Prepared for

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

FEASIBILITY STUDY

EAST CENTRAL PHOENIX
24th STREET AND GRAND CANAL
WATER QUALITY ASSURANCE REVOLVING FUND SITE
PHOENIX, ARIZONA

Prepared by

Geosyntec consultants

engineers | scientists | innovators

11811 N. Tatum Boulevard, Suite P-186
Phoenix, Arizona 85028

Project Number: SP0158F

September 2019

Feasibility Study
East Central Phoenix
24th Street and Grand Canal
Water Quality Assurance Revolving Fund Site
Phoenix, Arizona

Prepared by

Geosyntec Consultants, Inc.
11811 N. Tatum Boulevard, Suite P-186
Phoenix, Arizona 85028

Registered Professional Engineer (Civil)
CERTIFICATE NO.
63188
ADLAR
BIRD
Date Signed 9/19/19
ARIZONA U.S.A.

REGISTERED GEOLOGIST
CERTIFICATE NO.
65652
FABRIZIO
MASCIONI
Date Signed 9/19/19
ARIZONA U.S.A.

Chad Bird
Project Manager

Fabrizio Mascioni (R.G. 65652)
Senior Geologist

Project Number: SP0158F
September 2019

TABLE OF CONTENTS

1. INTRODUCTION 1
   1.1 Purpose and Scope of the Feasibility Study Report 1
   1.2 Report Organization 2

2. SITE BACKGROUND 3
   2.1 Site Description 3
   2.2 Site Physiography 3
   2.3 Nature and Extent of Impacts 4
   2.4 Site History 5
   2.5 Risk Evaluation Summary 7
      2.5.1 Soil 7
      2.5.2 Soil Vapor 8
      2.5.3 Groundwater 8

3. FEASIBILITY STUDY SCOPING 10
   3.1 Regulatory Requirements 10
   3.2 Delineation of Remediation Areas 10
      3.2.1 Vadose Zone 11
      3.2.2 Groundwater 11
      3.2.3 Areas of Uncertainty 12
   3.3 Remedial Objectives 12
      3.3.1 Remedial Objectives for Land Use 13
      3.3.2 Remedial Objectives for Groundwater Use 13
      3.3.3 Remedial Objectives for Surface Water Use 14

4. IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES 15
   4.1 Remedial Strategies 15
   4.2 Remedial Measures and Technologies Screening Assumptions 15
      4.2.1 Concentrations of COCs in Vadose Zone and Groundwater 16
      4.2.2 Groundwater Chemistry and Natural Attenuation Conditions 16
   4.3 Screening of Treatment Technologies 16
      4.3.1 No Action 16
      4.3.2 Institutional Controls 17
      4.3.3 Groundwater Extraction and Treatment 17

4.3.4 *In Situ* Chemical Oxidation 18
4.3.5 *In Situ* Chemical Reduction 19
4.3.6 Enhanced Reductive Dechlorination 19
4.3.7 Air Sparge 20
4.3.8 Monitored Natural Attenuation 21

5. DEVELOPMENT OF REFERENCE REMEDY AND ALTERNATIVE REMEDIES 22
5.1 Reference Remedy 22
5.1.1 Plume Remediation 22
5.1.2 Monitoring 24
5.1.3 Contingencies 25
5.1.4 Permits and Agreements 26
5.2 More Aggressive Alternative Remedy 27
5.2.1 Plume Remediation and Controlled Migration 27
5.2.2 Monitoring 28
5.2.3 Contingencies 28
5.2.4 Permits and Agreements 28
5.3 Less Aggressive Alternative Remedy 28
5.3.1 Plume Remediation 28
5.3.2 Monitoring 28
5.3.3 Contingencies 29
5.3.4 Permits and Agreements 29

6. COMPARISON OF REMEDIES 30
6.1 Comparison Criteria 30
6.1.1 Reference Remedy 30
6.1.2 More Aggressive Alternative Remedy 32
6.1.3 Less Aggressive Alternative Remedy 33
6.2 Comparison of Remedies 34
6.2.1 Practicability 34
6.2.2 Protectiveness (Risk) 35
6.2.3 Cost 35
6.2.4 Benefits 35

7. PROPOSED REMEDY 36
7.1 Process and Reason for Selection 36
7.2 Achievement of Remedial Objectives 36
7.3 Achievement of Remedial Action Criteria Pursuant to ARS §49-282.06 . 36
7.4 Consistency with Water Management and Land Use Plans 37

8. COMMUNITY INVOLVEMENT 38

9. REFERENCES 39

LIST OF TABLES

Table 1: Remediation Technology Screening Summary

Table 2: Remedy Evaluation

Table 3: Remedial Alternative Cost Summary

Table 4: Remedial Alternative Scoring

LIST OF FIGURES

Figure 1: Site Vicinity

Figure 2: Site Plan

Figure 3: PCE Groundwater Isoconcentration Map

LIST OF APPENDICES

Appendix A: Detailed Cost Analysis

LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
1,1-DCE	1,1-dichloroethene
AAC	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AMA	Active Management Area
ARS	Arizona Revised Statutes
AS	air sparge
AWQS	Aquifer Water Quality Standard
CAB	Community Advisory Board
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cis-1,2-DCE	cis-1,2-dichloroethene
COCs	constituents of concern
COP	City of Phoenix
CSM	Conceptual Site Model
CVOCs	chlorinated volatile organic compounds
ECP	East Central Phoenix
ERA	Early Response Action
ERD	enhanced reductive dechlorination
ESA	Environmental Site Assessment
Former Carnation	the former Carnation 1 Hour Cleaners
Former McKean's	former McKean's Model Laundry & Dry Cleaning
FS	Feasibility Study
ft	feet
ft bgs	feet below ground surface
ft/day	feet per day
Geosyntec	Geosyntec Consultants, Inc.
GETS	groundwater extraction and treatment system
H+A	Hargis + Associates
HHRA	human health risk assessment
ISCO	*in situ* chemical oxidation
ISCR	*in situ* chemical reduction
LAU	Lower Alluvial Unit
LGAC	liquid-phase granular activated carbon
MAU	Middle Alluvial Unit
MNA	monitored natural attenuation
NPV	net present value
O&M	operations and maintenance
P&T	pump-and-treat
PA	preliminary assessment
PCE	tetrachloroethene

PI	preliminary investigation
RI	Remedial Investigation
ROI	radius of influence
ROs	Remedial Objectives
ROW	right-of-way
SRL	Soil Remediation Level
SRP	Salt River Project
SVE	soil vapor extraction
SVP	soil vapor probe
TCE	trichloroethene
the site	the East Central Phoenix (ECP) 24th Street and Grand Canal Water Quality Assurance Revolving Fund (WQARF) site
trans-1,2-DCE	trans-1,2-dichloroethene
UAU	Upper Alluvial Unit
VC	vinyl chloride
VOC	volatile organic compound
WQARF	Water Quality Assurance Revolving Fund
WSRV	West Salt River Valley
ZVI	zero valent iron

1. INTRODUCTION

1.1 Purpose and Scope of the Feasibility Study Report

The East Central Phoenix (ECP) 24th Street and Grand Canal Water Quality Assurance Revolving Fund (WQARF) site (the site), located in Phoenix, Arizona is one of six WQARF sites collectively included in the ECP area. The site encompasses two former source areas (former dry-cleaning facilities that operated northeast of the intersection of 24th Street and Thomas Road), as well as other properties in the vicinity. The area encompassing the plume is herein referred to as the "site boundary," which is defined by the approximate limits of the tetrachloroethene (PCE) plume; it is approximately bounded by Thomas Road to the north, 24th Street to the east, East Sheridan Street to the south, and North 17th Street to the west (Figure 1).

This Feasibility Study (FS) Report was prepared by Geosyntec Consultants, Inc. (Geosyntec) for the Arizona Department of Environmental Quality (ADEQ) in accordance with Arizona Administrative Code (AAC) Title 18, Environmental Quality, Chapter 16, Department of Environmental Quality WQARF Program, Article 4, Remedy Selection (R18-16), and is based on the data and findings of previous investigations, including the Remedial Investigation (RI) Report, prepared by Geosyntec (2019a). This FS Report was prepared in accordance with the FS Work Plan prepared by ADEQ (2018).

The objectives of this FS are as follows:

1. Identify remedial alternatives that will achieve the Remedial Objectives (ROs) as outlined in the Remedial Objectives Report (ADEQ, 2019); and
2. Evaluate the identified remedies, recommend alternatives, and comply with the requirements of Arizona Revised Statutes (ARS) §49-282.06.

Based on the objectives stated above, the FS presents recommendations for the preferred remedy, which:

1. Assures the protection of public health, welfare, and the environment;
2. To the extent practicable, provides for the control, management, or cleanup of hazardous substances to allow for the maximum beneficial use of waters of the state;
3. Is reasonable, necessary, cost-effective, and technically feasible; and
4. Addresses groundwater wells used for municipal, domestic, industrial, irrigation or agricultural purposes that could produce water that would not be fit for its current or reasonably foreseeable end use without treatment.

1.2 Report Organization

The remainder of this FS Report is organized as follows:

- Section 2, "Site Background," presents a summary of the site description, physiographic setting, nature and extent of impacts, and a risk evaluation summary;
- Section 3, "Feasibility Study Scoping," presents the regulatory requirements presented in statute and rule, delineates the remedial areas, and presents the ROs identified in the RI;
- Section 4, "Identification and Screening of Remediation Technologies," presents the evaluation and screening of various remedial measures and strategies related to the impacts in soil vapor and groundwater and lists the technologies that have been retained for evaluation as part of the reference and alternative remedies pursuant to AAC R18-16-407 (E) and (F);
- Section 5, "Development of Reference Remedy and Alternative Remedies," presents the selected Reference Remedy, a More Aggressive Alternative Remedy, a Less Aggressive Alternative Remedy, and discussions of the associated remedial measures and remedial strategies pursuant to AAC R18-16-407 (E);
- Section 6, "Comparison of Remedies," compares the remedies to each other based on the comparison criteria of practicability, cost, risk, and benefit. Uncertainties associated with the remedies and comparison criteria are discussed pursuant to AAC R18-16-407 (H);
- Section 7, "Proposed Remedy," presents the proposed remedy as required in AAC R18 16 407 (I), and discusses how it will achieve the ROs, how the comparison criteria were considered, and how the proposed remedy will meet the requirements of ARS §49-282.06;
- Section 8, "Community Involvement," documents the community involvement activities conducted in association with the FS; and
- Section 9, "References," provides a list of references cited in this FS.

2. SITE BACKGROUND

This section presents a summary of the site background, physiographic setting, the nature and extent of impacts, and a risk evaluation. A detailed background and chronology are included in the RI Report (Geosyntec, 2019a).

2.1 Site Description

The site is located in the vicinity of the intersection of 24th Street and Thomas Road, and the site boundary is approximately bounded by Indian School Road to the north, Interstate 10 to the south, 32nd Street to the east, and 7th Street to the west (Figure 1).

The site has historically housed dry-cleaning since the 1950s. After several years of investigations, PCE source areas that resulted in chlorinated volatile organic compound (CVOC) impacts to soil and groundwater were determined to be located at two dry-cleaning facilities: the former Carnation 1 Hour Cleaners (Former Carnation) and the former McKean's Model Laundry & Dry Cleaning (Former McKean's). These facilities historically operated on the northeast of the intersection of 24th Street and Thomas Road, herein referred to as "the Former Carnation/Former McKean's property."

2.2 Site Physiography

A detailed description of the site physiography is provided in the RI Report (Geosyntec, 2019a). Briefly, the site is located in the West Salt River Valley (WSRV) sub-basin of the Phoenix Active Management Area (AMA), which is a broad alluvial valley filled with layers of unconsolidated sand, gravel, silt, and clay. Total depth to bedrock is unknown, but it estimated to be at least 1,500 feet below ground surface (ft bgs). The site hydrogeology is typical for the WSRV, consisting of three alluvial units:

- Upper Alluvial Unit (UAU) – The UAU consists of unconsolidated sands and gravels deposited by flowing drainages and is the most permeable unit. According to the Arizona Department of Water Resources (ADWR), the UAU is typically 300 to 400 feet (ft) thick in the WSRV. Where thick saturated sections of the UAU are present, the groundwater production rates are the highest in the region;
- Middle Alluvial Unit (MAU) – The MAU is composed primarily of silt, clay, mudstone, and gypsiferous mudstone, interbedded with silty sand and gravel. As is the case with the UAU and Lower Alluvial Unit (LAU), coarser-grained sediments predominate near the Basin margins, where the MAU is indistinguishable from the overlying or underlying units; and
- LAU – The LAU consists mainly of conglomerate and gravel near the margins of the Salt River Valley. It grades into finer grained mudstone, gypsiferous and

anhydritic mudstone, and anhydrite toward the center of the basin. Parts of the WSRV also contain some interbedded lava flows. The LAU overlies crystalline and volcanic bedrock.

The hydrostratigraphic units have been defined based on review and evaluation of data generated during groundwater assessments at the ECP WQARF sites. The hydrogeology has been investigated to a maximum depth of approximately 407 ft bgs within the UAU. The base of the UAU has not been encountered during drilling activities to date; the UAU ranges in thickness from approximately 125 to more than 300 ft in the ECP WQARF sites region (Geosyntec, 2019a).

Groundwater elevations in the UAU have been monitored since April 1992. Monitoring wells installed at the site are screened across both shallow (water table) and deeper intervals within the UAU. Water levels in co-located shallow and deeper screened monitoring wells are generally nearly identical. During the period of record for source area monitoring wells at the site, the depth to water has ranged from approximately 43 ft bgs in 2002 to approximately 55 ft bgs in 2017. In 2018, groundwater at the distal end of the PCE plume was reported at approximately 106 ft bgs (Geosyntec, 2019a).

The direction of groundwater flow historically has been to the west-southwest with gradients ranging from approximately 0 to 0.007 feet per foot. Vertical gradients between the shallow and deeper zones of the UAU monitored at the site are generally negligible. The estimated horizontal hydraulic conductivity of the UAU is variable due to the heterogeneity of the UAU but it is estimated to range from 1 to 250 feet per day (ft/day). The highest estimates of hydraulic conductivity in the WSRV are found near the Salt River (Corkhill et al., 1993; Freihoefer et al., 2009).

2.3 Nature and Extent of Impacts

The purpose of the RI was to determine the nature and extent of impacts at the site. The RI also identified present and reasonably foreseeable uses of land and waters of the state that have been or are threatened to be impacted by site constituents of concern (COCs). Based upon the data collected, the following represents the interpretations and conclusions reached as a result of the RI (Geosyntec, 2019a). The results of the RI indicate the occurrence of one plume of impacted groundwater within the report focus area. This plume is herein referred to as the site plume. Prior Conceptual Site Models (CSMs) had presumed that the site plume was commingled with the ECP 32nd Street and Indian School Road WQARF site plume (Figure 2). As reported in the RI, there appears to be an interaction (overlap) of the PCE plumes associated with the Former Carnation and Former McKean's facilities (site sources), and the PCE impacts to groundwater associated with the ECP 32nd Street and Indian School Road WQARF site. The

two plumes, however, are in fact largely discrete, separate plumes, travelling alongside each other and at different vertical elevations, with the plume associated with the ECP 24th and Grand Canal WQARF site being shallower and located to the southeast. The independence of these plumes is shown in Figures 15 and 17 in the RI Report (Geosyntec, 2019a). The focus of this FS is the site plume. The ECP 32nd Street and Indian School Road WQARF site plume is being addressed in a separate FS.

The RI Report concluded that the Former Carnation and Former McKean's dry-cleaning establishments appear to be the source of most volatile organic compounds (VOC) impacts to the site. The site plume appears to originate from this facility and extend to the southwest. This plume is adjacent to a CVOC plume from the 32nd Street and Indian School Road WQARF site. The site plume is comprised primarily of PCE-impacted groundwater (Figure 3).

Site COCs include the following, due to the nature of the potential release from the two dry-cleaning establishments, their historical presence, and/or their potential to be generated through biological transformations:

- PCE;
- Trichloroethene (TCE);
- cis-1,2-Dichloroethene (cis-1,2-DCE);
- trans-1,2-Dichloroethene (trans-1,2-DCE); and
- Vinyl chloride (VC).

2.4 Site History

The following site chronology is summarized from the RI Report (Geosyntec, 2019a) and the first semiannual 2019 groundwater monitoring event (Geosyntec, 2019b).

1982: Salt River Project (SRP) production well 16E-6.8N was reportedly first sampled.

1995: VOCs were detected in SRP production well 16E-6.8N, and PCE was detected above its Arizona Aquifer Water Quality Standard (AWQS) of 5 micrograms per liter (µg/L).

1997: The ECP WQARF Priority site was divided into six WQARF Registry Sites.

2000: The site was placed on the WQARF Registry with a score of 29 out of a possible 120. Reported PCE concentrations in samples collected from SRP Well 16E-6.8N had generally been conducted annually from 1990 to 2015 and consistently exceeded the AWQS (Geosyntec, 2019a).

2000 – 2001: Due to these PCE detections, several properties in the ECP region were investigated to locate potential sources. Preliminary investigations (PIs) were initiated. A Phase I Environmental Site Assessment (ESA) identified the Former Carnation and Former McKean's properties as potential sources, and site investigations commenced.

2001 – 2007: Soil, soil vapor, and groundwater PIs were performed at the two dry-cleaning facilities and at surrounding commercial and residential properties.

2007: In June 2007, ADEQ sent out notices in accordance with ARS §49 287.03 initiating the RI for the site. RI activities were conducted through 2018.

2015: An Early Response Action (ERA) commenced with construction and operation of a soil vapor extraction (SVE) system to reduce VOC concentrations in soil vapor.

2018: Geosyntec conducted a human health risk assessment (HHRA) in October 2018 as part of the most recent ERA activity (Geosyntec, 2018). The results of the vapor intrusion HHRA indicate that concentrations of COCs in soil vapor do not pose an unacceptable risk to site receptors, with a calculated cumulative excess lifetime cancer risk less than 10^{-6} (one in a million) under a conservative residential exposure scenario.

2001 – 2019: Groundwater monitoring, sampling, and monitoring well installations occurred at the site between 2001 and April 2019. A total of 17 wells were sampled as part of the most recent groundwater monitoring event in April 2019 (Geosyntec, 2019b). These wells include recently installed triple-nested monitor well 24MW-21S/M/D. Compared to previously collected data, these data indicate that the PCE plume extends farther south and decreases in elevation along the flow path. Although the PCE plume is potentially larger than previously determined, the current size of the plume does not affect the remedial approach in this FS at this time.

2019: The RI Report prepared by Geosyntec for ADEQ (Geosyntec, 2019a) was issued summarizing activities to date, describing the nature and extent of impacts at the site, risk analyses, and proposed ROs.

2.5 Risk Evaluation Summary

The risk evaluation provided in the RI Report provided the following:

- An assessment of the COCs and relevant potential human receptors;
- An evaluation of potential exposures and pathways present at the site; and
- A characterization of human health concerns associated with the site-related COCs through a comparison to the relevant Arizona standards for groundwater and soil impacts and risk-based screening levels for soil vapor.

The soil, soil vapor, and groundwater monitoring results from the site were included in the evaluation. This section provides a summary of the relevant sections of the RI Report.

An evaluation of current land and water use was performed for the site. Land use includes commercial, industrial, and residential occupancy. Potential receptors therefore include residents and commercial/industrial workers. Impacted media at the site include groundwater, soil, and soil vapor. Because no natural points of discharge of groundwater to surface water exist in the vicinity of the site, the RI Report concluded that no risk characterization for surface water was necessary.

The identification of potentially complete exposure pathways is based on four components, which include:

- A source and mechanism of release;
- Retention or transport media;
- An exposure point (i.e., a setting where contact with impacted media occurs); and
- A route of exposure (e.g., ingestion).

2.5.1 Soil

Investigative activities described in the RI include extensive soil borings during the initial phases of site characterization, including exploratory borings and installation of monitoring wells. Soil samples have not been collected during recent years of site investigation; instead site assessments have focused on soil vapor, which typically provides better indication of the broad/regional subsurface conditions than soil results, which generally provide more discrete/localized conditions. However, potential residual soil concentrations for the Former Carnation/Former McKean's property were estimated by calculating theoretical equilibrium concentrations with the measured soil vapor concentrations. The resulting concentrations for the site were below soil cleanup levels,

including below default State of Arizona Soil Remediation Levels (SRLs). As such, no additional remedial actions are warranted at the Former Carnation/Former McKean's facility vadose zone based on soil concentrations and associated cleanup criteria.

2.5.2 Soil Vapor

The SVE system located at the Former Carnation/Former McKean's property was commissioned in July 2016. Baseline soil vapor samples were collected from the soil vapor probes (SVPs) and the individual SVE wells prior to startup of the SVE system. The system was shut down in August 2017 for a rebound evaluation. Samples collected approximately three months later did not contain elevated concentrations; no significant soil vapor rebound was observed.

The RI Report concluded that SVE has effectively mitigated shallow soil vapor impacts at the Former Carnation/Former McKean's property, and further corrective action was likely not warranted for the shallow soil, pending completion of a site-specific vapor intrusion HHRA. Geosyntec performed an HHRA using results from the December 2017 soil vapor rebound monitoring event for potential vapor intrusion risk under a commercial/industrial exposure scenario, and under a conservative potential future site redevelopment residential exposure scenario. The results of the vapor intrusion HHRA indicate that residual concentrations of COCs still present in soil vapor do not pose an unacceptable risk to site receptors with a calculated cumulative cancer development risk less that is less than the point of departure of "one in a million" (10^{-6}). The results support a conclusion that no further action is required to address residual vadose zone soil vapor COCs concentrations, and as such, the SVE ERA is no longer warranted. Thus, this FS does not evaluate remedies for soil/soil vapor, as remedial actions are no longer warranted.

2.5.3 Groundwater

The RI Report states that possible exposure routes for VOC impacted groundwater include direct ingestion, inhalation, or dermal contact. General population inhalation exposures to VOCs could occur from volatilization from water during activities such as showering, bathing, or washing. However, site groundwater is currently not used as a water supply. Potable use of groundwater is therefore not currently a complete pathway at the site. Several water supply wells that produce from the deeper portion of the aquifer are present in and adjacent to the site. If these supply wells are utilized in the future for water supply, this exposure pathway would require re-evaluation.

The transport mechanism for a groundwater pathway is advection/dispersion and off-gassing/vapor intrusion; the secondary impacted media is indoor air (Geosyntec,

2019a). Since nearby production wells are currently inactive, the exposure pathway would only become potentially complete if pumping is resumed. The indoor air inhalation exposure route presents a potentially complete exposure pathway from COCs off-gassing from groundwater, both on- and offsite, and associated vapor intrusion into indoor air; however, the risk is likely negligible since the vadose zone at the site is considered to be fully characterized and remediated (Geosyntec, 2019a; and Section 3.2.1 below).

3. FEASIBILITY STUDY SCOPING

The following presents the regulatory requirements of pertinent statutes and rules, the delineation of the remediation areas, and the ROs identified by ADEQ.

3.1 Regulatory Requirements

Per ARS §49-282.06, the following factors must be considered for selecting remedial actions:

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

The Remedy Selection Rule, AAC R18-16-407, states that an FS is a process by which to identify a reference remedy and alternative remedies that appear to be capable of achieving ROs and to evaluate the remedies based on the comparison criteria to select an approach that complies with ARS §49-282.06.

3.2 Delineation of Remediation Areas

The following subsections discuss the delineation of impacts to the vadose zone and groundwater at the site, as well as the uncertainties associated with the delineations.

3.2.1 Vadose Zone

Historical site characterization associated with the RI, as well as PIs, Preliminary Assessments (PAs), and ESAs, have demonstrated that the vadose zone was significantly impacted at the Former Carnation/Former McKean's property. Soil and soil vapor VOC impacts, primarily from PCE, have been observed. Historical investigations and ongoing soil vapor monitoring using a network of dedicated SVPs and extraction wells have provided requisite delineation of the vertical and lateral extent of VOC vadose zone impacts.

Approximately two years of SVE remediation have effectively performed vadose zone cleanup, reducing soil vapor concentrations to below the site-specific cleanup goals, including during a rebound evaluation performed three months after final shutdown of the SVE system. Residual VOC concentrations do not pose unacceptable vapor intrusion risk under a residential site redevelopment scenario, which is significantly more conservative than the current commercial site use and exposure scenario.

3.2.2 Groundwater

Based on data collected in 2017, 2018, and 2019, the COC suspected source concentrations begin within generally lower permeability material at the Former Carnation/Former McKean's property. COCs historically migrated vertically through the vadose zone through relatively low permeability geology until they reached approximately 75 ft bgs. COCs then migrated through sandy silt, and silty gravel until they reached groundwater approximately 80 ft bgs. The COCs then migrated in a southwesterly direction while vertically migrating downward until contacting a relatively consistent lean clay layer at approximately 103 ft bgs. The lean clay layer appears to have restricted, vertical migration of COC impacts allowing the groundwater plume to stay relatively shallow as it continued to migrate. The resulting plume, originating at the Former Carnation/Former McKean's property at concentrations above 100 µg/L, extends southwest approximately 5,000 ft with most of its mass at a depth of less than 120 ft bgs (Geosyntec, 2019a).

Investigation data presented in the RI suggests that PCE, TCE, and cis-1,2-DCE impacts to groundwater associated with the site have been naturally attenuating over time. The remaining site COCs (trans-1,2-DCE and VC) have not been detected in groundwater above their respective AWQS.

Groundwater impacted from historical vadose zone sources has advected hydraulically downgradient. SVE implementation beneath the former dry-cleaner businesses

effectively remediated vadose zone impacts in these areas, thereby mitigating ongoing impacts to groundwater.

It is expected that the extent of the groundwater PCE plume will continue to migrate and expand unless remedial action to address groundwater impacts is implemented. Plume expansion may also be accelerated in future years if SRP and City of Phoenix (COP) further develop their groundwater extraction well network and pumping capacities in the region.

3.2.3 Areas of Uncertainty

The following data gaps were identified as part of the RI (Geosyntec, 2019a):

- Petroleum hydrocarbon impacts that were identified during the completion of the ERA (SVE) at the site should be delineated back to their original source area. However, these impacts are not associated with the Former Carnation/McKean's dry-cleaning facilities and have not been encountered in site groundwater, therefore they are not expected to affect the proposed remedy.
- The extent of the groundwater plume has been estimated in some areas based on available data and expected plume behavior. Additional monitor wells should be installed to allow for remedy performance monitoring in the future.

3.3 Remedial Objectives

The ROs for the site were developed by ADEQ pursuant to AAC R18-16-406 of the Remedy Selection Rule. ROs are established for the current and reasonably foreseeable uses of land and waters of the state that have been or are threatened to be affected by a release of a hazardous substance. Pursuant to AAC R18-16-406 (D), it is specified that 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 one hundred 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. Hargis + Associates (H+A) prepared a Land and Water Use Report for the site (H+A, 2018) as part of the RI Report, based on information gathered during the public involvement process. Results of land and water use questionnaires are described in the Use Report and are included in Appendix H of the RI Report (Geosyntec, 2019a). Not every use identified in the land and water use questionnaires will have a corresponding RO, based on whether or not the use is reasonably foreseeable.

The ROs must be stated in the following terms: (1) protecting against the loss or impairment of each use; (2) restoring, replacing, or otherwise providing for each use; (3) when action is needed to protect or provide for the use; and (4) how long action is needed to protect or provide for the use

The following sections summarize the ROs established for the site in the RO Report (ADEQ, 2019).

3.3.1 Remedial Objectives for Land Use

PCE concentrations at the site have exceeded residential SRLs and site-specific risk-based levels for soil gas. Impacts to the soil have been detected within the source areas, whose current and reasonably foreseeable use is commercial/non-residential. Based on this information, the RO for the soil is:

> *Protect against the loss or impairment of land threatened by contaminants of concern at the 24th Street and Grand Canal WQARF site and restore land that has been impaired by contaminants of concern at the 24th Street and Grand Canal WQARF site to below applicable remediation levels. Action is needed for the present time and for as long as necessary to ensure that the level of contamination in the soil associated with the Site no longer exceeds applicable remediation levels.*

3.3.2 Remedial Objectives for Groundwater Use

PCE concentrations exceed the AWQS in groundwater at the site. Currently, groundwater within the site is used only for irrigation. However, reasonably foreseeable future groundwater use at this site includes both irrigation and potable supply. Therefore, the ROs for groundwater use at the site are as follows:

The RO for irrigation use at the site is:

> *Protect against the loss or impairment of irrigation water threatened by contaminants of concern at the 24th Street and Grand Canal site. Where protection cannot be achieved in a reasonable, necessary or cost-effective manner; restore, replace, or otherwise provide for irrigation water that is lost or impaired by contaminants of concern at the 24th Street and Grand Canal WQARF site. Action is needed for as long as necessary to ensure that, while the water exists and the resource remains available, the contamination associated with Site does not prohibit or limit the designated use of groundwater.*

The RO for potable use at the site is:

> *Protect against the loss or impairment of potable water threatened by contaminants of concern at the 24th Street and Grand Canal WQARF site. Where protection cannot be achieved in a reasonable, necessary or cost-effective manner; restore, replace, or otherwise provide for potable water that is lost or impaired by contaminants of concern at the 24th Street and Grand Canal WQARF site. Action is needed for as long as necessary to ensure that, while the water exists and the resource remains available, the contamination associated with Site does not prohibit or limit the designated use of groundwater.*

3.3.3 Remedial Objectives for Surface Water Use

There are no known current impacts from the site directly to the surface water in the SRP canals.

Current surface water use in the area of the site is irrigation from man-made canals containing pumped groundwater. The projected future use of the canal water includes drinking water. However, ROs for surface water use are not necessary, as ROs for groundwater pumped into the canal address protection of this use.

4. IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES

This section presents the evaluation and screening of various remedial strategies and measures related to the impacts in soil and groundwater and lists the technologies that have been retained for evaluation as part of the reference and alternative remedies. A detailed discussion of the remediation technologies evaluated for potential implementation at the site is provided.

4.1 Remedial Strategies

The Remedy Selection Rule, AAC R18-16-407 (Feasibility Study), prescribes six remedial strategies to be developed, incorporating one or more remediation technologies or methodologies. These strategies are:

1. Plume remediation, a strategy to achieve water quality standards for COCs in waters of the state throughout the site;
2. Physical containment, a strategy to contain impacts within definite boundaries;
3. Controlled migration, a strategy to control the direction or rate of migration but not necessarily to contain migration of the impacts;
4. Source control, a strategy to eliminate or mitigate a continuing source of impacts;
5. Monitoring, a strategy to observe and evaluate the impacts at the site through the collection of data; and
6. No action, a strategy that consists of no action at the site.

4.2 Remedial Measures and Technologies Screening Assumptions

This section provides a discussion of the identification and screening of remediation technologies for potential implementation at the site. Technologies are identified and screened separately for remediation of the groundwater. As the ERA completed at the site was successful in remediating the vadose zone, soil and soil vapor remedies are not discussed in this FS.

Remediation technologies that would meet site ROs and comply with requirements of AAC R18-16-407 and ARS §49-282.06 were identified and screened according to the following criteria:

- Contaminant treatment effectiveness;
- Constructability;

- Flexibility/expandability;
- Operations and maintenance (O&M) requirements;
- Operational hazards; and
- Cost-effectiveness.

The remediation technologies that passed screening were retained for use in development of the Reference Remedy and alternative remedies described in Section 5. The following were assumed during the identification and screening of remedial technologies.

4.2.1 Concentrations of COCs in Vadose Zone and Groundwater

To evaluate potential remedial alternatives to address groundwater impacts, the August 2018 maximum PCE concentration of 600 µg/L was assumed (Geosyntec, 2019a). PCE concentrations are significantly higher than other COCs; thus, PCE concentrations are the driver for site remedy evaluations.

4.2.2 Groundwater Chemistry and Natural Attenuation Conditions

Groundwater velocity at the site was assumed to be ranging between 0.01 and 25 ft/day to the southwest. Aquifer performance testing has not been conducted onsite to date. No significant non-remedial pumping was expected to occur. Data collected during groundwater monitoring suggest aquifer conditions to be generally aerobic, with insignificant organic carbon availability for biotic attenuation of the COCs by native biota. In the absence of an engineered intervention, attenuation of the COCs is expected to be driven primarily by dilution, dispersion, and phase separation.

4.3 Screening of Treatment Technologies

Technologies described below are commonly used for remediation of chlorinated hydrocarbons. The basic treatment mechanisms and the suitability and limitations of the technologies are also discussed. An initial screening is presented below for each technology for applicability to site conditions, plume extent, and VOC concentrations. Those technologies that were potentially applicable were then evaluated in detail using the technology screening criteria discussed above. The results of the initial technology screening are summarized in Table 1.

4.3.1 No Action

The No Action Alternative assumes that no remediation efforts would be implemented for the site, and that current conditions would continue in the Project Area. Elevated VOC concentrations in the northern portion of the groundwater plume would not be remediated,

resulting in a continued source of chlorinated solvents to the dilute groundwater plume, which could potentially propagate further downgradient. As a result, under the No Action Alternative, the ROs for the site would not be met and the alternative is not retained.

4.3.2 Institutional Controls

Institutional controls such as a land use restriction are commonly utilized for sites where residual soil impacts may exist and the future use of a property is likely to be commercial or industrial. Institutional controls can consist of items such as a deed restriction limiting the use of a property to non-residential development and/or the utilization of an engineering control. If soil impacts were to remain in place above Non-Residential SRLs, an engineering control would also need to be implemented. The source area of the site has been remediated through operation of an SVE system at the Former Carnation/McKean's facility (Geosyntec, 2019a). The facility is zoned Intermediate Commercial (C-2) and it is not anticipated to change. Because the Former Carnation/McKean's facility has met conservative residential cleanup standards, and additional SVE remediation is not necessary in the vadose zone, neither institutional nor engineering controls are retained as a remedy for site vadose zone and/or groundwater.

4.3.3 Groundwater Extraction and Treatment

Groundwater extraction and treatment systems (GETS), also referred to as "pump-and-treat" (P&T), are a technology for groundwater that can be effective for hydraulic containment and/or migration control for sites impacted by VOCs and soluble metals such as hexavalent chromium. GETS systems typically utilize submersible pumps in extraction wells to extract groundwater and transfer it via conveyance piping into an aboveground treatment system. The post-treatment water is subsequently discharged to a municipal sewer, a canal or other surface water, an infiltration basin, or re-injected into the subsurface with an injection well. These systems can control the subsurface flow of impacted groundwater, mitigating migration and/or reducing the footprint of the impacts. Liquid-phase granular activated carbon (LGAC) is typically employed for VOC removal via adsorption onto the media surface, while ion exchange resin is commonly employed for the removal of soluble metals.

The primary limitation for GETS is typically long cleanup times when used as the primary remedial measure in heterogeneous formations where diffusion from fine-grained layers provides a secondary source. As a dissolved-phase plume treatment alternative, GETS is not typically cost-effective for large, dilute plumes. However, GETS is a widely implemented and proven component for source control and mitigation of localized, high-concentration groundwater impacts. This measure is implementable with respect to both the design and operation of a treatment system and is amenable to the hydrostratigraphy

of the site. However, because of the extensive size of the plume, and the expected length of remediation required for GETS at the site, GETS was not retained as a remedial measure for additional evaluation.

4.3.4 *In Situ* Chemical Oxidation

In situ chemical oxidation (ISCO) relies on injection of a chemical agent to oxidize VOCs. Several oxidants are available and have been proven effective for chlorinated VOCs, including potassium permanganate, sodium persulfate, hydrogen peroxide, and ozone. These oxidants are considered effective for oxidizing PCE and its biological degradation products, TCE, cis-1,2-DCE, and VC (Interstate Technology and Research Council, 2005). The oxidant is generally delivered to the site in concentrated formulations or as solids, mixed in the field, and then injected through injection wells or temporary injection points. For the case of ozone, a mobile ozone generation and sparge system can be mobilized, and injected as a gas through sparge wells.

These highly reactive amendments oxidize the COCs to produce innocuous byproducts. Catalysts may be included or required to promote reactions for some amendments, such as sodium persulfate or potassium permanganate. ISCO, as with other *in situ* methods, typically includes higher capital costs than *ex situ* methods such as GETS, but may provide significant savings through long-term O&M cost reductions and reduced time to closure. It is capable of rapidly reducing high concentration VOCs and well suited for targeted remediation of small source areas. However, these strong oxidants require robust safety considerations for safe handling and if applied at too high of concentrations can potentially result in unintended changes to aquifer geochemistry. For example, persulfate may result in an increase in groundwater sulfate (SO_{4-2}) concentrations, whereas permanganate may result in increasing manganese dioxide (MnO_2) concentrations in groundwater. Additionally, because of the presence of naturally occurring chromium in site sediments, ISCO remedies such as alkaline activated sodium persulfate and excessive amounts of potassium permanganate have the potential to react with the site mineralogy and have the potential to result in the conversion of stable and innocuous trivalent chromium into hexavalent chromium, a relatively mobile and acutely toxic substance. Unlike other oxidizing agents, the processes involving ozonation are unlikely to lead to any persistent changes in aquifer geochemistry.

Ozone sparge pilot testing was performed at the 7th and Missouri WQARF site, located approximately 5 miles northwest of the site as part of an ozone injection pilot study. Similar to the site, the 7th and Missouri WQARF site is characterized by the same COCs (CVOCs released from a former dry-cleaner), mode of transport, lithology, and hydrogeologic properties. At the 7th and Missouri WQARF site, groundwater laboratory results and field observations indicate that VOC results suggest positive remedial effect

associated with the ozone treatment in areas downgradient of the source area. In the vicinity of the source area, VOC reductions have been modest, likely due to continued source addition attributed to continued dissolution of PCE into the local area groundwater. Based on the results of this ozone pilot study indicating successful oxidation of VOCs, the large radius of influence (ROI), and the lack of insoluble trivalent chromium conversion to soluble hexavalent chromium, ozone sparge is considered also capable of achieving the applicable ROs for the site.

As stated above, ISCO will require relatively large capital costs associated with installation of additional injection wells, trenching, and ozone sparge system; however, ozone will be effective as a treatment at the elevated VOC groundwater concentrations near the former source area and other targeted areas. Therefore, ISCO is retained as a potential remedial alternative.

4.3.5 *In Situ* Chemical Reduction

In situ chemical reduction (ISCR) can abiotically reduce VOC concentrations by chemically breaking the bonds within the VOC molecules using chemical reductants, such as zero valent iron (ZVI). ZVI can also be combined with an electron donor to promote concurrent biotic and abiotic reduction of VOCs. Because groundwater at the site is typically aerobic or moderately chemically oxidizing, a large quantity of the injectate would be consumed in reactions associated with ambient groundwater general chemistry as opposed to reduction of target COCs. Given the thickness of the impacted groundwater zone, and the depth to groundwater, installation, and the expected large volume of injectate that would be necessary, ISCR would be both technically and economically infeasible. Based on these limitations, this technology was not retained for further consideration.

4.3.6 Enhanced Reductive Dechlorination

Enhanced reductive dechlorination (ERD) involves stimulation or augmentation of naturally occurring microbial populations to expedite the anaerobic biodegradation (reductive dechlorination) of CVOCs through injections of electron donor (e.g., sodium lactate or emulsified vegetable oil). In the presence of sufficient electron donor, natural microbial activity will produce the required anaerobic conditions conducive to reductive dechlorination. If a sufficient population of bacteria capable of completely degrading PCE and its daughter products are not naturally present, the natural bacterial population can be augmented with a commercially available and regulatorily approved consortium of bacteria capable of completely degrading PCE and its daughter products.

Successful implementation of ERD includes adequate spatial distribution of the electron donor to achieve strongly reducing conditions; a microbial community capable of complete reductive dechlorination; groundwater pH greater than 5.5 and less than 9.0; sufficient concentration of chlorinated VOCs to support the growth of the microbial culture (typically a minimum of 100 µg/L); absence of high concentrations of inhibitory constituents; and low concentrations of competing electron acceptors, such as sulfate and nitrate. If these conditions are not initially present in an aquifer, measures must be taken to alter conditions to become conducive to active reductive dechlorination. Although reduction can be ultimately stimulated in most aquifers, the greater the initial deviation from these ideal conditions, the more difficult and costlier ERD will be to implement.

The natural groundwater condition at the site is generally aerobic and would require significant amounts of electron donor to become sufficiently reducing. Given the size of the plume and the site geochemical conditions, significant amounts of bacterial culture would be required to establish the necessary bacterial population for successful ERD at the site.

Although ERD is potentially capable of achieving the applicable ROs for the site, there are challenges posed by the predominantly aerobic groundwater conditions, the low PCE concentrations in the downgradient dissolved plume, the depth to groundwater, and the size of the plume. The successful implementation of ERD would be prohibitively costly as a treatment alternative for the overall plume; however, ERD may be effective as a treatment for targeted areas in combination with other treatment methodologies.

4.3.7 Air Sparge

Air sparge (AS) systems introduce compressed atmospheric air below the water table through injection wells, where the air expands and travels upward through the saturated zone to the unsaturated zone. VOCs partition from impacted groundwater into the introduced bubbles or air channels and are removed by advection to the vadose zone. AS can enhance SVE remediation by increasing contaminant mass removal from the saturated zone. As a complimentary system to SVE, AS would provide groundwater treatment while the SVE system provides overlying soil vapor mitigation.

AS promotes aerobic biological activity and degradation of some VOCs that are known to degrade under aerobic conditions. PCE, the primary COC at the site, is not expected to be degradable under aerobic conditions. Furthermore, AS is impractical for the treatment of large dilute plumes. Based on these factors, AS has been eliminated from further consideration.

4.3.8 Monitored Natural Attenuation

Monitored natural attenuation (MNA) is a widely-applied remedial measure when natural processes are expected to reduce COC concentrations over time. Such natural processes include dilution, dispersion, sorption, volatilization, and chemical or biological stabilization or transformation. For CVOCs, such as PCE, TCE, and 1,1-dichloroethene (1,1-DCE), natural reductive dechlorination (via biological and/or abiotic degradation processes) is usually the most significant degradation process when conditions are favorable (i.e., anaerobic environment with available organic carbon). Application of MNA requires the identification of the most likely attenuation processes and an estimation of the time required for these processes to meet the remedial objectives. MNA also includes implementation of a plan to observe the progress of the remedy to monitor that natural attenuation proceeds and that unexpected migration of impacts does not occur.

For large and very dilute plumes, such as the site plume, MNA is often the only technically feasible solution. MNA is frequently included as a component in a larger remedial strategy, sometimes coupled with more active remediation at source areas. Thus, MNA is retained as a feasible remedial measure for additional evaluation.

5. DEVELOPMENT OF REFERENCE REMEDY AND ALTERNATIVE REMEDIES

This section presents the selected Reference Remedy, a More Aggressive Alternative Remedy, and a Less Aggressive Alternative Remedy for residual impact at the site. Evaluations of the alternatives include a discussion of the associated remedial measures and strategies pursuant to AAC R18-16-407 (E). The reference and alternative remedies for the impacts are summarized in Table 2.

The Reference Remedy and alternative remedies consist of combinations of remedial strategies and their associated remedial measures, selected to achieve the ROs for the site. The remedies also include contingent remedial strategies (contingencies) to address reasonable uncertainties regarding the achievement of ROs, or uncertain timeframes in which ROs will be achieved. Where remedial measures are necessary to achieve ROs, such remedial measures will remain in effect as long as required for continued achievement of those objectives.

5.1 Reference Remedy

The remedial strategies for the Reference Remedy are:

- Plume remediation to achieve water quality standards for COCs in waters of the state throughout the site;
- Monitoring to observe and evaluate the contamination at the site through the collection of data; and
- Contingency remedial measures to address potential uncertainties.

5.1.1 Plume Remediation

Under the Reference Remedy, the ISCO implementation will provide plume remediation for high-concentration groundwater impacts; dilute groundwater impacts will be mitigated by natural attenuation.

5.1.1.1 Reference Remedy – ISCO

Implementation of ISCO for the Reference Remedy will comprise the following:

- Installation of ozone sparge injection wells and associated ozone sparge system equipment to be tied into the former SVE conveyance system (six dual nested ozone sparge wells assumed for cost estimating purposes) at the Former Carnation/McKean's property;

- Installation of ozone sparge injection wells and associated ozone sparge system equipment (seven dual nested ozone sparge wells assumed for cost estimating purposes) along Grand Canal, located south of the Embassy Suite property on the southwest corner of North 24th Street and Thomas Road;
- Installation of performance monitoring groundwater wells (two triple nested monitoring wells assumed for cost estimating purposes);
- MNA of the dilute PCE plume downgradient of the Grand Canal; and
- Operation, maintenance, and monitoring to assess remedial progress and system performance.

An ozone sparge system would be installed within the compound of the former SVE system located at the Former Carnation/Former McKean's property, near the northeast corner of North 24th Street and Thomas Road. Six former SVE wells are present onsite. Five of the six SVE wells will be over-drilled, and the pilot holes will be used for the installation of ozone sparge injection wells. A total of six injection wells are proposed: five within former SVE wells, and one within a new pilot boring. The injection wells would then be tied into the existing SVE conveyance system, connected to the proposed ozone generator system. This installation approach would provide a cost saving measure, resulting in a decommissioning of the SVE wells, and utilization of existing SVE infrastructure for the proposed ozone sparge injection.

A second ozone generator system will be installed south of the Embassy Suite property located on the southeast corner of North 24th Street and Thomas Road. This ozone generator will be tied into conveyance piping to a row of injection wells drilled within private property north of the Grand Canal.

The indicated injection well configuration would intercept the anticipated path of the plume along the ambient gradient towards the southwest. This remedy would treat groundwater with highest VOC concentrations near the former source area, cut off the plume, and inhibit migration of PCE further downgradient, ultimately mitigating the elevated impacts near the former source, with natural attenuation mitigating the dilute impacts further downgradient. Ozone sparge operations are expected to last for a period of up to three years at each location, with three additional years of post-ozone injection MNA (six years of monitoring total were assumed for this FS).

5.1.1.2 Reference Remedy MNA

Due to the large area covered by the dilute plume, the application of MNA is appropriate for the peripheral portions of the plume where the COCs may be reasonably anticipated to be attenuated by natural processes (e.g., dilution and dispersion) downgradient of or

away from the ozone sparge system. As a result, the ozone sparge system does not need to be designed to capture the entire footprint of the plume as it presently exists. Due to the aerobic conditions in the groundwater, abiotic MNA processes such as dilution, dispersion, volatilization, and sorption are likely to be the dominant mechanisms for concentration reductions in the VOC plume over time.

5.1.2 Monitoring

Implementation of monitoring for the Reference Remedy will comprise the following:

- Installation of two system performance monitoring wells for the downgradient dilute plume;
- Semiannual groundwater monitoring of the monitor well network, along with the proposed system performance wells, to evaluate plume stability, VOC concentrations, and natural attenuation parameters; and
- Continued semiannual groundwater elevation measurements to evaluate flow direction and hydraulic gradient.

Semiannual groundwater monitoring of 19 monitor wells will be continued for up to six years for the monitor well network (three years during active remediation, and three additional years of monitoring post remediation). If the PCE plume appears to be stable, the groundwater monitoring frequency may be reduced to annual and the number of monitor wells may be decreased.

As part of the Reference Remedy, two additional system performance monitoring wells will be installed for the downgradient dilute plume to monitor the upper, middle and lower portions of the UAU in this area. The sentinel well will be triple nested with 2-inch diameter casings, which will be screened as shallow, middle, and deep wells. This well will monitor for the potential migration of the PCE further downgradient.

The proposed groundwater monitor well network for the Reference Remedy would include:

- Upgradient – VCMW-17, 24MW-09A;
- Former source area – 24AS-01, 24MW-06B;
- Downgradient – 24MW-02A, 24MW-04A, 24MW-10A/B, 24MW-11, 24MW-12, 24MW-14, 24MW-15, 24MW-17, 24MW-21S, 24MW-21M, 24MW-21D; two downgradient system performance wells; and
- Cross-gradient – 24MW-01A, 24MW-03A, 24MW-13, and 24MW-19.

These wells define the current downgradient and cross-gradient PCE impacts exceeding the AWQS of 5 µg/L.

5.1.3 Contingencies

The following contingency remedial measures have been identified to address potential uncertainty in the achievement of the ROs.

5.1.3.1 Dissolved Plume Remediation Contingencies

- If COC response to ozone sparging in fine grained lithology is slow, hydrogen peroxide may be injected simultaneously with the ozone as a mist added to all the ozone sparging wells;
- If the PCE concentrations continue to be greater than the AWQS after six years of monitoring, then one additional year, or until concentrations are less than the AWQS, of groundwater monitoring will be performed;
- If persistent elevated PCE concentrations are measured further downgradient from the former source area, additional oxidant injection wells (up to seven for cost estimating purposes) may be installed south of the Grand Canal, within City right-of-way (ROW), for injection of a liquid oxidant (e.g., catalyzed hydrogen peroxide, potassium persulfate, or potassium permanganate). The use of a liquid oxidant is based on the potential need to implement a contingency remedy that requires minimal time-frame for execution, and access agreement. This contingency injection, if implemented, will occur as a onetime application;
- If PCE concentrations continue to be greater than the AWQS in the areas surrounding SRP, COP, or other production wells that have the potential to be impinged by COC impacts above the AWQS, additional ozone sparge injection wells and a mobile ozone sparge system can be installed near the extraction well to restore the surrounding groundwater quality;
- If SRP, COP, or other wells that have the potential to be impinged by COC impacts above the AWQS resume pumping before PCE concentrations are below AWQS, then wellhead treatment using LGAC or modification of the production well (e.g., sleeving) may be performed to allow groundwater usage. Wellhead treatment with LGAC would be installed at a production well if monitoring results indicate PCE concentrations are greater than the AWQS and the well owner requires drinking water quality out of the production well. The treated groundwater would then be pumped into the distribution system. For the Reference Remedy, additional coordination with the well owner would be

required for the design and location access of the wellhead treatment system or modification of the production well; and

- One of the existing SVE wells will be maintained on site for SVE if elevated ozone detections are detected in the vadose zone below the CVS property. If elevated ozone gas is measured, a system consisting of a 2-horsepower blower may be required to reduce the potential for the accumulation of ozone in the subsurface. This contingency assumes that the SVE blower will be connected to the existing vapor extraction well and conveyance piping, and that no additional wells will be required. This contingency also assumes that if VOCs are encountered in the soil vapor, resulting in exceedances of local emission standards, additional measures may be necessary for abatement of VOCs.

5.1.4 Permits and Agreements

Multiple permits and/or agreements would be necessary to authorize installation and operation of the Reference Remedy, including:

- Pre-construction notifications (i.e., ADWR Notice of Intent to Drill) and post-construction reporting (Driller's Reports) would be prepared for any new groundwater injection/monitor wells that are installed, and for modifications of existing SVE wells to ozone sparge injection wells;
- Well construction and/or modification work must be conducted by an ADWR-licensed driller. New wells must comply with ADWR standards found in ARS §45-594, -595, -596 and -600 of the Groundwater Code;
- General construction and ROW construction permits would be required from COP for the installation of a new injection system and associated conveyance piping. This would require preparation and submittal of design plans and specifications (i.e., civil, plumbing, mechanical, electrical) to COP; and
- Access agreements with private landowners would be required if the injection system components and/or associated conveyance piping needs to be located on private property.

5.2 More Aggressive Alternative Remedy

The following subsections present the More Aggressive Alternative Remedy that has been developed for the site. The remedial strategies for the More Aggressive Alternative Remedy are:

- Plume remediation to achieve water quality standards for COCs in waters of the state throughout the site;
- Controlled migration to control the direction or rate of migration, but not necessarily to contain migration of contaminants;
- Monitoring to observe and evaluate the contamination at the site through the collection of data; and
- Contingency remedial measures to address potential uncertainties.

The More Aggressive Alternative Remedy includes the measures listed in the Reference Remedy, plus additional remedial strategies and contingencies.

5.2.1 Plume Remediation and Controlled Migration

The dissolved plume remedial measures for the More Aggressive Alternative Remedy includes the Reference Remedy along with implementation two of its contingencies:

- Installation of hydrogen peroxide injection wells and associated injection equipment within the Former Carnation and Former McKean's dry-cleaning facility (six wells assumed for cost estimating purposes); and
- Installation of ISCO injection wells and associated injection equipment located south of the Grand Canal, within the COP ROW (seven for cost estimating purposes), for injection of a liquid oxidant (e.g., persulfate or potassium permanganate).

The More Aggressive Alternative Remedy would include ozone sparging at the former source area and the Grand Canal areas as detailed in the Reference Remedy. Additionally, the More Aggressive Alternative Remedy will include the injection of a liquid oxidant, such as hydrogen peroxide, to target PCE within the fine-grained lithology of shallow groundwater at the former source area, where elevated concentrations have been detected. Six additional oxidant injection wells are proposed, in addition to the six proposed ozone sparge wells within the Former Carnation and Former McKean's dry-cleaning facility. The injection wells would be installed within the property and tied into existing conveyance piping of the SVE system. Each well will be screened within the shallow

portion of the UAU. The former SVE system compound will be used to house an oxidant tank, pump, and manifold to distribute hydrogen peroxide to the proposed injection wells.

5.2.2 Monitoring

Monitoring measures for the More Aggressive Alternative Remedy are taken from the Reference Remedy and are not changed.

5.2.3 Contingencies

Contingency measures for the More Aggressive Alternative Remedy are taken from the Reference Remedy and are not changed.

5.2.4 Permits and Agreements

The same permits requirements as those specified in Section 5.1.4 would be required for the More Aggressive Alternative Remedy.

5.3 Less Aggressive Alternative Remedy

The following subsections present the Less Aggressive Alternative Remedy that has been developed for the plume. The remedial strategies for the Less Aggressive Alternative Remedy are:

- Monitoring to observe and evaluate the contamination at the site through the collection of data; and
- Contingency remedial measures to address potential uncertainties.

The Less Aggressive Alternative Remedy includes a subset of the measures listed in the Reference Remedy.

5.3.1 Plume Remediation

The dissolved plume remedial measures for the Less Aggressive Alternative Remedy are limited to MNA. This remedy will include the installation of one performance monitoring well.

5.3.2 Monitoring

Monitoring measures for the Less Aggressive Alternative Remedy are taken from the Reference Remedy and are not changed. For cost evaluation purposes, it was assumed that monitoring would be semiannual for 30 years. However, as part of this remedy, a groundwater flow and transport model and natural attenuation model would be completed

to estimate the extent of PCE impacts over time. The groundwater model will be updated every five years to reevaluate the timeline for PCE natural attenuation to concentrations below AWQS.

5.3.3 Contingencies

Contingencies for the Less Aggressive Alternative Remedy are limited to the following:

- If PCE concentrations continue to be greater than the AWQS in the areas surrounding SRP, COP, or other production wells that have the potential to be impinged by COC impacts above the AWQS, additional ozone sparge injection wells and a mobile ozone sparge system can be installed near the extraction well to restore the surrounding groundwater quality; and
- If SRP, COP, or other wells that have the potential to be impinged by COC impacts above the AWQS resume pumping before PCE concentrations are below the AWQS, then wellhead treatment using LGAC or modification of the production well (e.g., sleeving) may be performed to allow groundwater usage. Wellhead treatment with LGAC would be installed at a production well if monitoring results indicate PCE concentrations are greater than the AWQS and the well owner requires drinking water quality out of the production well. The treated groundwater would then be pumped into the SRP distribution system. Additional coordination with the well owner would be required for the design and location access of the wellhead treatment system or modification of the production well.

5.3.4 Permits and Agreements

Permits and agreements for the Less Aggressive Alternative Remedy are taken from the Reference Remedy and are not changed, as they relate to installation of an additional monitoring well.

6. COMPARISON OF REMEDIES

The following section compares the Reference Remedy and alternative remedies to criteria described in AAC R18-16-407H.3.

6.1 Comparison Criteria

In accordance with AAC R18-16-407E.3, the FS has been completed to identify a Reference Remedy and alternative remedies that are potentially capable of achieving ROs, and to evaluate the remedies based on the comparison criteria in order to select a remedy that complies with ARS. §49-282.06. AAC R18-16-407H specifies that practicability, risks, costs, and benefits are the primary remedy evaluation criteria.

Practicability includes the assessment of feasibility, short- and long-term effectiveness, and the reliability of the remedial alternative. The risk criteria include assessment of the overall protectiveness of public health and the environment in terms of fate and transport of the COCs, current and future land and water uses, exposure pathways and durations of potential exposure, changes in risk during remediation, and residual risk at the end of remediation. The cost analysis includes capital, O&M, and life cycle costs. Evaluation of benefits includes the assessment of lowered risk, reduced COC concentration or volume, decrease in liability, and preservation of existing and future uses.

Table 2 presents a detailed evaluation of the remedies for VOCs impacts in the vadose zone and groundwater with respect to the comparison criteria. The following subsections detail how the remedies perform against these criteria.

For cost analyses, the estimates are conceptual and assumed to have similar margins of error between +50% and –30% (i.e., the actual costs are expected to be between 30% less than and 50% more than the estimated costs).

6.1.1 Reference Remedy

6.1.1.1 Practicability

The groundwater Reference Remedy involves technologies that are known and reliable remediation technologies. For the groundwater Reference Remedy, ozone injection is a well-established technology that can be highly effective in the short-term. Ozone sparge systems are comprised of generally compact equipment, requiring minimal storage requirements. Although initial capital improvements may be high in order to install injection wells and the associated piping, the effectiveness of ozone at remediating groundwater VOC plumes results in a significant decrease in costs and risk associated with MNA over a long period of time.

6.1.1.2 Protectiveness (Risk)

The groundwater Reference Remedy is protective in that it provides active remediation of PCE impacts at the northeast extent of the plume where concentrations are highest, which will ultimately enhance natural attenuation further downgradient. Additionally, the Reference Remedy provides continued monitoring of the dissolved-phase contaminant plume and nearby SRP production wells with the contingency of wellhead treatment.

6.1.1.3 Cost

The cost of the Reference Remedy is presented in Table 3, and detailed costs are presented in Appendix A. The Reference Remedy costs include operation, maintenance, and monitoring of the ozone sparge system at the former source area, and a downgradient segment along Grand Canal. The costs were developed based on the assumptions detailed in Section 5.1.

From Table 3, $2.3 million (M) would be required for ozone sparge system installation. Total estimated O&M costs (excluding contingencies) are approximately $0.7M (accounting for a net present value [NPV] discounted at 5%), based on the estimation that O&M would be conducted for three years and groundwater monitoring activities would be conducted for six years after the capital improvements are installed (three years during ozone sparging and up to three years post injection). Total estimated contingency costs are approximately $4.3M based on the assumptions included in Appendix A. Contingency costs conservatively assume one additional year of ozone sparge operation, SVE of one onsite well if warranted based on elevated ozone soil vapor detections below the CVS building, injection of hydrogen peroxide at the CVS property ozone sparge injection wells, injection of a liquid oxidant downgradient of Grand Canal, installation of two additional ozone sparge injection wells near production wells, and wellhead treatment of production wells in lieu of extraction well modification (e.g., sleeves) with 20 years of O&M costs. The total cost for the Reference Remedy including contingency is approximately $7.3M, with a margin of error between $5.1M (-30%) and $11.0M (+50%).

6.1.1.4 Benefit

The groundwater Reference Remedy is considered beneficial by providing immediate decrease of PCE concentrations at the former source area and the dilute downgradient plume, and continued monitoring of the PCE plume as a means of evaluating the effectiveness of remediation.

6.1.2 More Aggressive Alternative Remedy

The practicability, risk, cost, and benefits for implementation of the More Aggressive Alternative Remedy are discussed in the following subsections.

6.1.2.1 Practicability

The More Aggressive Alternative Remedy for the plume expands the Reference Remedy ozone sparge system to include injection of a liquid oxidant such as hydrogen peroxide, which would expand treatment of the most impacted shallow groundwater at the former source area, where impacts are found in fine grained materials. Hydrogen peroxide injection is a well-established technology for remediation of VOCs impacted groundwater. This approach will involve the installation of seven additional injection wells within the CVS property, tied into the existing SVE conveyance infrastructure. As a result, this remedy is considered feasible.

6.1.2.2 Protectiveness (Risk)

The More Aggressive Alternative Remedy for the plume is comparably protective of human health and the environment with the Reference Remedy.

6.1.2.3 Cost

Costs for the More Aggressive Alternative Remedy are presented in Table 3; detailed costs are presented in Appendix A. Capital costs for the groundwater More Aggressive Alternative Remedy are higher than for the Reference Remedy because the general scope includes injection of hydrogen peroxide simultaneous to ozone sparging and injection of a liquid oxidant downgradient of Grand Canal. The More Aggressive Remedy would result in more capital costs earlier in the remediation process since both stages of remediation are implemented simultaneously. Capital costs are estimated to be approximately $3.0M and O&M costs are estimated to be approximately $0.7M. The total estimated cost for the More Aggressive Alternative Remedy including contingency is approximately $7.4M, with a margin of error between $5.2M (-30%) and $11.2M (+50%).

6.1.2.4 Benefit

The More Aggressive Alternative Remedy expands active treatment of the plume and is less reliant upon MNA compared to the Reference Remedy. Additionally, it is expected to decrease the timing required for remediation of elevated VOCs at the former source area; however, for cost estimating purposes, a conservative remediation period of three years has been retained as in the More Aggressive Alternative Remedy.

6.1.3 Less Aggressive Alternative Remedy

The practicability, risk, cost, and benefit of the Less Aggressive Alternative Remedy for the plume are discussed in the following subsections.

6.1.3.1 Practicability

The Less Aggressive Alternative Remedy for the plume consists of MNA, a well-established remedial measure that has been demonstrated to have long-term effectiveness. MNA does not provide short-term effectiveness, but does enable the implementation of contingencies that would have short-term effectiveness. No significant technological or hydrogeological barriers to application are anticipated. This remedy is considered to be feasible.

6.1.3.2 Practicability (Risk)

No aquatic or terrestrial biota are at risk from the impacts at the plume. The Less Aggressive Alternative Remedy for the site is protective of human health because it mitigates the potential for exposure via the groundwater consumption pathway by monitoring potential plume migration towards potential production wells where an exposure pathway could be completed, and including the contingency of applying wellhead treatment for production wells if installed, thereby mitigating exposure.

6.1.3.3 Cost

Costs for the Less Aggressive Alternative Remedy are presented in Table 3; detailed costs are presented in Appendix A. The capital costs for the groundwater Less Aggressive Alternative Remedy are limited to installation of performance monitoring wells. Capital costs are estimated to be approximately $0.3M, and O&M costs are estimated to be approximately $1.5M. The total cost for the Less Aggressive Alternative Remedy including contingency is approximately $5.4M, with a margin of error between $3.8M (-30%) and $8.1M (+50%).

6.1.3.4 Benefits

The Less Aggressive Remedy for the plume provides less benefit than the Reference or More Aggressive Alternative Remedies for the site because it can be anticipated to take the longest period of time to remediate groundwater impacts.

6.2 Comparison of Remedies

Comparison of the remedies is required under the AAC R18 16-407(H). Table 4 presents a ranking of the comparison criteria for each of the remedies. Each remedy was ranked from zero to five, with five indicating the most relative benefit and zero indicating the least relative or no benefit. The following sections describe the practicability, risk, cost, and benefits comparison for remedies.

6.2.1 Practicability

There are four considerations for practicability as follows:

- Feasibility involves the ability to put the remedy in place;
- Short-term effectiveness represents how much the remedy removes the COCs and limits the potential for exposure in the short-term;
- Long-term effectiveness represents how much the remedy removes the COCs and limits the potential for exposure in the long-term; and
- Reliability involves whether the technologies comprising the alternative are expected to perform reliably.

The groundwater Reference Remedy consists of two ozone sparge injection systems, installed at the Former Carnation and Former McKean's facility and along Grand Canal. The More Aggressive Alternative Remedy consists of the proposed Reference Remedy, with the addition of hydrogen peroxide injection simultaneously with the ozone at the Former Carnation and Former McKean's facility, and ISCO (e.g., persulfate or potassium permanganate) at new injection wells installed south of the Grand Canal. Both remedies scored high in practicability (25 and 24, respectively), however the feasibility of the More Aggressive Alternative Remedy is considered slightly more challenging, since it would require installation and monitoring of separate injection systems, and more impact to the public ROW for the installation of the injection system south of the Grand Canal. Both remedies are considered effective in the short and long term and reliable. The Less Aggressive Alternative Remedy scored lowest (total score of 21). It is moderately reliable, as an expansion to the monitor well network may be needed should an exceedance of the AWQS be measured further downgradient from wells with current concentrations below AWQS. Additionally, the Less Aggressive Alternative Remedy scored low in short to long term effectiveness, since MNA of the plume with no active remediation would result in a significantly extended monitoring period.

6.2.2 Protectiveness (Risk)

The groundwater More Aggressive Alternative Remedy is more protective than the Reference Remedy due to the installation and operation of a hydrogen peroxide system at the Former Carnation and Former McKean's facility, and injection of a liquid based ISCO oxidant further downgradient and south of Grand Canal. The groundwater Less Aggressive Alternative Remedy ranked lowest for protectiveness since it involves no active groundwater remediation; however, all proposed remedies include contingencies to mitigate potential risks to groundwater resources in the vicinity of the site.

6.2.3 Cost

The three remedies have varying capital and O&M costs. Including the capital, O&M, and contingency costs, it is estimated that Less Aggressive Alternative Remedy would cost the least ($5.4M), the Reference Remedy cost would be moderate ($7.3M), and the More Aggressive Alternative Remedy would cost the most ($7.4M). However, the More Aggressive Alternative Remedy would have higher initial capital investment, compared to other remedies, due to the simultaneous implementation of ozone sparging and liquid oxidant injection.

6.2.4 Benefits

The groundwater Reference Remedy and More Aggressive Alternative Remedy had similar benefits since they both include active groundwater remediation systems; however, the Reference Remedy scored higher, since it is more feasible due to less logistical challenges, and has significantly lower capital costs. The Less Aggressive Alternative Remedy, implementing MNA with the existing monitor well network, scored lowest since it would result in the potential spread of the plume further downgradient as more PCE mass dissolves into groundwater and further degrades the aquifer, and because the period of MNA monitoring is expected to be at least 30 years.

7. PROPOSED REMEDY

The following presents the proposed remedy for groundwater, as well as the basis for selecting the proposed remedy. Detailed cost information for the remedial alternatives is included in Appendix A.

7.1 Process and Reason for Selection

The Reference Remedy is recommended as the proposed remedy at the site. The Reference Remedy includes a ozone sparge system installed within the Former Carnation/Former McKean's property, and additional ozone sparge wells and ozone sparge generator system installed downgradient from the former source area, in private property along the north side of the Grand Canal. Semiannual groundwater monitoring will be used to assess the PCE plume stability and monitor decreasing VOC concentrations at the site (Section 5.1).

This recommendation is based on what is the best combination of remedial effectiveness, practicably, cost, and benefit for restoration and use of groundwater resources. The groundwater Reference Remedy scored the highest when ranking in accordance with the comparison criteria specified in AAC R18 16-407H.3.e (Section 6).

7.2 Achievement of Remedial Objectives

The Reference Remedy for PCE in groundwater will achieve the ROs for the site (Section 3.3.) It will provide active remediation by ozone sparging both the elevated PCE at the former source area and the dilute plume, which will result in a decreased number of years required for MNA of the PCE plume concentrations.

7.3 Achievement of Remedial Action Criteria Pursuant to ARS §49-282.06

To meet the remedial action criteria listed in ARS §49-282.06, it is recommended that the Reference Remedy for PCE in groundwater be selected as the Final Remedy for the site. The Reference Remedy will:

- Provide for adequate protection of public health and welfare and the environment;
- Provide a thorough and timely means for continued remediation and monitoring of the existing groundwater impacts, including evaluation of the progress of remediation over time;
- To the extent practicable, provide for the control, management, and cleanup of the COCs in the groundwater;
- Provide for the beneficial use of the groundwater resource by SRP; and

- Be reasonable, cost-effective, and technically feasible.

7.4 Consistency with Water Management and Land Use Plans

The Reference Remedy for groundwater is consistent with water management plans and general land use plans.

8. COMMUNITY INVOLVEMENT

ADEQ will issue a Notice to the Public announcing the availability of FS on ADEQ's website at www.azdeq.gov. The notice may be mailed to the Public Mailing List for the site, water providers, the Community Advisory Board (CAB), and any other interested parties. ADEQ may also present a summary of this FS and the remedial alternatives in a CAB meeting.

Interested parties can also review the FS and other site documents at the ADEQ Main Office located at 1110 West Washington Street, Phoenix, Arizona. With 24-hour notice, an appointment can be made to review related documentation.

9. REFERENCES

Arizona Department of Environmental Quality (ADEQ), 2018. Feasibility Study Work Plan, ECP 24th Street and Grand Canal WQARF Site, Phoenix, Arizona. November.

ADEQ, 2019. Remedial Objectives Report, ECP 24th Street and Grand Canal WQARF Site, Phoenix, Arizona. 2 May.

Corkhill, E.F., S. Corell, B.M. Hill, and D.A. Carr, 1993. A Regional Groundwater Flow Model of the Salt River Valley—Phase I. Phoenix AMA Hydrogeologic Framework and Basic Data Report. April. http://azgs.arizona.edu/azgeobib/regional-groundwater-flow-model-salt-river-valley-phase-i-phoenix-active-management-area

Freihoefer, A., D. Mason, P. Jahnke, L. Dubas, and K. Hutchinson, 2009. Regional Groundwater Flow Model of the Salt River Valley, Phoenix Active Management Area, Model Update and Calibration. April.

Geosyntec Consultants, Inc. (Geosyntec), 2018. Human Health Risk Assessment, ECP – 24th Street and Grand Canal. 10 October.

Geosyntec, 2019a. Remedial Investigation Report, ECP 24th Street and Grand Canal WQARF Site, Phoenix, Arizona.

Geosyntec, 2019b. First Semiannual Groundwater Monitoring Event, ECP 24th Street and Grand Canal WQARF Site, Phoenix, Arizona.

Hargis + Associates (H+A), 2018. Land and Water Use Report, ECP 24th Street and Grand Canal WQARF Site, Phoenix, Arizona. 2 February.

Interstate Technology and Resource Council, 2005. Technical and Regulatory Guidance for *In Situ* Chemical Oxidation of Contaminated Soil and Groundwater, Second Edition. Interstate Technology and Regulatory Cooperation Work Group, *In Situ* Chemical Oxidation Work Team. January.

TABLES

Table 1
Remediation Technology Screening Summary
24th Street and Grand Canal WQARF Site
Phoenix, Arizona

Technology	Retained?	Reason for Retention or Elimination
No Action	No	The dilute groundwater plume could potentially propagate further downgradient. As a result, the ROs for the Site would not be met and the alternative is not retained.
Institutional Controls	No	The Site vadose zone has been remediated by use of a SVE system, therefore institutional controls are not retained as a remedy for the Site.
Groundwater Extraction & Treatment System (GETS)	Yes	Effectiveness for disperse dilute plume reduced but retained as effective for control of VOCs in groundwater and as potential wellhead treatment for contingency.
In Situ Chemical Oxidation (ISCO)	Yes	Cost prohibitive for overall plume due to relatively small radius of influences, low VOC concentrations, and size and depth of plume; retained for targeted treatment areas, including the VOCs source and areas immediately downgradient of the source, along the Grand Canal, using ozone sparge. Also includes the option of using a targeted liquid oxidant injection, such as hydrogen peroxide, for the More Aggressive Remedy.
In Situ Chemical Reduction (ISCR)	No	Technically and economically infeasible due to thickness of impacted groundwater zone and the size and depth of the plume.
Enhanced Reductive Dechlorination (ERD)	Yes	Cost prohibitive for overall plume due to predominantly aerobic groundwater conditions, low VOC concentrations, and the size and depth of the plume; retained for potentially targeted treatment areas.

Abbreviations:
VOC – Volatile Organic Compounds

Table 1
Remediation Technology Screening Summary
24th Street and Grand Canal WQARF Site
Phoenix, Arizona

Air Sparging	No	Not likely to be cost-effective or improve treatment due to low groundwater concentrations immediately downgradient of the plume, the large extent of the dilute plume, and residual VOC mass in fine grained intervals.
Monitored Natural Attenuation (MNA)	Yes	Retained remedial technology (primarily for abiotic processes).

Abbreviations:
VOC – Volatile Organic Compounds

Table 2
Remedy Evaluation
24th Street and Grand Canal WQARF Site
Phoenix, Arizona

Remedial Alternative	Vadose Zone / Groundwater	Will Alternative Meet Remedial Objectives?	Practicability			Protectiveness (Risk)	Costs	Benefits	Regulatory/Public Acceptance
			Feasibility	Short/Long Term Effectiveness	Reliability				
Reference Remedy	**ISCO Using Ozone Sparge, and Semiannual MNA Monitoring of Groundwater Well Network**	Yes	Ozone injections is an established groundwater remediation measure, and successful VOCs cleanup in groundwater is well documented. MNA monitoring is very feasible as groundwater monitoring is currently conducted at the site.	Ozone injection and MNA is a known and effective remedy; Ozone will quickly reduce VOCs concentrations, and ultimately reduce the number of years for MNA monitoring; continued semiannual groundwater monitoring of existing monitoring well network will assess effectiveness.	Ozone injection and MNA are known and reliable remediation technology.	The reference remedy is protective, in that it will reduce VOCs concentrations at the source and immdeiately downgradient of the source, and it continues to monitor and evaluate Site contamination through the collection of data.	Although ozone injection would result in intially high capital costs related to installation of injection wells, associated piping, and purchase of ozone generators, its effectiveness will result in a significant decrease in the number of years required for MNA monitoring; Cost savings may be achived by retrofitting the current SVE system infrastructure for ozone sparge; MNA monitoring costs would be similar to current semiannual groundwater monitoring costs.	Ozone injection would result in achiving the groundwater RO within a relatively short period of time, and it would prevent further dilution of VOCs in groundwater, and the potential expansion of the plume. MNA monitoring would provide data to evaluate VOC concentrations throughout the VOC plume and monitor for the potential need of implementing wellhead treatment as a contingency for the production wells, if pumping at these well is resumed.	Likely
More Aggressive Remedy	**ISCO Using a Combitation of Ozone Sparge and Hydrogen Peroxide, Downgradient Liquid Oxidant Injection, and Semiannual MNA Monitoring of Groundwater Well Network**	Yes	In addition to the the statement above, targeted injection of a liquid oxydant, such as hydrogen peroxyde at the CVS property and persulfate/potassium permanganate south of Grand Canal, is a well documented remedy for source areas impacted with VOCs and consisting of fine-grained litholgy.	In addition to the statement above, the application of a liquid oxydant will reduce the VOCs concentrations in shallow groudnwater, and reduce the amount of time needed to reduce the concentrations of VOCs below the source area.	Ozone injection, liquid oxidant injection and MNA are known and reliable remediation technologies.	The More Aggressive Remedy is protective, in that it will reduce VOCs concentrations at the source, and it continues to monitor and evaluate Site contamination through the collection of data.	In addition to the comment above, the addition of a liquid oxidant injection would increase the overall capital costs associated with the number of injection wells required for the implementation of the More Aggressive Remedy.	In addition to the benefits mentioned above, the injection of a liquid oxidant will likely expedite the remediation of the dilute plume.	Likely
Less Aggressive Remedy	**Semiannual MNA Monitoring of Groundwater Well Network**	Yes	MNA monitoring is very feasible as groundwater monitoring is currently conducted at the site. MNA monitoring of the current well network is feasible considering the current conditions of the plume; However, if continued contribution of VOCs results in expansion of the dilute plume beyond its current footprint, additional monitoring wells may be required.	MNA is a known and effective remedy given the condition of the plume; semiannual monitoring will assess effectiveness.	MNA is a known and reliable remediation technology.	The less aggressive remedy is protective, in that it continues to monitor and evaluate Site contamination through the collection of data. However, it will not remediate groundwater conditions in the vicinity of the productions wells. If production wells are reactivated within the VOC plume, impacted water may continue to be drawn into the well.	MNA monitoring costs for this remedy would be similar to the current groundwater monitoring costs. Additional capital costs may be required if owners reactivate the production wells located within the VOC plume or its vicinity, resulting in the need for wellhead treatment.	MNA monitoring would provide data to evaluate VOC concentrations throughout the PCE plume and monitor for the potential need of implementing wellhead treatment as a contingency to the production wells.	Moderately Unlikely

Abbreviations:
LGAC - liquid-phase granular activated carbon
MNA - Monitored Natural Attenuation
O&M - Operation and Maintenance
PCE = Tetrachloroethene
SRP - Salt River Project
SVE - Soil Vapor Extraction
TOG - Town of Gilbert
VOC - Volatile Organic Compound

Table 3
Remedial Alternatives Cost Summary
24th Street and Grand Canal WQARF Site
Phoenix, Arizona

Remedial Alternative	Vadose Zone / Groundwater	Estimated Capital Costs	Estimated O&M Costs and Monitoring	Total Estimated Cost (Not Including Contingency)	Contingency	Total Remedy Estimated Cost Including Contingency		
						Total Cost	(-30%)	(+50%)
Reference Remedy	Ozone Sparge - Source Area and Gand Canal Injection; Semiannual Monitoring; Installation of Downgradient Monitoring Well	$2,251,000	$735,000	**$2,986,000**	$4,348,000	**$7,334,000**	**5,134,000**	**11,000,000**
More Aggressive Remedy	Source Area Ozone Sparge and ISCO Using Hydrgen Peroxyde; Grand Canal Ozone Sparge; Semiannual Monitoring; Installation of Downgradient Monitoring Well	$3,045,000	$735,000	**$3,780,000**	$3,658,000	**$7,438,000**	**5,207,000**	**11,200,000**
Less Aggressive Remedy	Semiannual MNA of Well Network and Installation of Downgradient Monitoring Well	$288,000	$1,520,000	**$1,808,000**	$3,600,000	**$5,408,000**	**3,786,000**	**8,112,000**

Abbreviations:
WQARF = Water Quality Assurance Revolving Fund
O&M = operations and maintenance
% = percent
$ = United States dollars
GETS = Groundwater Extraction & Treatment System
VOCs = volatile organic compounds
SVE = soil vapor extraction
MNA = monitored natural attenuation

Notes:
Costs are rounded off to the nearest thousand
Costs are based on 2019 dollar values
Costs for O&M and contingencies include an assumed Net Present Value of 5%

Table 4

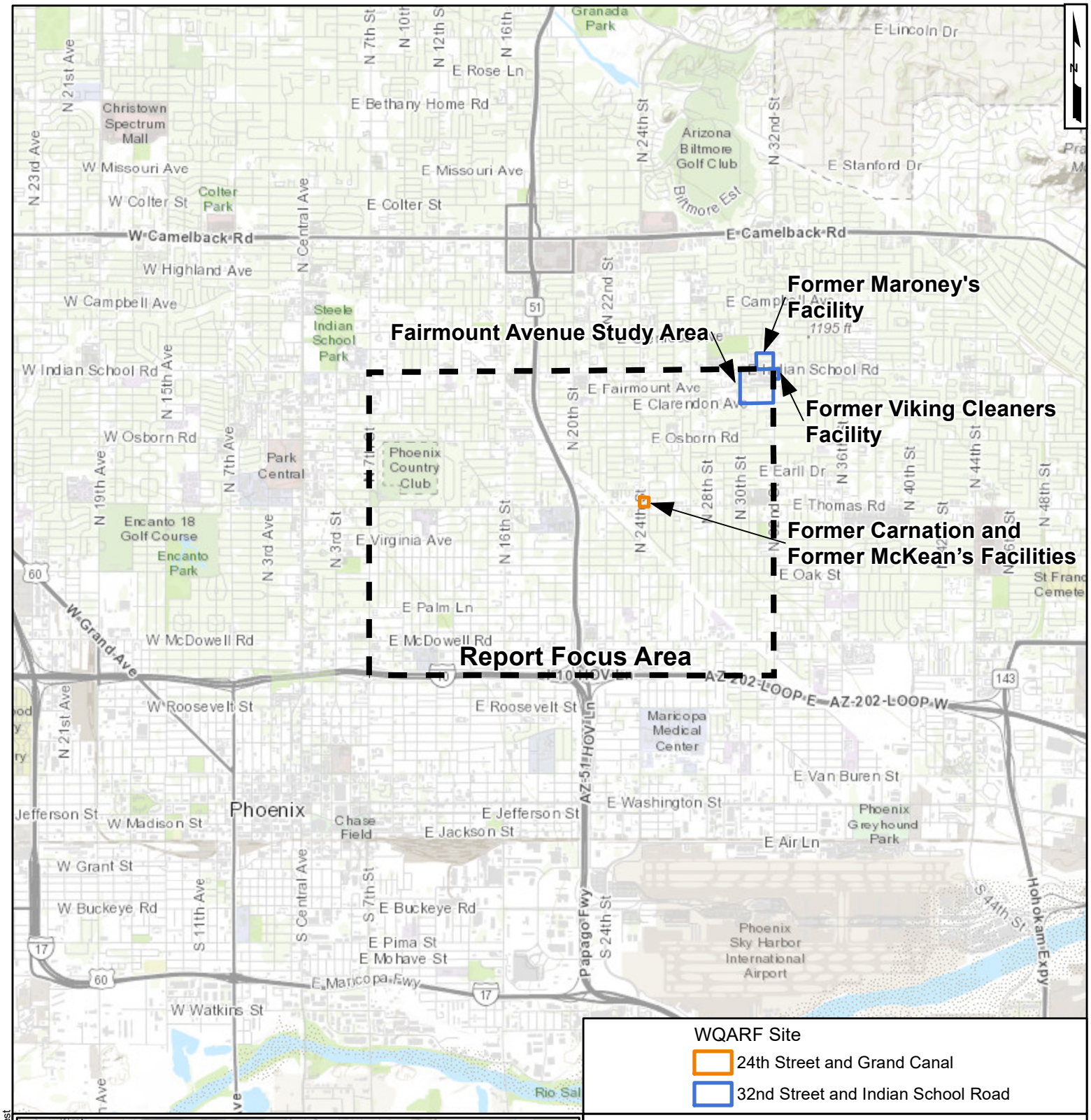
Remedial Alternative Scoring
24th Street and Grand Canal WQARF Site
Phoenix, Arizona

Remedial Alternative	Vadose Zone / Groundwater	Will Alternative Meet Remedial Objectives?	Practicability			Protectiveness (Risk)	Cost	Benefits	*Total Score*	*Total Estimated Cost (Not Including Contingency)*	*Total Remedy Estimated Cost (Including Contingency)*
			Feasibility	Short/Long Term Effectiveness	Reliability						
Reference Remedy	**Disolved Plume Ozone Sparge**	Yes	5	4	4	4	4	4	***25***	**$2.99M**	**$7.33M**
More Aggressive Remedy	**Dissolved Plume Ozone Sparge, Source Area Hydrogen Peroxide Injection, and Downgradient Liquid Oxidant Injection**	Yes	3	5	4	5	2	5	***24***	**$3.78M**	**$7.44M**
Less Aggressive Remedy	**Semiannual MNA Monitoring of Current Monitoring Well Network**	Yes	5	4	2	2	5	3	***21***	**$1.81M**	**$5.41M**

Abbreviations:
SVE - soil vapor extraction
MNA - monitored natural attenuation
VOCs - volatile organic compounds
GETS - Groundwater Extraction and Treatment System

Scoring:
Scores ranged from zero to five, with five indicating the most relative benefit and zero indicating the least relative or no benefit.

FIGURES



WQARF Site

- 24th Street and Grand Canal
- 32nd Street and Indian School Road

1 0.5 0 1 Miles

Site Vicinity

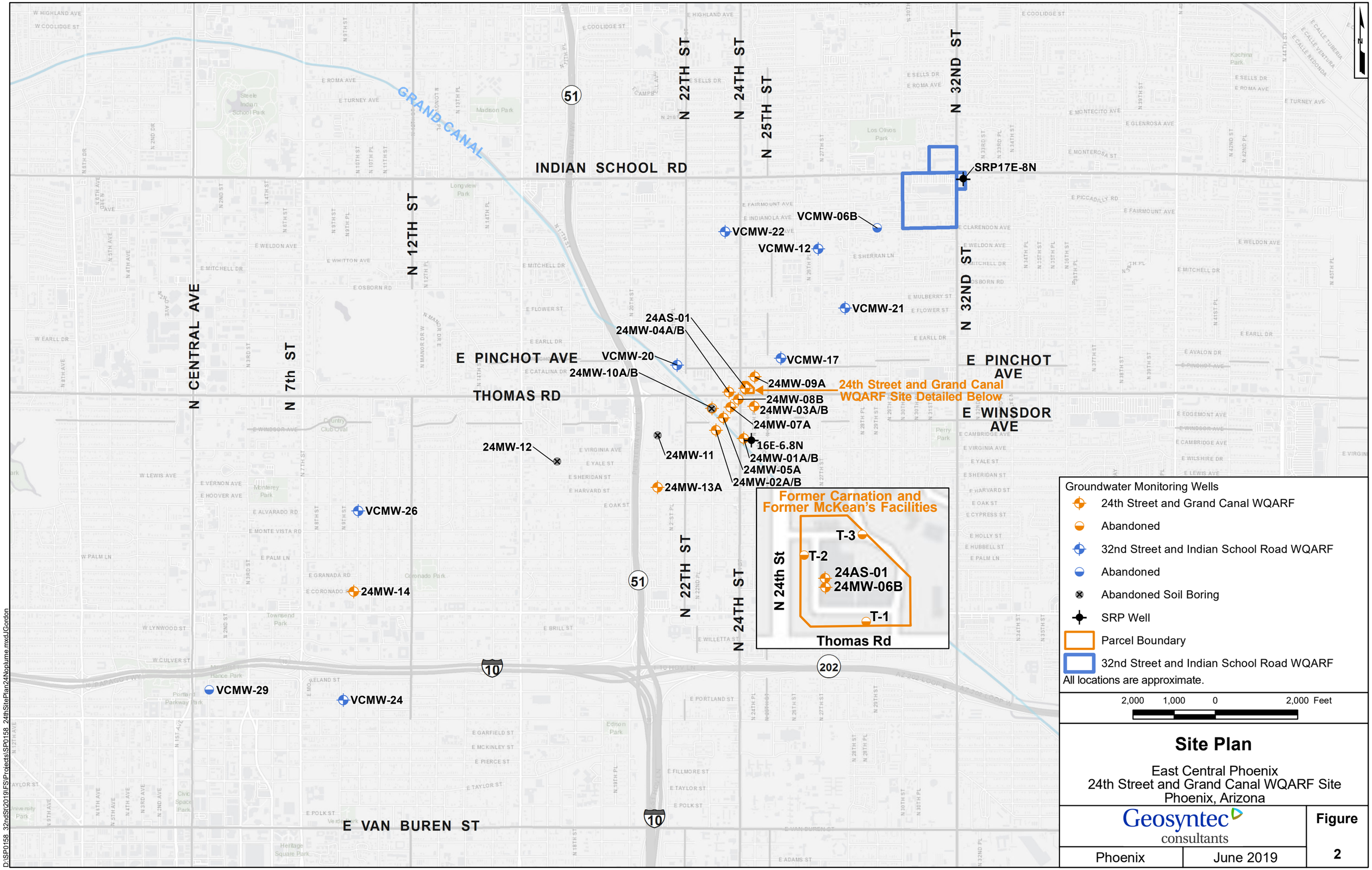
East Central Phoenix
24th Street and Grand Canal WQARF Site
Phoenix, Arizona

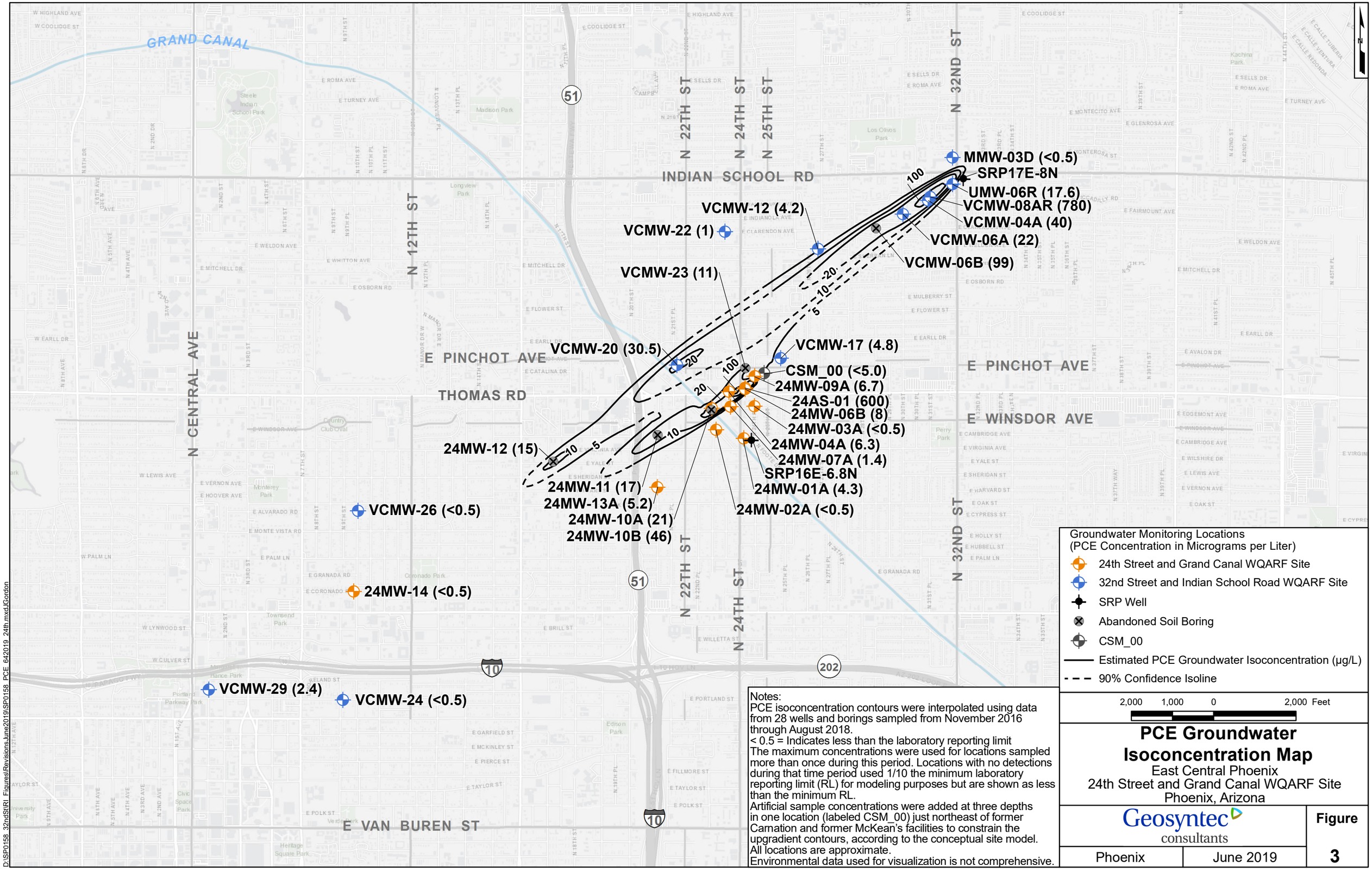
Geosyntec consultants

Phoenix | February 2019

Figure 1

D:\SP0158_32ndSt\RI_Figures\24th\SiteVicinity24th.mxd.Test


INDIAN SCHOOL RD
N 22TH ST
N 24TH ST
N 25TH ST
N 32ND ST
N 12TH ST
N CENTRAL AVE
N 7th ST
E PINCHOT AVE
THOMAS RD
E WINSDOR AVE
E VAN BUREN ST
GRAND CANAL
51
10
202
SRP17E-8N
VCMW-06B
VCMW-22
VCMW-12
VCMW-21
VCMW-17
VCMW-20
VCMW-26
VCMW-29
VCMW-24
24AS-01
24MW-04A/B
24MW-10A/B
24MW-09A
24MW-08B
24MW-03A/B
24MW-07A
16E-6.8N
24MW-01A/B
24MW-05A
24MW-02A/B
24MW-12
24MW-11
24MW-13A
24MW-14
24th Street and Grand Canal WQARF Site Detailed Below
Former Carnation and Former McKean's Facilities
T-3
T-2
24AS-01
24MW-06B
T-1
N 24th St
Thomas Rd
Groundwater Monitoring Wells
24th Street and Grand Canal WQARF
Abandoned
32nd Street and Indian School Road WQARF
Abandoned
Abandoned Soil Boring
SRP Well
Parcel Boundary
32nd Street and Indian School Road WQARF
All locations are approximate.
2,000 1,000 0 2,000 Feet
Site Plan
East Central Phoenix
24th Street and Grand Canal WQARF Site
Phoenix, Arizona
Geosyntec consultants
Figure
2
Phoenix
June 2019
D:\SP0158_32ndSt\2019\FS\Projects\SP0158_24thSitePlan24Noplume.mxd/JGordon



Notes:
PCE isoconcentration contours were interpolated using data from 28 wells and borings sampled from November 2016 through August 2018.
< 0.5 = Indicates less than the laboratory reporting limit
The maximum concentrations were used for locations sampled more than once during this period. Locations with no detections during that time period used 1/10 the minimum laboratory reporting limit (RL) for modeling purposes but are shown as less than the minimum RL.
Artificial sample concentrations were added at three depths in one location (labeled CSM_00) just northeast of former Carnation and former McKean's facilities to constrain the upgradient contours, according to the conceptual site model.
All locations are approximate.
Environmental data used for visualization is not comprehensive.

PCE Groundwater Isoconcentration Map
East Central Phoenix
24th Street and Grand Canal WQARF Site
Phoenix, Arizona

Geosyntec consultants

Phoenix	June 2019	Figure 3

APPENDIX A

Detailed Cost Analysis

Table A-1
Estimated Costs for Reference Remedy
24th St and Grand Canal WQARF Site
Phoenix, Arizona

	Quantity	Unit	Unit Cost	Total Cost	Estimated Low Range (-30%)	Estimated Upper Range (+50%)
Groundwater (GW) - Source and Extended Area Ozone Sparge and MNA Monitoring of Existing Well Network						
Estimated Groundwater Capital Costs						
Ozone System Remedy Final Design						
Ozone System Remedy Final Design	1	LS	$100,000	$100,000	$70,000	$150,000
IW Installations						
Source area IWs at CVS Property Installation and Oversight	6	EA	$70,000	$420,000	$294,000	$630,000
Grand Canal IWs Installation and Oversight	7	EA	$70,000	$490,000	$343,000	$735,000
Vertical Profile, Survey, Permitting, IDW Disposal	1	LS	$40,000	$40,000	$28,000	$60,000
Ozone Systems Installations						
Ozone Generator Purchase (Including Conex Box and Telemetry)	2	LS	$230,000	$460,000	$322,000	$690,000
Earthwork, Trenching and Pipe Installation (CVS Property)	100	FT.	$150	$15,000	$11,000	$23,000
Earthwork, Trenching and Pipe Installation (Grand Canal Property)	800	FT.	$150	$120,000	$84,000	$180,000
Asphalt Repair (Grand Canal Property)	800	FT.	$40	$32,000	$22,000	$48,000
Related Appurtenances, Equipment and Repairs	1	LS	$30,000	$30,000	$21,000	$45,000
Downgradient Performance Well Installation						
Triple-Nested Monitoring Well Installation and Oversight	2	LS	$100,000	$200,000	$140,000	$300,000
Vertical Profile, Survey, Permitting, Traffic Control, IDW Disposal, Tech Memo	2	LS	$25,000	$50,000	$35,000	$75,000
Project Management/Oversignt/Administration	15%	n/a	n/a	$294,000	$206,000	$441,000
Capital Costs Subtotal				**$2,251,000**	**$1,576,000**	**$3,377,000**
Estimated Ozone O&M and GW Monitoring Annual Costs						
Ozone System Annual O&M	1	YR	$50,000	$50,000	$35,000	$75,000
Semiannual GW Monitoring/Reporting	2	EA	$40,000	$80,000	$56,000	$120,000
Miscellaneous Sampling & Field Supplies	1	YR	$6,000	$6,000	$4,000	$9,000
Equipment Repairs (as needed)	1	YR	$10,000	$10,000	$7,000	$15,000
Project Management/Oversight/Administration	15%	n/a	n/a	$22,000	$15,000	$33,000
Annual Costs for Ozone O&M Subtotal				**$50,000**	**$35,000**	**$75,000**
Annual Costs for GW Monitoring O&M Subtotal				**$118,000**	**$83,000**	**$177,000**
6-Year Costs Life Cycle (3-Yrs. Ozone O&M + 6 GW Monitoring)				**$858,000**	**$830,000**	**$1,770,000**
Total GW Monitoring Costs for 6 Years (Net Present Value - Discounted 5%)				**$735,000**	**$641,000**	**$1,367,000**
Reference Remedy Capital, Monitoring, and O&M Costs				**$2,986,000**	**$2,090,000**	**$4,479,000**
Estimated GW Contingency Costs						
Ozone System O&M and GW Monitoring for 1 Additional Year	1	LS	$118,000	$118,000	$83,000	$177,000
SVE of One Existing Well for Subsurface Ozone at CVS	1	LS	$30,000	$30,000	$21,000	$45,000
Hydrogen Peroxide Injection at CVS						
Hydrogen Peroxide Injection at CVS Remedy Design	1	EA	$30,000	$30,000	$21,000	$45,000
Equipment/Repairs	1	LS	$30,000	$30,000	$21,000	$45,000
ISCO Injection, O&M, and Consumables	1	LS	$80,000	$80,000	$56,000	$120,000
ISCO Downgradient of Grand Canal						
Ozone System Remedy Design	1	EA	$50,000	$50,000	$35,000	$75,000
ISCO IWs Installation South of Grand Canal	7	LS	$50,000	$350,000	$245,000	$525,000
IDW Disposal	1	LS	$10,000	$10,000	$7,000	$15,000
Asphalt Repair	200	FT.	$50	$10,000	$7,000	$15,000
Equipment/Repairs	1	LS	$30,000	$30,000	$21,000	$45,000
One-time ISCO Injection and Oversight	1	LS	$100,000	$100,000	$70,000	$150,000
Ozone Sparge IWs Near Production Well (Installation and Oversight)	2	EA	$50,000	$100,000	$70,000	$150,000
IDW Disposal	1	LS	$5,000	$5,000	$4,000	$8,000
Earthwork, Trenching and Pipe Installation	100	FT.	$150	$15,000	$11,000	$23,000
Asphalt Repair	100	FT.	$50	$5,000	$4,000	$8,000
Equipment/Repairs	1	LS	$30,000	$30,000	$21,000	$45,000
Use of Source Area Generator and O&M for 1 Year	2	LS	$40,000	$80,000	$56,000	$120,000
Vertical Profile, Survey, Permitting, IDW Disposal, Tech Memo	1	LS	$25,000	$25,000	$18,000	$38,000
Project Management/Oversignt/Administration	15%	n/a	n/a	$39,000	$28,000	$59,000
Wellhead Treatment						
Engineering Design/Procurement Services	15%	n/a	$228,000	$228,000	$160,000	$342,000
Treatment Compound (Foundation, Fencing, Mechanical, Instrumentation and Controls, Site Improvements, etc.)	1	LS	$500,000	$500,000	$350,000	$750,000
Estimated 2,000 gpm Treatment System (Two LGAC Vessels [including offload/installation[, Bag Filtration System, Interconnecting Piping)	1	LS	$985,000	$985,000	$690,000	$1,478,000
Conveyance Piping Modifications	1	LS	$30,000	$30,000	$21,000	$45,000
System Commissioning and Startup	1	LS	$35,000	$35,000	$25,000	$53,000
Construction Services (System Installation, Oversight, etc.)	15%	n/a	n/a	$233,000	$163,000	$350,000
O&M costs (assuming 20 Years Net Present Value - Discounted 5%)	1	LS	$1,200,000	$1,200,000	$840,000	$1,800,000
GW Contingency Costs Subtotal				**$4,348,000**	**$3,044,000**	**$6,522,000**
Total Reference Remedy Costs (Including Contingencies)				**$7,334,000**	**$5,134,000**	**$11,000,000**

Table A-1
Estimated Costs for Reference Remedy
24th St and Grand Canal WQARF Site
Phoenix, Arizona

Abbreviations:

WQARF = Water Quality Assurance Revolving Fund
% = percent
ERA - early response action
GW - groundwater
IDW - Investigation Derived-Wastes
IW - injection well
LF = linear feet
LGAC = liquid phase granular activated carbon
LS = lump sum
MNA = monitored natural attenuation
MO - month
O&M = operations and maintenance
PLC = programmable logic controller
VGAC = vapor phase granular activated carbon
VOCs = volatile organic compounds

Notes:

1. Total costs are rounded up to the nearest thousand dollars ($1000).
2. Pricing is subject to commodity pricing increases. Contingencies for possible price escalation due to steel or other tariffs is not included.
3. No estimated costs have been included for taxes or other fees relative to the project.
4. Net Present Value - The labor, materials or equipment value in the present of a sum of money, in contrast to a future value when it has been invested at compound interest (assumed at 5%).

Wellhead Treatment Assumptions:

1. Wellhead treatment system installation would be adjacent to SRP Well 14.0E-9.6N within available existing property with adequate footprint.
2. Estimated costs do not include land acquisition and/or access agreements.
3. Estimated costs do not include permitting.
4. LGAC system includes two, 20,000-pound lead/lag systems in parallel for maximum flowrate of up to 2,200 gallons per minute.
5. Treated water recipient will accept a system flowrate of 2,200 gpm.
6. The existing production well pump will have enough capacity to overcome hydraulic head of wellhead treatment system.
7. No production well pump, booster pumps, effluent discharge pumps, or inclusion of equalization tanks will be required for wellhead treatment.
8. Treated water discharge will be tied in to the existing production well conveyance pipeline.
9. Treatment system concrete slab will be 1-foot thick on grade with secondary containment curbing.
10. Treatment system metal mesh fencing will be 8-feet in height.
11. Treatment system would have at minimum a gravel pathway to the treatment compound from the nearest paved roadway.
12. Installation of a new electrical service/transformer will not be required.
13. Instrumentation and controls will be connected to existing PLC.
14. No modifications will be needed for existing wellhead instrumentation and controls.
15. O&M costs assume monthly bag filter changeouts, quarterly sampling, and bi-annual carbon vessel changeouts for a total of 80,000 pounds of LGAC per year.
16. O&M costs exclude utility costs.

Table A-2
Estimated Costs for More Aggressive Alternative Remedy
24th St and Grand Canal WQARF Site
Phoenix, Arizona

	Quantity	Unit	Unit Cost	Total Cost	Estimated Low Range (-30%)	Estimated Upper Range (+50%)
Groundwater (GW) - Source and Extended Area Ozone Sparge and MNA Monitoring of Existing Well Network						
Estimated Groundwater Capital Costs						
Ozone System Remedy Final Design						
Ozone System Remedy Final Design	1	LS	$100,000	$100,000	$70,000	$150,000
IW Installations						
Source area IWs at CVS Property Installation and Oversight	6	EA	$70,000	$420,000	$294,000	$630,000
Grand Canal IWs Installation and Oversight	7	EA	$70,000	$490,000	$343,000	$735,000
Vertical Profile, Survey, Permitting, IDW Disposal	1	LS	$40,000	$40,000	$28,000	$60,000
Ozone Systems Installations						
Ozone Generator Purchase (Including Conex Box and Telemetry)	2	LS	$230,000	$460,000	$322,000	$690,000
Earthwork, Trenching and Pipe Installation (CVS Property)	100	FT.	$150	$15,000	$11,000	$23,000
Earthwork, Trenching and Pipe Installation (Grand Canal Property)	800	FT.	$150	$120,000	$84,000	$180,000
Asphalt Repair (Grand Canal Property)	800	FT.	$40	$32,000	$22,000	$48,000
Related Appurtenances, Equipment and Repairs	1	LS	$30,000	$30,000	$21,000	$45,000
Hydrogen Peroxide Injection at CVS						
Hydrogen Peroxide Injection at CVS Remedy Design	1	EA	$30,000	$30,000	$21,000	$45,000
Equipment/Repairs	1	LS	$30,000	$30,000	$21,000	$45,000
ISCO Injection, O&M, and Consumables	1	LS	$80,000	$80,000	$56,000	$120,000
ISCO Downgradient of Grand Canal						
Ozone System Remedy Design	1	EA	$50,000	$50,000	$35,000	$75,000
ISCO IWs Installation South of Grand Canal	7	LS	$50,000	$350,000	$245,000	$525,000
IDW Disposal	1	LS	$10,000	$10,000	$7,000	$15,000
Asphalt Repair	200	FT.	$50	$10,000	$7,000	$15,000
Equipment/Repairs	1	LS	$30,000	$30,000	$21,000	$45,000
One-time ISCO Injection and Oversight	1	LS	$100,000	$100,000	$70,000	$150,000
Downgradient Performance Well Installation						
Triple-Nested Monitoring Well Installation and Oversight	2	LS	$100,000	$200,000	$140,000	$300,000
Vertical Profile, Survey, Permitting, Traffic Control, IDW Disposal, Tech Memo	2	LS	$25,000	$50,000	$35,000	$75,000
Project Management/Oversignt/Administration	15%	n/a	n/a	$398,000	$279,000	$597,000
Capital Costs Subtotal				**$3,045,000**	**$2,132,000**	**$4,568,000**
Estimated Ozone O&M and GW Monitoring Annual Costs						
Ozone System Annual O&M	1	YR	$50,000	$50,000	$35,000	$75,000
Semiannual GW Monitoring/Reporting	2	EA	$40,000	$80,000	$56,000	$120,000
Miscellaneous Sampling & Field Supplies	1	YR	$6,000	$6,000	$4,000	$9,000
Equipment Repairs (as needed)	1	YR	$10,000	$10,000	$7,000	$15,000
Project Management/Oversignt/Administration	15%	n/a	n/a	$22,000	$15,000	$33,000
Annual Costs for Ozone O&M Subtotal				**$50,000**	**$35,000**	**$75,000**
Annual Costs for GW Monitoring O&M Subtotal				**$118,000**	**$83,000**	**$177,000**
6-Year Costs Life Cycle (3-Yrs. Ozone O&M + 6 GW Monitoring)				**$858,000**	**$830,000**	**$1,770,000**
Total GW Monitoring Costs for 6 Years (Net Present Value - Discounted 5%)				**$735,000**	**$641,000**	**$1,367,000**
Reference Remedy Capital, Monitoring, and O&M Costs				**$3,780,000**	**$2,646,000**	**$5,670,000**
Estimated GW Contingency Costs						
Ozone System O&M and GW Monitoring for 1 Additional Year	1	LS	$118,000	$118,000	$83,000	$177,000
SVE of One Existing Well for Subsurface Ozone at CVS	1	LS	$30,000	$30,000	$21,000	$45,000
Ozone Sparge IWs Near Production Well (Installation and Oversight)	2	EA	$50,000	$100,000	$70,000	$150,000
IDW Disposal	1	LS	$5,000	$5,000	$4,000	$8,000
Earthwork, Trenching and Pipe Installation	100	FT.	$150	$15,000	$11,000	$23,000
Asphalt Repair	100	FT.	$50	$5,000	$4,000	$8,000
Equipment/Repairs	1	LS	$30,000	$30,000	$21,000	$45,000
Use of Source Area Generator and O&M for 1 Year	2	LS	$40,000	$80,000	$56,000	$120,000
Vertical Profile, Survey, Permitting, IDW Disposal, Tech Memo	1	LS	$25,000	$25,000	$18,000	$38,000
Project Management/Oversignt/Administration	15%	n/a	n/a	$39,000	$28,000	$59,000
Wellhead Treatment						
Engineering Design/Procurement Services	15%	n/a	$228,000	$228,000	$160,000	$342,000
Treatment Compound (Foundation, Fencing, Mechanical, Instrumentation and Controls, Site Improvements, etc.)	1	LS	$500,000	$500,000	$350,000	$750,000
Estimated 2,000 gpm Treatment System (Two LGAC Vessels [including offload/installation[, Bag Filtration System, Interconnecting Piping)	1	LS	$985,000	$985,000	$690,000	$1,478,000
Conveyance Piping Modifications	1	LS	$30,000	$30,000	$21,000	$45,000
System Commissioning and Startup	1	LS	$35,000	$35,000	$25,000	$53,000
Construction Services (System Installation, Oversight, etc.)	15%	n/a	n/a	$233,000	$163,000	$350,000
O&M costs (assuming 20 Years Net Present Value - Discounted 5%)	1	LS	$1,200,000	$1,200,000	$840,000	$1,800,000
GW Contingency Costs Subtotal				**$3,658,000**	**$2,561,000**	**$5,487,000**
Total More Aggressive Alternative Remedy Costs (Including Contingencies)				**$7,438,000**	**$5,207,000**	**$11,200,000**

Table A-2
Estimated Costs for More Aggressive Alternative Remedy
24th St and Grand Canal WQARF Site
Phoenix, Arizona

Abbreviations:

WQARF = Water Quality Assurance Revolving Fund
% = percent
ERA - early response action
GW - groundwater
IDW - Investigation Derived-Wastes
IW - injection well
LF = linear feet
LGAC = liquid phase granular activated carbon
LS = lump sum
MNA = monitored natural attenuation
MO - month
O&M = operations and maintenance
PLC = programmable logic controller
VGAC = vapor phase granular activated carbon
VOCs = volatile organic compounds

Notes:

1. Total costs are rounded up to the nearest thousand dollars ($1000).
2. Pricing is subject to commodity pricing increases. Contingencies for possible price escalation due to steel or other tariffs is not included.
3. No estimated costs have been included for taxes or other fees relative to the project.
4. Net Present Value - The labor, materials or equipment value in the present of a sum of money, in contrast to a future value when it has been invested at compound interest (assumed at 5%).

Wellhead Treatment Assumptions:

1. Wellhead treatment system installation would be adjacent to SRP Well 14.0E-9.6N within available existing property with adequate footprint.
2. Estimated costs do not include land acquisition and/or access agreements.
3. Estimated costs do not include permitting.
4. LGAC system includes two, 20,000-pound lead/lag systems in parallel for maximum flowrate of up to 2,200 gallons per minute.
5. Treated water recipient will accept a system flowrate of 2,200 gpm.
6. The existing production well pump will have enough capacity to overcome hydraulic head of wellhead treatment system.
7. No production well pump, booster pumps, effluent discharge pumps, or inclusion of equalization tanks will be required for wellhead treatment.
8. Treated water discharge will be tied in to the existing production well conveyance pipeline.
9. Treatment system concrete slab will be 1-foot thick on grade with secondary containment curbing.
10. Treatment system metal mesh fencing will be 8-feet in height.
11. Treatment system would have at minimum a gravel pathway to the treatment compound from the nearest paved roadway.
12. Installation of a new electrical service/transformer will not be required.
13. Instrumentation and controls will be connected to existing PLC.
14. No modifications will be needed for existing wellhead instrumentation and controls.
15. O&M costs assume monthly bag filter changeouts, quarterly sampling, and bi-annual carbon vessel changeouts for a total of 80,000 pounds of LGAC per year.
16. O&M costs exclude utility costs.

Table A-3
Estimated Costs for Less Aggressive Alternative Remedy
24th St and Grand Canal WQARF Site
Phoenix, Arizona

	Quantity	Units	Cost Per Unit	Total Cost	Total Cost (-30%)	Total Cost (+50%)
Groundwater - MNA Monitoring Limited Well Network Annually						
Estimated Capital Costs						
Downgradient "Toe" Monitoring Well Installation						
Triple-Nested Monitoring Well Installation and Oversight	2	LS	$100,000	$200,000	$140,000	$300,000
Vertical Profile, Survey, Permitting, Traffic Control, IDW Disposal, Tech Memo	2	LS	$25,000	$50,000	$35,000	$75,000
Project Management/Oversignt/Administration	15%	n/a	n/a	$38,000	$27,000	$57,000
Capital Costs Subtotal				**$288,000**	**$202,000**	**$432,000**
Estimated Monitoring Costs						
Semiannual Groundwater Monitoring/Reporting	2	LS	$40,000	$80,000	$56,000	$120,000
Miscellaneous Sampling & Field Supplies	1	LS	$6,000	$6,000	$4,000	$9,000
Project Management/Oversignt/Administration	15%	n/a	n/a	$13,000	$9,000	$20,000
Annual Groundwater Monitoring Subtotal				**$99,000**	**$69,000**	**$149,000**
30-Year Life Cycle				**$2,970,000**	**$2,079,000**	**$4,455,000**
Total Groundwater Monitoring Costs for 30 Years (Net Present Value - Discounted 5%)				**$1,520,000**	**$1,064,000**	**$2,280,000**
Groundwater Monitoring Capitol and O&M Costs				**$1,808,000**	**$1,266,000**	**$2,712,000**
Estimated Groundwater Contingency Costs						
Ozone Sparge IWs Near Production Well (Installation and Oversight)	2	EA	$50,000	$100,000	$70,000	$150,000
IDW Disposal	1	LS	$5,000	$5,000	$4,000	$8,000
Earthwork, Trenching and Pipe Installation	100	FT.	$150	$15,000	$11,000	$23,000
Asphalt Repair	100	FT.	$50	$5,000	$4,000	$8,000
Equipment/Repairs	1	LS	$30,000	$30,000	$21,000	$45,000
Use of Source Area Generator and O&M for 1 Year	2	LS	$40,000	$80,000	$56,000	$120,000
Vertical Profile, Survey, Permitting, IDW Disposal, Tech Memo	1	LS	$25,000	$25,000	$18,000	$38,000
Project Management/Oversignt/Administration	15%	n/a	n/a	$39,000	$28,000	$59,000
Wellhead Treatment						
Engineering Design/Procurement Services	15%	n/a	$228,000	$228,000	$160,000	$342,000
Treatment Compound (Foundation, Fencing, Mechanical, Instrumentation and Controls, Site Improvements, etc.)	1	LS	$500,000	$500,000	$350,000	$750,000
Estimated 2,000 gpm Treatment System (Two LGAC Vessels [including offload/installation[, Bag Filtration System, Interconnecting Piping)	1	LS	$985,000	$985,000	$690,000	$1,478,000
Conveyance Piping Modifications	1	LS	$30,000	$30,000	$21,000	$45,000
System Commissioning and Startup	1	LS	$35,000	$35,000	$25,000	$53,000
Construction Services (System Installation, Oversight, etc.)	15%	n/a	n/a	$233,000	$163,000	$350,000
O&M costs (assuming 20 Years Net Present Value - Discounted 5%)	1	LS	$1,200,000	$1,200,000	$840,000	$1,800,000
Groundwater Contingency Costs Subtotal				**$3,600,000**	**$2,520,000**	**$5,400,000**
LESS AGGRESSIVE REMEDY COSTS (INCLUDING CONTINGENCY)				**$5,408,000**	**$3,786,000**	**$8,112,000**

Abbreviations:

WQARF = Water Quality Assurance Revolving Fund
% = percent
LS = lump sum
LF = linear feet
VOCs = volatile organic compounds
PLC = programmable logic controller
O&M = operations and maintenance
Qtrly = quarterly
MNA = monitored natural attenuation
LGAC = liquid phase granular activated carbon

Notes:

Net Present Value - The value in the present of a sum of money, in contrast to some future value it will have when it has been invested at compound interest (Assumed 5%)
Costs rounded off to nearest thousand

Wellhead Treatment Assumptions

1. Wellhead treatment system installation would be adjacent to SRP Well 14.0E-9.6N within available existing property with adequate footprint.
2. Estimated costs do not include land acquisition and/or access agreements.
3. Estimated costs do not include permitting.
4. LGAC system includes two, 20,000-pound lead/lag systems in parallel for maximum flowrate of up to 2,200 gallons per minute.
5. Treated water recipient will accept a system flowrate of 2,200 gpm.
6. The existing production well pump will have enough capacity to overcome hydraulic head of wellhead treatment system.
7. No production well pump, booster pumps, effluent discharge pumps, or inclusion of equalization tanks will be required for wellhead treatment.
8. Treated water discharge will be tied in to the existing production well conveyance pipeline.
9. Treatment system concrete slab will be 1-foot thick on grade with secondary containment curbing.
10. Treatment system metal mesh fencing will be 8-feet in height.
11. Treatment system would have at minimum a gravel pathway to the treatment compound from the nearest paved roadway.
12. Installation of a new electrical service/transformer will not be required.
13. Instrumentation and controls will be connected to existing PLC.
14. No modifications will be needed for existing wellhead instrumentation and controls.
15. O&M costs assume monthly bag filter changeouts, quarterly sampling, and bi-annual carbon vessel changeouts for a total of 80,000 pounds of LGAC per year.
16. O&M costs exclude utility costs.