screened intervals. As described previously, an "S," "M," or "D" following the well number is used for well/sample identification to indicate, in most cases, the shallow, medium, or deep screened interval of the well or the interval from which a sample was collected.

Decreasing groundwater elevations beneath the ECDC Landfill have rendered multiple monitor wells un-usable. In November 2014, Pima County and their contractor, Haley & Aldrich, designed and installed four new wells to replace wells that were either out-of-commission for some time or recently dry (Haley and Aldrich, 2015). The new wells (CDC-W16R, CDC-17R, CDC-19R, and CDC-PW2R) were installed with the top of the screens near the water table between approximately 163-168 ft bgs and the bottom of the screens set from approximately 243 to 248 ft bgs. These wells have not yet been sampled. The locations of these wells are depicted in Figure 37 of Appendix Q.

Groundwater Monitoring

Wells SRC-W30M and SRC-W33M were installed in 2003 downgradient of well CDC-W24, which had previously been the furthest downgradient well associated with the former ECDC WQARF site to be impacted with COCs. Groundwater samples taken from these wells indicated the presence of site COC's above the AWQS, confirming that contamination in this area was located in deeper portions of the aquifer than could be sampled using shallow-screen wells such as CDC-W25. Well SRC-W30M had an initial PCE concentration of 120 µg/L. PCE concentrations in this well began declining in 2005 with the most recent concentration of 22.5 µg/L measured in May 2013. PCE concentrations in well SRC-W33M remained between approximately 70-80 µg/L from its installation in 2003 to 2006, when concentrations began declining. The PCE concentration in this well was 8.4 µg/L in 2013. PCE concentrations in well SRC-W48M have been consistently above AWQS, with concentrations detected in this well between 95-120 µg/L during recent sampling events.

Several shallow-zone monitor wells are collocated with wells screened in the medium portion of the aquifer. Water quality results from these wells indicate that contamination exists primarily in the medium zone of the aquifer downgradient (northeast) of the area near well CDC-W24. For example, well SRC-W30S has never had detectable concentrations of PCE despite contamination detected above AWQS in SRC-W30M. Well SRC-33S did not have detectable concentrations of site COC's until 2008, with PCE concentrations remaining at or below 1.5 µg/L thereafter. PCE concentrations in well SRC-W47S, installed in 2008 have ranged from 8 – 15 µg/L, making this the furthest downgradient well in which a Site COC has been detected in the shallow portion of the aquifer.

Collocated shallow- and medium-zone wells installed closer to the I-10 corridor indicate contamination is located primarily in the shallow portion of the aquifer upgradient (southwest) of the area near well CDC-W24. Collocated wells designated SRC-W38 were installed in March 2005 to replace CDC-W24. PCE concentrations in these wells have been consistently above AWQS in both the shallow (SRC-W38S) and medium (SRC-W38M) portions of aquifer. However, the medium-zone well SRC-W32M, installed in 2003 approximately 375 ft upgradient (southwest) of these wells, has never had detectable concentrations of Site COCs.

These groundwater monitoring results indicate that a single plume extends from the ECDC landfill and moves deeper in the aquifer north of I-10, eventually reaching the South Shannon production well. Due in part to these findings, the former ECDC and SRRC WQARF sites were administratively combined in the fall of 2004. Since this time, groundwater sampling activities have been completed at the combined SR/ECDC Site.

PCE concentrations in wells screened in the shallow portion of the aquifer immediately northeast of the I-10 corridor (e.g. SRC-W32S, SRC-W42S, SRC-W43S) have consistently been greater than the AWQS. The highest concentrations of PCE detected at the Site persist in the area of well SRC-W38S, though PCE concentrations in this well have decreased from a maximum concentration of 350 µg/L measured in 2005 to 122 µg/L in 2013.

Wells SRC-W34 and SRC-W50S were installed to assess contamination in the I-10 corridor as many private wells can no longer be sampled. PCE concentrations in these wells have remained less than 55 µg/L and were less than 20 µg/L during the sampling event conducted in May 2013.

PCE concentrations in monitor wells near the ECDC Landfill have generally continued to decrease. PCE concentrations in well CDC-W17 continued to decrease to 23.5 µg/L in 2004, the last year that this well was sampled. PCE concentrations had decreased to below AWQS in both CDC-W5 and CDC-W16 by April 2006 and have generally remained below this level in subsequent sampling events. Well CDC-W5 was last sampled in 2008 due to declining water levels. One exception to this trend has been well CDC-W14, in which concentrations increased as high as 120 mg/L in 2008. PCE concentrations in this well subsequently decreased, likely due to groundwater treatment operations that began in 2009, as discussed in Section 5.4. The PCE concentration in this well during the May 2012 sampling event was 11.8 µg/L.

As discussed previously, the depth to the bottom of the screen in deep-zone wells typically ranges from 330 to 400 ft bgs. PCE has not been detected above the AWQS of 5 µg/L in any well screened at these depths.

Several wells have been installed in an effort to provide greater delineation of the downgradient portion of the plume. Site COC's have never been detected in wells SRC-W35S/M, SRC-W49M, SRC-W51S and SRC-W52M, indicating this area of the plume is well-delineated. VOC's were detected in well SRC-W31M, located immediately downgradient of the South Shannon production well, following the temporary cessation of pumping in 2005 to install a new treatment system. Shortly after the South Shannon well was placed back into service, concentrations in SRC-W31M decreased to below the method detection limit.

During the 2013 sampling event, ADEQ requested that URS sample for 1,4-dioxane. 1,4-dioxane was detected in groundwater samples collected from shallow, medium, and deep zoned wells. The highest level of 1,4-dioxane was detected in the sample collected from SRC-W48M at a concentration of 3.0 µg/L. Currently, there is no AWQS for 1,4-dioxane. As this was the first year ADEQ requested sampling for 1,4-dioxane, there are insufficient data for trend analyses. Appendix D includes a map showing the 1,4-dioxane detections and contains the 2013 analytical data.

5.4 Groundwater Treatment

In June 2009, Pima County began operation of a groundwater pump and treat pilot system. The system consisted of a single well located downgradient of the Landfill (PEX1, Figure 2). An air stripper and granular activated carbon were used to treat the extracted water and off-gas, respectively. The objectives of the proposed pilot test were threefold:

1. To attain hydraulic containment of the impacted groundwater;
2. To reduce the total amount of remaining VOC mass and concentrations within the groundwater to levels that can further be degraded via monitored natural attenuation to concentrations below AWQS; and
3. If No. 2 was not possible, identify the need and potential benefits for an amendment to be injected into the plume to assist with attaining a level of VOC concentrations that can result in a long-term remedy.

From June 2009 to January 2011, approximately 131 million gallons were treated and it is estimated that over 37 pounds of VOCs were removed. On January 27, 2011, in response to the presence of filter pack material in the discharge of the extraction well (PEX-1) and the decreasing production rate, the pump was removed to evaluate if repairs or replacement would be required. Video logging of PEX-1 indicated extensive bacterial fouling and scale formation along the entire length of the well screen as well as damage to the screen which allowed the filter pack material to enter the well screen. During this period, rebound monitoring was performed and data collected confirmed that COC concentrations remained below or slightly above the AWQS. Because of relatively stable VOC concentrations and the cost of rehabilitating the extraction well, the system was shut down January 2011 (Brown and Caldwell, 2011b).

Pima County installed a new extraction well (PEX2; Appendix Q, Figure 37) to resume operation of the pilot study groundwater treatment system in early 2012. Equipment was moved from the previous well location to the new well location at that time (Haley and Aldrich, 2015). The system sat idle for some time pending approval of applications for permits to extract and discharge treated groundwater and for an electrical service hook-up from Tucson Electric Power. During that time, Pima County's contract with their contractor, Brown and Caldwell, expired. Pima County contracted Haley & Aldrich in March 2014 to resume operation and maintenance of the groundwater treatment system (Haley and Aldrich, 2015).

Groundwater extraction restarted on June 28, 2014. Except for routine maintenance activities, the system operated continuously until November 7, 2014. During this period, the system operated for over 3,200 hours and extracted and treated more than 32 million gallons of groundwater at a rate of approximately 163 gallons per minute (Haley & Aldrich, 2014). Concentrations of PCE and TCE measured at the system inlet remained at, or slightly above the Aquifer Water Quality Standard of 5 μg/L. The system was shut down on November 7, 2014 to allow static water levels to stabilize prior to installing new groundwater monitor wells (Haley & Aldrich, 2014).

5.5 Summary of the Extent of Groundwater Contamination

VOC contamination in groundwater extends north from the ECDC Landfill area to the South Shannon Production Well. The PCE/TCE plume is well-characterized distally and is moving northeast where it appears to be hydraulically contained by Metro Water's South Shannon well. Although the plume has temporarily extended north of South Shannon well following a period of temporary cessation of pumping, SRC-W31M has not contained detectable concentrations of Site COCs since 2010, and monitor well SRC-W35S/M to the west and SRC-W52M to the east of South Shannon have historically been non-detect for Site COCs. CDC-W23 and CDC-W26, which had historically defined the plume on the eastern side, are currently dry and were last sampled in 2008 and 2011, respectively. Thus, the eastern boundary of the PCE/TCE plume is not well-defined by the most recent sample events. The 2013 water quality data indicate that the areas that demonstrate the highest exceedance of AWQS are at shallow well SRC-W38S and medium well SRC-W48M. PCE and TCE concentrations in wells in the vicinity of the landfill, particularly CDC-W14, have decreased following the start of groundwater extraction activities. Other factors such as groundwater recharge and production well pumping in the area may be contributing to the changes in plume shape, water flow, and contaminant distribution. Contaminant fate and transport at the Site is further discussed in Section 6.0.

6.0 CONTAMINANT FATE AND TRANSPORT

As discussed in Section 2.3, COCs within the WQARF site include PCE, TCE, 1,1-DCE, cis-1,2-DCE and vinyl chloride. COPCs at the Site are TCA, 1,4-dioxane, DCA, Freon 11, Freon 12, chromium, lead, benzene-toluene-ethylbenzene-xylenes (BTEX), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and nitrate plus nitrite. Where available, the Agency for Toxic Substances and Disease Registry (ASTDR) ToxGuides™ are provided for the COCs and COPCs in Appendix W.

This section discusses those processes that affect the fate and transport of COCs in groundwater beneath the Site. In general, potentially complex physical, geochemical, and biological processes control the movement and transformation of compounds in the subsurface. These processes are functions of site-specific environmental characteristics and geochemical properties, including, but not necessarily limited to, soil and groundwater pH, oxidation-reduction potential, dissolved oxygen, major ion chemistry, soil-bulk density, hydraulic conductivity, soil stratigraphy, and microorganism populations. These characteristics can vary considerably within a small area, both vertically and laterally. However, for the purposes of this evaluation these characteristics are assumed to be an average value over a large area. Sections 6.1-6.3 below provide general information about the COCs and transport processes and their impact at this Site. In Section 6.4, this general information is applied to the Site.

6.1 CHEMICAL CHARACTERIZATION OF CHLORINATED ETHENES

Chlorinated ethenes are halogenated aliphatic organic compounds. The chemical structure of ethene consists of four hydrogen atoms attached to a carbon-carbon double bond. The chemical structure of PCE consists of an ethene molecule that has all four hydrogen atoms replaced by chlorine atoms. TCE consists of an ethene molecule that has three chlorine atoms replacing three of the hydrogen atoms. DCE consists of an ethene molecule that has two chlorine atoms replacing two of the hydrogen atoms. The three isomers of DCE are cis-1,2-DCE, trans-1,2-DCE and 1,1-DCE, which refer to the location of the chlorine atoms on the molecule. The chemical structure of vinyl chloride consists of the same ethene structure that has one hydrogen atom replaced by a chlorine atom. Of the chlorinated ethenes, PCE has the highest oxidized state. PCE, TCE, DCE, and vinyl chloride are only susceptible to reduction under highly reducing groundwater conditions favorable for transfer of electrons. However, dehalogenation of chlorinated ethenes by certain bacteria can occur under non-reductive conditions.

6.2 CHEMICAL PROPERTIES RELATED TO FATE AND TRANSPORT

Some of the standard chemical properties that influence the fate and transport of COCs include:

- Specific gravity,
- Solubility in water,
- Vapor pressure,
- Henry's Law constant

Specific gravity is a measure of the density of a compound relative to water. When the specific gravity is greater than 1.0 g/cm^3 (the specific gravity of water) this indicates the compound is denser than water: PCE, TCE, and DCE all have specific gravities greater than water, at 1.63 g/cm^3 1.46 g/cm^3 and 1.27 g/cm^3, respectively, and are therefore classified as dense non-aqueous phase liquids (DNAPLs). These types of compounds are expected to migrate downward within a water column. Vinyl chloride, while often classified with PCE, TCE, and DCE, is slightly less dense than water, at 0.91 g/cm^3.

Solubility defines how readily a compound dissolves in water. PCE is the least soluble of the chlorinated ethenes, with a solubility of approximately 150 mg/L at 20 °C. While this value represents a very low solubility, it is still many orders of magnitude larger than the regulatory standard for PCE in groundwater (150,000 μg/L compared to the AWQS of 5 μg/L). With the loss of chlorine molecules, chlorinated ethenes generally become more soluble, so TCE is more soluble than PCE, and DCE is more soluble than TCE. The solubility of TCE at 20 °C is approximately 1,100 mg/L, DCE solubility ranges from 2,200 to 6,300 mg/L, depending on the isomer, and vinyl chloride has a solubility of approximately 2,700 mg/L. In the field, conditions are such that dissolved chlorinated ethenes are rarely detected at levels near their solubility; therefore a rule of thumb has been developed that if the concentrations observed are near 10% of the solubility value, DNAPL may be present. The highest PCE concentration reported since monitoring began in 1987 was 480 μg/L in the Kaylor Trailer well, which is 0.34% of the solubility of PCE, indicating that at least since that time there likely has been no DNAPL phase directly in contact with groundwater present at this Site.

Vapor pressure is a measure of the volatility of a compound. PCE, TCE, DCE, and vinyl chloride each have high vapor pressure, and are therefore classified as volatile compounds. In the vadose zone, this high vapor pressure is one of the reasons these compounds are more often detected in soil-gas than in soil samples. This property can lead to soil contamination affecting groundwater through the migration of contaminated soil-gas.

Henry's Law constant describes the partitioning of a compound between vapor phase and dissolved phase. Therefore, if contaminants are at equilibrium among the phases, it is theoretically possible to estimate groundwater concentrations from vapor phase detections at the groundwater table. However, equilibrium conditions rarely occur under field conditions. Therefore, equilibrium calculations using Henry's constant are often used as a screening tool to determine what maximum concentrations might be expected in one phase given mass transfer from another.

6.3 TRANSPORT AND DEGRADATION PROCESSES

6.3.1 Physical Processes

Given the arid environment and generally low moisture content of soils at the Site, the primary mechanism whereby the COCs migrate from the contaminated soils to soil gas is likely through volatilization. As described in Section 6.2, the high vapor pressures of the COCs allow them to move readily from the liquid to vapor phase. Once in the vapor phase, the COCs are transported by advection or diffusion. Advection is flow resulting from pressure gradients, while diffusion is flow resulting from concentration gradients. At the ECDC landfill, the gaseous transport is assisted by the generation of landfill gas (e.g. methane and carbon dioxide) in the refuse, displacing the COCs, and forcing them downward (Walter et al, 2003). VOCs are transported into the saturated zone at the capillary fringe, as COCs in soil gas partition into groundwater. This transport mechanism is governed by Henry's Law as discussed in Section 6.2.

Contaminants may also have reached groundwater as a result of a large infiltration event such as a heavy rainfall or flood. In this case, water infiltrating from the surface may dissolve contaminants present in the soil or soil gas and then percolate to groundwater. Large infiltration events have occurred periodically at the Site. Such events have been shown to cause a temporary rise in water levels. Rising water may submerge contaminated soil and soil gas and thus increase mass transfer of contaminants into the groundwater. In some circumstances contaminants may be released in sufficient quantity such that they can percolate directly through the vadose zone and into groundwater.

The movement of VOCs and inorganic constituents in groundwater is dependent on several processes, such as advection, hydrodynamic dispersion, diffusion, sorption/desorption, dilution, and volatilization that affect the site-specific mobilities of these compounds. In general, solutes are transported in groundwater by advection and dispersion and retained by chemical or physical interactions within the saturated zone such as sorption/desorption. The retardation factor is a measure of the effect of the sorption/desorption process on the rate at which some compounds move in groundwater.

Advection is the transport of dissolved compounds with groundwater flow, and is controlled by the groundwater velocity. Therefore, advection is the process that is influenced by infiltration events such as those that would occur along the Santa Cruz River and Rillito Creek, and by groundwater pumping, such as those from the Metro Water wells (e.g. South Shannon) and historical Tucson Water wells. Dispersion is the result of two processes, molecular diffusion and mechanical dispersion. Molecular diffusion is the transport of a compound caused by random molecular movement, resulting in a net movement from higher to lower concentrations. This mechanism is slow in comparison to other mechanisms, and is generally only important when advective flow is slow (e.g. low permeability soils). Molecular diffusion can also cause the movement of contaminants into low permeability zones. These contaminants can then diffuse back out of these zones when concentrations in higher permeability areas are reduced – thus extending the time it takes to remediate a site.

Mechanical dispersion can spread the plume in both the longitudinal (direction of flow) and transverse (normal to flow) directions. Mechanical dispersion occurs when flowpaths diverge or when water moves through a porous media at rates that are both greater and less than the average linear velocity. Mechanical dispersion can also occur on the macro scale, where areas of higher hydraulic conductivity result in higher flow velocities than the surrounding areas. Such channels likely exist at the Site, as the basin fill local aquifer sediments consist of alluvial deposits from the Santa Cruz River and Rillito Creek; however such macro-scale geological features are difficult to detect given their size relative to the large spatial area over which they occur and the distance between wells.

Sorption refers to the movement of a solute from the aqueous phase to the porous media surface – most commonly to clay particles and organic matter. Desorption is the reverse of this process. For chlorinated ethenes, the sorption/desorption process is slow when compared to advective transport. Sorption/desorption therefore creates a retardation in the movement of the solute, causing it to transport at a rate slower than that of groundwater flow velocity.

6.3.2 Chemical and Biological Transformation Processes

Chemical and biological transformation processes can also have a significant effect on the fate and transport of compounds in the subsurface. Chemical processes include hydrolysis, oxidation, and reduction reactions. Hydrolysis is the direct reaction of dissolved compounds with the water molecules. For chlorinated ethenes, hydrolysis would only occur very slowly or under high temperatures. Most oxidation and reduction reactions that occur in the environment are a result of microbial activity, although some oxidation and reduction reactions can occur abiotically. Reductive dechlorination is a key process that will break down chlorinated ethenes; however, as the majority of the plume at the SR/ECDC Site is located in areas exhibiting oxidizing and aerobic conditions, this process is not expected to have a significant effect over the larger Site area. However, conditions within the ECDC Landfill are known to be reductive, and reductive dechlorination processes are known to have caused biotransformation in the landfill (Malcolm Pirnie, 1997).

Biotransformation of chlorinated ethenes can occur in the presence of water under anaerobic conditions and has been well documented in research literature over the last 20 years. The biotransformation of a contaminant is actually a series of microbially induced oxidation-reduction reactions, which require an electron acceptor (oxidizer) and an electron donor (reducer). In general, the highly chlorinated ethenes do not act as electron donors or substrates due to their highly oxidized state, and therefore are generally only biotransformed by reductive processes.

Sequential reductive dehalogenation of PCE produces the breakdown products TCE and then cis- and trans-1,2-DCE. Under some conditions this sequential dehalogenation may continue, resulting in the production vinyl chloride and, finally, ethene. Reductive dehalogenation of VOCs becomes more difficult for each successive step in the sequence from PCE to ethene. For example, the reduction of PCE to TCE is much easier than the reduction of 1,2-DCE to vinyl chloride. As mentioned above, the reduction of chlorinated ethenes was observed in the ECDC Landfill (Malcolm Pirnie, 1997).

In summary, the fate and transport mechanisms considered to play a primary role at the SR/ECDC Site are advection/dispersion spreading the plume, sorption/desorption retarding the plume, and biotransformation in the ECDC Landfill area generating the daughter products of PCE.

6.4 OBSERVED VOC MIGRATION IN GROUNDWATER

An evaluation of the distribution of VOCs in regional groundwater is necessary to understand the fate of these contaminants at the Site. To assist with this evaluation, a cross section showing well locations, screen intervals and concentration time-series graphs (log concentration versus time) of PCE and TCE, the primary COCs, in the regional aquifer was prepared and is presented as Figure 21. The associated time-series graphs are included in Appendix P.

6.4.1 Contamination Variations in the Regional Groundwater

PCE and TCE Distribution

Generally, the groundwater contaminant plume extends from its source at the ECDC Landfill area north and east to the Metro Water South Shannon well. As previously discussed, the major components of the groundwater plume include TCE and PCE, with generally lesser concentrations of cis-1,2-DCE, vinyl chloride, and other Site COPCs. Much of this analysis is based on an evaluation of the PCE and TCE trends as these appear to be the primary components of the contaminant plume.

Historically, the highest concentrations of PCE and TCE have been detected near the northeast corner of the ECDC Landfill and immediately north and south of I-10 in the shallow aquifer zone, and immediately south of the Rillito Creek in the medium aquifer zone. Historical plume distribution maps are provided in Appendix M. Using the AWQS for PCE and TCE, overall the plume appears to be bounded to the south by well CDC-W-11; the west by wells CDC-PW1, CDC-W21, and SRC-W51S; to the east by wells CDC-W18, CDC-W23, CDC-W25, SRC-W49M, and Z-006; and to the north by wells SRC-W35M, SRC-31M, and SRC-W52M. However, due to steadily declining water levels, several wells that have historically been used as “sentinel” wells have become dry and could not be sampled. Therefore, some uncertainty as to the western plume boundaries in areas near SRC-W47, SRC-W46M, and SRC-W35 may exist, although the degree of uncertainty is low based on historic concentrations. Figures 5-8 present the 2012 interpretation of the plumes for TCE and PCE.

An overview of contaminant contours for selected wells is presented in Appendix M. Time-series graphs for selected wells are presented in Appendix P and Appendix S. Though an area of high concentration was detected near the I-10 properties during early monitoring events, these concentrations likely originated from the landfill prior to the start of monitoring activities. The general movement of PCE and TCE can be interpreted from time-series graphs along a given transect of the plume. For example, wells CDC-W17, CDC-W14, the Cowtown/CDC-W24 well pair, and the Kaylor Trailer well appear to show generally similar, though temporally offset, trends. This would be expected if groundwater were flowing parallel to this particular transect.

As the plume progresses to the north, specific concentration trends are more difficult to discern. This is likely due to a combination of mechanical dispersion and limited historical data sets in the area. In general, PCE and TCE concentrations observed as wells were installed in this area are similar in magnitude to concentrations observed historically in wells nearer the landfill. Taken as a whole, the COC concentration trend data do not provide clear evidence that a significant PCE or TCE source exists downgradient of the ECDC landfill.

The South Shannon well pumps a significant volume of water throughout the year with monthly average pumping rates in 2014 ranging from approximately 380 to 820 gallons per minute (gpm). Aquifer testing and capture-zone modeling completed in 2005 showed that this well has the capacity to fully capture the plume (URS, 2005a). To maintain this capacity, the wellhead treatment system was removed and a granular activated carbon system was installed on the South Shannon well from 2005-2006. During construction, the plume migrated north and was detected in monitor well SRC-W31M, immediately downgradient of the production well. Shortly after the South Shannon well was placed back into service, concentrations in SRC-W31M decreased to below the method detection limit. Contaminants have historically not been detected in monitor wells SRC-W31S, SRC-W35S/M and SRC-W52M, which surround the South Shannon well. This supports the conclusions of the 2005 capture-zone modeling. In 2013, engineering improvements were made at the South Shannon well to expand the service area of the treated water (Metro

Water, 2014). This allowed for an increase in pumping capacity and enhanced the ability of the well to capture the plume.

In an effort to further evaluate the potential existence of an additional source, the PCE/TCE ratio was calculated for selected wells across the Site (Appendix T). In comparing the overall ratios, the data generally show two distinct ratio signals emanating from the landfill. In the center of the plume, PCE generally occurs at a concentration higher than two times the TCE concentrations; the estimate of this ratio ranges from approximately two to four. Outside of this portion of the plume, the PCE/TCE ratios are generally lower. Near the landfill in the eastern portion of the plume (e.g. CDC-W16), ratios were historically near two but have since decreased to less than one. An associated increase in the chlorinated ethene daughter products cis-1,2-DCE and vinyl chloride indicate that this behavior may be attributable to bio-transformation of PCE to TCE in this portion of the Site. This trend in PCE/TCE ratios is generally propagated downgradient north of I-10. Figures in Appendix T show that PCE/TCE ratios in the Quality Truck well and later well CDC-W20 appear to follow the behavior of CDC-W16 as the biologically degraded plume migrates downgradient.

Well SRC-W41S, located on the E.C. Winter property, and well SRC-W40 located northeast of this property have exhibited a relatively constant PCE/TCE ratio near one since their installation in the mid-2000's. These ratios appear slightly lower than expected compared to historical ratios in upgradient wells and accounting for the approximate rate of groundwater flow in the area. Given the lack of PCE and TCE biodegradation products and the generally aerobic conditions in the vicinity of the E.C. Winter property, the PCE/TCE ratios may be indicative of a minor source of TCE in this area.

Similar to the concentration magnitudes, PCE/TCE ratio trends become more difficult to discern as the plume continues to migrate further from its source and the effects of dispersion become more apparent. However, ratios in downgradient wells do not appear significantly different from upgradient wells. Thus, the available groundwater quality data do not provide clear evidence that a significant source of PCE or TCE exists downgradient of the ECDC landfill.

Occurrence of Freon

Freon 12, and to a lesser extent Freon 11, concentrations are also detectable in groundwater throughout the plume. While the concentrations are not high enough to be considered a Site COC, the location of the detectable concentrations provides insight into the nature and source of the contaminant plume.

Freon 11, or trichlorofluoromethane, is a halogenated VOC. The chemical structure consists of one carbon atom bonded to three fluorine atoms and one chlorine atom. Freon 12, or dichlorodifluoromethane, is also a halogenated VOC with a chemical structure consisting of one carbon atom bonded to two fluorine atoms and two chlorine atoms. Both Freon 11 and 12 are primarily used as propellants and refrigerants and are common landfill contaminants that are often detected in landfill gas. Similar to PCE and TCE, Freons are typically persistent in the environment and are not readily degradable and are therefore reliable tracer compounds for evaluating potential sources of groundwater impacts.

Freons are useful tracer compounds because once released to the environment they are typically persistent and do not readily degrade. Historically, Freons have been detected in groundwater samples at about the same frequency and in the same samples as PCE and TCE, but at roughly one or two orders of magnitude less in concentration (Appendix O). The difference in groundwater concentrations of PCE and TCE versus Freons may be attributable to the higher volatility of Freons relative to chlorinated ethenes, causing Freons to preferentially remain in the vapor phase. This co-occurrence of Freon at wells with significant PCE and TCE across the Site and at different depths within the aquifer is an indication that there is a common source area of the PCE, TCE and Freon.

Occurrence of 1,4-Dioxane

Historically, 1,4-Dioxane has not been analyzed in groundwater samples collected in association with the SR/ECDC plume. Much of the work to complete this RI was accomplished prior to the recognition of this compound as an emerging contaminant. However 1,4-dioxane was evaluated in the 2013 sampling event. 1,4-Dioxane, or 1,4-diethyleneoxide, is a non-halogenated VOC. The chemical structure consists of four carbon atoms bonded to eight hydrogen atoms and two oxygen atoms. 1,4-Dioxane is primarily used as a stabilizer for chlorinated solvents and is found in some groundwater plumes associated with other VOCs, typically 1,1,1-TCA. In contrast to PCE and TCE, 1,4-dioxane mixes with water readily and experiences low sorption; therefore, it is transported in groundwater far in advance of associated solvents.

Results of the 1,4-dioxane analysis indicate concentrations were detected above 1 μg/L in wells SRC-W37M, SRC-W48M, SRC-W38S, SRC-W44S, SRC-W43, and SRC-W45S (Appendix D, Figure D 2.1). These wells generally represent the central portion of the known VOC plume. Lower concentrations of 1,4-dioxane between 1 μg/L and 0.35 μg/L generally surround the locations exhibiting concentrations above 1 μg/L and include wells SRC-W34M, SRC-W40S/M/D, SRC-W50S, SRC-W33S/M, SRC-W46M, SRC-W47S, SRC-W51S, SRC-W30M, SRC-W39M and Sunset Plaza.

The highest concentrations appear to be correlated with areas of highest PCE and TCE contamination, suggesting they likely have a common source. The broader distribution of 1,4-

dioxane compared to other site contaminants is not entirely unexpected given the transport properties of the compound discussed above. However, additional sampling rounds for 1,4-dioxane are necessary to fully assess the spatial and temporal trends of this contaminant.

Currently there are no WQARF regulatory limits for 1,4-dioxane. The Arizona Department of Health Services (ADHS) completed a health risk assessment for the 1,4-dioxane concentrations observed at the Site and concluded that the highest detections at the Site present a “very low” risk to human health. For detailed information on the ADHS analysis, see Appendix V.

Vertical VOC Distribution

North of I-10, the VOC plume shows a clear pattern of transport downward within the aquifer as it moves north. The plume does not appear to be migrating north of well SRC-W47S within the shallower portions of the aquifer. VOCs that are observed north of this well are evident primarily in wells screened within the medium interval indicating downward transport within the aquifer. This phenomenon of the VOC plume being transported downward in the northern part of the Site can be observed in the time-series charts shown in Figure 21. PCE and TCE concentrations in medium depth wells W33M and W30M are much greater than the low levels detected in the shallower screened intervals at the same locations (Figure 21). The increasing depth of the PCE and TCE plumes is also illustrated by Figures 5 through 8.

The “diving” of the plume may potentially be due to subtle variations in geology perhaps due to formations created by the Rillito Creek, and pumping of groundwater from a deeper portion of the aquifer at the South Shannon well. This well with its long screened interval and deep pump setting results in a significant area of influence (i.e. drawdown) when pumping.

Fate and Transport Conclusions

The concentrations of VOCs observed in the groundwater across the Site are indicative of a source area southwest of the I-10 corridor. As discussed in the source area description, the VOC plume is likely the result of surface releases or disposal of solvents and/or solvent containing liquids and leachate from buried debris at or near the ECDC Landfill, and from migration of soil gas within the landfill down to the water table. Biodegradation of the chlorinated solvents appears to have occurred and may still be occurring in and beneath the landfill, but there is little evidence of further biodegradation in the larger plume. Pulsed releases from the landfill area may have been caused by intermittent releases from buried debris and from periodic large infiltration events. These pulse releases may be the cause of observed high concentrations areas downgradient of the landfill.

Once transported through the vadose zone to the aquifer, the contaminants are transported via the primary site-specific transport mechanism of advection with the regional groundwater flow and may be influenced by localized geologic variations, high volume production wells and infiltration events. Generally, the contaminant plume begins to change direction and depth north of I-10 which may indicate this is where the influence from these production wells begins to impact the shape and migration of the plume. Specifically, it appears that the dissolved VOC plume moves downward and northeast towards the high capacity South Shannon well where current evidence indicates it is being hydraulically captured and prevented from migrating farther north. In general, the plume boundaries have been fairly well defined, with some uncertainty along the eastern boundary due to dry monitor wells and access issues with local property owners.

Extensive efforts have been made to identify potential groundwater contaminant sources downgradient of the ECDC landfill. Examination of PCE and TCE time-series data and ratios did not identify evidence of a significant additional source. Historical research was completed in 2002 to identify any potential source areas based on a review of historical records. Several potential sources have been investigated over many years through active and passive soil-gas surveys, soil and groundwater sampling, and other remedial actions. Results of this work suggest that the E.C. Winter property may have been a minor source of TCE in groundwater. However, no other significant sources of contamination to regional groundwater have been identified as a result of these extensive investigative efforts. Given the multiple lines of evidence presented herein, it is unlikely that another significant source of contamination exists at the Site outside of the ECDC Landfill area.

7.0 CONCEPTUAL SITE MODEL

Hydrogeology

Soil underlying the Site generally consists of sandy gravels to silty gravels, with some areas of sand, gravel, and clays, consistent with the Ft. Lowell Formation of the Tucson Basin. The regional aquifer appears to have significant communication across the various depths as little to no hydraulic head difference is detected at wells with multiple screened depths to approximately 400 ft bgs. The depth to groundwater within the Site as of the April-May 2013 monitoring event was approximately 155-160 ft bgs. Perched groundwater does not appear to be a factor at this site.

Water levels in the area have been declining steadily since the late 1940's at a rate of approximately 1.5 ft/yr. Thus, water levels were likely more than 50 ft higher during landfill operation. Given the documented depth-to-waste of approximately 85 ft bgs, waste was likely deposited in relative close proximity to the groundwater surface (Figure 3).

The direction of the groundwater hydraulic gradient in the vicinity of the Site has been historically variable and appears to be locally influenced by flooding events and regional groundwater pumping. Groundwater flow in the area is currently affected by pumping from Metro Water's South Shannon and DeConcini wells, though other production wells have influenced groundwater flow in the past. Significant infiltration events have occurred in the past, though infrequently, in the form of wide-spread flooding. These events can cause short-term changes in the direction of the hydraulic gradient.

The determination of the general direction of the groundwater flow is likely complicated by complex hydrogeologic features present due to the Site's location near the confluence of two major drainage channels of the Tucson Basin. Characteristics of these features can be difficult to identify given the limited lithologic data points available. Therefore, the determination of the general groundwater flow direction considers multiple lines of evidence including: measured hydraulic gradient, the effects of pumping, historical contaminant concentration data, and information on potential source areas collected during extensive field investigations. In general, groundwater at the site appears to flow in a direction to the north-northeast across the Site.

Contaminant Fate and Transport

COCs at the site are the chlorinated solvents PCE, TCE, 1,1-DCE, cis-1,2-DCE and vinyl chloride. Given the arid environment and generally low moisture content of soils at the Site, VOCs migrate readily from contaminated soils to soil gas via evaporation and volatilization. The high vapor pressures of these compounds allow them to move easily from the liquid to vapor phase. At the landfill, COCs are part of the landfill gas mixture along with methane and carbon dioxide generated due to the degradation of waste. As organic wastes in the landfill degrade, landfill gas is generated resulting in increasing gas pressure within the landfill. As gas pressure within the landfill increases, landfill gas will migrate radially out of the waste impacting soil vapor adjacent to the landfill and groundwater underlying the landfill. VOCs are transported from the gas phase into the saturated zone at the capillary fringe as the landfill gas constituents partition into groundwater. Contaminants may also have impacted groundwater as a result of large infiltration events such as a heavy rainfalls or floods. However, large infiltration events occur infrequently at the Site.

Biotransformation of chlorinated ethenes has likely occurred in the ECDC Landfill area due to the methanogenic conditions present within the landfill. Sequential reductive dehalogenation of PCE produces the breakdown products TCE and then cis- and trans-1,2-DCE. Under some conditions, this sequential dehalogenation may continue, resulting in the production vinyl chloride and, finally, ethene. The reduction of chlorinated ethenes to ethene gas has been observed at the ECDC Landfill.

Concentration time-series graphs indicate that the plume migrated from its source near the ECDC landfill to the north-northeast and beneath the I-10 freeway. This is generally consistent with the direction of groundwater flow in this area. It is likely that areas of high concentration observed in the I-10 corridor area in the first years of groundwater sampling had migrated from beneath the landfill prior to the time of initial sampling.

The mechanisms controlling contaminant transport at the Site have likely led to the irregular distribution of contaminants over both space and time. As described above, the mass transfer of contaminants to groundwater may have periodically increased following large infiltration events. Additionally, chemical containers disposed of in the ECDC Landfill may have degraded at different rates causing contaminant releases at various times throughout the history of the Site. The migration of these contaminants in groundwater following such events likely explains isolated areas of higher concentration observed downgradient of the ECDC Landfill.

As the plume progresses north and east of the I-10 freeway, it moves deeper within the regional aquifer. Several collocated medium- and shallow-zone wells confirm that contamination exists primarily in the shallow zone upgradient of well SRC-W38. Downgradient of this area, contamination exists primarily in the medium zone of the aquifer. PCE was detected in the South Shannon well as early as 1994 despite the fact that VOCs were not detected in some monitor wells located upgradient of the Shannon well, but screened in the shallow zone. This was likely due to the fact that contamination had migrated below the shallow-zone well network in place at the time. None of the available data indicate an additional source has existed in the vicinity of the South Shannon well. The conceptualization of plume movement is depicted in Figure 3. Based on COC concentration trends, it appears that the groundwater plume at the Site has been generally well-defined and is not expanding.

Freon 12 and to a lesser extent Freon 11 have been detected in groundwater throughout the plume. While the concentrations are not high enough to be considered Site COCs, the locations of detectable concentrations provides insight into the nature and source of the contaminant plume. Both Freon 11 and 12 are primarily used as propellants and refrigerants and are commonly detected in landfill gas. Similar to PCE and TCE, Freons are typically persistent in the environment and are not readily degradable and are therefore reliable tracer compounds for evaluating potential sources of groundwater impacts. The co-occurrence of Freon at wells with significant PCE and TCE across the site and at different depths within the aquifer is an indication that there is a common source area of the PCE, TCE and Freon.

In April 2013, 1,4-dioxane was detected in each of the sampled wells at the Site. The highest concentrations appear to be correlated with areas of highest PCE and TCE contamination, suggesting they likely have a common source. The large area of 1,4-dioxane detection is likely a result of the hydrophilic properties of the compound, which allow it to move readily with groundwater. However, additional sampling events are warranted to further assess spatial and temporal trends of 1,4-dioxane in groundwater at the Site.

PCE has generally occurred at slightly elevated concentrations relative to TCE in groundwater throughout the plume. More recently, however, TCE concentrations in some areas have been higher than PCE concentrations. Current and historical PCE/TCE ratios in the center of the plume do not appear to be significantly different over time in downgradient wells compared to upgradient wells. Along the eastern edge of the plume, PCE/TCE ratios appear to show evidence of the biodegradation of PCE into TCE and other associated breakdown products due to localized anaerobic conditions in the vicinity of the ECDC landfill. PCE degradation compounds then appear to have migrated downgradient beneath the I-10 corridor. These PCE/TCE ratios provide no definitive indication that a significant source of PCE or TCE exist downgradient of the ECDC landfill.

PCE/TCE ratios in wells located near the former E.C. Winter property (SRC-W41S, SRC-W40) appear slightly lower than expected when compared to historical ratios in upgradient wells and accounting for the approximate rate of groundwater flow in the area. Given the lack of PCE and TCE biodegradation products and the generally aerobic conditions in the vicinity of the property, the PCE/TCE ratios may be indicative of a minor source of TCE in this area.

The South Shannon well pumps a significant volume of water throughout the year. Aquifer testing and capture-zone modeling in 2005 suggested that this well likely has the capacity to sufficiently capture the plume (URS, 2005). Groundwater monitoring results from wells surrounding the

South Shannon well indicate the South Shannon well provides hydraulic containment of the VOC plume and prevents it from migrating farther north. Improvements to the South Shannon well were completed in 2013 to increase pumping capacity and maintain hydraulic containment of the plume.

Site-Specific Source Investigations

Investigations conducted at the ECDC Landfill as part of a remedial investigation completed in 1997 indicate that the landfill area is a source of contamination at the Site. As presented above, groundwater data are generally consistent with this conclusion. Though groundwater data do not definitively indicate another significant source at the Site, several potential source areas in the Site vicinity have been identified through historical research and environmental investigations. These areas include: the I-10 corridor properties, the former E.C. Winter Oil Service facility, the former AMRI Oil facility, the land that Acacia Gardens Mobile Home Park now occupies, Curtis Landfill, and the south bank of Rillito Creek.

Extensive site-specific investigations conducted at these facilities over many years have yielded no indication of impacts to groundwater from these properties with the exception of the former E.C. Winter facility. TCE concentrations in soil gas beneath the E.C. Winter property indicate there may have been an impact to groundwater, though groundwater in this area is likely also impacted by contamination originating from the landfill area. The results of early response actions and recent sampling results described in Section 4.3 indicate the former E.C. Winter property does not likely represent an ongoing threat to groundwater quality in the area.

Remedial Actions

Potential contaminants likely remain in the ECDC Landfill. However, Pima County has installed and maintained a native soil cover ranging in thickness from approximately 5 to 20 ft to reduce exposure of contaminants and improve drainage away from the landfill. Pima County installed a landfill gas collection system in 1996 and a soil vapor extraction system in 2001. The extraction of soil gas was discontinued in 2004. Pima County has also installed a groundwater pump and treat system that operated from 2009 to 2011 and was modified and restarted in 2014. These remedial actions have begun to decrease the groundwater COC concentrations at the ECDC Landfill and the contaminant mass emanating from the ECDC Landfill area, though higher concentration areas persist downgradient (Figures 5-8).

In addition to the numerous investigations that have been conducted throughout the site, several ERAs have been implemented in an effort to reduce the risk of human exposure to contaminants and the potential for contaminants to migrate to groundwater. Contaminated soil was excavated at several properties in the I-10 corridor, and at the former AMRI Oil and E.C. Winter properties. A soil vapor extraction system was constructed at the E.C. Winter property that removed several pounds of VOCs. These removal actions have minimized the potential for human exposure to soils contaminated above relevant regulatory standards and minimized the potential for future impacts to groundwater beneath the properties.

8.0 CONCLUSIONS AND DATA GAPS

8.1 CONCLUSIONS

The PCE and TCE concentrations in the groundwater, while above AWQSs, do not appear to pose an immediate health risk to the public. Properties with private wells at the Site that were found to have elevated concentrations of VOCs have been connected to the public water supply. The affected Tucson Water wells in the area (Z-004 and Z-006) have been taken out of service. Acacia Gardens Mobile Home Park has been connected to the public water supply and its well abandoned in 2001. The South Shannon production well, in which concentrations have been detected above AWQSs, has had a granular activated carbon treatment system installed to remove the COCs prior to distribution. A Health Risk Assessment conducted by Arizona Department of Health Services (ADHS) in 2014 indicated that 1,4-dioxane, for which the current treatment system is ineffective, poses a “very low” risk to human health given concentrations detected at the Site. The other production wells in the vicinity of the Site are routinely monitored but have not historically contained concentrations of Site COCs greater than AWQSs.

The groundwater plume originates from the ECDC Landfill area. North of I-10, the plume begins to move deeper in the aquifer and migrates northeast toward the South Shannon well. The downward movement of the plume is potentially related to subtle changes in geology near Rillito Creek as well as drawdown induced by the production wells to the northeast, primarily the Metro Water South Shannon well. Groundwater monitoring results and capture-zone modeling indicate the plume is being captured by the South Shannon well and does not extend beyond this point. Wellhead treatment has been in place at the South Shannon well since 1997.

A native soil cover has been maintained at the ECDC landfill to improve drainage away from the landfill, eliminate ponding, and reduce infiltration into landfill materials. An SVE system and a groundwater pump and treat system were later installed in the area to reduce contaminant mass discharge, although there is currently no active landfill-gas collection system operating at the landfill. Remedial actions conducted at the former E.C. Winter and AMRI properties (Wrecksperts, Western Stucco/Western Trailer Park facilities) included soil removal and testing, and SVE operations at the former E.C. Winter property.

The RI field activities undertaken by URS were designed to provide data to evaluate the sources, nature, and extent of VOC contamination in soils and groundwater and to characterize the hydrogeology beneath the Site. Additionally, factors that influence the fate and transport of COCs at the Site were considered. URS conducted historical research of area properties, a geophysical survey, passive and active soil-gas surveys, soil sampling, and groundwater sampling.

Based on data currently available, the only confirmed source of groundwater contamination is the ECDC Landfill. Investigations conducted at the former E.C. Winter property indicate TCE contamination may have impacted groundwater, though groundwater in that area appears to be primarily impacted by the source at the ECDC Landfill. Additionally, remedial actions have been implemented at the former E.C. Winter property such that it does not likely present an ongoing source of groundwater contamination at the Site.

8.2 DATA GAPS

Based on the data obtained from the numerous investigations conducted at the Site, additional work appears warranted to address remaining data gaps including:

1. Conduct at least one comprehensive sampling round on as many wells as practical, including monitor wells south of I-10 near the ECDC Landfill, to ensure sufficient monitoring points to determine current chemical characteristics of the entire groundwater plume.
2. Expand the analytical sampling suite to include, at a minimum, COCs and COPCs that need further definition.
3. Replace key groundwater monitor wells that no longer have water with deeper wells so that the lateral extent of the VOC plume can be more accurately defined.
4. Install a monitor well with a screen in the medium aquifer zone in the area west of current monitor well SRC-W48M to fully delineate the plume in this area to the northwest.
5. Collect samples of landfill gas at the ECDC Landfill to evaluate the concentrations of VOCs, methane, and carbon dioxide in landfill gas and record potential pressures in existing landfill gas extraction wells to evaluate current conditions at the landfill that may still be contributing to groundwater contamination.
6. Private water well use within the Site should be further investigated in the FS due to the limited survey responses received as part of the Land and Water Use Study to ensure that all users are adequately protected from exposure.

It is not expected that additional work will substantially change the conclusions presented herein. Rather the results of the additional work would be used to refine the current Conceptual Site Model, and help in the preparation of the Feasibility Study and Proposed Remedial Action Plan for the Site

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