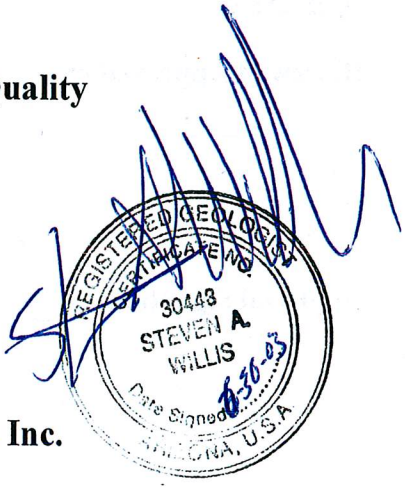
Remedial Investigation Report

Tyson Wash WQARF Site
Quartzsite, Arizona

June 30, 2003

Prepared for:

Arizona Department of Environmental Quality
1110 West Washington Street
Phoenix, Arizona 85007



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REMEDIAL INVESTIGATION REPORT STATEMENT OF RESPONSIBILITY

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Site Location: Quartzsite, Arizona

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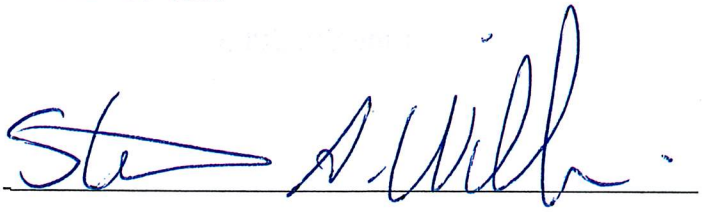
Preparer's Signature: 

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EXECUTIVE SUMMARY

This report presents the results of the Remedial Investigation conducted at the Arizona Department of Environmental Quality (ADEQ) Tyson Wash Water Quality Assurance Revolving Fund (WQARF) Site. The Site is located northwest of the intersection of State Highway 95 and Business Route Interstate 10 in the Town of Quartzsite, La Paz County, Arizona. The shallow perched aquifer, with the water table located at a depth of approximately 42 to 55 feet below the ground surface, has been impacted with dissolved-phase volatile organic compounds (VOCs), primarily tetrachloroethene (PCE), at concentrations exceeding the ADEQ Aquifer Water Quality Standards (AWQSs). There are no indications of the existence of non-aqueous phase liquids in soils or groundwater at the Site. VOC concentrations exceeding ADEQ Soil Remediation Levels have not been reported in any soil samples collected during the investigation.

Land use at the Site is primarily low-density residential and seasonal commercial RV parking. Eighteen privately owned wells located within or immediately adjacent to the Site have been identified as being completed in the shallow contaminated aquifer. Historically, those wells have been used for both potable and non-potable purposes. The VOC plume has impacted seven domestic wells, five of which are currently in use. Seven additional wells are threatened.

The Remedial Investigation focused on three properties: The Welcome RV Park, the former Hi-Ali Motel, and the Cast (formerly Braswell) property. The greatest PCE concentration detected at the Site (200 µg/l) was reported in the domestic well at the Welcome RV Park. Trichloroethene (TCE) concentrations exceeding the AWQS have also been reported periodically in the Welcome RV Park domestic well, and two separate soil vapor surveys conducted at the property indicated anomalously high PCE concentrations. The site formerly contained two septic tanks, one of which was abandoned in March 2002. Although historical property use has not involved the storage or handling of PCE or other VOCs, discharge of contaminants directly into the septic system could account for the occurrence of those contaminants in the groundwater.

At the former Hi-Ali Motel, historical property use reportedly included a dry cleaner and/or laundromat, and the property contained at least two septic tanks and associated leach fields. Analytical data from soil and groundwater sampling indicate that VOC concentrations in groundwater at the property are generally an order of magnitude less than that reported at the Welcome RV Park. One soil vapor sample collected at a depth of 8 feet below ground surface near the former Hi-Ali Motel indicated an anomalously high PCE concentration.

At the Cast property, historical use included a truck wash where solvents may have been used. PCE concentrations exceeding the ADEQ AWQS have been detected in two domestic wells. However, soil vapor PCE concentrations were significantly lower than those reported at the adjacent Welcome RV Park, and the property does not appear to be a source of groundwater contamination.

Groundwater monitoring results through the Second Quarter 2002 indicate that PCE concentrations

exceeding the ADEQ AWQS persist in monitoring wells QMW-1, QMW-3, QMW-4, QMW-5, and QMW-7, and in domestic wells located at the Cast, Welcome RV Park, Rhoades, and La Casa Del Rancho Restaurant properties. TCE concentrations have also periodically exceeded the AWQS in monitoring well QMW-3 and the Welcome RV Park domestic well.

Within the Site, subsurface soils consist of two main alluvial units. From the ground surface to a depth ranging from 60 to 70 feet, soils consist of clayey to silty sand, with interbedded layers of well-cemented gravel and clay. A calichified lens occurs at a depth of 8 to 12 feet. Below approximately 65 feet, soils consist of silty clay to clay, with estimated clay percentage ranging from 50% to nearly 100%. This layer may reach a thickness greater than 400 feet, and appears to act as an aquitard, inhibiting the vertical flow of groundwater to the deep confined aquifer. To date, there is no indication that the deep aquifer has been impacted by VOCs.

Groundwater flow across the Site is toward the northeast. Flow appears to have been strongly influenced by the pumping of domestic wells at the Cast property, with the remaining domestic wells having a lesser effect. Given the known groundwater flow regime, a source at the Welcome RV Park does not explain the VOC concentrations reported in up gradient monitoring wells QMW-1, QMW-5, and QMW-7, nor at the domestic wells at the Rhoades and Kauffman properties. The occurrence of a source or sources at the former Hi-Ali Motel could account for the VOC concentrations detected in wells QMW-1, QMW-5, and QMW-7. However, The source of PCE concentrations in wells at the Rhoades and Kauffman properties remains problematic.

The primary processes affecting movement of contaminants at the Site are advection and dispersion. Laboratory analyses of groundwater samples do not indicate significant natural attenuation of PCE through biodegradation processes, although there is some evidence that TCE is biodegrading. Environmental conditions within the shallow aquifer fluctuate between slightly anaerobic and aerobic. High nitrate concentrations within the VOC plume may also inhibit biodegradation of PCE. Groundwater modeling results suggest that, without active groundwater remediation, the primary changes in the future extent of the PCE plume will be a reduction of the contaminated area on the former Hi-Ali Motel property, minor spreading of the plume boundaries, and little change in concentrations near the center of the plume. This model is based on the known historical groundwater flow regime. A future reduction in groundwater withdrawal from the shallow aquifer is expected as a result of completion in September 2001 of the municipal water supply to residents and businesses within the Site. The reduced groundwater withdrawal could result in increased downgradient plume migration.

Based on results of a Health Consultation, the ADEQ implemented interim measures to reduce exposure to the contaminated groundwater. Signs warning of poor groundwater quality were posted at each location where public access to the contaminated groundwater is possible (e.g., outdoor spigots). In-line water filters were provided to two properties (Rhoades and La Casa Del Rancho Restaurant) to be placed on indoor faucets and showerheads. The ADEQ also provided bottled water to the Welcome RV Park, Rhoades property, Eric's RV Repair, and La Casa Del Rancho Restaurant.

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1.0 INTRODUCTION

In accordance with Arizona Department of Environmental Quality (ADEQ) Draft Remedy Selection Rules, MACTEC has completed this Remedial Investigation (RI) Report for the Tyson Wash Water Quality Assurance Revolving Fund (WQARF) Site (Site). The report summarizes the results of previous investigations performed at the Site by the ADEQ, as well as the more current results and conclusions from additional investigative data obtained and or collected by MACTEC.

During completion of the RI, several interim or topical reports were generated, including quarterly groundwater monitoring reports and a Health Consultation. Copies of these documents are available at ADEQ. A repository for major project reports has also been established at the Town of Quartzsite Library, 465 North Plymouth Avenue, Quartzsite, Arizona.

The RI is the first step in the process of identifying a final remedial alternative for the Site. The specific purpose of the RI is to provide a detailed assessment of site conditions, and to collect information about land and water uses to support the selection of remedial objectives and the subsequent remedial action. The Land and Water Use Study, which is included in Appendix A, presents a summary of current and future uses of land and water within and in the vicinity of the Site using information gathered from discussions with property owners, water providers, municipalities, and well owners.

Following completion of the Draft RI Report, a Proposed Remedial Objectives Report must be completed to identify those land and water uses considered "reasonably foreseeable". The Proposed Remedial Objectives Report is stated in terms of the following: protecting against the loss or impairment of an existing use; restoring, replacing or otherwise providing for each listed use; establishing time frames when action is needed to protect or provide for the use; and identifying the projected duration of the action needed. The report includes an analysis,

evaluation, and interpretation of data obtained from the Land and Water Use Study, and reflects public input obtained during a comment period and public meetings. The Final Proposed Remedial Objectives Report is included in Appendix B.

After the Final RI Report is issued, the ADEQ may elect to conduct an Early Response Action to expedite remediation of the contaminated media. A Feasibility Study (FS) may be conducted to identify proposed remedies that may be capable of achieving the remedial objectives, and to select a preferred remediation methodology. The FS will include the evaluation of a Reference Remedy, and at least two Alternative Remedies. The FS will identify remedial strategies and develop the remedial measures to be employed by each strategy. A remedial strategy may be plume remediation, physical containment, controlled migration, source control, monitoring, or no action. A comparative evaluation of the remedies including practicality, risk, costs, and benefit, as well as consistency with water provider plans, will be included in the FS.

Following completion of the FS Report, a Proposed Remedial Action Plan (PRAP) will be prepared incorporating the preferred remedy. The PRAP will describe how the proposed remedy will meet each of the remedial objectives identified in the Final RI Report, and how accomplishment of the remedial objectives is to be measured.

After conclusion of all required public comment periods, the ADEQ will issue a Record of Decision regarding the PRAP. The Record of Decision will include a description of the remedy, a summary of comments received on the PRAP, and a demonstration that the remedy meets the remedial objectives and will remain in place as long as necessary to ensure continued achievement of those objectives. The Record of Decision will also include time frames for implementing and completing the remedy, and the total estimated cost of the remedy.

Following issuance of the Record of Decision, the remedial design and implementation phase will begin. This stage will include the development of the engineered design of the selected remedy and implementation of the remedy through the construction phase. A period of remedial

system operation and maintenance may follow the design and construction activities.

1.1 SITE LOCATION

The Site is located northwest of the intersection of State Highway 95 and Business Route Interstate 10 in the Town of Quartzsite, La Paz County, Arizona. Quartzsite is located 125 miles west of Phoenix along U.S. Interstate 10, approximately 18 miles east of the Colorado River. The Site is located in the southeast quarter of Section 21, and the northeast quarter of Section 28, Township 4 North, Range 19 West, as shown on the Quartzsite, Arizona U.S. Geological Survey 7.5 minute Topographic Quadrangle (Figure 1). The current boundaries of the Site are shown on Figures 1 and 2. The Site boundary is defined by those properties that have been affected, or are potentially affected, by the dissolved phase groundwater plume containing the chemicals of concern (COCs).

The Site lies within a residential/commercial area near the center of the Town of Quartzsite. Properties within the Site include five year-round residences, one seasonal residence, one residential property which is currently vacant, one year-round commercial property, three seasonal commercial properties, and one government property (Quartzsite Post Office). Tyson Wash forms the western Site boundary adjacent to the vacant lot of the former Hi-Ali Motel. A Site Vicinity Map that identifies the properties located immediately adjacent to the Site is included as Figure 3. A more detailed description of the Site and its vicinity is included in Section 3.2.

1.2 REMEDIAL INVESTIGATION OBJECTIVES

The Remedial Investigation (RI) process is designed to provide a stepwise evaluation of the presence, magnitude and extent of soil and groundwater contamination, and to assess potential contaminant source areas. The objective of the RI is to provide sufficient information to identify appropriate remedial alternatives and technologies for screening during the Feasibility Study phase. A Feasibility Study is conducted to identify proposed remedies that may be capable of

achieving remedial objectives and to select a preferred remedy (from among them) which: 1) assures the protection of public health, welfare, and the environment; 2) to the extent practicable, provides for the control, management, or cleanup of hazardous substances so as to allow for the maximum beneficial use of waters of the state; 3) is reasonable, necessary, cost-effective, and technically feasible; and 4) addresses any well that either supplies water for municipal, domestic, industrial, irrigation, or agricultural uses or is part of a public water system, if the well would now or in the reasonably foreseeable future produce water that would not be fit for its current or reasonably foreseeable end use without treatment.

2.0 SITE CONCEPTUAL MODEL

The Site Conceptual Model (SCM) is intended to facilitate understanding of the more detailed site investigation data, and to assist the reader in better understanding the major Site features that control contaminant fate and transport. Key interrelated elements of the SCM include potential sources of groundwater contamination, hydrogeology, groundwater chemistry, and exposure pathways.

2.1 POTENTIAL SOURCES OF GROUNDWATER CONTAMINATION

Contamination of the shallow aquifer has been identified at the Site through various investigative techniques, but mainly through analysis of groundwater quality data. Analysis of this data indicates the primary COC at the Site is tetrachloroethene (PCE). The original source of Site groundwater contamination has not been confidently identified. Analytical data suggest the source is located at the Welcome RV Park. Additional potential sources are located at the former Hi-Ali Motel property (Figure 2).

Laboratory results of groundwater samples collected from the domestic well at the Welcome RV Park, and in monitoring well QMW-3, have consistently indicated the greatest PCE concentrations identified at the Site. Those concentrations have generally exceeded 100 micrograms per liter (µg/l), and have been as high as 200 µg/l. Results from two separate soil vapor surveys also indicated anomalously high PCE vapor concentrations adjacent to two septic tanks at the Welcome RV Park property. Although historical property use has not involved the storage or handling of PCE or other volatile organic compounds (VOCs), discharge of contaminants directly into the septic tanks could account for the occurrence of those contaminants in the groundwater.

At the former Hi-Ali Motel, historical property use reportedly included a dry cleaner. Typically, dry cleaners use PCE as a solvent to clean fabrics. According to the current property manager

and local residents, the site historically contained at least two septic tanks and associated leach fields. The ADEQ collected groundwater samples from two domestic wells on the property prior to those wells being abandoned in 1997 or 1998. PCE concentrations were 24 µg/l and 8.2 µg/l, respectively, in former wells HA-1 and HA-2. Groundwater samples collected from eight temporary wells (HAP 1 through HAP-8 and HAP-11) at the property in March 1996 indicated PCE concentrations ranging from non-detectable to 34 µg/l. More recently, two temporary wells (TY1 and TY2) were installed in April 2001.

Groundwater analytical results indicated PCE concentrations of 9 µg/l and 3 µg/l, respectively, in wells TY1 and TY2. One soil vapor sample collected from boring SV-7 at a depth of 8 feet below ground surface (bgs) near the former motel building contained a PCE concentration of 106 µg/l, but PCE was not detected in vapor samples collected below this depth from adjacent boring SV-19.

Groundwater modeling results, which are discussed in detail in Section 8.0, suggest that releases from both the Welcome RV Park and the former Hi-Ali property have contributed to groundwater contamination. Given the current and known historical groundwater flow direction, a source or sources located only at the Welcome RV Park cannot explain the occurrence of PCE concentrations in monitoring wells QMW-1, QMW-5, and QMW-7, located on Cowell Street up gradient of that property. Modeling results improve if sources at the former Hi-Ali Motel are introduced. However, neither model explains PCE concentrations detected in groundwater samples collected from domestic wells at the Rhoades and Kauffman properties, located west of the Welcome RV Park.

2.2 GROUNDWATER CONTAMINATION

The primary contaminant identified in groundwater at the Site during the RI is PCE, which has been identified in monitoring wells QMW-1, QMW-3, QMW-4, QMW-5, QMW-7, and QMW-8 (Table 1). PCE has also been detected in domestic wells at the Welcome RV Park, Cast (formerly Braswell),

former Hi-Ali Motel, Rhoades, Kauffman, Adams, La Casa Del Rancho Restaurant, Quartzsite Post Office, and Eric's RV Repair properties (Table 2). Trichloroethene (TCE) has been detected in monitoring wells QMW-1, QMW-3, QMW-4, and QMW-5, and in domestic wells at the Welcome RV Park and Cast properties.

Historically, PCE concentrations have been highest in the domestic supply well at the Welcome RV Park, in monitoring well QMW-3, located on Washington Avenue immediately west of the Welcome RV Park, and in well QMW-5, located approximately 80 feet southwest of the Welcome RV Park. A PCE concentration of 200 µg/l was initially reported in the Welcome RV Park domestic well in November 1995. PCE concentrations were highest in well QMW-3 in July and October 1997, and November 2001, when concentrations were reported at 160 µg/l. In well QMW-5, PCE concentrations were as high as 180 µg/l in August 1998. PCE concentrations have also exceeded the ADEQ Aquifer Water Quality Standard (AWQS) of 5 µg/l in monitoring wells QMW-1, QMW-4, and QMW-7.

The estimated horizontal extent of the PCE plume is shown on Figure 4. The south, or up gradient, boundary of the plume, which is confirmed by analytical data from monitoring well QMW-6 and temporary monitoring well ESE TY2, bisects the former Hi-Ali Motel property approximately half-way between Cowell Street on the north and Main Street (Business I-10) on the south. The maximum down gradient extent has been confirmed by analytical data from monitoring well QMW-10 located on the La Casa Del Rancho Restaurant property. To the east, PCE concentrations in monitoring well QMW-2 have been consistently below laboratory reporting limits. On the southeast, the current plume boundary is defined by the non-detectable concentrations in a domestic well at Eric's RV Repair. The western plume boundary is defined by domestic wells at the Adams property, in which PCE concentrations have remained below the ADEQ AWQS, and in the Parsons domestic well, where VOC concentrations have remained below laboratory reporting limits.

There are no indications of the existence of dense non-aqueous phase liquids (DNAPLs) in soil

or groundwater at the Site. EPA guidance (EPA/600/R-92/030) suggests that dissolved concentrations within 10 percent (%) of the solubility of the solvent may indicate the presence of a DNAPL in the groundwater system. Thus, for PCE, dissolved concentrations greater than 10,000 µg/l may indicate the presence of a DNAPL. Based upon the Site's observed data (highest PCE concentration of 200 µg/l), a source of the primary solvent no longer appears to exist within the soils or groundwater at the Site.

Other than PCE and TCE, groundwater contaminants reported during the RI (and their frequency of occurrence) include chloroform (85), methylene chloride (7), cis-1,2-dichloroethene (15), bromoform (7), dichlorodifluoromethane (2), dibromochloromethane (2), 1,1-dichloroethene (1), and isopropylbenzene (1). Detectable concentrations of these compounds ranged from 0.45 µg/l to 3.4 µg/l. All of these concentrations are below ADEQ AWQSs.

In addition to the VOC plume identified during the RI, much of the shallow aquifer beneath the Town of Quartzsite has been degraded due to the extensive use of unregulated private septic systems. Nitrate concentrations exceeding the AWQS of 10 milligrams per liter (mg/l) have been reported beneath an area extending approximately from the intersection of Kofa Road and I-10, northeast to the intersection of Main Street and Central Avenue, and north between Central Avenue and Tyson Wash to Pyramid Drive. Nitrate concentrations ranging from 5 to 29 mg/l have been reported in groundwater samples collected from Site monitoring wells. Nitrate concentrations have not exceeded laboratory reporting limits in Cast well B-3, which is the only deep well located in the Tyson Wash WQARF Site. However, nitrates have been reported in at least one deep well located outside the boundary of the WQARF area.

Two leaking underground storage tank (LUST) sites located near the southeast boundary of the Site have also impacted the shallow groundwater (Figure 3). At the Quik Chek Market, groundwater sampling has indicated the presence of phase-separated hydrocarbons. Dissolved phase hydrocarbons, including benzene, have also been reported in monitoring wells located on

the property. According to the ADEQ, the full lateral extent of the dissolved phase plume has not been determined.

A second LUST site, formerly known as Dolly's/Steve's Gas N Go, is located directly east of the Quik Chek Market. Groundwater monitoring conducted through October 2000 indicated that petroleum hydrocarbon concentrations exceeded the ADEQ AWQS in several wells. Active soil and groundwater remediation at the site was initiated in July 2000. Recent groundwater sampling has indicated that contaminant concentrations in the source area monitoring wells have decreased to below AWQSs. As a result, the groundwater remediation system has been shut down and closure of the LUST file is pending.

Laboratory analyses of groundwater samples for natural attenuation parameters do not indicate significant natural attenuation of PCE through biodegradation processes at the Site. Analytical results indicate that the environmental conditions within the aquifer system fluctuate between slightly anaerobic and aerobic conditions, and suggest a manganese and/or iron-reducing environment. High nitrate concentrations may also inhibit biodegradation. The observed decrease in the PCE concentrations in wells QMW-1 and QMW-5 may be the result of advection or dilution of the plume. There is some evidence that TCE is degrading to form *cis*-1,2-dichloroethene (*cis*-1,2-DCE). That compound has been reported at low concentrations in well QMW-3 during each of the past four monitoring events. TCE is known to biodegrade under both aerobic and anaerobic conditions.

2.3 HYDROGEOLOGY

At the Site, subsurface soils consist of two main units. From the ground surface to a depth ranging from 60 to 70 feet bgs, soils consist of interbedded layers of well-cemented gravel, sand, silt, and clay. The upper 20 to 25 feet of this unit generally contain silty sand and silty gravel. A highly calichified lens occurs at a depth ranging from 8 to 12 feet bgs. The remainder of the upper unit consists of interbedded layers of silty clay and silty sand.

Below a depth ranging from 60 to 70 feet across the Site, soils consist of silty clay to clay, with the estimated clay percentage ranging from 50% to nearly 100%. This clay-rich unit appears to act as an aquitard, inhibiting the vertical flow of groundwater from the shallow aquifer to the deep aquifer. Groundwater flow in the upper aquifer is primarily horizontal through the coarser grained soils above the clay layer. The estimated depth to the top of the clay layer within the Site is shown on Figure 5. Geologic cross-sections are included on Figures 6 and 7.

The shallow aquifer is believed to be perched and is estimated to extend at least 5 miles north of the Town of Quartzsite. A thick, extensive clay/limestone layer separates the shallow aquifer from a deeper confined aquifer. The deep aquifer consists of semi-consolidated sand, gravel, and clay that are typically encountered between 400 and 500 feet bgs. To date, there is no indication that the deep aquifer has been impacted with VOCs.

Depth to groundwater at the Site ranges from approximately 41 to 55 feet bgs. Groundwater flow across the Site was generally toward the east-northeast between May 2000 and September 2001. During that time period, the groundwater flow appeared to be strongly influenced by the pumping of domestic wells at the Cast property, and possibly the La Casa Del Rancho Restaurant. Three shallow wells on the Cast property (B-1, B-2, and B-4) were formerly used to supply water to a laundromat.

Pumping of the Cast domestic wells also appears to have influenced the groundwater flow direction at the nearby LUST sites, particularly the Quik Chek Market. Groundwater flow at that site was toward the northwest during the noted time period, or toward the WQARF Site. At the former Dolly's/Steve's Gas N Go, located further to the east, the groundwater flow direction is toward the north and northeast, indicating decreasing influence of the pumping wells at the Cast property. To date there does not appear to be any commingling of the petroleum hydrocarbon plume with the PCE plume.

The influence of the Cast domestic wells also is indicated by the seasonal changes in the groundwater table elevation. Between May and September 2000 the groundwater table, as measured in monitoring wells QMW-1 through QMW-9 at the Site, generally increased or was relatively stable. Beginning in mid-October, and corresponding to the increased winter population, the groundwater table elevation decreased through March 2001, with the greatest change being noted in monitoring wells QMW-9 and QMW-2 on the Cast property. During April 2001, the water table decline ceased and elevations either stabilized or began to rise. This response corresponded to a decrease in water usage as the Town's population quickly declined near the end of March and early April. With the exception of the furthest up gradient wells (QMW-6 and QMW-7), the groundwater table elevation has increased steadily since the end of the Spring 2001 season, which coincides with the shutting down of the shallow domestic wells at the Cast property. Depth-to-groundwater measurements collected since the Third Quarter 2001 also indicate a slight change in the groundwater flow direction toward to the north.

An apparent groundwater mound occurs at well QMW-3. This may be due to a relatively greater localized recharge at the Welcome RV Park property, where two septic tanks were in use through March 2002. A leach field reportedly exists near the west boundary of the property, in the vicinity of well QMW-3. Increased use of the former west septic tanks during the winter months may explain the groundwater mound noted in well QMW-3.

2.4 EXPOSURE PATHWAYS

The primary pathway for human exposure to contaminants at the Site is through the domestic wells that are completed in the shallow impacted aquifer. Five wells currently in use are impacted. Those wells include the Adams (2), Rhoades, Welcome RV Park, and La Casa Del Rancho Restaurant west wells (Figure 4). The Cast wells B-1 and B-2 have also been impacted, but are currently out of service. Between 1999 and August 2001, the ADEQ provided bottled drinking water to the Rhoades, Welcome RV Park, and La Casa Del Rancho Restaurant properties. A deep well at the Cast property (well B-3) formerly provided drinking water to the

residents there, whereas the impacted shallow wells were previously piped directly into a laundromat. Exposure to groundwater from the impacted shallow wells is considered *de minimus*.

There is no evidence that surface soils have been impacted, so the potential exposure pathway from surface soil is incomplete. No indication of a free-phase liquid plume has been encountered in the site characterization investigations, and there is no associated surface water, so those pathways are also incomplete. Exposure pathways associated with volatilization from subsurface soil are insignificant based on the low VOC concentrations and their depth below ground surface.

3.0 PHYSICAL SETTING

3.1 PHYSIOGRAPHIC SETTING

3.1.1 Regional Geology

The following description of regional geology is based on reports by the Arizona Department of Water Resources (2001), Dames & Moore (1999), IT Corporation (1999), and Metzger and others (1973).

The Town of Quartzsite is located in the southwestern part of the Basin and Range Physiographic Province of Arizona. More specifically, the Town is located within the La Posa Plain, in the southeast corner of the Parker Basin. The Parker Basin covers approximately 2,145 square miles (ADWR, 2001). Mountain ranges in the area include the Buckskin, Plomosa, Dome Rock, New Water, Kofa, Castle Dome, and Chocolate Mountains. Elevations in the basin range from 3,600 feet above mean sea level in the New Water Mountains to less than 200 feet above mean sea level at the Colorado River.

Metzger and Others (1973) described the subsurface geology of the area as consisting of, in descending order, alluvial deposits, the Pliocene Bouse Formation, and fanglomerate. The alluvial deposits overlying the Bouse Formation consist of clay, silt, sand, and gravel. Sediments of the Bouse Formation are believed to have been deposited in an embayment of the Gulf of California and consist of a basal limestone overlain by volcanic tuff and interbedded clay, silt, and sand. The Bouse Formation reaches a thickness greater than 770 feet and yields are limited to moderate quantities of water. The upper zone of the Bouse Formation contains large volumes of medium to coarse grained sand. The lower zone, which essentially serves as an aquitard, consists of fine to very fine grained sand and clay. Basin depth within the study area is unknown. One Town of Quartzsite supply well was drilled to 1,260 feet without encountering bedrock.

3.1.2 Regional Hydrology

3.1.2.1 Groundwater Occurrence

The groundwater system in the vicinity of Quartzsite generally consists of two aquifers. The upper, unconfined aquifer consists of unconsolidated sand and gravel (alluvial deposits and upper zone of the Bouse Formation) with a static water level ranging from about 20 to 80 feet bgs. The upper aquifer is believed to be perched and is estimated to extend at least 5 miles north of the Town (Dames & Moore, 1999). However, the actual extent of this aquifer is currently unknown.

The lower, confined aquifer consists of semi-consolidated sand, gravel, and clay that are typically encountered between 400 and 500 feet bgs. Locally, artesian conditions may occur in the lower aquifer. A thick, extensive clay/limestone layer (lower zone of the Bouse Formation) separates the upper and lower aquifers. This clay layer can reach a thickness of more than 400 feet and locally serves as an aquitard (ADWR, 2001).

Recharge to shallow groundwater in the Parker Basin comes from the Colorado River, precipitation, seepage from canals and irrigated land, and underflow from the bordering mountains. Recharge to the deep groundwater within the basin occurs through precipitation at the mountainous boundaries, which runs off rapidly down the valleys and out onto the alluvial fans, where it infiltrates into the alluvium. The water then moves through the sand and gravel layers toward the center of the basin. The Colorado River contributes the greatest volume of recharge to the Basin.

3.1.2.2 Groundwater Quality

Water quality in the Parker Basin is generally poor due to the high concentration of total dissolved solids (ADWR, 2001). Total dissolved solids concentrations range from 390 to 4,200 mg/l (ADWR, 2001). Fluoride concentrations range from 0.3 to 6 mg/l, with the highest concentrations reported in the Bouse Formation (ADWR, 2001). The Arizona Department of Water Resources has established special well construction standards for the Quartzsite area. New

and replacement wells in the area must be completed in the deep aquifer and may not be completed in the shallow aquifer. These standards were implemented due to nitrate contamination in the area, possibly due to the numerous septic tanks present.

3.1.2.3 Groundwater Use

Groundwater development in the Parker Basin has been relatively low due to the availability of surface water from the Colorado River and relatively low population. The ADWR estimates approximately 14 million acre-feet of water are stored within the basin to a depth of 1,200 feet bgs. Less than 4,000 acre-feet were withdrawn in 1985 (ADWR, 2001). Groundwater is pumped for municipal, domestic, and drainage purposes. Domestic wells are concentrated in the Colorado River floodplain and the Town of Quartzsite. Depth to groundwater ranges from 5 to 25 feet bgs in the Colorado River floodplain, and from 40 to 500 feet bgs outside of the floodplain.

3.1.3 Climate and Ecology

The Site is located within the Sonoran Desert Section of the Basin and Range Physiographic Province. The climate is characterized as arid to semi-arid with the area receiving an average of just less than eight inches of rain annually. The majority of this rain falls during two periods: the summer monsoon season, which typically extends from the beginning of July through early September, and the winter rainy season that occurs mainly during January and February. Summer daytime temperatures are hot with daytime highs typically averaging more than 100 degrees Fahrenheit (°F). Winter daytime high temperatures average between 60 °F and 70 °F.

Because rainfall events are generally infrequent, and rainfall amounts are small relative to evaporation, rainfall may not contribute significantly to aquifer recharge. Most aquifer recharge from precipitation is considered to occur in the major stream or wash channels. Because of the Site's proximity to Tyson Wash, high volume rainfall events can recharge the shallow aquifer in the WQARF area.

This part of the Sonoran Desert is characterized by sparse vegetation with creosote bush and mesquite being the predominant vegetation type in the desert lowlands. Most of the Site has been altered, and vegetation is minimal with limited amounts of grasses, weeds and an occasional bush and tree. There are no known endangered plant or animal species at the Site.

3.2 LAND AND WATER USE STUDY

MACTEC completed a Land and Water Use Report as required by the Draft WQARF Remedy Selection Rules. The following sections present a summary of that report. A complete copy of the Use Report, which presents a more detailed description of current and future land and water use at the Site, is included in Appendix A.

While the Use Report does identify various uses of land and water, the decision to classify a use as "reasonably foreseeable" is not made in the Use Report. "Reasonably foreseeable" uses will be identified in the Proposed Remedial Objectives (RO) Report and will be made with stakeholder input through public comment periods, Community Advisory Board meetings, and public meetings. There may be uses discussed in the Use Report that have little or no bearing on the ROs selected for the site. Also, the accuracy of information obtained from property owners, water providers, and reports and planning documents can not be guaranteed. The Use Report includes the collection of the following information:

- Information regarding current and reasonably foreseeable uses of water for each aquifer that is impacted or threatened by the release. This information was collected in consultation with water providers and includes:
  - locations and uses of existing wells (including all wells already impacted);
  - locations and uses of any planned wells (if known); and
  - any written water management plans used by water providers whose water supplies may be impacted by the release.

- Information regarding current and reasonably foreseeable uses of water for each segment of surface water impacted or threatened by the release (collected in consultation with water providers).

- Information regarding current and reasonably foreseeable uses of land impacted or threatened by the release. This information, collected in consultation with local governments having land use jurisdiction, includes:
  - current landscape including type of use, density, character, property ownership, and governmental jurisdiction; and
  - future land use changes using population projections, growth, plans for future development, and local land use plans.

3.2.1 Land Use

Land use at the Site is primarily low density residential and seasonal commercial RV parking. There are no individual properties determined to be current contamination source areas at the Site. Future land use within the Site is expected to remain similar to current land use, with an increase in commercial development near the intersection of Highway 95 and Business Loop I-10. According to the Town of Quartzsite there are currently no pending zoning changes for the area, or general planning changes that would significantly change the character of the site.

A recently adopted Wellhead Protection Plan affects both land and water uses in Quartzsite. The plan requires all existing and new developments to connect with the municipal sewer system if they are within 200 feet of a sewer main, and designates Wellhead Protection Areas in the vicinity of existing municipal supply wells. Uses that potentially discharge contaminants to the groundwater are prohibited within a Wellhead Protection Area. In the future the Wellhead Protection Areas may be expanded to include all areas within Town of Quartzsite boundaries.

3.2.2 Groundwater Use

The Town of Quartzsite's municipal groundwater supply comes from the deep aquifer below a

depth of 500 feet. Prior to the completion of the municipal water supply to residents living within the Site, groundwater extracted for private use came primarily from wells completed in the shallow aquifer at depths generally less than 100 feet. Groundwater quality in the shallow aquifer has been degraded through the use of septic tanks, leaking underground petroleum storage tanks, and other chemical releases of unknown origin.

In 1996 the Town of Quartzsite began the process of designing a municipal water delivery system to residents west of Central Avenue because of concerns over the potentially adverse health effects resulting from use of the shallow aquifer. In addition, many shallow wells were going dry. In April 2001, the Town began construction of the new water system to extend the municipal water supply to residents within the WQARF Site. This phase of the expanded water distribution system was completed in September 2001.

Currently, the Town supplies water to residents east of Oregon Avenue from two deep wells located approximately 0.7 mile northeast of the Site. The two wells provided up to 286,000 gallons per day during the peak of the 2001-2002 tourist season, dropping to approximately 168,000 gallons per day during June 2002.

The Town has initiated plans to drill and install an additional deep supply well west of Kofa Avenue on land currently owned by the U.S. Bureau of Reclamation. The Town also plans to construct a new water storage tank located on "Q Mountain" southwest of the developed area. Construction of the tank is expected to be concurrent with installation of the new well.

According to current ADWR records, there are 544 registered wells within an approximate ½-mile radius of the Site, of which 471 are completed in the shallow aquifer. Although groundwater extracted for private use comes primarily from wells completed in the shallow aquifer (generally less than 100 feet deep), the ADWR lists 111 registered deep wells (i.e., greater than 250 feet) in the Quartzsite area. Historically, many of these wells have been used for potable (i.e., drinking and cooking) purposes.

Nineteen privately owned wells are located within, or on properties located immediately adjacent to, the Site. Eighteen of those wells are completed within the shallow perched aquifer at depths of 70 to 100 feet. Wells that have been impacted by PCE at concentrations exceeding the ADEQ AWQS of 5 µg/l, but which are still in use, include those at the Rhoades, Welcome RV Park, and La Casa Del Rancho Restaurant properties. The unused wells at the Cast, Kauffman and Post Office properties have also been impacted with PCE at concentrations exceeding the AWQS. During the March 2002 sampling event, PCE was reported at concentrations of 0.64 µg/l and 0.61 µg/l in the Adams north and Adams south wells, respectively.

One deep well (Cast well B-3) is located within the Site. This well is screened in the deep aquifer at a depth of 540 - 640 feet. Historically, water from this well was used to supply two residences and a beef jerky store. Well B-3 has not been used since the Cast property was connected to the municipal water supply in September 2002. However, the submersible pump has not been removed and the electrical service to the well is still functional. Analytical data indicate that the VOC plume has not impacted well B-3.

Because of the expanded municipal water supply and provisions of the Wellhead Protection Plan that will limit or prohibit the installation of new wells within the Town, domestic well use in the area is expected to decline in the future. Nevertheless, many residents have indicated a desire to continue using their wells for either potable or non-potable purposes.

4.0 PREVIOUS INVESTIGATIONS

Prior to the current Remedial Investigation (RI), the ADEQ conducted Preliminary Assessment/Site Inspection (PA/SI) and Expanded Site Inspection (ESI) investigations at the Site. These investigations were authorized by the U.S. Environmental Protection Agency (EPA) under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986. The purpose of the PA/SI and ESI investigations was to determine whether a release of a regulated substance had occurred, and to assess the relative threat associated with an actual or potential release of a hazardous substance at the Site. By contrast, the RI process is designed to gather detailed information regarding the magnitude and extent of soil and groundwater contamination, and to provide sufficient data to identify appropriate remedial alternatives.

Investigation of the groundwater VOC plume at the Site was initiated by the ADEQ in August 1995 following the discovery of chlorinated solvents in the groundwater. The ADEQ conducted additional site investigations between 1996 and 1998 in an attempt to identify the source and extent of VOCs in groundwater in the area. Activities included the installation of 5 permanent groundwater monitoring wells, and the collection of soil, soil vapor, and groundwater samples. Three properties were the primary focus of those investigations: the Welcome RV Park, the Cast property, and the former Hi-Ali Motel. In addition to these property investigations, the ADEQ also conducted several groundwater sampling events at nearby properties.

This section summarizes the known operating histories of the properties, and the major components of the technical investigations conducted by the ADEQ prior to the RI. Appendix C includes a summary of soil, soil vapor, and groundwater analytical results compiled by the ADEQ during those investigations. Detailed accounts of the previous investigations summarized in this section are available in the following reports, which are included in Appendix D.

- Preliminary Site Assessment/Inspection Hi-Ali Motel/Laundromat, ADEQ August 8, 1997
- Expanded Site Inspection Report, Hi-Ali Motel/Laundromat, ADEQ February 23, 1999
- Expanded Site Inspection Report, Welcome RV Park, ADEQ July 13, 1999
- Expanded Site Inspection Report, Braswell Laundromat, ADEQ September 28, 1998

4.1 WELCOME RV PARK INVESTIGATIONS

4.1.1 Property Use History Investigation

The current property owners, Mr. And Mrs. Stanley Metcalf, purchased the property in April 1986 from Robert and Dorothy Wray. Property ownership and use prior to 1986 is unknown. Since 1986, the site has been used for seasonal RV parking. In 1994, the current owners acquired a business license from the Town of Quartzsite to use the property as a dry camp area for parking RVs. With this license, RVs are not allowed to connect to either sewer or water mains. However, during a site visit on May 25, 1999, the Quartzsite Fire Department found approximately fourteen sewer and electrical connections and several water connections provided for RVs.

The Welcome RV Park occupies approximately 4.5 acres. There is one main building on the site, which is used as a seasonal residence by the property owners. An additional building houses the domestic well. The remainder of the site is an open unpaved lot. Historically, two septic tanks on the property reportedly drained into two separate leach fields. The Welcome RV Park was identified as a potential hazardous waste site and entered into the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) on May 11, 1998.

4.1.2 Preliminary Assessment/Site Inspection

In November 1995, the ADEQ collected a groundwater sample from the Welcome RV Park domestic well as part of a preliminary investigation of the area. Analytical results indicated a PCE concentration of 200 µg/l. TCE was reported at a concentration of 6.2 µg/l. The ADEQ AWQS for each of these compounds is 5 µg/l. In March 1996, ADEQ installed two temporary

wells on the property (HAP-9 and 10). Locations of those wells are included on Figure 8. Analysis of groundwater samples from the temporary wells indicated PCE concentrations of 76 µg/l in well HAP-9 and 48 µg/l in well HAP-10.

In May 1996, the ADEQ supervised the drilling of three soil borings (SB-1, SB-3, and SB-4) at the Welcome RV Park (Figure 9). Soil samples were collected at 5-foot intervals to a depth of 40 feet bgs. Analytical results did not indicate VOC concentrations exceeding laboratory reporting limits.

One additional boring (JB1) was drilled on the Welcome RV Park property in May 1996 during ADEQ's investigation of the adjacent Cast property. One soil vapor sample collected from this boring did not contain detectable VOC concentrations.

4.1.3 Expanded Site Inspection

An Expanded Site Inspection (ESI) was performed at the Welcome RV Park after the PA/SI indicated the need for additional investigations. The ESI included a survey to locate septic tanks and leach fields, the collection of sludge samples from septic tanks, and the installation of five temporary monitoring wells on, and immediately adjacent to, the property. The objective was to determine if there was a release of VOCs at the site from the septic tanks and associated leach fields.

In March 1998, eight soil vapor samples (TY1SV and TY8SV) were collected from seven locations adjacent to the two septic tanks (Figure 10). The soil vapor samples were collected at an estimated depth of 4.5 feet bgs. Soil samples were collected from the borings at depths ranging from 5.5 to 7 feet bgs. In addition, two sludge samples (S1 and S2) were collected from the two on-site septic tanks (Figure 10). Two temporary monitoring wells (TYT1 and TYT2) were installed on the property. Three temporary wells (TYT3, TYT4, and TYT5) were installed on the adjacent streets.

Analytical results, included in Tables 3 and 4, indicated soil vapor PCE concentrations ranging from 21 parts per billion/volume (ppb/v) to 980 ppb/v. The highest concentration (980 ppb/v) was reported in boring TY8SV, located near the septic tank on the east side of the property. The highest concentration adjacent to the west septic tank was 510 ppb/v.

PCE concentrations of 24 µg/l and 15 µg/l were reported in the sludge samples collected from the west and east septic tanks, respectively. A TCE concentration of 18 µg/l was reported in the sludge sample collected from the west septic tank. VOCs were not detected in any of the soil samples.

Analytical results from groundwater sampling indicated PCE concentrations of 92 µg/l and 21 µg/l in temporary wells TYT1 and TYT2, respectively. PCE concentrations ranged from 2 µg/l to 52 µg/l in adjacent temporary wells TYT3 through TYT5. TCE concentrations were 4.2 µg/l in well TYT1, and 1.7 µg/l in well TYT2. TCE concentrations in wells TYT1 through TYT5 ranged from <0.5 µg/l to 0.74 µg/l.

4.2 CAST PROPERTY INVESTIGATIONS

4.2.1 Property Use History Investigation

Since 1997, Mr. and Mrs. Robert Cast have owned the property and its associated businesses. The businesses currently operated are a self-service laundromat, The Beef Jerky Store, and a private recreational vehicle repair garage.

Operational history prior to 1985 is unknown. From 1985 to 1997, Mr. John Braswell owned the property and operated the laundromat and, for a short period of time in 1985, a restaurant. From 1987 to 1990, Mr. Braswell also operated a high-pressure truck wash. Solvents such as PCE and TCE may have been used as degreasers for engines and auto parts. The truck wash building has since been converted into the previously noted private garage. During a site visit in August 1995, the ADEQ noted the storage on the property of lead-acid batteries, used tires, and drums

containing what appeared to be petroleum-based solvents. The property was identified as a possible hazardous waste site and entered into CERCLIS on February 27, 1995.

According to the ADEQ and local residents, Mr. Braswell constructed a gray water injection pond near the north boundary of the property for the laundromat wastewater. It is likely that the pond was unlined. Runoff from the truck wash was pumped to a surface impoundment located approximately 150 feet west of the truck wash where the solids settled out of the wash water and the remaining liquid was then pumped to an underground holding tank. That water was subsequently pumped out and hauled away by trucks.

The property occupies approximately 2.6 acres and currently includes the laundromat/office building, Beef Jerky Store, garage, and two residential trailers. There are currently four domestic wells on the property. Groundwater from the on-site shallow wells B-1, B-2, and B-4 was formerly used to supply water to the washing machines in the laundromat. Deep well B-3 was used to supply water to the beef jerky operation and the two residences until September 2001. The property is unpaved.

4.2.2 Preliminary Assessment/ Site Inspection

In November 1993, the ADEQ retained GTI to perform an investigation at the former Don's Café, located approximately 500 feet southeast of the Cast property. GTI's investigation included the collection of groundwater samples from well B-2 located on the southwest corner of the Cast property. PCE and TCE concentrations were reported at concentrations of 39 µg/l and 0.7 µg/l, respectively.

Sampling conducted by GTI in February and June 1994, and September 1995, indicated that well B-2 contained PCE concentrations ranging from 14 µg/l to 32 µg/l, and TCE concentrations ranging from 0.7 µg/l to 1.5 µg/l.

Based on these results, the ADEQ conducted PA/SI activities beginning in 1995 and concluding in 1997. This initial investigation was designed to identify potential source areas, and to determine the extent of VOC impact to groundwater through the collection of groundwater, soil, and soil vapor samples.

The ADEQ collected groundwater samples from wells on the property in August 1995 and July and October 1997. Analytical results indicated PCE concentrations ranging from 1.3 µg/l to 20 µg/l in well B-2. Wells B-1 and B-4 contained PCE concentrations of 1.4 µg/l and 0.8 µg/l, respectively, in August 1995. TCE was reported in well B-1 at concentrations ranging from non-detectable to 0.88 µg/l, and in well B-2 at concentrations ranging from non-detectable to 2.1 µg/l.

In May 1996, soil and soil vapor samples were collected at eight locations on the property (Figure 9). Borings JB2 and JB3 were drilled at the location of the former truck wash surface impoundment. Boring JB4 was located near the former holding tank. Borings JB5 and JB6 were located adjacent to the former truck wash and laundromat, respectively. Borings JB7, JB8, and JB9 were located in the vicinity of the former laundromat wastewater injection pond. Analytical results from borings JB-2 through JB-9 did not indicate VOC concentrations above laboratory reporting limits in any sample.

4.2.3 Expanded Site Inspection

From March 23 to April 3, 1998, the ADEQ conducted additional sampling at the property. This ESI included collecting samples for analyses of soil and soil vapor. The objective was to determine if there was a release of PCE at the site from the former truck wash.
Three borings (TY19SV, TY20SV, and TYSV21) were drilled for the purpose of collecting soil and soil vapor samples (Figure 10). Soil vapor samples were collected from a depth of approximately 6 feet bgs. Soil samples were collected from undisturbed soil at a depth of 10-12 feet bgs from borings TY19SV and TY20SV. A third soil sample was collected from boring TY21SV at a depth of 6 feet bgs.

Analytical results did not indicate the presence of VOCs above laboratory reporting limits in any of the soil samples. Soil vapor PCE concentrations ranged from 1.3 ppb/v to 5.2 ppb/v. Based on the results of the ESI, the ADEQ concluded that activities at this property do not appear to have contributed to the relatively high PCE concentrations in groundwater in this area (ADEQ, 1998).

4.3 FORMER HI-ALI MOTEL PROPERTY INVESTIGATIONS

4.3.1 Property Use History Investigation

The former Hi-Ali Motel property, located at the southwest corner of Cowell Street and Johnson Avenue, was identified as a potential hazardous waste site and entered into CERCLIS on February 27, 1995. According to the ADEQ, Mr. Lester Bonner sold the property in 1972 to Mr. Merle Walker and Mrs. Doris Walker. Mr. Walker reportedly operated the facility as a motel/laundromat, and also a self-service dry cleaner. The dry cleaner business was reportedly only operated for a short period of time, perhaps only 6 months. Mr. La Mar Walker and Mr. James Kirk, as partners, operated the property as a motel, laundromat, and swap meet from 1977 to 1994. In 1994, the property was sold to Mrs. Marjorie Reid, who continued to operate the property as a motel, laundromat, and swap meet. According to the ADEQ, Mrs. Reid closed the motel and laundromat in 1997. Mr. La Mar Walker currently owns the property, which is used as a swap meet during the winter months.

There were reportedly two to three septic tanks on the property that drained into at least two leach fields. Two domestic wells were located near the north boundary of the property west of the building. The wells were reportedly abandoned sometime during 1997 or1998.

The property occupies approximately 6.4 acres. There are currently two buildings on the site. The former motel, which is currently vacant, was reportedly built in 1970. There is also a trailer located on the southeast corner of the property that is used seasonally for tourist information. The remainder of the property is an unpaved lot.

4.3.2 Preliminary Assessment/ Site Inspection

In July and August 1995, the ADEQ collected groundwater samples from the two former domestic wells wells HA-1 and HA-2 (Figure 4). Laboratory analytical results indicated PCE concentrations of 24 µg/l in well HA-1, and 8.2 µg/l in well HA-2. TCE was reported in well HA-1 at a concentration of 0.8 µg/l.

In March 1996, the ADEQ installed nine temporary monitoring wells (HAP1-8, and HAP-11) on the property. Well locations are indicated on Figure 8. PCE concentrations ranged from non-detectable in well HAP-1 to 34 µg/l in well HAP-8, located at the northeast corner of the property. TCE concentrations ranged from non-detectable to 1.9 µg/l.

On May 20-24, 1996, the ADEQ conducted an additional soil, soil vapor, and groundwater sampling event at the Site (Figure 9). Wells HA-1 and HA-2 contained concentrations of 25 µg/l and 7 µg/l of PCE, respectively. TCE was also detected in wells HA-1 and HA-2 at concentrations of 0.8 µg/l and 0.2 µg/l, respectively.

Seventeen soil vapor samples were collected from borings HA1 through HA12 and HA18 at a depth of 5 feet bgs. Boring locations are included on Figure 9. Fourteen soil samples were collected from the same borings at a depth of approximately 5.5 to 7 feet bgs. Analytical results from the soil and soil vapor samples did not indicate the presence of VOC concentrations above laboratory reporting limits.

4.3.3 Expanded Site Inspection

In March 1998, nine soil vapor samples (TY9SV through TY12SV, and TY14SV through TY18SV) were collected from eight locations adjacent to suspected septic tanks and along the estimated location of drainage piping (Figure 10). The soil vapor samples were collected at an estimated depth of 6 feet bgs. One soil sample was collected from temporary well TYT6 at an unknown depth. In addition, two sludge samples (S1 and S2) were collected from two onsite

septic tanks. Sample locations are included on Figure 10.

Analytical results indicated soil vapor PCE concentrations ranging from 2.9 ppb/v to 77 ppb/v. The highest concentration (77 ppb/v) was reported in boring TY12SV, located near a suspected septic tank on the southeast corner of the property. A PCE concentration of 75 µg/l was reported in the sludge sample collected from the southeast septic tank. VOC concentrations were not detected in the sludge sample collected from the septic tank located immediately south of the former motel building. VOCs were not detected in any soil samples.

4.4 ADDITIONAL INVESTIGATIONS

4.4.1 Domestic Well Sampling

Between July 1995 and May 1999, the ADEQ collected groundwater samples from 23 domestic wells located within, and in the vicinity of, the Site. Analytical results are included in table format in Appendix C. In addition to the VOC concentrations previously noted in domestic wells at the Welcome RV Park, Cast, and former Hi-Ali Motel properties, PCE was also reported at a concentration of 8.5 µg/l in a domestic well located at the Quartzsite Post Office. The Quartzsite Post Office well is located at the southeast corner of Cowell Street and Johnson Avenue (Figure 3). PCE concentrations exceeding the AWQS were also reported at the Kauffman and Rhoades properties located west of the Welcome RV Park. PCE was reported at a concentration of 0.7 µg/l in a sample collected at the La Casa Del Rancho Restaurant in October 1995. However, it is not known which of the two domestic wells at that property were sampled.

Of the remaining domestic wells sampled by the ADEQ during this time period, one sample from the T & S Truck and Auto Repair facility, collected in July 1995, contained TCE at a concentration of 1.3 µg/l. The T & S facility is located approximately ¼ mile southeast of the Site. VOC concentrations did not exceed laboratory reporting limits in any other domestic well sampled during this phase of the investigation.

4.4.2 Monitoring Well Installation

In April 1997, the ADEQ supervised the installation of groundwater monitoring wells QMW-1, QMW-2, and QMW-3. Two additional monitoring wells (QMW-4 and QMW-5) were installed in March 1998. Well construction information is included in Appendix E. All of the wells were constructed of 4-inch diameter PVC well casing and screen. Wells QMW-1 through QMW-3 were each constructed to a depth of approximately 80 feet bgs, with a screened interval extending from 30 to 80 feet. Well QMW-4 was drilled to a depth of 60 feet bgs and screened from 30 to 60 feet. Well QMW-5 was drilled to 65 feet bgs, and was screened from 35 to 65 feet. Between July 1997 and May 1999, the ADEQ collected groundwater samples from these wells on several occasions. Laboratory analytical results from those sampling events consistently indicated PCE concentrations exceeding the ADEQ AWQS in wells QMW-1, QMW-3, QMW-4, and QMW-5 (Table 1). TCE concentrations exceeded the AWQS in well QMW-3 during sampling events conducted on July 30 and October 29, 1997. VOCs were not present above laboratory reporting limits in well QMW-2 at any time.

4.4.3 Leaking Underground Storage Tank (LUST) Investigations

The ADEQ Underground Storage Tank Unit is currently directing investigations at two LUST sites located adjacent to the southeast boundary of the Site. Although these investigations are not part of the WQARF Program, the proximity of the LUST sites to the WQARF Site makes them relevant to the discussion. The following details of the LUST investigations were obtained from information contained in ADEQ files, and discussions with the ADEQ LUST file case managers.

4.4.3.1 The Texaco Quik Chek Market (ADEQ Lust File No. 3215.01)

The Quik Chek Market is located on the northwest corner of Main Street and Central Blvd. The site has been an active convenience store and retail fuel station since the 1970's. The current UST system includes one 10,000 gallon and two 8,000 gallon gasoline USTs, and two 12,000 gallon diesel fuel USTs. In November 1993, an ADEQ inspector noticed fuel dripping from the leak detector on the premium unleaded tank submersible pump. The leak was subsequently

repaired and one soil boring was drilled to a depth of 35 feet adjacent to the pump. Analytical results indicated soil contamination extending to a depth of 30 feet.

A second release was reported to the ADEQ in September 1997. The subsequent investigation indicated that groundwater had been impacted with petroleum hydrocarbons. The most recently reported groundwater monitoring event conducted at the site (September 2000) indicated the presence of phase-separated hydrocarbons (i.e., floating gasoline) in one well located near the northwest boundary of that property. Dissolved phase hydrocarbons were also present, including benzene at a maximum concentration of 440 µg/l. This concentration exceeds the ADEQ AWQS of 5 µg/l. Toluene was present at a concentration of 510 µg/l, and total xylenes at 1,500 µg/l. Based on these findings, the ADEQ has determined that the full horizontal extent of the petroleum hydrocarbon plume has not been determined.

The groundwater flow direction at the Quik Chek Market is reported to be toward the north/northwest at a gradient of 0.02 foot per linear foot, which places that site directly up gradient of the WQARF study area. Groundwater flow appears to have been influenced by the pumping of domestic supply wells on the Cast property.

4.4.3.2 Steve's Gas N Go/Dolly's Restaurant (ADEQ LUST File 0972.01)

The site, on the northeast corner of Central Blvd. and Main Street, previously included a gasoline service station identified as Steve's Gas N Go, but is currently known as The Satellite Relay. Groundwater contamination was first reported to the ADEQ in November 1989 with the discovery of petroleum hydrocarbons and 1,2-dichloroethane in three private domestic wells located north and east of the site. Following the initial investigation, ten monitoring wells were installed at the site and surrounding properties. Four USTs were removed from the site in 1993. One additional UST was discovered and removed from the property during Town of Quartzsite water pipe installation in 1995.

Groundwater flow at the site is reported to be toward the northeast at a gradient of 0.01 to 0.02 foot per linear foot. This suggests that the groundwater flow at the site has been relatively unaffected by the pumping wells at the Cast property. Soil and groundwater remediation activities were initiated in February 2000. Groundwater monitoring conducted through March 2001 indicates that contaminant concentrations in the source area monitoring wells are currently below the respective ADEQ AWQSs. As a result, the groundwater remediation system has been shut down and closure of the LUST file is pending.

5.0 REMEDIAL INVESTIGATION ACTIVITIES

MACTEC, under the direction of the ADEQ WQARF Program, began RI activities in September 1999. RI field activities, which began with groundwater sampling conducted in November 1999, included:

- completion of a near-surface geophysical survey, and the subsequent collection of soil, soil vapor, and groundwater samples in a further effort to determine the source of groundwater contamination at the site.

- installation of five additional permanent groundwater monitoring wells to determine the full horizontal extent of VOC contaminated groundwater in the shallow aquifer.

- collection of groundwater samples from monitoring and domestic wells on a quarterly basis, and the collection of continuous depth to groundwater measurements from dedicated down-hole dataloggers.

- performance of two aquifer pumping tests to determine aquifer hydraulic properties.

- completion of a Health Consultation to address the potential health risks to those well users possibly exposed to the contaminated groundwater.

- completion of groundwater flow and contaminant transport models capable of simulating current and future PCE concentrations in the shallow alluvial aquifer at the Site.

5.1 SOURCE INVESTIGATION

Because results from the previous investigations did not clearly identify sources of groundwater contamination, additional source investigation activities were conducted as part of the RI.

Unlike the previous investigations, however, the RI source investigation focused on only two properties – the Welcome RV Park and former Hi-Ali Motel. Results from the previous soil and soil vapor sampling at the Cast property did not indicate VOC concentrations suggesting the existence of a source, and therefore additional source investigations were not conducted on that property.

5.1.1 Geophysical Survey

On July 25 and 26, 2000, MACTEC supervised a geophysical survey in an effort to identify the locations of septic tanks, drain lines, and leach fields at the Welcome RV Park and former Hi-Ali Motel. Hydrogeophysics, Inc. (HGI), of Tucson, Arizona, conducted the survey. A copy of HGI's complete report and geophysical survey plots are included in Appendix F.

HGI used magnetic and electromagnetic surveys in an effort to locate buried septic system components. Five grids covering 1.9 acres were surveyed. Two grids were surveyed at the Welcome RV Park and three grids were established at the former Hi-Ali Motel.

5.1.1.1 Welcome RV Park

The two grids completed at the Welcome RV Park covered suspected locations of leach fields and septic tanks. Locations of the grids are included on Figure 11 and in Appendix F. One grid was established on the west side of the property covering an area 100' x 120'. The property owner had previously identified this area as containing a septic tank and drain field, and previous ADEQ soil vapor sampling indicated PCE concentrations as high as 510 ppb/v. The second grid, covering an area of 55' x 100' was established on the east side of the property. According to the property owner, a fiberglass septic tank was buried in this area. A PCE soil vapor concentration of 980 ppb/v was previously reported here.

The survey was successful only in identifying the west septic tank. This tank was physically confirmed by shallow excavation to the clean-out lid. The septic tank on the east side of the

property was not identified by the geophysical survey, most likely because the septic tank was dry. However, the location of this tank was confirmed by using a Subsite system, which is essentially a sewer "snake". Three drain lines on the west and north sides of the residential building were traced for short distances using the Subsite system, and are indicated on the final survey plot (Appendix F). The location of a fourth drain line near the fence on the east property boundary was estimated based on the locations of several sewer clean-outs. No septic leach fields were detected. No unexplainable responses were evident at this property.

5.1.1.2 Former Hi-Ali Motel

At the former Hi-Ali Motel, three grids were surveyed. The west grid included an area 300' x 150' near the center of the property, where a leach field and associated drain lines were suspected to occur. A second grid was established near the trailer located at the southeastern corner of the property. The second grid covered an area of 70' x 100'. The ADEQ had collected a sludge sample from a septic tank in this area during a previous investigation in 1998. No evidence of the tank remains, and it is unknown whether the tank was removed or abandoned in place. The third grid was set up covering an area of 70' x 50' immediately south of the former motel building. The remains of a concrete septic tank are still visible in this third grid area.

At the west grid, several unknown responses were noticed. The smaller unknown responses were likely caused by small, shallowly buried, ferrous objects not associated with the septic system. The survey identified a linear response, oriented north-south, which was interpreted as possibly representing a buried metallic pipe. No septic tanks, septic leach field, or associated drain pipes were detected. Any leach field located in this area would have been unused for several years, and was likely too dry to be detected.

One buried drain line was traced from the septic tank south of the building to the trailer located at the southeast corner of the property. A second buried PVC pipe was traced from the identified septic tank toward the southwest for approximately 40 feet. This pipe headed in the general

direction of the west survey grid near the center of the property. Excavation was conducted at the location where the pipe could no longer be traced, but the pipe ended with no indication of any connections. One unknown response was noted in each of the south and southeast grids. No septic tanks or leach fields were identified in the southeast grid.

5.1.1.3 Geophysical Survey Conclusions

Results from the geophysical survey were inconclusive. The only subsurface features positively identified were the septic tank west of the Welcome RV Park residential building, the septic tank immediately south of the former Hi-Ali Motel, and PVC drain lines at both properties. No leach fields were identified at either property. Identification of septic tank and leach field boundaries was based on contrasting conductivity values between undisturbed native soil and buried septic system components, leachate, and/or disturbed soil. However, the conductivity contrast was too low to identify any of the objects of concern. In the case of the former Hi-Ali Motel property, the septic system has been unused for several years. The septic system at the Welcome RV Park had been unused for several months when the geophysical survey was completed.

5.1.2 Soil and Soil Vapor Sampling

On August 7-9, 2000, MACTEC supervised the drilling of eighteen borings (SV1-SV18) for the collection of soil and soil vapor samples (Figure 11). One additional soil vapor boring (SV-19 was drilled on October 26, 2000.

Borings SV-1 through SV-18 were drilled by Tracer Research Corporation (Tracer) of Tucson, Arizona using Tracer's *Vapor Trace*® technology. During the drilling, 36 soil vapor samples were collected at depths ranging from 5 to 30 feet bgs. Four soil samples were collected at depths ranging from 5.5 to 11.5 feet bgs. In addition, one soil vapor sample (identified in Tracer's report as WRV-Septic-SG) was collected directly from the septic tank on the west side of the residence at the Welcome RV Park. A copy of Tracer's report dated August 7-9, 2000, which includes a complete description of Quality Assurance/Quality Control procedures, is

included in Appendix G.

Soil boring locations were based on results of the previously completed geophysical survey as well as results from the previous soil vapor sampling conducted by the ADEQ. MACTEC's initial sampling plan approved by the ADEQ provided for the collection of soil vapor samples from a maximum of 20 borings at an anticipated depth of 8 feet bgs, which was the anticipated depth to the bottom of the septic tanks. Based on the soil type encountered, analytical results, and technical problems with the drilling rig, the original sampling plan was revised during the investigation, as indicated in the following sections.

On October 26, 2000, MACTEC retained a drilling crew from Art's Manufacturing and Supply, Inc. (AMS) to drill three additional proposed borings at the former Hi-Ali Motel for the collection of soil, soil vapor, and groundwater samples. AMS used a Power Probe™ 9600 drill rig to complete the borings.

5.1.2.1 Sampling Rationale and Boring Locations

Welcome RV Park

Nine borings were drilled at the Welcome RV Park based on results of the geophysical investigation. Soil boring locations are indicated on Figure 11.

- Five borings (SV-8, SV-9, SV-10, SV-11, and SV-17) were drilled adjacent to the west septic tank. Borings SV-8, SV-9, and SV-10 were drilled to a depth of 8 feet bgs, which is the estimated depth to the bottom of the tank. Soil vapor samples were collected at 8 feet bgs from those borings. Boring SV-11 was drilled to a depth of 15 feet bgs, and boring SV-17 was drilled to 20 feet bgs. Soil vapor samples were collected at 5-foot interval from borings SV-11 and SV-17.

- Four borings (SV-12, SV-13, SV-14, and SV-18) were drilled next to the east septic tank.

Borings SV-13 and SV-14 were drilled to a depth of 8 feet bgs, with soil vapor samples being collected at 8 feet bgs. Borings SV-12 and SV-18 were each drilled to a depth of 15 feet bgs, with soil vapor samples being collected at 5-foot intervals from each boring.

During the course of drilling, four soil samples were collected. While drilling boring SV-11, an attempt was made to collect soil samples at 5-foot intervals. Following collection of soil samples at 5.5 and 11.5 feet bgs, the boring was advanced through a caliche layer to 15 feet bgs where a soil vapor sample was collected. A subsequent attempt was made to collect a soil sample at this depth, but the soil sampler became wedged in the undisturbed soil. After several attempts to retrieve the sampler, the drill rod broke, leaving the sampler and lower rod in the ground.

A similar scenario occurred while drilling boring SV-12 on the east side of the property. Soil samples were collected at depths of 6 and 11.5 feet bgs. The caliche layer was again encountered at approximately 12 feet bgs. After collecting a soil vapor sample at 15 feet bgs, the drill rod broke a second time while attempting to retrieve the soil sampler, and no further soil samples were collected from boring SV-12 or any other boring.

Former Hi-Ali Motel

Ten soil borings were drilled at the former Hi-Ali Motel. Locations were also chosen on the basis of results from the geophysical survey. Borings SV-1 through SV-7 were each drilled to a depth of 8 feet bgs. One soil vapor sample was collected from each of these borings at the 8-foot depth. Borings SV-15 and SV-16 were drilled to depths of 20 feet and 30 feet bgs, respectively, with soil vapor samples being collected at 5-foot intervals from each boring. Boring locations, indicated on Figure 11, are as follows:

- Boring SV-1 was drilled adjacent to the identified septic tank and drain line immediately south of the former motel/laundromat building.

- Boring SV-2 was drilled near the suspected location of a former leach field at the southeast corner of the property. During the geophysical survey, a drain line had been identified running to this area from the septic tank south of the former motel building. The geophysical survey had also indicated a small unknown disturbance in this area.

- Boring SV-3 was drilled at the northeast corner of the west geophysical grid, where the magnetic survey indicated an unknown response that may have been a buried metal object.

- Borings SV-4, SV-5, and SV-6 were drilled at the location of a suspected drain field, and where the geophysical survey indicated a north-south trending linear feature interpreted as a possible drain line.

- Boring SV-7 was drilled approximately 7 feet north of the former motel building.

- Boring SV-15 was drilled west of the former motel building.

- Boring SV-16 was drilled approximately 6 feet south of the building.

- Boring SV-19 was drilled at the north side of the former motel building, adjacent to the previously drilled boring SV-7. Boring SV-19 was initially drilled using a hollow-stem auger attachment through the caliche layer to a depth of approximately 15 feet bgs. The drill rig was then converted to the Power Probe™ direct push system to complete the boring. Soil vapor samples were collected from boring SV-19 at depths of 20, 28.5, 35, and 41 feet bgs. Groundwater was encountered at approximately 42 feet bgs. An attempt was made to collect a soil sample following collection of the vapor sample at 41 feet bgs, but equipment failure prevented sample collection. Equipment failure also prevented collection of a groundwater sample in this boring.

One other attempt was made during the October 2000 sampling event to drill a boring immediately east of the former motel building. Auger refusal was encountered in the caliche layer at a depth of approximately 11 feet bgs. When attempting to retrieve the drill rod, the auger head broke and the rod could not be retrieved. No samples were collected from this boring, and no further drilling was attempted.

5.1.2.2 Sampling Methodology

Custom fabricated 3 to 5-foot lengths of 1.5-inch outside diameter steel drill rods were assembled and pushed and/or pounded to the chosen depth with the hydraulic system. Upon reaching the desired sampling depth, an adapter was attached to a section of clean polyethylene tubing and lowered into the drill rod. The tubing was then rotated to thread the adapter into a point holder at the end of the probe. An O-ring at the top of the adapter ensured an air-tight seal with the point holder. The above ground end of the poly-tubing was attached to an evacuation pump for sampling.

Soil vapor samples were collected in a glass syringe by inserting a syringe needle through a section of silicon rubber connecting the tubing to the pump. Three to five tubing volumes of air were evacuated prior to collecting a sample. The vacuum was monitored by a vacuum gauge to ensure an adequate gas flow from the vadose zone.

Soil samples were collected using Tracer's Direct Push Technologies piston soil sampler, which collects a sample 24 inches long and one inch in diameter. In order to collect a soil sample, a small diameter rod containing a clear plastic liner was lowered through the 1.25-inch diameter probe string and a threaded stop pin was released. The sampler was then driven one additional foot into the undisturbed soil. As the sampler was driven into the soil, the soil was displaced into the sampler and the sampler was retrieved.

5.1.2.3 Analytical Methodology

Upon collection of soil and soil vapor samples, the samples were immediately submitted to Tracer's mobile analytical laboratory. Samples were analyzed for VOC's using EPA method 8021 (modified) by gas chromatography/electron capture/flame ionization detector. A complete description of the analytical methodology is included in Appendix G. Analytical results were provided daily by the Tracer laboratory technician.

Two duplicate soil samples were submitted to Del Mar Analytical for VOC analysis by method 8260B. Those samples were collected following procedures outlined in EPA Method 5035. The soil samples were collected by pushing an EnCore™ sampler into the soil core until the sampler was full. The EnCore™ sampler was then retracted. A cap was placed over the sampler and locked on by twisting and pushing the cap. The sample was then removed from the T-handle and prepared for shipment.

The soil vapor samples collected from boring SV-19 on October 26, 2000 were submitted to Del Mar Analytical Laboratories for analysis using U.S. EPA Method 8260B.

5.1.3 Analytical Results

5.1.3.1 Soil Vapor Samples

Welcome RV Park

Analytical results, presented in Table 3, indicated soil vapor PCE concentrations ranging from 3 to 151 ppb/v in samples collected at depths of 5 to 10 feet bgs adjacent to the west septic tank. On the east side of the property, PCE concentrations ranged from 0.45 to 60 ppb/v in samples collected at 5 to 10 feet bgs. In soil vapor samples collected below 10 feet bgs, PCE concentrations ranged from non-detectable to 3 ppb/v. In addition to PCE, 1,1,1-trichloroethane (TCA) was reported at a concentration of 1.5 ppb/v in boring SV-1 at a depth of 8 feet bgs, and 3 ppb/v in boring SV-11 at a depth of 10 feet bgs.

Former Hi-Ali Motel

Analytical results indicated PCE concentrations ranging from non-detectable to 106 ppb/v in soil vapor samples collected at the Hi-Ali property. The greatest concentrations were reported in boring SV-7 at a depth of 8 feet bgs (106 ppb/v) and boring SV-16 at 30 feet bgs (90 ppb/v).

5.1.3.2 Soil Samples

Analytical results of the 4 soil samples analyzed by Tracer indicated PCE concentrations ranging from 0.01 to 0.2 µg/kg. In the duplicate samples analyzed by Del Mar Analytical, PCE was not detected above the laboratory reporting limit of 100 µg/kg. The difference in reporting limits between the two laboratories is due to different analytical methods. The ADEQ Residential Soil Remediation Level for PCE is 53,000 µg/kg.

5.1.4 Temporary Monitoring Well Installation at the Former Hi-Ali Motel

Based on the results of the RI soil vapor survey, two additional temporary groundwater monitoring wells were installed near the former motel building. Groundwater samples were collected from the wells in a further effort to determine whether a source of contaminants might exist on the property. The samples also served to confirm results from previous groundwater sampling and to close a data gap between monitoring well QMW-1, located on Cowell Street north of the former motel, and well QMW-6, located in the ADOT right of way south of the former Hi-Ali Motel property. ADEQ had previously attempted to procure an access agreement with the property owner to install one or more permanent monitoring wells on the property, but was unsuccessful.

On April 24, 2001 MACTEC personnel supervised the drilling of two borings. Boring ESE-TY1 was drilled on the north side of the former motel building, in the vicinity of previous soil vapor borings SV-7 and SV-19 (Figure 11). Boring ESE-TY2 was located south of the building where several soil vapor borings had been previously drilled. Each boring was drilled to a depth of 65 feet bgs. Soil samples were collected at 5-foot intervals and were field screened for VOCs using

an FID. Two soil samples were collected from each boring and were submitted to Del Mar Analytical for analysis of VOCs using EPA Method 8260B.

Two-inch diameter PVC well casing, screened between 40 and 65 feet bgs, was installed in each boring. The annulus was backfilled with sand to approximately 2 feet above the top of the well screen. Bentonite pellets were then poured into the annulus and hydrated to complete a seal. After letting the seal set for approximately 2 hours, the well was developed by gently surging followed by bailing. The following day, MACTEC personnel measured water levels and purged each well using a submersible Grundfos™ pump. Groundwater samples were then collected and submitted to Del Mar Analytical for analysis of VOCs using EPA Method 8260B.

Following groundwater sampling, the PVC casing was pulled from the wells, and each well was backfilled with a neat cement grout from the bottom of the well to approximately 2 feet below grade. After allowing the cement grout to settle, the upper two feet of the borehole was backfilled with drill cuttings to match the existing ground surface. Drill cuttings and purged groundwater were containerized in 55-gallon drums and transported to the Town of Quartzsite Public Works yard pending disposal. Following receipt of analytical results, Pacific Waste Disposal, Inc transported the drums from the site. Soil and groundwater disposal procedures and documentation are included in Appendix H and Appendix I, respectively.

5.1.4.1 Analytical Results

Groundwater analytical results indicated PCE concentrations of 9.7 µg/l and 3 µg/l, respectively, in wells TY1 and TY2. Chloroform was also detected at 2.2 µg/l in well TY1. Laboratory analytical reports and quality control data are included in Appendix J.

Analytical results of the soil samples did not indicate VOC concentrations exceeding laboratory reporting limits in any sample. Soil sample laboratory analytical reports and laboratory quality control data are included in Appendix K.

5.2 INVESTIGATION TO DETERMINE THE HORIZONTAL EXTENT OF CONTAMINATED GROUNDWATER

In March and April 2000, MACTEC completed the installation of four permanent groundwater monitoring wells (QMW-6, QMW-7, QMW-8, and QMW-9) for the purpose of delineating the horizontal extent of the dissolved phase PCE plume. Five additional borings were advanced and converted to observation wells for use in subsequent aquifer testing events. In February 2001, one additional well (QMW-10) was installed to complete the characterization of the down gradient extent of the PCE plume.

Drilling was conducted by Geomechanics Southwest, Inc. (GSI), of Phoenix, Arizona, using a Central Mining Equipment Company Model 75 (CME-75) hollow-stem auger drilling rig. With the exception of well QMW-10, monitoring wells and observation points were drilled to maximum depths of 70 to 75 feet bgs. Well QMW-10 was drilled to 140 feet bgs before being backfilled and constructed to a total depth of 75 feet.

5.2.1 Well Locations and Construction Details

Wells QMW-6 through QMW-9 were completed with 4-inch diameter Schedule 40 PVC well casing and well screen. The well locations, which are indicated on Figure 4, were chosen based on historical laboratory analytical results, and were approved by ADEQ prior to initiating drilling activities. Well construction diagrams and soil boring logs are included in Appendix E. MACTEC daily field notes are included in Appendix L. Specific well locations and well screen intervals are as follows:

- Well QMW-6 was drilled to a depth of 70 feet bgs within the ADOT right-of-way south of the Hi-Ali property. This location was chosen to provide an upgradient compliance point and to determine whether contaminants were migrating onto the Site from an upgradient source. The well was placed in the ADOT right of way because access to install a permanent monitoring well on the former Hi-Ali property could not be obtained from the property

owner. The well was screened from 35 to 70 feet bgs.

- Well QMW-7 was drilled on the north edge of Cowell Street, approximately 250 feet west of Washington Avenue, to determine the western extent of the plume. The well was screened from 35 to 70 feet bgs.

- Well QMW-8 is located on the Welcome RV Park property, near the north boundary of that property. In addition to providing a monitoring point to determine the northern extent of the plume, this serves as a sentinel well upgradient of the York domestic well. Well QMW-8 was drilled to 75 feet bgs and is screened from 34 to 74 feet.

- Well QMW-9 was drilled to a depth of 70 feet bgs at the north end of the Cast property, and is screened from 35 to 70 feet bgs. This well serves to delineate the northeastern extent of the PCE plume.

- Wells OB-1, OB-2, and OB-3 were drilled for use as observation wells during the aquifer test conducted on well QMW-7. Each well was drilled to 70 feet bgs, and is screened from 35 to 70 feet bgs. Wells OB-1 and OB-2 are located on the north edge of Cowell Street, 16 feet east and 32 feet west of well QMW-7, respectively. Well OB-3 is located on the south edge of Cowell Street, 30 feet south of well QMW-7.

- Wells OB-4 and OB-5 were drilled for use as observation wells during the aquifer test conducted on well QMW-6. Each well was drilled to 70 feet bgs, and is screened from 35 to 70 feet bgs. Well OB-4 is located in the ADOT right of way, approximately 26 feet southwest of well QMW-6. Well OB-5 is located 16 feet southeast of well QMW-6.

Based on groundwater sample analytical results compiled through the Fourth Quarter 2000, which indicated increasing PCE concentrations in the La Casa Del Rancho Restaurant west

domestic well, MACTEC recommended the installation of one additional groundwater monitoring well (QMW-10) to laterally characterize the down gradient extent of the VOC plume. Well QMW-10 was subsequently installed on the northwest corner of the La Casa Del Rancho Restaurant property, approximately 110 feet down gradient of the west domestic well (Figure 4). The pilot boring for well QMW-10 was drilled to a depth of 140 feet bgs. The boring was backfilled with bentonite chips from 140 feet to the 75-foot depth, and the remaining open borehole was over-drilled using 11-inch outside diameter augers in preparation to set the well. Five-inch diameter schedule 40 PVC well casing was used in the construction of the well, with the screened interval extending from 45 to 75 feet bgs.

5.2.2 Well Development and Dedicated Pump Installation

Approximately 48 hours after completion of well construction, each of the monitoring wells was developed by GSI. Development was initially conducted by wire line block and surging techniques followed by bailing of settled and suspended sediments, and then by pumping. Prior to well development, initial water levels were taken using a water level meter and recorded in the field logbook. A groundwater sample was initially extracted for visual observations (i.e., sediments, clarity, etc.) and to obtain initial measurements of the field parameters turbidity, conductivity, pH, and temperature. Field parameter measurements were collected periodically during well development, and values were recorded in the field logbook. Groundwater was pumped until turbidity was less than 50 Nephilitic Turbidity Units.

Drill cuttings and well development water were stored at the Site prior to disposal. Soil and groundwater disposal procedures and documentation are included in Appendix H and Appendix I, respectively.

MACTEC installed a 1/3 horsepower Grundfos™ SP4 4-inch stainless steel dedicated pump (model #5S03-9) in each monitoring well to depths of approximately 65 to 68 feet bgs. At the same time, MACTEC installed In-Situ, Inc. TROLL™ SP 4000 dataloggers in all ten

monitoring wells for the purpose of remotely collecting groundwater elevation measurements. Sampling frequency for the datalogger/transducers was initially set to collect a data point at continuous two-minute intervals. In addition to the datalogger in well QMW-10, a one-inch sounding tube was also installed in the well.

5.2.3 Well Elevation Survey

Elevations of the newly installed wells (wells QMW-6 through QMW-9), in addition to previously existing wells QMW-1 and QMW-5, were surveyed by a registered surveyor from Lemme Engineering, Inc. on June 30, 2000. Review of the survey data indicated a discrepancy in the listed elevations for wells QMW-1 and QMW-5. Therefore, the surveyor returned to the site on July 25 to re-survey elevations of wells QMW-1 through QMW-5, and to ensure that all of the monitoring wells were tied to the same survey network. Lemme Engineering, Inc. surveyed well QMW-10 on March 7, 2001. Survey data is included in Appendix M.

5.2.4 Soil Sampling

During the drilling of monitoring wells QMW-6 through QMW-9 and the observation wells, soil samples were collected using a split spoon sampler every 5 feet for lithologic descriptions in accordance with ASTM D2488. The onsite geologist also monitored drill cuttings and soil samples for VOC concentrations using a field vapor monitor to assist in determining the presence, if any, of VOC constituents in subsurface soils. A continuous core sampling method using a five-foot long, three-inch diameter core barrel was used to collect soil samples during the drilling of well QMW-10. Drilling auger flights and soil sampling equipment were decontaminated between borings following procedures outlined in the Field Sampling Plan, dated March 15, 2000.

Field screening results did not indicate VOC concentrations above background levels in any soil samples. Therefore, no soil samples were submitted for laboratory VOC analyses.

Soil samples collected from well QMW-10 were submitted to Aquatics Consulting and Testing Inc. to be analyzed for soil moisture content using ASTM Method D2216, bulk density using ASTM Method D4531, and specific gravity using ASTM Method D854. Porosity of the samples was also calculated from the results of bulk density and specific gravity. These analyses were conducted in an effort to gain a better understanding of soil properties, and to gather information necessary for the subsequent groundwater modeling process. Results of the sampling are discussed in Section 6.0.

5.2.5 Investigation Results

Approximately one week following well development, groundwater samples were collected from each of the newly installed monitoring wells. Analytical results were used to determine whether the lateral extent of the VOC plume was adequately defined to concentrations below the AWQS of 5 µg/l for both PCE and TCE.

Results from well QMW-6, which did not contain detectable VOC concentrations, defined the upgradient boundary of the plume. That boundary has since been refined by results from temporary monitoring well ESE-TY2. Currently, the upgradient boundary is estimated to bisect the former Hi-Ali Motel property south of the former motel building (Figure 4).

Well QMW-9 was installed to determine the northeast, or down gradient, extent of the plume. Initial VOC concentrations in this well were below laboratory reporting limits. Subsequent sample results from the west domestic well at the La Casa Del Rancho Restaurant suggested that the PCE plume was migrating further to the north/northeast, and was not being intercepted by well QMW-9. Therefore, well QMW-10 was installed directly downgradient of the impacted domestic well. The maximum down gradient extent of the plume has been confirmed by analytical data from monitoring well QMW-10, which contained a maximum PCE concentration of 1.6 µg/l in November 2001.

To the east, the plume boundary is defined by non-detectable VOC concentrations in previously installed monitoring well QMW-2. In addition, Cast well B-4 contained a maximum PCE concentration of 0.8 µg/l in a sample collected in August 1995. The most recent sample from that well was collected in November 1999, at which time all VOC concentrations were below laboratory reporting limits.

Well QMW-7, which was installed in an effort to define the western plume boundary, contained an initial PCE concentration of 7.3 µg/l, which exceeds the AWQS. On August 9, 2000, groundwater samples were collected from observation well OB-2, which is located 32 feet west of well QMW-7. Analytical results for well OB-2 indicated a PCE concentration of 5.7 µg/l, which is slightly higher than the AWQS. Because there are no domestic wells directly west of wells QMW-7 and OB-2, and PCE concentrations were only slightly greater than the AWQS, it was determined not to drill any additional wells in this area. Further north, the western boundary of the VOC plume has been confirmed in samples collected from the Parsons and Adams domestic wells. Therefore, the western extent of the plume appears to be adequately defined.

Although no monitoring wells were installed southeast of the Welcome RV Park, the current plume boundary is defined by the domestic well at Eric's RV Repair. PCE was reported at a concentration of 0.5 µg/l in that well in February 2000. Since that time, samples collected from the well have not indicated detectable concentrations of any VOC.

5.3 GROUNDWATER MONITORING

MACTEC conducted quarterly groundwater sampling and monthly water level measurements from monitoring and domestic wells between May 2000 and April 2002. The purpose of the sampling was to evaluate both monitoring wells and domestic wells for the presence of VOCs. Depth-to-groundwater measurements from all monitoring wells were downloaded monthly from the dataloggers to a laptop computer. Depth to groundwater and calculated groundwater elevations for each well are listed in Table 5.

In addition to the regularly scheduled sampling and analysis for volatile organic compounds

(VOCs), samples were also collected from selected monitoring wells for analysis of natural attenuation parameters in May and August 2000, and in April 2002. Details and results of the natural attenuation sampling are included in Section 8.0

MACTEC also conducted two sampling events using passive diffusion bag (PDB) samplers. On October 31, 2001, PDBs were deployed in monitoring wells QMW-3, QMW-4, QMW-5, QMW-6, and QMW-9. Groundwater samples were collected from the PDBs on November 21, 2001. PDB samplers were installed in monitoring wells QMW-1 through QMW-5, and QMW-8 through QMW-10 on April 4, 2001. Groundwater samples were collected from those PDBs on April 19, 2002.

Those domestic wells regularly sampled include Cast B-1 and B-3, Welcome RV Park, La Casa Del Rancho east and west wells, Eric's RV Repair, York, Rhoades, Parsons, Adams north and Adams south. In November 1999, samples were collected from domestic wells at the Quartzsite Post Office, former Beauty Shop (currently Mark's Family Restaurant) , and well B-4 at the Cast property. The Post Office well was shut down shortly after the November 1999 sample event, and has not been sampled since. Based on non-detectable VOC concentrations, the former Beauty Shop well was not sampled again after November 1999. Attempts were made to collect additional samples from well B-4, but that well was not pumping during subsequent sampling events. Cast wells B-1, B-2, and B-4 were shut down following the winter-spring 2001 tourist season, and were taken out of service permanently after the property facilities were connected to the municipal water supply in September 2001. The pump in the Eric's RV Repair has been inoperable since the May 2001 sampling event.

MACTEC sampled two additional domestic wells adjacent to the Site in February 2000 at the request of the property owners. VOC concentrations in those wells, located at the Poltz and Chapman residences, were not detected above laboratory reporting limits.
Groundwater samples collected from each of the monitoring wells were submitted to Del Mar

Analytical Laboratories for analysis of VOCs using U.S. EPA Method 8260B. Samples collected from domestic wells were submitted to Del Mar Analytical for analysis of VOCs using U.S. EPA Method 524.2. Groundwater sample laboratory analytical reports, laboratory quality control data, and chain of custody documentation are included in Appendix J. Groundwater sampling field notes are included in Appendix L.

A detailed discussion of groundwater monitoring results is included in Section 6.0. Further details of the monitoring results are included in MACTEC's previously submitted quarterly groundwater monitoring reports listed in the Reference section of this report.

5.3.1 Groundwater Sample Collection Procedures

5.3.1.1 Purged Groundwater Samples

Prior to sampling the monitoring wells, each well was purged using a dedicated Grundfos™ submersible pump. During purging activities, groundwater was field screened for conductivity, pH, dissolved oxygen, ORP, and temperature using a YSI Model 6820 water quality meter with a flow-through chamber. The meter was connected in line with the dedicated pump and initial field parameter readings of pH, temperature, specific conductivity, ORP and DO were recorded in the field logbook. After every 5 to 10 gallons of water had been removed, the field screening parameters were read, logged and recorded in the field logbook. Well purging continued until the field screening parameters had stabilized (i.e., no more than a 10% difference between successive readings). Field parameter measurements are included on the field logbook sheets in Appendix L. Groundwater purging rates for the monitoring wells were approximately 3 to 7 gallons per minute (gpm). Purged groundwater disposal procedures and documentation are included in Appendix I.

Groundwater samples were collected when field parameters had stabilized. All sampling was conducted using a sampling "T" valve, with water being discharged from one side of the valve into a holding tank on the MACTEC sampling trailer, while groundwater samples were collected

at slower flows from the other side of the valve.

Samples were collected in 40-milliliter glass vials preserved with hydrochloric acid. Upon groundwater sample collection, vials were capped, labeled, and stored in portable ice chests containing ice. Field personnel delivered samples directly to Del Mar Analytical, generally within 24 hours of sample collection. Chain-of-custody documentation accompanied all sample deliveries and shipments.

5.3.1.2 Domestic Wells

In general, domestic wells were purged for three to five minutes prior to sampling. The shorter purging time was used on continuously pumping wells, such as Cast wells B-1 and B-3. All of the domestic wells had dedicated pumps installed. Because of the low purge volumes required, all purge water was discharged to the ground surface adjacent to the sampled well.

Groundwater samples were collected from the domestic wells at the following locations:

- **York:** Samples were collected from the York well from a spigot located at the east side of the house, north of the wood deck that covers the well.

- **La Casa Del Rancho Restaurant:** Samples from the west well were collected from a spigot located south of the manager's residence during the May 2000 sampling event. During the Third Quarter 2000, samples from the west well were collected directly from the well casing using a new disposable bailer. Following installation of a new submersible pump by the property owner in November 2000, samples from the west well were collected from a spigot located at the wellhead. Samples collected from the east well were collected from a spigot located at the wellhead.

- **Cast:** Well B-1 was sampled by loosening a pressure fitting on the PVC piping on the east side of the well. Samples were collected from well B-3 from a spigot located at the top of the

wellhead.

- **Welcome RV Park:** The sample collected in November 1999 was taken from a spigot located outside of the well house, at the northwest corner of the building. Samples were collected from a spigot located immediately adjacent to the well in the pump house.

- **Parsons:** Samples were collected from a spigot inside a small pump house at the west end of the property.

- **Eric's RV:** Samples were collected from a spigot on the north side of a pump house located on the west end of the property.

- **Adams:** Samples from the Adams south well were collected from a spigot on the side of a pump house located on the south end of the property. Samples from the Adams north well were collected from a spigot on the east side of the main residence located on the north end of the property.

Groundwater samples were collected when it was estimated that the water lines and/or pressure tank associated with the particular system were flushed. Groundwater samples were collected at the lowest practical flow to ensure sample integrity. Upon groundwater sample collection, bottles were capped, labeled, and stored in portable ice chests containing ice. All samples from the domestic wells were delivered to Del Mar Analytical on the day of sample collection. Chain-of-custody documentation accompanied all sample deliveries and shipments.

5.3.1.3 Passive Diffusion Bag (PDB) Samples

Pilot testing of the PDB sampling methodology was conducted during two quarterly monitoring events to assess the applicability of this sampling method at the Tyson Wash Site. A string of samplers was deployed in each of the selected wells to develop vertical profiles of contaminant concentration gradients through the shallow aquifer, and to determine differences in analytical

results between the PDB samples and historical purged samples. Comparison of the results will allow for an assessment of the viability of using the lower cost PDB sampling methodology for long term monitoring at the Site.

The PDB samplers consist of polyethylene tubes filled with 350 milliliters (ml) of deionized water and hung on a rope at predetermined depths within the screened interval of each well. The PDBs require a standard minimum deployment time of 14 days to insure equilibration between well water and formation water.

On October 31, 2001, PDBs were installed in monitoring wells QMW-3, QMW-4, QMW-5, QMW-6, and QMW-9. The distribution of PDB samplers used during this sampling event was limited to the upper 9 to 16 feet of the water column because the dedicated pumps prevented the deployment of samplers across the entire screened interval. The PDB samplers were suspended at the following depths, as measured from the mid-point of each sampler:

- Well QMW-3: 44.0 ft, 48.0 ft, 52.0 ft, 56.0 ft, and 60.0 ft below the top of casing.
- Well QMW-4: 47.2 ft, 50.2 ft, 53.2 ft, and 56.2 ft below the top of casing.
- Well QMW-5: 44.5 ft, 47.5 ft, 50.5 ft, and 53.5 ft below the top of casing.
- Well QMW-6: 44.0 ft, 48.0 ft, 52.0 ft, 56.0 ft, and 60.0 ft below the top of casing.
- Well QMW-9: 51.0 ft, 54.0 ft, 57.0 ft, and 60.0 ft below the top of casing.

On November 20, 2001, each of the PDB samplers was removed from the wells. The content of each sampler was carefully poured into laboratory-supplied 40-ml glass vials preserved with hydrochloric acid. The remaining water was discharged to the ground surface adjacent to the well. Each vial was overfilled to produce a meniscus, capped in a manner to eliminate headspace, labeled, and stored in a portable ice chest containing ice. The samples were delivered to Del Mar Analytical on the day of sample collection. Chain-of-custody documentation accompanied all sample deliveries and shipments.

A second PDB sampling event was conducted following the scheduled First Quarter 2002 purged groundwater sampling event. On April 4, 2002 the dedicated submersible pumps were removed from wells QMW-1 through QMW-5, and QMW-8 through QMW-10. PDB samplers were deployed in those wells, and in well OB-3, located approximately 30 feet south of monitoring well QMW-7. In order to investigate the vertical distribution of contaminants in the wells, four to seven PDBs were attached in vertical alignment to nylon cord and lowered into each well. The PDB samplers were suspended at the following depths:

- Well OB-3: 48.8', 53.8', 58.8', 63.8', and 68.8' below the top of casing (TOC);
- Well QMW-1: 48' 53' 58', 63', and 68' below TOC;
- Well QMW-2: 58.2', 63.2', 68.2', and 73.2' below TOC;
- Well QMW-3: 44.4' 50.4' 56.4', 62.9', 67.9', 72.9', and 77.9' below TOC;
- Well QMW-4: 50.3', 53.3', 56.3', 59.3', and 63.3' below TOC;
- Well QMW-5: 50.1', 53.1', 56.1', and 58.7', below TOC;
- Well QMW-8: 57.9', 62.9', 67.9', and 72.9' below TOC;
- Well QMW-9: 48.6', 53.6', 58.6', 63.6', and 68.6' below TOC;
- Well QMW-10: 57.1', 62.1', 67.1', and 72.1'

On April 19, 2002, the PDB samplers were retrieved and groundwater samples were collected following the previously described procedures.

5.3.2 Groundwater Sampling QA/QC

During each sampling event, one blind duplicate groundwater sample was collected from a chosen monitoring well, and was labeled as well QMW-A. The purpose of the duplicate sample was to assess laboratory precision. Duplicate samples were collected using the same sampling procedures as previously described, and were analyzed for VOCs using EPA method 8260B.

On August 9, 2000 a duplicate sample, designated as well QMW-A, was collected from well QMW-1. However, because the samples were not logged in properly at the laboratory, and VOC analyses were not conducted on samples QMW-1, QMW-3, QMW-4, QMW-5, QMW-6, and QMW-9, results from duplicate sample QMW-A were reported as well QMW-1.

In addition to the duplicate samples, one laboratory-prepared trip blank accompanied the VOC groundwater samples in the field. Each trip blank consisted of organic-free reagent water kept with the field sample containers from the time it left the laboratory until it was returned to the laboratory. The purpose of trip blanks is to determine whether samples are being contaminated during transit or sample collection. There are no specific procedures for collecting the trip blank since it is prepared in the analytical laboratory. Equipment rinsate blanks were not collected because the groundwater samples were collected using dedicated pumps.

During each of the PDB sampling events, one sample was collected from the reagent grade deionized water used during sampler deployment. One blind duplicate groundwater sample was collected on April 4, 2002 from the PDB installed in well QMW-3 at a depth of 77.9 ft. The duplicate sample was labeled as QMW-A. One laboratory-prepared trip blank accompanied the PDB groundwater samples in the field during each sampling event.

6.0 DATA ANALYSIS

6.1 DISTRIBUTION OF CONTAMINANTS

The following sections describe the distribution of contaminants in both soil and groundwater. The analysis is based on laboratory analytical results from 128 soil samples, 87 soil vapor samples, and 361 groundwater samples. This includes samples collected during the RI as well as those samples collected prior to the RI for which there is adequate documentation. The primary contaminant reported in the samples is PCE, which was detected in 3% of the soil samples, 67% of the soil vapor samples, and 57% of the groundwater samples. Fifty percent (179) of the groundwater samples collected during the investigation contained PCE at concentrations exceeding the ADEQ AWQS of 5 µg/l.

TCE was detected in 2% of the soil vapor samples and 31% of the groundwater samples. TCE was not detected in any soil samples. TCE exceeded the AWQS of 5 µg/l in 15 groundwater samples, or 4% of the total groundwater samples collected. The next most common contaminant is chloroform, which was reported in 8% of the soil vapor samples and 23.5% of the groundwater samples. Chloroform was not detected in any soil samples.

6.1.1 Soil Contamination

6.1.1.1 Distribution of PCE

During the investigations, 42 soil samples were collected at the Welcome RV Park at depths between 5 feet and 70 feet bgs. Sixteen soil samples were collected at the Cast property between depths of 5 feet and 70 feet bgs. Thirty-one soil samples were collected at the former Hi-Ali Motel at depths ranging from 6 feet to 45 feet bgs. Thirty additional soil samples were collected from temporary and permanent monitoring wells located on Cowell Street or Washington Avenue. Nine soil samples were collected from drill cuttings for disposal characterization.

The only contaminant detected in the soil samples was PCE, which was detected in four samples

collected at the Welcome RV Park. Those four soil samples were collected at depths of 5.5 to 12 feet bgs adjacent to the two septic tanks on the Welcome RV Park property. PCE concentrations ranged from 0.01 µg/kg to 0.2 µg/kg. These concentrations are significantly below the ADEQ Residential Soil Remediation Level of 53,000 µg/kg for PCE in soil.

The distribution of PCE in soil vapor samples collected during August 2000 is shown on Figure 11. The concentration contours represent samples collected at depths of 8 to 10 feet bgs. The contours indicate two areas where concentrations exceeded 100 ppb/v.

At the Former Hi-Ali Motel, PCE was reported in boring SV-7, located approximately 15 feet north of the former motel building, at a concentration of 106 ppb/v. Concentrations decrease to the southwest, or hydraulically upgradient. The highest PCE concentration previously reported was 77 ppb/v near the southeast corner of the property. One soil vapor sample collected near the southeast corner of the property in August 2000 contained a PCE concentration of 15 ppb/v. In general, there was good correlation between results of the August 2000 and earlier soil vapor surveys in borings drilled near the center of the property, where PCE concentrations ranged from non-detectable to 30 ppb/v. However, borings were not drilled at the same locations in August 2000 as in the earlier surveys, due to the uncertainty regarding potential source locations.

A second area of concentrations exceeding 100 ppb/v is located at the Welcome RV Park property, near the septic tank on the west side of the residence. The highest PCE concentration reported at this location was 151 ppb/v, which is nearly an order of magnitude lower than concentrations previously reported by the ADEQ in samples collected at similar depths and in the same general locations.

As indicated in the discussion of the geophysical survey results, the septic tanks and leach fields were likely dry during the August 2000 soil vapor sampling event. The previous ADEQ soil vapor sampling event was conducted during late March and early April 1998. It is likely that

during the ADEQ March-April 1998 sampling event there was water in the septic tanks and leach fields, and that much, if not all, of that water was groundwater that had been pumped from the domestic well on the property. The higher PCE vapor concentrations noted in the earlier samples could be due to volatilization from the impacted water remaining in the tanks/leach fields.

Overall, soil vapor sample results suggest the location of one and possibly two potential sources. During both the August 2000 and previous soil vapor surveys, the highest concentrations have been reported at the Welcome RV Park near the east or west septic tank. Concentrations generally decrease away from this area. Hydraulically downgradient of the Welcome RV Park, PCE concentrations at the Cast property did not exceed 5.2 ppb/v in shallow soil vapor samples collected at suspected source locations. Hydraulically upgradient, PCE soil vapor concentrations were generally lower at the Former H1-Ali Motel. However, results from the August 2000 soil vapor sampling event suggest a possible additional source near the former motel building, with PCE concentrations rapidly decreasing upgradient from that potential source area.

6.1.1.2 Distribution of Other Contaminants

Tables 3 and 4 list all of the VOCs detected in soil vapor samples. In addition to PCE, the most commonly detected compounds were benzene and toluene, which were detected in 13 samples each, and acetone, which was detected in 10 samples. All of these detections were reported in samples collected during the March 1998 ADEQ soil vapor sampling event.

Benzene and toluene, as well as ethylbenzene, which was reported in 4 samples, and xylenes, which were detected in 5 samples, are commonly associated with petroleum hydrocarbon releases. Benzene and toluene were reported in soil vapor samples at the Welcome RV Park at concentrations ranging from 4.5 ppb/v to 17 ppb/v. At the Former Hi-Ali Motel, concentrations of those compounds ranged from 0.69 to 15 ppb/v.

Benzene and toluene concentrations were highest in samples collected at the Cast property,

where maximum concentrations were 130 ppb/v and 120 ppb/v, respectively. These higher concentrations could be due to the fact that the Cast property is closer to the source of the petroleum release at the Quik Chek Market. This is further supported by the occurrence in soil vapor samples TY19SV and TY20SV of 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene, two other compounds commonly associated with gasoline releases.

Given the proximity of the Site to the Quik Chek Market, and the known groundwater flow direction, detection of these compounds could indicate migration of the petroleum hydrocarbon plume toward the Site. However, benzene and toluene, which are typically detected at the leading edge of a petroleum hydrocarbon plume, have not been reported in any groundwater samples collected to date within the Site. It should also be noted that both benzene and toluene were detected in the soil vapor Field Blank sample collected by the ADEQ on March 26, 1998, which creates some uncertainty as to the validity of the reported detections.

Other compounds commonly used as solvents, such as acetone, methylene chloride, 2-butanone, and chloroethane, were also reported in soil vapor samples. Acetone was reported in boring TY19SV at the Cast property at a concentration of 510 ppb/v. Concentrations of the remaining constituents did not exceed 17 ppb/v.

6.1.2 Groundwater Contamination

The following sections describe distribution of VOCs in groundwater at the Site. Laboratory analytical results of purged groundwater samples collected from monitoring wells QMW-1 through QMW-10 and Site domestic wells are included on Tables 1 and 2. Table 6 presents results of PDB sample analyses. VOC concentration vs time graphs for those wells having detectable PCE concentrations are shown on Figures 12 through 27.

6.1.2.1 Distribution of PCE

Results indicate that PCE concentrations exceeding the ADEQ AWQS persist in monitoring

wells QMW-1, QMW-3, QMW-4, QMW-5 and QMW-7, and in domestic wells at the Welcome RV Park, Kauffman and Rhoades properties, and Cast well B-1. PCE concentrations exceeding the AWQS have also been reported in the Quartzsite Post Office well, which was shut down in February 2000, in Cast well B-2, which was last sampled in May 1999, and in monitoring well QMW-8 (August 2001). At the Former Hi-Ali Motel, PCE concentrations exceeding the AWQS were reported in samples collected in May 1996 from two supply wells, and more recently, in one temporary well located immediately north of the former motel building. The greatest PCE concentrations have been reported at the Welcome RV Park and monitoring wells QMW-3 and QMW-5.

The maximum PCE concentration reported at the Site (200 µg/l) was detected in the Welcome RV Park domestic well in November 1995. Concentrations in that well decreased to 100 µg/l in November 2000, and 120 µg/l in December 2001. With one exception, PCE concentrations have exceeded 100 µg/l in the Welcome RV Park well during each sampling event. PCE was reported at 74 µg/l (79 µg/l in a sample duplicate) in November 1999. However, that sample was collected from a spigot located outside of the well house, on the outlet side of the pressure tank, and is not considered a valid result.

The greatest concentration reported in a monitoring well was 180 µg/l in well QMW-5 in August 1998. A high concentration of 160 µg/l was reported in well QMW-3 in October 1997 and November 2001. PCE concentrations have ranged from 34 to 97 µg/l in well QMW-1, from 29 to 57 µg/l in well QMW-4, and from 7.3 to 12 µg/l in well QMW-7.

With the exception of the Welcome RV Park well, the highest PCE concentration reported in a domestic well is 42 µg/l, which was detected in Cast well B-2 in May 1999. Elsewhere, PCE concentrations have ranged from 1.4 to 12 µg/l in well B-1, from 4.4 to 10 µg/l at the Rhoades property, from 11 to 29 µg/l in the Kauffman well, and from 4 to 10 µg/l in the La Casa Del Rancho restaurant west well. A PCE concentration of 21 µg/l was detected in the Post Office

well prior to its being shut down in February 2000.

PCE concentrations above laboratory reporting limits, but below the ADEQ AWQS of 5 µg/l, have been reported in purged samples collected from monitoring wells QMW-8, QMW-9, QMW-10, and domestic wells B-4 at the Cast property, the Adams north and south wells, La Casa Del Rancho Restaurant east, and Eric's RV Repair.

PCE concentrations measured during both PDB sampling events were significantly lower than those concentrations reported in the purged groundwater samples. PCE concentrations were also generally lower in samples collected on April 19, 2002 than in samples collected from diffusion bags in November 2001 (Figures 22 through 27).

The maximum PCE concentrations of the multiple samples collected from each well were:

- 1.9 µg/l in well OB-3;
- 35 µg/l in well QMW-1;
- 94 µg/l in well QMW-3;
- 20 µg/l in well QMW-4;
- 20 µg/l in well QMW-5;
- 2.7 µg/l in well QMW-8;
- <1 µg/l in wells QMW-2, QMW-6, QMW-9, and QMW-10.

Analytical results from the November 2001 sampling event indicated that PCE concentrations generally increased with depth in wells QMW-3 and QMW-5 (Table 6). Results from April 2002 did not indicate a significant increase in contaminant concentrations with depth. Although some stratification was noted in wells QMW-1, QMW-3, and QMW-5 during that sampling event, the concentrations stabilized or decreased near the bottom of the sampled zone, suggesting attenuation of contaminant concentrations in the confining clay layer.

The higher VOC concentrations reported in the purged samples might be due to those samples being collected from groundwater drawn into the respective wells from zones of higher concentrations. The purged samples may also contain clay particles, which could result in higher concentrations due to adsorption of contaminants onto the clay.

6.1.2.2 Distribution of TCE

TCE concentrations exceeding the AWQS of 5 µg/l were reported periodically in well QMW-3, where the high concentration of 10 µg/l was detected in July 1997. TCE most recently exceeded the AWQS in well QMW-3 in March 2002, with a concentration of 5.2 µg/l.

TCE concentrations have also exceeded the AWQS in the Welcome RV Park well. The highest TCE concentration in that well was 7 µg/l reported in November 1995. A TCE concentration of 5.5 µg/l was reported in the most recent sample collected from that well (December 2001).

TCE has also been reported at concentrations below the AWQS in wells QMW-1, QMW-4, and QMW-5, and in Cast wells B-1 and B-2.

Analytical results for TCE concentrations in PDB samples generally confirmed the purged sample results. The greatest TCE concentrations were reported in wells QMW-1 and QMW-3. TCE concentrations in those wells ranged from non-detectable to 4.8 µg/l (Table 6). TCE concentrations ranging from non-detectable to 1.6 µg/l were reported in PDB samples collected from wells QMW-4 and QMW-5. TCE did not exceed the laboratory reporting limit of 1 µg/l in wells OB-3, QMW-2, QMW-6, QMW-8, QMW-9, and QMW-10.

6.1.2.3 Distribution of Other Contaminants

In addition to PCE and TCE, other groundwater contaminants reported during the RI include 1,1-dichloroethene (1,1-DCE), *cis*-1,2-DCE, isopropylbenzene, dichlorodifluoromethane, dibromochloromethane, bromoform, methylene chloride, and chloroform. Detectable

concentrations of these compounds ranged from 0.45 µg/l to 4.3 µg/l. All of these concentrations are below ADEQ AWQSs.

At Eric's RV Repair, 1,1-DCE and isopropylbenzene were detected at 3 µg/l and 1.7 µg/l, respectively in February 2000. This occurrence could be due to the property's proximity to the petroleum hydrocarbon plume at the Quik Chek Market.

The occurrence of *cis*-1,2-DCE, which has been reported only in well QMW-3, may indicate the biodegradation of TCE, which can degrade under either anaerobic or aerobic conditions. *Cis*-1,2-DCE concentrations have not exceeded 1.6 µg/l, which is below the AWQS of 70 µg/l.

Chloroform, which was detected in 85 groundwater samples, can be formed as a by-product of chlorinated water in public water supply systems and municipal sewer systems, and is also formed by the aqueous reaction of chlorine with organic matter (i.e., sediments and soil). Chloroform can also be formed through biological processes in septic tanks, which is the most likely reason for its occurrence in site wells.

Chloroform is also a degradation product of carbon tetrachloride. However, since carbon tetrachloride has not been detected at the site, there is little evidence to suggest that the chloroform detected in the wells is the result of carbon tetrachloride degradation. In addition, strongly anaerobic/reducing conditions are required for dechlorination of carbon tetrachloride to chloroform. Since aquifer conditions aren't strongly reducing, it is unlikely that the chloroform is derived from carbon tetrachloride.

6.1.2.4 Concentration Trends

As the VOC concentration vs time graphs (Figures 12 through 21) indicate, PCE concentrations have generally declined with time in monitoring wells QMW-1, QMW-5, and the Welcome RV Park domestic well, all of which are located near the suspected source area. Throughout the

course of the investigation, those wells have contained some of the highest PCE concentrations. The concentration decline is most noticeable in well QMW-5, where PCE concentrations have declined from 180 µg/l in August 1998, to 34 µg/l in October 2000, and 31 µg/l in March 2002. PCE concentrations in well QMW-1 decreased from 97 µg/l in July 1997 to 51 µg/l in March 2002. PCE concentrations in the Welcome RV Park domestic well declined from 200 µg/l in November 1995 to 100 µg/l in November 2000, and have ranged from 110 µg/l to 130 µg/l since that time.

Both PCE and TCE have generally increased in well QMW-3 since September 2000. PCE concentrations increased from 80 µg/l in September 2000 to 160 µg/l in November 2001 and 140 µg/l in March 2002. VOC concentrations have fluctuated or remained relatively stable in wells QMW-4, QMW-7, and QMW-8.

PCE concentrations have increased in domestic wells at the Rhoades residence, Cast wells B-1 and B-2, and the La Casa Del Rancho Restaurant west well. In the Rhoades west well, PCE was reported at 4.9 µg/l in October 1997. The PCE concentration first exceeded the AWQS in that well in February 1999, with a concentration of 5.1 µg/l. PCE decreased to 4.4 µg/l in May 1999, but has exceeded the AWQS during each sampling event since that date. The greatest PCE concentration reported in the Rhoades west well was 10 µg/l in August 2001. PCE concentrations in Cast well B-1 increased from 1.4 µg/l in August 1995 to 12 µg/l in August 2000, before decreasing to 8.2 µg/l in May 2001. In well B-2, PCE increased from a low measured concentration of 1.3 µg/l in July 1997 to 42 µg/l in the most recent sample collected from that well (May 1999).

PCE concentrations exceeding the laboratory reporting limit were first reported in well QMW-9 in August 2001 (1.5 µg/l), and in well QMW-10 in November 2001 (1.6 µg/l). PCE was also reported for the first time during March 2002 in the two domestic wells at the Adams property near the west boundary of the Site. The Adams north well contained a PCE concentration of 0.64

µg/l, and the Adams south well contained PCE at 0.61 µg/l.

These concentration trends indicate dispersion of the contaminants. In general, PCE concentrations in wells near and upgradient of the suspected source area at the Welcome RV Park have decreased, while concentrations in wells near the margins of the plume have increased. At well QMW-4, which is essentially mid-way between the suspected source area at the Welcome RV Park and the northern plume boundary, PCE concentrations have fluctuated. The concentration fluctuations in well QMW-3 may be due to its location near the suspected leach field on the west side of the Welcome RV Park. Although the concentration trend in this well does not correlate well with seasonal use at the property, the slight groundwater mounding at this location further suggests an effect from the leach field.

6.1.2.5 Groundwater Sample Data Validation

Upon receipt of the groundwater sample laboratory analyses, MACTEC reviewed laboratory reports and laboratory quality control data for the completion of required measurements including parameter results, sample holding time, method detection limits, and dilution factors.

MACTEC performed data assessment/validation on the groundwater VOC analytical results received from Del Mar Analytical Laboratories. The primary goal of the data assessment/validation program was to ensure that the data reported during the investigation have undergone appropriate QC checks and meet appropriate method acceptance criteria. This assessment also verifies the laboratory's QC performance of all data assessment calculations and determines whether there were any deviations from established method-specific laboratory protocols. The external data assessment was based on the following assessment criteria: Accuracy, Sensitivity, Precision, Representativeness, and Completeness. The results of the data assessment/validation for selected VOCs are presented in Tables 7 through 15.

MACTEC's data validation review indicated that, with the exception of samples collected from

wells QMW-1, QMW-3, QMW-4, QMW-5, QMW-6, and QMW-9 on August 9, 2000, all other groundwater samples collected during the monitoring program were properly preserved, collected, and met appropriate holding times. As previously indicated, the samples collected on August 9, 2000 were not logged in properly at the laboratory, and VOC analyses were not conducted on the samples listed above. Those wells were re-sampled on September 8, 2000. In addition, all samples were analyzed with appropriate standard analytical methods required in the QAPP, and appropriate method detection limits were met.

During the Second Quarter 2000 sampling event, the sample collected from the Welcome RV Park domestic well on April 3 contained methylene chloride at a concentration of 0.5 µg/l. Methylene chloride was also detected in the laboratory Method Blank at a concentration of 0.8 µg/l. Therefore, the validity of the result for this constituent is questionable. For the domestic well samples collected on May 12, 2000, methylene chloride recovery was outside of acceptable limits in the Method Blank sample. However, since methylene chloride was not detected in any of the wells sampled on that date, the presence of this constituent in the Method Blank did not have an impact on the representativeness of the data. All other assessment criteria were within acceptable limits on this date.

During the First Quarter 2001, methylene chloride was detected in the laboratory method blank above reportable concentrations. This was noted on the laboratory report as probable laboratory contamination because it shows up in the trip blank sample.

For samples collected during the August/September 2001 monitoring event, PCE was not reported in the initial sample run of well QMW-3 due to an unspecified laboratory Quality Control issue. During the second sample run, the sample was diluted and the laboratory reporting limit was raised to 4 µg/l, compared to the Method Detection Limit of 2 µg/l. PCE recovery in the Method 8260B Matrix Spike Duplicate sample was low. However, recovery from the Laboratory Control Sample was within acceptable limits.

7.0 HYDROGEOLOGY

Contaminant migration at the Site occurs primarily via groundwater transport in the subsurface. Important hydrologic properties affecting contaminant transport include the spatial distribution and magnitude of hydraulic conductivity, the saturated thickness of the aquifer, groundwater gradients, and the effect that domestic wells have on the groundwater flow regime.

7.1 SITE STRATIGRAPHY

Geologic cross-sections transecting the Site are included on Figures 6 and 7. As the cross-sections indicate, subsurface soils consist of two main alluvial units. From the ground surface to a depth ranging from 60 to 70 feet bgs, soils consist of interbedded layers of moderately to well cemented gravel, sand, silt, and clay. The upper 20 to 25 feet of that unit generally contain well cemented silty sand and silty gravel. A hard calichified lens occurs at a depth ranging from 8 to 12 feet bgs. Below 20 to 25 feet, the upper unit consists primarily of interbedded layers of silty clay to silty sand.

Below a depth ranging from 60 to 70 feet across the Site, soils consist of silty clay to clay, with the estimated clay percentage ranging from 50% to nearly 100%. The clay layer was encountered in all borings that extended to a depth of at least 70 feet bgs. The estimated depth to the top of the clay layer within the Site is shown on Figure 5. In well QMW-10, the clay layer was encountered at a depth of approximately 68 feet bgs. Continuous core soil samples collected during the drilling of monitoring well QMW-10 indicate the clay layer extends to a depth of at least 140 feet at the Site, and appears to correlate with the confining layer noted by Metzger and others (1973). In well QMW-10, a noticeable increase in soil moisture was noted at a depth of approximately 62 feet. Between approximately 66 and 68 feet, a saturated zone was encountered. Below this, the soil appeared to dry out rapidly.

Soil samples collected from well QMW-10 were analyzed for moisture content, dry bulk density,

specific gravity, and porosity. Results are listed in Table 16. The highest bulk density values are indicated in the upper 30 feet of soil, which correlates with the greater degree of cementation and caliche noted in those samples. Porosity generally increases with depth, reflecting the increased clay content of the soils. Soil TOC values (percent total organic carbon) are consistent throughout the boring, with values ranging from 0.02% to 0.06%. As expected, the lowest moisture values were reported in soil samples collected in the vadose zone, with the driest samples coming from the upper 30 feet of soil. Below the water table, moisture content increases, and is generally greater than 25%. The moisture content value for the soil sample collected at a depth of 67 feet bgs does not reflect field observations. Field observations indicated that the 67-foot sample was saturated, and soil samples dried out noticeably below that depth. The calculated moisture content for the sample collected at a depth of 67 feet bgs is 16.8%, which is the lowest calculated moisture content below the water table. The reason for the difference is unknown, although moisture may have been lost from this sample during transport to the laboratory.

7.2 AQUIFER HYDRAULIC PROPERTIES

7.2.1 Aquifer Pumping Tests

Two aquifer pumping tests were conducted for the purpose of estimating aquifer hydraulic properties, including hydraulic conductivity and transmissivity. Although aquifer hydrogeologic parameters can be measured in the laboratory, laboratory testing provides values only at a given point in space, whereas field pumping tests provide measurements, which are averaged over a large area of the aquifer. Results from field testing are thus more useful, and were used here to refine the SCM, and to construct the groundwater model described in Section 8.0. Test results will also aid in the assessment of remedial technologies such as pump and treat during the Feasibility Study phase.

7.2.1.1 Test Procedures

Monitoring Wells QMW-6 and QMW-7 were selected for aquifer testing. The wells were chosen because of the low to non-detectable VOC concentrations in the wells. Well QMW-6 is located up gradient of the VOC plume, within the ADOT right of way, and well QMW-7 is located on Cowell Street, near the west margin of the plume. To increase the maximum pumping capacity in each well, MACTEC installed Grundfos™ model 10S03-6 pump heads in the two wells. The pump heads, when added to the previously installed SP4 pumps, increase pumping rates to a maximum of 14 gpm at 50 feet of head.

The aquifer tests were conducted by pumping groundwater from wells QMW-6 and QMW-7, and measuring drawdown and recovery in the pumping wells and adjacent observation wells. Two observation wells were used to monitor drawdown and recovery during the well QMW-6 pump test. Well OB-4 is located approximately 26 feet southwest of well QMW-6. Well OB-5 is located 16 feet southeast of well QMW-6. Three observation wells were used during the aquifer test conducted at well QMW-7. Well OB-1 is situated approximately 16 feet east of well QMW-7; well OB-2 is approximately 32 feet west of well QMW-7; well OB-3 is located approximately 30 feet south of well QMW-7. During the aquifer tests, a "T" discharge valve was installed at the wellhead to facilitate simultaneous groundwater pumping and sampling. Troll™ SP4000 data loggers were installed in both pumping wells and all observation wells.

For each aquifer test well, a step-drawdown test was first conducted to determine drawdown in the well for successively increasing flow rates. Data collected during the step-drawdown tests was used to determine the optimum discharge rate for the subsequent constant rate aquifer tests. Upon completion of each step-drawdown test, the test well was allowed to recover overnight prior to starting the constant rate aquifer test. During the actual tests, the greatest consistent pumping rate obtained was 10 gpm.

7.2.1.2 Aquifer Test Results

Drawdown and recovery data collected during the constant-rate tests were analyzed using the aquifer test solution software AQTESOLV™ (Duffield, 1995) as applied to the Jacob-Cooper, Theis, and Neuman methods. An assumed aquifer thickness of 25 feet, which is the approximate average water column in the test wells, was used to complete the data reduction. During the constant rate tests, maximum drawdown was 11.5 feet in well QMW-6, and 14.6 feet in well QMW-7. Drawdown recorded in the observation wells ranged from approximately 0.9 feet in well OB-3 to 1.87 feet in well OB-1.

Results from the pumping test indicated a minimum radius of influence of approximately 26 feet around well QMW-6 and 32 feet around well QMW-7. The radius of influence is the maximum distance from the pumping well at which a measurable water level decrease is observed. Therefore, the radius of influence only refers to the distance at which a change in water level due to pumping is observed. By contrast, the capture zone of a well refers to the area surrounding a pumping well from which groundwater is pulled into, or "captured" by a well. The capture zone is dependent on the groundwater hydraulic gradient, and is generally smaller than the radius of influence. The capture zone is also greatest up gradient, and smallest down gradient, from the pumping well, because the groundwater extraction must counteract the natural flow of water away from the well in the down gradient direction.

Results of hydraulic conductivity calculations from pumping wells QMW-6 and QMW-7 indicated values ranging from 9.9×10^{-4} centimeters per second (cm/s) to 2.2×10^{-3} cm/s. Values calculated from observation wells were slightly higher, and ranged from 6.6×10^{-3} to 1×10^{-2} cm/s. This is to be expected, given that the stress placed on the pumping wells is greater than that on the observation wells. The calculated hydraulic conductivity values correlate with those commonly reported in fine grained sediments. Complete aquifer test data and the AQTESOLV™ computer printouts are included in Appendix N.

7.3 GROUNDWATER FLOW CONDITIONS

7.3.1 Depth to Groundwater Measurements

In an effort to better understand the groundwater flow regime and the effect that the domestic wells have on Site groundwater conditions, the dataloggers in the monitoring wells were initially set to collect groundwater levels at two-minute intervals. After two quarters of measurements, during which the groundwater flow direction and gradient remained relatively unchanged, the dataloggers were reset to collect measurements at ten minute intervals.

Depth to groundwater during the period May 2000 through March 2002 ranged from approximately 41 to 54 feet below the tops of the individual well casings (Table 5). Depth to groundwater was deepest in wells on the east and northeast side of the Site (QMW-2, QMW-9, and QMW-10), and shallowest in upgradient well QMW-6. A groundwater elevation hydrograph depicting the change in the groundwater table elevation between May 2000 and March 2002 is included on Figure 28. Hydrographs of individual wells are included in Appendix O.

Seasonal changes in the water table elevation appear to be related to the pumping of groundwater from the shallow aquifer by the domestic wells. Between May and September 2000 the water table, as measured in monitoring wells QMW-1 through QMW-9, generally increased or was relatively stable. The greatest change in the water table was noted in well QMW-9, in which the water table increased approximately 3 feet. Beginning in mid-October 2000, the groundwater table elevation decreased through March 2001, corresponding to increased pumping. The greatest decrease in the water table elevation was noted in wells QMW-2 and QMW-9, where the decline ranged from approximately 2 to 3 feet. The seasonal trend continued in April and May 2001, when the water table decline ceased and elevations either stabilized or began to rise. This response corresponded to a decrease in water usage as the Town's population quickly declined near the end of March and early April.

As was the case during 2000, the groundwater table elevation remained relatively stable in all

monitoring wells except wells QMW-2 and QMW-9 during the summer months and into the Third Quarter of 2001. The water table elevation increased in wells QMW-2 and QMW-9 by 1.45 feet and 2.29 feet, respectively during this time period. This response was likely due to the cessation of pumping from Cast well B-1 and decreased seasonal pumping in Cast wells B-2 and B-4.

A change in the seasonal groundwater flow regime was noted beginning with the Fourth Quarter 2001. In contrast to the groundwater conditions measured during the same time period one year earlier, the groundwater elevation increased in all wells except well QMW-6. The greatest difference in the elevation change was observed in well QMW-2, which increased 1.17 ft during the Fourth Quarter 2001, compared to a decline of 0.76 ft during the same period in 2000 (a relative increase of 1.93 ft). In September 2001, the Cast domestic wells were shut down because the property owner began using the newly installed municipal water supply. The resulting decreased pumping during the Fourth Quarter 2001 appears to be responsible for the change from a measured water table decline during the Fourth Quarter 2000 to the increased water levels observed during the Fourth Quarter 2001. Data collected during the First Quarter 2002 indicate a continued rebound of the water table in wells QMW-1 through QMW-4, and QMW-8 through QMW-10. Slight declines were measured in wells QMW-5 (-0.4 ft), QMW-6 (-0.14 ft), and QMW-7 (-0.12 ft). Wells QMW-5, QMW-6, and QMW-7 are located farthest from the domestic wells at the Site and are least affected by the domestic well pumping regime.

With the exception of well QMW-9, water level fluctuations in individual wells were not significant. As indicated on the hydrographs, water levels fluctuations in well QMW-9 were much greater than in any other monitoring wells during periods of both rising and declining water levels. This appears to be a result of the well's location near wells B-1, B-2, and B-4 on the Cast property, and the domestic wells at the La Casa Del Rancho Restaurant. However, the variations in water levels in this well did not appear to have any overall effect on groundwater flow.

7.3.2 Groundwater Flow and Gradient

Groundwater flow appears to be controlled by the pumping regimes of the numerous domestic wells in the area. Through September 2001 the primary control on groundwater flow across the Site appeared to be the three shallow wells on the Cast property, and possibly the two domestic wells at the La Casa Del Rancho Restaurant. This effect can be seen not only in the northeast flow direction, but also in the increased gradient across the site. The groundwater gradient across the Site through September 2001 increased from approximately 0.01 (1 foot per 100 linear feet) upgradient of wells QMW-2 and QMW-4, to 0.05 (5 feet per 100 linear feet) downgradient of well QMW-4. Quarterly groundwater elevation contour maps for May 2000 through March 2002 are included on Figures 29 through 36.

A comparison of groundwater elevation contours between October and December 2001 further suggests a change in the groundwater flow regime due to the decreased pumping from the shallow domestic wells. As indicated on Figure 35, the groundwater flow direction in the eastern half of the Site appeared to change slightly during the Fourth Quarter 2001, with the flow direction becoming more northerly each month. Measurements collected between January and April 2002 indicate a continued shift of the groundwater flow toward the north (Figure 36).

As shown on Figures 29 through 36, groundwater flow contours indicate a noticeable groundwater mound at well QMW-3. This may be due to a relatively greater localized recharge at the Welcome RV Park property. Although the geophysical survey did not identify the locations of the septic tank drain fields at this property, a drain field reportedly exists near the west boundary of the property, in the vicinity of well QMW-3. Historical use of the septic tanks during the winter months may explain the groundwater mound noted in well QMW-3.

Regional groundwater flow in the area appears to have a strong northeast flow component due to the many domestic wells located outside of the immediate area. According to the ADWR, there are currently 544 registered wells within an approximate ½ mile radius of the Site, of which 471

are completed in the shallow aquifer. Most of these wells are located north or northeast of the Site.

The effect of the domestic wells can also be seen in the shape of the contaminated groundwater plume (Figure 4). Lateral dispersion is greater than would be expected in a contaminated groundwater plume having such a consistent groundwater flow direction. Dispersion of the plume is exaggerated due to the variable pumping regimes of the domestic wells. At any given time, a well in one area of the Site may be pumping, while at the same time, other wells may be shut off.

A review of Site soil boring logs and geotechnical soil sample analyses indicates that the shallow aquifer is perched on a relatively impermeable clay layer. As previously discussed, this clay layer occurs at a depth of between 60 and 70 feet across the site. Depth to the top of the clay layer is shallowest near the south part of the Welcome RV Park, between monitoring wells QMW-2 and QMW-3 (Figure 5), and deepest near monitoring well QMW-6, located near the south boundary of the Site.

Results from the aquifer pumping tests indicate a hydraulic conductivity ranging from 1×10^{-2} to 9.9×10^{-4} in the saturated zone above the clay layer. Laboratory hydraulic conductivity measurements conducted on soil samples from borings QMW-1, QMW-2, and QMW-3 indicate much lower values in the clay layer below a depth of 60 feet bgs (see Appendix E). The laboratory measured values ranged from 5.2×10^{-7} to 2.8×10^{-10} in the samples collected from the clay layer. This suggests that horizontal groundwater flow in the shallow aquifer occurs primarily in the upper saturated zone above the clay layer.

As indicated on the geologic cross-sections (Figures 6 and 7), thickness of the saturated sediments above the clay layer decreases from south to north. At wells QMW-6 and QMW-7, where the pump tests were conducted, saturated thickness is 25 feet or more. At monitoring well

QMW-10, the saturated thickness may be 10 feet or less. Assuming consistent hydraulic conductivity across the site, transmissivity is likely to be much lower in the north part of the Site. During the development of well QMW-10 in March 2001, the well was pumped dry twice. Well QMW-4 has also been pumped dry during past groundwater purging and sampling events, suggesting either lower hydraulic conductivity or a relatively thinner saturated zone.

To date, no data has been obtained regarding vertical hydraulic conductivity. However, vertical conductivity in clay layers is typically insignificant relative to horizontal conductivity.

8.0 CONTAMINANT FATE AND TRANSPORT

This section describes the mechanisms involved in fate and transport of groundwater contaminants at the Site, and results of groundwater modeling. The contaminant most frequently identified in the study area groundwater is PCE. The mechanisms involved in fate and transport of contaminants are the same mechanisms that control natural attenuation of contaminants. There are two main types of processes that control the fate and transport and natural attenuation of contaminants. These include physical and biological processes in the aquifer that act to reduce contaminant concentrations and limit the extent of migration of contaminants. Chemical transformations can also contribute to the attenuation of contaminants. However, direct measurement in an aquifer is difficult and chemical processes are thought to represent only a small portion of the total contaminant attenuation.

8.1 DESCRIPTION OF NATURAL PROCESSES

The primary physical processes that affect the distribution of a contaminant in groundwater include advection, dispersion, sorption, volatilization, and dissolution from residual contaminants located in a source area. Advection and dispersion will reduce the chemical concentrations in groundwater, but will not cause a net loss in the mass of chemicals in the aquifer system. Sorption will tend to reduce the dissolved chemical concentration and limit the migration of the aqueous phase, but will not result in a loss of contaminant mass from the aquifer. Volatilization is also a partitioning process of the chemical from the aqueous phase to the vapor phase. Although volatilization actually removes chemical mass from the aquifer, it has not historically been thought of as a significant attenuation mechanism. Dissolution is the process of residual chemicals located in a source area dissolving into the aqueous phase of the aquifer. Chemicals may be held in the soil matrix above or below the water table at residual saturation (residuals) or at saturation. Seasonal fluctuations in the water table can dissolve contamination from previously unsaturated aquifer material. Dissolution, dispersion and

advective transport are three of the more significant physical processes that control the magnitude and extent of groundwater contamination.

Aerobic and anaerobic biological processes, which are present at the Site, account for both chemical concentration reduction and loss of chemical mass from an aquifer. Aerobic biodegradation relies on dissolved oxygen as the electron acceptor used by the microorganisms. Although aerobic biodegradation takes place at relatively higher rates than anaerobic processes, it is often limited by the available supply of oxygen to the chemical plume. Anaerobic processes refer to a variety of biodegradation mechanisms that use nitrate, sulfate, iron, and carbon dioxide as terminal electron acceptors by the microorganisms.

8.1.1 Physical Processes

As previously noted, there are several types of physical processes that affect contaminant fate and transport. The physical processes that have been characterized at the Site include advection, dispersion, sorption, volatilization and dissolution. Because the effects of these processes are sometimes cumulative, it can be difficult to quantify the cause and effect relationships between a particular process and the observed result. Therefore, the physical processes related to fate and transport effects at the Site are discussed in terms of observed trends at select locations. These observed trends are then extrapolated over similar areas.

Advective Transport

Advective transport results in the movement of contaminants at the same rate and in the same direction as the average linear velocity of the groundwater. The predominant groundwater flow regime at the Site results in a northeasterly flow direction. Advective transport typically follows the general groundwater flow direction, with the VOC concentrations being greatest near the source.

It should be noted that some individual compounds might not always follow the same trend of

higher concentrations at the source and declining concentrations away from the source. This is due to degradation of compounds unrelated to advective transport.

Dispersion

Dispersion is the process by which chemical constituents in groundwater are spread and mixed within the formation water by diffusion and mixing caused by microscopic variations within and between the pores. Dispersion is caused by differences in the velocity that water travels at the pore volume and differences in the rate at which water travels through different strata in the flow path. Dispersion causes dilution of contaminants both longitudinally and laterally to the groundwater flow direction. There is no loss of contaminant mass through dispersive processes, and the dilution occurs by spreading the contaminant over a larger area. Thus dispersion is in part responsible for lateral or cross-gradient migration of contaminants in groundwater.

Lateral dispersion at the Site is relatively high, because of the overall low groundwater flow velocity that results from the generally fine grained nature of the alluvium at the Site. The domestic wells in the area may also act to increase lateral dispersion through extraction of the groundwater. The apparent cross-gradient extent of contamination, based on PCE concentrations exceeding the AWQS, is approximately 675 feet. The cross-gradient extent is estimated in the northwest-southeast direction because the predominant groundwater flow direction is to the northeast.

Sorption

Sorption is the process by which chemicals are sorbed onto the surface of sediments. This process results because the surfaces of solids, especially clays and organic soil material, have an electrical charge due to isomorphous replacement, broken bonds, or lattice imperfections. The electrical charge is imbalanced, and may be satisfied by adsorbing a charged ion. Halogenated VOCs characteristically have a high affinity to organic material, and can be adsorbed to the surface of organic material in an effort to achieve an ionic balance.

Based on the nature of sediments at the Site, which are fine grained and relatively low in organic material, and the lack of detectable VOCs in the soil, it appears that sorption plays a relatively small role in the distribution of VOCs at the Site.

Volatilization

Volatilization refers to mass transfer from liquid and soil to the gaseous phase. Thus, depending on the nature of contamination at different sites, chemicals in the soil gas may be derived from the presence of nonaqueous phase liquids (NAPL), dissolved chemicals, or adsorbed chemicals. Chemical properties affecting volatilization include vapor pressure and solubility. Other factors influencing volatilization rates are: concentration in soil, soil moisture content, soil air movement, sorptive and diffusive characteristics of the soil, soil temperature, and bulk properties of the soil such as organic-carbon content, porosity, density, and clay content. Because no NAPLs have been reported at the Site, volatilization likely occurs from dissolved or adsorbed chemicals.

The rate of VOC volatilization at the Site is relatively low. This is illustrated by the soil vapor investigations conducted as part of the RI. During the ADEQ 1998 soil vapor investigation, the greatest PCE concentration in soil vapor was reported in the vicinity of the Welcome RV Park east septic tank at a concentration of 980 ppb/v.

The overall low concentrations of VOCs in the soil gas suggest that there are no areas with residual NAPL or abundant adsorbed chemicals in the vadose zone and support the conclusion that volatilization from both soils and groundwater plays a minor role in the distribution of contaminants at the Site.

Dissolution

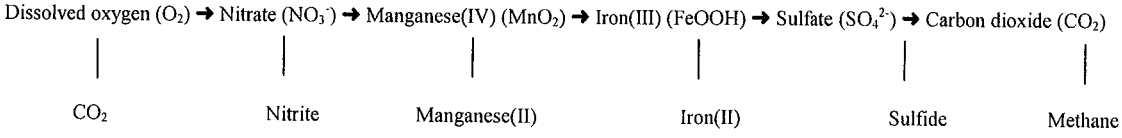
Dissolution is the process by which soluble organic components dissolve in groundwater or dissolve in infiltration water and form a groundwater contaminant plume. The highest

concentrations of dissolved contaminants at the Site are present in the groundwater beneath the Welcome RV Park.

8.1.2 Biological Processes

Biotic transformations caused by microorganisms are generally the most important transformation mechanisms in groundwater systems (Wiedemeier et al., 1996). Biodegradation of chlorinated aliphatic hydrocarbons (CAH) such as PCE and TCE has been shown to occur via three mechanisms: use as an electron acceptor (reductive dechlorination), use as an electron donor (primary substrate oxidation), and cometabolism. These mechanisms can work alone or in combination (Wiedemeier et al., 1998).

Microbial populations use a variety of electron acceptors. Elucidating the relative importance of the terminal electron-accepting processes is the key to understanding which of the biodegradation mechanisms may be important at the site. Generally, microorganisms use the electron acceptor that will provide them with the most energy. Consequently, electron acceptors are used, as available, in the following order of preference (beneath each electron acceptor is its resulting reduced metabolic by-product):



8.1.3 Reductive Dechlorination

During reductive dechlorination an available organic carbon source is used as the primary substrate (electron donor) and the CAH, in this case either PCE or TCE, is used as the terminal electron acceptor. Because the CAH is used as the electron acceptor, for the process to occur there must be a carbon source to support microbial growth. The carbon source can be natural organic matter or anthropogenic sources such as petroleum hydrocarbons. Transformation of

CAH under anaerobic conditions proceeds by sequential dechlorination through the stepwise transfer of two electrons from the donor to the CAH, forming intermediate daughter products (Sewall and Gibson, 1997). At this site, reductive dechlorination of parent products (e.g., PCE) may occur through the series of reactions shown below:

PCE→ TCE → DCE → Vinyl Chloride (VC) → *ethene*

cis-1,2-DCE is the predominate form of DCE produced when TCE undergoes reductive dechlorination. The occurrence of *cis*-1,2-DCE at low concentrations in monitoring well QMW-3 suggests that some degradation of TCE is occurring at the Site.

Reductive dechlorination occurs most rapidly under sulfate reducing and methanogenic conditions (i.e., oxidation-reduction potentials [ORP] less than -200 millivolts [mV]), but has been demonstrated under denitrification and iron (III) reducing conditions. Reductive dechlorination will result in a decrease of parent compounds and accumulation of daughter products and chloride ions. All of the chlorinated ethenes may be degraded by reductive dechlorination, though the rate of transformation typically decreases with decreased chlorination (Wiedemeier et al., 1996). Consequently, dechlorination of TCE to DCE can occur under moderate reducing conditions whereas dechlorination of DCE to VC generally requires more strongly reducing conditions. Specifically, methanogenic conditions are reportedly required to further reduce DCE and VC (Semprini et al., 1995). If reducing conditions are not strong enough, DCE and VC will not be degraded through reductive dechlorination. These intermediates may then either accumulate or be degraded through other mechanisms.

8.1.4 Direct Oxidation (Metabolism)

In the process of direct oxidation, microorganisms utilize the CAH as the electron donors in a series of oxidation-reduction (redox) reactions. Unlike reductive dechlorination, the CAH are oxidized (i.e., used as the primary growth substrate by the microbial consortium) instead of being

reduced. Subsurface microorganisms may directly metabolize DCE, resulting in mineralization to carbon dioxide, water, and chloride. The lesser-chlorinated ethenes (e.g., DCE) can be used as primary substrates. The more highly chlorinated ethenes (PCE and TCE) are not likely to serve as primary substrates or electron donors. It is important to note that this process may be either aerobic or anaerobic. For example, direct oxidation of *cis*-1,2-DCE has been shown to occur either aerobically (Bradley and Chapelle, 1998, Sewall and Gibson, 1997) or anaerobically during the reduction of manganese and naturally occurring organic matter (Bradley, Chapelle and Lovley, 1998; Bradley, Lanmeyer and Dinicola, 1998). Several studies have indicated that DCE and VC can be oxidized in iron reducing and methanogenic conditions in addition to aerobic conditions (Bradley and Chapelle, 1997, 1996; Klier et al., 1998).

Cometabolism

A CAH biodegraded through cometabolism is degraded by an enzyme or cofactor that is fortuitously produced by organisms for other purposes. During cometabolism CAHs are indirectly transformed by bacteria using another substrate to meet their energy requirements. The bacteria then derive no benefit from the degradation of the CAHs. Cometabolism is best documented under aerobic conditions but may occur under anaerobic conditions. The rate of cometabolism of CAH compounds is reported to increase as the degree of chlorination decreases (for example VC will degrade by cometabolism more quickly than PCE or TCE) (Wiedemeier, 1998).

8.2 NATURAL ATTENUATION SAMPLING

During May and August 2000, and April 2002 groundwater monitoring events, additional groundwater samples were collected for the analysis of natural attenuation parameters. Monitoring wells QMW-1, QMW-6 and QMW-9 were sampled in May 2000. Wells QMW-1, QMW-3, QMW-4, QMW-5, QMW-6, and QMW-9 were sampled in August 2000. Samples were collected from all wells in April 2002. The samples were analyzed for the following natural attenuation parameters.

- Dissolved Oxygen (field analysis)
- Oxidation-reduction potential (field analysis)
- Carbon Dioxide – EPA Test Method SM4500-CO2-C
- TOC – EPA Test Method 415.1
- Dissolved Methane, Ethane, and Ethene – EPA Test Method RSKSOP175
- Nitrogen as NH_4 - EPA Test Method 350.3
- Nitrate – EPA Test Method 300.0
- Nitrite – EPA Test Method 300.0
- Manganese – EPA Test Method 200.7
- Iron – EPA Test Method 200.7
- Sulfate - EPA Test Method 300.0
- Sulfide - EPA Test Method SM4500-S-C,D
- Chloride – EPA Test Method 300.0
- Alkalinity as $CaCO_3$ – EPA Test Method SM2320B

Samples were submitted to Del Mar Analytical Laboratories for analyses. Evergreen Analytical, Inc. under contract to Del Mar, analyzed samples for dissolved methane, ethane, and ethene

Examining indicator parameter measurements and contaminant concentrations from the sampling events provides some insight into the geochemical environment in groundwater at the Site. Table 17 presents a comparison of the geochemical conditions within the core of the plume, as indicated in wells QMW-1, QMW-3, QMW-4, QMW-5, and QMW-7, to those conditions in the up gradient (well QMW-6) and at the leading edge of the plume (wells QMW-2, QMW-8, QMW-9, and QMW-10).

A comparison between the groundwater chemistry at the background well, wells located within the core of the plume, and leading edge wells based on the three natural attenuation sampling events indicates the following:

- Average DO concentrations are highest in up gradient well QMW-6 (4.98 mg/l). The average DO concentration is 2.5 mg/l in the core of the plume, and 2.33 mg/l in the leading edge wells;

- Average ORP concentrations are highest in up gradient well QMW-6 (150.2 mV). The average ORP concentration is 140.6 mV in the core of the plume, and 64.1 mV in the leading edge wells;

- Average CO_2 concentrations are highest in the core of the plume (58.7 mg/l), and lowest in the background well (38 mg/l). The average CO2 concentration is 51 mg/l in the leading edge wells;

- TOC concentrations range from an average of <1 mg/l in up gradient well QMW-6 to 2.2 mg/l in leading edge wells and 3.08 mg/l in wells within the core of the plume;

- Average methane concentrations are highest in the core of the plume (0.0045 mg/l). Methane was not detected in up gradient well QMW-6 during any sampling event, and averaged 0.0019 mg/l in leading edge wells. Ethane and ethene concentrations were not detected in any well during any of the sampling events;

- Average nitrate concentrations are highest in the core of the plume (20.3 mg/l). Nitrate concentrations are similar in the up gradient well (13 mg/l) and at the leading edge of the plume (11 mg/l). NH_4 and nitrite concentrations were not detected in any sample;

- Manganese and iron concentrations are similar in all wells, with average manganese concentrations <0.04 mg/l, and average iron concentrations <0.3 mg/l;

- Average sulfate concentrations are similar in the leading edge wells (517 mg/l) and within the core of the plume (500 mg/l), and are significantly lower in up gradient well QMW-6 (17 mg/l). Sulfide has not exceeded laboratory reporting limits in any well;

- Average chloride concentrations are highest in leading edge wells (243 mg/l) and within the core of the plume (227 mg/l), and lowest in up gradient well QMW-6 (80 mg/l);

- Average alkalinity concentrations are similar in the background well (237 mg/l), within the core of the plume (240 mg/l), and in the leading edge wells (257 mg/l).

The U.S. EPA (1998) has developed a method to determine the likelihood that biodegradation of CAHs under anaerobic conditions (i.e., reductive dechlorination) is occurring within a contaminant plume. The method uses a scoring system in which values are assigned to certain

criteria, as indicated in Table 18. Accordingly, if the total score is 15 points or greater, then anaerobic biodegradation is likely occurring.

Table 19 shows the scoring results using the EPA methodology for the Tyson Wash WQARF Site. The total score of 1 indicates that it is unlikely that biodegradation of CAHs is occurring at the Site through the process of reductive dechlorination. The average reported DO and ORP concentrations are indicative of aerobic to slightly anaerobic conditions. As previously indicated, the process of reductive dechlorination requires anaerobic conditions, and proceeds most rapidly under strongly anaerobic (i.e., sulfate-reducing or methanogenic) conditions. Other factors that appear to limit reductive dechlorination at the Site include:

- TOC concentrations in the contaminated zone range from <1 mg/l to 9.5 mg/l. TOC concentrations >20 mg/l are required to drive dechlorination (EPA, 1998);
- Nitrate concentrations within the contaminated zone range from 9.2 mg/l to 37 mg/l. At these concentrations, it is likely that nitrate will compete with the reductive pathway and inhibit the dechlorination of the CAHs. With the exception of one sample collected from well QMW-1, nitrite and NH4 have not been detected in any sample, indicating that conditions within the aquifer do not approach a strongly reducing state;
- Sulfate concentrations within the contaminated zone range from 89 mg/l to 1,000 mg/l. According to the U.S. EPA (1998) sulfate concentrations greater than 20 mg/l are likely to compete with the reductive pathway, thus inhibiting dechlorination of CAHs. Sulfide has not been detected in any sample, a further indication that conditions within the aquifer do not approach a strongly reducing state;
- Methane concentrations do not exceed 0.019 mg/l in the contaminated zone. Although methane is an ultimate reductive daughter product of biodegradation, it is unlikely, given the other factors discussed, that these concentrations are the result of biodegradation of the CAHs. The methane may be derived from biological processes in the septic tanks that were formerly used throughout the Site. Ethane and ethene were not detected in any samples, indicating that methanogenesis is not occurring;
- Alkalinity concentrations are similar in all wells. According to the U.S. EPA (1998) there is a positive correlation between zones of microbial activity and increased alkalinity. Since alkalinity concentrations within the contaminated zone at the Site are similar to those of

background levels, it does not appear that there is an increase in microbial activity within the plume;

- VOC concentration trends do not support the occurrence of significant biodegradation. With the exception of wells QMW-1 and QMW-5, and the Welcome RV Park domestic well, PCE concentrations have not shown any significant decreases, and daughter products (TCE, DCE, and VC) have not increased in concentrations in any wells.

Despite these observations there does appear to be some evidence of biological activity. The elevated chloride concentrations within the core of the plume relative to background suggest degradation of the CAHs within the plume. *Cis*-1,2-DCE has been detected within the core of the plume in well QMW-3. Cis-1,2-DCE is the most common form of DCE produced during biodegradation of TCE.

The occurrence of the petroleum hydrocarbon plume to the southeast of the Site PCE plume, and the possibility of future commingling of the plumes, could favorably affect the biodegradation of PCE. Petroleum hydrocarbons, particularly benzene, are readily used as a food source for hydrocarbon degrading bacteria. The introduction of benzene into the PCE plume could result in increased growth of bacterial colonies, and the subsequent degradation of PCE. However, benzene concentrations would have to be in the hundreds of parts per billion for any significant bacterial growth to occur. In addition, the relatively high nitrate concentrations within the PCE plume would still inhibit biodegradation of PCE.

8.3 GROUNDWATER MODELING

The primary objective of the groundwater modeling task was to develop groundwater flow and transport models capable of simulating current and future contaminant concentrations in the shallow aquifer underlying the Site. The transport and flow models were used to evaluate important factors that are likely contributing to the observed PCE contamination in groundwater, and to provide insight into the relative importance of these factors.

Based on the results of laboratory analytical data discussed in the Section 6.0, PCE was chosen as the contaminant of concern for the model. Although TCE has also been reported in Site wells at concentrations exceeding the ADEQ AWQS, the areal distribution of TCE is much smaller than that of PCE. In addition, the mechanisms governing fate and transport of TCE are similar to those influencing TCE.

The model was calibrated to match as closely as possible the existing data, and to conduct a simulation of predicted concentration changes over the next 10-year period. Factors taken into account during construction of the groundwater model included estimated pumping regimes of the numerous shallow domestic wells in the area, aquifer properties such as hydraulic conductivity, and natural attenuation mechanisms such as biodegradation, advection, dispersion, and dilution.

8.3.1 Overview of Modeling Approach

The models were calibrated to match existing hydraulic and chemical data. The flow model was designed to represent long-term average conditions in the aquifer and, therefore, simulated steady-state hydraulic conditions. Although conditions within the aquifer are dynamic in nature and transient events such as those caused by a change in the pumping regime of domestic wells may produce short-term changes in flow direction, the mean groundwater flow directions ultimately control contaminant transport. To determine the appropriate mean groundwater flow patterns for use as the calibration target for the flow model, water level data collected during the RI was carefully reviewed. Groundwater pathlines were computed and the simulated flow field was adjusted until the existing groundwater contours were satisfactorily reproduced. Because the calibration is dependent on historical information, future changes in important parameters could affect the model predictions. For example, a reduction in pumping from domestic wells following extension of the municipal water supply into the area is likely to have an effect on the future groundwater flow conditions.

The contaminant transport model used the computed groundwater velocities from the flow model to simulate VOC concentrations in the aquifer. Assumptions were made as to the suspected source locations and release dates.

8.3.2 Domestic Well Groundwater Pumping

The effect domestic wells in the area have on the local groundwater flow regime and contaminant distribution is an important factor in constructing a groundwater model for the Site. An understanding of pumping rates and schedules is necessary to develop a flow model that can be used as a starting point for the contaminant transport model. Nineteen privately owned wells have been identified within or immediately adjacent to the Site. Eighteen of the wells are completed within the shallow perched aquifer at depths of 70 to 100 feet.

Typically, groundwater from a domestic supply well is pumped directly from the well into a pressure tank located adjacent to the well. When the pressure tank is filled, the well's pump automatically shuts off. As the water is used, the water level in the tank declines. When the water reaches a pre-determined level, the pump automatically turns on again and re-fills the tank. In this manner, groundwater is pumped from a given well several times each day for what may be only a few minutes during each pumping cycle. Although the domestic wells in the Site area may be capable of pumping at 5 to 10 gallons per minute, average daily pumping rates are much less because of the constant turning on and off of the pumps. Therefore, the pumping rates used in the groundwater model are average, rather than maximum rates.

Three shallow domestic wells have been used at the Cast property. According to the property owner, historical well use has been greatest during the winter tourist season, when water use may have exceeded 10,000 gallons per day. This equals an average daily pumping rate of 2-3 gallons per minute from each of the three wells during the peak use season. At the peak of the season (January and February) the wells may become dry. In fact, wells B-1 and B-4 were shut down in February 2001 for that reason. During the summer months the volume of water historically

pumped from these wells decreased significantly.

Other wells in the area that pump seasonally (i.e., during the months of October through March) include those at the Welcome RV Park, Eric's RV Repair, La Casa Del Rancho Restaurant, La Mirage RV Park, and at the Adams and Parsons residential properties. Domestic wells at the Rhoades and York residential properties pump year-round.

A domestic well at the Quartzsite Post Office was shut down in February 2000 due to increasing PCE concentrations. According to the ADEQ, two domestic supply wells located at the former Hi-Ali Motel were abandoned in 1997 or 1998.

Final pumping rates chosen for use in the model were based on the fact that many of the wells are shut down for 6 months. Therefore modeled rates were half of the estimated actual rates. In the model, the Quartzsite Post Office well was shut off in February 2000, and the former Hi-Ali domestic wells were shut off in January 1998.

8.3.3 Groundwater Flow Model

8.3.3.1 Flow Code

The computer codes MODFLOW (McDonald and Harbaugh, 1988; Harbaugh and McDonald, 1996) and MT3D99 (Zheng, 1999; Zheng and Wang, 1998), utilizing the Visual MODFLOW user interface developed by Waterloo Hydrogeologic, were used as the numerical algorithms with which to build the model. MODFLOW has become what is generally considered the industry standard groundwater flow code. Complete documentation of the hydraulic theory and numerical solution techniques is provided in the referenced documents (Section 12.0).

8.3.3.2 Grid System

The first step in the flow model construction was to create a finite-difference grid (i.e., a group of three dimensional cells) to represent the geometry of the clayey sand layer that generally extends

to a depth of about 60 to 70 feet bgs. The clayey sand unit was modeled as one layer of cells, and the underlying clay layer was assumed to represent a no-flow boundary along the bottom of the model. Representing the clay unit as a no-flow boundary is supported by the vertical transition of soil lithology from the clayey sand unit to the clay layer, and the significant reduction in hydraulic conductivity with depth, as measured in monitoring wells QMW-1 and QMW-2.

Figure 37 shows the entire final grid system in a regional view, and Figure 38 shows the grid in the vicinity of the Site. The extent of the model domain was selected in order to represent the regional hydrology and related groundwater flow patterns and to minimize boundary condition effects (Section 2.1.4) in the Site area. The final grid contains 9,408 cells that are formed by 98 north-south columns, 96 east-west rows, and 1 layer. Cell dimensions were reduced near extraction wells and areas of increased PCE concentration to improve the accuracy of the computed water levels and concentrations.

8.3.3.3 Input Parameters

Each cell in the grid was assigned horizontal and vertical hydraulic conductivity (K) values. The horizontal conductivity of the clayey sand layer was estimated as 3 feet/day based on the aquifer test results from wells QMW-6 and QMW-7, measured horizontal hydraulic gradients, and the estimated average pumping rates for Site production wells. The value of K=3 feet/day corresponds to a representative aquifer transmissivity of about 75 feet^2/day (0.05 feet^2/minute), which lies within the range of values measured during the aquifer tests. Vertical conductivity was estimated as one-tenth of the horizontal value. However, this parameter is not important in the model because only one layer is used and, as a result, the modeled groundwater flow is horizontal.

A localized zone of low conductivity soil (K=0.03 feet/day) was added in the vicinity of monitoring wells QMW-4, QMW-8, and QMW-10 based on lithologic logs and measured water levels in this area. The geologic cross-sections illustrate the increased silt and clay content of the

soils in this area. The match between measured and simulated water levels in monitoring wells QMW-8, QMW-9, QMW-10, and QMW-2 were significantly improved by the addition of the low-K zone.

Groundwater recharge was added into selected cells in the upper layer to account for estimated inflows to the aquifer. Zero recharge was added to the remaining cells based on water budget estimates. Non-zero recharge rates were estimated during the model calibration process. A recharge rate of 5.3 inches/year was assigned to Tyson Wash cells, and a mean recharge rate of 1.5 inches/year was estimated for Plomosa Wash to the east and the unnamed wash to the west of Tyson Wash. A recharge rate of 150 inches/year was estimated for the septic system leach field at the Welcome RV Park based on water level calibration and the expected water usage (assumed 1 gallon per minute pumping rate from the Welcome RV supply well).

8.3.3.4 Boundary Conditions

No-flow conditions were specified along the eastern, western, and southern model boundaries. These boundaries were located a sufficient distance from the Site to ensure that that the nature of the boundary condition (e.g., no-flow versus constant head) in these areas had a negligible effect on simulated Site groundwater levels. A constant-head boundary condition was specified along the northern boundary, with the water level linearly varying from 800 feet above mean sea level (MSL) at the northwestern most cell to 795 feet above MSL at the northeastern most cell. The purpose of the northern constant-head boundary was to establish a regional hydraulic gradient that is consistent with Site data and to allow groundwater to naturally discharge from the model domain. Simulated Site water levels are not very sensitive to the northern boundary condition.

8.3.3.5 Flow Model Calibration

The March 2001 groundwater elevations were used as the calibration target for the flow model. The March date was selected because it is most representative of the relatively steady hydraulic conditions that are seasonally established at the Site after several months of groundwater

extraction for water supply.

The simulated steady-state water table configuration based on the final model input parameters is plotted on Figure 39. The overall match between measured and simulated water levels is good. All water level residuals (difference between measured and simulated value) are less than one foot with the exceptions of monitoring wells QMW-4, QMW-8, and QMW-10. The larger residuals at these locations may be due to unresolved variations in hydraulic conductivity. However, because contaminant transport is the ultimate focus of this model, flow directions (i.e., hydraulic head gradients) are more important than absolute water level values. As discussed in Section 8.3.5, the simulated PCE concentration variations at wells QMW-4, QMW-8, and QMW-10 provide relatively close matches with measurements, indicating that the simulated flow directions in the vicinity of these wells are reasonably accurate.

8.3.4 Transport Model

Details of the governing contaminant transport equations and the numerical solution techniques used in MT3D99 are outlined in the user's manuals for the code (Zheng, 1999; Zheng and Wang, 1998). The Modified Method of Characteristics (MMOC) option, also known as the Eulerian-Lagrangian method, was used to solve the advection terms. The implicit solution option was selected for the dispersion terms. The implicit solution technique is much more numerically stable than the explicit solution used in previous versions of MT3D and leads to shorter computer simulation times because the model time step can be much larger.

8.3.4.1 Input Parameters

Input data requirements for transport analysis include: effective porosity, soil-water partition coefficient for PCE, and longitudinal and transverse dispersivities. Laboratory results of groundwater samples collected during the RI did not indicate significant natural attenuation of PCE through biodegradation processes at this site. Therefore, the PCE biodegradation rate in the model was assumed to be zero. Molecular diffusion is negligible compared to mechanical

dispersion in silty sand and sand and gravel aquifers (e.g., Bear, 1972) and was also assumed to be zero at the Site. Based on published data (Baes and Sharp 1983) and physical characteristics of Site soil samples, an effective porosity value of n_e=0.3 was selected for the transport model.

For nonionic organic compounds such as PCE the soil-water partition coefficient, k_d (cm^3/g), can be estimated from the following correlation with the organic carbon content of the soil:

$$k_d = f_{oc}\, k_{oc} \qquad (f_{oc} \geq 0.001) \qquad \textbf{(1)}$$

where f_{oc} is the fraction of organic carbon in the soil (grams organic carbon per gram soil) and k_{oc} is the organic carbon/water partition coefficient (cm^3/g). A minimum soil organic carbon content of 0.001 is generally used with Equation (7) because when f_{oc} is less than this value other sorption processes (e.g., adsorption to mineral surfaces) become more predominant, and the effective soil-water partition coefficient does not significantly reduce (Karickhoff, 1981). Published k_{oc} values are available from several sources (e.g., Lyman et al., 1982). The value used in this study is $(k_{oc})_{PCE}$=364 cm^3/g.

Based on the low organic carbon content of the soils at the Site (i.e., f_{oc} <0.001) and the fact that, as discussed above, f_{oc} = 0.001 is the minimum value recommended for calculating k_d, this value was used to compute k_d values. Using f_{oc}=0.001 and Equation (1) the k_d value used in the model simulations is $(k_d)_{PCE}$=0.364 cm^3/g.

Dispersivities were estimated from published values measured during large-scale field tracer studies and were adjusted during the model calibration. Using a representative Site scale of 400 feet (120 meters), the expected longitudinal dispersivity based on these field studies lies in the range of 10-30 feet (3-10 meters). The ratio of horizontal transverse (a_{TH}) to longitudinal dispersivity, a_{TH}/a_L, is typically in the range of 0.05-0.3 (Fetter, 1993). The following values of dispersivity were estimated during the calibration process:

a_L=20 feet; a_{TH}=6.6 feet

8.3.4.2 Boundary Conditions

A specified concentration variation with time was established at grid cells representing the septic system leach fields at the Welcome RV Park. Based on historical analytical data from monitoring well QMW-3 and the Welcome RV Park domestic supply well (Tables I and 2), groundwater PCE concentrations at the Welcome RV Park leach fields were assumed to linearly reduce from 200 µg/l in 1990 to 120 µg/l in 1998. After 1998 the groundwater PCE concentrations at this location were assumed to remain constant at 120 µg/l.

A starting date of 1990 was chosen for the model based on the known property use history and historical laboratory analytical data. The Welcome RV Park has been used for recreational vehicle parking since 1986. In 1994, the current owners acquired a business license from the Town of Quartzsite to use the property as a dry camp area for parking RVs. In addition, according to the ADEQ, PCE was first reported at the Tyson Wash Site in November 1993 in a groundwater sample collected from well B-2 at the Cast property, immediately east of the Welcome RV Park. Therefore, a source is assumed to have started at the Welcome RV Park between 1986 and 1993.

At the former Hi-Ali Motel property, two PCE source locations were postulated. The assumed locations are a suspected leach field near the center of the property, and the area around the former motel building where anomalously high soil vapor concentrations were detected.

An initial PCE concentration of 100 µg/l in 1990 was estimated based on groundwater and soil vapor sample analytical results from several locations on the property. During the model run, the assumed 1990 PCE concentrations were allowed to naturally advect and disperse with the groundwater flow.

8.3.5 Model Results

8.3.5.1 Simulated PCE Distribution with Sources at the Welcome RV Park

Figure 40 shows the simulated January 2001 groundwater PCE distribution (units of µg/l) in the clayey sand unit assuming a leach field release occurred in January 1990 at the Welcome RV Park. During this simulation, all domestic wells in the area were assumed to be pumping according to the rates and schedules discussed previously.

The simulated PCE concentrations represent a reasonable match with the measurements at most of the wells, which suggests that a PCE release is likely to have occurred on the Welcome RV Park property. In general, simulated concentrations in wells downgradient of the assumed source area are higher than measured concentrations. This is likely due to the strong northeast groundwater flow component established in the flow model. Simulated concentrations in the Welcome RV Park well decrease over time due to advection and dispersion of the plume. Based on this model, monitoring wells QMW-1, QMW-5, and QMW-7, located on Cowell Street, are not impacted by the Welcome RV Park source. The recent groundwater sampling results for these three wells indicate PCE concentrations in the range of 7.3 µg/l to 60 µg/l. In addition, the domestic wells at the Kauffman and Rhoades Properties are also outside of the simulated PCE plume. Measured PCE concentrations at those wells ranged from 7.9 µg/l to 11 µg/l during the first half of 2001.

Given the northeasterly groundwater flow direction, and the fact that PCE contamination has been detected on the former Hi-Ali Motel property, these results suggest that groundwater contamination from a source southwest of the Welcome RV Park may have contributed to Site contamination.

8.3.5.2 Simulated PCE Distribution with Contribution from Sources at the Welcome RV Park and the Former Hi-Ali Motel

Based on the initial model results, an additional flow and transport model was constructed to

evaluate the effects of potential additional PCE release scenarios at the former Hi-Ali Motel. Two source locations were assumed based on groundwater and soil vapor analytical results, and results from the geophysical survey. One source was assumed in the area surrounding the former motel building, and a second area was assumed to be located at the suspected leach field near the center of the property.

For this model run the two domestic supply wells at the former Hi-Ali Motel were operating at assumed rates of 2 gallons per minute (gpm) in the eastern well (HA-1) and 1 gpm in the western well (HA-2). The initial PCE concentrations at the Hi-Ali property were estimated based on the 1995 PCE concentrations measured in the two supply wells, and results from soil gas measurements collected on the property.

Figure 41 shows the simulated January 2001 PCE plume, with the former Hi-Ali Motel wells having been deactivated after January 1998. Comparison of Figure 41 with Figure 40 indicates that the assumed release at the former Hi-Ali Motel significantly improves the match with the measurements at monitoring wells QMW-1, QMW-5, and QMW-7. The modeled concentrations in the Welcome RV Park supply well are also improved, having been increased by nearly 50 percent. The Hi-Ali source contribution does not have a significant effect on other Site wells.

8.3.5.3 Projected PCE Concentration Trends

In a final model simulation, PCE concentrations in groundwater were projected to the year 2010. Key assumptions made in this simulation were that the Welcome RV Park PCE source concentration remains constant at 120 µg/l, and no new PCE mass was added to the source areas (i.e., the assumed 1990 contamination was allowed to naturally advect and disperse with the groundwater flow).

Figure 42 shows the projected year 2010 PCE plume. A comparison with Figure 41 (year 2001 simulated plume) shows that the plume size does not significantly increase during the 10-year

period 2001 through 2010, and the concentrations are relatively similar. The primary change in simulated plume extent is a reduction of the contaminated area on the former Hi-Ali Motel property, minor spreading of the plume boundaries, and little change in concentrations near the center of the plume. Moderate increases are estimated to occur in the northeastern limits of the Site (e.g., QMW-8 and the western La Casa Del Rancho property supply well).

8.3.6 Uncertainties

The degree of confidence in the model results depends upon the accuracy of the input parameters. Several of the input parameters used in model were based on assumptions. Parameters having a substantial degree of uncertainty include the assumed source locations, the timing of the release and initial concentrations, and estimated pumping rates of domestic wells.

Source locations at the Welcome RV Park were based primarily on analytical results from groundwater and soil vapor samples collected during the RI and in previous investigations conducted by the ADEQ. The assumed location of a leach field source near the center of the former Hi-Ali Motel property was chosen based on results of soil vapor sample analyses, the geophysical survey, and discussions with the current property manager.

Timing of the release and initial concentrations are unknown, and were estimated based on the known historical property use and laboratory analyses. The release occurred prior to 1993, which is the date PCE was first reported in well B-2 at the Cast property. Commercial use at the Welcome RV Park is reported to have begun in 1986. Although it is reported that a dry cleaner was operated for a short time period during the mid 1970's at the former Hi-Ali Motel, that cannot be confirmed.

Initial PCE concentrations were chosen during the model calibration process. At the Welcome RV Park an initial concentration of 200 µg/l was chosen. This represents the highest observed PCE concentration at the Site, and resulted in the best fit to the observed data during the transport

model calibration process. At the former Hi-Ali Motel, an initial concentration was chosen that would result in a close match with the actual PCE concentrations observed at wells HA-1 and HA-2. The chosen starting concentration of 100 µg/l also provided a better fit to the observed data in wells QMW-1, QMW-5, and QMW-7.

Actual domestic well pumping rates and schedules are unknown. An attempt was made to determine the flow rate and volume of groundwater pumped at Cast well B-1. An in-line flow meter was installed on the well's discharge pipe in February 2001. However, very shortly after installing the meter, the well went dry and no reliable readings were recorded on the meter.

Pumping rates at the Cast property were initially estimated at 2-3 gallons per minute based on the peak season water usage at the property of approximately 10,000 gallons. These rates were then reduced by half to reflect the seasonal usage of the wells, and further adjusted during the calibration process. For example the average pumping rate at well B-4 was established as 0.1 gpm. A pumping rate higher than this resulted in the PCE plume being extended beyond monitoring well QMW-2. Actual PCE concentrations have not exceeded laboratory reporting limits in this well. Rates for the remaining wells were also adjusted during the calibration process.

Despite the uncertainties, the model does a relatively good job of matching known conditions. The calibrated flow model matched well with existing water levels, with the exception of monitoring wells QMW-4, QMW-8, and QMW-10. The larger disparity at these locations may be due to unresolved variations in hydraulic conductivity.

9.0 HEALTH CONSULTATION

In response to an action initiated by ADEQ to protect the users of the groundwater within the Site, MACTEC prepared a Health Consultation Report addressing the potential health effects of the selected COCs. The Health Consultation Report provided a conservative estimate for the potential impact that the COCs may have on the groundwater users. For purposes of the Health Consultation, seven properties with domestic wells (Welcome RV Park, Cast, Rhoades, Kauffman, La Casa Del Rancho Restaurant, Quartzsite Post Office, and Eric's RV Repair) were identified for risk screening.

To evaluate potential health impact, two exercises were conducted. First the maximum concentrations of the COCs to date were compared to EPA standards for short-term, acute exposure to a child. For 1-day, 10-day, and longer-term exposure, the standards are in milligrams per liter of water (parts per *million*). The maximum concentrations associated with the Tyson Wash groundwater plume can be measured in micrograms per liter (parts per *billion*), which is a thousand times lower. Since the movement of groundwater constituents through soil causes dispersion to lower concentrations, it is unlikely that significantly higher concentrations will be detected in the plume, assuming no addition of contaminants. Therefore, the evaluation for acute, short-term effects was considered complete with that direct comparison to the short-term standards.

Secondly, a screening risk assessment was prepared to evaluate long-term, low level exposures. The parameters of the evaluation corresponded to a resident who was born, grew through childhood over a 6-year period, and remained on the same property for 24 years as an adult. This exposure scenario was established by the Environmental Protection Agency (EPA) as the reasonable maximum exposure for the 90th percentile of residential exposures, the most stringent conditions that would apply to use of the groundwater.

Modification of the exposure parameters was conducted for site-specific conditions. For example, at the Welcome RV Park, the exposure duration was modified for a 20-year exposure instead of the standard 30-year exposure to recognize the seasonal residents who travel from northern states to live on the site for several weeks to as much as six months each year.

For the purposes of the Health Consultation, the chosen COCs were PCE, TCE, 1,1-DCE, *cis*-1,2-DCE, 1,1-dichloroethane (1,1-DCA), and isopropylbenzene. The screening risk assessment considered the maximum concentrations of the COCs in the soil and groundwater. The result of the screening risk assessment indicated three of the COCs (1,1-DCA, *cis*-1,2-DCE, and isopropylbenzene) present *de minimis* threat to health based on the analyzed data, and are not of concern.

The results of the incremental lifetime cancer risk (ILCR) of the three remaining COCs are included in Table 20. Results indicate the ILCR exceeded the EPA criterion of one-in-a-million ILCR for 7 domestic wells on 6 of the residential properties (Cast, Rhoades, Kauffman, Welcome RV Park, La Casa, and the Quartzsite Post Office). The criterion of one-in-ten-thousand ILCR was exceeded in one of the five monitoring wells (QMW-5) not used for potable purposes. According to the U.S. EPA National Contingency Plan (NCP), risks above one-in-a-million, but below one-in-ten-thousand are acceptable exposures but warrant risk management to reduce exposure.

Based on the results of the risk screening, MACTEC made several property-specific response recommendations to reduce exposure to the groundwater by residents and the general public. A complete copy of the final Health Consultation Report for the Tyson Wash WQARF site is included in Appendix P.

9.1 Welcome RV Park

For the Welcome RV Park property, the risk assessment included modification for the potential

exposure of the 50-plus-year-old residents for six months. It also included the conservative assumption that the same seasonal residents come back to the park each year for 20 years and are exposed to the maximum COC concentrations uniformly over that time. The exposure puts this property within the risk management range. According to the NCP criteria, the maximum concentrations of the COCs results in an acceptable exposure, but practicable efforts to reduce exposure are recommended. The Welcome RV Park warrants additional consideration to reduce exposure because of the estimated maximum size of the population (50-60 residents) involved

As an interim measure to reduce exposures, the ADEQ supplies bottled drinking water to the property owner. In addition, MACTEC has posted a sign warning of poor groundwater quality at the spigot located on the north side of the well house.

9.2 Cast

The shallow domestic wells B-1, B-2, and B-4 are plumbed directly into the washers at the laundromat. There are no sinks or toilets at the laundromat, and therefore, no direct public access to the water at that facility. There is, however, access to the water from wells B-2 and B-4 through spigots at the well heads. The risk assessment for wells B-1, B-2 and B-4 include a modification from the standard default factors to estimate risk due to exposure over a 20-year time span. This is also conservatively based on no change in current VOC concentrations. Results indicate acceptable exposure for Well B-4, while steps to reduce exposure should be implemented for wells B-1 and B-2, per the NCP criteria. It must be remembered that the NCP criteria indicate that the exposure to groundwater from wells B-1 and B-2 is acceptable but that risk reduction measures are recommended where practicable (NCP, 1990).

Based on the results of the assessment, MACTEC has posted signs warning of poor groundwater quality at wells B-1, B-2, and B-4.

9.3 Rhoades

At the Rhoades property, the risk assessment is based on the maximum concentrations of the COCs detected in the well and includes a modification for a 20-year exposure of the residents to the COCs. A modification is also included for the regular use of their hot tub filled with groundwater. The Rhoades property well has acceptable exposure by NCP criteria for hot tub and showering use alone (inhalation and dermal contact), and also for all potable water uses. However, action to reduce exposure is recommended where practicable for this well.

MACTEC has posted signs at well outlets. In addition, the ADEQ is currently providing bottled water to the residents, and has provided filters for indoor sinks, faucets and showers,

9.4 Kauffman

There is currently no water well use at the Kauffman property. Further, there is apparently no need to draw water from the Kauffman property well. Since it is unknown when this well may be put into service by the property owner, and service could be started without ADEQ's knowledge, MACTEC has posted a sign warning of poor groundwater quality at this well, and has confirmed that the steel plate covering the well is properly sealed.

9.5 La Casa Del Rancho Restaurant

MACTEC prepared a risk assessment for the two domestic wells in use at this property. Most of the groundwater water used at the property is extracted from the west well. Inside the restaurant, the water is used in kitchen and restroom sinks, and in the evaporative cooling system. Outside, the groundwater is used primarily for irrigation. However, additional exposure is possible where spigots are located adjacent to seasonal RV parking spaces. All of these activities are included in the development of the risk-based concentrations used in the risk assessment.

Exposures to patrons of the restaurant are transient and do not support a continuing scenario for evaluation of risk. Exposures to restaurant workers and the owner could occur on a continuing basis. The risk assessment includes a modification for the exposure over a 25-year occupational

tenure for the six months each year when the restaurant is in operation instead of the 30-year residential tenure upon which the tap water PRGs are based.

The risk assessment results for La Casa Del Rancho Restaurant indicate acceptable exposure for both the east and west wells. However, it is recommended that, if necessary, the "east" well be used preferentially for non-potable needs of the restaurant and that the "west" well be used for other purposes. MACTEC posted signs warning of poor water quality at fourteen outdoor spigots. In addition, in-line carbon absorption filters were provided to the property owner for placement under sinks within the restaurant. In addition, the ADEQ provides bottled water for potable uses in the restaurant between the operating months of October through March.

9.6 Quartzsite Post Office

The risk assessment result for the Post Office indicates acceptable exposure under the NCP criteria with a recommendation to reduce exposure where practicable. The risk assessment includes a modification for the occupational tenure of 25 years instead of the residential tenure of 30 years upon which the tap water PRG is based.

It is understood that the Post Office has access to an alternate potable water supply in the form of a water tank on their property. The domestic well on the property is currently out of service. Therefore, signing spigots is not necessary at this property.

9.7 Eric's RV Repair

The risk assessment results for Eric's RV Repair are unique in that the COC with the primary contribution to risk is 1,1-DCE and not PCE or TCE, as with the other wells. Nonetheless, the overall exposure is acceptable under the criteria of the NCP with risk management of exposure recommended where practicable. MACTEC has posted a sign warning of poor groundwater quality on the spigot located at the north side of the well house. ADEQ provides bottled drinking water to the facility between the operating months of October through March.

10.0 COMMUNITY INVOLVEMENT

This section provides a summary of the established processes to respond to issues of community concern, detailed in the Community Involvement Plan (CIP), dated March 2000. The CIP was prepared to assist the Town of Quartzsite, La Paz County, and the ADEQ in disseminating information about the Site to the local community. Generally, the CIP discusses the Site history, physical description, and findings from the ongoing Site investigation, and key issues of concern to the local community. A Community Involvement Area has been established to include area approximately ½ mile beyond site boundaries in all directions (Figure 1).

10.1 HISTORICAL SUMMARY

The ADEQ has been investigating the extent and source of contaminated groundwater at the Site since November 1999. Historically, many Quartzsite residents used the groundwater in this area as a source of drinking water. In order to reduce potential exposure, the ADEQ provided bottled water and water filters to residents with impacted private wells until the Town of Quartzsite brought the municipal water supply to those residents.

10.2 COMMUNITY ADVISORY BOARD

A Community Advisory Board (CAB) for the Site was formed in January of 2000. The CAB consists of Quartzsite residents, business owners, and government officials. The central function of the CAB is to promote communication between ADEQ and the public in and around the Site. The main duty of the CAB is to advise the department of issues and concerns related to the cleanup of the Site. The Tyson Wash CAB has: provided input to ADEQ on clean up goals, specific clean up methods, and other issues related to the Site; represented a diversified cross section of the community in and around the Site; made site visits; and met at least four times a year to discuss Site issues.

10.3 SUMMARY OF PREVIOUS COMMUNITY INVOLVEMENT ACTIVITIES

ADEQ and La Paz County held a public meeting in the Town of Quartzsite on September 25, 1996 to inform the community about current drinking water and groundwater issues including information on Tyson Wash.

A 287.01 Notice, which is required by state statute to inform residents of ADEQ's intent to place a Site on the WQARF Registry, was mailed to property owners on June 29, 1998. The notice was published in the *Quartzsite Times* on August 22, and September 2, 1998. The 30 day public comment period closed on October 16, 1998.

ADEQ was also required to publish a 287.03 Notice that provides information on the Department's intent to conduct an RI/FS. The 287.03 Notice for Tyson Wash was published in the *Quartzsite Times* on October 14 and 21, 1998. The 30 day public comment period ended on December 4, 1998. A Responsiveness Summary listing and responding to all public comment was issued by ADEQ on December 14, 1998.

On November 29, 1999, the Town Mayor and Council invited representatives from ADEQ to a public meeting to discuss the Tyson Wash project status. ADEQ staff reviewed groundwater monitoring results and presented an outline and schedule for the remedial investigation and feasibility study.

On October 4, 2000, ADEQ's technical contractor for the Site, Mr. Steve Willis with MACTEC Engineering and Consulting, gave a presentation on the progress and findings of the remedial investigation from November 1999 to date. Ms. Jeanene Hanley, ADEQ Risk Assessor, gave a presentation on the recently completed Health Consultation for the Site, and explained that the reason for doing a health consultation is to make sure that short-term issues related to public health were taken care of prior to the beginning the work on a more in-depth study like a Risk Assessment.

On December 13, 2000, Bruce Clendenning, the ADEQ Community Involvement Coordinator, gave a brief update on progress at the Site, and discussed the process that ADEQ would use to gather information from the community regarding the setting of remedial objectives for the Site, which will be used by ADEQ to determine the remediation methodology to be used. It was decided that ADEQ's technical contractor for the Site, Mr. Willis, should be invited to the next meeting to help the CAB understand the exact status of information and knowledge about the Site.

On February 7, 2001, the ADEQ staff discussed the remedial objectives process, summarized the Site investigations to that date, and briefly discussed actions taken towards gathering information on "beneficial uses" of land and water.

At a public meeting on March 20, 2001, the Town Manager presented an overview and update on the installation of the drinking water system. Ms. Andrea Domanik of the ADEQ presented an overview of the project and the early response actions that have been implemented to ensure residents have safe drinking water. Mr. Steve Willis of MACTEC presented an overview of the investigation that has been completed to determine the extent of the groundwater and possible soil contamination. Mr. Bruce Clendenning, the ADEQ Community Involvement Coordinator, presented an overview of the Arizona WQARF, which is the program that is investigating and cleaning up the PCE groundwater contamination at Tyson Wash.

10.4 COMMUNITY INVOLVEMENT PLAN

The primary objective of the CIP is to provide a framework to facilitate an ongoing dialogue with the surrounding community. In order to achieve this goal the CAP includes the following elements:

- Maintenance of Site Mailing list;
- Preparation and distribution of fact sheets;
- Maintenance of an information repository;

- Potential Site Tours;
- Public Meetings and workshops;
- Assistance with responding to information requests form the general public; and
- Briefing of public officials.

The public can review and make a copy of the CIP by visiting the local Quartzsite library.

11.0 SUMMARY AND CONCLUSIONS

This section briefly summarizes the major components of the RI, and provides conclusions from which the consideration of technologies and alternatives for groundwater remediation can be based. During the RI, activities were conducted to determine the extent and degree of contamination of both soil and groundwater. Based on the results of the investigation, the environmental media of concern is groundwater, and contaminants of interest are PCE and TCE, with PCE being the primary chemical of concern. Groundwater contaminants at the Site occur in the dissolved phase. There are no indications of the existence of dense non-aqueous phase liquids (DNAPLs) in soils or groundwater at the Site. Based on the known current uses of the properties, contamination does not appear to be ongoing. Key elements of the Site Conceptual Model include potential sources of groundwater impact, groundwater chemistry, hydrogeology, contaminant fate and transport, and exposure pathways.

11.1 POTENTIAL SOURCES OF GROUNDWATER CONTAMINATION

Although the original source of contamination has not been identified unequivocally, analytical data and results from groundwater modeling suggest a source in the vicinity of the existing and former septic tanks and leach fields at the Welcome RV Park. Analytical data supporting this includes samples having the greatest concentrations of PCE in soil vapor (980 ppb/v) and groundwater (200 µg/l) identified during the investigation. Throughout the investigation, PCE concentrations in groundwater have been consistently highest in samples collected from the Welcome RV Park well and monitoring well QMW-3, located adjacent to the reported leach field on the west side of the property. In addition, the only detection of PCE in soil samples was also reported near the Welcome RV Park septic tanks.

A second possible source is located at the former Hi-Ali Motel, where PCE concentrations exceeding the ADEQ AWQS have been detected in groundwater samples collected from two former domestic wells and several temporary monitoring wells. The highest PCE concentration

in groundwater reported at the property is 34 µg/l. Soil vapor PCE concentrations as high as 106 ppb/v have also been reported at the property. Results from groundwater modeling suggest that a source at the former Hi-Ali Motel is necessary to account for PCE concentrations detected in monitoring wells QMW-1, QMW-5, and QMW-7.

Land use practices that may be suspected of contributing to groundwater contamination are no longer in use at the Site. The former truck wash operations and surface water impoundments at the Cast property have been removed. At the former Hi-Ali Motel, septic tanks have reportedly been abandoned or removed, and reported laundromat and/or dry cleaning facilities are no longer in operation at the property. At the Welcome RV Park, the known land use – RV parking - would not normally be associated with impact to groundwater. However, past discharge of contaminants directly into the septic tanks could account for the occurrence of those contaminants in the groundwater. Although the known property use does not include the storage or handling of PCE or other VOCs, and the west septic tank has been abandoned, the possibility of ongoing contamination does exist as long as the east septic tank remains in place.

11.2 DISTRIBUTION OF CONTAMINANTS IN GROUNDWATER

Results indicate that dissolved PCE concentrations exceeding the ADEQ AWQS persist in monitoring wells QMW-1, QMW-3, QMW-4, QMW-5 and QMW-7, and in domestic wells at the Welcome RV Park, Kauffman and Rhoades properties, and Cast well B-1. PCE concentrations exceeding the AWQS have also been reported in the Quartzsite Post Office well, and in Cast well B-2. At the Former Hi-Ali Motel, PCE concentrations exceeding the AWQS were reported in samples collected in May 1996 from two domestic wells, and more recently, in one temporary well located immediately north of the former motel building

PCE concentrations above laboratory reporting limits, but below the ADEQ AWQS have been reported in monitoring wells QMW-8, QMW-9, and QMW-10, and domestic wells B-4 at the Cast property, La Casa Del Rancho Restaurant east well, Eric's RV Repair, Adams north, and

Adams south wells.

TCE concentrations exceeding the AWQS have been reported periodically in the Welcome RV Park domestic well, and in monitoring well QMW-3. TCE has also been reported at concentrations below the AWQS in wells QMW-1, QMW-4, and QMW-5, and in Cast wells B-1 and B-2.

PCE concentrations have generally declined since the start of the investigation in monitoring wells QMW-1 and QMW-5, and the domestic well at the Welcome RV Park. PCE concentrations have fluctuated or increased in monitoring wells QMW-3, QMW-4, QMW-7, and QMW-8. PCE concentrations have generally increased during the RI investigation in domestic wells at the Rhoades residence, Cast well B-1, and La Casa Del Rancho Restaurant.

The horizontal extent of groundwater impacted with PCE concentrations exceeding the ADEQ AWQS has been defined. The maximum downgradient extent of the plume is defined by monitoring well QMW-10, located near the northwest corner of the La Casa Del Rancho Restaurant. The upgradient extent is estimated to bisect the former Hi-Ali Motel property. To the west, the plume is delineated by the non-detectable PCE concentrations in domestic wells at the Parsons and Adams properties. The eastern extent of the plume is defined by monitoring well QMW-2, and the southeastern extent by the domestic well at Eric's RV Repair.

A review of site hydrogeology suggests that contaminants are confined to the perched aquifer, which occurs at depths of 42 to 55 feet bgs at the Site. Thickness of the saturated zone is estimated to be no greater than approximately 25 feet within the Site, and may be no greater than 10 feet in the vicinity of monitoring well QMW-10.

PCE mass calculations, which were based on both soil and groundwater concentrations reported during the investigation, indicate that the total PCE mass currently in the aquifer is equivalent to

approximately 2.5 kilograms, or 0.4 gallons, of pure PCE solvent. Based on this calculation, approximately 5 kilograms, or 0.8 gallons, entered the aquifer during the time period 1990 – 2001. These calculations indicate that approximately 2.5 kilograms of PCE, or 0.4 gallons, has been extracted from Site wells during the same time period.

11.3 HYDROGEOLOGY

Subsurface soils consist of two main alluvial units. The upper unit, which extends to a depth of approximately 60 to 70 feet bgs, consists of interbedded layers of moderately to well-cemented gravel, sand, silt, and clay, with the percentage of fine-grained material increasing with depth. A hard calichified lens occurs at a depth ranging from 8 to 12 feet bgs across the site.

Beginning at a depth ranging from 60 to 70 feet across the Site, soils consist of silty clay to clay. Depth to the top of the clay layer is shallowest near the center of the plume, and deepest in the vicinity of well QMW-6. Continuous core soil samples collected during the drilling of monitoring well QMW-10 indicate the clay layer extends to a depth of at least 140 feet at the Site. Results from aquifer pumping tests and laboratory measurements indicate hydraulic conductivity values in the clay layer below a depth of approximately 65 feet bgs are much lower than in the saturated soils above that depth. This suggests that horizontal groundwater flow in the shallow aquifer occurs primarily in the upper saturated zone above the clay layer.

Groundwater flow at the Site is controlled by the pumping regimes of the numerous domestic wells in the area. Historically, the primary control on groundwater flow has been the three shallow wells on the Cast property, and possibly the two domestic wells at the La Casa Del Rancho Restaurant. This effect is reflected in the northeast flow direction, and the increasing groundwater gradient to the north and northeast. Beginning in October 2001 the groundwater flow direction appears to have swung slightly more to the north, which may be a response to the shutting down of the Cast shallow domestic wells. Regional groundwater flow also appears to be influenced by shallow domestic wells located north or northeast of the Site.

Pumping of groundwater from the domestic wells has also affected the shape of the contaminated groundwater plume, as indicated by the exaggerated cross-gradient extent of the PCE plume. Pumping of shallow wells at the Cast property has also affected groundwater flow at the adjacent Quik Chek Market, where additional groundwater contamination by a petroleum hydrocarbon release has been documented. To date, there does not appear to be any commingling of the petroleum hydrocarbon plume with the PCE plume. However, the occurrence of isopropylbenzene in a groundwater sample collected from the Eric's RV Repair domestic well in February 2000 suggests that commingling of the plumes remains a possibility.

11.4 CONTAMINANT FATE AND TRANSPORT

The primary processes affecting movement of contaminants at the Site are advection and dispersion. This is indicated by the decrease in PCE concentrations over time in monitoring wells QMW-1, QMW-5, and the Welcome RV Park domestic well, all of which are located near the center of the plume, coupled with an increase in concentrations near the boundary of the plume. Although these processes act to change contaminant concentrations at individual sample locations, the total mass of contaminants in the aquifer does not change.

Laboratory analyses of groundwater samples for natural attenuation parameters do not indicate significant natural attenuation of PCE through biodegradation processes at the Site. Environmental conditions within the aquifer system fluctuate between slightly anaerobic and aerobic conditions, and suggest a manganese and/or iron-reducing environment. High nitrate concentrations within the plume may also inhibit biodegradation. The occurrence of *cis*-1,2-DCE suggests that biodegradation of TCE is occurring. TCE is known to biodegrade under both aerobic and anaerobic conditions.

Based on the results of groundwater modeling, the primary change in the future extent of the PCE plume, assuming no remedial actions are taken, will be a reduction of the contaminated area

on the former Hi-Ali Motel property, minor spreading of the plume boundaries, and little change in concentrations near the center of the plume.

Any future decrease in concentrations is dependent on the assumption of no new PCE mass being added to the property. Similarly, PCE concentrations near and down gradient of the Welcome RV Park leach fields are directly dependent on the future variation of PCE levels in the leach field area. For example, if the leach field PCE concentrations decrease in the future, then the down gradient PCE concentrations will also decrease, assuming no other sources are present. Future groundwater PCE levels will also depend on the magnitude, extent, and persistence of the contamination that is impacting monitoring wells QMW-5 and QMW-1, which in the model simulations was assumed to be due to dispersion of contamination from the Hi-Ali property.

Although results from groundwater modeling indicate that the rate of plume migration under the current groundwater flow regime is relatively slow (approximately 3 to 4 feet per year in the vicinity of monitoring wells QMW-8 and QMW-9), changes in the groundwater flow regime at the Site could increase the migration rate. With the completion of the municipal water supply into the Site, it is assumed that the volume of water extracted from the shallow aquifer in the area has already begun to decrease. Because the three shallow wells at the Cast property have been entirely shut off, the rate of migration of the PCE plume to the east/northeast is likely to increase, because those wells no longer act as extraction wells to capture the plume.

11.5 ASSESSMENT OF RISK

In response to an action initiated by the ADEQ to protect the users of the groundwater within the Site, MACTEC prepared a Health Consultation Report addressing the potential health effects of selected COCs. The Health Consultation Report provided a conservative estimate for the potential impact that the COCs may have on the groundwater users.

Potential health impacts were evaluated for both short-term, acute exposures, and long-term, low level exposures. Results indicate exposures at six of the residential properties (Cast, Rhoades, Kauffman, Welcome RV Park, La Casa, and the Quartzsite Post Office), which fall within the EPA NCP guidelines for those exposures that are acceptable but warrant risk management.

Based on the results of the risk screening, MACTEC recommended interim actions to reduce exposures at the affected properties. The ADEQ provided bottled drinking water at the Welcome RV Park, Eric's RV Repair, the Rhoades residence, and the La Casa Del Rancho Restaurant through September 2001. The ADEQ also provided water filters to the Rhoades residence for indoor faucets and shower heads, and to the La Casa Del Rancho Restaurant for indoor faucets. In addition, signs warning of poor groundwater quality have been posted at spigots where residents and the general public have access to the contaminated groundwater.

The primary pathway for human exposure to contaminants at the Site is through the domestic wells completed in the shallow impacted aquifer. Remaining pathways, such as volatilization from impacted subsurface soils, and exposure from surface soils or surface water, are insignificant or non-existent.

11.6 DATA GAPS AND LIMITATIONS

One of the keys to successful completion of any remedial investigation is the identification of data gaps and data limitations, which may affect the final conclusions. The following data gaps and limitations in the Tyson Wash RI have been identified:

11.6.1 Groundwater Analytical Data

Groundwater samples have not been collected from Cast well B-2 since May 1999, and well B-4 since November 1999. Well B-2 contained PCE and TCE concentrations of 42 µg/l and 2.1 µg/l during the May 1999 sampling event. This well is located near the southwest corner of the Cast property and is an indicator of plume migration to the southeast. MACTEC attempted to sample

well B-2 in May 2001, but the well was not pumping at that time. Sampling of well B-4 does not appear to be necessary at this time, based on the continued non-detectable VOC concentrations in well QMW-2.

The Kauffman domestic well was not sampled between May 1998 and May 2001. Results from the May 2001 sampling event indicate that PCE concentrations in that well decreased from 29 µg/l in May 1999 to 11 µg/l. Although this appears to represent a declining concentration trend, it is not known whether concentrations in that well are actually declining, as in monitoring well QMW-5, or have fluctuated, as in monitoring well QMW-3. The Kauffman well has not been sampled since May 2001 because the submersible pump no longer works.

11.6.2 Soil Vapor Analytical Data

Locations of soil vapor samples collected during the previous investigations, as indicated on Figures 9 and 10, are approximate. Documentation of those sample locations is not complete (i.e., sample locations were not surveyed), and therefore, the locations described here are based on descriptions in the referenced ADEQ PA/SI and ESI documents.

11.7 UNANSWERED QUESTIONS

Questions which remain unanswered following completion of the RI relate to: 1) the location(s) of the original source(s) of contamination, 2) past groundwater flow regime, and 3) aquifer hydraulic conductivity in the area of wells QMW-4, QMW-8, and QMW-10. The latter point was addressed in previous sections of this report.

Results of the groundwater modeling suggest that a source or sources may have occurred at both the Welcome RV Park and the former Hi-Ali Motel. However, given the current and known historical groundwater flow direction and gradient, a source at either location does not explain PCE concentrations at the Rhoades and Kauffman properties. PCE concentrations at those properties may be due to a different groundwater flow direction in the past. Although the current

regional groundwater flow direction appears to be to the north/northeast, the flow may have been different in the past if the domestic well pumping regime was different.

Lateral dispersion of the plume is more pronounced than that seen in typical VOC plumes. The exaggerated dispersion is at least partly due to the pumping of the domestic wells, and could explain the occurrence of PCE in the Rhoades and Kauffman wells.

11.8 RECOMMENDATIONS

Based on the results of the investigation, MACTEC makes the following recommendations:

- Due to the potential for increased migration of the contaminated groundwater plume, continued quarterly groundwater sampling is warranted to protect the groundwater users whose wells may be threatened, and to monitor PCE concentration trends in the impacted wells.

- Although it is not recommended at this time, further characterization of the horizontal extent of the PCE plume may become necessary in the future if significant changes to the groundwater flow regime occur.

- One additional aquifer pumping test may be necessary to determine aquifer characteristics in the north part of the Site, in the vicinity of monitoring wells QMW-4, QMW-8, and QMW-10. As previously discussed, there is reason to believe that hydraulic conductivity of soils in the saturated zone may be different in this area than in the area of wells QMW-6 and QMW-7, where the previous aquifer tests were conducted.

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