FINAL FEASIBILITY STUDY REPORT
FOR THE LOWER SAND AND GRAVEL SUBUNIT

WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA

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May 16, 2012

Project No. 2209.004

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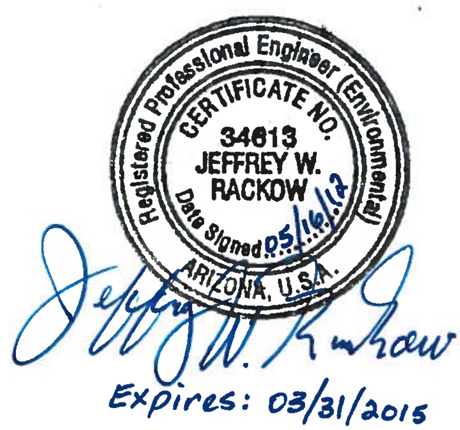

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APPENDICES

LIST OF ACRONYMS

AS	Air Sparging
AAC	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
ADOT	Arizona Department of Transportation
ADWR	Arizona Department of Water Resources
ARS	Arizona Revised Statutes
ATC	Approval to Construct
AWQS	Aquifer Water Quality Standard
AZPDES	Arizona Pollutant Discharge Elimination System
BCC	Brown and Caldwell Consultants
bgs	Below Ground Surface
BHHRA	Baseline Human Health Risk Assessment
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cfm	Cubic Feet per Minute
COCs	Contaminants of Concern
COP	City of Phoenix
DCE	Dichloroethene
DO	Dissolved Oxygen
DSD	Development Services Department
EGA	East Grand Avenue
EPA	U.S. Environmental Protection Agency
ERA	Early Response Action
EVO	Emulsified Vegetable Oil
EW	Extraction Well
^{o}F	Degrees Fahrenheit
FS	Feasibility Study
ft	Foot; Feet
GAC	Granular Activated Carbon
GPL	Groundwater Protection Level
gpm	Gallons per Minute
hp	Horse Power
IRA	Interim Remedial Action
ISB	In-situ Bioremediation
IW	Injection Well
K	Thousand
lbs	Pounds
LC	Life Cycle
LGAC	Liquid-phase Granular Activated Carbon
LSGS	Lower Sand and Gravel Subunit
MCESD	Maricopa County Environmental Services Department
MCLs	Maximum Contaminant Levels

mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Liter
µg/L	Micrograms per Liter
$\mu g/m^3$	Micrograms per Cubic Meter
M	Million
MNA	Monitored Natural Attenuation
MW	Monitoring Well
NCP	North Canal Plume
NPV	Net Present Value
O&M	Operation and Maintenance
ORP	Oxidation Reduction Potential
PCE	Tetrachloroethene (also known as Perchloroethene)
P&T	Pump-and-Treat
PVC	Polyvinyl Chloride
RI	Remedial Investigation
ROI	Radius of Influence
ROs	Remedial Objectives
ROW	Right-of-Way
SGWS	Shallow Groundwater System
SRP	Salt River Project
scfm	Standard Cubic Feet per Minute
SVE	Soil Vapor Extraction
SVOCs	Semi-Volatile Organic Compounds
TCA	Trichloroethane
TCE	Trichloroethene
TDS	Total Dissolved Solids
UAU	Upper Alluvial Unit
UIC	United Industrial Corporation
VGAC	Vapor-phase Granular Activated Carbon
VOCs	Volatile Organic Compounds
WCC	Woodward-Clyde Consultants
WCP	West Central Phoenix
WGA	West Grand Avenue
WOC	West Osborn Complex
WQARF	Water Quality Assurance Revolving Fund

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE OF THE FEASIBILITY STUDY REPORT

Groundwater contamination at the West Osborn Complex (WOC) Water Quality Assurance Revolving Fund (WQARF) Site (the Site), located in Phoenix, Arizona, consists of two plumes: the Lower Sand and Gravel Subunit (LSGS) plume, and Shallow Groundwater System (SGWS) plume. The WOC Facility boundary and surrounding area of the Site is shown on Figure 1-1. The Final Feasibility Study (FS) report for the SGWS plume was prepared by GeoTrans, Inc. (GeoTrans) and submitted to Arizona Department of Environmental Quality (ADEQ) on January 12, 2012 (GeoTrans, 2012); the report was approved by ADEQ on March 27, 2012. This Final FS report was prepared by GeoTrans for the LSGS plume pursuant to: the ADEQ-approved FS Wok Plan for the Site (GeoTrans, 2005); ADEQ letter dated July 3, 2007 (ADEQ, 2007); ADEQ April 5, 2011 final comments (ADEQA, 2011) for the Draft LSGS Report that was prepared by GeoTrans and submitted to ADEQ on January 22, 2009 (GeoTrans, 2009); ADEQ decision regarding remedial alternatives for the LSGS (ADEQ, 2011); and discussions with ADEQ.

This report was prepared in accordance with Arizona Administrative Code (AAC) R18-16-407 based upon the data and findings of the Remedial Investigation (RI) and additional investigations that have been conducted by United Industrial Corporation (UIC) and others[1] from 1984 through 2007. UIC was later purchased by AAI Corporation, which was in turn acquired by Textron. The objectives of the FS are as follows:

1. Identity a reference and alternative remedies capable of achieving the Remedial Objectives (ROs) defined by the May 2005 Final Remedial Objectives Report, prepared by the ADEQ.

2. Evaluate each of the identified remedies and recommend the best alternative that will meet the ROs and comply with the requirements of Arizona Revised Statutes (AR5) §49-282.06.

Based on the objectives stated above, the FS presents a recommendation for the preferred remedy 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.

[1] Previous investigators include Woodward-Clyde Consultants (WCC), on behalf of Lansdale Semiconductor, Inc. (Lansdale) in 1987 (WCC, 1987), Brown and Caldwell Consultants (BCC), on behalf of Components Incorporated in 1991 and 1992 (BCC, 1992), and the ADEQ as early as 1984 (WCC, 1987).

3. Is reasonable, necessary, cost-effective and technically feasible.
4. Addresses any well (used for municipal, domestic, industrial, irrigation or agricultural purposes) that could produce water that would not be fit for its current or reasonably foreseeable end use without treatment.

The FS was conducted in accordance with the ADEQ WQARF Remedy Selection Rule, as presented in Title 18, Environmental Quality, Chapter 16, Department of Environmental Quality Water Quality Assurance Revolving Fund Program, Article 4, Remedy Selection, R18-16-407, Feasibility Study.

1.2 REPORT ORGANIZATION

The FS report has been organized into the following sections:

- Section 1.0 – INTRODUCTION: This section summarizes the purpose and scope of the FS Report.
- Section 2.0 – SITE BACKGROUND: This section presents a summary description of the Site and its LSGS, physiographic setting, nature and extent of contamination, and a risk evaluation.
- Section 3.0 – FEASIBILITY STUDY SCOPING: This section presents the regulatory requirements presented in statutes and rules, delineates the remediation areas, and presents the ROs identified in the ADEQ May 2005 report.
- Section 4.0 – EARLY RESPONSE ACTIONS: This section presents the Early Response Actions (ERAs) that have been undertaken at the Site.
- Section 5.0 – IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES: This section presents an evaluation and screening of various remedial technologies related to contamination in groundwater, and lists the technologies that have been retained for inclusion into the reference and alternative remedies. In addition it describes options for discharge of treated groundwater and end use of the water.
- Section 6.0 – DEVELOPMENT OF REFERENCE REMEDY AND ALTERNATIVE REMEDIES: This section presents the selected reference remedy, a more aggressive remedy, and a less aggressive remedy. Each of the remedies identified includes a discussion of its associated strategy and measures for multiple remediation systems which comprise each remedy.
- Section 7.0 – DETAILED COMPARISON OF THE REFERENCE REMEDY AND THE ALTERNATIVE REMEDIES, IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES: The three selected

remedies are compared to each other based on practicability, permitting, source control, cost, risk and benefit. Any uncertainties associated with each remedy are also discussed in this section.

- Section 8.0 – PROPOSED REMEDY: This section presents:

  1. The recommended remedy.

  2. A discussion of how the recommended remedy will achieve the ROs.

  3. Consistency with water management plans.

  4. How the comparison criteria for the selected remedies were considered.

  5. How the proposed remedy will meet the requirements presented in ARS §49-282.06 and AAC R18-16-407.

2.0 SITE BACKGROUND

This section presents a summary of the Site background, physiographic setting, nature and extent of contamination, and a risk evaluation. Additional details are available in the Final RI Report (RI Report) for the Site prepared by GeoTrans (GeoTrans, 2004).

2.1 SITE DESCRIPTION

The Site is located in Phoenix, Arizona, and consists of the WOC Facility and two groundwater plumes originating from it, the SGWS plume and the LSGS plume. Figures depicting the SGWS plume are presented in the January 27, 2012 FS for the SGWS. The estimated plume boundary based on the September 2010 and September 2011 groundwater sampling events are depicted in Figures 3-1 and 3-2, respectively. The WOC Facility consists of three adjoining properties, located at street addresses of 3536 (East Parcel), 3600 (Middle Parcel), and 3640 (West Parcel), West Osborn Road, Phoenix, Arizona (Figure 2-1). The WOC Facility is bounded by the Grand Canal on the north, Osborn Road on the south, 35^{th} Avenue on the east, and the extension of 37^{th}Avenue on the west.

2.2 SITE REGISTRY

In 1982, trichloroethylene (TCE) was detected in City of Phoenix (COP) wells COP-70 and COP-71, located downgradient of the WOC Facility (Figure 3-1). Detected TCE concentrations exceeded the U.S Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) of 5 micrograms per liter (µg/L).

In 1984, the Arizona Department of Health Services (ADHS) identified dissolved-phase volatile organic compounds (VOCs) in the on-Site production well (hereafter called “the WOC irrigation well”[2] or “the Pincus Well”) located on the Middle Parcel. In 1987, Woodward-Clyde Consultants (WCC), under a contract with Lansdale Semiconductors, Inc. (occupant of the Middle Parcel at that time) collected 10 surface soil samples and one groundwater sample from the Pincus Well. Two soil samples were found to contain 285 and 2,020 µg/kg TCE, and the groundwater sample was found to contain 256 µg/L TCE, thus above the MCL of 5 µg/L.

The WOC Facility and the plumes originating from it were originally designated as the West Central Phoenix (WCP) WQARF Site in 1987. However, in 1998, the WCP WQARF Site was divided into five WQARF registry sites, one of which is the Site.

2.3 SOURCE AREA DEFINITION

The results of the extensive soil sampling consisting of about 150 samples indicated that the soil contamination at the WOC Facility was due to VOCs. Low levels of primarily TCE and even lower concentrations of 1,1-dichloroethene (1,1-DCE) and tetrachloroethene (PCE) were identified at the WOC Facility in the contents of and in native soil adjacent to various

[2] This well was designated the WOC irrigation well based on its observed use for landscape irrigation in 1987, when environmental investigation was undertaken by WCC.

waste/wastewater disposal facilities (GeoTrans, 2004). The detected concentrations were all below Arizona Soil Remediation Levels (SRLs) (both residential and non-residential), and with the exception of six samples, were below established Groundwater Protection Levels (GPLs). However, no specific location(s) were identified as the source(s) of the VOCs contamination in the unsaturated zone soils and SGWS. Based on these soil sampling results, an area in the north-northwest portion of the Middle Parcel appeared to have the largest mass of VOCs in the vadose zone. Therefore, an Early Response Action (ERA) consisting of soil vapor extraction (SVE) was implemented in the apparent source area. Follow-up vapor sampling and confirmation soil sampling verified that the SVE effectively removed approximately 449 pounds of VOCs from the vadose zone soils.

When the Grand Canal was lined in January 1998, groundwater levels at the WOC Facility immediately declined, and at the same time, concentrations of VOCs in monitor wells also declined. VOCs (TCE, 1,1-DCE, and PCE) that were formerly in the shallow groundwater and in the capillary zone remained trapped in the vadose zone and may still be affecting groundwater quality, along with any other residual VOC contamination that may be present in on-site soils.

Based on extensive sampling/analytical testing for metals in septic tank contents and soil at the time septic tanks and piping were removed, heavy metals were not detected in soil in concentrations greater than SRLs and/or GPLs, except for a few samples with arsenic concentrations above the SRLs but still well below the GPLs. However, based on the results of the Baseline Human Health Risk Assessment (BHHRA; see Section 2.7 below) and the known history of manufacturing operations at the WOC Facility (including information obtained from employee interviews conducted by the ADEQ), arsenic was not considered a COC at the WOC Facility.

2.4 CHRONOLOGY OF SITE ACTIVITIES

The following outlines many of the events and investigative milestones for the project:

1987 — WCC reports that ADHS identified dissolved-phase VOCs in the on-site production well (hereafter called “the WOC irrigation well” or “the Pincus Well”) in 1984 (WCC, 1987). WCC collects 10 soil samples at the Lansdale facility on the Middle Parcel and analyzes them for VOCs. The results are reported in a preliminary site investigation for Lansdale.

1989 — Earth Technology Corporation (Earth Tech) begins regional groundwater investigations for ADEQ (Earth Tech, 1989; 1994; 1996).

ADEQ conducts site inspections of all three WOC Facility parcels (ADEQ, 1989a,b,c) after the results of preliminary assessments recommended further investigations based on evidence of historic TCE usage at the WOC Facility. ADEQ conducts a soil-gas survey on all three parcels in conjunction with drilling operations as part of the site investigations.

1991 — Applied Environmental Consultants completes a Phase I RI/FS on the West Parcel of the WOC Facility on behalf of May Industries to identify any soil contamination.

July 1991 BCC begins a preliminary site characterization of the WOC Facility (on behalf of Components, Inc.) that includes a geophysical survey and a subsurface soil investigation. The results of the geophysical survey are used to identify subsurface utilities in order to select locations for the subsurface soil investigation. Five groundwater monitoring wells are installed into the SGWS at the WOC Facility (MW-1S thru MW-5S).

1996 UIC completes the Phase I and Phase II Soil Investigation, which includes the following:

- Excavation and sampling of test trenches and pits to locate waste disposal features, such as septic tanks, tile lines, and seepage pits.
- Removal of contaminated septic tanks as a source control measure.
- Drilling of soil borings in potential source areas to determine the horizontal and vertical extent of the VOC contamination.
- Evaluation of potential releases from piping.

Ten groundwater monitoring wells (MW-6S, MW-7S, MW-2M, MW-3M, MW-4M, MW-6M, MW-7M, MW-4L, MW-6L and MW-7L) are installed in the SGWS (S-series wells), LSGS (M-series wells), and Middle Alluvial Unit (MAU; L-series wells) at locations designated in the 1996 Consent Decree and ADEQ-approved Work Plan. Monitoring and sampling of all groundwater monitoring wells installed by BCC begins.

1997 Nine groundwater monitoring wells (MW-100S, MW-l01S, MW-102S, MW-103S, MW-104S, MW-102M, MW-105M, MW-106M, and MW-13M) are installed in the SGWS and LSGS pursuant to ADEQ approvals. Monitoring and sampling of these wells begins, in addition to continued monitoring and sampling of the 15 wells already in place. Additional monitoring wells are installed over the next 10 years to define the lateral extent of the TCE impacts to the SGWS and LSGS. All new wells are added to the groundwater monitoring network upon their completion. Groundwater monitoring well construction information is provided in Table 2-2.

January 1998 The Salt River Project (SRP) constructs the lining of the Grand Canal located adjacent north of the WOC Facility. Prior to 1998, the Grand Canal was unlined in the vicinity of the WOC Facility and served as a source of groundwater recharge.[3]

[3] The recharge created a water table mound, which acted as a groundwater divide between the North Canal Plume (NCP)

June 1999 — An SVE system is installed as part of an ERA at the Middle Parcel of the WOC Facility and is initiated in August 1999.

September 2002 — Confirmation soil borings and soil sampling are completed to evaluate the progress of the SVE remediation. Based on these results, the SVE system is decommissioned in October 2002. A total of approximately 449 pounds of VOCs are removed from the vadose zone between August 1999 and October 2002.

July 2004 — GeoTrans issues the RI Report. As part of the RI, the WOC irrigation well is abandoned in accordance with Arizona Department of Water Resources (ADWR) regulations. ADEQ issues the Land and Water Use Report for the Site.

May 2005 — ADEQ issues the RO Report for the Site.

2005- 2010 — Groundwater sampling of SGWS monitoring wells is conducted in June 2005, September 2006, June 2007, December 2007, May 2008, September 2008, December 2008, March 2009, September 2009, and September 2010. Groundwater sampling of LSGS wells is conducted in July 2005, September 2006, September 2007, September 2008, March 2009, September 2009, and September 2010. This work is performed concurrently with additional downgradient characterization of contamination in the SGWS and LSGS, including the installation and sampling of wells MW-203S through MW-209S, and MW-203M.

2.5 WOC FACILITY DESCRIPTION

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

West Parcel – The West Parcel totals approximately 8 acres and is comprised of six individual parcels, as identified by the Maricopa County Assessor's Office. Seven buildings and asphalt parking lots are currently located on the West Parcel; two of the seven buildings are industrial buildings, and five are multi-tenant office buildings. Until 2000, the majority of the West Parcel, with exception to the northeastern most parcel, was owned by Mr. Charles May and occupied by May Industries, Inc. (May Industries). The May Industries' portion of the property included one industrial building that housed a precision machine shop and 2.6

WQARF Site and the Site. After the groundwater mound dissipated over time, many shallow wells near the Grand Canal dried up. In addition, groundwater flow north of the Grand Canal shifted to the south, allowing contaminants to migrate from the NCP onto the Site.

acres of land in the northwest portion of the West Parcel. The other building, located at the northeastern corner of the parcel, was occupied by Metal Joining, and affiliate of May Industries, Inc. The parcel transferred ownership to Elm Properties, LLC in February 2000. The northeastern parcel of the West Parcel was owned by Ms. Gloria Chestnut until April 2000, when it was sold to Elm Properties, LLC.

Middle Parcel – The Middle Parcel is approximately 3.9 acres in size and is partially enclosed with a chain-link fence. Structures on the Middle Parcel include a large main building and a small storage shed located north of the main building. There are three, relatively small, unpaved dirt areas located along the western and eastern boundaries of the Middle Parcel. The remaining exterior areas are paved, primarily with asphalt. The Middle Parcel is currently owned by Mr. Charles Delaney, who has owned the property since December 1992, when he purchased it from Lenore U. Pincus Family Trust. A mattress and furniture liquidation and used furniture auctioning and sales have been the tenants at the Middle Parcel since approximately December 1992. The Pincus Well was located in the northwest part of the Middle Parcel and was abandoned in July 2004.

East Parcel – The East Parcel is approximately 3.2 acres in size and is completely enclosed by a chain-link fence. One multi-tenant commercial/industrial building is located on the parcel. The driveways and parking areas are paved with asphalt. Till September 2002, the property was owned by Eugene and Laura Perri, and the main tenant was Western Dynex, Inc. Since September 2002, the East Parcel has been owned The Seven Angels, LLC. The East Parcel is currently occupied by Industrial Chassis, Inc.

2.6 WOC FACILITY HISTORY

Like most of the central part of the Phoenix metropolitan area, beginning in 1889, the WOC Facility and the surrounding area were used for agricultural purposes and irrigated with water from the Grand Canal. The history of development at the WOC Facility was previously provided by others (WCC, 1987; ADEQ, 1989a,b,c; U.S. Environmental Protection Agency [EPA], 1989; and BCC, 1992) and summarized below.

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

The WOC Facility ownership history is shown in Table 2-1. According to the ADEQ, from 1957 to 1989, all entities operating at the facility were involved in the manufacturing of electronic components, their manufacturing processes were similar, and each used trichloroethene (TCE) as a solvent (ADEQ, 1989a,b,c). The ADEQ evaluated manufacturing processes and solvent usage by conducting interviews with employees and former employees. ADEQ also obtained purchase records for solvents and disposal records for wastes, and asked former and present owners and tenants to fill out hazardous waste questionnaires. The results of these activities are summarized in the ADEQ's site investigation reports (ADEQ, 1989a,b,c).

Topp Industries, Inc. purchased the property in July-1959; they merged with United Industrial Corporation (UIC) the same month, with UIC as successor in merger. Later that month, the deed was transferred from UIC to U.S. Semiconductor Products, Inc., a subsidiary of UIC. In May 1962, the property was acquired by Nucor Corporation, which sold the property to Components, Inc. (old) in October 1965. Components, Inc. sold the property in June 1971 to Corning Glass Works. Components, Inc. (new), a subsidiary of Corning Glass Works, operated at the WOC Facility between June 1971 and October 1976. Between 1976 and 1978, Corning Glass Works, through Components, Inc. (new), subdivided the WOC Facility into three separate properties (the East, Middle, and West Parcels) and sold them starting in October 1976. The ownership of the three parcels is presented in Table 2-1.

The East Parcel was purchased by Eugene and Laura Perri in November 1976. Western Dynex, Inc. operated at the East Parcel, and assembled computer disk drives from November 1976 through September 2002. The Middle Parcel was sold to Marbar Corporation (controlled by the Pincus family) in October 1976. Lansdale Transistor & Electronics, Inc., who produced transistors and semiconductors, operated on the Middle Parcel between November 1976 and February 1987, followed by Lansdale Semiconductor, Inc. The property was sold to Mr. Charles Delaney (current property owner) in December 1992. The West Parcel was sold to Mr. Charles May in June 1978 and operated as a multiple-tenant office and industrial park with many operating business that included, but are not limited to: May Industries, Inc., Metal Joining, Arizona Textile, and Aztec Chemical.

After the subdivision and sale, the WOC Facility continued to be used for electronics manufacturing and assembly. Lansdale Transistor & Electronics, Inc., and subsequently Lansdale Semiconductor, Inc., leased the Middle Parcel from approximately October 1976 through December 1988 for the manufacture of transistors. Western Dynex, Inc. assembled computer disk drives on the East Parcel from November 1976 through September 2002. According to the ADEQ, both of these facilities used solvents: TCE at Lansdale, and TCE and TCA at Western Dynex, Inc. May Industries began operations at the West Parcel in about 1980 and used TCA, along with other chemicals.

In 1982, TCE was detected in City of Phoenix (COP) wells COP-70 and COP-71, located downgradient of the WOC Facility, at concentrations exceeding the EPA Maximum Contaminant Level (MCL) of 5 µg/L. The WOC Facility and the plumes originating from it were originally designated as the West Central Phoenix (WCP) WQARF Site in 1987. However, in 1998, the WCP WQARF Site was divided into five WQARF Registry Sites, one of which is the Site.

2.7 RISK EVALUATION FROM RI REPORT

2.7.1 Baseline Human Health Risk Assessment

In February 2000, Roy F. Weston (currently Weston Solutions) prepared a BHHRA for the Site to evaluate potential chemicals of concern (COCs) (Weston, 2000):

- Soil: Arsenic and TCE at the WOC Facility.
- Groundwater: TCE, PCE, 1,1-DCE, bromodichloromethane, and chloroform in

groundwater at and downgradient of the WOC Facility.

The BHHRA was divided into the following exposure areas and evaluated separately:

- Surface soils at the WOC Facility.

- Four subsurface soil areas at the WOC Facility.

- Five groundwater exposure areas.

The no-action alternative was evaluated based upon soil and groundwater use at the WOC Facility (on site) and groundwater use in the downgradient residential neighborhood (off site). The following exposure pathways were evaluated:

- Exposure to surface soils at the WOC Facility by current on-site industrial/commercial workers and trespassers.

- Exposure to groundwater by current residents of downgradient neighborhoods living above contaminated groundwater.

- Exposure to subsurface soils at the WOC Facility by current on-site construction workers, future residents, and future industrial/commercial workers.

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

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

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

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

- Future On-Site Child and Adult Residents:
  - On-Site Soil:

    - *Total Carcinogenic Risk*: 1.4E-07 to 1.8E-05, depending on the location; based on arsenic and/or TCE.
    - *Total HIs*: <1, thus below the benchmark of concern.
  - Groundwater:
    - *Total Carcinogenic Risk*: 3.5E-04; majority of risk (51 percent) due to inhalation of VOCs during non-ingestion groundwater use, and groundwater ingestion (approximately 47 percent); 1,1-DCE accounted for about 75 percent of the risk.
    - *Total HIs*: 7.2 for child and 4.8 for adult; TCE accounted for about 94 percent of the Total HIs.

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

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

2.7.2 Summary

The BHHRA calculations indicated TCE, 1,1-DCE, PCE, and/or arsenic to be the primary chemical of potential concern. The BHHRA concluded the following:

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

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

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

- On-Site Soil and Groundwater: Future on-Site industrial/commercial workers.

2.7.3 Conclusions

Because no direct domestic or municipal use of groundwater is currently occurring, and no future use is planned without treatment, it was concluded that the groundwater exposure pathway is not complete for on- or off-site receptors. For this reason, the risks identified in this assessment are believed to be over-estimated for groundwater exposure at the Site.

Risk assessment calculations for exposure to arsenic in soils at the WOC Facility are based upon soil samples which include one anomalously high concentration of 120 milligrams per kilogram (mg/kg). This has resulted in an overestimated risk from arsenic in soils at the WOC Facility. Consequently, there is no need for remediation of on-site soils.

Thus, based on the BHHRA findings and the known history of manufacturing operations at the WOC Facility (including information obtained from employee interviews conducted by the ADEQ), it was concluded by GeoTrans that TCE, PCE, and 1,1-DCE are the only COCs for the Site.

3.0 FEASIBILITY STUDY SCOPING

3.1 REGULATORY REQUIREMENTS

According to ARS §49-282.06, the following factors must be considered in selecting remedial actions:

- Population, environmental and welfare concerns at risk.
- Routes of exposure.
- Amount, concentration, hazardous properties, environmental fate, such as the ability to bio-accumulate, persistence and probability of reaching the waters of the state and the form of the substance present.
- Physical factors affecting environmental exposure, such as hydrogeology, climate and the extent of previous and expected migration.
- The extent to which the amount of water available for beneficial use will be preserved by a particular type of remedial action.
- The technical practicality and cost-effectiveness of alternative remedial actions applicable to a site.
- The availability of other appropriate Federal or state remedial action and enforcement mechanisms including, to the extent consistent with this article, funding sources established under the Comprehensive Environmental Response Compensation and Recovery Act (CERCLA), to respond to the release.

The Remedy Selection Rule R-18-16-407, Feasibility Study, states that a FS is a process to identify a reference remedy and alternative remedies that appear to be capable of achieving ROs and to evaluate the remedies based on the comparison criteria, to select a remedy that complies with ARS §49-282.06.

3.2 CONCEPTUAL SITE MODEL SUMMARY

3.2.1 Site History

A detailed history of the Site, including documentation on timing of contamination, a Site timeline, and the significant events and their impact to the Site and associated contamination is presented in the RI Report (GeoTrans, 2004b).

Originally, the WOC Facility consisted of about 15 acres that are presently subdivided into three parcels: East, Middle, and West. Beginning in 1957, the WOC Facility was used by different owners to manufacture electronic components. Solvents, including TCE, were used in the manufacturing processes. When the WOC Facility was first developed, there was no municipal sewer service, and on-site systems, consisting of septic tanks and seepage pits, were used for wastewater disposal. Although the time period over which contamination occurred is unknown, and chlorinated solvent use at the WOC Facility occurred until after 1980, it is believed that TCE was introduced to the ground via drainage from seepage pits during the time period between 1957 and 1965. GeoTrans found five septic tanks and 17 seepage pits during a 1996 soil investigation, described in detail in the RI report. TCA contamination is believed to have occurred between 1978 and 1990, associated with its use on the West Parcel and East Parcel by May Industries and Western Dynex, respectively. Additionally, TCE contamination is believed to have impacted the LSGS aquifer via the WOC irrigation well, a 581-ft deep well located at the northern end of the Middle Parcel of the WOC Site, subsequently abandoned in July 2004.

Upon being introduced to the soil, the chlorinated solvents began downward infiltration, driven by gravity, and periodic precipitation. They reached the SGWS aquifer, and began dissolving in the groundwater and flowing south, away from the Grand Canal. Some of the solvent likely remained in the soil as NAPL or sorbed to the finer-grained clays beneath the Site, which impeded their downward progress. Ultimately, the downward infiltration of solvents introduced to subsurface soils at the seepage pits was stopped by the higher clay content in the middle fine-grained unit, from which they likely continued to dissolve, contributing to the groundwater plume in the SGWS. In accordance with the RI/FS Work Plan that was incorporated into the Consent Decree, an interim remedy was implemented to achieve shot-term mass removal of VOCs from investigated sources. This remedy consisted of a SVE system, which operated in an area where former septic tanks and seepage pits were installed at the Middle Parcel to remove VOCs that would otherwise be susceptible to contaminating groundwater. The SVE system was installed in June 1999 and operated from August 4, 1999 through October 21, 2002. A total of approximately 447 pounds of VOCs were extracted from the subsurface and treated with vapor-phase granular activated carbon (VGAC) to remove VOC prior to discharge into the atmosphere.

On behalf of UIC, GeoTrans submitted a technical letter on September 11, 2001 to ADEQ, requesting ADEQ's approval to permanently shut-down the SVE system operation. Consequently, confirmatory drilling/sampling was conducted in September 2002. The results showed that no detectable VOCs were present in 39 subsurface samples collected from the SVE remediation zone. Based on these results, the justification specified in GeoTrans' September 11, 2001 letter was accepted by ADEQ, and the SVE system was shut down on October 21, 2002. The activities and the analytical results associated with the confirmatory soil drilling and sampling were all contained in the GeoTrans' report regarding confirmatory drilling/soil sampling results for shut-down of interim SVE remediation system at the Middle Parcel (GeoTrans, 2004a). Currently, based on the results of the SVE confirmation borings, there is no continuing on-site source of VOCs to the shallow groundwater.

3.2.2 Site Hydrogeology

In 1993, the ADWR released the results of its modeling study of the Salt River Valley (Corkhill, et al. 1993). For modeling purposes, the ADWR defined three hydrogeologic units that are generally correlative with the hydrostratigraphic units defined by the U. S. Bureau of Reclamation in 1976. These include: the Upper Alluvial Unit (UAU), the Middle Alluvial

Unit (MAU), and the Lower Alluvial Unit (LAU). For this report, the ADWR's hydrostratigraphic nomenclature has been used. The wells that were drilled at the WOC were denominated with the suffixes S, M, and L. The S-series wells were completed in the upper part of the UAU, the M-series wells were completed in the deepest part of the UAU, and the L-series wells were completed in the MAU. No wells at the WOC were completed in the LAU. Therefore, the S-, M-, and L-series wells will be referred to as simply the shallow, intermediate, and deep wells.

In the vicinity of the WOC Facility, the aquifer units of concern include the UAU, and to a lesser extent the MAU. The UAU is the uppermost basin fill unit in the Salt River Valley and, where saturated in the West Salt River Valley, is the most prolific water producer. It is composed mainly of silt, sand, and gravel, but local, usually relatively thin, clay layers can be present. Near the WOC, the UAU is much finer-grained than approximately 1.5 miles to the south, closer to the Salt River channel. The UAU has been encountered in all of the previous wells that have been drilled in the West Central Phoenix WQARF Study Area. Most of these have been shallow water-table wells and have only penetrated the top approximately one-half of the Unit. However, the entire thickness was drilled at several locations for the WOC RI, and at most of these, three or four subunits of the UAU can be recognized. Of particular relevance are the SGWS, consisting of silts and sands, typically present at a depth of 70-130 feet bgs, the Middle Fine-Grained Unit (MFGU), typically consisting of silt and clay, and present beneath the SGWS, and the LSGS, a sand and gravel present beneath the MFGU. The LSGS is the most significant water-bearing zone in the vicinity of the WOC. Its distinctive geophysical signature is present on most of the well logs, and shows relatively good continuity between all wells that were drilled to a sufficient depth. Aquifer tests show that it also has the capacity to transmit large quantities of water (Section 5.0, RI Report; GeoTrans, 2004b). It was the target zone for the M-series wells that were drilled for the RI.

3.2.3 Groundwater Flow and Contaminant Transport

Groundwater flow directions and gradients at the WOC Facility have varied based on aquifer characteristics. Prior to lining of the Grand Canal, groundwater flowed radially away from the canal within the underlying SGWS. At greater depth, the flow direction in the LSGS was slightly south of east to west. Groundwater recharge associated with the Grand Canal is believed not to have significantly influenced flow direction or gradient in the LSGS due to the presence of the middle fine-grained unit. Following lining of the canal, flow gradients in the SGWS decreased from 0.05 to 0.001 feet per feet (ft/ft). Although flow direction in the SGWS did not significantly change, the elevation of the water table declined at the WOC Facility area over time by approximately 40 feet from 1996 to 2011.

Figures 3-5 through The direction and value of groundwater gradients for the LSGS over the period of 2003 through 2011 are depicted on the water level contours maps At the LSGS wells, horizontal gradients have been consistently south-southwest, except in June 1997, when the SRP well was pumping. The value of the horizontal gradient in the area of the WOC Facility has ranged from about 0.005 to 0.01 ft/ft. Southwest and downgradient of the WOC Facility at the Site, between MW-107M and MW-110M, the gradient is about 0.002 ft/ft.

At present, groundwater contamination continues to move downgradient from the WOC

Facility in the direction of groundwater flow. Based on groundwater monitoring results, the SGWS plume has impacted groundwater at MW-208S, which is the farthest well to the south in the existing WOC Site well network. The groundwater plume in the LSGS is believed to be delineated at the downgradient edge by MW-108M, which has typically been below the 5.0 μg/L Arizona Aquifer Water Quality Standard (AWQS) for TCE. Water seepage velocities in the LSGS have been estimated in a range from 2 to 14 feet per day (ft/day). TCE concentrations initially detected at MW-108M in 2003 have not significantly increased since, suggesting that the LSGS plume has stabilized.

A second chlorinated VOC groundwater plume has historically been present north of the WOC Facility and its associated plumes. The North Canal Plume (NCP) consists of similar contaminants, including TCE, PCE and 1,1-DCE, in different concentrations than those of the WOC plumes, in particular containing elevated concentrations of PCE not seen in the WOC plumes. Until the Grand Canal was lined in 1998, the NCP remained entirely north of the Canal and was prevented from moving southward past the canal by the mounded water infiltrating through the canal bottom. As the hydraulic mound of the leaky canal dissipated in the early 2000's, the NCP began flowing southward, co-mingling with the WOC plume, as indicated by increasing concentrations of PCE in the SGWS since the canal was lined. Concentrations of TCE and 1,1-DCE in the SGWS also began to increase following lining of the canal.

Additionally, following canal lining, PCE concentrations in the LSGS began increasing, suggesting a pathway from the SGWS to the LSGS. The annular space around the well casing of the WOC irrigation well (abandoned in 2004) is believed to have been the former pathway between the SGWS and LSGS, enabling contaminants from the NCP SGWS to infiltrate through the MFGU to the LSGS.

3.2.4 Hydraulic Communication Between SGWS and LSGS

Hydraulic communication between the SGWS and the LSGS is believed to be minimal. The hydrostratigraphic unit between the SGWS and LSGS consists of a thick sequence of silts and clays that act as an aquitard. Groundwater flow directions and potentiometric surface elevations are significantly different in the SGWS compared to the LSGS. As noted in the RI report, there are large vertical groundwater gradients at the WOC Facility noted between the two aquifers. Hydraulic stresses affecting one aquifer have minimal effect on the other. In particular, the set of data collected during the March 1997 through December 1997 time period reveals a direct correlation between large water level changes in the LSGS (MW-6M), likely due to regional pumping, with much smaller and slightly lagged-in-time responses in the shallow (MW-6S) and deep (MW-6L) monitor wells. While 30 to 35 feet of drawdown was observed in LSGS wells MW-2M, -3M, -4M,-6M, -7M, and the WOC irrigation well as a result of this pumping (at an estimated rate of 2,600 gallons per minute [gpm]), the observed drawdown in the shallow aquifer monitoring wells was generally 2 feet or less. The connection appears to be so poor that the two zones behave very differently in response to most aquifer stresses (e.g., canal recharge to the SGWS, or regional pumping in the LSGS). Although a poor hydraulic connection between the water table system (i.e., SGWS) and the LSGS appears to exist, no apparent changes in the gradient in the LSGS associated with the canal lining have been observed. This supports the interpretation of a poor hydraulic connection and subsequent low vertical flux between the SGWS and the LSGS subunit (GeoTrans, 2004b).

For these reasons, the SGWS and LSGS are believed to represent aquifers for which the degree of hydraulic connection is extremely low. As a result, the two aquifers may be treated as though they are essentially hydraulically isolated and independent of each other for the purposes of remedial system design.

3.2.5 Baseline Human Health Risk Assessment

As discussed in Section 2.7, Weston prepared a BHHRA for the Site (Weston, 2000). In summary, the BHHRA calculations indicated TCE, arsenic, and/or 1,1-DCE to be the primary chemical of potential concern, resulting in the following:

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

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

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

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

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

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

3.3 DELINEATION OF REMEDIATION AREAS

According to the ADEQ-approved FS Work Plan (GeoTrans, 2005), no further remediation is required for the unsaturated zone at the WOC Facility based on the success of the on-site SVE system and the results of the subsequent confirmation borings. Therefore, for the purpose of the FS, only compounds whose groundwater concentrations have exceeded the relevant AWQSs are considered for the determination of the extent of contamination in LSGS groundwater. The following is a summary of the extent of contamination:

- Based on GeoTrans' review of the historical groundwater quality data and the groundwater quality data from September 2011, as presented in Table 3-1, TCE, PCE, and 1,1-dichloroethene (1,1-DCE[4]) are the contaminants of concern (COCs).

- The groundwater remediation area consists of portions of the LSGS with concentrations of TCE and PCE above the AWQSs (5 µg/L for each) as of September 2011 (Figure 3-2).

3.3.1 Groundwater

A comprehensive understanding of the type and extent of contamination and fate and transport of the COCs is essential to define the nature and extent of contamination at the Site, meet the ROs, and determine the remedial alternatives.

3.3.1.1 Aquifer Characteristics

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

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

Transmissivity estimates from tests at MW-7M and MW-6M are very similar to the average transmissivity values derived by the ADWR for two separate groundwater flow modeling efforts. In its 1982, two-dimensional Salt River Valley groundwater model (Long, et al., 1982), the ADWR calculated that the average transmissivity for the one-square mile section that includes the Site (Section 27, T2N, R2E) at 10,700 ft^2/day (80,000 gallons per day per foot). In its three-dimensional model (Corkhill, et al., 1993), the ADWR used a hydraulic

[4] Detected concentrations of 1,1-DCE in the LSGS monitoring wells are below the AWQS of 7 µg/L.

conductivity of 40 ft/day for the Upper Alluvial Unit (UAU) in Section 27. Based on the ADWR's initial average saturated thickness of about 275 feet for the UAU, the associated transmissivity is 11,000 ft^2/day (275 feet x 40 ft/day). Even though data interpretation in small-diameter monitor wells tested at low pumping rates for relatively short time periods needs to be done carefully and the results used with caution, the consistency reflected in the various estimates provided above adds confidence in the results.

Transmissivity values for tests at MW-6L and MW-7L are 3 ft^2/day and 80 ft^2/day, respectively. Because of the low rates of pumping, well inefficiencies due to turbulent, near-well flow were likely small, and results from drawdown and recovery phases of the tests were similar at both wells. The transmissivities for both wells are low, and both wells have very low yields. The screened formation is considered an aquitard. Although a small response was observed on the resistivity log, no recognizable coarse-grained material was observed in the formation samples. At MW-7L, the screen was set in a unit that had a recognizable resistivity signature. Formation samples contained fine gravel.

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

3.3.1.2 Groundwater Movement

Complete results of water elevation measurements for the RI groundwater investigation at the Site are presented in the RI Report, Table 5-6 (GeoTrans, 2004b). During the 1996 through 2003 time period, significant changes were observed in the depth to groundwater, the direction of the horizontal gradient, and the values of the vertical and horizontal gradients. As shown on Figure 3-3, presenting LSGS groundwater elevations and flow direction for June 1997, pumping from the SRP well 9.5E-7.7N had major impacts on the LSGS water levels, groundwater gradient and flow direction. Figures 3-3 through 3-8 show LSGS groundwater elevations and flow direction for November 1997 (when the SRP well 9.5E-7.7N was apparently not pumping), June 2003, January 2004, September 2006, September 2007, and September 2008, respectively.

As is evident in the previous discussion, most of the hydrogeologic changes that have been observed during the RI are directly related to the SRP water delivery system, which includes both the Grand Canal, SRP well 9.5E-7.7N, and other nearby wells. The canal system was constructed in the early 1900's, and with the exception of a gunite lining placed by the SRP in January 1998, all of the present features were in place by 1950, before the Site was first developed. Table 3-2 presents the annual pumping by the SRP well 9.5E-7.7N through 1999, when SRP agreed to discontinue pumping at the request of ADEQ. As is evident in Table 3-2, prior to 1999, the SRP wells near the Site pumped a considerable volume of water.

The declining water levels in the LSGS are likely due to increased regional groundwater pumping. As a result, the aquifer has been depressurized, and groundwater moves vertically into the unit from both above and below. At the start of the RI, and under non-pumping conditions, the downward vertical gradients from the water table aquifer to the LSGS ranged.

from 0.05 to 0.18 ft/ft. Upward vertical gradients to the LSGS ranged from 0.03 to 0.09 ft/ft.

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

At the LSGS wells, horizontal gradients have been consistently south-southwest, with the exception of June 1997, when the SRP well 9.5E-7.7N was pumping (Figure 3-3). At the WOC Facility, the value of the horizontal gradient has ranged from about 0.005 to 0.01 ft/ft. Southwest of the Site, between MW-107M and MW-110M, the gradient is about 0 002 ft/ft. A poor hydraulic connection between the water table system and the LSGS appears to exist, since no changes in the gradient in the LSGS obviously attributable to canal lining have been observed.

Horizontal groundwater seepage velocities in the saturated zone were estimated using the following relationship

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

Where:

K_h = the horizontal hydraulic conductivity.
i = horizontal hydraulic gradient.
n_e = effective porosity (estimated at 0.2).

Prior to canal lining, the estimated horizontal seepage velocities in the shallow water-table aquifer ranged from about 4 to 1.3 ft/day. In the LSGS, the estimated range of horizontal seepage velocities was 2 to 14 ft/day.

3.3.1.3 Extent of LSGS Contamination

The estimated aerial extent of the September 2008 LSGS plume, consisting of TCE and PCE, is presented on Figure 3-9. The upgradient lateral extent of the TCE has been drawn assuming that the upgradient boundary of the plume is at the Site Middle Parcel property boundary. This is not believed to be the case with the PCE, and as such, the PCE portion of the LSGS plume is not defined upgradient (east) of the Site. The following summarizes the extent of groundwater contamination:

- Groundwater contamination in the LSGS by TCE at concentrations greater than 5 µg/L is defined by the following monitor wells: MW-106M to the northwest, MW-102M to the south-southeast, MW-108M and MW-109M to the southwest, and MW-110 to the west.

- PCE at concentrations greater than 5 ųg/L have been detected historically in LSGS wells MW-2M, MW-3M, MW-4M, MW-7M, and MW-105M. Note that according to historical WOC facility information, PCE was not used in manufacturing; therefore, it is assumed that PCE has migrated onto the site from one or more upgradient sources.

- The extent of the LSGS plume is dependent on the continued shutdown of pumping by the SRP well 9.5E-7.7N. As was discussed in the RI Report, the operation of the SRP well causes the LSGS groundwater plume to migrate to the northwest, towards the hydrologic cone of depression caused by the well.

A complete record of groundwater quality monitoring for VOCs in the LSGS monitoring wells at the Site is provided in Table 3-1, and results of inorganic analyses for monitoring wells MW-6M and MW-108M are provided in Table 3-3. Note that VOC contamination was never detected in the L-series wells, which are screened below the LSGS in the lower part of the MAU.[5] Results of LSGS wells VOC analyses for six sampling events (November 1997, June 2003, January 2004, September 2006, September 2007, and May 2008) are presented graphically on Figures 3-9 through 3-14. The November 1997 sampling event was selected because it represents a period before the canal was lined. The June 2003, January 2004, and September 2007 sampling events were selected to display more recent results, and September 2007 was selected as the most current snapshot of water-quality conditions. Results and observations from groundwater-quality monitoring are discussed below.

Distribution of VOCs

Historical analytical results for VOCs are provided in Table 3-1 and summarized below. Note that PCE was not used in manufacturing at the Site (ADEQ, 1989a,b,c). Therefore, it is believed that PCE has migrated onto the Site from an upgradient source(s).

TCE

Historical TCE concentrations in LSGS monitoring wells are presented in Table 3-1; well locations are shown on Figure 3-2. TCE was detected during all rounds of groundwater-quality monitoring completed to date. The highest concentration measured in WOC LSGS monitoring wells was 120 µg/L in MW-2M (located at the Site) during the November 1997 sampling round (Figure 3-4). Over the course of the project, concentrations of TCE in LSGS wells have behaved as follows: remained below the detection limits in MW-106M and MW-203M; decreased in MW-3M to below detection limits; decreased in MW-2M and MW-102M and MW-107M; increased in MW-6M, and MW-7M; and remained roughly the same in all other monitoring wells (Figures 3-13 and 3-23).

[5] The M-series (LSGS) monitoring wells are completed in the deepest part of the UAU, and pilot holes were drilled deep enough (about 300 to 400 feet bgs, depending on location) to confirm the top of the underlying MAU. L-series monitoring wells were drilled from depths ranging from 740 to 810 feet bgs and were completed in the lower part of the MAU. According to the ADWR's classification of basin fill, the UAU extends to a depth of approximately 400 feet bgs; the UAU ranges in depth from approximately 400 to 975 feet bgs.

In September 2006, concentrations of TCE exceeded the AWQS of 5 µg/L in MW-2M (56 µg/L), MW-4M (13 µg/L), MW-6M (56 µg/L), MW-105M (60 µg/L), MW-107M (52 µg/L), and MW-108M (6.1 µg/L) (Figure 3-16).

The latest round of LSGS groundwater sampling was performed in September 2011, when a total of nine wells were sampled: MW-2M, MW-4M, MW-6M, MW-105M, MW-107M, MW-108M, MW-109M, MW-110M, and MW-203M. Concentrations of TCE exceeded the 5 µg/L AWQS in six of the nine LSGS wells: MW-2M (29 µg/L), MW-4M (9.4 µg/L), MW-6M (9.0 µg/L), MW-105M (41 µg/L), MW-107M (35 µg/L), and MW-108M (9.2 µg/L). (Figure 3-23). The TCE concentration was below the laboratory detection limit in MW-203M. From September 2006 to September 2011, concentrations remained below the detection limits in one well only (MW-203M), and fluctuated as follows in the remaining wells sampled:

- MW-2M: Concentrations decreased from 56 µg/L to 29 µg/L.
- MW-4M: Concentrations decreased from 13 µg/L to 9.4 µg/L.
- MW-6M: Concentrations decreased from 56 µg/L to 9.0 µg/L.
- MW-105M: Concentrations decreased from 60 µg/L to 41 µg/L.
- MW-107M: Concentrations decreased from 52 µg/L to 35 µg/L.
- MW-108M: Concentrations increased from 6.1 µg/L to 9.2 µg/L.
- MW-109M: Concentrations increased from below detection limits (<1 0 µg/L) to 3.2 µg/L.
- MW-110M: Concentrations remained essentially the same at 2.0 µg/L to 2.8 µg/L.

PCE

Of the other VOCs, only PCE has been detected in concentrations greater than the AWQS. In the LSGS wells, PCE and at times trace 1,l-DCE have been detected in multiple LSGS monitor wells (Table 3-1). The highest concentration of PCE (34 µg/L), was measured at MW-4M in June 2003. In January 2004, concentrations of PCE exceeding the 5 µg/L AWQS were detected in LSGS wells MW-2M (11 µg/L), MW-3M (9.6 µg/L), MW-4M (27 µg/L), MW-7M (20 µg/L) and MW-105M (8.9 µg/L). In September 2006, concentrations of PCE greater than 5 µg/L were measured in LSGS wells MW-2M (12 µg/L), MW-4M (21 µg/L), and MW-105M (13 µg/L). In September 2011, wells that had concentrations of PCE greater than 5 µg/L included MW-2M (13 µg/L), MW-4M (6.8 µg/L), and MW-105M (11 µg/L).

3.3.2 Flow and Transport of Contaminants

Based on the absence of TCE breakdown products (i.e., cis-l,2-DCE, trans-1,2-DCE, vinyl chloride, ethene, ethane), and likely low levels of organic carbon in the LSGS, historic and future movement of the dissolved TCE and PCE groundwater plumes can largely be described by the advective movement of the groundwater. As previously described in Subsection 3.2.1.2, Groundwater Movement, the estimated horizontal seepage velocity in the LSGS is approximately 3 to 15 ft/day. A gradual decrease in dissolved contaminant mass will naturally occur as the plume migrates downgradient. This decrease in concentrations is due to sorption to organic material and/or clay minerals within the aquifer or aquitard matrix, and dilution caused by dispersion.

3.3.3 Areas of Uncertainty

Existing uncertainties in our understanding of the extent and fate and transport of the COCs in LSGS groundwater are listed below; however, it is believed that these uncertainties do not preclude the selection of a preferred remedy.

- Migration of the dissolved-phase TCE plume in the LSGS will continue to occur to some degree; however, due to sorption and natural dilution, as described in Section 3.2.2, the lateral extent of the 5 µg/L contour is not expected to migrate far beyond the existing monitoring well network.

- Migration of the dissolved-phase PCE plume in the LSGS will also likely continue to occur to some degree. This plume is believed to have originated from a source to the north-northeast of the Site (in particular, the North Canal Plume [see Section 3.4]) and, as such, its fate and transport within the LSGS is not as certain as TCE. Continued migration and/or increasing concentrations of PCE may need to be addressed in the future by ADEQ.

- The past and present shut-down of SRP well 9.SE-7.7N and COP wells COP-70 and COP-71 has greatly facilitated UIC's ability to define the LSGS plume. Resumption of pumping from any of these wells will affect the current definition of the plume and estimates of its future transport, and may cause the spatial extent of the LSGS plume to change. Remedy pumping from one or more of these wells would be expected to capture/contain the plume, and shrink its size over time as groundwater is remediated.

3.4 EVALUATION OF IMPACTS TO SITE FROM NCP

3.4.1 Trilinear Plots

Trilinear plots were constructed to illustrate changes in the PCE, TCE, and 1,1-DCE ratios in the LSGS portion of the aquifer at the Site after the lining of the SRP Grand Canal in January 1998. Plots were developed using NCP wells located nearest to the Grand Canal that have an adequate amount of historical water quality data. Figure 3-24 shows the locations of both the

NCP and WOC monitoring wells used in the groundwater contamination impacts evaluation. Prior to the lining of the Grand Canal in January 1998, infiltration of canal water into the subsurface created an artificial groundwater mound, which formed a hydraulic barrier separating the NCP from the WOC plume in the SGWS. While the groundwater mound existed, the flow directions in the SGWS were to the north, north of the canal, and to the south, in areas south of the canal. After the mound dissipated, the flow direction in the SGWS north of the canal reversed and aligned with the SGWS regional groundwater flow direction, which was generally to the south. Therefore, the ratios of PCE, TCE, and 1,1-DCE in the NCP SGWS remained unchanged regardless of groundwater flow direction. Although the concentrations of each compound from different sources are chemically indistinguishable, a comparison of ratios in a trilinear diagram yields site-specific chemical "fingerprints."

The following sections compare the chemical fingerprint of the WOC LSGS plume to the NCP SGWS plume before the lining of the canal (pre-lining), while the mound was dissipating (intermediate), and after the mound had disappeared (post-lining). Chemical fingerprints were generated to evaluate any impacts of the NCP SGWS on the WOC LSGS plume. Note that based on available data from three LSGS wells installed at the NCP site (wells WCP-13M and WCP-63M, WCP-208M), non-detect concentrations of PCE, TCE, and 1,1-DCE have been observed in these wells, suggesting the absence of impacts to the LSGS at the NCP site. According to data provided to GeoTrans by the ADEQ, we understand that there are no other LSGS monitoring wells at the NCP Site.

3.4.2 NCP Fingerprint

When plotted on a trilinear graph comparing percent abundances of PCE, TCE, and 1,1-DCE, the NCP data cluster into three primary areas, as shown on Figure 3-25. The largest population of points is centered in an area with a very high percentage of TCE, a low to intermediate percentage of 1,1-DCE, and almost no PCE (Area 1). The second area is in a region with an intermediate percentage of PCE and TCE, and no detectable 1,1-DCE (Area 2). The third and least populated region represents samples with nearly equivalent concentrations of 1,1-DCE and PCE, and slightly higher relative concentrations of TCE (Area 3).

3.4.3 WOC LSGS Fingerprint

3.4.3.1 Pre-Lining

Prior to the lining of the Grand Canal, five rounds of groundwater monitoring data were collected from WOC monitoring wells between November 1996 and February 1998; the results are plotted with the NCP data for comparison in Figure 3-26. The WOC results indicate most samples consisted almost entirely of TCE, no PCE, and little or no 1,1-DCE.

3.4.3.2 Intermediate and Post-Lining

As the mound began to dissipate after the lining of the canal, the fingerprint of the same WOC wells begins to show a range of increasing PCE percentages and correspondingly decreasing TCE percentages. The increase of PCE in the LSGS suggests that a conduit existed between the shallow and LSGS portions of the aquifer. This conduit, which was likely the Pincus

Well, allowed for the downward migration of PCE into the LSGS after the mound dissipated and PCE migrated southward onto the Site from the NCP[6]. The percent of 1,1-DCE remains minimal (Figure 3-27). A similar fingerprint currently persists (Figure 3-28).

3.4.4 Time Series Plots – WOC LSGS Wells

In addition to the trilinear plots, which compared series of data grouped into three general time frames, time-series plots were generated to evaluate the effects of the lining of the Grand Canal on the concentrations of PCE, TCE, and 1,1-DCE. Groundwater monitoring data from MW-2M, MW-3M, MW-4M, MW-6M, MW-7M, MW-102M, MW-105M, MW-106M, and MW-203M are provided in Appendix A, Figures A-1 through A-9, respectively. A discussion of the time-series plots is presented below.

3.4.4.1 MW-2M

Monitoring well MW-2M has detected large fluctuations of TCE concentrations since its installation in 1996, including a brief spike in concentration in November 1997 and February 1998, coinciding with construction of the canal lining. Overall, TCE concentrations have generally decreased. Conversely, PCE concentrations were below laboratory detection limits prior to February 1999 and slowly increased to a maximum of 13 μg/L in September 2010 and 2011. This appearance of elevated concentrations of PCE considerably after the appearance of TCE in the LSGS suggests a continuing source and/or conduit from the SGWS to the LSGS. The continuing source is believed to be the southern migration of PCE from the NCP.

3.4.4.2 MW-3M

Much like the behavior observed in MW-2M, TCE concentrations in MW-3M spiked prior to the lining of the canal in May 1997, and again in February 1999. Between November 1999 and January 2004, TCE concentrations were below laboratory detection limits. Over this same time frame, PCE concentrations increased from below laboratory detection limits prior to November 1998 to a maximum concentration of 9.6 μg/L in January 2004. Subsequent fluctuations in contaminant concentrations were not observed because the well has not been sampled since January 2004.

3.4.4.3 MW-4M

Concentrations of TCE in MW-4M fluctuated slightly, but generally decreased between December 1996 and February 1999, after which concentrations increased to a maximum of 18 μg/L in June 2003. Prior to February 1999, PCE concentrations were below laboratory detection limits, but increased to a maximum of 34 μg/L in June 2003. TCE and PCE concentrations generally declined in subsequent sampling events. Concentrations of 1,1-DCE were below laboratory detection limits prior to June 2003, but have since been occasionally detected at low concentrations.

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[6] Due to the age of the Pincus Well, the drilling method was likely to be by cable tool. The typical practice for installing old wells when cable tool techniques were commonly used was to omit placing annular materials between the open borehole and well casing. This created conduits to the subsurface including permeable conduits between successive aquifer units through which the borehole was drilled.

3.4.4.4 MW-6M

TCE concentrations in MW-6M decreased slightly immediately following the lining of the canal, but have generally increased since May 1998. Concentrations of PCE and 1,1-DCE have largely remained below laboratory detection limits, with occasional low-level detections.

3.4.4.5 MW-7M

TCE concentrations in MW-7M spiked in August 1997 prior to the lining of the canal in January 1998. Since reaching a minimum concentration of 1.9 μg/L in November 1998, concentrations of TCE increased, reaching a maximum concentration of 22 μg/L during the last sampling event in January 2004. Over this same time frame, PCE concentrations increased from below laboratory detection limits prior to November 1999 to a concentration of 20 μg/L in June 2003 and January 2004. Concentrations of 1,1-DCE similarly increased during the same time frames from below laboratory detection limits to a maximum of 1.9 μg/L in January 2004. Subsequent fluctuations in contaminant concentrations were not observed because the well has not been sampled since January 2004.

3.4.4.6 MW-102M

Concentrations of TCE decreased after the lining of the canal from a maximum of 15 μg/L in May 1998, to 1.1 μg/L in January 2004. Concentrations of PCE and 1,1-DCE have remained below laboratory detection limits since the well was first sampled in February 1998. Subsequent fluctuations in contaminant concentrations were not observed as the well was not sampled since January 2004.

3.4.4.7 MW-105M

Monitoring well MW-105M has also detected large fluctuations of TCE concentrations since it was first sampled in February 1998, shortly after the lining of the canal. The maximum TCE concentration was 60 μg/L detected in September 2006 and September 2008. PCE concentrations were below laboratory detection limits prior to February 1999 and slowly increased to a maximum of 13 μg/L in samples from June 2005, September 2006, and September 2008. Like the behavior observed in MW-2M, the appearance of elevated concentrations of PCE much after the appearance of TCE in the LSGS again suggests a continuing source and/or conduit from the SGWS to the LSGS. The source is believed to be the southern migration of PCE from the NCP. Concentrations of 1,1-DCE in MW-105M have also fluctuated, but have increased slightly over the same time frame.

3.4.4.8 MW-106M

Unlike the other LSGS monitoring wells, MW-106M has never contained detectable concentrations of TCE or 1,1-DCE. Instead, PCE has been the primary contaminant in the well since it was initially sampled in February 1998. With the exception of the initial sampling event, which was below laboratory detection limits for PCE, concentrations of PCE in MW-106M have remained relatively steady, fluctuating slightly between a minimum of 2.6 μg/L in August 1998 and February 1999 and a maximum of 4.1 μg/L in November 1999. Because the primary COC at the Site is TCE, the complete absence of TCE in the well indicates a secondary source of contamination unrelated to the Site. Subsequent fluctuations in contaminant concentrations were not observed because the well has not been sampled since January 2004.

3.4.4.9 MW-203M

Concentrations of TCE, PCE, and 1,1-DCE have remained below laboratory detection limits in MW-203M since it was initially sampled in June 2005, with the exception of a single detection of TCE in May 2008 at a concentration of 0.53 μg/L. Note that MW-203M is located hydraulically cross-gradient from the Site, in the southeast direction.

3.4.5 Conclusions

Monitoring wells completed in the LSGS have demonstrated mixed variations in TCE concentrations over time, which are not clearly indicative of the influence of either the lining of the Grand Canal (i.e., impacts from the NCP) or the abandonment of the Pincus Well. However, concentrations of PCE in the LSGS, which were not associated with the release at the Site, increased dramatically after the lining of the canal and the dissipation of the associated groundwater mound. After the mound disappeared, it is believed that PCE contamination migrated south of the canal and down the conduit from the SGWS to the LSGS at the Pincus Well. This is most strongly supported by the observations that the maximum PCE concentrations in the LSGS were detected in MW-4M, located in the immediate vicinity of the Pincus Well and just south of the canal. The increase in the detected PCE concentrations occurred abruptly between 2000 and 2003, and also decreased quickly after the Pincus Well was abandoned in 2004. Similar increases in PCE concentrations were observed, to a lesser extent, in other LSGS wells located roughly downgradient of the Pincus Well. The apparent PCE plume extends towards the west-southwest, beyond MW-105M, but has not yet reached MW-107M.

The presence of PCE in the LSGS strongly indicates that an upgradient source with high PCE concentrations in its chemical fingerprint has impacted the WOC LSGS. According to available data from WCP-13M and WCP-63M, and WCP-208M installed at the NCP, no PCE, TCE, or 1,1-DCE has been detected in the LSGS at the NCP. Thus, this further supports the assertion that PCE originating in the NCP SGWS caused PCE in the WOC LSGS via migration down the conduit of the Pincus Well. The original release at the Site consisted solely of TCE, as indicated by the trilinear diagrams and time-series plots of groundwater samples collected prior to the lining of the Grand Canal in January 1998. After the groundwater mound dissipated over time, PCE began appearing in the LSGS groundwater monitoring wells associated with Site. Given that PCE cannot be generated from TCE by any in-situ reaction mechanisms, it is believed that PCE must be migrating into the Site from the NCP.

3.5 REMEDIAL OBJECTIVES

The ROs for the Site were developed by ADEQ pursuant to R18-16-406 of the Remedy Selection Rule (the rule). ROs are established for the current and reasonably foreseeable uses of land and waters of the state that have been, or are threatened to be, impacted by a release of a hazardous substance. The rule specifies that the reasonably foreseeable uses of water are those likely to occur within 100 years, unless a longer time period is appropriate [RI 8-1 6-406(D)]. Reasonably foreseeable uses are those likely to occur based on information obtained from water providers, well owners, land owners, local governments, and the general public. Not every use identified in the Land and Water Use Report will have a corresponding RO; uses identified may or may not be addressed based on information gathered during the public involvement process and whether the use is reasonably foreseeable.

The ROs for the Site were formalized in the ADEQ's May 2005 Remedial Objectives Report (ADEQ, 2005), including comments received by the COP at that time. The ROs were developed with input from land owners, local governments, water providers, and the public and were originally documented in Appendix L of the RI Report (GeoTrans, 2004b). The Land and Water Use Report (ADEQ, 2004) is documented as Appendix K of the RI Report. At that time, the established ROs for the Site were consistent with the COP's and SRP's Water Management Plans and General Land Use Plan. The ROs were established based upon the current and reasonably foreseeable uses of land and reasonably foreseeable beneficial uses of water at the Site for drinking water purposes by the COP, and for SRP irrigation wells.

The ROs were prepared for each listed use in the following terms:

- Protecting against the loss for impairment of each listed use that is threatened to be lost or impaired as a result of a release of a hazardous substance.

- Restoring, replacing, or otherwise providing for each listed use to the extent that it has been or will be lost or impaired as a result of a release of a hazardous substance.

- Time frames when action is needed to protect against or provide for the impairment or loss of the use.

- The projected duration of the action needed to protect or provide for the use.

3.5.1 Remedial Objectives for Land Use

The current zoning designation for the WOC property, as defined by the West, Middle and East Parcels, is A-2 Industrial (ADEQ, 2004). Based on meetings with the COP Planning Department, GeoTrans understands that there are no foreseeable plans to alter the current zoning districts in the Site vicinity, and the area is expected to remain predominantly industrial (A-2) or light industrial (A-l). Based on the completion of remediation activities on the Middle Parcel, no restrictions to the current or foreseeable future land uses are present.

Soil remediation conducted at the Site, through the use of an SVE system, meets soil remediation standards established in ARS §49-152 and AAC R18-7-2. The soil analytical results presented in a letter report dated January 23, 2004 indicate no detections of TCE. The Residential Soil Remediation Level for TCE is 27 mg/kg. The minimum groundwater protection level (GPL) for TCE is 0.61 mg/kg. Based on this information, ADEQ granted a permanent shutdown of the SVE system at the Site on March 1, 2004.

Based on the above information, no ROs are needed for this use.

3.5.2 Remedial Objectives for Groundwater Use

Four current and/or potential groundwater uses were identified within the Site: 1) the current and future use of groundwater for drinking water purposes by the COP; and 2) the current and future use of SRP irrigation wells. The COCs in the groundwater at the Site are TCE and PCE.

3.5.2.1 COP Municipal Use

The COP is not currently operating any wells within a one-mile radius of the Site boundary. The following is a discussion of the COP wells currently or potentially impacted by the WOC LSGS plume. Two municipal wells, COP-70 and COP-71, were removed from service in 1982 due to TCE groundwater contamination at the Site. According to COP, loss of these wells has reduced Phoenix's overall well system capacity and ability to meet service area water demands, especially during droughts or temporary water system outages. COP- 157 is located downgradient and approximately 0.5-mile west/southwest from the edge of the WOC LSGS plume (Figures 3-1 and 3-2). This well has been inactive (but not capped) since 1989 due to high nitrates.

In August 2000, COP requested funding for an interim remedial action (IRA) for COP-70 and COP-71 pursuant to ARS §49-282 03. The IRA requested funding to recover the 1,500 gallons per minute (gpm) total well capacity lost due to the TCE contamination associated with the Site.

The RO for the COP current municipal use is:

> *To restore, replace, or otherwise provide for the COP groundwater supply that has currently been lost due to PCE and/or TCE contamination associated with the Site. This action is needed as soon as possible. This action is needed for as long as the need for the water exists, the resource remains available, and PCE and/or TCE concentrations in the water prohibits or limits its use.*

COP's continued interest in future well development in the Central Phoenix wellfields led COP to the development of computerized tools that would assist the City in evaluating the suitability of groundwater resources in the Central Phoenix area. The primary goal of the project was to aid the City in evaluating the general location and timing of future groundwater resources development for the COP public water supply. As part of the project, COP evaluated the entire water service area for future well development and assigned numerical score, based on established criteria. Based strictly on the statistical evaluation of the scores, COP indicates that areas with scores in at least the 75^{th} percentile (scores >81) may warrant consideration for future well development. The area where the WOC LSGS plume is located scored 80 to 85; therefore, it may be considered for future well development for drought protection. The area immediately downgradient of the WOC LSGS plume scored 78 to 80;

therefore, it is not currently considered for future well development (after year 2010). However, in a letter received by ADEQ from COP dated May 12, 2005, COP indicated that site-specific considerations and operational/services needs may require the location of wells in lower scoring areas. COP's current analysis is that scores in the 78 to 80 range, or perhaps lower in certain circumstances, may indicate generally favorable well development conditions.

The RO for the COP future municipal supply use is:

> *To protect for the use of the COP municipal groundwater supply threatened by the PCE and/or TCE contamination emanating from the Site. According to the COP, this use may be needed by the year 2010. This action would be needed for as long as the level of contamination in the identified groundwater resource threatens or prohibits its use.*

3.5.2.2 SRP Municipal and Irrigation Use

SRP owns several irrigation wells in the area and will continue to need operational wells to supplement surface water supplies. SRP wells 9.5E-7.7N and 8.5E-7.5N are located within close proximity to the north and crossgradient of the LSGS plume at the Site. However, it is known from the RI that pumping of SRP well 9.5E-7.7N causes the LSGS groundwater contamination at the base of the UAU to migrate to the northwest, towards a hydrologic cone of depression caused by the well. Pumping from SRP 8.5E.7.5N is also expected to shift the gradient of the plume. Due to this problem, the wells are currently not being pumped in accordance with a previous agreement between ADEQ and SRP, and apparently due to low current demands for irrigation water. The policy for not pumping the irrigation wells may remain in place until a remedy selection has been made. Also, a water treatment plant may be built in the Grand Canal sometime in the future, which would change the use of groundwater from irrigation to drinking water.

The proposed RO for the SRP current and future municipal and irrigation use of the wells is:

> *To protect for the use of the SRP groundwater supply threatened by the PCE and/or TCE contamination emanating from the Site. According to SRP, this use may be needed as soon as is technically feasible. This action would be needed for as long as the level of contamination in the identified groundwater resource threatens or prohibits its use.*

4.0 EARLY RESPONSE ACTIONS

For the purposes of removing the source area and to prevent further aquifer contamination, the following three activities, including one ERA activity, were conducted at the Site:

- Removal of actual and potential sources of contamination:
  - Contents of five septic tanks, ST-1. thru ST-5 (as detailed in the RI Report).
  - Four septic tanks (ST-l, ST-2, ST-3 and ST-5) and the associated piping connected to seepage pits.

- Installation and operation of an SVE system: (a formal ERA activity) to remove VOCs in the vadose zone.

- Abandonment of the on-site irrigation well (Pincus Well).

The following is a description of these activities, which forms the basis of the FS for the WOC LSGS plume.

4.1 SEPTIC SYSTEM REMOVAL

The sampling, excavation and removal of the contents and/or tanks associated with ST-I through ST-5 occurred during the Phase I Soil Investigation and are described in detail in the RI Report, Section 4.3.1, and will not be discussed in detail here. However, their removal effectively removed the likely on-site source(s) of VOCs.

4.2 SVE SYSTEM INSTALLATION, START-UP, AND OPERATION

4.2.1 SVE System Installation and Start-Up

In accordance with the RI/FS Work Plan, an ERA using SVE was conducted at the Site to meet the short-term remedial action objective specified in the RI/FS Work Plan. The primary objective of this work was to reduce the mass of contaminants in the vadose zone to prevent further leaching to, and contamination of, groundwater.

The ERA SVE system at the Middle Parcel was installed in June 1999. Note that this ERA fulfilled the requirement in the Consent Decree for implementing an Interim Remedial Action. The SVE system consisted of three pairs of nested SVE wells, underground conveyance piping, a conventional extraction blower package, and vapor-phase granular activated carbon (GAC) treatment vessels. The general layout of the system is shown on Figure 4-1. The system was designed to remove residual TCE from the shallow and deep vadose zone in the area identified by ADEQ's soil vapor and by the only detections of VOCs in soil borings. The nested SVE wells were installed in the vicinity of the storage shed near the northwest (SVE-1 nest), southeast (SVE-2 nest), and south (SVE-3 nest) sides of the storage shed. Each nest consisted of two, 2-inch, polyvinyl chloride (PVC) wells installed in the same borehole, but screened at different depth intervals: the shallow SVE wells and deep SVE wells were screened from approximately 10 to 40 feet bgs, and approximately 65 to 110 feet bgs, respectively. Each SVE well was equipped with a 2-inch butterfly flow control valve and a monitoring port to allow measurement of the applied well vacuum and to collect samples of extraction vapor. Street-rated, flush-to-grade vaults were installed over the SVE wells.

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

Initial periodic testing of the SVE remediation system began on August 4, 1999, and official start-up began on August 5, 1999.

4.2.2 SVE System Operation

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

The ERA SVE remediation system successfully remediated significantly more contamination than was originally anticipated. Table 4-1 and Figure 4-2 present SVE system performance data with respect to the cumulative VOC mass removal over time. Using average SVE flow rates, average analytical results, and system operation time, GeoTrans calculated that approximately 449 pounds of VOCs were removed from the subsurface during the 706 days of operation between August 4, 1999 and October 21, 2002. System downtime equated to approximately 167 days as a result of equipment repairs/maintenance, periodic power outages, and intentional shut-down periods for response tests and “pulse-mode” operations. Because the density of TCE is approximately 12 pounds per gallon, the 449 pounds of total remediated VOCs represents approximately 37.41 gallons of liquid TCE.

4.2.3 SVE System Shut-Down

On behalf of UIC, GeoTrans submitted a technical letter on September 11, 2001 to ADEQ requesting approval to shut down the SVE system permanently. Confirmatory drilling and sampling, conducted in September 2002, verified that VOC concentrations were below laboratory detection limits in all 39 subsurface samples collected from the SVE system area of influence. Based on these results, ADEQ approved the SVE system shut down, which occurred on October 21, 2002.

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

4.3 PINCUS WELL ABANDONMENT

The on-site irrigation well (Pincus Well) was believed to be the primary pathway for dissolved-phase TCE migration from the SGWS or surface activities, downward into the LSGS. Abandoning this well greatly reduced the potential for further migration of impacted groundwater from the SGWS to the LSGS.

The Pincus Well was abandoned in accordance with ADWR regulations on July 26 through 28, 2004, by perforating the casing from surface to a depth of 540 feet (confirmed with a video log) and pumping more than 23 cubic yards of neat cement into the well. Although the actual source of TCE in the LSGS was never identified, the proper abandonment of the Pincus Well is believed to have eliminated any potential for further migration of impacted groundwater from the SGWS to the LSGS.

5.0 IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES

5.1 TECHNOLOGY SCREENING

This section defines screening assumptions for one active and one passive remediation technology. The active technology, pump and treat (P&T), is considered to be the only practicable remediation technology for implementation due to the relatively large geographic area which the LSGS plume occupies (approximately 2 miles long x 0.7-mile wide). A comprehensive discussion of treatment technologies for removing VOCs from the extracted groundwater is included in this section. The passive remediation technology discussed in this section is monitored natural attenuation (MNA), which would rely on multiple processes to continue with natural degradation of VOCs within the LSGS aquifer. Both the active and passive technologies are considered ultimately capable of achieving the ROs with compliance to requirements under AAC Rl8-16-407. The following assumptions and system requirements will be used during the identification and screening of the two remediation technologies:

- Contaminants in the LSGS:
    - TCE at a concentration of 60 µg/L in groundwater.
    - PCE at a concentration of 15 µg/L/ in groundwater.
    - 1,1 -DCE at a maximum of 5 µg/L in groundwater.

- Remedial Efficiency – Ultimately must achieve drinking water standards for VOCs (MCLs and AWQSs).

- End Use – Domestic consumption, irrigation, and groundwater reinjection and/or recharge. These uses are compared based on discharge option screening and alternative remedial scenarios.

- Flow Rates – A pumping rate 500 gpm is proposed for a downgradient P&T system, capable of containing potential further migration of VOCs downgradient of MW-108M (Figure 3-2), and for active/gradual remediation of the plume. Wellhead treatment systems at the location of COP-70/71 and at the SRP wells are also discussed. Based on aquifer characteristics described in Sections 3.2.2 through 3.2.4, and data provided in Table 5-6, a total pumping capacity of 750 to 1,000 gpm is assumed for the COP-70/71 well site. For the two nearest SRP production wells (8.5E-7.5N and 9.5E 7.7N), pumping rates of 1,600 gpm and 2,600 gpm are assumed (see Table 5-6). Pumping rates have been modeled to evaluate capture zones for scenarios at the two pumping locations - 500 gpm for the downgradeint and 750 gpm for COP-70/71, respectively.

- Cost – Capital, operation and maintenance (O&M), and present-value, life-cycle costs are compared, based on each remedial scenario, including passive MNA.

The list of potential treatment technologies for extracted groundwater under P&T remediation and/or wellhead treatment technology was developed from feasible technologies used for treating groundwater impacted by VOCs in environmental and domestic water supply applications. As described above, the characterized LSGS plume is approximately 2 miles long and 0.8--mile wide (Figure 3-2). P&T technology has been selected as the presumptive remedy for the LSGS at the Site, as it is the only practical alternative to enable hydraulic containment and remediation of the large contaminant plume. Since impacted soils were previously addressed by the septic tank removal actions and the ERA SVE remediation system (refer to Section 4.0), no evaluation of technologies was conducted to address soils.

The appropriate remediation technologies for the impacted LSGS groundwater were identified and screened according to the following criteria:

- Contaminant treatment effectiveness.
- Compatibility with drinking water systems.
- Constructability.
- Flexibility/expandability.
- O&M requirements.
- Chemical use/operational hazards.
- Cost-effectiveness.

The remediation and treatment technologies described in this section that pass the technology screening will be retained for use in development of the reference remedy and alternative remedies presented in Section 6.0.

5.1.1 Flow Rate

The flow rate of P&T systems will depend on the remedial strategy (Section 6.0). To satisfy the COP's potential water needs, a total estimated rate of 750 to 1,000 gpm is used, which would partially restore the 1,500 gpm of total well capacity reportedly lost due to the TCE contamination at the Site. For the downgradient P&T scenario l, a 500 gpm flow rate has been estimated based on computer modeling to attain capture of the approximate full width of the LSGS plume.

5.1.2 Contaminants

Historically, the principal contaminant of concern at the Site has been TCE, with much lower concentrations of PCE, and 1,1-DCE intermittently identified in select wells. The PCE has predominantly been observed in the northernmost LSGS wells, including MW-2M, MW-4M, and MW-105M. Treatment options were screened and evaluated on the basis of estimated influent concentrations of 60 µg/L of TCE, and up to 15 µg/L PCE and 5 µg/L 1,1-DCE. At the present time, these concentrations are considered conservative for a P&T system operating at the downgradient margin of the LSGS plume. Such concentrations are considered realistic for capture zones induced by pumping from the central portion and COP-70/71 area of the plume.

5.1.3 Mass Removal

The predicted contaminant mass removal rates are generally low for the existing LSGS plume concentrations and the evaluated P&T system flow rates. Assuming influent concentrations of 60 µg/L of TCE, 15 µg/L PCE, and 5 µg/L 1,l-DCE, the following VOC mass removal rates would be realized:

- At 300 gpm = 0.29 pounds per day (lbs/day) total VOCs.
- At 500 gpm = 0.48 lbs/day total VOCs.
- At 750 gpm = 0.72 lbs/day total VOCs.
- At 1,000 gpm = 0.96 lbs/day VOCs.

5.1.4 Removal Efficiency

The selected treatment technology, or combination of technologies, must achieve drinking water standards (Federal MCLs) and Arizona AWQSs for the COCs. At the present time, the criteria for discharge of treated water into the SRP Grand Canal (an option being considered for the downgradient P&T system), a non-drinking water source, may be more relaxed than MCLs and AWQSs. However, according to the SRP there is a potential use of the water as a potable source if a water treatment plant is installed on the Grand Canal in the future. Furthermore, the treated groundwater concentrations would need to comply with Arizona Pollutant Discharge Elimination System (AZPDES) permit requirements, assuming the water was being discharged to either the Grand Canal or COP storm sewer.

5.1.5 End Use

The end use of the treated groundwater will be based on the remedial scenario discharge alternatives; however, domestic consumption from the COP municipal water system is one of the proposed end uses based on the ROs (ADEQ, 2005). For this use, the selected technology and system design(s) must comply with all applicable Federal, state and local requirements, including ADEQ Drinking Water Section Bulletins 8 and 10 (ADEQ, 1978a, 1978b).

5.1.6 Pre-Treatment

Removal of hardness (calcium and magnesium carbonates, such as $CaCO_3$) is not a treatment objective specified by the ADEQ. Hardness control was considered only in the context of treatment system O&M, as hardness may result in scaling problems with piping and equipment. High total suspended solids, manganese, and dissolved iron in groundwater can also cause problems with fouling of treatment media and/or equipment. Pretreatment considerations are addressed in this FS based on the evaluated technologies that are most likely to be affected.

5.2 TREATMENT TECHNOLOGIES FOR EXTRACTED GROUNDWATER

The common groundwater P&T technologies for the levels of VOCs in the LSGS plume are described below. The treatment mechanism and typical water treatment applications are mentioned and the suitability and limitations of the technology for the Site are discussed. The reasons a technology was retained for further evaluation or eliminated from consideration are also discussed. Note that all in-situ technologies, such as air sparging, chemical oxidation, thermal treatment, and in-well air stripping, were eliminated from consideration. This is because implementing these technologies is unrealistic and impractical due to the large number of boreholes/remediation wells that would be required to deliver sparge air, oxidants, heat, nutrients, etc. into the subsurface to enable effective remediation. Note that the area of the Site is densely populated with primarily residential homes, thus limiting the feasibility and practicality of employing such technologies.

5.2.1 Carbon Adsorption

GAC is an appropriate treatment media for many organic compounds, including VOCs, semi-VOCs (SVOCs) and other non-VOCs. The VOC contaminants present in the LSGS plume (TCE and trace PCE and l,1-DCE) are amenable to treatment by GAC. Carbon adsorption is commonly used in water treatment as either a primary treatment mechanism or in combination with other treatment methods. Depending on the type of GAC and its containment vessel characteristics, both liquid-phase GAC (LGAC) and vapor-phase GAC (VGAC) are proven to efficiently remove VOCs from water and vapor streams, respectively.

Carbon adsorption is a relatively low-cost, low-maintenance and reliable alternative for treating non-polar organic contaminants, which can be removed from water by adsorption to GAC. Prepackaged systems are available from multiple manufacturers and installation of modular components is relatively quick and easy. Carbon-use rates are a function of the influent concentration and the adsorptive capacity of the carbon for the specific contaminants. Pretreatment by air stripping or advanced oxidation can reduce carbon use, but will add other O&M costs. System maintenance for GAC consists of periodic removal and replacement of the carbon when the adsorption capacity is reached or when pressure through the canisters is lost because of entrapped sediment, which can be avoided with pretreatment for hardness and sediment removal. Carbon adsorption was retained as a treatment alternative for the Site.

5.2.2 Air Stripping

Air stripping is an effective treatment technology for removing VOCs and, to a limited extent, SVOCs from groundwater. Air stripping removes VOCs from the waste stream by transferring the compounds from the aqueous phase to the vapor phase. In a packed-tower, air stripper, contaminated water flows downward by gravity through a circular or rectangular column filled with packing material. The packing material is designed to maximize the available surface area for contact between the water and process air, for volatilization of contaminants from the water. A blower delivers air into the tower which flows upward through the packed bed countercurrent to the flow of water. Air stripping is a demonstrated technology with numerous systems treating groundwater reliably for decades. Packed-tower systems can treat high flows with low liquid pressure drop. Other types of air strippers typically used to treat lower flows include shallow cascading trays, bubble aeration, and aspiration (venturi-type strippers).

Air-stripping systems are simple, relatively inexpensive, and reliable. O&M costs are generally low, because systems can be operated unattended and associated labor and material costs are minimal. Prepackaged systems are available from numerous manufacturers and installation of modular components is relatively quick and easy. They are also commonly manufactured to meet specific requirements of each application. Computer models are available to design and optimize shallow-tray and packed-tower air strippers. Electrical power consumption is a function of the air-to-water ratio required for treatment and the system groundwater flow rate. O&M includes periodic inspections and servicing of the aeration blower. Depending on water characteristics, such as concentrations of dissolved iron, manganese, and hardness, the air-stripper internal structures, effluent piping, and/or internal packing typically require periodic cleaning. Concentrations of hardness in the LSGS groundwater range from about 250 to 300 milligrams per liter (mg/L), which can be a problem depending on how it precipitates. However, some fouling can be prevented with pretreatment for hardness removal. Biological fouling can also be a problem with air strippers if the untreated water contains sufficient organic matter to sustain biological growth. Biological fouling can be prevented by injecting disinfectants (e.g., sodium hypochlorite) to the untreated water with proper feed rates so as to minimize the production of potentially harmful by-products, such as trihalomethanes.

Iron fouling of air strippers is another common problem when ferrous iron comes in contact with oxygen during the stripping process; it is oxidized to ferric iron, forming an insoluble precipitate causing fouling. The concentrations of dissolved iron (ferrous + ferric iron) in the LSGS groundwater are less than 2 mg/L; therefore, the potential for significant iron fouling of air-stripper components is low.

Particularly for drinking water end use, air stripping is commonly followed by carbon adsorption to remove residual contaminants from groundwater. Treatment of air-stripper off-gas could also be required, depending on effluent concentrations and corresponding mass discharge rates of VOCs into the atmosphere. Air stripping was retained as a treatment alternative for the LSGS plume.

5.2.3 Chemical Oxidation

Chemical oxidation is often used in water treatment to remove iron and manganese, control biological growth, and remove color, tastes and odor. Chemical oxidants can also react with organic contaminants and oxidize the chemicals to harmless end-products. However, chemical oxidants are often highly selective, reaction rates are often slow, and competing reactions can reduce the effectiveness of oxidants for treating organic chemical contaminants. Therefore, use of common chemical oxidants is usually not cost-effective, in particular at the relatively low concentrations present in the WOC LSGS plume.

Treatability testing would be required before chemical oxidation could be applied with confidence at the WOC LSGS plume. Chemical oxidation was not retained as a treatment option because the treatability of target contaminants by chemical oxidation is uncertain and treatment requires the use of hazardous chemicals (oxidants).

5.2.4 UV Oxidation

Advanced oxidation, such as photo-oxidation, can be used to destroy all types of organic compounds and does not need off-gas treatment. Photo-oxidation uses high-intensity ultraviolet (UV) light to generate hydroxyl radicals from an oxidant, such as hydrogen peroxide. The hydroxyl radicals induce a chain of oxidation reactions that mineralize organic pollutants to bicarbonate, or ultimately to carbon dioxide. A potential advantage of UV oxidation is that contaminants are transformed into harmless end-products, eliminating the need for air emission treatment or disposal of sorbed contaminants. UV oxidation is effective in treating a broad range of organic contaminants, including some constituents that are not easily removed by other methods (e.g., 1,4-dioxane).

UV/peroxide treatment is becoming more common for treating organic contaminants in water, and packaged systems are available from several manufacturers. Considerations for application include maintenance requirements, required pre- and post-treatment and overall cost. Regular maintenance of UV systems is required to sustain transmittance and treatment efficiency. Pretreatment for hardness removal can be required to minimize interference by carbonates and maintain light transmittance. Post-treatment by carbon is often used to minimize UV system requirements and to remove residual hydrogen peroxide and untreated contaminants.

The capital and O&M costs are typically higher for UV oxidation compared to air stripping and GAC. Also, UV oxidation is considerably more likely to require pretreatment for metals and/or solids to prevent fouling compared to air stripping and GAC. UV oxidation is very sensitive to fouling and can result in poor performance due to increased turbidity, hardness, and iron and manganese content. For treatment of the relatively low concentrations of VOCs present in the LSGS at the Site (i.e., less than 100 µg/L total VOCs), and the need to pump groundwater at relatively high flow rates to ensure plume capture, UV oxidation is believed to be an inappropriate and impractical treatment alternative. Therefore, UV oxidation was not retained as a treatment option for pumped groundwater from the WOC LSGS plume.

5.2.5 Ion Exchange

Ion exchange removes ions from the aqueous phase by the exchange of cations or anions between the contaminants and the exchange medium. Ion exchange materials may consist of resins made from synthetic organic materials that contain ionic functional groups to which exchangeable ions are attached. They also may be inorganic and natural polymeric materials. After the resin capacity has been exhausted, resins can be regenerated for reuse (http://www.frtr.gov/matrix2/section4/4-49.html).

The most common application of ion exchange is for water softening. Target ions are adsorbed onto the medium in exchange for a loosely bound ion, such as sodium. Ion exchange is particularly effective for treating high-contaminant concentrations, especially with on-site regeneration. Ion exchange can also be appropriate for treating some constituents that are not effectively removed by GAC.

Treatment by ion exchange is contaminant-specific and not appropriate for treating process water that contains many constituents. Ion exchange is more expensive than GAC for many of the common contaminants at typical concentrations found in groundwater. Therefore, ion exchange was not retained as a treatment option for contaminated LSGS groundwater at the Site.

5.2.6 Membrane Filtration

Membrane processes include several different technologies, such as reverse osmosis, electro-dialysis, and ultra-filtration. In domestic water treatment, membrane processes are most commonly used in desalinization and for removing ions that are otherwise difficult to displace. Reverse osmosis and ultra-filtration can remove some dissolved organic compounds. However, membrane processes are generally not effective at removing low molecular weight compounds, such as those present in LSGS groundwater at the Site. Membrane processes are generally expensive and maintenance-intensive. For these reasons, membrane processes were not retained as treatment alternatives for the WOC LSGS plume.

5.2.7 Biological

Biological treatment can mineralize dissolved contaminants to the harmless end-products of carbon dioxide and water. It is often effective for treating constituents that are not easily removed by air stripping or GAC. Chlorinated hydrocarbons have been successfully treated by aerobic biodegradation. However, aerobic biodegradation of chlorinated hydrocarbons typically requires a co-substrate, such as methanol or phenol. Biological processes are typically not used for treating drinking water because of concerns about transmitting microorganisms into the drinking water supply. Biological treatment is relatively operator-intensive compared to air stripping or GAC, and it generates solids that may need disposal. Therefore, biological treatment was not retained as a treatment alternative for the LSGS of the Site.

5.3 RETAINED TREATMENT TECHNOLOGIES FOR EXTRACTED GROUNDWATER

Under a P&T scenario at the downgradient portion of the plume, and/or contingency wellhead treatment at COP-70/71, and/or the nearest two SRP wells (8.5E-7.5N and 9.5E-7.7N), treatment technologies retained for further evaluation are air stripping and carbon adsorption. The specific treatment alternatives evaluated are as follows:

- Alternative 1: Groundwater P&T with air stripping only.
- Alternative 2: Groundwater P&T with air stripping and VGAC treatment.
- Alternative 3: Groundwater P&T with air stripping and LGAC treatment.

- Alternative 4: Groundwater P&T with air stripping, VGAC, and LGAC Treatment.
- Alternative 5: Groundwater P&T with LGAC only treatment.

5.4 DETAILED EVALUATION OF TREATMENT TECHNOLOGIES FOR EXTRACTED GROUNDWATER

The retained treatment technologies are compatible with drinking water treatment and can treat the target VOC contaminants. The detailed analysis below evaluates the five retained treatment alternatives with respect to contaminant removal efficiency and O&M requirements. The recommended treatment technology is discussed in Section 5.4.6.

5.4.1 Alternative 1 – Air Stripping Only

This alternative pertains to the treatment of extracted groundwater from a P&T system installed to control and remediate groundwater from the downgradient margin of the plume at the Site. It could also pertain to contingency treatment of pumped groundwater at the COP-70/71 well site.

5.4.1.1 Treatment Efficiency

The design treatment efficiency for air stripping of the VOCs present in the LSGS groundwater can exceed 99 percent. Air strippers are designed to achieve the air-to-water ratio required to attain the target removal efficiency. However, stripper size and power consumption must increase to achieve a higher removal efficiency. Therefore, air strippers are generally designed to meet minimum design requirements, In this case, the design criterion is to attain Arizona AWQS and Federal drinking water MCLs for the VOCs in the treated effluent from the air stripper with a factor of safety over 2 (e.g., design air-stripper effluent TCE levels of <2.5 µg/L). Air strippers are often designed with carbon adsorption units to "polish" the effluent down to non-detectable levels and protect against any loss of treatment efficiency due to mechanical/electrical failure, unusual influent characteristics, or fouling.

5.4.1.2 O&M

Air strippers typically have relatively low maintenance requirements and are reliable, assuming significant sealing problems difficult to control do not frequently occur. Periodic inspections (up to weekly) are recommended to confirm proper operation. Routine maintenance would include servicing the aeration blower, checking ancillary equipment and controls, and cleaning as necessary to mitigate fouling.

Using the concentrations described in Section 5.0 (60 µg/L TCE, 15 µg/L PCE, and 5 µg/L 1,1-DCE) and total flow rates of 500 gpm, 750 gpm, 1,000 gpm, 1,600 gpm and 2,600 gpm the total calculated mass of VOCs in the influent to the air stripper would be 0.48, 0.72, 0.96 lbs/day, 1.54 lbs/day, and 2.49 lbs/day, respectively. Assuming 100 percent mass transfer to air, and pursuant to the Maricopa County Health Services Department Air Pollution Control Regulations, Rule 200, emissions do not need to be treated when the potential to emit VOCs is less than 3.0 lbs/day. Therefore, there would be no regulatory requirement for equipping an air stripper with off-gas treatment at the Site. However, the LSGS plume area encompasses predominantly residential neighborhoods; consequently, there may be political and/or public perception concerns that would warrant consideration for using off-gas treatment. Under this option, vapor-phase GAC would definitely be the most reliable and cost-effective technology to abate the low-concentration air-stripper emissions.

Carbonair has performed model calculations of the efficiency of its shallow-tray air strippers given the estimated VOC influent concentrations. Copies of the model runs are included in Appendix B. The results for the scenarios which would most likely be employed at the Site (see Section 6.0) indicate the following:

- At a flow rate of 500 gpm, a system using 4 trays and a 3,500 cfm air blower provides a removal efficiency ranging from 98.67% for TCE to 99.52% 1,1-DCE. The bhp realized by a 40-hp blower motor would range from 18 to 34 bhp, at 15- and 45- "wc pressure, respectively, depending on the degree of biological, iron, and/or hardness fouling on the trays.

- At a flow rate of 750 gpm, a system using 5 trays and a 3,500 cfm air blower provides a removal efficiency ranging from 98.13% for TCE to 99.30% 1,1-DCE. The bhp realized by a 40-hp blower motor would range from 21 to 34 bhp at 26- and 45- "wc pressure, respectively, depending on the degree of fouling.

- At a flow rate of 1,000 gpm, a system using 6 trays and a 3,500 cfm air blower provides a removal efficiency ranging from 97.95% for TCE to 99.27% 1,1-DCE. The bhp realized by a 40-hp blower motor would range from 24 to 35 bhp, at 25- and 45- "wc, respectively, depending on the degree of fouling.

Note that for all the above options, except for the l,000-gpm option, the air strippers could be equipped with additional trays (up to 6 trays) to attain even higher contaminant removal efficiencies.

5.4.2 Alternative 2 – Air Stripping with VGAC Treatment

This alternative also pertains to the treatment of extracted groundwater from a P&T system installed to control and remediate groundwater from the downgradient margin of the plume at the Site. It could also pertain to contingency treatment of pumped groundwater at the COP-70/71 well site.

5.4.2.1 Treatment Efficiency

As described for Alternative 1 above, the treatment efficiency for removal of VOCs from groundwater by air stripping can exceed 99% with proper design. In addition to groundwater treatment, this alternative assumes that ADEQ would require VGAC treatment downstream of the air stripper discharge vent to provide a high degree of public protection against potential exposure to VOCs in air. Compared with other off-gas treatment technologies, VGAC would definitely be the most reliable and cost-effective technology to abate the low-concentration air-stripper emissions. With proper monitoring and management of the VGAC, the treatment efficiency would be greater than 99% removal of VOCs prior to discharge into the atmosphere.

To improve the VGAC adsorption capacity (and frequency of change-out), a duct heater could be used in the plumbing between the air stripper and VGAC units to reduce RH in the VOC-laden vapor. Another option would be to plumb the air blower in an induced draft arrangement whereby the air would flow upwards through the aeration trays under negative (vacuum) pressure rather than positive pressure. This arrangement raises the vapor temperature on the pressure side of the blower to reduce RH.

5.4.2.2 O&M

The O&M considerations for Alternative 2 are similar to those described for Alternative 1 (Section 5.4.1.2) except that additional O&M associated with VGAC performance monitoring and periodic change-outs of spent VGAC would be necessary. A portion of the operating costs associated with Alternative 2 will be VGAC replacement. For typical VGAC systems, the lead (primary) vessel is replaced within an optimum time-frame after breakthrough occurs, and manifold valving is then switched, so that the lag (secondary) vessel serves as the lead vessel. Regardless of the air stripper blower arrangement, O&M of the off-gas treatment would involve monitoring concentrations, sampling vapor emissions, and replacing spent VGAC.

Post-air stripping VGAC usage isotherms were provided by Prominent Systems, Inc. (Prominent) and Siemens Water Technology (Siemens), both reputable vendors of GAC treatment systems. Inputs to the isotherms (i.e., vapor concentrations and temperature, air flow rates, temperature, relative humidity, etc.) were provided to the vendors by GeoTrans, based on data derived from an air stripper modeler that demonstrated greater than 99% removal efficiency of VOCs from the groundwater by the air stripping process.[7]

- For 500 gpm air stripping, approximately 54 lbs/day of VGAC usage is predicted based on performance of a Bisco Model 41251 ShallowTray® air stripper operating at 3,500 scfm.

- For 750 gpm air stripping, approximately 68 lbs/day of VGAC usage is predicted based on performance of a Bisco Model 41251 ShallowTray® air stripper operating at 3,500 scfm.

[7] GeoTrans used output from Bisco/NEEP Systems ShallowTray® Modeler V6.12e to obtain simulated air stripper performance data, including air flow rates, number of trays, VOC removal efficiencies, and VOC off-gas concentrations.

Note that the above VGAC usage rates represent the average of VGAC usage rates predicted by the Prominent and Siemens isotherms (Appendix B).

5.4.3 Alternative 3 – Air Stripping with LGAC Treatment

This alternative also pertains to the treatment of extracted groundwater from a P&T system that would be installed to control and remediate groundwater from the downgradient margin of the plume at the Site. It could also pertain to contingency treatment of pumped groundwater at the COP-70/71 well site.

5.4.3.1 Treatment Efficiency

Air strippers are often designed with subsequent LGAC units to "polish" the effluent down to non-detectable levels, and protect against any loss of treatment efficiency due to mechanical/electrical failure, unusual influent characteristics, or fouling. This alternative assumes use of LGAC, but not VGAC with air stripping.

Although a well-designed air stripper alone could achieve high removal efficiency (greater than 99% VOC removal from groundwater), LGAC polish treatment is an option to achieve an even higher degree of treatment efficiency and supplemental safety factor to protect receiving waters.

5.4.3.2 O&M

The O&M considerations for Alternative 3 are similar to those described for Alternative 1 (Section 5.4.1.2) except that additional O&M associated with LGAC performance monitoring and periodic change-outs of spent LGAC would be necessary. Furthermore, it is recommended to install either bag filters or cartridge filters for pre-treating the influent groundwater upstream of the air stripper and LGAC. The purpose of filtration would be to enhance the adsorption capacity and longevity of the LGAC by removing fine sediments. It may also benefit by reducing the scale potential of the water during the air stripping process. O&M for filtration involves periodic monitoring of the pressure drop across the filter vessels, and replacing the filter media (i.e., filter bags or cartridges) on an as-needed basis.

Post-air stripping LGAC usage isotherms were provided by Prominent Systems, Inc. (Prominent) and Siemens Water Technology (Siemens), both reputable vendors of GAC treatment systems. Inputs to the isotherms were provided to the vendors by GeoTrans, based on data derived from an air stripper modeler that demonstrated greater than 99% removal efficiency of VOCs from the groundwater by the air stripping process.

- For 500 gpm air stripping, approximately 24 lbs/day of LGAC usage is predicted based on performance of a Bisco Model 41251 ShallowTray® air stripper operating at 3,500 scfm.

- For 750 gpm air stripping, approximately 36 lbs/day of VGAC usage is predicted based on performance of a Bisco Model 41251 ShallowTray® air stripper operating at 3,500 scfm.

Note that the above LGAC usage rates represent the average of LGAC usage rates predicted by the Prominent and Siemens isotherms (Appendix B).

5.4.4 Alternative 4 – Air Stripping with VGAC and LGAC Treatment

This alternative also pertains to the treatment of extracted groundwater from P&T systems installed to control and remediate groundwater from either the downgradient margin of the WOC Facility, or from the central, downgradient portion of the plume.

5.4.4.1 Treatment Efficiency

As described for Alternatives 1 through 3 above, the treatment efficiency for removal of VOCs from groundwater by air stripping can exceed 99% with proper design. Under this alternative, both VGAC and LGAC would also be used to provide off-gas treatment and effluent polish, respectively. The combination of VGAC and LGAC used downstream of the air stripper would provide the highest degree of treatment efficiency, capable of removing VOCs below standard levels of laboratory detection. This alternative also provides the greatest safety factor to ensure that treatment criteria are met and that potential exposure from VOCs is minimized.

5.4.4.2 O&M

The O&M considerations for this alternative involve the collective activities and information described for air stripper Alternatives 1 through 3 above. Air stripping with LGAC and VGAC would involve the most labor-intensive and costly O&M of the air stripping options. However, as described above, it provides the highest degree of treatment efficiency and greatest safety factor for air stripper operations.

A significant portion of the operating costs associated with Alternative 5 would be both VGAC and LGAC usage costs. Estimated carbon usage rates for post-air stripping VGAC and LGAC are described above in Sections 5.4.2.2 and 5.4.3.2, respectively. The procedures for monitoring, switching vessels, and replacing spent carbon are essentially the same, as described above.

5.4.5 Alternative 5 – LGAC Only Treatment

5.4.5.1 Treatment Efficiency

Carbon-only treatment systems can reliably achieve high removal efficiency. Dissolved organic contaminants that pass through a LGAC vessel are completely removed until the contaminant breaks through, first at low concentrations. If the carbon was not replaced, effluent concentrations would increase until the effluent concentration equaled the influent concentration. Before breakthrough, the effluent concentration is generally zero and the treatment efficiency is 100 percent.

The adsorption capacity of carbon for a particular contaminant is characterized by an empirical adsorption isotherm. The isotherm is described by an equation that defines the capacity of the carbon for the sorbed contaminant and the strength of the attraction. For a given carbon vessel, the isotherm is used to estimate the time to breakthrough for a specific contaminant and mass loading rate, allowing the carbon-use rate to be calculated.

5.4.5.2 O&M

Carbon-adsorption systems are reliable and typically require little routine maintenance. Routine operation consists of periodic checks of pressure drop across the carbon vessels and monitoring for contaminant breakthrough in the vessel effluent. Increased pressure could result from sediment accumulation. Bag filters (typically 10 to 25 microns) are often installed upstream of the carbon vessels to minimize the degree of sediment accumulation in the LGAC. If pressure buildup occurs, the LGAC vessels are backwashed to remove sediment and restore the carbon's permeability. For this FS, it is assumed that the carbon would be backwashed once per quarter. Typical backwash water contains sorbed contaminant and sediment, which is collected in a sedimentation tank. Supernatant water is pumped through the treatment system and collected solids are characterized and treated off site. Once the carbon capacity is reached and contaminant breakthrough occurs in the first vessel, in a typical 2-vessel lead/lag configuration, the spent carbon requires replacement. By changing valve positions, the second vessel becomes the first in the series, and the first vessel is replaced. Carbon-use rates are also dependent on contaminant and hydraulic load changes via the possible addition of other extraction wells.

Parallel carbon systems are typically configured to allow independent operation of each leg of the parallel system. This configuration allows an individual system to be isolated for backwash or carbon exchange with minimal disruption of groundwater pumping.

LGAC-only treatment systems are simple, quiet and produce no emissions. The largest readily available units contain 20,000 pounds of LGAC and treat up to 1,000 gpm. For treating flows greater than approximately 1,000 gpm, the treatment system typically includes two pairs of series-configured units (i.e., lead/lag vessels) arranged in parallel.

One of the main operating costs associated with LGAC systems will be carbon replacement. LGAC in the lead (primary) vessel typically is replaced when breakthrough occurs, then manifold valving is switched so that the lag (secondary) vessel serves as the lead vessel. LGAC-only usage was modeled by Prominent and Siemens; both entities are reputable vendors of GAC treatment systems. The isotherm model predictions from these two vendors are included in Appendix B. GeoTrans incorporated a safety factor of 1.75 in estimates of usage rates. The safety factor accounts for the impact of natural organic matter and other unknown organic compounds that would adsorb to the LGAC. The average results of Prominent's and Siemens' isotherms, based on the estimated conservative VOC influent concentrations of 60 µg/L of TCE, and up to 15 µg/L PCE and 5 µg/L 1,1-DCE, are:
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- Approximately 166 lbs/day of GAC usage at 500 gpm.

- Approximately 249 lbs/day of GAC usage at 750 gpm.

Copies of the two vendors' model outputs are included in Appendix B.

5.4.6 Recommended Treatment Alternative

A cost analysis has been performed for the three acceptable treatment alternatives using a design flow rate of 750 gpm (see Tables 5-1 through 5-5). This is the presumed flow rate of a pumping system equipped with wellhead treatment at the COP-70/71 well site (see Sections 6.0 and 7.0). At this flow rate, the estimated present value costs for Alternative 2 (air stripping with VGAC) and Alternative 3 (air stripping with LGAC) are nearly the same. Alternative 1 (air stripping only treatment) and Alternative 4 (air stripping with VGAC and LGAC treatment) are the highest and lowest cost alternatives, respectively. LGAC only treatment (Alternative 5) is the second most cost-effective alternative, and is the recommended treatment alternative to remove the relatively low concentrations of contaminants in the LSGS groundwater. LGAC-only adsorption has been selected because it is a proven and reliable treatment technology because it is cost-effective and provides no air emissions and is a more failsafe system. Furthermore, the LGAC treatment process will not produce any noise associated with air blower equipment required to operate air stripper systems.

LGAC systems are relatively easy to install, operate, and maintain. Low-cost, turn-key, carbon-replacement services can be contracted from a GAC service provider. LGAC-only does not require off-gas treatment and required management of waste residuals (e.g., handling of backflush water during carbon replacement) is minimal.

5.5 EVALUATION OF OPTIONS FOR SRP PRODUCTION WELLS

Several alternatives exist to address the ROs for the SRP water supply for irrigation and/or future municipal use (Section 3.4.2.2). These alternatives involve either restoring use to, or continuing not to use, SRP production wells 8.5E-7.5N and 9.5E-7.7N. Table 5-6 includes construction data for these production wells that are installed adjacent to the Grand Canal near the northern boundary of the LSGS plume (Figure 3-2). Due to the near proximity and high pumping rates of these production wells, contamination from the LSGS plume will be pulled to the north if the wells are pumped, causing the spread of contamination laterally and possibly vertically towards the wells. Alternatives for the SRP production wells being considered in this FS include:

<u>Alternative 1</u>: Modifying one or both of the SRP production wells to focus groundwater extraction from the LSGS, and installing wellhead treatment equipment. Under this alternative, the SRP could pump one or more of its production wells SRP 8.5E-7.5N and 9.5E-7.7N on an as-needed basis, providing maximum operational flexibility for its water supply needs.

<u>Alternative 2</u>: Drilling/deepening one or both of the SRP production wells to focus extraction of clean water from far below the impacted LSGS. Under this alternative, no wellhead treatment would need to be installed or maintained, and the SRP could pump one or more of its two nearby production wells on an as-needed basis, providing maximum operational flexibility for its water supply needs.

Alternative 3: Receiving treated water on primarily a continuous basis into the Grand Canal from remedy pumping within the Site. This alternative would be in lieu of restoring pumping at one or both of SRP's production wells.

Alternative 4: Continuing the current policy of not pumping the SRP production wells due to the environmental impacts at the WOC and NCP WQARF Sites. In addition, there would be no discharges of treated groundwater into the Grand Canal from remedy pumping at the Site. This alternative assumes that the SRP could once again receive replacement water from the Central Arizona Project (CAP) in lieu of pumping its two production wells in the near vicinity of the Site. The cost of replacement water would be reimbursed to SRP by the ADEQ under a negotiated agreement.

The following sections further describe the four alternatives to address the SRP's ROs.

5.5.1 Alternative 1 – Modify Perforated Interval of SRP Well(s) and Install Wellhead Treatment

Either one or both of the SRP's production wells could be restored to operation by modifying the well perforated interval(s) and installing wellhead treatment equipment. A general process diagram of the treatment equipment and instrumentation is included as Figure 5-1. The perforated intervals of wells 8.5E-7.5N and 9.5E-7.7N are 255 to 685 feet bgs, and 220 to 685 feet bgs, respectively. According to the historic well boring logs from the nearest Site monitor wells, the bottom of the LSGS is estimated to be approximately 345 and 300 feet bgs at the SRP wells, respectively. Thus, both production wells have casings perforated through the LSGS which extend into the MAU below. Based on completed sampling during the RI, the MAU is not impacted with VOCs.

The aquifer material of the MAU below the LSGS is predominantly clay, based on drill cuttings, relatively undisturbed drive samples, and geophysical logs from drilling the RI/FS monitor wells. In the deep RI/FS monitor wells, a few, thin coarse-grained zones capable of producing small quantities of water are present. However, the yields from these zones are low and there is no evidence of lateral continuity (HSI GeoTrans, 2000).

An evaluation of the implications of resumed pumping of a modified SRP well 9.5E-7.7N is included in Appendix C. Pumping this well at historical rates will induce significant drawdown in the LSGS, resulting in a broad capture zone of VOCs across the LSGS plume (see Appendix C, Figure 3). Due to the highly transmissive properties of the LSGS in comparison to the MAU, and the presence of a pronounced vertical upward gradient from the MAU to the LSGS (Appendix C, Figure 4), resumed periodic pumping of the modified SRP wells is not expected to draw contamination into deeper portions of the aquifer. However, to be more certain that this would not occur, the SRP wells could be modified by pressure-grouting the bottom portion of the well/borehole that exists in the MAU. In other words, after modification, only the perforated interval of the wells, constructed within and above the LSGS, would be open to yield groundwater when the wells are pumped. Sealing the bottom portion of the wells would be performed by a licensed drilling contractor using conventional abandonment techniques.[8] Note that the LSGS is known to be the highest yielding water-bearing zone of the aquifer. However, only pump-testing of the modified wells would enable determination of actual well yields.

Pumping the modified SRP wells will create a significant cone of depression, drawing contamination from the LSGS to the north beyond the current plume boundary (see Figure 3-2). However, this spreading of contamination would be over a relatively short geographic distance, and thus may not be considered significant enough to warrant concern by the ADEQ. Despite the slight spread of contamination, pumping of the modified SRP well(s) would have an overall beneficial effect on enhancing remediation of the LSGS plume.

This alternative would need to include installation of GAC wellhead treatment at the production wellhead(s) to remove VOCs from the pumped groundwater prior to discharge into the Grand Canal. The primary advantage of this alternative is that SRP would be able to use its production wells on an as-needed basis with optimum operational flexibility. Disadvantages of this option would include the high capital costs, potentially high O&M costs, and the uncertainty of pumping capacity after well modifications are made.

5.5.2 Alternative 2 – Significantly Deepen Existing SRP Production Wells

One or both of the SRP production wells could be significantly deepened to penetrate into the Lower Alluvial Unit (LAU).[9] The perforated or screened interval of the well(s) could be constructed such that it would extend 600 feet into the LAU. The LAU does not have a role in the occurrence or movement of PCE or TCE at the Site. It is hydrogeologically isolated from the shallower, water-bearing units by several hundred feet of overlying clay (HSI GeoTrans, 2000). This deep well design would serve to enable pumping of VOC-free groundwater with very little to no threat of spreading contamination either laterally or vertically from the existing LSGS plume. Furthermore, the need for installing and maintaining a GAC wellhead treatment system(s) could be avoided.

An evaluation of the implications of pumping a deepened SRP production well is included in Appendix C. Based on characteristics of the aquifer materials transitioning from the LSGS and into the MAU and LAU, an estimated perforated/screened interval from 1,000 to 1,600 feet for the deepened production well(s) is believed to be conservatively appropriate. Assuming a pumping rate of up to 2,600 gpm for well SRP 9.5E-7.7N, this degree of physical separation (over 650 feet) between the bottom of the LSGS and top of the perforated/screened interval is expected to be more than adequate for preventing lateral and vertical migration of VOC contamination from the LSGS toward the SRP pumping well(s). This conceptual deepened well design may yield a reasonably productive pumping rate; however, only pump-testing of the deepened production well(s) would enable determination of actual well yields.

Prior to well modifications, the existing turbine pumps and associated downhole piping would

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[8] Mechanical brushing to remove corrosion from the well perforations followed by pressure-grouting from the well bottom upwards using a tremie pipe is the typical procedure. Prior to this work, a video log of the well would be recommended to assess the condition of the well casing and its perforations to plan for potential additional work prior to grout emplacement.

[9] According to the ADWR's classification of basin fill, the LAU ranges from approximately 975 to 1,450 feet bgs.

be removed. Then either one or both of the wells could be deepened by lowering a drill bit and pipe through the existing 700 feet of 20-inch diameter casing, and drilling a 17-1/2 diameter borehole to a depth of 1,600 feet below the existing wells (i.e., 900 feet of new drilling). The wells would be cased with new 16-inch diameter steel casing, with perforations or screen installed from 1,000 feet to 1,600 feet. Annular materials would consist of a gravel or sand filter pack placed around the well perforations or screen, a bentonite seal above the perforations or screen, and neat cement grout above the bentonite seal.

In addition to minimizing the threat of spreading contamination laterally and vertically via pumping the production well(s) and eliminating the need for wellhead treatment, SRP also could realize optimum operational flexibility on the Grand Canal in the Site vicinity by implementing this alternative. However, similar to Alternative 1, disadvantages of this alternative are the high up-front capital costs for deepening and re-constructing the production well(s), and the uncertainty of well pumping capacity after the wells are deepened.

5.5.3 Alternative 3 – Receive Treated Water into Grand Canal from Remedy Pumping

Under this alternative, there would be no well modifications to, and no wellhead treatment for, the SRP production wells. Instead, the SRP would receive treated groundwater into the Grand Canal from two individual remedy P&T systems: one installed at the downgradient margin of the Site for remediation of the LSGS plume, and one installed at the downgradient margin of the WOC Facility for remediation of the shallow groundwater system (SGWS) plume.[10] Depending on the number of remedy P&T systems (Section 6.0), it is estimated that the SRP could receive flows ranging from 500 to 550 gpm of treated groundwater into the Grand Canal, typically on a continuous basis. Per the SRP's requirements, the remedy P&T system(s) would need to be equipped with remote shut-down controls so that in case there was an emergency event on the Grand Canal, the P&T system(s) could be shut off to cease discharge into the canal.

At the present time, GeoTrans understands that SRP does not need additional water in the Grand Canal to meet its irrigation needs. They currently are receiving generally a continuous flow of treated groundwater into the canal from the Motorola 52nd Street Superfund Site, Operable Unit 2, P&T system; plans are also in place to discharge treated groundwater into the canal from the 56th Street and Earll Drive WQARF Site P&T system.

Based on the RO report (ADEQ, 2005), GeoTrans also understands that SRP has no current plans to have surface water drawn from the Grand Canal for municipal water treatment, which could significantly increase canal water demands. However, if there was a need for additional canal water in the future, Alternative 3 offers a possible solution to increase the water supply. However, this alternative has several disadvantages: 1) the capital costs for installing relatively long pipelines to the canal from one or more remedy pumping systems within the LSGS plume would be high; 2) not only would the design and permitting be difficult, but construction of long pipelines in the COP's right-of-way (ROW) may be impractical due to

[10] A description of remedy pumping and associated discharge alternatives for treated water is part of the approved FS for the SGWS Discharging treated water to the Grand Canal has been recommended for a 30 gpm P&T system at the WOC facility, which includes 3 extraction wells installed at the downgradient portion of the WOC facility..

conflicts with existing utilities, traffic control challenges, etc.; 3) the remedy P&T system(s) would need to be shut off for approximately one month each year during the SRP's canal dry-up period to perform canal maintenance (which may potentially affect plume capture); and 4) the SRP would likely lose operational flexibility on the Grand Canal system if it typically received relatively continuous flows of treated groundwater into the canal rather than flows associated with actual periodic demands.

5.5.4 Alternative 4 – Continue Current No-Pumping Policy for SRP Wells

The SRP may not want to receive supplemental flows of treated groundwater on primarily a continuous basis into the Grand Canal.[11] As the development in the Phoenix west metropolitan area continues to expand, replacing agricultural land, GeoTrans suspects that demands for the Grand Canal irrigation water will continue to decline. Assuming there are no plans in the foreseeable future to install a municipal water treatment plant which utilizes the Grand Canal water supply, there may be little justification for constructing well modifications and/or installing wellhead treatment systems for one or both production wells 8.5E-7.5N and 9.5E-7.7N. If this is true, the SRP could continue its current policy of not pumping these production wells.

GeoTrans understands that for a period of time ending in about 2005, ADEQ was paying the SRP a fee of $13 per acre-foot for water that would have been pumped from its production wells located in the area of the Site to meet demands for irrigation water. Payment was made in accordance with an agreement established between the ADEQ and SRP, whereby ADEQ would reimburse SRP a portion of its costs to secure CAP water from the CAP Banking Authority rather than pump its groundwater production wells. The rationale for keeping the wells off was not to cause the potential spread of groundwater contamination and/or complicate the ongoing groundwater studies being conducted in the WCP WQARF areas. However, based upon communications with ADEQ in October 2008, GeoTrans understands that an agreement no longer is in place, because there is no CAP water available to offset losses from keeping SRP's wells off. If CAP water was to become available again in the future, Alternative 4 could involve reestablishing an ADEQ/SRP agreement, which would provide compensation to SRP for water that would have been pumped to meet irrigation demands.

5.5.5 Recommended Alternative for SRP Production Wells

Estimated costs for the SRP production well alternatives are presented in Table 5-7. To compare the alternatives, net present value (NPV) costs have been calculated over a presumed 30-year life cycle using a discount rate of 7 percent. The NPV is the amount needed to be set aside at the initial point in time to assure that funds will be available in the future as they are needed, assuming certain economic conditions (EPA, 2000).

For the purpose of evaluating costs, the following assumptions have been made for the above-described alternatives:

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[11] Flow of treated groundwater into the Grand Canal is already occurring from a P&T system installed at the Motorola 52nd Street OU2 NPL site, and plans are underway for SRP to accept treated groundwater into the Grand Canal from a P&T system installed at the Motorola 56th and Earll WQARF sites.

Alternative 1

- Either one or both of the SRP production wells (8.5E-7.5N, 9.5E-7.7N) would be modified to seal the bottom portion of each 700-foot deep well up to the depth of the bottom of the LSGS (approximately 350 feet deep).

- Costs assume that a video log of the well casing would be conducted prior to well modification(s), and that mechanical brushing and/or jetting would be sufficient to prepare the well perforations prior to abandonment.

- The modified production well(s) would operate at a pumping rate up to 1,500 gpm, matching the presumed design capacity of the GAC treatment system(s).

Alternative 2

- The wells would be deepened in the manner described above in Section 5.5.2 for Alternative 2.

- That there is sufficient room at and adjacent to the existing well sites to facilitate the drilling logistics using a large, adequately sized drill rig and the necessary support equipment. However, the relatively nominal costs to temporarily remove and replace the existing chain-link security fencing are included for this alternative.

Alternative 3

- The location of a potential downgradient remedy pumping system for the LSGS and associated discharge pipeline to the Grand Canal is presented in Section 6.0. Estimated unit costs of $140 per lineal foot for pipeline construction within the COP ROW.

Alternative 4

- An agreement between the ADEQ and SRP could be reestablished to compensate SRP for water that again could be provided by the CAP Banking Authority in lieu of pumping the SRP production wells.

- That the SRP would require an average of 458 acre feet (AF) of water per year to meet its potential demands for irrigation water. This volume is based on the approximate average combined pumpage of wells 8.5E-7.5N and 9.5E-7.7N for the 10-year period from 1990 to 1999.

- That the cost to ADEQ for water that would not be pumped, but would instead be provided by the CAP Banking Authority, is assumed to be $100 per AF.

Results of the cost evaluation are presented in Table 5-7. The two least costly alternatives are modifying/deepening well 9.5E-7.7N to an assumed depth of 1,600 feet (Alternative 2a), and continuing a no-pumping policy for the two SRP production wells (Alternative 4), assuming replacement water could again be obtained from the CAP. The most costly alternative would be constructing well modifications with installation/operation of wellhead treatment systems for both SRP production wells (Alternative 1b).

It appears that each of the alternatives presented in Table 5-7 address the SRP RO to protect for the current and future municipal and irrigation use of the groundwater supply. However, there may be concerns over flow capacity and loss in operational flexibility under Alternative 3. Also, there is no guarantee that replacement water needed by SRP will be available for purchase from the CAP under Alternative 4. However, it was determined that it is likely that there would be replacement water at a reasonable cost, or that the SRP no longer needs or desires more water into the Grand Canal for the foreseeable future, Alternative 4 is recommended. This recommendation is based on Alternative 4 being the most practicable and lowest-cost alternative. Alternative 1b is the most costly due to high capital investment and potentially high, long-term O&M costs associated with the use of a wellhead treatment systems. If replacement water cannot be economically provided from another source to the SRP, it appears that Alternative 2a (significantly deepening one SRP production well such that no wellhead treatment would be necessary) is the next best alternative. It appears to strike a balance between cost and practicability; it also provides operational flexibility to the SRP to meet its potential supplemental water needs on the Grand Canal. Given the preceding arguments, either Alternative 2a or Alternative 4 is recommended as the best alternative.

5.6 EVALUATION OF WELL MODIFICATIONS OR REPLACEMENT FOR COP-70/71

The following is a discussion of two alternatives that would restore pumping at COP-70/71. This strategy would be anticipated to restore a considerable portion of the 1,400-gpm well capacity lost as a result of groundwater contamination at COP-70/71 (Table 5-6). Note that installing one or two significantly deeper replacement production wells for COP-70/71, which is believed could pump VOC-free water from the LAU far below the LSGS, is not being considered in this evaluation. Although this option may be technically feasible, it is believed to be more costly and ADEQ is concerned of the possibility of drawing VOC-laden water into the deeper LAU.

5.6.1 Alternative 1 – Rehabilitate/Modify COP-70 and COP-71 to LSGS Depth

Construction features of COP-70 and -71 are included in Table 5-6. Based on records obtained from the ADWR, production well COP-70 has a 16-inch diameter steel casing, is 701 feet deep, has an undocumented/unknown perforated interval, and has a pumping capacity of 600 gpm. Well COP-71 also has a 16-inch diameter casing, is 545 feet deep, is perforated from 260 to 441 feet bgs, and has a pumping capacity of 800 gpm. COP-70 and -7l were constructed in the mid 1950’s. Thus, both wells are approximately 50 years old. Wells COP-70 and -71 are installed within a common compound less than 150 feet apart. Therefore, due to their proximity and somewhat similar construction, it is assumed that during their operational time periods, the two wells pumped alternately rather than simultaneously.

Significant encrustation/corrosion of the well casing and its perforations is expected within each well, requiring rehabilitation. Prior to rehabilitation, each well would be video-logged and possibly cement bond-logged to assess the visible physical condition of the casing and perforations, and to determine the possible presence of any cement grout voids. The results of these logs would be used to develop an appropriate strategy for well rehabilitation. The techniques for well rehabilitation could include wire-brushing, high-pressure jetting, air-lift development, and relining of the wells. Well relining entails installing a smaller diameter casing within the old, potentially frail, original casing.

The top and bottom of the LSGS at the location of COP-70/71 are approximately 300 and 370 feet bgs, respectively. Because each of these COP production wells extends appreciably below the LSGS, it is recommended that the casings be re-perforated using a mills-knife technique, then pressure-grouted from the total depth up to approximately 370 feet bgs to seal the borehole annulus and lower portion of each well. Sealing with grout in this manner would serve to prevent potential contamination into deeper zones of the aquifer resulting from pumping. After the bottom portion of each well is grouted, it is assumed that each well would then be relined with a smaller diameter casing (probably 12-inch diameter) to provide a new, more structurally sound well. The screened intervals of modified wells COP-70 and COP-71 would be installed from approximately 300 to 370 feet bgs, and a blank casing (i.e., sump) could be installed below each well screen, from 370 to 380 feet bgs. Pumping from the zone of the LSGS is expected to yield high quantities of water, because it is highly transmissive, and known to be the most significant water-bearing zone of the aquifer.

The feasibility of well rehabilitation using the above-described techniques will depend on the visible condition of the well casings and associated perforations, as determined by video logging. If the existing steel wells are assessed as not structurally sound, brushing, jetting, and/or re-perforating could cause breakage and collapse of the well casings, preventing the use of the wells.

5.6.2 Alternative 2 - Install Replacement Wells to LSGS Depth

New replacement production wells could be drilled at the COP-70/71 well site. Under this option, existing wells COP-70 and -71 would be properly abandoned in accordance with the ADWR's requirements. As described for Alternative 1, well rehabilitation may not be considered feasible if well casing conditions are assessed as very poor. In this case, drilling and installing new replacement wells would be recommended. For purposes of this FS, we have assumed that each replacement production well would be constructed of 16-inch diameter, high-strength, low-alloy (HSLA) steel casing, a louver HSLA screen (placed from approximately 300 to 370 feet bgs), and would include conventional annular materials.

5.6.3 Recommended Alternative for COP-70/71 Production Wells

A cost estimate has been developed for the two desired alternatives associated with the COP 70/71 production wells. The estimated costs are presented in Table 5-8. Alternative 2 (installing new production wells) is estimated to be approximately $157,000 more than Alternative 1 (well rehabilitation/modification). Although it is higher cost, Alternative 2 is considered the best option to ensure that the production wells have sufficient integrity and longevity to meet the COP's needs. When combined with GAC wellhead treatment, pumping from the replacement wells screened in the LSGS will minimize risk of contaminating deeper portions of the aquifer by the pumping process, and serve to provide a supplemental municipal water source for the COP.

5.7 EVALUATION OF OPTIONS FOR TREATED WATER DISCHARGE

Significant quantities of water could possibly be extracted and treated by contingent P&T system(s) for the LSGS groundwater remedy. It is important, particularly in the arid southwest, to consider the value of the treated water when evaluating discharge options. Viable options may include discharge to:

- The COP municipal water supply system.
- The SRP's Grand Canal for current irrigation and/or future municipal water supply use.
- The COP storm water collection system.
- The subsurface, via reinjection into the aquifer.

This section describes the discharge options and those retained for further analysis.

5.7.1 Discharge to COP Municipal Water System

The ADEQ's May 2005 Remedial Objectives Report specifically describes that there are ROs to restore, replace, or otherwise provide for the current and future COP groundwater supply. Due to the LSGS groundwater contamination associated with the Site, the municipal water supply from wells COP-70 and COP-71 was lost when these wells had to be removed from service in 1982. Therefore, all three remedies evaluated in this FS include provisions for installing a wellhead treatment system at the COP-70/7l well site, such that pumped groundwater could be used as part of the municipal water supply. The treated water would be connected to a COP water main that presumably exists at the well site.

5.7.2 Discharge to SRP's Grand Canal

Currently, there are two SRP production wells in the near vicinity of the LSGS groundwater plume (Figure 3-2). These wells were shut down under an agreement between the ADEQ and SRP to prevent migration of the plume towards the northwest, and potentially into deeper portions of the aquifer. The ADEQ's May 2005 ROs report presents an RO to protect for the use of the SRP groundwater supply threatened by the contamination emanating from the Site.

Discharging treated groundwater from a remedy P&T system(s) into the SRP Grand Canal is another identified option. This would involve installing a conveyance pipeline(s) from groundwater treatment facilities to the SRP's Grand Canal to supplement SRP's needs for irrigation water, particularly during times of drought. The supplemental water could also potentially provide a source for municipal water, assuming a future water treatment plant was

built on the Grand Canal at or downstream of the Site area.
Discharge of treated water to the Grand Canal will require obtaining an Individual AZPDES Permit from the ADEQ. The properly monitored GAC treatment facilities would operate such that Federal MCLs and Arizona AWQS for VOCs would be achieved prior to discharge. However, it is anticipated that comprehensive sampling and monitoring activities of the discharge would be required by the AZPDES Permit.

A potential advantage of this option is that the SRP would receive the treated water for its desired use(s). Disadvantages may include: 1) more stringent and costly sampling requirements compared with other discharge options; 2) significantly higher capital and maintenance costs associated with installing relatively long conveyance pipelines from treatment facilities to the Grand Canal; and 3) potential loss in the SRP's operational flexibility to control the amount of water in the Grand Canal.

5.7.3 Discharge to Groundwater Reinjection Wells

Another discharge option is to return treated water into the subsurface using infiltration galleries, infiltration basins, or injection wells (IWs). Reinjection would serve to conserve groundwater as a resource. Because space is limited in the residential areas of the Site, and relatively slow water infiltration rates are expected through the silty sand vadose zone, the use of infiltration galleries or basins is not considered feasible. However, the use of IWs designed to return the treated water back into the transmissive LSGS aquifer is considered viable.

The potential advantages of groundwater injection include: 1) return of treated water to the LSGS could potentially enhance hydraulic containment near the downgradient margin of the plume; 2) sampling and reporting requirements for the treated discharge are expected to be less rigorous compared with other options; and 3) reinjection serves to conserve groundwater as a natural resource.

An important disadvantage is that the use of IWs likely will require more maintenance due to fouling of the IW screens and adjacent aquifer. Biological or mineral precipitation can periodically clog the IW screens. Clogging of the aquifer could also occur due to entrained air, or from ionic reactions that result in dispersion of clay particles and swelling of colloids in a sand-and-gravel aquifer (EPA, 1999). The degree of IW maintenance would be based on the frequency of fouling/clogging. Typical fouling mitigation techniques would involve mechanical brushing of the IW screens and air-lift well development, as needed to maintain system operations.

5.7.4 Discharge to COP Storm Sewer

Although it is discouraged by the COP, water from P&T system facilities could potentially be discharged to the COP storm sewer collection system, either on a continuous basis, or solely during the SRP's seasonal dry-up period for canal maintenance. Water from treatment facilities would be conveyed by storm sewers, which outfall into the Papago Diversion Channel (owned by the Arizona Department of Transportation [ADOT]), located in the north ROW of Interstate 10, south of the Site. This channel flows west through Glendale, Arizona, and ultimately into the Agua Fria River, which recharges the UAU via percolation beneath the river. For this option, an Individual AZPDES Permit would also be required by the ADEQ. Regulation of the discharge by the COP would also be applicable to ensure compliance with its AZPDES Municipal Separate Storm System (MS4) Permit. It is anticipated that relatively frequent sampling of the discharge would be required by the City.

A key advantage of this option is that, compared with discharge to the SRP's Grand Canal, pipeline lengths for connection of treatment facilities to extraction wells and/or storm sewers could be minimized to reduce capital and maintenance costs for the P&T system(s). The significantly less pipeline construction would also minimize the degree of traffic disruption, including potentially for emergency vehicles and for pedestrians in the public ROW. A disadvantage is that similar to the option for discharge to the Grand Canal, more rigorous sampling and reporting requirements would be required. Discharging the treated water to the COP storm sewer has been retained as an option for further evaluation.

5.8 USE OF MONITORED NATURAL ATTENUATION AS A PASSIVE REMEDY

5.8.1 Application Description

The USEPA Office of Research and Development describes MNA as follows:

> *Natural attenuation is the reduction of contaminants in soil or groundwater through natural physical, chemical, or biological processes. These processes degrade or dissipate contaminants and include aerobic and anerobic biodegradation, dispersion, volatilization, and sorption. MNA is a technique used to monitor or test the progress of the attenuation process. It may be used with other remediation processes as a finishing option or as the only remediation process. Natural processes can then mitigate the remaining amount of pollution, and regular monitoring of the soil or groundwater can track those reductions. MNA is increasingly used in cleanup actions* (EPA, 2007).

Chlorinated solvents and their byproducts are the primary target analytes for monitoring natural attenuation. These analytes are used to determine concentration and distribution of contaminants, and their daughter products, in the aquifer. The degradation process of chlorinated solvents is generally termed dechlorination, and the biotic process of dechlorination is as follows:

PCE → TCE → DCE (typically cis-1,2-DCE) → Vinyl Chloride → Ethene

The contaminants of concern at the Site are VOCs, specifically PCE, TCE, and 1,1-DCE, all of which would be ideal analytes for monitoring degradation at the Site. Other groundwater quality parameters may be collected and analyzed to better understand the degradation processes and rates; and include oxidation-reduction potential, pH, temperature, conductivity, oxygen, nitrates, methane, iron (II), sulfates, alkalinity, and chloride. Site-wide groundwater levels should also be collected to monitor the hydraulic gradient across the Site in order to document the physical aspects of MNA, such as dispersion (EPA, 1998).

5.8.2 Implementation at WOC Site

Implementation of MNA at the Site would involve the continuation of groundwater monitoring of the existing network of LSGW wells. Monitoring would include both the gauging of water levels to determine the direction and value of the hydraulic gradient, and water quality sampling to determine the concentrations and composition of VOCs. The data trends for VOC parameters would be tabulated and plotted to evaluate the degree of concentration reduction and sustained attenuation, respectively.

Advantages

Compared to engineered, active remediation technologies, remedies relying on MNA often have the following advantages:

- Significantly less volume generation of remediation-related wastes and reduced potential for cross-media transfer of contaminants that are typically associated with ex-situ treatment processes.
- Reduced risk of exposure to contaminated media.
- The elimination of installing invasive or intrusive infrastructure (i.e., no need for surface structures).
- Potential for application to either all or select portions of the Site.
- Can be used in conjunction with, or as a follow-up to, other active remedial measures.
- Lower overall remediation costs compared to those associated with active remediation technologies (EPA, 1998).

For purposes of this FS, it is assumed that semi-annual groundwater monitoring of the existing network of 13 LGWS wells would be performed for a period of up to 30 years.

6.0 DEVELOPMENT OF REFERENCE REMEDY AND ALTERNATIVE REMEDIES

This section develops a Reference Remedy for groundwater along with two alternative remedies known as a More Aggressive and Less Aggressive Remedy. These three remedies are based on retained remedial technologies and evaluation of remedial measures, strategies, and discharge considerations to achieve ROs for the Site. The remedial strategies to be developed are discussed below. Because source control in soil was achieved through the removal of septic tanks and implementation of the SVE ERA at the WOC Middle Parcel (Sections 4.1 and 4.2), source control will not be an element of the Reference Remedy or alternative remedies. Source control to prevent further contamination of the LSGS was also achieved by properly abandoning the Pincus Well at the WOC Facility Middle Parcel (Section 4.3).

A strategy may incorporate more than one remediation technology or methodology. As provided in AAC Rl8-16-407(F), remedial strategies for consideration may include:

- Plume remediation to achieve water-quality standards for COCs in waters of the state throughout the Site.

- Physical containment to contain contaminants within definite boundaries.

- Controlled migration to control the direction or rate of migration, but not necessarily to contain migration of contaminants.

- Source control to eliminate or mitigate a continuing source of contamination;

- Monitoring to observe and evaluate the contamination at the Site through the collection of data.

- No action as a strategy that consists of no action at the Site.

Remedial measures necessary for each alternative remedy have been identified with consideration of the needs of the water providers (COP and SRP) and their customers, including the quantity and quality of water, water rights, other legal constraints, reliability of water suppliers, and any operational implications. Such remedial measures may include, but are not limited to, well replacement, well modification, water treatment, provision of replacement water supplies, and engineering controls. Where remedial measures are necessary to achieve ROs, such remedial measures will remain in effect as long as required to ensure the continued achievement of those objectives.

The combination of the remedial strategy and remedial measures for each alternative remedy are designed to achieve the ROs. The Reference Remedy and each alternative remedy also may include contingent remedial strategies or remedial measures to address reasonable uncertainties regarding the achievement of ROs or uncertain time frames in which ROs will be achieved. The Reference Remedy and the alternative remedies are described below.

6.1 REFERENCE REMEDY – STRATEGY AND MEASURES

6.1.1 Requirements

- The Reference Remedy must allow for the continued definition and monitoring of the contaminated LSGS aquifer under the current monitoring well network.

- The Reference Remedy must provide for the ability of the COP to utilize groundwater at the Site in a timely manner, if and when necessary.

- The Reference Remedy must provide for the ability of the SRP to utilize groundwater at the Site, or provide a provision for replacement water. This action may be needed as soon as is technically feasible.

- The Reference Remedy must provide for remediation of characterized COCs and any daughter products.

- The Reference Remedy must be capable of achieving the ROs for the Site.

6.1.2 Remedial Strategy and Measures

The remedial strategies and measures for the Reference Remedy are:

1. Remediation of the LSGS aquifer over time by MNA. Evaluation of groundwater data collected from LSGS monitoring wells over the past five years indicates an overall declining trend of VOC concentrations in the majority of wells (Table 3-1 and Appendix A). Concentrations in the downgradient wells have fluctuated up and down; however, they remain near the AWQSs. Thus, it is reasonable to conclude that concentrations will continue to decline due to physical, geochemical, and/or biological processes.

   MNA will include both the gauging of water levels to determine the direction and value of the hydraulic gradient, and water quality sampling to determine the concentrations and composition of VOCs. To assess the adequacy of this remedy, groundwater samples would be collected and analyzed semi-annually for VOCs, and annually for pertinent MNA parameters, including nutrients and electron donors and acceptors. The data trends would be tabulated and plotted to evaluate contaminant attenuation. Technical reporting of results would be completed on a semi-annual basis.

2. Assuming it is desired by the COP, restoration of the municipal groundwater supply by 1) installing up to two new replacement production wells for COP-70/-71 2) installing a LGAC wellhead treatment plant at the COP-70/71 well site to remove VOCs from pumped groundwater; and 3) pumping the treated groundwater into the potable water distribution system on an as-desired/ as-

needed basis by the COP. ADEQ considers installation of the replacement well(s) to be the responsibility of the COP. If necessary, chlorination of the LGAC-treated groundwater would also be performed by the COP, prior to pumping the treated groundwater into the municipal distribution system. The replacement production wells would be screened solely through the LSGS to minimize risk for causing deeper aquifer contamination via the pumping process. An estimated total pumping capacity of 750 gpm would be restored.[12] The existing old wells[13] would be properly abandoned in accordance with the ADWR's requirements.

6.1.3 Pumping Modeling and Results

If the COP chooses to pump groundwater to meet its water supply needs from one or two replacement wells installed at COP-70/71, it is recommended that the well(s) be screened solely through the LSGS to minimize the potential for causing deeper contamination of the aquifer, which according to the RI, has not been detected below the LSGS.[14]. The most transmissive portion of the UAU is the LSGS, which is capable of yielding high volumes of water. Therefore, screening or perforating the replacement well(s) through the LSGS would be the least costly alternative to maximize yield and minimize well construction costs. As described in multiple sections above, a wellhead LGAC treatment system could be installed at COP-70/71 to remove VOCs from groundwater prior to pumping it into the municipal water distribution system. As groundwater is pumped, a zone of influence will propagate represented by the depression of water levels (i.e., drawdown in the well and induces cone of depression). The magnitude of the zone of influence will depend on the operating frequency and duration that the well is pumped.

To assess the effects of pumping at COP-70/71, modeling was performed using the EPA WhAEM code which simulates two-dimensional flow. Use of WhAEM requires situations where the aquifer can be modeled as having constant thickness and is horizontal. Although neither condition may be absolutely true in the LSGS, the assumptions should be acceptable for the purpose of assessing the location and zone of influence of pumping wells. Aquifer hydraulic properties used as inputs for modeling were estimated based on lithologic logs of well borings drilled at the Site, aquifer tests performed on LSGS monitoring wells MW-6M and MW-7M at the Site, aquifer test data from SRP's production wells 7.5E-7.5N, 8.5E-7.5N, and 9.5E-7.7N, and available ADWR groundwater models.

Simulated COP-70/71 zones of influence induced from continuous pumping over 15, 45, and 90-day operation periods are shown on Figure 6-1. These periods were assumed as possible time frames in which the wells would actually be pumped to fulfill the COP's needs to meet water demands for drought redundancy and operating flexibility, including peaking and

[12] The ADWR records indicate that the individual pumping capacities of COP-70 and COP-71 are 600 and 800 gpm, respectively. However, actual pumping rates attainable from new replacement wells COP-70 and COP-71 are unknown, as is the combined rate that could be realized from simultaneous pumping of the two rebuilt wells. For purposes of this FS, it is assumed that a minimum total pumping rate of 750 gpm could be sustained.

[13] COP-70 and COP-71 were constructed in 1957 and 1955, respectively.

[14] Based on sampling L-Series monitor wells MW-4L, MW-6L, and MW-7L during the RI, the aquifer below the LSGS has no detected VOC contamination.

periods for system maintenance. It should be noted however, that continuous pumping of water system production wells is normally not practical, because operation is controlled based on water-use and system pressure demands that typically require intermittent pumping to fill reservoirs and/or pipelines as needed. Because this remedy includes a strategy to keep the SRP's irrigation wells shut off, more sophisticated modeling involving competing pumping between COP-70/71 and SRP's nearby production wells was not performed.

6.1.4 Well Site COP-70/71 System

A conceptual layout for an LGAC wellhead treatment system at the COP-70/71 well site is shown on Figure 6-3. This system could be installed as deemed necessary by the COP to restore a portion of its water supply that was lost due to the groundwater plume at the WOC Site. A discussion of alternative measures for the production wells is presented in Section 5.6. The recommended alternative to control costs would be to drill/install one new replacement well for COP-70 and/or -71 that is specifically screened in the LSGS, and to abandon both of the existing old wells.

With regard to well abandonments, the ADWR records for the production wells are:

- COP-70 has a 16-inch diameter steel casing, is 701 feet deep, with an undocumented/unknown screen interval, and was constructed in 1957.

- COP-7l has a 16-inch diameter steel casing, is 545 feet deep and screened from 545 to 441 feet bgs, and was constructed in 1955.

Due to the age of the production wells, annular materials sealing the boreholes from the casings are probably absent. If the structural condition of the casing is acceptable based on video-logging each well, a mills-knifing technique could be performed to create openings for grout to enter the surrounding formation. A rig-mounted tremie pipe would be used to emplace cement grout from the bottom of the well upwards under pressure to seal all voids, including the annular space between the borehole and well casing and inside the well. The top 10 to 20 feet of well casing could be removed, and any remaining casing and open borehole must be filled with a cement grout plug extending from the land surface to a minimum of 20 feet below the land surface.

6.1.5 Permitting for Wellhead Treatment System

Permits will be required to authorize installation and operation of a wellhead treatment system at the COP-70/71 well site. Permitting requirements, organized by regulatory agency, are described below.

6.1.5.1 ADWR

The COP may elect to either rehabilitate or install new replacement wells for COP-70 and/or -71. If so, pre-construction notifications (Notice of Intent forms) and post-construction reporting (Driller's Reports) would need to be prepared for the COP-70 and/or -71 replacement wells. Well construction and/or modification work must be conducted by an

ADWR-licensed driller. New wells must also comply with the ADWR's well construction standards, which are found in ARS §45-594, -595, -596 and -600 of the Groundwater Code. In addition, a land subsidence and hydrological groundwater impact study may need to be performed pursuant to AAC R12-l5-302.

Pursuant to A.R.S. § 45-516, a Poor Quality Groundwater Withdrawal Permit (PQGWWP) will be required from the ADWR to authorize pumping at COP-70/71 within the Phoenix Active Management Area. This process involves completing an application (DWR Form 516) and submitting a fee to the ADWR. Information on the application forms must include a detailed description of the specific purposes for which poor quality groundwater will be withdrawn, and should indicate that it is associated with a remedial action at the West Central Phoenix, WOC WQARF Site. At a minimum, the permit will specify the groundwater withdrawal monitoring requirements (i.e., volume measurement, water quality sampling) and reporting requirements, most notably the submittal of annual reports to document measured total pumpage volumes.

6.1.5.2 COP

Several permits from the COP will be required to authorize installation and operation of the wellhead treatment system as noted below:

- Construction permits from the COP Development Services Department (DSD) will need to be obtained. This will require preparation and submittal of design plans and specifications (i.e., civil, plumbing, mechanical, electrical) to the City.

- In accordance with the COP Zoning Ordinance Section 622056, a Use Permit will need to be obtained from the COP Zoning Department to allow installation and operation of an environmental treatment facility.

- The LGAC treatment units will need to be backwashed periodically to remove inorganic fouling of the carbon. GeoTrans understands that a Class B Groundwater Discharge Permit is likely to be required by the COP Water Services Department, Pollution Control Division (PCD), to authorize and regulate discharges of LGAC backwash water to the COP sanitary sewer. The process would involve completing the appropriate PCD application forms and submitting a filing fee. An issued permit would contain specific conditions including discharge limitations, periodic monitoring/sampling requirements, reporting requirements, and various other standard conditions.

6.1.5.3 MCESD

The Maricopa County Environmental Services Department (MCESD) Drinking Water Program has been delegated authority by the ADEQ to administer portions of the drinking water program. MCESD oversees inspections, engineering plan reviews, and compliance and enforcement activities for all public water systems within Maricopa County. In order to reconnect production wells COP-70/71 to the City's municipal water distribution system, a Source Approval must be obtained from the MCESD Drinking Water Program. This involves submitting an Application for Drinking Water Source Approval that includes comprehensive laboratory results of the untreated groundwater for all drinking water parameters, and well construction information. After the source application is approved, an Approval to Construct (ATC) application is required that includes engineering design plans with a description of the water treatment system. When the ATC is granted, the system can be installed and samples of the treated water would need to be collected for "commissioning and validation approval." A licensed engineer would inspect and certify that the system was installed in accordance with design plans and specifications, and submit the signed certification to the County. Once the system is operating, MCESD will require regular sampling/monitoring and reporting in accordance with AAC R18-4, Article 2. Due to the presence of VOCs in the untreated water, increased frequency of monitoring would be required pursuant to AAC R18-4-212(G).

6.1.6 Source Control

Source control must be considered as an element of the Reference Remedy and all alternative remedies. Source control of TCE at the WOC Facility has been achieved through the removal of the septic tanks, implementation of the interim SVE system at the Middle Parcel, and abandonment of the Pincus Well. Additional source control for the LSGS will not be included in the Reference Remedy for the LSGS. However, the FS for the SGWS evaluates remedial strategies and measures for supplemental source control of VOCs present in shallow groundwater at the WOC Facility (GeoTrans, 2012). More specifically, the Reference Remedy for the SGWS includes a recommended P&T system with extraction wells located at the downgradient margin of the WOC Facility. The system would contain and remediate remaining SGWS contamination derived from the WOC Facility (i.e, source areas), as well as contamination that has and continues to migrate into the Site from the NCP.

6.1.7 Uncertainties and Contingencies

Although LSGS monitoring conducted over the past ten years indicates that the plume is generally stable, the long-term plume stability is not definitively certain. MNA of the Reference Remedy includes continued long-term gauging and sampling of the existing LSGS monitoring well network; however, there is a potential for the plume to migrate beyond the existing well network. If this was to occur, installing supplemental monitor wells and/or sentinel wells may also be appropriate for use with assessing groundwater conditions beyond the existing LSGS well network.

6.1.8 Proposed Remedy to Evaluate

The remedial strategies and measures for the Reference Remedy are presented above. Based on the general declining VOC concentrations in the LSGS wells over the past five years (Appendix A), it appears that MNA may be a viable remedial strategy to achieve AWQS for the COCs at the Site. In Section 7.0, the costs for the Reference Remedy, including MNA and contingency costs for possible pumping/treating groundwater at COP-70/71, will be compared and evaluated against two main other alternatives.

6.2 MORE AGGRESSIVE ALTERNATIVE REMEDY - STRATEGY AND MEASURES

6.2.1 Requirements

- The More Aggressive Remedy must allow for the continued definition and monitoring of the contaminated LSGS under the current monitoring well network.

- The More Aggressive Remedy must provide for the ability of the COP to utilize groundwater at the Site in a timely manner, if and when necessary.

- The More Aggressive Remedy must provide for the ability of the SRP to utilize groundwater at the Site, or provide a provision for replacement water. This action may be needed as soon as is technically feasible.

- The More Aggressive Remedy must provide for remediation of characterized COCs and any daughter products.

- The More Aggressive Remedy must be capable of achieving the ROs for the Site.

6.2.2 Remedial Strategy and Measures

The More Aggressive Remedy includes the same proposed remedial strategies and measures for COP-70/71 and the SRP's production wells; however, active pumping to contain and remediate groundwater at the downgradient margin of the plume would be implemented in conjunction with passive MNA for the upgradient portion of the plume. Specifically, the More Aggressive Remedy would consist of:

1. Passive remediation of the upgradient portion of the LSGS plume by MNA. As groundwater moves downgradient under the influence of the LSGS hydraulic gradient, it would be captured and further remediated by an active P&T system (Figure 6-2). MNA would include the gauging of water levels in LSGS monitoring wells to confirm the direction of groundwater flow, and to evaluate changes in the value of the hydraulic gradient. It would also include water quality sampling to determine the concentrations and composition of VOCs, and to assess pertinent MNA parameters, including nutrients and electron donors and acceptors. The data trends would be tabulated and plotted to assess contaminant attenuation. The frequency of monitoring and laboratory testing, as well as technical reporting of results is described below.

2. Assuming it is desired by the COP, restoration of the municipal groundwater supply by 1) installing up to two new replacement production wells for COP-70 and COP-71; 2) installing a GAC wellhead treatment plant at the COP-70/71 well site to remove VOCs from the pumped groundwater; and 3) pumping the treated groundwater into the potable water distribution system on an as-

desired/as-needed basis by the COP. Installation of the replacement well(s) is considered by ADEQ to be the responsibility of the COP. If necessary, chlorination of the LGAC-treated groundwater would be the performed by the COP prior to pumping into the water distribution system. The replacement production wells would be screened solely through the LSGS to minimize risk for causing deeper contamination of the aquifer by the pumping process. An estimated total pumping capacity of 750 gpm would be restored. The existing old wells would be properly abandoned in accordance with the ADWR's requirements.

3. Installation of a single EW for hydraulic containment and remediation of the LSGS aquifer at the downgradient margin of the plume. The pumping rate of this EW will be approximately 500 gpm to capture the approximate full width of the plume. A LGAC treatment plant would be installed at the wellhead area, and depending on approvals from SRP, ADWR, or COP, the treated water would be discharged either to the Grand Canal, back into the LSGS aquifer using two injection wells (Figure 6-2a), or to the COP storm sewer.

4. Installation of two piezometer wells to evaluate the capture zone of the downgradient EW in conjunction with existing monitoring well MW-108M.

5. For the first two years of P&T system operations, monthly water levels and quarterly sampling of the existing LSGS monitoring well network would be performed, along with quarterly reporting for system performance/groundwater monitoring. This is pursuant to the ADEQ's WQARF Program's typical policy.

6. After the second year of P&T system operation, groundwater monitoring would involve quarterly gauging of water levels, semi-annual sampling for VOCs, and semi-annual reporting for groundwater and performance of the P&T system

7. Continuing the current policy of not pumping SRP's production wells 8.5E-7.5N and 9.5E-7.7N due to the environmental impacts at the WOC and NCP WQARF Sites. If deemed necessary by SRP to meet its current or future water supply demands, this strategy assumes that SRP could once again receive replacement water from the CAP in lieu of pumping the two production wells in the near vicinity of the Site. The cost of replacement water would be reimbursed to SRP by the ADEQ under a negotiated agreement. Furthermore, remedy pumping from a downgradient P&T system that would discharge treated water to the Grand Canal is an option for augmenting the SRP's water supply (see below).

6.2.3 Pumping Modeling and Results

To assist with conceptual design of the More Aggressive Remedy, modeling using the EPA WhAEM code was performed to evaluate plume capture by from a downgradient EW. The general assumptions and basis of hydraulic properties used for modeling are consistent with that described for the Reference Remedy in Section 6.1.3. Model-simulated capture zones of the More Aggressive Remedy pumping well and IWs described above are shown on Figures 6-2, 6-2a, 6-2b, and 6-2c. Results of WhAEM simulations predict that capture of the estimated full width of the downgradient portion of the plume may be accomplished using one EW with a pumping rate of 500 gpm.

6.2.4 COP-70/71 Wells and Wellhead Treatment System

The location for installation of the estimated 750-gpm capacity wellhead treatment system at the COP-70/71 well site would be as described for the Reference Remedy in Section 6.1.4. An aerial photograph and conceptual layout for this system is shown on Figure 6-3. The recommended alternative for the production wells is to drill/install one new replacement well specifically screened in the LSGS, and to abandon the existing old wells COP-70/ 71. Installation of the replacement well(s) and abandonment of the existing wells are considered by ADEQ to be the responsibility of the COP

With regard to well abandonments, the ADWR records for the wells are:

- COP-70 has a 16-inch diameter steel casing, is 701 feet deep, with an undocumented/unknown screen interval, and was constructed in 1957.

- COP-7l has a 16-inch diameter steel casing, is 545 feet deep, screened from 545 to 441 feet bgs, and was constructed in 1955.

Due to the age of the wells, annular materials sealing the boreholes from the casings are probably absent. If the structural condition of the casing is acceptable based on video-logging each well, a mills-knifing technique could be performed to create openings for grout to enter the surrounding formation. A rig-mounted tremie pipe would be used to emplace cement grout from the bottom of the well upwards under pressure to seal all voids, including the annular space between the borehole and well casing and inside the well. The top 10 to 20 feet of well casing could be removed, and any remaining casing and open borehole must be filled with a cement grout plug extending from the land surface to a minimum of 20 feet below the land surface.

6.2.5 Potential Locations of Downgradient P&T System

Installation of an EW pumping at 500 gpm at the downgradient margin of the LSGS plume is expected to effectively contain plume migration. Review of aerial photographs indicates that land in the near downgradient vicinity of MW-108M generally is fully developed. The majority of this area is residential, with some localized commercial development at and south of the corner of North 51st Avenue and West Thomas Road (Figure 6-4). A review of vacant land area reveals that a portion of Parcel l03-54-095D, 2602 North 51st Avenue, located approximately 0.60-mile southwest of MW-108M would be ideal for installation of a P&T system. The west side of this parcel is a large paved area/parking lot, and the east side is currently occupied by the Beacon Light Seventh Day Adventist Church (Figure 6-5). The owner of Parcel l03-54-095D is listed in Maricopa County Assessor's records as the Arizona Conference Corporation Seventh Day Adventist Church, Scottsdale, Arizona.

6.2.5.1 Option for Discharge to Canal from Downgradient P&T System

If the SRP agrees to receive treated groundwater from the downgradient P&T system to augment its irrigation supplies, a strategy is necessary for maintaining system operation (and thereby plume containment) during the SRP's winter dry-up period for maintenance of the Grand Canal. A solution may be to divert the treated discharge to the COP storm sewer system during the annual winter dry-up period (typically January/early February). A pipeline connection from the GAC treatment plant to the COP's existing 72-inch storm sewer located in 51st Avenue could potentially be constructed. GeoTrans understands that this storm sewer outfalls to the ADOT's Papago Drainage Ditch, which parallels the north side of Interstate 10, and flows through Glendale, Arizona, to the Agua Fria River (COP, 2007). Conceptual routes for pipelines from P&T systems to the Grand Canal and COP storm sewer are shown on Figure 6-4.

6.2.5.2 Option for Discharge to Reinjection Wells from Downgradient P&T System

A conceptual pipeline route, with potential locations for reinjection wells, is shown on Figure 6-6. It appears that there are portions of land on several parcels with sufficient space for installation of a north IW (IW-l). These include Parcel 103-54-001B, 5237 West Thomas Road; Parcel 103-54-095N, located adjacent to the east of 2861 North 52nd Avenue; and Parcel 103-54-095Q, 5109 West Thomas Road. Based on current listings in Maricopa County Assessor's records, Parcel 103-54-001B is occupied by the Saint Thomas Church, and is owned by the Saint Thomas Evangelical Lutheran Church, Phoenix, Arizona. The owners of Parcels 103-54-095N and 103-54-095Q are Mr. Sergio Gonzales, Goodyear, Arizona, and AZUSA World Ministries, respectively. An aerial photograph showing potential locations for the north IW is included as Figure 6-7.

Sufficient vacant space may also be available for installation and operation of a south IW (IW-2) on Parcel 103-17-340, 2450 N. 51st Avenue. This land is currently used for the Springwood Apartments. The landowner is listed in Maricopa County Assessor's records as Morales Properties, Inc., Phoenix, Arizona. An aerial photograph showing potential locations for the south IW is shown on Figure 6-8.

6.2.5.3 Option for Discharge to COP Storm Sewer from Downgradient System

The most direct, least costly alternative for discharge of the treated water from the downgradient P&T system would be connection to the existing COP's 72-inch diameter storm sewer located in 51st Avenue. The length of the pipeline from the location of the conceptual treatment plant area on Parcel 103-54-095D would be only approximately 550 feet (Figure 6-9), compared with distances of approximately 4,250 and 2,600 feet for the Grand Canal (Figure 6-4) and two injection well (Figure 6-6) discharge options, respectively

6.2.6 Permitting for Potential COP-70/71 Wellhead Treatment and Downgradient P&T

Multiple permits will be necessary to authorize installation and operation of the potential COP-70/71 wellhead treatment system and the downgradient P&T system being considered for the More Aggressive Remedy at the Site. Permitting requirements, organized by regulatory agency, are described below.

6.2.6.1 ADWR

Pre-construction notifications (Notice of Intent forms) and post-construction reporting (Driller's Reports) will need to be prepared for the downgradient EW, and if applicable, installation of rehabilitated or new replacement wells for COP-70 and/or COP-71. Well construction and/or modification work must be conducted by an ADWR-licensed driller. New wells must also comply with the ADWR's well construction standards, which are found in ARS §45-594, -595, -596 and -600 of the Groundwater Code.

The COP may elect to either rehabilitate or install new replacement wells for COP-70 and/or -71. As described above, ADEQ considers this to be the responsibility of the City. Permitting associated with rehabilitating or replacing COP-70/71 is described in Section 6.1.5.1.

A PQGWWP will be required from the ADWR as a result of pumping the VOC-impacted groundwater from COP-70/71. Requirements to obtain this permit are also described in Section 6.1.5.1.

6.2.6.2 COP

Several permits from the COP will be required to authorize installation and operation of the wellhead treatment and P&T groundwater remedies as noted below:

- Construction permits from the COP Development Services Department (DSD) will need to be obtained. This will require preparation and submittal of design plans and specifications (i.e., civil, plumbing, mechanical, electrical) to the City.

- ROW permits will need to be obtained from COP DSD to allow installation of conveyance pipelines in the public ROW.

- A Revocable Permit from the COP Street Transportation Department will need to be obtained to authorize installation of conveyance pipelines and, if applicable, any other infrastructure from P&T systems located in the public ROW. These facilities would be considered encroachments. The revocable permit requirements are found in the Phoenix City Code Sections 31.80 to 31.84.

- In accordance with the COP Zoning Ordinance Section 622056, a Use Permit will need to be obtained from the COP Zoning Department to allow installation/operation of environmental remediation facilities (e.g., the P&T facilities.

- A COP Industrial Discharge Permit would be required from the COP Street Transportation Department, Storm Water Management, if the treated discharge from the downgradient P&T system was either diverted to the COP storm sewer during the SRP's winter dry-up period (see above), or discharged on a continuous basis to the COP storm sewer. Storm water quality protection is detailed in the Phoenix City Code Chapter 32C.

6.2.6.3 ADEQ and MCESD

Obtaining AZPDES permits from the ADEQ Surface Water Section would be required to discharge treated groundwater from the downgradient P&T system to the SRP's Grand Canal and to the COP storm sewer. Note that discharge to the storm sewer would not be covered under the COP's MS4 AZPDES Permit, because MS4 permits pertain solely to storm water discharges. The AZPDES permit requirements are pursuant to the Clean Water Act and the AAC R18-9-A902(B).

The Maricopa County Environmental Services Department (MCESD) Drinking Water Program has been delegated authority by the ADEQ to administer portions of the drinking water program. MCESD oversees inspections, engineering plan reviews, and compliance and enforcement activities for all public water systems within Maricopa County. In order to reconnect production wells COP-70/71 to the City's municipal water distribution system, a Source Approval must be obtained from the MCESD Drinking Water Program. This involves submitting an Application for Drinking Water Source Approval that includes comprehensive laboratory results of the untreated groundwater for all drinking water parameters, and well construction information. After the source application is approved, an Approval to Construct (ATC) application is required that includes engineering design plans with a description of the water treatment system. When the ATC is granted, the system can be installed and samples of the treated water would need to be collected for "commissioning and validation approval." A licensed engineer would inspect and certify that the system was installed in accordance with design plans and specifications, and submit the signed certification to the County. Once the system is operating, MCESD will require regular sampling/monitoring and reporting in accordance with AAC R18-4, Article 2. Due to the presence of VOCs in the untreated water, increased frequency of monitoring would be required pursuant to AAC R18-4-212(G).

6.2.6.4 SRP

Based on telephone conversations between GeoTrans and the SRP, we understand that the following would be required by SRP if treated water from a P&T system was proposed for discharge to the Grand Canal.

- An explanation letter describing the requested discharge that would include pertinent information on the proposed location, flow rates, duration of flows, water quality, and environmental permitting of the discharge.

- Submittal of construction drawings for the pipeline and headwall structure routed within the canal ROW.

- Execution of a formal License Agreement with the SRP to authorize access to the Grand Canal.

The SRP would also likely require that the P&T system be equipped with a remote shut-down control feature that would allow the SRP to shut off the EW in the event of an emergency situation on the Grand Canal.

6.2.7 Source Control

Source control, which must be considered as an element of the Reference Remedy and all alternative remedies, has been achieved through removal of the septic tanks, implementation of the ERA SVE at the source area, and Pincus Well abandonment. Thus, additional source control is not included in the More Aggressive Remedy. Definition of the source area of the PCE is upgradient of the Site and is considered the responsibility of others.

6.2.8 Uncertainties and Contingencies

A primary uncertainty is the ability to obtain land access for installation and operation of the downgradient P&T system facilities. It is assumed that the ADEQ would take the lead role in negotiating access agreement(s).

New piezometer wells to be installed in the area of the downgradient EW would be used to evaluate groundwater elevations and the related effectiveness of plume capture. Furthermore, the sentinel monitoring well to be installed between this particular EW and COP-157 would be regularly gauged and sampled to evaluate plume containment. If necessary, a contingency plan could be implemented to either increase the pumping rate of the downgradient EW, or install/operate an additional EW(s) to enhance plume containment. In addition, if the VOC plume was to migrate beyond the existing monitor well network, installing supplemental monitor wells and/or sentinel wells to further evaluate the distribution of VOCs may be necessary.

If injection is selected for discharge of treated groundwater, the IWs will need to be periodically maintained (i.e., brushing the well screen, air-lift development) to mitigate fouling and restore their infiltration capacity (see Section 5.5.3). Depending on the severity of declines in infiltration capacity over time, it is likely that one or more replacement IWs would need to be installed over the course of groundwater remediation.

6.2.9 Proposed Remedy to Evaluate

The remedial strategy and measures for the More Aggressive Remedy are presented above. Evaluation of pumping rates from proposed EWs to achieve effective capture zones for the LSGS plume have been evaluated by WhAEM model simulations. Because it is assumed that the SRP's irrigation wells will remain shut off, more sophisticated modeling that involves competing pumping was not performed. In Section 7.0, the capital and O&M costs for the P&T remedies will be compared and evaluated.

6.3 LESS AGGRESSIVE ALTERNATIVE REMEDY- STRATEGY AND MEASURES

6.3.1 Requirements

- The Less Aggressive Remedy must allow for the continued definition and monitoring of the LSGS under the current monitoring well network.

- The Less Aggressive Remedy must provide for the ability of the COP to utilize groundwater at the Site in a timely manner, if and when necessary.

- The Less Aggressive Remedy must provide for the ability of the SRP to utilize groundwater at the Site, or provide a provision for replacement water. This action may be needed as soon as it is technically feasible.

- The Less Aggressive Remedy must address remediation of characterized COCs and any daughter products.

- The Less Aggressive Remedy must be capable of achieving ROs for the Site.

6.3.2 Remedial Strategy

The remedial strategy and measures for the Less Aggressive Remedy involve solely MNA for LSGS groundwater that has been characterized with elevated VOCs at the WOC Site. This FS assumes that the entire network of existing, active LSGS would be included in the MNA program. This network currently consists of 13 LSGS monitoring wells (Figure 3-2). Consistent with MNA described for the Reference Remedy, groundwater level measurements and samples would be collected on a semi-annual basis. Sample analysis for VOCs and MNA parameters would occur on a semi-annual and annual basis, respectively. Technical reporting to evaluate the direction and value of the hydraulic gradient, and to assess MNA performance, would also occur on a semi-annual basis.

6.3.3 Permitting and Approvals

The only permitting and approvals anticipated to be necessary for the Less Aggressive Remedy would be associated with drilling/installing potential new or replacement groundwater monitoring wells. New wells could be necessary to support MNA strategy for more fully characterizing the extent of the dynamic VOC plume, if it migrate further downgradient than MW-108M.

The permitting and approvals associated with installing new and/or replacing groundwater monitoring wells is described below.

6.3.3.1 ADWR

Pre-construction notifications (Notice of Intent forms) and post-construction reporting (Driller's Reports) would need to be prepared and submitted to the ADWR for each new or replacement monitoring well. Well construction and/or modification work would need to be conducted by an ADWR-licensed driller. Any new wells must also comply with the ADWR's well construction standards, which are found in ARS §45-594, -595, -596 and -600 of the Groundwater Code.

6.3.3.2 COP

If any of the new or replacement wells would be located within the COP right-of-way (ROW), the COP DSD would require obtaining a ROW Building Permit. This will require preparation/submittal of an application form, the well design plans and specifications, and applicable permitting fees to the City.

A Revocable Permit (RP-97020) currently exists between UIC (owned by Textron) and the COP, which authorizes use of the public ROW for monitoring the investigation groundwater wells. However, this permit is not transferrable. Based on recent discussions with the COP, GeoTrans understands that a new permit will need to be established between ADEQ and COP.

6.3.3.3 Access Agreements with Land Owners

GeoTrans understands that ADEQ would negotiate/obtain access agreements with the current land owners at the WOC Facility to authorize groundwater monitoring and potential well installation activities. Information on the names of the specific current land owners and corresponding Maricopa County Assessor's parcel numbers for the subject properties are included in Table 2-1.

6.3.4 Source Control

Source control must be considered as an element of the Less Aggressive Remedy and all alternative remedies. Source control of TCE and 1,1-DCE at the Site has been initially achieved through the removal of septic tanks, implementation of the ERA SVE, and abandonment of the Pincus well at the WOC Facility.

6.3.6 Uncertainties and Contingencies

There is no contingency wellhead treatment at COP-70/71 for the Less Aggressive Remedy. The primary uncertainties and contingencies are considered to be whether or not the Less Aggressive Remedy would be responsive to the City's needs to utilize the Site groundwater in a timely manner, consistent with its possible future needs.

6.3.7 Proposed Remedy to Evaluate

The remedial strategy and measures for the Less Aggressive Remedy are presented above. A description of the procedures for MNA, including technical reporting is presented in Section 6.1.2 above. In Section 7.0, the costs for Site-wide MNA of the LSGS will be evaluated. evaluated.

7.0 DETAILED COMPARISON OF REFERENCE REMEDY AND ALTERNATIVE REMEDIES, IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES

7.1 COMPARISON CRITERIA: PRACTICABILITY, COST, RISK AND BENEFIT

In accordance with the Remedy Selection Rule (R18-16-407, Feasibility Study), this FS has been completed to identify a reference remedy and alternative remedies that appear to be capable of achieving ROs, and to evaluate the remedies based on the comparison criteria to select a remedy that complies with ARS §49-282.06. The Remedy Selection Rules specify that practicability, costs, risks, and. benefits are the primary basis for which to evaluate remedies.

7.2 DETAILED EVALUATION OF REMEDIES

7.2.1 Reference Remedy

The following is a summary of the Reference Remedy practicability, costs, risks, and benefits.

7.2.1.1 Practicability

The Less Aggressive Remedy, which consists of MNA for remediation of the LSGS plume presumably slowly over time, is by far the most cost-effective and practicable strategy. There would be no active remedy pumping of groundwater requiring any installation and permitting for extraction wells, conveyance pipelines, treatment facilities, or re-injection wells. Essentially, MNA of the Reference Remedy would utilize solely the LSGS monitoring wells already present at the Site.

To provide for the use of groundwater at the Site by the COP is a specific RO (Section 3.4.2.1). If the City decides that it would like to utilize the groundwater in a timely manner upon approval of the FS, GeoTrans has recommended installing up to two replacement wells and LGAC wellhead treatment at the existing COP-70/71 well site. The replacement well(s), screened solely in the LSGS, would likely yield high pumping rates without drawing contamination into deeper portions of the aquifer below the LSGS. The existing old COP-70/71 wells would be abandoned in accordance with ADWR requirements.

Note that there is an existing 130 feet by 95 feet block-fenced compound that encloses the area of the COP-70/71 well site. The area of the compound is expected to be sufficient to install the LGAC treatment and backwash equipment (see Figure 6-3), which would minimize construction costs and eliminate costs for obtaining land/land access at another property. Therefore, the collective strategies and measures of the Reference Remedy are considered to be highly practicable.

7.2.1.2 Cost

Estimated costs for the Reference Remedy are summarized in Table 7-1. The capital cost for installing up to two recommended replacement production wells at the City's existing COP-

70/71 well site is estimated to be approximately $520K (Table 5-8). Note that ADEQ considers these costs to be the responsibility of the COP. The estimated cost for construction of the COP-70/71 wellhead treatment system utilizing bag filtration, LGAC, and backwash facilities is approximately $615K. The O&M and reporting costs for both MNA and the wellhead treatment system are estimated to be approximately $169K annually for the first two years of system operation, and approximately $129K for the next 28 years of operation.

O&M costs for electric power and LGAC usage assume a 25 percent operation time (approximately 90 days per year) with an up to 100 horsepower (HP) pump and 750 gpm flow rate, respectively. Because the COP would be using the treated water for its municipal water supply, ADEQ considers costs for electric power (estimated to be approximately $22,800 per year based on a rate of $0.14 per kilowatt-hour and 25 percent total operation time) to be the COP's responsibility.

7.2.1.3 Risk

Currently, the risk posed by the existing LSGS groundwater contamination is low because of the absence of groundwater pumping within the area. The risk posed by future use of groundwater by the COP is addressed through the installation of a contingency wellhead treatment system at the COP-70/71 well site, assuming the City would like this installed to fulfill its ROs for groundwater.

The Reference Remedy has an increased risk compared to the More Aggressive Remedy (Section 7.2.2), simply because no active remediation involving source control or containment of VOCs from a P&T system would exist. Instead, the Reference Remedy would rely solely on passive remediation via MNA over a presumed long period of time. Consequently, the absence of active remediation represents a greater risk to potential future downgradient receptors. The COP or SRP may consider that the use of groundwater within the plume area (or outside the plume area but within the zone of influence/capture of the plume area) may not be possible within an acceptable time period.

7.2.1.4 Benefit

If desired by the COP, pumped groundwater at COP-70/71 would be beneficially used to supplement the COP's municipal water supply. Although it represents passive remediation over a presumed longer time period, MNA for remediation of the plume containing VOCs is the most practicable and cost-effective approach.

The source of VOCs originating from the Site that provided a conduit to the LSGS (i.e., former Pincus Well) has been removed. In conjunction with MNA, maintaining shut-down of pumping from SRP's two relatively large-capacity production wells 8.5E-7.5N (1,640 gpm), and 10.5E-7.5N (3,200 gpm) will facilitate groundwater remediation by preventing lateral and potential vertical spreading of contamination beyond the limits of the existing LSGS plume.

7.2.2 More Aggressive Remedy

The following is a summary of the More Aggressive Remedy practicability, costs, risks, and benefits:

7.2.2.1 Practicability

The More Aggressive Remedy includes a P&T system at the downgradient toe of the plume. As described in Section 5.0, P&T is a well-established technology considered to be the only technically appropriate and practicable solution for active remediation of the LSGS groundwater. P&T will provide hydraulic containment/remediation of the large-scale and relatively deep LSGS plume. This has been determined from the results of the technology screening described in Section 5.0. The technology screening has also identified that LGAC-only will be most practicable and reliable treatment technology for removal of VOCs from pumped groundwater.

With respect to 1) installation of a LGAC wellhead treatment system at the COP-70/71 well site to addresses the City's ROs, 2) use of MNA for passive remediation of upgradient portion of the plume (i.e., upgradient of the P&T system capture zone [see Figures 6-2 through 6-2c]); and 3) continuing the no-pumping policy for the SRP's production wells with provisions for replacement water, the More Aggressive Remedy is considered practicable for the same reasons described above for the Reference Remedy. However, the downgradient P&T system of the More Aggressive Remedy will require installing pipelines in the City ROW. One option for discharge of the treated groundwater would require installation of an approximately 4,250-foot long pipeline to convey treated groundwater from the LGAC treatment plant to the Grand Canal (Figures 6-2 and 6-4). The pipeline would be installed primarily to the north in the public ROW of 51st Avenue. It would be costly and problematic due to high anticipated design/permitting costs, probable construction conflicts with existing underground utilities, traffic and logistical challenges, and public safety concerns. However, the installation of the EW and associated treatment plant for the downgradient system is expected to be practicable, assuming an access agreement for installation and operation of the system on private property could be obtained (See section 6.2.5 and Figures 6-4 and 6-5).

It should be noted that there are two other options that have been considered in this FS for discharge of the treated groundwater from the downgradient P&T system: 1) to groundwater reinjection wells; and 2) to the COP storm sewer. The modeled pumping capture and injection zones, along with the conceptual designs for the treatment plant and injection well pipeline routes are depicted in Figures 6-2a through 6-2c, and Figures 6-6 through 6-8). Discharge to reinjection wells would involve the construction of approximately 2,600 lineal feet of pipeline primarily in City alleys. Connection to the COP storm sewer would involve constructing only an approximately 550-foot long pipeline (Figure 6-9). Due to its much shorter pipeline distance compared to the Grand Canal and injection well options, the storm sewer discharge option would clearly be the most practicable.

7.2.2.2 Cost

Table 7-2 provides estimated costs for the alternatives considered for the More Aggressive Remedy. Capital and annual O&M costs for the P&T system at the COP-70/71 well site are the same as those described for the Reference Remedy (Section 7.2.1). When combined with the downgradient P&T system with discharge of the treated water to the SRP's Grand Canal, capital costs are estimated to be approximately $3.8M (Table 7-2). If the system utilized reinjection wells for discharge of the treated groundwater, capital costs would increase by only an estimated $135K respectively. For connection to the storm sewer, the estimated capital costs would be approximately $648K less (Table 7-2). The annual O&M for the system, assuming it utilized the Grand Canal alternative for discharge of treated water, is estimated to be approximately $347K.

Total Estimated Costs – More Aggressive Remedy

Total estimated costs for the downgradient P&T and wellhead treatment system (COP-70/71) of the More Aggressive Remedy, assuming discharge of the treated groundwater from the downgradient system to the Grand Canal, are presented in Table 7-1. The total costs for a 30-year project life are estimated to be $14.2M. This includes an estimated approximately $400K and $345K in annual P&T system O&M, MNA, and reporting for the first two years and following 28 years of system operations, respectively (Table 7-1). The NPV of costs, using a 30-year life cycle and 7 percent discount rate, is estimated to be approximately $8.17M.

7.2.2.3 Risk

The More Aggressive Remedy reduces risk compared to the other two alternative remedies. Similar to the Reference Remedy, the More Aggressive Remedy involves potential pumping at COP-70/71; the risk posed by future use of groundwater by the city is addressed through installation and O&M of the LGAC wellhead treatment system at the COP-70/71 site. Risks to human health and the environment are further reduced by operation of the downgradient P&T system which would provide active plume containment for protection of currently inactive well COP-157 (Figures 6-2 to 6-2c). The new piezometer wells and sentinel well, that would be installed between the downgradient EW and COP-157, would serve to evaluate the adequacy of plume capture and provide an early warning sign in the unlikely event that VOCs were to migrate to the southwest beyond the downgradient system EW. Using a series (lead/lag) configuration of LGAC treatment vessels, in conjunction with routine monitoring and change-out of spent LGAC, would mitigate risk to the environment and end users of the extracted/treated groundwater.

7.2.2.4 Benefit

Compared with the other two remedies, the More Aggressive Remedy provides the greatest degree of certainty for containing the plume, and attaining remediation of VOCs in the LSGS over time to meet AWQS. Presumably, the time to complete remediation would also be less. Depending on the selected discharge option for the downgradient P&T system, treated water could be beneficially used for augmenting SRP's irrigation water supply (the recommended alternative), or could recharge the aquifer to conserve groundwater as a resource. Note that discharge to the COP storm sewer appears to provide the least benefit; however, some recharge of the pumped groundwater would occur upon ultimate discharge at the Agua Fria River.

7.2.3 Less Aggressive Remedy

7.2.3.1 Practicability

Like the Reference Remedy, the Less Aggressive Remedy also consists solely of MNA for passive remediation of the LSGS plume, presumably slowly over time. This strategy is by far the most practicable and cost-effective approach. e because the existing LSGS monitoring well infrastructure is already installed and no new extraction wells, treatment facilities, pipelines, re-injection wells, or other infrastructure would need to be designed, permitted, or installed. However, unlike the Reference and More Aggressive Remedies, the Less Aggressive Remedy assumes that no LGAC wellhead treatment system at COP-70/71 would be desired or needed by the City. In effect, it assumes that the presumed long time-frame required to complete remediation by MNA will be consistent with the COP's needs.

7.2.3.2 Cost

Costs for the Less Aggressive Remedy are presented in Table 7-1. Estimated costs are approximately $2.03M for 30 years of assumed MNA and reporting. Compared with the approximate 30-year estimated costs for the Reference Remedy ($4.57M) and More Aggressive Remedy ($14.2M), the Less Aggressive Remedy is approximately $2.54M and $12.2M lower in cost, respectively. The calculated NPV of costs for the Less Aggressive Remedy is only approximately $880K. This information is presented in Table 7-1.

7.2.3.3 Risk

The Less Aggressive Remedy has an increased risk compared to the More Aggressive Remedy simply because there is no active groundwater remediation involving source control or containment of VOCs via the downgradient P&T system. The absence of active remediation represents a greater risk to potential future downgradient receptors. However, MNA presumably will remediate groundwater to AWQS over a longer period of time.

7.2.3.4 Benefit

The benefit identified for the Less Aggressive Remedy is significantly lower costs. Furthermore, all construction-related disruptions associated with installing extraction wells, conveyance pipelines, treatment plants, injection wells and/or any other infrastructure could be avoided.

7.3 COMPARISON OF REMEDIES

Comparison of the remedies with each other is required under the Remedy Selection Rule, R18-16-407, Feasibility Study. For this reason, a comparison of the remedies is presented below.

7.3.1 Practicability

Each of the selected remedies is considered to be technically and operationally practicable. Due to the installation of conveyance pipelines in the public ROW, the More Aggressive

Remedy is less practicable than the other two remedies.

7.3.2 Cost

The estimated costs for the three evaluated remedies are presented in Table 7-1. The NPV is the best measure to compare costs among multiple alternatives. The least costly alternative by far is the Less Aggressive Remedy, which relies solely on MNA (NPV approximately $880K; total estimate approximately $2.03M). The Reference Remedy has the median cost (NPV estimate approximately $2.3M; total estimate approximately $4.57M). The More Aggressive Remedy has the highest cost (NPV approximately $8.2M; total estimate approximately $14.2M).

7.3.3 Risk

The Less Aggressive Remedy shares the same risks as the Reference Remedy, which are greater compared to the More Aggressive Remedy. This is because both the Less Aggressive and Reference Remedies have no active groundwater remediation involving source control or containment of VOCs from the downgradient P&T system. MNA presumably can remediate groundwater to AWQS over a longer period of time. However, the absence of active remediation represents a greater risk to potential future downgradient receptors.

Because the More Aggressive Remedy includes the active P&T groundwater remediation system that would operate to contain and remediate the downgradient approximately two-thirds of the LSGS plume, its risks are considered to be less than those of the Reference and Less Aggressive Remedies. Wellhead treatment at COP-70/71 is included to address the City's ROs in a timely manner for both the Reference and More Aggressive Remedies, Liquid GAC treatment is well-documented as being operationally simple, effective, and reliable to achieve VOC removal to non-detectable laboratory concentration levels. The key to its safe use is to implement an appropriate routine LGAC monitoring, backwashing, and change-out program. Note that there are numerous municipalities across the United States and in foreign countries that utilize LGAC treatment technology successfully for removing VOCs (including PCE and TCE) from groundwater prior to municipal use. In Arizona, a good example is the Expanded Groundwater Treatment System which has been operating safely and reliably at the Payson PCE WQARF Site since October 1998.

The More Aggressive Remedy is considered to have less risk compared to the Reference Remedy, due to the addition of the downgradient P&T system. This downgradient system would utilize piezometer wells and a sentinel well to evaluate the adequacy of plume capture, and ensure protection of currently inactive well COP-157 which is located approximately 0.5-mile south/southwest of the toe of the LSGS plume (Figures 6-2 through 6-2c).

7.3.4 Benefit

Each of the three remedies benefits the environment through remediation of the LSGS groundwater plume over time. The Reference and More Aggressive Remedies restore use of the groundwater resource in a timely manner for the COP. If water is needed in the foreseeable future by SRP, each remedy includes provisions for replacement water in lieu of pumping SRP's two production wells located in close proximity to the Site. The More

Aggressive Remedy would also provide a 500 gpm supplemental beneficial water source into the Grand Canal, should additional water be desired or needed by SRP. Furthermore, because the More Aggressive Remedy includes a P&T system downgradient of COP-70/71, it provides the greatest benefit for completeness of remediation and protection of potential downgradient receptors (most notably, well COP-157).

Although it is clearly the lowest cost, the Less Aggressive Remedy does not include active P&T to contain/remediate the contaminated LSGS groundwater, nor does it provide a wellhead LGAC treatment system at COP-70/71, should the City decide it would like to utilize groundwater at the Site for its municipal supply. The primary uncertainties and contingencies are considered to be whether or not the Less Aggressive Remedy would be responsive to the City's needs to utilize the Site groundwater in a timely manner, consistent with its future needs.

The Reference Remedy provides the benefit of cost control, water supply at COP-70/71, and MNA for gradual remediation of the entire VOC plume. The remedial strategy and costs for the Reference Remedy are considered practicable given the current situation of limited funding in the Arizona WQARF program.

8.0 PROPOSED REMEDY

8.1 PROCESS AND REASON FOR SELECTION

The Reference Remedy is recommended as the proposed remedy. This recommendation is based on what is considered to be the best combination of remedial effectiveness, practicality, cost, and benefit for restoration and timely use of the groundwater resource.

8.2 ACHIEVEMENT OF REMEDIAL OBJECTIVES

The Reference Remedy achieves the ROs for the Site as described in Section 3.4. Implementation of MNA would presumably remediate the LSGS groundwater over time, ultimately to attain applicable AWQS for the COCs at the Site. If the City chooses to use the Site groundwater in a timelier manner, installation of a wellhead LGAC treatment system at the COP-70/71 (the property of which is owned by the City) is included in the Reference Remedy. This would restore capacity and protect for the use of the groundwater resource by the COP. By continuing the no pumping policy for SRP's wells SRP 9.5E-7.7N and SRP 8.5E-7.5N, as well as providing for the purchase of replacement water (if required based on demands), the Reference Remedy also fulfills the SRP's ROs for water.

8.3 ACHIEVEMENT OF REMEDIAL ACTION CRITERIA PURRSUANT TO ARS §49-282.06

It is recommended that the Reference Remedy be selected as the Final Remedy that will address groundwater remediation for the LSGS portion of the aquifer at the WOC WQARF Site. This remedy, in conjunction with the recommended Reference Remedy for the SGWS, is designed to achieve the remedial action criteria pursuant to §ARS 49-282.6. The LSGS Reference Remedy appears to:

- Provide for the protection of public health, welfare and the environment.
- Provides a thorough and timely means for continued monitoring of the existing groundwater contamination, including determining the progress of MNA remediation over time.
- To the extent practicable, provides for the control, management, and cleanup of the COCs in the LSGS groundwater.
- Provides for the beneficial use of the groundwater resource by the COP, and includes the benefit of providing replacement water if necessary to the SRP.
- Is reasonable, cost-effective, and technically feasible.

8.4 CONSISTENCY WITH WATER MANAGEMENT PLANS

GeoTrans has reviewed the COP's 2011 Water Resources Plan to determine if the proposed remedial actions are generally consistent with the COP's written plans. Although the COP currently uses groundwater for less than 3% of its total demands, wells are important for providing water supply, operational flexibility, and backup sources during surface water shortages. Of the City's 200 groundwater production wells it has installed over the years, there are currently only about 20 active wells, capable of generating a total of 28 million gallons per day. Many of the COP's groundwater wells have been removed from service due to age, reduced efficiency, and/or groundwater contamination. The city reports that the total loss of production from its wells from 1981 through 2000, resulting from elevated concentrations of organic and inorganic contaminants exceeds 90,000 acre-feet of water per year. Currently, the City's groundwater capacity is sufficient in meeting at least 7 percent of its annual demand from well water, though available active wells are not distributed uniformly throughout the service area (COP, 2011).

The disconnection and/or abandonment of the City's production wells due to water-quality concerns and aging equipment has left the COP capable of only meeting 10 to 15 percent of its peak demand with groundwater. In addition to VOCs in groundwater that have impacted COP wells located within WQARF sites, nitrate, arsenic, heavy metals, and hydrocarbons have also affected wells located outside and within WQARF sites (COP, 2011). GeoTrans understands that wellhead treatment facilities for arsenic and nitrate removal have been installed and currently operate as part of the COP's network for municipal water sources.

The COP has identified a need to substantially rebuild its well capacity for drought redundancy, operating flexibility, and system emergencies. Groundwater needs for operating flexibility, including peaking, and system emergencies, are reportedly more compelling in the short term than needs to offset drought impacts (COP, 2006). In correspondence and discussions with the ADEQ and EPA, the COP has emphasized that the Central Phoenix Aquifer is an important future water supply that the COP will need to be able to access

The Water Resources Plan, 2005 Update, indicated that the COP would work closely with ADEQ and FPA on cleanup strategies for the Central Phoenix contamination issues. In Chapter 5, Strategic Concepts, of the 2005 Update, the COP considers environmental benefits and costs in the analysis of water supply and demand management efforts. This section states that:

> *"strategic location and operation of wells may also bring benefits with regard to plume containment and cleanup efforts. As potential well sites are evaluated, ongoing or planned plume remediation efforts would be considered to determine if the locations would support such efforts without compromising the quality of the water supply."*

The proposed Reference Remedy, which appears to be consistent with the COP's latest published 2011 Water Resources Plan , and is consistent with the Site ROs (ADEQ, 2005), provides an opportunity for a solution that fulfills timely restoration of COP-70/7l as part of rebuilding COP's well capacity (particularly in the Central Phoenix area. Furthermore, if the City chooses to implement VOC wellhead treatment at the COP-70/71 property, there is more than sufficient space to accommodate the proposed treatment infrastructure, and land acquisition costs to install the facilities could be avoided. Funding for design, permitting, construction and O&M of the LGAC treatment of VOCs would be provided by the ADEQ.

According to discussions with the COP, a functional Groundwater and Reclaimed Water Management Plan has been developed. Phase 1 of this plan, which provided a broad overview of the Phoenix-area needs, was completed in about 2008. Phase 2 of this plan, was specifically concerned with groundwater and provides more detailed information on the needs/plans for groundwater in specific areas, including Central Phoenix. The title of this plan is Final Report for Groundwater Management Plan, Phase II, September 2009.

On April 4, 2012, GeoTrans met with the COP's lead Hydrologist to discuss the City's September 2009 Groundwater Management Plan (GMP) and its implications on the WOC Site. According to Mr. Gin, the land between the Arizona Canal on the north and Salt River on the south is known as "Member" land, meaning the water rights are owned by the SRP. The WOC Site is located in the geographic area of "Member" land. Mr. Gin stated that in general, the COP is not interested in restoring/utilizing its many production wells within "Member" land because the water credits would go against the SRP's account. In contrast, the area to the north, located between the Central Arizona Project Canal on the north, and Arizona Canal on the south, is being actively used for groundwater production by the COP. This geographic area is known as "Non-Member" land, meaning it is outside the area of SRPs designated water rights, and thus, we understand that are much less restrictions for its use by the COP.

GeoTrans specifically asked Mr. Gin if the City has any plans for restoring/utilizing its wells COP-70/71, COP-68, and COP-157 at the WOC Site (see Figure 3-2). He indicated that they do not in either the near or foreseeable future for at least 30 years. This answer has strong implications on this FS for the LSGS, as well as the FS for the SGWS (GeoTrans, 2012). It should be noted that this information also contradicts that which is discussed in the ADEQ's 2005 RO report (ADEQ, 2005). Based on earlier input from the COP, the RO report states that the COP does desire to restore its well pumping capacity of 1,500 GPM due to the contamination at the Site of its wells COP-70/71, and COP-68. The result of the new GMP information effectively means that these wells and COP-157 are not planned to be restored to operation for at least 30 years by the COP. Thus, it appears that the Reference Remedy, like the Less Aggressive Remedy, would involve solely MNA for remediation of LSGS groundwater at the Site, without wellhead treatment at COP-70/71. However, just in case COP does desire or need to restore groundwater pumping capacity within the time frame of the next 30 years at the Site, provisions for wellhead treatment at COP-70/71 are included in the Reference Remedy.

8.5 CONSISTENCY WITH GENERAL LAND USE PLANNING

As discussed in the RO Report (ADEQ, 2005), the zoning pattern in the Site area has long been established, and there are no foreseeable changes for the future. If the More Aggressive Remedy was selected, installation of the downgradient P&T system at the conceptual locations identified in this FS, would require negotiation of land access with private and public land owners including the COP. Although formal discussions have not taken place, the presence of available land suggests that the installation of the downgradient P&T system under the More Aggressive Remedy, and installation of the optional wellhead treatment system at the COP-70/71 well site under the Reference and More Aggressive Remedies would be feasible.

8.6 CONTINGENCIES

If the LSGS plume unexpectedly becomes unstable, perhaps migrating substantially further downgradient beyond the southwest boundary of the current plume, contingency actions may be necessary. For example, if in the unlikely event that the City decided that it needed to restore operation of production well COP-157 in the future (see Figures 6-2a through 6-2c), transitioning to strategy of wellhead treatment using LGAC at COP-157 may be warranted. Installing a new LSGS monitor well and new sentinel well to evaluate plume migration under the influence of pumping at COP-157 would also be recommended.

If a water treatment plant is ever built along the Grand Canal downstream of the Site, the SRP may wish to receive treated water from the downgradient P&T system, or possibly restore operation of one or more of its production well(s) located along the Grand Canal adjacent to the Site (i.e., potentially including wells 8.5E-7.5N and/or 9.5E-7.7N). If this is the case, contingency actions may include: 1) constructing a pipeline conveyance from the downgradient treatment system to the Grand Canal, and 2) modifying/deepening the SRP's production well(s) 8.5E-7.5N and 10.5E-7.5N, such that they are screened far below the contaminated LSGS.

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