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Arizona Department of Environmental Quality (ADEQ)
1110 W. Washington Ave.
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ENVIRONMENT

Subject:
Submittal of Final Feasibility Study for the 7th Avenue and Bethany Home Road WQARF Registry Site located at Phoenix, Arizona

Date:
November 19, 2012

Contact:
Michael Nesky

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Our ref:
01761119.0000

Dear Mr. Goodwin:

ARCADIS U.S., Inc. (ARCADIS) is hereby submitting the attached Final Feasibility Study (FS) for the 7th Avenue and Bethany Home Road WQARF Registry Site located at Phoenix, Arizona. The Final FS incorporates responses to address ADEQ's September 19, 2012 comments on the June 2012 Draft Feasibility Study.

If you have any questions or comments concerning this project, please contact me at 480.905.9311.

Sincerely,

ARCADIS U.S., Inc.

Michael Nesky

Michael P. Nesky
Principal Environmental Engineer

Attachment(s)
Final Feasibility Study

Copies: Andre Chiaradia
7th Avenue & Bethany Home Road WQARF Site File

Imagine the result

Arizona Department of Environmental Quality

FINAL

Feasibility Study

7th Avenue and Bethany Home Road
WQARF Site, Phoenix, Arizona

November 19, 2012

ARCADIS

FINAL
Feasibility Study

7th Avenue and Bethany Home Road, WQARF Site, Phoenix, Arizona

Saumyaditya Bose
Project Geologist

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Prepared for:
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1. Introduction

The Arizona Department of Environmental Quality (ADEQ) has requested that ARCADIS U.S., Inc. (ARCADIS) prepare a Feasibility Study (FS) for the 7th Avenue and Bethany Home Road Water Quality Assurance Revolving Fund (WQARF) Site (the Site). The FS was prepared in accordance with the ADEQ Remedy Selection Rule (the Rule) as presented in Title 18, Environmental Quality, Chapter 16, Department of Environmental Quality WQARF Program, Article 4, Remedy Selection; Section 407 Feasibility Study. The purpose of the FS is to evaluate alternatives for the remediation of contaminated groundwater at the Site and identify the best option or options for achieving defined Remedial Objectives (ROs).

The FS relies upon the data and findings of the Early Response Action (ERA) and subsequent Remedial Investigation (RI) activities that have been conducted by ADEQ at the Site. The alternatives were screened with consideration of the Site's current conditions, as discussed in **Section 3**. The alternatives selected for detailed analysis are presented in **Sections 3.1** through **3.3**, and a comparative analysis is presented in **Section 3.4**.

1.1 Organization of Feasibility Study

This section presents the organization of this FS. The FS is organized as follows:

Section 1 – Introduction: The introduction presents details related to site background, nature and extent of contamination, contaminants of concern (COCs), and applicable remedial objectives.

Section 2 - Identification of Technologies: This section presents details related to applicable technologies used to develop the remedial alternatives.

Section 3 - Development and Screening of Alternatives: This section presents details related to each of the selected remedial alternatives. The details included in each alternative subsection include a description and assessment of the remedial alternatives.

Section 4 - Alternative Selection and Discussion: This section presents details on the following items for the selected alternative:

- Pilot testing discussion, and

- Conceptual description of design and FS costing.

Section 5 - References: This section lists the references used throughout this document.

1.2 Background Information

1.2.1 Site Description

The 7th Avenue and Bethany Home Road WQARF Site lies within the southwestern quarter of section 8, Township 2 North, Range 3 East of the Gila and Salt River Baseline and Meridian. The Site is bounded to the north by Rose Lane, to the south by Bethany Home Road, to the east by 5th Avenue and to the west by 8th Avenue (**Figure 1**). The groundwater contamination plume boundary varies and may extend beyond the streets listed, and those locations are considered part of the WQARF Site. The 7th Avenue and Bethany Home Road WQARF Site consists of two properties: The Bayless Investment and Trading Company property (Bayless property), located at 540 West Bethany Home Road (**Figure 2**), and the SCI Arizona Funeral Services property (SCI property), located at 710 West Bethany Home Road (**Figure 3**), which together are referred to as the Site.

A detailed description of the regional and site-specific geology and hydrogeology is provided in the RI Report (Malcolm Pirnie, Inc. [Malcolm Pirnie] and ADEQ, 2011a). A brief summary is provided below.

Stratigraphy in the vicinity of the Site is composed of thick basin fill sediments of unconsolidated to semi-consolidated clastic sediments deposited from Late Tertiary to Quaternary. Lithologic descriptions from soil borings indicated that the Site is predominantly underlain by fine-grained sediments composed of very fine sand, silts, silty sands, and clays with a few sand and gravel lenses that are generally less than 10 feet in thickness. The uppermost sand and gravel lenses are typically encountered at approximately 30 to 50 feet below ground surface (bgs) and ranged from fine to coarse in size distribution. Sieve analysis and hydrometer tests of selected soil samples indicated that the fine-grained components (silts and clays) made up a fraction of the soil samples retrieved. Hydrometer test of silts and clays also indicated that silts constituted the dominant fraction (by weight) of the fines. The total depths of most of the on-site borings seldom exceed 130 feet bgs; therefore, most borings only encounter the Upper Alluvial Unit at the Site, which is reported to be approximately 200 feet thick in the surrounding area. A deep monitor well at the Site (MW-9), drilled to a

depth of 225 feet, may have encountered the Middle Alluvial Unit at a depth of approximately 215 feet. Boring logs with detailed lithologic descriptions and drilling observations are included in the RI Report (Malcolm Pirnie and ADEQ, 2011a). South to north and west to east geologic cross sections are presented on **Figures 4** and **5**, respectively.

As described in the RI Report (Malcolm Pirnie and ADEQ, 2011a), the average horizontal hydraulic conductivity for the Site has been estimated to be between 25 and 76 feet per day. Using an estimated porosity of 30 percent and a calculated horizontal hydraulic gradient of 0.0036 foot per foot (ft/ft) from the January 2012 sampling event, the calculated groundwater velocity in the aquifer beneath the Site is estimated to range from 110 to 334 feet per year. This estimate closely matches the calculated velocity range of 113 to 342 feet per year mentioned in the RI Report (Malcolm Pirnie and ADEQ, 2011a).

1.2.2 History

A detailed history of the site investigation and remediation activities is available in the RI Report (Malcolm Pirnie and ADEQ, 2011a). A concise summary is presented below.

1.2.2.1 Investigation and Remediation: Bayless Property

The property was originally developed into a small shopping center in 1952, which included a market, a variety of commercial shops, and a dry cleaning facility. The dry cleaning facility began operation in 1953 at the shopping center. Between 1952 and 1960, the shopping center was connected to an on-site septic system. In 1960, the shopping center was connected to the Phoenix sewer system and discharge to the septic system is believed to have terminated.

Site investigations were conducted at the Bayless property between 1995 and 2001. The results of these investigations confirmed the presence of tetrachloroethene (PCE) and other volatile organic compounds (VOCs) in the soil and groundwater beneath the property. In 2004, ADEQ conducted a Preliminary Investigation at the Site and placed the Site on the WQARF Registry with a score of 29 out of a possible 120. ADEQ and the property owner, Bayless, entered into a consent decree in April 2005.

In 2005, ADEQ initiated an ERA to address impacted soil and groundwater associated with the Bayless property (**Figure 2**). Malcolm Pirnie was contracted by

ADEQ to initiate the ERA investigation and to collect data to characterize the PCE impacted source area below the Site. The main focus of the ERA investigation was to 1) assess the extent in the vadose zone and groundwater impacted by PCE at the property and to 2) determine if a source area soil vapor extraction (SVE) system could be used to efficiently reduce vapor phase VOC constituents within the vadose zone.

Based on the results of the ERA investigation, there appeared to be significant concentrations of PCE gas vapors in the vadose zone below the location of the former septic system. Therefore, ADEQ directed Malcolm Pirnie to design, install, and operate an SVE system to reduce the VOC mass in the vadose zone. The SVE system began operation in June 2005 and ran continuously until asymptotic mass recovery was observed and rebound testing was conducted in April 2006. The rebound testing indicated that SVE recovery had reached the limits of its effectiveness. During the operation of the SVE system, approximately 380 pounds of PCE were removed. Prior to the decommissioning of the SVE system, two verification soil borings were drilled within the SVE system extraction area. PCE was not detected in the soil samples at or above the laboratory reporting limit of 0.050 milligram per kilogram (mg/kg), the Groundwater Protection Level (GPL) of 0.8 mg/kg, or the residential soil remediation level of 5.1 mg/kg in any of the soil samples collected from the two verification soil borings.

ADEQ granted the property owner of the Bayless property a No Further Action (NFA) determination for soil at the property in December 2008 (ADEQ, 2008). The soil NFA is for VOCs in soil and does not address any other area of land, groundwater, or other constituents.

Subsequent groundwater samples collected during additional monitoring well installation and quarterly sampling activities indicated that PCE concentrations ranged from less than 2 micrograms per liter (µg/L) to 2,200 µg/L. The most recent groundwater sampling, in January 2012, indicated concentrations of PCE as high as 2,300 µg/L in monitoring well MW-4 (Malcolm Pirnie, 2012). MW-4 is located immediately downgradient from the suspected source area; the former septic tank locations (see **Figure 6**).

The Salt River Project (SRP) well 13.1E -10.5N (55-608426) is located in the SW/4 of the SW/4 of the NW/4 of Section 8, Range 2N, Township 3E (**Figure 7**). The well is located near the intersection of 7th Avenue and Maryland, approximately one-quarter mile north of the 7th Avenue and Bethany Home Road Site boundary. The Arizona

Department of Water Resources (ADWR) database indicates that well 13.1E-10.5N is cased from land surface to a depth of 600 feet and the interval open to the aquifer for water production is from 240 to 600 feet. Historical groundwater sample results from this well are available from 1986 to 2009. Over this time period, PCE concentrations were non-detect at 0.5 µg/L until 2000, increased to 4.6 µg/L in 2006, and then decreased to 2.4 µg/L in 2009. The most recent data from January 2012, provided by the SRP, indicated that PCE was detected in the well at the Aquifer Water Quality Standard (AWQS) of 5 µg/L.

1.2.2.2 ERA Investigation: SCI Property

The SCI property consists of four separate parcels (**Figure 3**). The two parcels of interest in the ERA investigation are Parcel 2 and Parcel 4. A dry cleaner operated on Parcel 2 from the 1950s until the 1990s. A dry well was installed on Parcel 2 in September 1982, approximately 20 feet west of the dry cleaning operations. The dry well is 120 feet deep with drainage fabric located at approximately 18 feet bgs with gravel pack beneath the fabric to total depth. Parcel 4 was occupied by a mortuary and parking lot and contained two surface drains; one drain led to a septic tank and one led to a brick-lined seepage pit. Previous investigations indicated that the former dry cleaning business may have released PCE to the dry well, sump, and septic system. From 1990 to 1992, PCE impacted soil was removed from the property.

Site investigations conducted during the first half of 1990 indicated that chlorinated VOCs (i.e., PCE, trichloroethene [TCE], and 1, 2-dichloroethene [1, 2-DCE]) were present in soil beneath the SCI property. The highest concentration of PCE was measured near the dry well at a depth of approximately 16.5 feet bgs during February 1990 sampling event.

The field investigations in the early 1990s indicated a release of PCE to the vadose zone, but groundwater beneath the SCI property was not evaluated at that time. Therefore, Malcolm Pirnie was contracted by ADEQ to initiate the ERA investigation and to collect data to characterize the PCE impacted source area below the SCI property. The purpose of the ERA investigation at the SCI property was to collect the data necessary to characterize the source areas potentially impacted by VOCs and determine if further remedial actions were necessary at the property. No concentrations were detected above regulatory standards, and no further remediation of the vadose zone at the SCI property was planned.

On March 18, 2008, groundwater samples were collected from monitoring wells MW-11 and MW-12 immediately after well development. Groundwater samples were analyzed for VOCs in accordance with United States Environmental Protection Agency (U.S. EPA) Method 8260B. PCE was detected in monitoring wells MW-11 and MW-12 at concentrations of 7.4 µg/L and 22 µg/L, respectively, both exceeding the Arizona aquifer water quality standard (AWQS) of 5 µg/L for PCE. TCE was also detected in monitoring well MW-12 at a concentration of 23 µg/L, which is above the AWQS of 5 µg/L for TCE. Vinyl chloride was also detected in monitoring well MW-12 at a concentration of 2.7 µg/L, exceeding the AWQS of 2 µg/L for vinyl chloride. The most recent groundwater sampling event, conducted in January 2012, indicated PCE was detected in monitoring wells MW-11 and MW-12, both at a concentration of 13 µg/L.

1.3 Nature and Extent of Contamination

ADEQ has identified PCE, TCE, and vinyl chloride as the COCs in the groundwater at the Site. A detailed discussion about the distribution of contaminants at the Bayless property and at the SCI property can be found in the RI Report (Malcolm Pirnie and ADEQ, 2011a).

The targeted treatment area was determined based on the distribution of chlorinated volatile organic compounds (CVOCs) in soils, soil vapor, and groundwater identified during previous investigations at the Site, which includes the former septic tank locations at the Bayless property, the former dry well, former septic system, and seepage pits at the Parcels 2 and 4 areas of the SCI property. The majority of the CVOC mass is present in the sandy clay/clay/silt layer that occurs in the interval from approximately 65 to 129 feet bgs (Malcolm Pirnie and ADEQ, 2011a). The groundwater target treatment interval includes the majority of the thickness of the fine-grained layer shown on **Figures 4** and **5**, extending from a depth of about 80 feet bgs to a depth of about 110 feet bgs. Groundwater monitoring conducted at the Site indicates that the water table occurs in the upper portion of this fine-grained layer at a depth of approximately 76 to 88 feet bgs (Malcolm Pirnie and ADEQ, 2011a).

The following sections summarize the COCs distribution in groundwater.

1.3.1 Bayless Property

With the exception of the east side of the Bayless property, the horizontal extent of PCE impacted groundwater is defined by the current site groundwater monitoring wells. According to analytical results from the January 2012 groundwater sampling

event, PCE exceeded the AWQS in groundwater at monitoring wells MW-3, MW-4, MW-5, and MW-10. PCE was measured at a concentration greater than the reporting limit but less than the AWQS at monitoring well MW-7. The PCE plume is generally oriented in the groundwater flow direction. Concentrations are generally higher in the vicinity of source areas and decline both longitudinally (downgradient) and laterally away from the source areas.

The downgradient extent of the PCE plume is estimated to be between monitoring wells MW-10 and MW-7. The January 2012 groundwater analytical results show PCE at a concentration of 2.5 µg/L from groundwater monitoring well MW-7 and below the laboratory report limit of 0.5 µg/L at monitoring well MW-8. Monitoring well MW-7 is located approximately 950 feet north of the Bayless property and monitoring well MW-8 is located approximately 1,350 feet north of the Bayless property. The January 2012 PCE plume distribution in groundwater at the Site and estimated groundwater elevation contours are presented on **Figure 6**.

Groundwater PCE concentration trends in on-site monitoring wells MW-3, MW-4, and MW-5 are shown on **Figure 8**. Historical data indicates that, in general, PCE concentrations decreased at these monitoring wells through September 2010. However, subsequent to the September 2010 sampling event, PCE concentrations showed an increase at all of these locations. The rebound in PCE concentrations might be attributable to either an increase in groundwater flux through the source zone or the increased groundwater elevations at the Site.

Analyses of groundwater samples collected from wells downgradient from the source area at the Bayless property do not contain significant amounts of chlorinated degradation products of PCE, indicating intrinsic dechlorination may not be occurring at this property (Malcolm Pirnie, 2011b).

1.3.2 SCI Property

Analytical results of the groundwater samples collected after the ERA investigation indicated that PCE concentrations ranged from 4.9 µg/L in monitoring well MW-11 to 24 µg/L in monitoring well MW-12. Monitoring well MW-12 is located near the former dry well while monitoring well MW-11 is located approximately 25 feet downgradient from the former septic tank and seepage pit (**Figure 3**). The January 2012 distribution of PCE concentrations in groundwater at the SCI property is presented on **Figure 6**. During the January 2012 sampling event, PCE was detected in groundwater samples collected from monitoring wells MW-11 and MW-12, both at a concentration of 13 µg/L.

Monitoring well MW-12 contains significant amounts of TCE, 1, 2-DCE, and vinyl chloride, indicating that intrinsic reductive dechlorination may be taking place at the SCI property. The concentrations and occurrence of these compounds are discussed in more detail in the RI Report (Malcolm Pirnie and ADEQ, 2011a).

Groundwater PCE concentration trends in monitoring wells MW-11 and MW-12 are shown on **Figure 8**. Only five quarters of data have been collected from these monitoring wells, and PCE concentrations appear to be declining over time at MW-12.

Due to the limited number of monitoring wells downgradient from the source area at the SCI property, it is difficult to determine the downgradient extent of PCE in groundwater, though, given the low dissolved phase concentrations in the source area, the extent is not anticipated to be as far as the Bayless property. The PCE plume is suspected to be generally oriented in the direction of the groundwater flow to the north. Concentrations are expected to be generally higher in the vicinity of the source area and decline both longitudinally (downgradient) and laterally away from the source.

1.3.3 Risk Summary

A detailed discussion about the baseline risk assessment can be found in the RI Report (Malcolm Pirnie and ADEQ, 2011a). To briefly summarize the conclusions, the surface water, air, and soil contact pathways were found to be complete at the Site. However, the concentrations of the COCs at the Site were not found to pose a substantial risk to human health.

Shallow soil gas samples were used to evaluate the air pathway and indoor air quality. This evaluation concluded that the calculated incremental risk associated with PCE vapors is well below ADEQ's acceptable cumulative excess cancer risk from 1 X 10-6 to 1 X 10-4 as stated in the soil remediation rule, RI8-7-206(D).

In addition, the domestic and municipal groundwater pathways were assessed to be incomplete at the Site. The domestic pathway was considered to be incomplete at the Site because the only private well with a listed use as domestic known in the area of the Site, the Young well, was located approximately one-quarter mile northwest of the site boundary and was not likely to be impacted by the groundwater contamination from the Site (**Figure 7**). The municipal pathway was considered to be incomplete for the Site because the inactive City of Phoenix municipal well number 58 (ADWR Registration 55-626549), which is approximately one-quarter mile northwest of the site

boundary (**Figure 7**), was not likely to be impacted by the groundwater contamination from the Site.

Based on public comment, the proposed ROs for current and future land use in the 7th Avenue and Bethany Home Road WQARF site are: Protect against possible exposure to hazardous substances from the release that could occur during typical industrial and residential uses.

Currently, the only undeveloped property in the area is the Bayless property. Based on soil samples collected during the ERA, the Bayless property can meet the residential Soil Remediation Levels.

1.3.4 Allowable Exposure/ARAR Analysis

These criteria address whether the remedial alternatives comply with applicable or relevant and appropriate requirements (ARAR; federal, state, and municipal chemical-specific, action-specific, and location-specific). The ARAR analysis is included as **Appendix A**.

1.4 Contaminants of Concern and Applicable Remedial Objectives

According to the ROs report prepared by the ADEQ (2011), the primary COCs present at the Site include the following:

- chloroform
- cis-1,2-dichloroethene
- trans-1,2-dichloroethene
- dichlorodifluoromethane
- trichloroethene (TCE)
- tetrachloroethene (PCE)
- methyl tertiary-butyl ether (MTBE)
- vinyl chloride (VC)

However, only PCE, TCE, and VC have been present at concentrations above their respective AWQS during and subsequent to the ROs Report. Hence, the primary COCs at the Site are PCE, TCE, and VC. The primary remediation goal for the

impacted groundwater at the Site was developed from the chemical-specific ARARs. The chemical-specific ARARs are defined as the applicable AWQS as well as the maximum contaminant level (MCL) for the COCs. The MCLs for the COCs are summarized in the table below. The MCLs apply to in-situ groundwater and treated groundwater that are to be injected or otherwise reused.

Constituent	Primary MCL (µg/L)
PCE	5
TCE	5
VC	2

ROs are established for current and reasonably foreseeable uses of land and waters of the state that have been or are threatened to be affected by a release of a hazardous substance. R-18-16406(D) specifies that the reasonably foreseeable uses of land are those likely to occur at the Site, and the reasonably foreseeable uses of water are those likely to occur within 100 years unless site-specific information suggests a longer time period is more appropriate. Reasonably foreseeable uses are those likely to occur based on information provided by water providers, well owners, land owners, government agencies, and others. The ADEQ ROs Report (2011) was prepared with stakeholder input gathered during the 7th Avenue and Bethany Home Road Community Advisory Board and public meetings, written comments received during the 45-day public comment period, as well as land and water use study questionnaires gathered during the RI.

The ROs chosen for the Site have been evaluated in this FS in **Section 3**, which compares proposed remedial alternatives that are required to meet ROs. As specified in the ROs Report, the proposed remedies are generally compatible with future land use specified by land owners. The remedial actions are reasonable, appropriate, and cost-effective.

1.4.1 Remedial Objectives for Groundwater Uses

Remedial objectives for this Site have been established for the following groundwater uses:

- municipal
- agricultural
- private use (including domestic and irrigation)

1.4.1.1 Municipal and Agricultural Remedial Objectives

Based upon review of public comment, the ROs were based on the following:

- Protect against possible exposure to hazardous substances in surface and subsurface soils that could occur during development of property based upon applicable zoning regulations.
- Protect against possible leaching of hazardous substances from the upper portion of the aquifer into deeper portions of the aquifer where groundwater use is occurring. The intent is to be protective of the concentration of PCE, in the upper aquifer at the Site, from impacting the lower portions of the aquifer where groundwater use is actually occurring.

Based on public comments, the proposed ROs for current and future municipal and agricultural groundwater use at the Site are similar and include:

- To protect the supply of groundwater for municipal and irrigational use and for the associated recharge capacity that is threatened by contamination emanating from the 7th Avenue and Bethany Home Road WQARF Site.

- To restore, replace, or otherwise provide the groundwater supply lost due to contamination associated with the 7th Avenue and Bethany Home Road WQARF Site. This action will be needed as long as the need for the water exists, the resource remains available, and the contamination associated with the 7th Avenue and Bethany Home Road WQARF Site prohibits or limits groundwater use.

Based on public comment, proposed ROs for current and future private groundwater use in the vicinity of the 7th Avenue and Bethany Home Road WQARF Site are:

- To protect, restore, replace, or otherwise provide a water supply for domestic and irrigation use by private well owners outside the current plume boundaries of the 7th Avenue and Bethany Home Road WQARF Site if the current use is impaired or lost due to contamination from the Site. This action will be needed until municipal connections can be confirmed, and the contamination associated with the 7th Avenue and Bethany Home Road WQARF Site prohibits or limits groundwater use.

Groundwater monitoring in January 2012 has demonstrated an increase in source-area contaminant concentrations since the last sampling event. Additionally, PCE was measured at 5 parts per billion (ppb) in SRP well 13.1E-10.5N during the January 2012 sampling event. The combination of increasing contaminant concentrations at the source area and at the leading edge of the plume in the vicinity of SRP well 13.1E-10.5N suggests that a “no action” alternative at the site may not be sufficient to meet the ROs.

2. Identification of Technologies

This report documents a focused evaluation of the feasibility of select technologies, and, therefore, the identification of screened technologies has been streamlined. This section summarizes the applicable technologies used to develop the remedial alternatives.

- Monitored natural attention (MNA): This technology refers to the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods (U.S. EPA, 1999).

- Enhanced reductive dechlorination (ERD): This technology refers to the injection of a readily degradable electron donor to stimulate native bacteria in situ to generate strongly reducing (i.e., sulfate reducing, acetogenic, and methanogenic) conditions, which leads to the creation of hydrogen and ultimately facilitates the removal of chlorine from CVOCs and results in benign end products such as ethene and ethane. Ethene and ethane further mineralize to carbon dioxide under natural conditions.

- In situ chemical oxidation (ISCO): This technology refers to the injection of an oxidant that chemically oxidizes the CVOC compounds and mineralized CVOCs to carbon dioxide.

- Groundwater Extraction and Treatment (GWET): This technology refers to the physical removal of impacted groundwater from the aquifer to control migration of contaminant plumes while slowly removing source mass.

- Ex situ treatment: This technology is coupled with a groundwater extraction technology and provides treatment of the impacted groundwater.

- Re-injection: This technology is coupled with groundwater extraction and ex situ treatment and provides a means to dispose of extracted groundwater efficiently.

These technologies have been combined to form three remedial alternatives that were screened against criteria to ultimately select the most appropriate alternative.

3. Development and Screening of Alternatives

Three remedial alternatives were identified for the FS, as summarized in **Table 1**. Although traditional U.S. EPA guidance suggests including a "no action" alternative, this was not considered further due to the detection of PCE at the AWQS of 5 µg/L in SRP well 13.1E-10.5N.

In the sections below, the three identified alternatives were evaluated based on the evaluation criteria outlined in the U.S. EPA's Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (U.S. EPA, 1988):

The evaluation criteria included:

- Overall protection of human health and the environment,
- Compliance with ARARs,
- Long-term effectiveness and permanence,
- Reduction of toxicity, mobility, and volume through treatment,
- Short-term effectiveness,
- Implementability, and
- Cost

A detailed analysis of each alternative is presented in **Sections 3.1, 3.2,** and **3.3**. The evaluation and comparative analysis of the three alternatives are provided in **Section 3.4**.

3.1 Alternative 1– In-Situ Enhanced Reductive Dechlorination with Monitored Natural Attenuation

Alternative 1 is a full-scale in-situ ERD system followed by an MNA program to monitor the remedy. In order for Alternative 1 to be successful, strong reducing conditions capable of supporting dehalorespiration of CVOCs to the innocuous by-products ethene and ethane will be required. This is achieved by periodically dosing the aquifer

with an organic carbon substrate to overcome the natural electron acceptor supply, monitoring the in situ parameters closely, and modifying the dosing strength, volume, and frequency as needed. The following sections describe the full-scale conceptual design.

3.1.1 Alternative 1 Description

The description of Alternative 1 includes a brief summary of the ERD technology, engineering estimates for the necessary injection infrastructure and operation, and an estimation of the remedial time frame.

3.1.1.1 ERD Technology Description

Reductive dechlorination is a microbiological process in which chlorinated compounds are reduced and undergo dechlorination as a result of either microbial metabolism or co-metabolism. ERD is stimulated by injecting a soluble carbon substrate (e.g., molasses, corn syrup, lactate, or whey) into the subsurface to create a biological in-situ reactive zone (IRZ). The carbon source is injected to promote the consumption of natural electron acceptors (e.g., oxygen, nitrate, ferric iron, manganese, sulfate, and carbon dioxide) by native bacteria within the aquifer matrix. The general sequence of alternate electron acceptor utilization and respiration by-product formation is as follows (from most thermodynamically favorable to least):

Electron Acceptors		Products
Nitrate (NO_3^-)	$\rightarrow$	Nitrogen (N_2)
Ferric Iron (Fe^{3+})	$\rightarrow$	Ferrous Iron (Fe^{2+})
Manganic Manganese (Mn^{4+})	$\rightarrow$	Manganous Manganese (Mn^{2+})
Sulfate (SO_4^{2-})	$\rightarrow$	Sulfide/Hydrogen Sulfide (H_2S)
Carbon Dioxide (CO_2)	$\rightarrow$	Methane (CH_4)

The added organic carbon source stimulates microbial activity, driving the groundwater environment to strongly reducing conditions, establishing an anaerobic IRZ. Within the IRZ, there are two primary processes by which microbes can degrade CVOCs dissolved in groundwater:

- Co-metabolism: In this process, CVOCs are fortuitously degraded by the enzymes and cofactors produced by microbes as they metabolize excess organic carbon.

- Dehalorespiration/metabolism: In this process, microbes use the CVOC molecule as an alternate electron acceptor to support respiration under the anaerobic and reducing environment maintained by the presence of excess organic carbon.

The characteristics and extent of an IRZ established are generally determined by the effectiveness of delivering the carbon source to subsurface microbes. Three basic goals are targeted with the delivery of degradable organic carbon into a contaminated aquifer:

- Overcome the natural recharge of electron acceptors: This includes oxygen, nitrates, and other electron acceptors that tend to support a more aerobic microbial community. As electron acceptors are consumed, the environment will become more reducing. During this process, the microbial community will adapt, encouraging proliferation of bacterial communities that participate directly in the dechlorination process.

- Stimulate fermentation and the production of molecular hydrogen: In the presence of excess organic carbon and a strongly reducing environment, fermenting bacteria will harvest energy by splitting organic compounds. This process generates hydrogen. The process of fermentation also generates enzymes, cofactors, alcohols, and other compounds that act as surfactants. This surfactant effect drives the dissolution of adsorbed and non-aqueous phase contaminant mass, making it available for treatment.

- Stimulate complete dechlorination of the target contaminants: Certain anaerobic bacteria can use the hydrogen produced during fermentation processes as an electron donor and the chlorinated alkenes as electron acceptors for respiration. The bacteria involved in these reactions are referred to as “dehalorespirers,” which include bacterial species from several genera, including *Desulfuromonas*, *Dehalospirillum, Dehalococcoides, Dehalobacter, and Desulfomonile*. In this process, the hydrogen atoms are substituted for chlorine atoms, resulting in a step-wise chemical reduction of the chlorinated solvent or other halogenated organic compound until it is completely converted to harmless end products. In the case of chlorinated alkenes, this follows the path from TCE → dichloroethene (DCE) → VC → ethene → ethane.

3.1.1.2 Injection and Monitoring Well Network

The locations of necessary ERD injection well transects and supporting monitoring wells are shown on **Figure 9**. As a conservative estimate, up to 26 stainless steel injections wells (as nested pairs, screened from 80 to 95 and 95 to 110 feet bgs) and six new groundwater monitoring wells may be necessary to implement the full-scale ERD system. The additional monitoring wells will be necessary to further monitor the extent of the degradation products of PCE down gradient of MW-12 and to further define the extent of contamination on the east side of the Bayless property. The design proposes two injection well transects on the Bayless property, with six nested injection locations per transect spaced at approximately 40 feet on center (i.e., 24 injection wells in total). The injection well transects are assumed to be approximately 200 feet in length with an assumed downgradient spacing of 500 feet. One additional nested injection well location is included on the SCI property (in the vicinity of MW-11) to address low-level dissolved phase PCE discussed in **Section 1.3.2**.

Injection wells would be connected to a main mixing location via subsurface piping. A concentrated carbon source would be delivered and offloaded into a storage tank. Water for the injection will be provided from the aquifer, and the carbon reagent will be mixed in-line and then directed out to the injection wells through a manifold.

Additional samples will be collected from SRP well 13.1E-10.5N to confirm the impact of this well by PCE above the AWQS. In addition, the City of Phoenix well, well number 58, (55-626549), which is located at 11th Avenue just south of Maryland, approximately one-quarter mile northwest of the Site (**Figure 7**), will be added to the monitoring program.

3.1.1.3 Operation and Maintenance

Implementation of Alternative 1 will require a field-scale treatability study that includes an injection test to establish crucial design criteria in support of the larger full-scale ERD system. The full-scale ERD system would be implemented following the treatability study that includes performance monitoring following the injection test. The selected carbon substrate and injection concentration, the appropriate well spacing, and the injection frequency will be finalized based on the results of the pilot injection test and post-injection monitoring. The CVOC trends in groundwater in existing and proposed monitoring wells located side-gradient and downgradient from the target treatment areas monitored following the pilot injection will ultimately determine the

requisite operation of the full-scale ERD system. It is assumed that Alternative 1 will take approximately 15 years to achieve MCL concentrations for COCs. Carbon injections will not be required throughout the entire 15-year remedial time frame, but necessary pore flushing to treat the entire footprint of the plume given the hydrogeological data indicates 15 years will be required.

3.1.1.4 Monitoring

Groundwater monitoring, including collection of groundwater samples for laboratory analysis and water level elevation data will be conducted quarterly for five years, semiannually for five years, and annually for five years during the anticipated 15-year operation of Alternative 1.

3.1.2 Feasibility Assessment

This section provides an analysis of Alternative 1 based on the evaluation criteria described in **Section 3**.

3.1.2.1 Overall Protection of Human Health and the Environment

Alternative 1 is protective of human health and the environment because VOCs are biologically destroyed, hence removing the contamination. Treated groundwater requires some time to re-equilibrate to ambient conditions to reach secondary water quality objectives. The secondary water quality effects typically associated with ERD systems generally include the following classes of parameters:

- Reagent related byproducts – ketones, biological oxygen demand, pH
- Redox sensitive metals – iron, manganese, arsenic
- Microbial metabolic byproducts – methane, hydrogen sulfide
- Degradation intermediates – DCE, VC

3.1.2.2 Compliance with ARARs

Alternative 1 is projected to comply with chemical-, location-, and action-specific ARARs identified in **Appendix A**.

3.1.2.3 Long-Term Reliability and Effectiveness

The endpoint of ERD is achieving ROs in the aquifer as a result of destroying VOCs. Therefore, there is no residual risk. The adequacy and reliability of ERD to reduce CVOC mass in groundwater is a proven and reliable remedial approach.

3.1.2.4 Reduction of Toxicity, Mobility, or Volumes of Wastes

ERD physically destroys CVOCs, resulting in benign end products. All hazardous material is destroyed, thereby permanently eliminating toxic mobility. ERD is an irreversible process.

3.1.2.5 Short-Term Effectiveness

ERD is a biological strategy and baseline data do not demonstrate a considerable degree of intrinsic reductive dechlorination, which may lead to a lag phase. The generation of methane may pose a threat to the community and workers, though adequate methane mitigation protocols have been developed to handle methane generated as a function of biological processes accordingly.

While ARCADIS' past experience has shown ERD to be an effective remedial technology for the targeted VOCs present at the Site, gaseous byproducts (e.g., methane and hydrogen sulfide) can be generated in the dissolved phase as a result of organic carbon substrate utilization and microbial metabolism. Hydrogen sulfide is not anticipated to represent a soil gas issue due to the availability of dissolved ferrous iron in reduced groundwater systems (which supports iron-sulfide mineralization reactions); however, dissolved-phase methane can be observed at concentrations near saturation. Gas production in groundwater can result in increased vapor phase concentrations at the soil gas-groundwater interface, where the gas-liquid equilibrium is controlled by the dissolved-phase concentration and the Henry's Law constants. Upon reaching the vadose zone, gases will diffuse away from the water surface and attenuate under a variety of biological, chemical, and/or physical mechanisms. These mechanisms act to restrict gas migration as it permeates through the subsurface soil. Tighter, fine-grained soil and a large vadose zone, both of which are present at the Site, also result in significantly longer subsurface residence times and allow for attenuation of gases. Based on the silts and clays observed above the proposed injection interval (approximately 80 to 95 and 95 to 110 feet bgs) and a greater than 50 feet bgs depth to water at the Site, it is anticipated that methane generated at the soil gas-groundwater interface will not represent a risk to either onsite or offsite buildings or

structures. Although the potential risk associated with excess methane generation is low, soil gas characterization and monitoring will be performed at the Site as part of Alternative 1 to assess baseline conditions and monitor methane levels during the injection program.

Risks to human health and the environment during construction and operation can be minimized through proper decontamination and use of secondary containment. Potential exposure pathways for workers include inhalation and dermal contact during installation of the injection wells and piping. The potential exposure pathways can be effectively managed through proper health and safety procedures and the use of personal protective equipment.

3.1.2.6 Implementability

Necessary equipment and labor are readily available. ERD is a proven technology that has transparent performance metrics to gauge effectiveness. Injected reagent is typically nonhazardous, and approval by regulatory agencies is anticipated to be obtainable.

3.1.2.7 Cost

A summary of the engineering cost estimate for Alternative 1 is shown in **Table 2**. The cost estimate includes total capital costs, the annual operation and maintenance (O&M) requirement, and the net present value for a 15-year period at a discount rate of 4 percent. The unit cost estimates have been developed based on ARCADIS' previous experience, RS Means, and vendor's quotes. The cost estimate has an accuracy range of ±30 percent. The approximated cost summarized in **Table 2** applies only to Alternative 1 under the assumptions defined in **Table 2**, and changes to the scope would result in changes to the engineering cost estimate.

3.2 Alternative 2 – In Situ Chemical Oxidation with Monitored Natural Attenuation

Alternative 2 is a full-scale in-situ chemical oxidation (ISCO) system followed by an MNA program to monitor the remedy. In order for Alternative 2 to be successful, a strong oxidant (sodium persulfate with iron activation) will be injected over the approximate footprint of dissolved phase impacts. This will be done by constructing a grid of injection wells over the targeted treatment area. The following sections describe the full-scale conceptual design.

3.2.1 Alternative 2 Description

The description of Alternative 2 includes a brief summary of the ISCO technology, engineering estimates for the necessary injection infrastructure and operation, and an estimation of the remedial time frame.

3.2.1.1 ISCO Technology Description

Sodium persulfate chemical oxidation is an accepted and proven technology for remediation of CVOCs, and it has been implemented at other sites in Arizona. The use of injection wells will help ensure that the sodium persulfate solution is evenly distributed throughout the target treatment area such that sufficient contact between the oxidant and the dissolved phase CVOCs is achieved.

Selection of the activation method is an important consideration in sodium persulfate applications. Activation of the persulfate anion is required for formation of sulfate radicals, which have similar oxidation strength as the hydroxyl radical utilized in Fenton's oxidation approaches. Equations 1 and 2 below illustrate the chemical equations for the catalysis of sodium persulfate ($Na_2S_2O_8$), and Equations 3 through 5 below present the subsequent chemical reactions associated with the catalysis of the persulfate anion ($S_2O_8^{-2}$) within the targeted soil/groundwater media.

$$Na_2S_2O_8 \rightarrow Na^{+2} + S_2O_8^{-2} \qquad \text{(Equation 1)}$$

$$S_2O_8^{-2} + Me^{n+} \rightarrow SO_4^{-}\bullet + Me^{n+1} + SO_4^{-2} \qquad \text{(Equation 2)}$$

$$S_2O_8^{-2} + H_2O \rightarrow HSO_4^{-} + SO_4^{-}\bullet + OH\bullet \qquad \text{(Equation 3)}$$

$$SO_4^{-}\bullet + H_2O \rightarrow HSO_4^{-} + OH\bullet \qquad \text{(Equation 4)}$$

$$2\ OH\bullet \rightarrow H_2O_2 \rightarrow H_2O + \tfrac{1}{2}\ O_2 \qquad \text{(Equation 5)}$$

The persulfate anion can be activated with chelated iron, base, hydrogen peroxide, or heat. Sodium persulfate may be activated at the surface prior to or during injection (e.g., addition of chelated iron, base, hydrogen peroxide, or heat of the solution or in-line immediately prior to injection). Alternatively, ambient conditions may be relied on to activate the persulfate anion. Ambient activation is a technique that works well with subsurface geochemical conditions that are anaerobic and reducing such that natural iron in the subsurface is in the dissolved, ferrous state. The reaction between the

sodium persulfate and ambient ferrous iron generally has an extended residence time (typically on the order of months) in most subsurface conditions. The chelated iron activated sodium persulfate approach was selected for application at the Site due to its appropriateness given the presence of persistent dissolved phase CVOCs.

Apart from sodium persulfate, the injected reagents will include potable water, ferrous sulfate hepta hydrate, and citric acid. The purpose of the citric acid is to keep the iron in solution as iron is a redox sensitive metal. In chemical equation 2, iron is capable of activating persulfate as ferrous iron (Fe^{2+}) or iron (II). Under strong oxidizing conditions, ferrous iron is oxidized to ferric iron (Fe^{3+}) or iron (III) and (in the absence of a chelating agent such as citrate) will preferentially form insoluble oxyhydroxide precipitates, reducing the effectiveness of iron activation. The citrate molecule can form weak bonds with iron (II), prolonging its duration in the aquifer to complete the activation and ultimately result in iron (III) (Fe^{3+}) precipitation per the chemical equation 2. Chemical equation 6 shows divalent metal (Fe^{2+}) activation:

$$S_2O_8^{2-} + Fe^{2+} \rightarrow Fe^{3+} + SO_4^{2-} + SO_4^{-}\bullet \qquad \text{(Equation 6)}$$

3.2.1.2 Injection and Monitoring Well Network

The locations of necessary ISCO injection and monitoring wells are shown on **Figure 10**. As a conservative assumption, up to 66 stainless steel injections wells (as nested pairs, screened from 80 to 95 and 95 to 110 feet bgs) and four new groundwater monitoring wells may be necessary to implement the full-scale ISCO injection. To maximize the efficiency of the technology, direct injection into MW-11 on the SCI property is proposed with downgradient dose response monitoring at MW-12.

Injection wells would be connected to a main mixing location via subsurface piping. Mixing associated with ISCO injections requires a high degree of engineering control to minimize the risks associated with the oxidants. Separate staging tanks will be required for mixing the sodium persulfate and activator to prevent ex-situ activation. Water for the injection will be provided from the aquifer, and the persulfate and activator will be mixed in-line and then directed out to the injection wells through a manifold. All components of the mixing system must be chemically compatible with sodium persulfate.

3.2.1.3 Operation and Maintenance

To appropriately scale an ISCO injection, a bench-scale treatability test would be required to understand the natural oxidant demand (NOD) of the site soils and groundwater. Typically, the soil and groundwater NOD drives the oxidant loading with the COCs representing a small portion of the oxidant demand. However, the NOD will aggressively scavenge the injected oxidant, and, in order to appropriately dose for treatment of COCs, understanding the NOD is necessary. Along with a bench-scale treatability test, a small-scale injection test will be required to understand the volume to distribution relationship in order to space injection wells appropriately. The full-scale ISCO implementation would be conducted after the bench-scale treatability and initial pilot tests. Approximately two to three ISCO injection events are anticipated over the course of approximately five years. After the targeted treatment area has been remediated, the limiting factor will be achieving the appropriate number of pore water flushes downgradient to achieve MCLs.

It is assumed that Alternative 2 will take approximately 15 years to achieve MCL concentrations for COCs.

3.2.1.4 Monitoring

Groundwater monitoring, including collection of groundwater samples for laboratory analysis and water level elevation data, will be conducted quarterly for five years, semiannually for five years, and annually for five years during the anticipated 15-year operation of Alternative 2.

3.2.2 Feasibility Assessment

This section provides an analysis of Alternative 2 based on the evaluation criteria described in **Section 3**.

3.2.2.1 Overall Protection of Human Health and the Environment

Alternative 2 can protect human health and the environment as CVOCs will be chemically destroyed, hence removing the contamination. Treated groundwater will require some time to re-equilibrate to ambient conditions for secondary water quality objectives. The secondary water quality effects typically associated with ISCO systems generally include the following classes of parameters: labile metals and organic byproducts (OBPs). Metal fate and transport in the subsurface is generally controlled

by precipitation–dissolution and sorption–desorption reactions, both of which are affected by pH extremes. The metals affected by the pH depression associated with ISCO might include aluminium, arsenic, chromium, manganese, zinc, nickel, cadmium, however concentrations of these metals are expected to return to baseline conditions once the pH has recovered within the treatment zone (assuming that the neutralizing capacity of the aquifer is not overwhelmed). The OBP production is site and activator specific and is expected to be transient, with the attenuation expected to be seen within 6 months of application. Examples of OBPs that are sensitive to oxidation and reduction reactions associated with ISCO include chloromethane and methylene chloride.

3.2.2.2 Compliance with ARARs

Alternative 2 is projected to comply with chemical-, location-, and action-specific ARARs identified in **Appendix A**.

3.2.2.3 Long-Term Reliability and Effectiveness

The endpoint of ISCO is achieving ROs in the aquifer as a result of destroying CVOCs. Therefore, there is no residual risk. ISCO with sodium persulfate activated with ferrous iron for remediation of CVOCs in groundwater is a proven and reliable remedial approach.

3.2.2.4 Reduction of Toxicity, Mobility, or Volumes of Wastes

Alternative 2 will utilize ISCO to physically destroy CVOCs in groundwater, resulting in benign end products. All hazardous material will be destroyed, thereby permanently eliminating toxic mobility. ISCO is an irreversible process.

3.2.2.5 Short-Term Effectiveness

ISCO is a chemical strategy and is expected to immediately reduce CVOCs assuming adequate distribution of the reagent is achieved in-situ. Implementation of ISCO will not pose a significant threat to the community or environment, but does pose a slight risk to workers. Risks to human health and the environment during construction and operation can be minimized through proper decontamination and use of secondary containment. Potential exposure pathways for workers include inhalation and dermal contact during installation of injection wells and piping, and with the oxidant during injection activities. The potential exposure pathways can be effectively managed

through proper health and safety procedures and the use of personal protective equipment, which slightly increases the cost compared to the other alternatives.

3.2.2.6 Implementability

Alternative 2 is projected to be readily implemented. Necessary equipment and labor are readily available. ISCO is a proven technology that has transparent performance metrics to gauge effectiveness. Sodium persulfate injections with iron activation have previously been completed in other locations of Arizona and it is anticipated that approval from regulatory agencies can be obtained.

3.2.2.7 Cost

A summary of the engineering cost estimate for Alternative 2 is shown in **Table 3**. The cost estimate includes total capital costs, the annual O&M requirement, and the net present value for a 15-year period at a discount rate of 4 percent. The unit cost estimates have been developed based on ARCADIS' previous experience, RS Means, and vendor's quotes. The cost estimate has an accuracy range of ±30 percent. The approximated cost summarized in **Table 3** applies only to Alternative 2 under the assumptions defined in **Table 3**, and changes to the scope would result in changes to the engineering cost estimate.

3.3 Alternative 3 – Groundwater Extraction and Treatment with Injection

Alternative 3 is a full-scale GWET system with re-injection inclusive of an MNA program to monitor the remedy. In order for Alternative 3 to be successful, adequate hydraulic control must be achieved over the dissolved phase plume. This will be done by constructing transects of extraction and injection wells. The following sections describe the full-scale conceptual design.

3.3.1 Alternative 3 Description

The description of Alternative 3 includes a brief summary of the GWET technology, engineering estimates for the necessary injection infrastructure and operation, and an estimation of the remedial time frame.

3.3.2 GWET Technology Description

GWET allows the contaminated groundwater to be extracted and treated ex-situ through various treatment methods to achieve the remediation goals. The treatment method for Alternative 3 would be 2,000-pound granular activated carbon (GAC) vessels. Treated groundwater would be injected into the aquifer through new injection wells. By extracting from the area of the highest dissolved phase concentrations and injecting clean water on the outer edges of the dissolved phase area, an engineered gradient is created leading to more rapid flushing.

The appropriate number of pore flushes to achieve adequate flushing of the impacted aquifer is greater than 60. This calculation is contingent upon many hydrogeologic and contaminant specific parameters, but essentially the equation is as follows:

$$NF = \ln\left(\frac{C_{GW}}{C_{CL}}\right) \times R$$

Where:
NF = the number of pore flushes to achieve the cleanup criteria;
C_{GW} = the impacted groundwater concentration (determined as a geometric mean over the dissolved phase footprint and determined to be 1,000 µg/L);
C_{CL} = the cleanup criteria (MCL for PCE of 5 µg/L);
R = the retardation coefficient.

The retardation coefficient is assumed to be the greater of porosity-driven retardation and sorption-based retardation. Porosity-driven retardation is a function of the relationship between the immobile and mobile porosity, and is calculated as follows:

$$Rf_{\theta} = 1 + \frac{\theta_i}{\theta_m}$$

Where:
Rf_{θ} = the porosity-driven retardation coefficient (determined to be approximately 3.8);
θ_i = Immobile porosity (assumed to be 28 percent at the Site);
θ_m = Mobile porosity (assumed to be 10 percent at the Site).

Sorption-based retardation is a function of the fraction of organic content in the aquifer and the octanol partitioning coefficient of the COC, which describes its affinity to sorb to the soil material. The sorption-based retardation coefficient is calculated as follows:

$$Rf_{oc} = 1 + \frac{\rho_b}{\theta_i} \times K_d$$

Where:
Rf_{OC} = the sorption-based retardation coefficient (determined to be approximately 12.6);
ρ_b = the bulk soil density (assumed to be 102 pounds per cubic feet [lb/ft^3] at the Site);
θ_i = Immobile porosity (assumed to be 28 percent at the Site);
K_d = the partitioning coefficient (calculated to be 2.63 liters per kilogram [L/kg] for the Site based on the octanol partition coefficient of PCE [263.03 L/kg] and the fraction of organic content of the aquifer [laboratory determined to be 0.01]).

Therefore, the driving form of retardation in this aquifer is most likely the sorption of PCE on the soil as groundwater migrates downgradient. These calculations result in greater than 60 required pore flushes to sufficiently flush residual dissolved phase contamination.

Using the available hydraulic conductivity data (approximate maximum of 80 feet per day [ft/d]), and the hydraulic gradient from the 2012 potentiometric surface map (**Figure 6**), a maximum darcy velocity of approximately 3 ft/d is calculated according to the following equation:

$$V_{GW} = \frac{K_H \times i}{\theta_m}$$

Where:
V_{GW} = the groundwater velocity (3 ft/d);
K_H = the hydraulic conductivity (80 ft/d);
i = the hydraulic gradient (0.0037 ft/ft):
θ_m = mobile porosity (assumed to be 10 percent at the Site).

Groundwater extraction and re-injection can increase the hydraulic gradient, resulting in a higher darcy velocity and more rapid flushing. ARCADIS' experience suggests that a two to four times increase in flushing can be achieved with GWET and re-injection.

3.3.2.1 Extraction Wells and Piping

The locations of necessary extraction, injection and monitoring wells are shown on **Figure 11**. The CVOC-contaminated groundwater plume at the Bayless property

would be contained and treated by a set of extraction and injection well transects on the Bayless property. The treated water will be re-injected back into the aquifer on the outer edges of the injection-extraction well transects. The treatment system will be composed of GAC vessels to reduce the CVOCs to concentrations below their respective remedial goals.

It is assumed that the extraction wells will be installed on the inside of the transects and will each operate at an assumed rate of 10 gallons per minute (gpm). The injection wells would be installed on the outer edges of the transects and receive approximately 5 gpm each**.** The locations of the injection wells were established to control plume migration and to assist with flushing of the targeted treatment area. It was assumed that new conveyance piping would be necessary to connect the new extraction wells to the treatment system and to connect the treatment system to the new injection wells. Piping would be buried in shallow underground trenches.

3.3.2.2 Treatment System

Extracted groundwater would be pumped through two GAC vessels to remove dissolved phase PCE. The GAC vessels will be of sufficient size to achieve the required residence time for PCE to sorb to the GAC. O&M of the GAC units (including periodic carbon change outs) will be necessary to minimize operational shutdowns. Groundwater that has been flushed through the GAC vessels for the appropriate time will be re-injected into the aquifer through injection wells on the periphery of the dissolved phase plume. The extraction rate in each well is estimated to be twice the injection rate, and thus there will be two injection wells for every one extraction well.

Approximately four stainless steel extraction wells will be required, and the extraction interval will be from 80 to 120 feet. Approximately eight injection wells will be required to re-inject the extracted groundwater. The injection wells will be constructed of polyvinyl chloride (PVC) with a screened interval from approximately 80 to 120 feet bgs. Nested injection and extraction wells with smaller screened intervals like in Alternatives 1 and 2 are not necessary as the purpose is bulk flushing and discretized extraction is not a primary focus.

The transects are proposed to be spaced approximately every 500 feet, as this distance equates to a 30-year remedial time frame under ambient flushing. If the GWET and re-injection increases the flushing by a factor of two, the remedial time frame is expected to be approximately 15 years.

3.3.2.3 Monitoring

Groundwater monitoring, including collection of groundwater samples for laboratory analysis and water level elevation data, will be conducted quarterly for five years, semiannually for five years, and annually for five years during the anticipated 15-year operation of Alternative 3.

3.3.3 Feasibility Assessment

This section provides an analysis of Alternative 3 based on the evaluation criteria described in **Section 3**.

3.3.3.1 Overall Protection of Human Health and the Environment

Alternative 3 can protect human health and the environment from risks caused by the CVOC groundwater contamination because VOCs will be physically removed from the aquifer and groundwater pumping will maintain control of the plume. However, relying on the effectiveness of GWET to achieve MCLs can be limited by matrix effects in the aquifer, and this may lead to an operating time frame that can be more difficult to predict accurately.

3.3.3.2 Compliance with ARARs

Alternative 3 is projected to comply with the other chemical-, location-, and action-specific ARARs identified in **Appendix A**. There is some uncertainty regarding the length of time required for achieving CVOC concentrations below the remedial goals, as many of the parameters used to determine the remedial time frame are approximated at this time.

3.3.3.3 Long-Term Reliability and Effectiveness

The endpoint of GWET for remediation of CVOCs in groundwater is achieving ROs by physically removing CVOCs from the aquifer. However, when the CVOCs are mainly present in fine-grained media, the rate of removal is diffusion limited and characterized as one-way diffusion (from immobile porosity to mobile porosity), which reduces the effectiveness of the treatment process. Enhanced flushing with GWET and re-injection can reduce this by creating a two-way diffusion pathway (immobile to mobile and mobile to immobile). As evidenced above, ambient flushing with the transect spacing will result in a greater than 30-year operating time frame. If the flushing can be

enhanced by a factor of two, the operating time frame can be reduced by 50 percent to 15 years.

3.3.3.4 Reduction of Toxicity, Mobility, or Volumes of Wastes

Alternative 3 will physically remove CVOCs from groundwater through extraction and treatment. The primary mechanism for hazardous material reduction is removal, thereby permanently eliminating toxic mobility. A certain portion of the impacts will be diluted through enhanced flushing. GWET is an irreversible process.

3.3.3.5 Short-Term Effectiveness

GWET will initially extract all readily available and mobile CVOCs and impose hydraulic control of plume migration, thus demonstrating high short-term effectiveness. Implementation of GWET will not pose a significant threat to the community, workers, or environment.

Risks to human health and the environment during construction and operation can be minimized through proper decontamination and use of secondary containment. Potential exposure pathways for workers include inhalation and dermal contact during installation of the groundwater injection and extraction wells and piping. The potential exposure pathways can be effectively managed through proper health and safety procedures and the use of personal protective equipment.

3.3.3.6 Implementability

Alternative 3 is readily implementable. Necessary equipment and labor is readily available. GWET is a proven technology that has transparent performance metrics to gauge effectiveness.

3.3.3.7 Cost

A summary of the engineering cost estimate for Alternative 3 is shown in **Table 4**. The cost estimate includes total capital costs, the annual O&M requirement, and the net present value for a 15-year period at a discount rate of 4 percent. The unit cost estimates have been developed based on ARCADIS' previous experience, RS Means, and vendor's quotes. The cost estimate has an accuracy range of ±30 percent. The approximated cost summarized in **Table 4** applies only to Alternative 3 under the

assumptions defined in **Table 4**, and changes to the scope would result in changes to the engineering cost estimate.

3.4 Comparative Analysis of Remedial Alternatives

In the following comparative analysis, the alternatives are considered in relation to one another and the evaluation criteria. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to each other.

3.4.1 Threshold Criteria

Each of the alternatives is protective of human health and the environment and reduces CVOC contamination in the targeted treatment area. Alternatives 1 and 2 directly reduce CVOCs in the targeted treatment area and in the groundwater downgradient from the targeted treatment area. Alternative 3 prevents further migration of the contaminated groundwater plume by containing, extracting, and treating the groundwater to the remediation goals.

Each of the alternatives complies with ARARs. However, the effectiveness of Alternative 3 can be limited by matrix effects in the aquifer leading to an indeterminate operating time frame. Alternatives 1 and 2 are projected to meet ARARs in a shorter time frame than Alternative 3.

3.4.2 Balancing Criteria

3.4.2.1 Long-Term Reliability and Effectiveness

ERD and ISCO are proven, reliable, and implementable technologies for the reduction of CVOCs. Long-term effectiveness relies on the ability of a remedial alternative to fully treat the CVOCs present in fine-grained media. The rate of removal from the fine-grained media is diffusion dependent, which reduces the effectiveness of GWET, although re-injection and engineered gradients can offset the diffusion dependency. After the GWET system is turned off, it is possible that the CVOC concentrations could rebound as residual CVOCs diffuse from the fine-grained media into the groundwater, or if the pore flushing calculations are inaccurate. Indefinite operation of GWET will provide protectiveness in the form of containment and treatment, but is not cost effective or sustainable. Likewise, diffusion rates of sodium persulfate into the fine-grained media are slow, and more than one injection of the oxidant may be necessary to meet the ARARs. The estimated remedial time frames are approximately 15 years. It

should be noted that there is considerable uncertainty regarding the time estimates to reach remediation goals for each alternative, and the estimates put forth in this FS are based on the available data and specific assumptions. Pre-design work related to any alternative may change the remedial time frame calculations.

3.4.2.2 Reduction of Toxicity, Mobility, or Volume of Waste

Alternatives 1 and 2 treat the contaminant mass by irreversible biological and chemical destruction. Alternative 3 treats the contaminants by physical removal. Alternatives 1 and 2 have the potential to treat the targeted treatment area in a shorter period of time than Alternative 3.

3.4.2.3 Short-term Effectiveness

Alternative 1 uses a biological strategy and baseline data do not demonstrate a considerable degree of intrinsic reductive dechlorination, which may lead to a lag phase. There is a concern of methane generation; however, with a deep aquifer (greater than 50 feet bgs), this is a minimal concern and can be managed appropriately with best practices. Alternative 2 is a chemical strategy and is expected to immediately reduce CVOCs, assuming adequate distribution of the oxidant. There are hazards to workers associated with Alternative 2, though these can be controlled with appropriate engineering controls and personal protective equipment. Alternative 3 will initially extract all readily available and mobile CVOCs and impose hydraulic control of plume migration, thus demonstrating high short-term effectiveness.

Risks to human health and the environment during construction and operation can be minimized through proper decontamination and use of secondary containment. Potential exposure pathways for workers include inhalation and dermal contact during installation of the necessary wells (extraction and/or injection) and during ISCO injection activities. The potential exposure pathways can be effectively managed through proper health and safety procedures and the use of personal protective equipment.

3.4.2.4 Implementability

Each of the alternatives is projected to be readily implementable and operable. Necessary equipment and labor are readily available for all alternatives. However, all alternatives would require design calculations, proper regulatory approval, and procurement of the infrastructure.

3.4.2.5 Cost

A summary table of the comparative costs for each alternative is presented in the following table:

Alternative	Total Capital Cost	Annual O&M Cost	Net Present Value
Alternative 1 – ERD with MNA	$971,300	$153,300 (Y1-Y5) $32,300 (Y5-Y10) $21,600 (Y10-Y15)	$1.8 M
Alternative 2 – ISCO with MNA	$1,391,800	$713,200 (Y1-Y5) $31,800 (Y5-Y10) $21,400 (Y10-Y15)	$3.7 M
Alternative 3 – GWET with Re-injection and MNA	$682,900	$125,500 (Y1-Y5) $114,600 (Y5-Y10) $108,300 (Y10-Y15)	$2 M

Alternative 1 has a lower net present value and O&M cost than Alternatives 2 and 3. Note that Alternative 2 only has an annual O&M cost of $713,200 during years where an ISCO injection event is conducted (years 1, 3, and 5), as the reagent cost is the cost driver. All of the remedial alternatives have a remedial time frame of approximately 15 years, and that is a function of the required number of pore flushes downgradient from treatment transects. The cost estimates have an accuracy range of ±30 percent. The cost details of the alternatives are included in **Tables 2 through 4**.

3.4.3 Comparative Analysis Conclusions

Based on the comparison described above, Alternative 1 is selected as the appropriate remedy for the Site. Implementation of Alternative 1 is preferred over a similarly priced Alternative 3 because Alternative 1 provides a destructive pathway for COC removal and has a potential benefit of being completed before the calculated remedial time frame of 15 years. Alternative 3 requires achieving pore flushes alone to reduce COC concentrations, which does not provide a potential accelerated time frame. Additionally, as extracted groundwater will be used for mixing the carbon source, during ERD injection events there will be an extraction-injection forced flushing component, for as long as the injection occurs. This means the system will be constructed to support injection and extraction, and the value addition of carbon for the destructive pathway is logical. The difference in net present value of the costs

between Alternatives 1 and 3 is the continuous operation of the GWET system for an indefinite period of time in Alternative 3 as compared to injections for 5 years with Alternative 1. Moreover, based on the aquifer response to carbon injections, fewer injections may be required.

4. Alternative Selection and Discussion

The selected alternative for remediation at the Site is Alternative 1 – ERD with MNA. This section discusses Alternative 1 and the requisite pilot testing.

4.1 Pilot Testing Discussion

In order to implement an effective in situ remedial strategy that is based on adequate distribution of an aqueous-based treatment reagent, a pre-design injection testing is required. The pilot test specific to Alternative 1 will be designed to be incorporated into the full-scale implementation. Therefore, the pilot test will be scalable and the objectives will pertain to developing crucial design details to support full-scale implementation.

The objectives of the pilot test in support of Alternative 1 will be as follows:

- Determine the required injection volume to achieve an in-situ “working strength” of the injected reagent at the targeted radius of influence (ROI).

This objective is specifically related to understanding the mobile pore space of the aquifer. The mobile pore space describes the fraction of the total porosity readily accessible for treatment and driving the downgradient transport of COCs. The immobile pore space is the fraction of the total porosity that may store the bulk of residual mass that slowly diffuses out over time. Understanding how much volume needs to be injected to achieve an appropriate concentration of carbon at the design ROI determines the length of injection and the ultimate achievable spacing of injection wells.

- Determine the injection pressures and flow rates achievable without exerting a pressure that could result in aquifer deformation.

High injection pressures may result in shear fractures resulting in more defined and arbitrary preferential pathways. Injection over a saturated interval will be influenced by available thicknesses of higher hydraulic conductivities. This is the reasoning behind

nesting injection wells over a 15-foot injection thickness, as there is more control of reagent distribution while injecting over 15 feet rather than 30 feet. If hydraulic fractures are introduced, the reliability of achieving adequate radial distribution drops dramatically.

- Determine the site-specific first order degradation constant of PCE and carbon substrate.

In order to more completely understand the remedial time frame associated with Alternative 1, the first order decay rate of PCE and the organic carbon substrate (as total organic carbon) will be derived over the course of the pilot test injection and monitoring period.

- Determine an accurate magnitude and direction of the transport and bulk groundwater velocities.

This objective is specifically related to verifying the pore flushing estimates developed to determine the remedial time frames. Transport groundwater velocity describes the darcy velocity, and is responsible for downgradient COC transport. The bulk groundwater velocity describes the collective mass of COCs as they migrate downgradient, influenced by both porosity-driven and sorption-based retardation.

4.2 Conceptual Description of Design and Feasibility Study Costing

The conceptual design of Alternative 1 is shown on **Figure 9** and the engineering cost estimate is provided in **Table 2**. Subsurface injection and groundwater extraction conveyance lines will be required for this system installation. A small remediation building will be necessary to store the carbon source, the equalization tank for extracted groundwater, the pumps, and the telemetry and injection controls to operate the semi-automated mixing and injection system.

Although the ROI and mobile porosity will be verified during the pilot test, reasonable approximations based on available data have been made for conceptual design and costing purposes. The injection volume into a well is governed by the following equation:

$$V_{inj} = \pi \times ROI^2 \times h_{screen} \times \theta_m \times 7.48$$

Where:
V_{inj} = the injected volume in gallons (14,100 gallons per well);
ROI = the radius of influence (assumed to be 20 feet);
h_{screen} = the injection thickness (assumed to be 15 feet);
θ_m = mobile porosity (assumed to be 10 percent at the Site);
7.48 = conversion from cubic feet to gallons.

The conceptualized injection volume per well is 14,100 gallons.

The targeted injection concentration will be determined during the pilot test, but will be between 0.5 and 5 percent by volume. Various carbon reagents are available each with specific characteristics that are necessary in different aquifers. With a rapid ambient flushing velocity through this aquifer of 3 ft/d, a slightly less soluble form of carbon (like an emulsified vegetable oil) may be a more appropriate reagent to manage frequency of injections. However, without strong baseline evidence of intrinsic reductive dechlorination, a more soluble carbon source (like molasses or sodium lactate) may be required to provide readily available carbon in excess to rapidly facilitate methanogenic conditions.

Prior to implementing Alternative 1 and during the pilot testing, some pre-design work will be necessary to further characterize the dissolved phase plume and better understand the geochemistry to support the implementation of Alternative 1.

5. References

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TABLES

Table 1
Alternative Screening for Groundwater
7th Avenue and Bethany Home Road Water Quality Assurance Revolving Fund (WQARF) Site
Phoenix, Arizona

Evaluation Criteria	Component of Criterion	Alternative 1 - In Situ Enhanced Reductive Dechlorination and Monitored Natural Attenuation	Alternative 2 - In Situ Chemical Oxidation and Monitored Natural Attenuation	Alternative 3 - Groundwater Extraction and Aboveground Treatment and Re-injection with Monitored Natural Attenuation
Threshold Criteria	Overall protection of human health and environment	**Moderate to High**. ERD is protective of human health and the environment because COCs are biologically destroyed hence removing the contamination. Treated groundwater requires sometime to re-equilibrate to ambient conditions for secondary water quality objectives.	**Moderate to High.** ISCO is protective of human health and the environment because COCs are chemically destroyed hence removing the contamination. Treated groundwater requires sometime to re-equilibrate to ambient conditions for secondary water quality objectives.	**Moderate.** GWET is protective of human health and the environment because COCs are physically removed from the aquifer and groundwater pumping maintains control of the plume. The effectiveness of GWET can be limited by matrix effects in the aquifer leading to an indeterminate operating timeframe.
	Compliance with ARARs	**Yes**. ARARs discussed in Appendix **A** and would be met by all proposed Alternatives.		
Primary Criteria	Long-term effectiveness and permanence	**High**. The endpoint of ERD is achieving RAOs in the aquifer as a result of destroying COCs. Therefore, there is no residual risk. The adequacy and reliability of ERD has been proven.	**High**. The endpoint of ISCO is achieving RAOs in the aquifer as a result of destroying COCs. Therefore, there is no residual risk. The adequacy and reliability of ISCO has been proven.	**Moderate**. The endpoint of GWET is achieving RAOs by physically removing COCs from the aquifer. This removal can be limited and therefore residual risk could remain in the aquifer to perpetuity.
	Reductions in toxicity, mobility, and volume through treatment	**High**. ERD physically destroys COCs resulting in benign end products. All hazardous material is destroyed thereby permanently eliminating toxic mobility. ERD is an irreversible process.	**High**. ISCO physically destroys COCs resulting in benign end products. All hazardous material is destroyed thereby permanently eliminating toxic mobility. ISCO is an irreversible process.	**High**. GWET physically removes COCs. All hazardous material is eventually removed thereby permanently eliminating toxic mobility. GWET is an irreversible process.
Primary Criteria	Short-term effectiveness	**Moderate**. ERD is a biological strategy and baseline data does not demonstrate a considerable degree of natural reductive dechlorination, which may lead to a lag phase. Implementation of ERD will not pose a significant threat to the community, workers, or the environment.	**Moderate to High**. ISCO is a chemical strategy and is expected to immediately reduce COCs. Implementation of ISCO will not pose a significant threat to the community or environment, but does pose a slight risk to workers.	**High**. GWET will initially extract all readily available and mobile COCs and impose hydraulic control of plume migration thus demonstrating a high short term effectiveness. Implementation of GWT will not pose a significant threat to the community, workers, or environment.
	Implementability	**High**. Necessary equipment and labor is readily available. ERD is a proven technology that has transparent performance metrics to gauge effectiveness. Injected reagent is typically edible, and approval by agencies can be readily obtained.	**Moderate to High**. Necessary equipment and labor is readily available. ISCO is a proven technology that has transparent performance metrics to gauge effectiveness. Injected reagent is typically regulated, though approval by agencies can be obtained.	**High**. Necessary equipment and labor is readily available. GWET is a proven technology that has transparent performance metrics to gauge effectiveness.
Primary Criteria	Cost[1]	Capital Cost:$971,300 Annual O&M Cost: $153,300 (Y1-Y5) $32,300 (Y5-Y10) $21,600 (Y10-Y15) Present Worth: $1,837,000	Capital Cost:$1,391,800 Annual O&M Cost: $713,200 (Y1-Y5) $31,800 (Y5-Y10) $21,400 (Y10-Y15) Present Worth: $3,680,000	Capital Cost:$682,900 Annual O&M Cost: $125,500 (Y1-Y5) $114,600 (Y5-Y10) $108,300 (Y10-Y15) Present Worth: $1,986,000

Notes:
[1] = Cost with 30% contingency
Threshold Criteria: Relate directly to statutory findings and must be met.
Primary Criteria: Key elements upon which evaluation of alternatives is completed.
ARAR - Applicable or Relevant and Appropriate Requirements
COCs - Constituents of Concern
ERD - Enhanced Reductive Dechlorination
GWET - Groundwater Extraction and Treatment
ISCO - In Situ Chemical Oxidation
MNA - Monitored Natural Attenuation
O&M - Operation and Maintenance
RAOs - Remedial Action Objectives

Table 2
Feasibility Costing for Alterantive 1
7th Avenue and Bethany Home Road Water Quality Assurance Revolving Fund (WQARF) Site
Phoenix, Arizona

Task Description	Unit	Unit Cost	Quantity	Cost	Cost with 30% Contingency	Source
Capital Investment for Enhanced Reductive Dechlorination						
Administrative/Regulatory Interface for ERD				**$200,000**	**$260,000**	
RDI/RD work plans, design, specifications, and documents	LS	$200,000	1	$200,000	$260,000	
Mobilization/Demobilization				**$45,000**	**$58,500**	
Site survey/Utility Mark Out	LS	$10,000	1	$10,000	$13,000	
Equipment & Manpower Mobilization/Demobilization	LS	$10,000	1	$10,000	$13,000	
Subcontractor/Equipment/Materials Procurement	LS	$25,000	1	$25,000	$32,500	
Injection and Monitoring Well Installation				**$248,000**	**$322,400**	
Injection Well Installation: 26 stainless steel wells, screened 15 feet. **New Monitoring Wells:** 5 PVC construction, screened 15 feet. Drilling, materials, per diem, decontamination, permits, IDW management, drums included.	LS	$7,500	31	$232,500	$302,250	
Drilling oversight (one staff professional)	Day	$1,000	15.5	$15,500	$20,150	
Injection Treatment System				**$207,500**	**$269,750**	
Trenching, piping, backfill, resurfacing	LF	$55	1,000	$55,000	$71,500	
Instrumentation and Piping Conveyance	LS	$25,000	1	$25,000	$32,500	
Equalization Tank	LS	$7,500	1	$7,500	$9,750	
Reagent Feed System/Tanks/Pumps/Filters	LS	$20,000	1	$20,000	$26,000	
Static Mixers	LS	$5,000	2	$10,000	$13,000	
Control Panel/Telemetry	LS	$50,000	1	$50,000	$65,000	
Building, piping, valves, fittings, other misc. equipment	LS	$10,000	1	$10,000	$13,000	
Electrical Install and Start Up	LS	$30,000	1	$30,000	$39,000	
Personnel Oversight Costs				**$67,500**	**$87,750**	
On-site resident construction engineer	Day	$1,000	50	$50,000	$65,000	
Truck, Health & Safety Monitoring Equipment, Expendables	Day	$350	50	$17,500	$22,750	
Treatability Pilot Testing				**$75,000**	**$97,500**	
Pilot Testing	LS	$75,000	1	$75,000	$97,500	
As-built and Pilot Test Reporting				**$40,000**	**$52,000**	
Report plus Meetings, Revisions	LS	$40,000	1	$40,000	$52,000	
Project Management and Administrative				**$88,300**	**$114,790**	
Project Management and Administrative (10% of capital cost)	LS	$88,300	1	$88,300	$114,790	
Project Management Subtotal				**$88,300**	**$114,800**	
Total Capital Investment for In Situ Groundwater Treatment				**$971,300**	**$1,262,700**	
Task Description	**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Cost with 30% Contingency**	
Operation and Maintenance Costs for ERD						
Annual Performance Monitoring Program Costs						
Task Description	**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Cost with 30% Contingency**	**Source**
Quarterly Monitoring for 5 Years (costs below include 4 full rounds of sampling of 14 wells including one duplicate and one field blank per year).						
Labor & Materials ($2,000 for two persons)	Day	$2,000	1	$2,000	$2,600	
Laboratory Sampling Costs	sample	$200	16	$3,200	$4,160	
Groundwater Sampling Kit, Truck, Expendables	Day	$750	1	$750	$975	
Report/Regulatory Interfacing/Administrative	LS	$15,000	1	$15,000	$19,500	
Monitoring/Reporting Per Event				**$5,950**	**$7,735**	
Annual Monitoring/Reporting Subtotal - Years 1 through 5				**$38,800**	**$50,400**	
SemiAnnual Monitoring for 5 Years (costs below include 2 full rounds of sampling of 14 wells including one duplicate and one field blank per year).						
Labor & Materials ($2000 for two persons)	Day	$2,000	1	$2,000	$2,600	
Laboratory Sampling Costs	sample	$200	16	$3,200	$4,160	
Groundwater Sampling Kit, Truck, Expendables	Day	$750	1	$750	$975	
Report/Regulatory Interfacing/Administrative	LS	$15,000	1	$15,000	$19,500	
Monitoring/Reporting Per Event				**$5,950**	**$7,735**	
Annual Monitoring/Reporting Subtotal - Years 5 through 10				**$26,900**	**$35,000**	
Annual Monitoring for 5 Years (costs below include 1 full round of sampling of 14 wells including one duplicate and one field blank per year).						
Labor & Materials ($2000 for two persons)	Day	$2,000	1	$2,000	$2,600	
Laboratory Sampling Costs	sample	$200	16	$3,200	$4,160	
Groundwater Sampling Kit, Truck, Expendables	Day	$750	1	$750	$975	
Report/Regulatory Interfacing/Administrative	LS	$15,000	1	$15,000	$19,500	
Monitoring/Reporting Per Event				**$5,950**	**$7,735**	
Annual Monitoring/Reporting Subtotal - Years 10 through 15				**$21,000**	**$27,300**	
Annual Operation and Maintenance						
Carbon Substrate (includes shipping)	LS	$40,000	1	$40,000	$52,000	
Injection Labor, Miscellaneous O&M Expenses:	LS	$50,000	1	$50,000	$65,000	
Subtotal Annual O&M				**$90,000**	**$117,000**	
Project Management and Administrative (PMA)						
Project Management and Administrative (PMA) - Years 1 through 5	LS	$24,500	1	$24,500	$31,850	
Project Management and Administrative (PMA) - Years 5 through 10	LS	$5,400	1	$5,400	$7,020	
Project Management and Administrative (PMA) - Years 10 through 15	LS	$600	1	$600	$780	
Present Worth (7% Interest Rate, 3% Inflation, 15 years)				**$1,837,000**	**$2,388,000**	

Notes:

Total Annual and Capital Costs have been rounded to the nearest $100.

LS = lump sum

Table 3
Feasibility Costing for Alterantive 2
7th Avenue and Bethany Home Road Water Quality Assurance Revolving Fund (WQARF) Site
Phoenix, Arizona

Task Description	Unit	Unit Cost	Quantity	Cost	Cost with 30% Contingency	Source
Capital Investment for In Situ Chemical Oxidation						
Administrative/Regulatory Interface for ISCO				**$200,000**	**$260,000**	
RDI/RD work plans, design, specifications, and documents	LS	$200,000	1	$200,000	$260,000	
Mobilization/Demobilization				**$45,000**	**$58,500**	
Site survey/Utility Mark Out	LS	$10,000	1	$10,000	$13,000	
Equipment & Manpower Mobilization/Demobilization	LS	$10,000	1	$10,000	$13,000	
Subcontractor/Equipment/Materials Procurement	LS	$25,000	1	$25,000	$32,500	
Injection and Monitoring Well Installation				**$544,000**	**$707,200**	
Injection Well Installation: 64 stainless steel wells, screened 15 feet. **New Monitoring Wells:** 4 PVC construction, screened 15 feet. Drilling, materials, per diem, decontamination, permits, IDW management, drums included.	LS	$7,500	68	$510,000	$663,000	
Drilling oversight (one staff professional)	Day	$1,000	34	$34,000	$44,200	
Injection Treatment System				**$293,750**	**$381,875**	
Trenching, piping, backfill, resurfacing	LF	$55	750	$41,250	$53,625	
Instrumentation and Piping Conveyance	LS	$50,000	1	$50,000	$65,000	
Equalization Tank	LS	$7,500	3	$22,500	$29,250	
Chemical Feed System/Tanks/Pumps	LS	$40,000	1	$40,000	$52,000	
Static Mixers	LS	$5,000	2	$10,000	$13,000	
Control Panel/Telemetry	LS	$75,000	1	$75,000	$97,500	
Building, piping, valves, fittings, other misc. equipment	LS	$15,000	1	$15,000	$19,500	
Electrical Install and Start Up	LS	$40,000	1	$40,000	$52,000	
Personnel Oversight Costs				**$67,500**	**$87,750**	
On-site resident construction engineer	Day	$1,000	50	$50,000	$65,000	
Truck, Health & Safety Monitoring Equipment, Expendables	Day	$350	50	$17,500	$22,750	
Treatability Pilot Testing				**$75,000**	**$97,500**	
Bench Testing	LS	$40,000	1	$40,000	$52,000	
Pilot Testing	LS	$35,000	1	$35,000	$45,500	
As-built and Treatability/Pilot Test Reporting				**$40,000**	**$52,000**	
Report plus Meetings, Revisions	LS	$40,000	1	$40,000	$52,000	
Project Management and Administrative				**$126,525**	**$164,483**	
Project Management and Administrative (10% of capital cost)	LS	$126,525	1	$126,525	$164,483	
Project Management Subtotal				**$126,525**	**$164,500**	
Total Capital Investment for In Situ Groundwater Treatment				**$1,391,800**	**$1,809,300**	
Task Description	**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Cost with 30% Contingency**	
Operation and Maintenance Costs for ISCO						
Annual Performance Monitoring Program Costs						
Task Description	**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Cost with 30% Contingency**	**Source**
Quarterly Monitoring for 5 Years (costs below include 4 full rounds of sampling of 13 wells including one duplicate and one field blank per year).						
Labor & Materials ($2,000 for two persons)	Day	$2,000	1	$2,000	$2,600	
Laboratory Sampling Costs	sample	$200	15	$3,000	$3,900	
Groundwater Sampling Kit, Truck, Expendables	Day	$750	1	$750	$975	
Report/Regulatory Interfacing/Administrative	LS	$15,000	1	$15,000	$19,500	
Monitoring/Reporting Per Event				**$5,750**	**$7,475**	
Annual Monitoring/Reporting Subtotal - Years 1 through 5				**$38,000**	**$49,400**	
SemiAnnual Monitoring for 5 Years (costs below include 2 full rounds of sampling of 13 wells including one duplicate and one field blank per year).						
Labor & Materials ($2000 for two persons)	Day	$2,000	1	$2,000	$2,600	
Laboratory Sampling Costs	sample	$200	15	$3,000	$3,900	
Groundwater Sampling Kit, Truck, Expendables	Day	$750	1	$750	$975	
Report/Regulatory Interfacing/Administrative	LS	$15,000	1	$15,000	$19,500	
Monitoring/Reporting Per Event				**$5,750**	**$7,475**	
Annual Monitoring/Reporting Subtotal - Years 5 through 10				**$26,500**	**$34,500**	
Annual Monitoring for 5 Years (costs below include 1 full round of sampling of 13 wells including one duplicate and one field blank per year).						
Labor & Materials ($2000 for two persons)	Day	$2,000	1	$2,000	$2,600	
Laboratory Sampling Costs	sample	$200	15	$3,000	$3,900	
Groundwater Sampling Kit, Truck, Expendables	Day	$750	1	$750	$975	
Report/Regulatory Interfacing/Administrative	LS	$15,000	1	$15,000	$19,500	
Monitoring/Reporting Per Event				**$5,750**	**$7,475**	
Annual Monitoring/Reporting Subtotal - Years 10 through 15				**$20,800**	**$27,000**	
Annual Operation and Maintenance						
Chemical Reagent (includes shipping)	LS	$1.5	380,000	$570,000	$741,000	
Injection Labor, Miscellaneous O&M Expenses:	LS	$30,000	1	$30,000	$39,000	
Subtotal Annual O&M				**$600,000**	**$780,000**	
Project Management and Administrative (PMA)						
Project Management and Administrative (PMA) - Years 1 through 5	LS	$75,200	1	$75,200	$97,760	
Project Management and Administrative (PMA) - Years 5 through 10	LS	$5,300	1	$5,300	$6,890	
Project Management and Administrative (PMA) - Years 10 through 15	LS	$600	1	$600	$780	
Present Worth (7% Interest Rate, 3% Inflation, 15 years)				**$3,680,000**	**$4,784,000**	

Notes:

Total Annual and Capital Costs have been rounded to the nearest $100.

LS = lump sum

Table 4
Feasibility Costing for Alterantive 3
7th Avenue and Bethany Home Road Water Quality Assurance Revolving Fund (WQARF) Site
Phoenix, Arizona

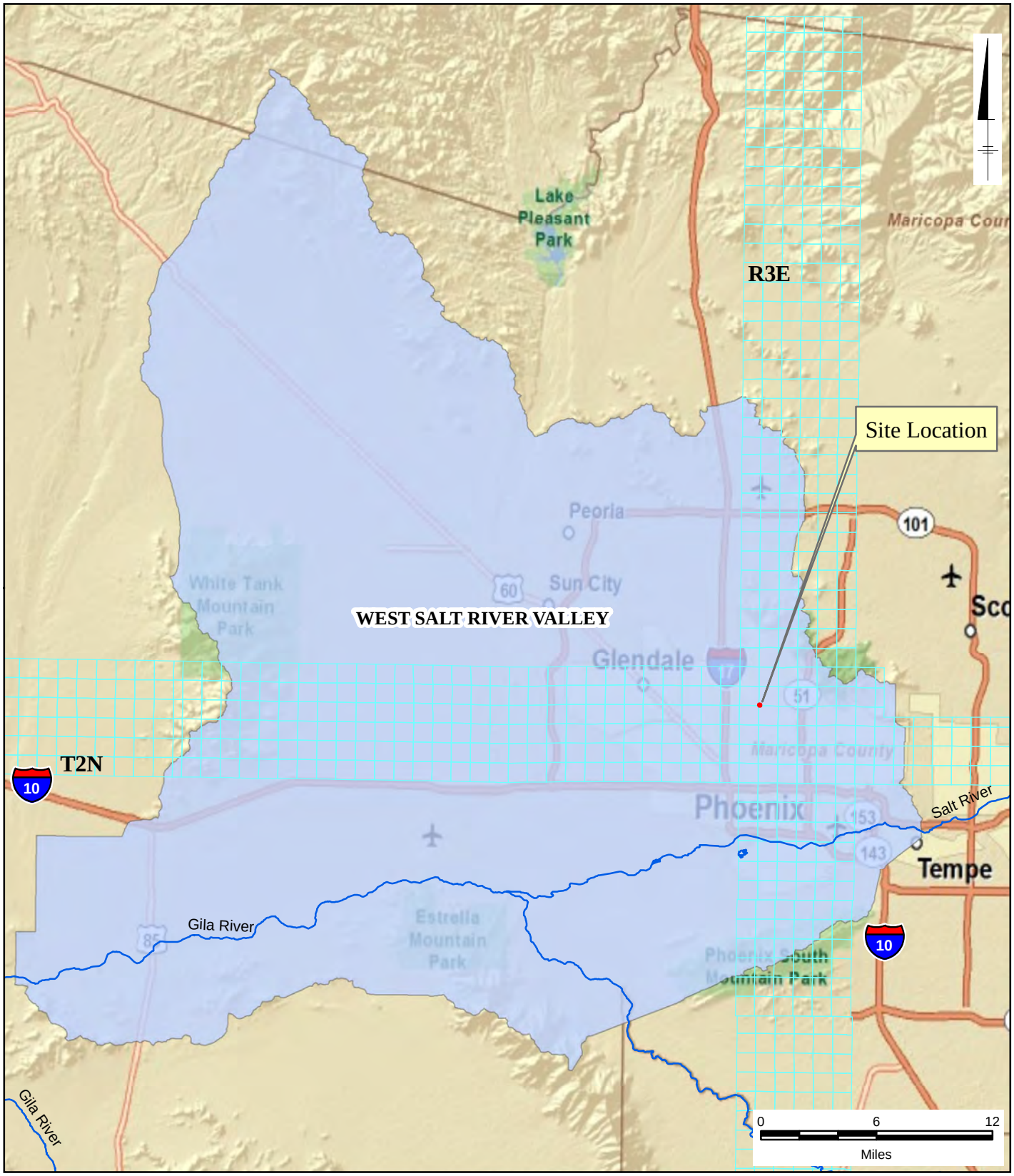
Task Description	Unit	Unit Cost	Quantity	Cost	Cost with 30% Contingency	Source
Capital Investment for Extraction						
Administrative/Regulatory Interface for GWET				**$200,000**	**$260,000**	
RDI/RD work plans, design, specifications, and documents	LS	$200,000	1	$200,000	$260,000	
Mobilization/Demobilization				**$45,000**	**$58,500**	
Site survey/Utility Mark Out	LS	$10,000	1	$10,000	$13,000	
Equipment & Manpower Mobilization/Demobilization	LS	$10,000	1	$10,000	$13,000	
Subcontractor/Equipment/Materials Procurement	LS	$25,000	1	$25,000	$32,500	
Extraction, Injection and Monitoring Well Installation				**$125,333**	**$162,933**	
Extraction Well Installation: 4 stainless steel wells screened 80 to 120 feet bgs. **Injection Well Installation:** 8 PVC wells screened 80 to 120 feet bgs. **New Monitoring Wells:** 4. Mobilization, per diem, decontamination, permits, IDW management, drums included.	LS	$7,500	16	$120,000	$156,000	
Drilling oversight (one staff professional)	Day	$1,000	5	$5,333	$6,933	
Extracted Groundwater Treatment System				**$163,000**	**$211,900**	
Submersible extraction pumps	LS	$1,500	4	$6,000	$7,800	
Trenching, piping, backfill, resurfacing	LS	$55	1,500	$82,500	$107,250	
Equalization Tank	LS	$7,500	1	$7,500	$9,750	
Granular activated carbon vessels	LS	$20,000	1	$20,000	$26,000	
Transfer Pump	LS	$2,000	1	$2,000	$2,600	
Control Panel/Telemetry	LS	$25,000	1	$25,000	$32,500	
Building, piping, valves, fittings, other misc. equipment	LS	$10,000	1	$10,000	$13,000	
Electrical	LS	$10,000	1	$10,000	$13,000	
Personnel Oversight Costs				**$65,000**	**$84,500**	
On-site resident construction engineer	Day	$1,000	50	$50,000	$65,000	
Truck, Health & Safety Monitoring Equipment, Expendables	Day	$300	50	$15,000	$19,500	
As-built Reporting				**$22,500**	**$29,250**	
Report plus Meetings, Revisions	LS	$22,500	1	$22,500	$29,250	
Project Management and Administrative				**$62,100**	**$80,730**	
Project Management and Administrative (10% of capital cost)	LS	$62,100	1	$62,100	$80,730	
Project Management Subtotal				**$62,100**	**$80,700**	
Total Capital Investment for In Situ Groundwater Treatment				**$682,900**	**$887,800**	
Task Description	**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Cost with 30% Contingency**	
Operation and Maintenance Costs for Extraction System Operation						
Annual Performance Monitoring Program Costs						
Task Description	**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Cost with 30% Contingency**	**Source**
Quarterly Monitoring for 5 Years (costs below include 4 full rounds of sampling 13 wells including one duplicate and one field blank per year).						
Labor & Materials ($1,000 for two persons)	Day	$2,000	1	$2,000	$2,600	
Laboratory Sampling Costs	sample	$200	15	$3,000	$3,900	
Groundwater Sampling Kit, Truck, Expendables	Day	$750	1	$750	$975	
Report/Regulatory Interfacing/Administrative	LS	$15,000	1	$15,000	$19,500	
Monitoring/Reporting Per Event				**$5,350**	**$6,955**	
Annual Monitoring/Reporting Subtotal - Years 1 through 5				**$36,400**	**$47,300**	
Semiannual Monitoring for 5 Years (costs below include 2 full rounds of sampling 13 wells including one duplicate and one field blank per year).						
Labor & Materials ($1,000 for two persons)	Day	$2,000	1	$2,000	$2,600	
Laboratory Sampling Costs	sample	$200	15	$3,000	$3,900	
Groundwater Sampling Kit, Truck, Expendables	Day	$750	1	$750	$975	
Report/Regulatory Interfacing/Administrative	LS	$15,000	1	$15,000	$19,500	
Monitoring/Reporting Per Event				**$5,750**	**$7,475**	
Annual Monitoring/Reporting Subtotal - Years 5 through 10				**$26,500**	**$34,500**	
Annual Monitoring for 5 Years (costs below include 1 full round of sampling 13 wells including one duplicate and one field blank per year).						
Labor & Materials ($2,000 for two persons)	Day	$2,000	1	$2,000	$2,600	
Laboratory Sampling Costs	sample	$200	15	$3,000	$3,900	
Groundwater Sampling Kit, Truck, Expendables	Day	$750	1	$750	$975	
Report/Regulatory Interfacing/Administrative	LS	$15,000	1	$15,000	$19,500	
Monitoring/Reporting Per Event				**$5,750**	**$7,475**	
Annual Monitoring/Reporting Subtotal - Years 10 through 15				**$20,800**	**$27,000**	
Annual Operation and Maintenance						
Lifecycle replacement equipment	LS	$10,000	1	$10,000	$13,000	
Electricity for All Equipment (4 hp x 0.75 = 3 kW/hr (operating 24 hrs & 330 days/year = 7920 hrs)	kW-hr	$0.15	30,000	$4,500	$5,850	
GAC Change Outs	LS	$5,000	1	$5,000	$6,500	
Waste disposal	Ton	$45	2	$90	$117	
Subtotal Annual O&M				**$19,590**	**$25,467**	
Treatment System O&M and Monitoring						
System Opearator	day	$1,000	26	$26,000	$33,800	
Groundwater Influent Monthly Samples	sample	$85	12	$1,020	$1,326	
Groundwater Effluent Monthly Samples	sample	$85	12	$1,020	$1,326	
Annual report plus meetings	LS	$30,000	1	$30,000	$39,000	
Subtotal First Treatment System Monitoring				**$58,040**	**$75,452**	
Project Management and Administrative (PMA)						
Project Management and Administrative (PMA) Years 1 through 5	LS	$11,400	1	$11,400	$14,820	
Project Management and Administrative (PMA) Years 5 through 10	LS	$10,400	1	$10,400	$13,520	
Project Management and Administrative (PMA) Years 10 through 15	LS	$9,800	1	$9,800	$12,740	
Present Worth (7% Interest Rate, 3% Inflation 15 years)				**$1,986,000**	**$2,536,000**	

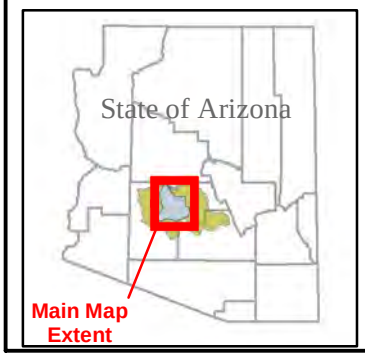
Notes:

Total Annual and Capital Costs have been rounded to the nearest $100.

LS = lump sum

FIGURES





LEGEND:

- River
- Section
- West Salt River Basin
- Phoenix AMA

7th Ave & Bethany Home Rd
WQARF Site

FEASIBILITY STUDY

Location Map

ARCADIS

FIGURE
1

CITY: (DENVER) DIV/GROUP:(ENV)
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LEGEND:

- Soil Boring (abandoned)
- New SVE Well
- Existing Monitor Well
- Former Buildings
- Site Boundary
- Septic Pipping

7th Ave & Bethany Home Rd
WQARF Site

FEASIBILITY STUDY

Site Map with Monitoring Well Network (Bayless Property)

ARCADIS

FIGURE
2

CITY: (DENVER) DIV/GROUP:(ENV)
PROJECT: ADEQ 7TH & BETHANY FS
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LEGEND:

- Monitor Well
- Former Seepage Pit
- Former Septic Tank
- Dry Well
- Former Septic System Area
- Limits of Excavation
- Parcel
- Former Tank Pit
- Property Boundary

Aerial Photo Copyright of Maricopa County Assesor, flown in 2007.

7th Ave & Bethany Home Rd
WQARF Site

FEASIBILITY STUDY

Site Map with Monitoring Well Network (SCI Property)

ARCADIS

FIGURE
3

CITY: (DENVER) DIV/GROUP: (ENV)
PROJECT: ADEQ 7TH & BETHANY FS
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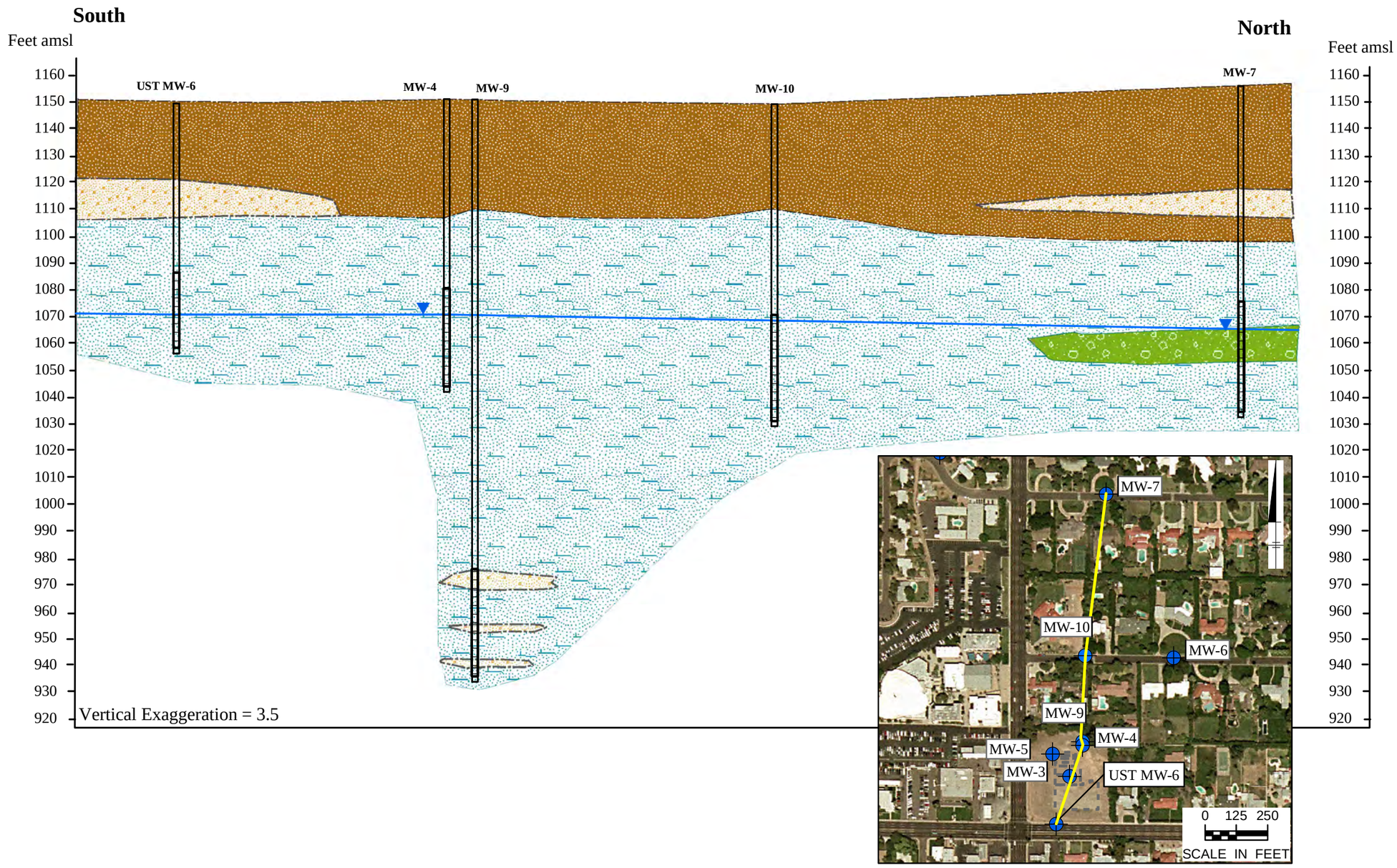

Legend

- Sandy Gravel
- Fine Sand/Silt
- Sandy Clay/Clay/Silt
- Groundwater Elevation
- Well Screen
- Existing Monitoring Well
- Former Buildings

7th Ave & Bethany Home Rd
WQARF Site
Feasibility Study

Geologic Cross Section (S-N)

ARCADIS

FIGURE
4

CITY: (DENVER) DIV/GROUP: (ENV)
PROJECT: ADEQ 7TH & BETHANY FS
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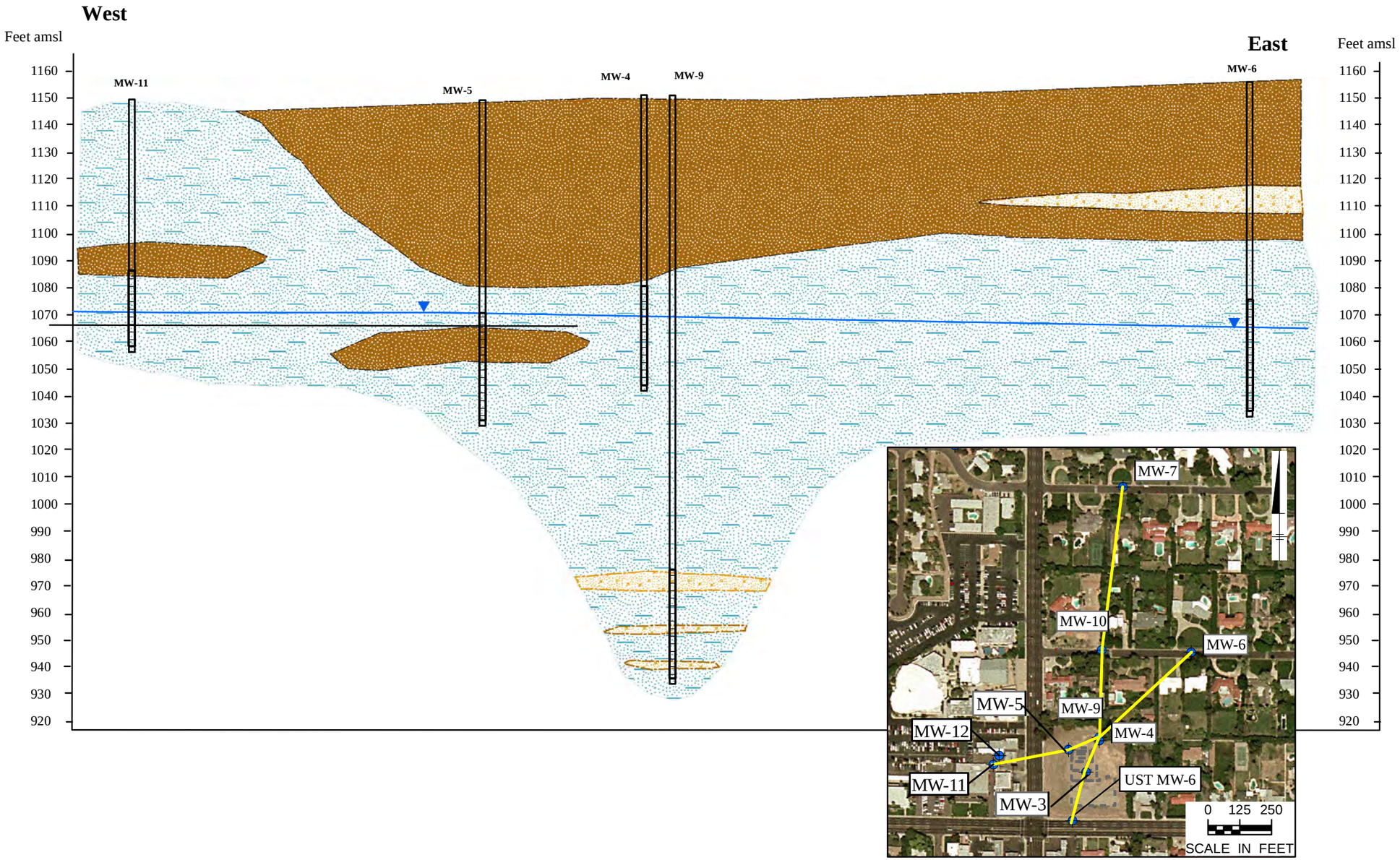

Legend

- Fine Sand/Silt
- Fine -Coarse Sand
- Sandy Clay/Clay/Silt
- Water Elevation
- Well Screen
- Existing Monitoring Well
- Former Buildings

7th Ave & Bethany Home Rd
WQARF Site
Feasibility Study

Geologic Cross Section (W-E)

ARCADIS

FIGURE
5

CITY: (DENVER) DIV/GROUP: (ENV)
PROJECT: ADEQ 7TH & BETHANY FS
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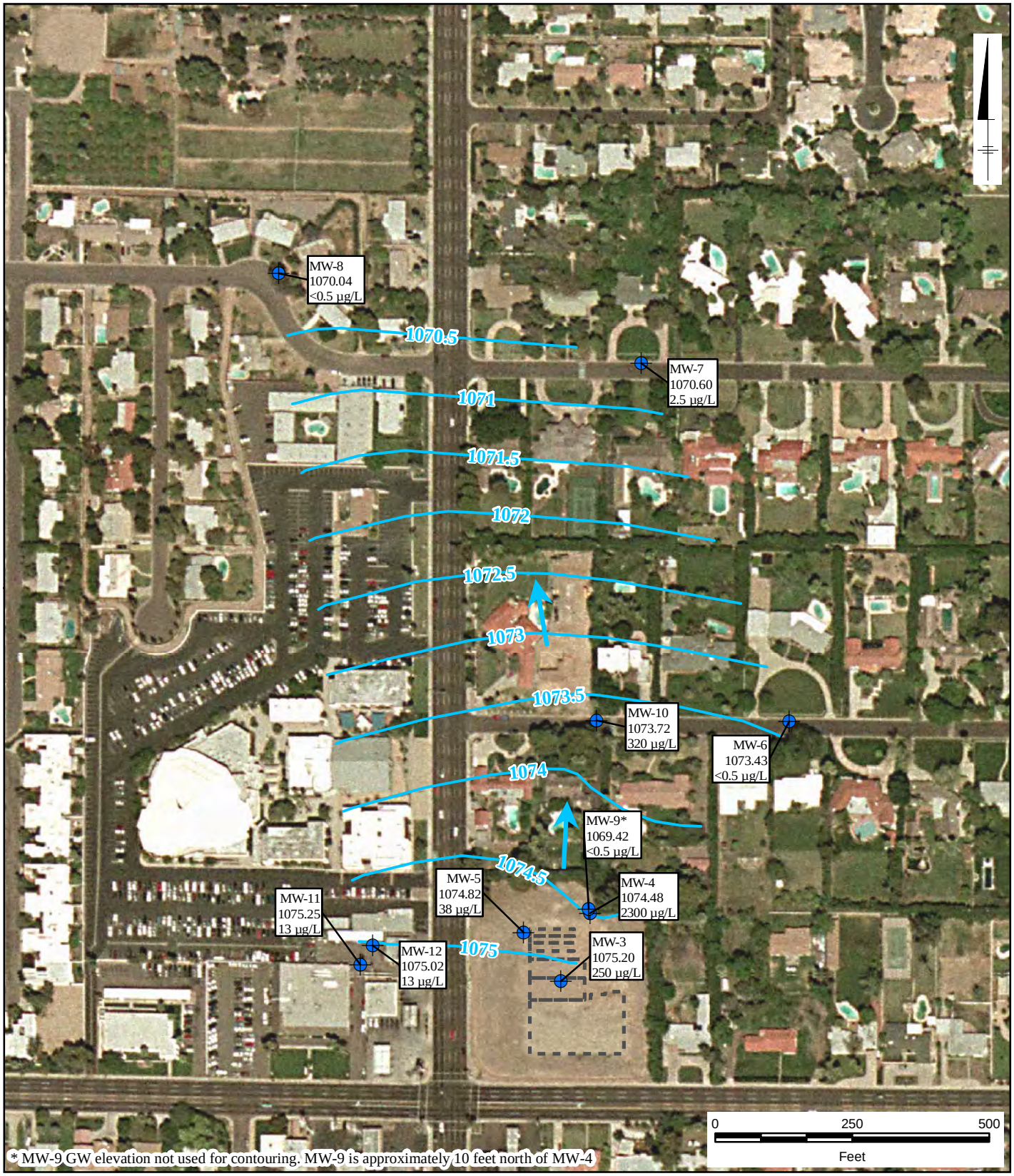

* MW-9 GW elevation not used for contouring. MW-9 is approximately 10 feet north of MW-4

LEGEND:

- Monitor Well
- January 2012 Groundwater Elevation Contours (ft amsl)
- Former Buildings
- MW-3 / 1075.20 / 250 µg/L — Monitor Well Name; January 17, 2012 Groundwater Elevation (ft amsl); PCE Concentration (µg/L)
- General Groundwater Direction

7th Ave & Bethany Home Rd
WQARF Site

FEASIBILITY STUDY

Sitewide Groundwater Elevations and PCE Concentrations (January 2012)

ARCADIS

FIGURE
6

CITY: (DENVER) DIV/GROUP: (ENV)
PROJECT: ADEQ 7TH & BETHANY FS
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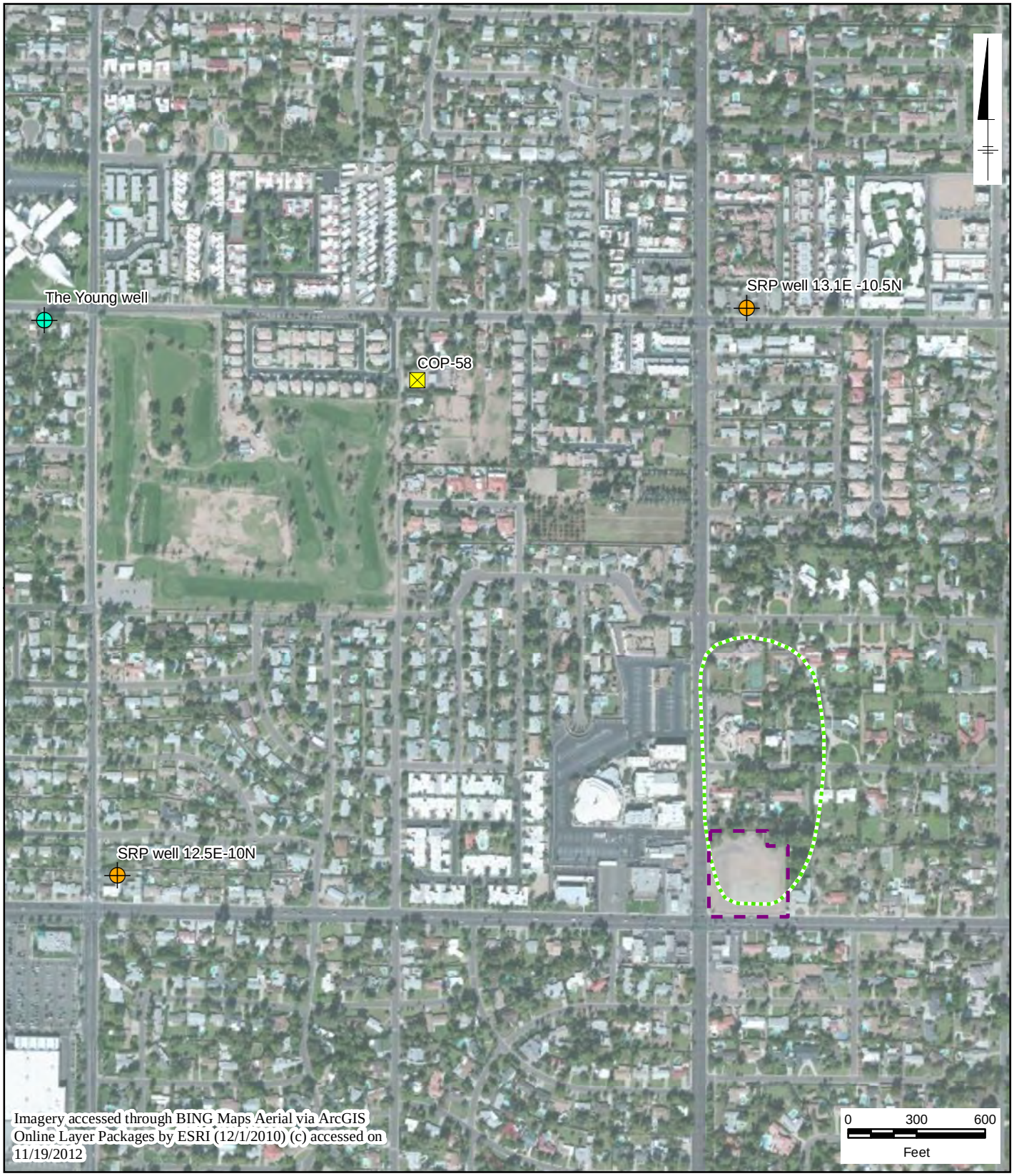

LEGEND:

- SRP Well
- Private Well
- City of Phoenix Well 58 (55-626549)
- Bayless Property Site Boundary
- Estimated Plume Boundary

7th Ave & Bethany Home Rd
WQARF Site

FEASIBILITY STUDY

Site Map with City of Phoenix Well, SRP Wells, and Estimated Plume Boundary

ARCADIS

FIGURE
7

CITY: (DENVER) DIV/GROUP:(ENV)
PROJECT: ADEQ 7TH & BETHANY FS
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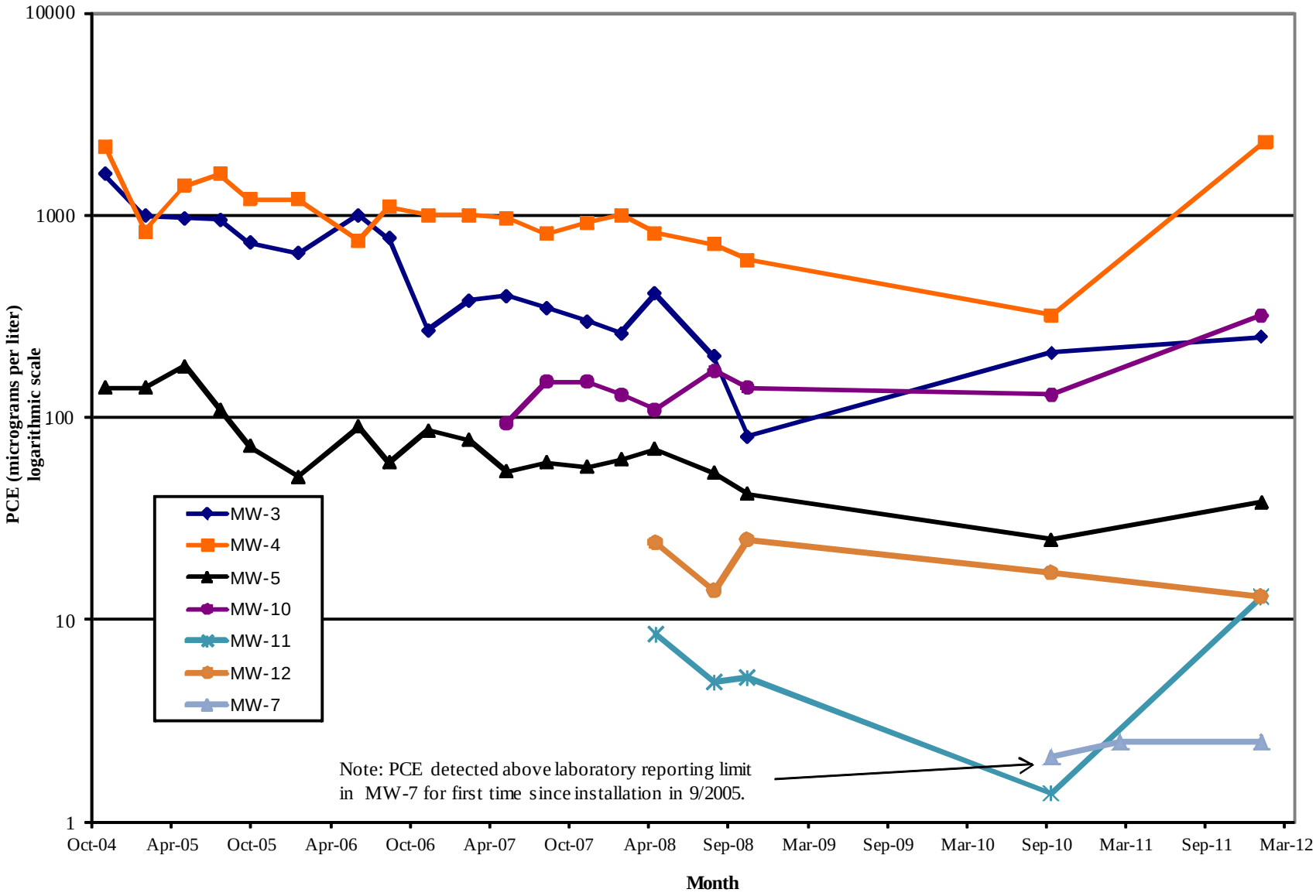

7th Ave & Bethany Home Rd
WQARF Site
FEASIBILITY STUDY

PCE Concentration Trend Graphs

ARCADIS

FIGURE
8

CITY: (DENVER) DIV/GROUP:(ENV)
PROJECT: ADEQ 7TH & BETHANY FS
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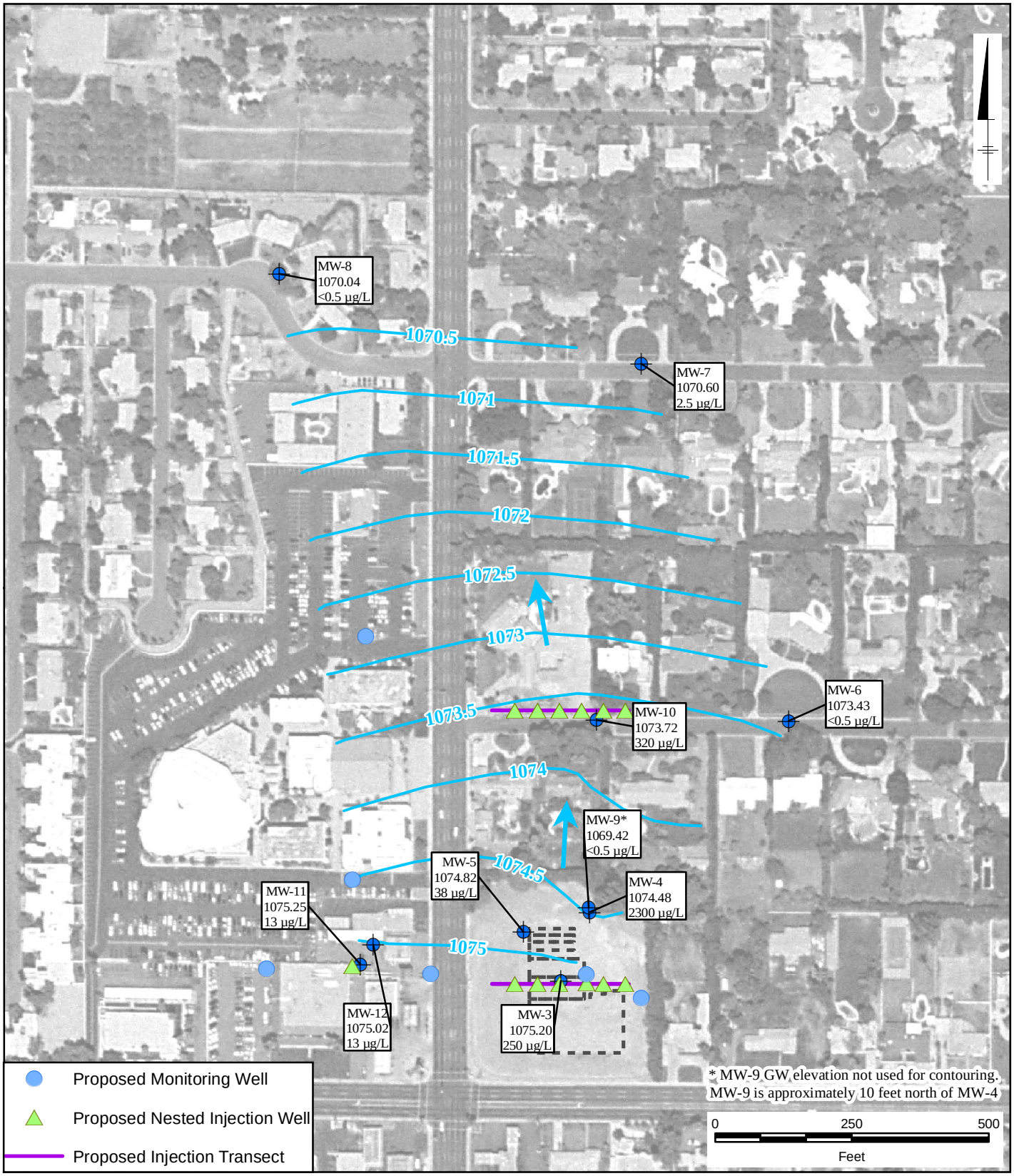

LEGEND:

- Monitor Well
- January 2012 Groundwater Elevation Contours (ft amsl)
- Former Buildings
- MW-3 / 1075.20 / 250 µg/L — Monitor Well Name; January 17, 2012 Groundwater Elevation (ft amsl); PCE Concentration (µg/L)
- General Groundwater Direction

7th Ave & Bethany Home Rd
WQARF Site

FEASIBILITY STUDY

Conceptual Design for Alternative 1: In Situ Enhanced Reductive Dechlorination with Monitored Natural Attenuation

ARCADIS

FIGURE
9

CITY: (DENVER) DIV/GROUP:(ENV)
PROJECT: ADEQ 7TH & BETHANY FS
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LEGEND:

- Monitor Well
- January 2012 Groundwater Elevation Contours (ft amsl)
- Former Buildings
- MW-3 / 1075.20 / 250 µg/L — Monitor Well Name; January 17, 2012 Groundwater Elevation (ft amsl); PCE Concentration (µg/L)
- General Groundwater Direction

7th Ave & Bethany Home Rd
WQARF Site

FEASIBILITY STUDY

Conceptual Design for Alternative 2: In Situ Chemical Oxidation with Monitored Natural Attenuation

ARCADIS

FIGURE
10

CITY: (DENVER) DIV/GROUP:(ENV)
PROJECT: ADEQ 7TH & BETHANY FS
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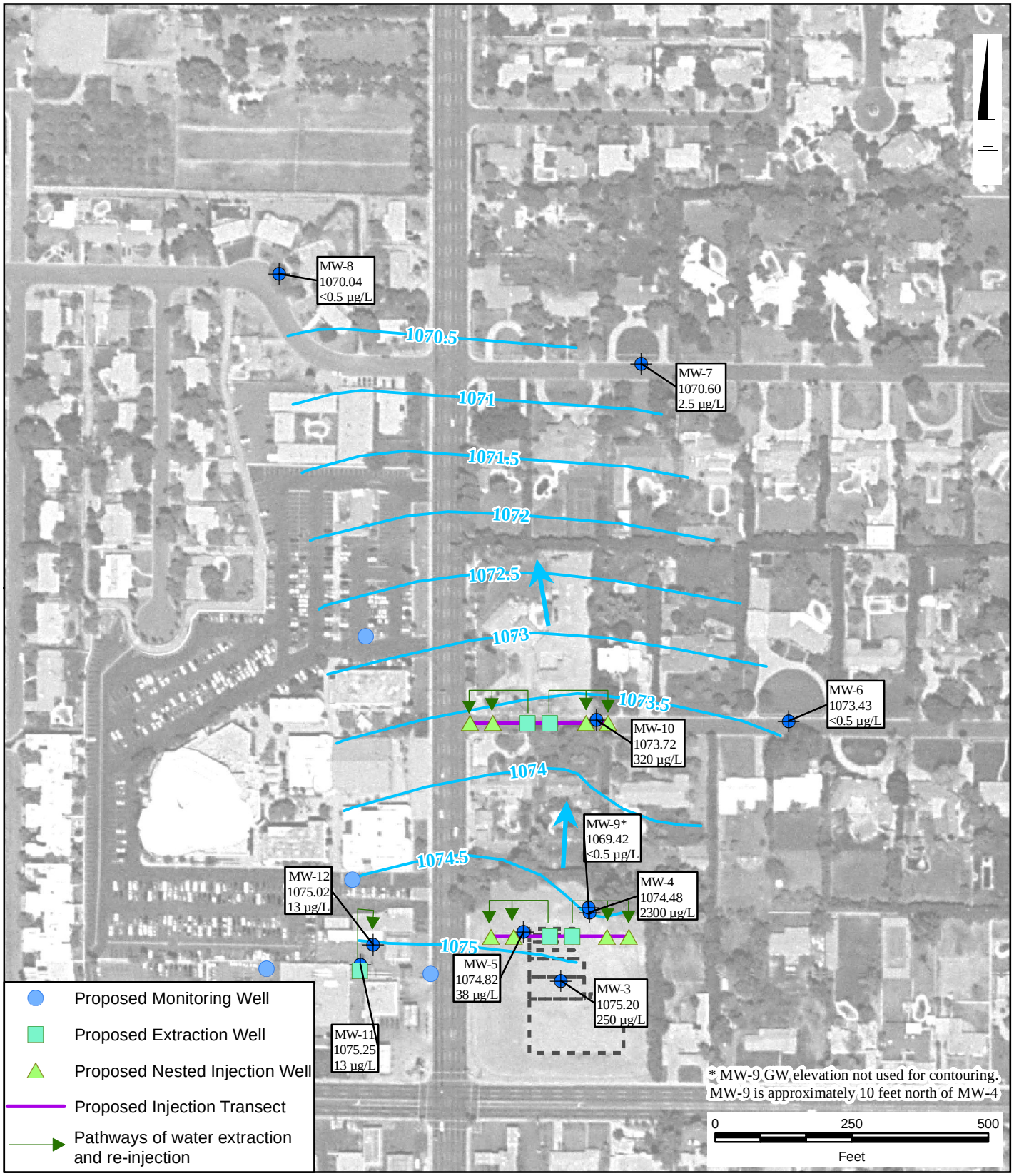

LEGEND:

- Monitor Well
- January 2012 Groundwater Elevation Contours (ft amsl)
- Former Buildings
- MW-3 / 1075.20 / 250 µg/L — Monitor Well Name; January 17, 2012 Groundwater Elevation (ft amsl); PCE Concentration (µg/L)
- General Groundwater Direction

7th Ave & Bethany Home Rd
WQARF Site

FEASIBILITY STUDY

Conceptual Design for Alternative 3: Groundwater Extraction and Treatment with Injection

ARCADIS

FIGURE
11

CITY: (DENVER) DIV/GROUP:(ENV)
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APPENDICES

Appendix A

ARAR Evaluation

Introduction

Federal and state statutes were considered as potential applicable or relevant and appropriate requirements (ARARs) for the 7th Avenue and Bethany Home Road Water Quality Assurance Revolving Fund Site (the Site) in Phoenix, Arizona. The ARARs for the chlorinated volatile organic compounds-(CVOCs-) contaminated groundwater remediation alternatives are presented in Table A-1 (chemical-specific ARARs for groundwater), Table A-2 (location-specific ARARs for groundwater), and Table A-3 (action-specific ARARs for groundwater).

TABLE A-1 Chemical-Specific ARARs for CVOC-Contaminated Groundwater

Standard, Requirement, Criteria, or Limitation	Applicable or Relevant and Appropriate	Description of Standard, Requirement, Criteria, or Limitation	Manner in Which ARAR Applies to Alternative
Safe Drinking Water Act (42 U.S.C. Sec 300g-1) 40 CFR Part 141 Subpart B, Maximum Contaminant Levels; Subpart G, National Primary Drinking Water Regulations: MCLs	Applicable	Establishes Maximum Contaminant Levels (MCLs). MCLs are standards that U.S. EPA has determined to be safe for drinking water and are applicable for groundwater that is or has the potential to be used as a drinking water source.	The remedial goals or the aquifer water quality standards (AWQSs) are defined as the MCLs for the contaminants of concern (COCs). The selected alternative will comply with these standards.
Clean Water Act (33 U.S.C. Secs 1311-1387)	Relevant and Appropriate	Regulates discharges of pollutants into waters of the United States and establishes water quality discharge standards for surface waters.	These standards would have been applicable if the selected alternative included discharge to a publicly owned treatment works (POTW).
Aquifer Water Quality Standards Arizona Administrative Code R18-11-405 and 406	Relevant and Appropriate	Establishes narrative and numeric aquifer water quality standards.	These standards are not applicable to the selected in situ alternative.

TABLE A-2 Location-Specific ARARs for CVOC-Contaminated Groundwater

Standard, Requirement, Criteria, or Limitation	Applicable or Relevant and Appropriate	Description of Standard, Requirement, Criteria, or Limitation	Manner in Which ARAR Applies to Alternative
Endangered Species Act (6 U.S.C. Sec 1531) 50 CFR 200 and 402	Applicable	Determines procedures for evaluating the presence of endangered and threatened species and their habitats, and for mitigating adverse impacts.	No endangered species have been found at the site. If plants or species are identified as endangered or threatened, construction or other activities will be mitigated to avoid adverse impacts for the species or habitat.
Archaeological Discoveries, Arizona Revised Statutes, Title 41, Chapter 4.1, Article 4	Applicable	Preserves archaeological artifacts.	If archaeological artifacts are found during excavation, construction, or other activities, the activity must temporarily stop to allow for investigation and preservation of artifacts.
Historic Preservation Arizona Revised Statutes, Title 41, Chapter 4.2 (865)	Applicable	Preserves remains.	If human remains or funerary objects are found during excavation, construction, or other activities, the activity must temporarily stop to allow for investigation and preservation of remains or objects.

TABLE A-3 Action-Specific ARARs for CVOC-Contaminated Groundwater

Standard, Requirement, Criteria, or Limitation	Applicable or Relevant and Appropriate	Description of Standard, Requirement, Criteria, or Limitation	Manner in Which ARAR Applies to Alternative
Arizona Remedial Action Requirements ARS § 49-282.06 (A)(2)	Applicable	Remedial actions must allow for the maximum beneficial use of the waters of the state.	Drinking water use is the maximum beneficial use of the regional aquifer.
Arizona Groundwater Management Act, ARS Title 45 ARS 45-454.01, 45-494, 45-496, 45-600	Applicable	Regulation exempts new well construction and withdrawal, treatment, and reinjection of groundwater into the aquifer that occur as a part of and on the site of a remedial action undertaken pursuant to CERCLA from obtaining ADWR approval to extract groundwater. Required to comply with certain provisions.	The intent of the provisions outlined in these sections will be met during construction and installation of new wells.
40 CFR Section 262.11 and AAC § R18-8-262	Applicable	Establishes procedures to determine if wastes are hazardous wastes. Waste generators from construction and operation of remedial actions are required to follow procedures to determine if wastes are hazardous wastes.	Applicable to management of waste materials generated from construction or operation of groundwater treatment system.
Clean Air Act 42 U.S.C. §§ 7401-7671q 40 CFR Part 61, Subparts A and V	Applicable	Regulates emissions of volatile organic compounds (VOCs) and air pollutants and requires leak detection and repair programs. Applies if the equipment treats a liquid that contains at least 10 percent volatile hazardous air pollutant.	VOC emissions reduction, leak detection, and repair programs for product accumulator vessels.

Standard, Requirement, Criteria, or Limitation	Applicable or Relevant and Appropriate	Description of Standard, Requirement, Criteria, or Limitation	Manner in Which ARAR Applies to Alternative
A.R.S. § 49-221: AAC § R18-11-101 et seq.	Relevant and Appropriate	Water quality standards for discharges to surface water.	Arizona State Water Quality Standards for Surface Waters apply to treatment systems when treated water is discharged to surface water. The chosen alternative includes extraction of groundwater from the aquifer, dosing with carbon source and re-injection into the aquifer. Hence the water quality standards for discharges to surface water do not apply in this case.
A.R.S. § 49-224	Relevant and Appropriate	Aquifers in the state identified and defined under A.R.S. § 49-224 and other aquifers subsequently discovered, identified, and defined shall be classified for drinking water protected use.	The Remedial Objectives for groundwater will be the federal drinking water standards.
40 CFR Part 122 and Part 125	Relevant and Appropriate	Implements treatment and monitoring requirements for discharges to surface water under the National Pollutant Discharge Elimination System (NPDES) Program	Requirements under the NPDES program apply to treatment systems when treated water is discharged to surface water.
40 CFR § 144.12 - 144.16	Applicable	Underground Injection Control (UIC) program criteria and standards, including current and future use, yield, and water quality characteristics. Regulates the reinjection of groundwater.	Injection wells must comply with the design, construction, operation, and maintenance requirements.
AAC § R12-15-818	Relevant and Appropriate	Prohibits new well construction within 100 feet of any hazardous waste facility.	The location of potential new wells relative to potential hazardous waste facilities will be considered.

Standard, Requirement, Criteria, or Limitation	Applicable or Relevant and Appropriate	Description of Standard, Requirement, Criteria, or Limitation	Manner in Which ARAR Applies to Alternative
Safe Drinking Water Act, 42 U.S.C. §300f *et seq*. 40 CFR 144.24(a), 146	Applicable	Regulates current and future use, yield, and water quality characteristics.	The chosen alternative includes re-injection of dosed groundwater back into the aquifer. Hence, these regulations apply to design, construction, operation, and maintenance of Class V injection wells.
Federal Clean Water Act, 40 CFR 403 Pima County Code, Title 13 Public Services, 13.36.070, Discharge	Relevant and Appropriate	Standards for the allowable discharge of industrial wastewaters to the POTW.	These standards are applicable when the selected remedy includes discharge to the POTW.