
Final Report

**Tucson International Airport
Area Superfund Site – Area B
Focused Feasibility Study**

Prepared for
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Executive Summary

The purpose of this focused feasibility study (FFS) is to reevaluate the remedial alternatives for Area B presented in the 2002 feasibility study (FS) of the Tucson International Airport (Airport) Area (TIAA) Superfund Site (Site) in Tucson, Arizona. Although the focus of this report is the former West-Cap facility, supporting information is provided for other project areas within Area B, including West Plume B (WPB), Arizona Air National Guard (AANG), and Texas Instruments (TI), to develop a comprehensive remedial strategy for Area B. The remedial alternatives are being re-evaluated because residual contamination within the source zones at the various project areas continues to impact the aquifer, extending the time required to operate the existing groundwater extraction and treatment systems. Incorporating operational data from the current remedy into the evaluation of remedial alternatives will allow for a more-realistic comparison of effectiveness and cost between alternatives. The evaluation of remedial alternatives for the former West-Cap facility is described in detail in this report. Information on the other project areas is included in the appendices and is referenced in the report to provide a more-comprehensive evaluation.

For the former West-Cap facility, the alternatives generated in the *FS of Former West-Cap Property and West Plume B with Supplemental West-Cap Remedial Investigation [RI] Results* (2002 FS; CH2M HILL, 2002), were re-evaluated with current conditions and incorporated into the evaluation. The following three major factors contributed to this reevaluation:

1. The facility that previously received and treated the groundwater produced by the groundwater extraction system at the West-Cap site is no longer operating.
2. Groundwater extraction and treatment, the alternative selected in the 2004 Record of Decision (ROD) Amendment (EPA, 2004), has not been effective at remediating source areas at the Site.
3. In-situ chemical oxidation (ISCO) has been tested at several locations within the Site, including the former West-Cap facility, and the results can be used to address previous concerns identified in the 2002 FS.

Five remedial alternatives were identified in the 2002 FS—no action, monitored natural attenuation (MNA), groundwater extraction and treatment, ISCO, and air sparging. These remedial alternatives were screened in light of current conditions and two alternatives were retained and developed for analysis. Both alternatives would treat primarily the source area, with downgradient contamination reduced through natural attenuation processes. The two alternatives are briefly described as follows.

ES.1 Alternative 1—Groundwater extraction and treatment using granular activated carbon

This alternative involves the extraction, treatment, and injection of groundwater to remove volatile organic compounds (VOCs) from groundwater. Groundwater would be extracted through one existing extraction well located in the source zone and one existing extraction

well and two new extraction wells located in the downgradient area. The extracted groundwater would be treated with liquid-phase granular activated carbon (LGAC). A new treatment system would be constructed on the West-Cap property and four new injection wells would be constructed to return treated groundwater to the aquifer. Contaminants in groundwater outside of the capture zone would be reduced through natural attenuation processes.

ES.2 Alternative 2—In Situ Chemical Oxidation Using Potassium Permanganate

This alternative involves the injection and recirculation of potassium permanganate within the source zone to reduce or eliminate the mass flux of VOCs out of the source area and into the downgradient plume area. Permanganate would also be injected across a portion of the downgradient plume to prevent contaminant migration beneath the airport runway to the west. Concentrations of VOCs outside of these treatment areas are significantly lower than those observed within the source area and would be reduced through natural attenuation processes and migration of permanganate from the injection points.

Cost estimates and net present value (NPV) calculations were prepared for both alternatives. The alternatives were evaluated individually and comparatively to determine the overall effectiveness and the relative strengths and weaknesses of each alternative. Both alternatives would provide overall protectiveness of human health and the environment, and meet the applicable or relevant and appropriate requirements (ARARs). Due to technical limitations related to treatment of VOC-containing groundwater within the fine-grained subsurface media present at the West-Cap site, Alternative 1 is considered much less effective. Rebound of contaminant concentrations would likely extend the operational time required for Alternative 1 for much longer than 30 years, while the estimated treatment time for Alternative 2 is between 13 and 20 years. Alternative 1, with an estimated NPV of about \$8.4 million over a 30-year period, is also considerably more expensive than Alternative 2, with an estimated \$1.5 million NPV.

Remedial alternatives for other Area B sites were combined with those generated for West-Cap into five more-comprehensive approaches for addressing contamination within Area B. These alternatives may be generally described as follows:

1. No action
2. Groundwater extraction and treatment
3. ISCO
4. ISCO combined with a permeable reactive barrier to prevent plume migration
5. ISCO combined with MNA outside of the treatment areas

These combined alternatives are developed and analyzed in a manner similar to that for West-Cap, but on an area-wide basis.

Contents

Section	Page
Executive Summary	i
ES.1 Alternative 1 – Groundwater extraction and treatment using granular activated carbon	i
ES.2 Alternative 2 – In Situ Chemical Oxidation Using Potassium Permanganate	ii
Contents.....	i
Abbreviations and Acronyms	v
1.0 Introduction.....	1-1
1.1 Organization of the FS	1-1
1.2 Background Information	1-2
1.2.1 Site Description	1-2
1.2.2 Site History	1-3
1.2.3 Nature and Extent of Contamination	1-4
1.2.4 Contaminant Fate and Transport	1-7
1.2.5 Risk Summary	1-8
2.0 Identification of Technologies.....	2-1
2.1 Introduction	2-1
2.2 Remedial Action Objectives	2-1
2.2.1 Contaminants of Interest	2-2
2.2.2 Allowable exposure/ARAR Analysis	2-3
2.2.3 Remediation Goals	2-4
2.3 General Response Actions	2-4
2.3.1 Institutional Controls	2-5
2.3.2 Monitoring	2-5
2.3.3 Containment	2-5
2.3.4 Extraction and Treatment	2-5
2.3.5 In Situ Treatment	2-6
2.4 Identification of Technologies Evaluated	2-6
2.4.1 Institutional Controls	2-6
2.4.2 Monitoring	2-6
2.4.3 Containment	2-7
2.4.4 Groundwater Extraction and Treatment	2-7
2.4.5 In Situ Treatment	2-7
3.0 Development and Screening of Alternatives – Former West-Cap Facility.....	3-1
3.1 Alternative 1 – Groundwater Extraction and Treatment	3-3
3.1.1 Description	3-3
3.1.2 Assessment	3-9
3.2 Alternative 2 – In Situ Chemical Oxidation	3-12
3.2.1 Description	3-12
3.2.2 Assessment	3-22
3.3 Comparative Analysis	3-25

3.3.1	Overall Protection of Human Health and the Environment.....	3-25
3.3.2	Compliance with ARARs	3-26
3.3.3	Long-Term Reliability and Effectiveness.....	3-26
3.3.4	Reduction of Toxicity, Mobility, or Volume of Waste.....	3-26
3.3.5	Short-term Effectiveness	3-27
3.3.6	Implementability	3-27
3.3.7	Cost.....	3-27
4.0	Detailed Analysis of Alternatives – Area B	4-1
4.1	Summary of Alternatives for the West Plume B, AANG, and TI Project Areas	4-1
4.1.1	West Plume B.....	4-1
4.1.2	Texas Instruments.....	4-4
4.1.3	Arizona Air National Guard.....	4-4
4.2	Comparative Analysis for Area B Remedial Alternatives	4-5
4.2.1	Development of Remedial Alternatives for Area B	4-7
4.2.2	Comparative Analysis of Remedial Alternatives for Area B	4-8
5.0	Works Cited.....	5-1

Tables

1-1	Summary of CERCLA Milestones for Area B
1-2	Summary Statistics for COPCs in Groundwater
1-3	Soil Gas Data Used for Risk Evaluation
1-4	Groundwater Risk Evaluation
1-5	Soil Gas Risk Evaluation
2-1	Maximum Contaminant Levels for the Primary Contaminants of Concern
3-1	Development and Screening of Alternatives
3-2	New Extraction Well Criteria
3-3	New Injection Well Criteria
3-4	Conveyance Piping Criteria
3-5	Summary of ISCO Pilot Study Results at the West-Cap Project Area
3-6	Potassium Permanganate Dosing Demand for West-Cap Source Area Remediation
3-7	Potassium Permanganate Dosing Demand for West-Cap Western Lobe Remediation
3-8	Cost Comparison
4-1	Cost Estimate for Monitored Natural Attenuation at West Plume B
4-2	Summary of the Remedial Alternative Evaluation for all Area B Project Areas
4-3	Summary of Comprehensive Remedial Alternatives for Area B
4-4	Estimated Costs for Comprehensive Remedial Alternatives for Area B

Figures

1-1	Area B Site Map
1-2	Well Location Map
1-3	Hydrostratigraphic Units of Area B
1-4	Generalized Geologic Cross-Section
1-5	Groundwater Elevations, January – March 2010
1-6	TCE Concentrations in Groundwater, January – March 2009
1-7	Elements of Risk Assessment

-
- 3-1 Conceptual Design for Groundwater Extraction and Treatment (Alternative 1)
 - 3-2 Conceptual Approach for In-Situ Chemical Oxidation (Alternative 2)
 - 3-3 Source Zone Implementation Schematic – Alternative 2
 - 4-1 Schematic of Comprehensive Remedial Alternatives for Area B

Appendices

- A ARARs Analysis for the West-Cap Area of the Tucson International Airport Superfund Site
- B Previous Evaluations of Monitored Natural Attenuation
- C Environmental Footprint Analysis
- D Cost Evaluation
- E Focused Feasibility Study for the Texas Instruments Project Area
- F Alternative Analysis for the Arizona Air National Guard Project Area

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Abbreviations and Acronyms

µg/L	microgram(s) per liter
µg/m ³	microgram(s) per cubic meter
1,1-DCE	1,1 dichloroethylene
2002 FS	<i>Feasibility Study of Former West-Cap Property and West Plume B with Supplemental West-Cap Remedial Investigation Results</i>
AANG	Arizona Air National Guard
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
AF	attenuation factor
AFP44	Air Force Plant 44
Airport	Tucson International Airport
ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
BHHRA	Baseline Human Health Risk Assessment for the Tucson International Airport Area Site
Btu	British thermal unit(s)
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	<i>Code of Federal Regulations</i>
cis-1,2-DCE	cis-1,2-dichloroethylene
COC	contaminant of concern
COPC	contaminant of potential concern
ECLR	excess lifetime cancer risk
EPA	United States Environmental Protection Agency
EPC	exposure point concentration
ESD	explanation of significant difference
FFS	focused feasibility study
FS	feasibility study

g permanganate/kg soil	gram(s) of potassium permanganate per kilogram of soil
g/L	gram(s) per liter
GAC	granular activated carbon
gpm	gallon(s) per minute
GRA	general response action
HI	hazard index
HQ	hazard quotient
IC	institutional control
ISCO	in situ chemical oxidation
KP	potassium permangante
lb	pound
LGAC	liquid-phase granular activated carbon
LSU	Lower Subunit
MCL	maximum contaminant level
MNA	monitored natural attenuation
NOD	natural oxidation demand
NPV	net present value
O&M	operations and maintenance
PCE	tetrachloroethene
PDEQ	Pima County Department of Environmental Quality
POTW	publicly owned treatment works
PRB	permeable reactive barrier
psi	pound(s) per square inch
PV	pore volume
PVC	polyvinyl chloride
QA/QC	Quality assurance and quality control
RAO	remedial action objective
RI	remedial investigation
ROD	Record of Decision
ROI	radius of influence

RSL	regional screening level
SDWA	Safe Drinking Water Act
SGZ	shallow groundwater zone
SHC	Southwest Hazard Control
Site	Tucson International Airport Area Superfund Site
SVE	soil vapor extraction
TCE	trichloroethene
TI	Texas Instruments
TIAA	Tucson International Airport Area
TTZ	target treatment zone
USU	Upper Subunit
VOC	volatile organic carbon
West-Cap Phase II RI	<i>Phase II Remedial Investigation Report, Former West-Cap Property and Vicinity, Area B, Tucson International Airport Area, CERCLA Site</i>
WPB	West Plume B
ZVI	zero-valent iron

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SECTION 1

Introduction

The U.S. Environmental Protection Agency (EPA) has requested CH2M HILL to prepare a focused feasibility study (FFS) for the former West-Cap facility, which is part of the Tucson International Airport (Airport) Area (TIAA) Superfund Site (Site) in Tucson, Arizona. The purpose of the FFS is to re-evaluate the remedial alternatives generated in the *Feasibility Study [FS] of Former West-Cap Property and West Plume B with Supplemental West-Cap Remedial Investigation [RI] Results* (2002 FS; CH2M HILL, 2002), incorporating current conditions into the evaluation. In addition, information from other project areas within Area B was included to provide a more-comprehensive evaluation of remedial strategies for Area B.

Three major factors that contributed to the reevaluation of remedial alternatives for the former West-Cap facility include the following:

1. The facility that previously received and treated the groundwater produced by the groundwater extraction system at the West-Cap site is no longer operating.
2. Groundwater extraction and treatment, the alternative selected in the 2004 Record of Decision (ROD) Amendment (EPA, 2004), has not been effective at remediating source areas at the Site.
3. In-situ chemical oxidation (ISCO) has been tested at several locations within the Site, including the former West-Cap facility, and the results can be used to address previous concerns identified in the 2002 FS.

The remedial alternatives from the 2002 FS were rescreened in light of current conditions, as described in **Section 3**, and two alternatives were identified for a detailed analysis, which is presented in **Sections 3.1** and **3.2**. A comparative analysis of the alternatives is presented in **Section 3.3**. Alternatives for all project areas within Area B are developed and evaluated in **Section 4**. The selection of a remedy for Area B will be documented in a ROD Amendment.

1.1 Organization of the FS

The organization of this document is as follows:

Section 1 describes the purpose and organization of the FFS and presents the background information, site description, site history, nature and extent of contamination, contaminant fate and transport, and baseline risk assessment.

Section 2 describes the identification of technologies and presents the remedial action objectives (RAO), remediation goals, and identification of technologies evaluated.

Section 3 describes the development the two alternatives for the former West-Cap facility and presents a comparative analysis.

Section 4 describes the integration and evaluation of alternatives for Area B. Alternatives that were generated for other project sites within Area B were combined with those for West-Cap to form comprehensive alternatives for addressing contamination across Area B.

Section 5 cites references used in this FFS.

Appendix A presents an analysis of legally applicable or relevant and appropriate requirements (ARARs).

Appendix B presents previous evaluations on monitored natural attenuation (MNA) at Area B.

Appendix C presents an Environmental Footprint Analysis.

Appendix D presents a cost evaluation.

Appendix E presents the evaluation of remedial alternatives for the Texas Instruments (TI) project area.

Appendix F presents the evaluation of remedial alternatives for the Arizona Air National Guard (AANG) project area.

1.2 Background Information

This section presents a site description and history, including the summaries of previous environmental investigations. Much of the information presented in this section was taken from the *Phase II Remedial Investigation Report, Former West-Cap Property and Vicinity, Area B, Tucson International Airport Area, CERCLA Site* (West-Cap Phase II RI; Arizona Department of Environmental Quality [ADEQ], 1998) and 2002 FS (CH2M HILL, 2002). Additions and modifications are based on additional investigation.

1.2.1 Site Description

In 1981, volatile organic carbons (VOCs), including trichloroethene (TCE), used as solvents by industries at and near the Airport were detected in the City of Tucson drinking water wells. In 1982, EPA began investigating groundwater contamination at various geographic locations within the proposed TIAA Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) site. In September 1983, the Site was officially included on the National Priorities List. For the purpose of investigating and remediating groundwater contamination, EPA divided the Site into the following three geographic areas: (1) the main groundwater contamination plume (main plume), (2) Western Area B, and (3) Eastern Area B.

In 1985, the U.S. Air Force adopted a remedy to address the groundwater contamination emanating in the upgradient portion of the main plume south of Los Reales Road. Three years later, in August 1988, EPA published a ROD addressing the groundwater contamination throughout the remainder of the Site (i.e., the northern portion). Within the ROD, the remedy was divided into Area A (the northern portion of the main plume) and Area B, which encompassed contaminated areas east of the main plume.

Area A includes the Tucson Airport Remediation project, Airport property, and Air Force Plant 44 (AFP44) project areas. Area B is located north of the Airport and includes the West Plume B (WPB), AANG, TI, and West-Cap project areas (see **Figure 1-1¹**). Because this FFS focuses primarily on West-Cap, information on Area A is not included.

¹ All figures are located at the back of the report.

Although the 1988 ROD presented a remedy for both Areas A and B, the ROD explained that the assumptions made regarding Area B were preliminary and were subject to further investigation. The ROD indicated that the remedy for Area B could require some alteration as additional information were gathered, as long as any remedial alternative achieved the same level of protection of human health and the environment and the same level of compliance with ARARs as the remedy selected in the 1988 ROD.

The current remedy for Area B consists of extracting contaminated groundwater, treating it to Site cleanup levels, and reusing the water. A summary of key milestones related to the investigation and implementation of remedial actions in Area B is provided in **Table 1-1**.

Data collected during RIs and remedial actions at the AANG and TI properties prior to 1996 indicated the existence of unidentified sources of groundwater contamination in the regional aquifer. Based on the location of the groundwater contamination and the direction of groundwater flow, the former West-Cap property was identified as a potential source of this contamination. A soil gas survey performed during 1996 and groundwater sampling performed during 1997 confirmed West-Cap as a source.

The source of VOCs in groundwater at West-Cap is attributed to improper storage or disposal of chlorinated solvents used in manufacturing. From the early 1960s to the late 1980s, the former West-Cap property was occupied by the West-Cap of Arizona Corporation, which manufactured small film capacitors and magnets, and used solvents as part of their manufacturing process. It is believed that solvents were disposed of into floor drains and then subsequently leaked from the floor drains and connecting sewer pipes into the soil (CH2M HILL, 2002).

1.2.2 Site History

Previous investigations prior to 2002 may be found in the 2002 FS (CH2M HILL, 2002). These investigations include records review, Phase I property assessment, shallow soil vapor survey, shallow soil sampling, Phase I RI, and Phase II RIs. The 2002 FS also describes work performed between 1998 and 2002 in response to recommendations identified in the West-Cap Phase II RI (ADEQ, 1998).

In early 1998, EPA initiated a time-critical removal action for the remediation of groundwater below the West-Cap project area. The purpose of this action was to mitigate and control the source of groundwater contamination in the area of the former West-Cap Building A. Four monitor wells and three extraction wells made up the extraction well system network. This included the installation of a pipeline connecting three new groundwater extraction wells (WC-3U1, WC-3U2, and WC-3L) to the existing TI (then Burr-Brown) groundwater treatment system. In addition to the extraction wells, four new groundwater monitor wells were installed (A5-U, BB-4, WC-4, and WC-5). Details of the EPA time-critical removal action are presented in *Final Report, Former West-Cap Facility, Tucson, AZ, EPA Time Critical Removal Action* (Southwest Hazard Control [SHC], 1999). The extraction well system started up in November 1998 with water piped to the existing TI air stripping facility. Treated water was reused by the TI facility for industrial use.

Several monitor wells (WC-4R, WC-6, WC-7, WC-8, and WC-9) were installed after the EPA time-critical removal action to further characterize vadose zone and groundwater contamination at and near the West-Cap project area. To help further delineate the extent of

TCE contamination in groundwater, two more groundwater monitor wells (WC-10 and WC-11) were constructed during May and June of 2004. The addition of these new wells increased the total number of active monitor wells at West-Cap to 22. Well locations are shown on **Figure 1-2**. A pilot soil vapor extraction (SVE) system operated at the West-Cap site for approximately 4 months in 2002. Rapidly decreasing concentrations of VOCs in the SVE influent and groundwater impact modeling based on rebound monitoring indicated that a full-scale SVE program was not necessary.

The original three extraction wells that were installed in June 1998 had not met performance expectations; WC-6 concentrations were rising, the three extraction wells were poor producers, and the existing plume was extended beyond the capture zone. Consequently, two new extraction wells (WC-13B and WC-14) were installed by CH2M HILL in September 2006 to increase the performance of the extraction system. In addition to increasing the amount of groundwater extracted, the new extraction wells were intended to lower the water table beneath the source area so that additional soil vapor monitoring and/or SVE could take place. The two new extraction wells were connected to the existing pipeline. The five extraction wells and piping, combined with the pre-existing groundwater treatment system located at TI, comprised the West-Cap groundwater extraction and treatment system. The TI system used air stripping to remove VOCs from groundwater at the West-Cap and TI sites, and TI used the treated water for onsite industrial activity. The capacity of the TI system was less than 80 gallons per minute (gpm).

The original three extraction wells were shut down on August 6, 2006, for installation of the new wells. Subsequently, the new wells produced more water than TI could use. TI indicated that it was reducing its capacity and no longer wanted to accept extraction well water for treatment. The TI facility has since ceased operation. As a result, the extraction wells have not been in operation since the August 2006 shutdown. The extraction well locations are shown on **Figure 1-2**.

During 2009, a treatability study was performed for the former West-Cap facility. The purpose of the treatability study was to evaluate the applicability of ISCO, MNA, and enhanced attenuation within Area B. CH2M HILL installed six multi-port monitoring wells and one single-port monitoring well during December 2008 and January 2009, prior to implementing the ISCO pilot test, to supplement the existing monitoring points. Potassium permanganate solution was injected into the subsurface during March 2009. Evaluation of the treatability study is reported in *Treatability Study for the Former West-Cap Facility, Tucson International Airport Area Superfund Site, Tucson, Arizona* (CH2M HILL, 2010). Results from the pilot test indicated that permanganate can be successfully delivered into the source area and that it could persist in the source area for 2 years or more, providing medium- to long-term treatment. The treatability study also indicated that natural attenuation could be effective for managing VOCs outside the source area.

1.2.3 Nature and Extent of Contamination

The estimated nature, magnitude, and lateral and vertical extent of groundwater contamination are described in the following section. Initial characterization was based on data collected during the West-Cap RIs. Modifications and additions were made based on additional data collection and interpretation efforts. The hydrogeology of the West-Cap site is presented first, followed by contaminant distribution.

Site Hydrogeology

The following description of Area B lithology was modified from information presented in the 2002 FS (CH2M HILL, 2002).

Saturated alluvial sediments within the Tucson Basin compose a single regional aquifer system. In the vicinity of the Site, the regional aquifer system is hydrogeologically complex because of lateral and vertical stratigraphic changes. The hydrogeology of Area B may be divided into three units below the vadose zone—the Upper Zone, the Middle Aquitard, and the Lower Zone. The Upper Zone is further divided into the Upper Unit and Lower Unit, which are separated by the Upper Aquitard. The relationship between these major units is shown in **Figure 1-3**. It should be emphasized that the designation of these subunits and intervening aquitards is made on a relatively local basis (i.e., within project areas and between adjacent project areas where sufficient hydrogeologic data exist). Because of the heterogeneous nature of the aquifer system, subunit correlation is generally difficult between areas where large hydrogeologic data gaps exist.

The focus of this FFS is the Upper Unit. The other hydrogeological units will not be described. A more detailed description of the hydrogeology at West-Cap is presented in the 2002 FS (CH2M HILL, 2002).

Within Area B, the Upper Unit occurs between approximately 85 and 145 feet below ground surface (bgs) and could contain one or two coarse-grained layers (subunits) in some areas, or consist entirely of fine-grained sediments. The coarse-grained subunits are termed the Upper Subunit (USU) and the Lower Subunit (LSU) based on their relative depths. The fine-grained sediments may be termed Shallow Groundwater Zones (SGZ). SGZs occur within the Upper Unit where unconfined saturated silt- and clay-rich sediments exist above the coarse-grained subunit(s) (the USU and/or the LSU). In these areas, continuously saturated conditions exist between the water table of the SGZ and the underlying subunit(s). SGZs consist predominately of saturated, fine-grained sediment, but may be locally interbedded with very thin (less than 1 foot), discontinuous, lenses of coarser-grained material. **Figure 1-4** shows a generalized geological cross-section of the West-Cap site to illustrate the relationship between the USU, LSU, and SGZ.

Regional groundwater movement is generally from southeast to northwest across Area B (see **Figure 1-5**). However, the direction and magnitude of the groundwater gradient vary significantly, in part because of hydrogeologic heterogeneity, and in part because of groundwater extraction and reinjection at the AANG property, which began in 1997. Groundwater extraction at the TI and West-Cap areas has also influenced groundwater flow during the times in which the extraction systems were operational.

In the northeast part of the AANG property, groundwater extraction and reinjection have caused significant localized changes in the magnitude and direction of the groundwater gradient in the USU. The most-significant change is a northwest-trending groundwater divide (i.e., hydraulic pressure ridge) at the eastern boundary of the AANG property. Groundwater to the southwest of the divide flows to the west-northwest, while groundwater to the northeast of the divide flows to the north until it is outside the influence of the reinjection wells, where it presumably again flows to the northwest in the natural direction of the regional gradient.

The regional groundwater flow in the LSU, under pumping and non-pumping conditions, is also generally to the north-northwest across Area B. In contrast to the USU, the groundwater reinjection to the vadose zone on AANG property has not hydraulically influenced the potentiometric surface of the LSU to a significant degree.

Contaminant Distribution

Contaminants of concern (COCs) in groundwater include VOCs, primarily TCE and tetrachloroethene (PCE). The West-Cap project area appears to have a distinct source zone, believed to be residual contaminants within fine-grained sediments at the base of the vadose zone, within the capillary fringe, and in the upper SGZ. **Figure 1-6** shows the general extent of VOC-affected groundwater near the West-Cap site in January 2009, prior to the potassium permanganate injection. The concentration contours were constructed with data from the USU, SGZ, and LSU. Consequently, the contours are not representative of a single layer and should be considered qualitative. Data from early 2009 is used throughout this evaluation because it provides the most-recent complete data set. Several wells near the source area have not been sampled for VOCs since March 2009 because permanganate is still present in the groundwater at this location.

The West-Cap plume is split along the northwest trending groundwater pressure ridge. Contamination south of the pressure ridge forms an elongated plume extending to the west-northwest, while contamination to the north of the pressure ridge forms a lobe to the north-northwest. The areal extent of this lobe has changed slowly over time; the need for additional monitoring will be evaluated as part of any remedial design. It is believed that the VOC plume extends onto the AANG property, where it has comingled with VOCs historically present at that site. The TI site is separate from West-Cap. Information for the AANG and TI sites is presented to provide context for this portion of Area B.

The highest level of contamination at the West-Cap project area is present in the SGZ at WC-17A. The concentration of TCE at WC-17A was 970 micrograms per liter ($\mu\text{g}/\text{L}$) during the January 2009 sampling event.

TCE concentrations in the USU, SGZ, and LSU prior to the ISCO pilot test are shown on **Figure 1-6**. The extent of TCE impact on each lithologic zone is discussed in the following paragraphs.

Shallow Groundwater Zone

The SGZ is typically bisected by the water table east of Plumer Avenue. The highest TCE concentrations are present in the SGZ. The maximum TCE concentration measured in January 2009 was 970 $\mu\text{g}/\text{L}$, in the lower SGZ port of Monitoring Well WC-17A. In general, results from the multi-port wells indicate that TCE concentrations increase with depth within the SGZ at the West-Cap project area.

Despite the high TCE concentrations in wells beneath the source area, TCE concentrations decrease within a short distance; for example, in Monitoring Well WC-7. Samples collected from monitoring wells near the edge of the former building foundation, such as WC-1, WC-15, and WC-16, contained approximately 100 $\mu\text{g}/\text{L}$ of TCE in January 2009.

Wells at the AANG project area are generally not screened within the SGZ. Wells at the TI project area are often screened across the SGZ and USU, and in this report results are attributed to the more transmissive USU.

Upper Subunit

VOCs are present in the USU near the former West-Cap facility and in a narrow band extending through Monitoring Well A-2U onto the AANG project area to the west-northwest (see **Figure 1-6**). Monitoring Well WC-17B contained the highest TCE concentrations within the USU prior to the ISCO pilot test, with the highest measured concentration of 240 µg/L in January 2009. West of Plumer Avenue, the highest concentration of TCE is at Well A-2U, with a concentration of 30 µg/L in January 2009. The highest concentration of TCE in the USU on the AANG property in January 2009 was 8.4 µg/L in Well MW-96-U. According to data obtained during drilling Wells WC-9 and WC-11, the USU is not continuous to the northwest of the former West-Cap facility. Recent concentrations of TCE in wells at the TI project area have generally been below the maximum containment level (MCL) of 5 µg/L with the exception of Extraction Well BB-2, which contained approximately 70 µg/L of TCE prior to initiation of a potassium permanganate injection pilot test in October 2009 (Malcolm Pirnie, 2010).

Lower Subunit

In the West-Cap project area, the LSU shows the largest areal impact from TCE, although concentrations are typically lower than those in the USU or SGZ. Concentrations of TCE in LSU monitoring wells ranged from less than 0.5 µg/L in Extraction Well WC-3L to 18 µg/L in Monitoring Well WC-9 in January 2009. The highest concentration of TCE in the LSU on the AANG property in January 2009 was 8.1 µg/L in Well MW-74-L.

1.2.4 Contaminant Fate and Transport

Contaminant fate and transport depends on the potential routes of migration and contaminant persistence in the environment. Persistence in the environment can depend, in part, on the chemical properties of the contaminants, contaminant transport, and degradation mechanisms in the natural environment.

Transport of VOCs within and out of the SGZ is limited by low groundwater velocity in the fine-grained material. This limits the amount of VOCs that are transported away from the source area, as evidenced by the relatively small area that contains TCE above 100 µg/L. Offsite transport is dominated by groundwater flow in the LSU, which contains lower VOC concentrations than the SGZ. Groundwater extraction at the AANG site likely contributes to the velocity and direction of groundwater flow within the USU and LSU, as previously discussed and, therefore, also contributes to the transport of VOCs away from the source area.

Attenuation mechanisms in groundwater include hydrodynamic dispersion, sorption, and biodegradation. Together, these mechanisms can decrease VOC concentrations over time and distance from the source area. Dispersion decreases VOC concentrations by moving molecules farther apart as groundwater moves through subsurface media. As subsurface soils contain low amounts of organic carbon, sorption is not a major attenuation factor. Biodegradation of chlorinated solvents can be slow in oxidative conditions that are present at the Site, but is likely occurring, based on data from the nearby West Plume B project area (CH2M HILL, 2009a). At that site, the presence of compounds such as 1,1-dichloroethene (1,1-DCE) and cis-1,2-dichloroethene (cis-1,2-DCE), which are products of biological reductive dechlorination, indicate that some biological degradation is occurring.

Without containment or treatment of the source area, VOCs will continue to migrate away from the source zones at the West-Cap and TI project areas. VOCs from the AANG property would also migrate into residential areas without some type of plume control south of Valencia Road.

1.2.5 Risk Summary

The purpose of this section is to describe the current and potential future human health risks and hazards related to exposure to contaminated groundwater and soil gas at the West-Cap project area. This analysis is based on the *Baseline Human Health Risk Assessment for the Tucson International Airport Area Site* (BHHRA; Arizona Department of Health Services [ADHS], 1996), which was updated based on recent contaminant concentration data. The BHHRA evaluated risks associated with soil, groundwater, and soil gas exposures to residential and/or industrial receptors under potential current/future land use conditions to chemicals from sources at the Site, the former Burr-Brown facility (TI), the former West-Cap property, and offsite residential properties. This risk assessment used validated data from the Airport property RI/FS and focused RI, Burr-Brown investigations, and investigations conducted at the former West-Cap property to evaluate health risks from potential exposure to contaminants in groundwater and soil gas. The exposure area evaluated encompasses the Site bounded by Valencia Road (north), Hughes Access Road (east and south), and Highway 89 (west), including the West-Cap property.

West-Cap Risk Summary

In the BHHRA, risk was evaluated for surface soil under current and future residential scenarios. The results showed excess lifetime cancer risk (ELCR) less than EPA's risk management range of 10^{-6} to 10^{-4} . A screening-level risk evaluation for soil gas and groundwater was performed in the BHHRA. Exposure to soil gas was evaluated for potential current and future occupational exposure through vapor intrusion. The ELCR for soil gas was less than the EPA's risk management range of 10^{-6} to 10^{-4} . Exposure to groundwater was evaluated for potential future residential exposure. The ELCR for groundwater exceeded EPA's risk management range of 10^{-6} to 10^{-4} . PCE, TCE, 1,1-DCE, and cis-1,2-DCE were identified as COCs in the groundwater. The risk summary for groundwater was updated in the 2002 FS (CH2M HILL, 2002).

Current/Future Exposure Pathways

Although the West-Cap project area currently contains no residential area, EPA has determined that potential risk exists for the future residential drinking water scenario (i.e., drilling new private wells for drinking water use). Updated risk calculations are presented in this section to supplement the previous risk assessment results with recent groundwater data.

Based on information provided in the BHHRA, Tucson Water production wells in the vicinity of the Site were shut down in 1981 after TCE was detected. Exposure to TCE contaminated water posed an unknown risk prior to 1981 because exposure levels are not known. A health assessment issued in 2001 determined that since contaminated municipal wells were closed and groundwater monitoring and remediation activities began, there have been no known significant exposures and no public health hazard from the city owned wells (ADHS, 2001). No significant exposures or public health hazards are known to have occurred since this document was issued in 2001.

Based on a private well assessment performed by the Pima County Department of Environmental Quality (PDEQ) in 2001, there were no known health concerns regarding private wells in the proximity of the West-Cap groundwater plume at that time (PDEQ, 2001). No health concerns related to private wells have become known since the assessment was issued in 2001, and there are no known residences between the West-Cap project area and AANG property. However, if there were a significant land use change in the future permitting residential development, no regulations are in place to prevent property owners from installing private wells within the plume areas. If private wells in plume areas were to be used for drinking water, there would be a completed exposure pathway.

Worker exposures to soil vapors, contaminated soil, or dust are the only current complete exposure pathways identified in the BHHRA (ADHS, 1996). These pathways were addressed in the EPA ROD for soils (EPA, 1997a). There is a possibility that private wells could become contaminated in the future if the groundwater plume were to migrate northwest, beyond the AANG facility. In addition, because no local ordinances or state laws prevent the drilling of private drinking water wells in contaminated areas, or converting an irrigation well into a drinking water well, there are additional potentially complete future exposure pathways (ADHS, 2000). If any of these potential pathways become complete, then ingestion of drinking water and using the contaminated water for cooking would be a concern, as would exposure to contaminants via bathing and showering (direct contact and inhalation of volatiles). Therefore, this FFS discusses the risks and hazards associated with possible future exposure to contaminants in groundwater using recent groundwater data.

Currently, numerous buildings are located in the West-Cap project area, and this area where these buildings are located is zoned as an industrial area. Therefore, an occupational worker was evaluated for the vapor intrusion pathway using soil gas data to update the previous risk assessment results with recent soil gas data. Methodologies from EPA's vapor intrusion guidance (EPA, 2002) were used in this evaluation.

Updated Risk Evaluation

This section presents an updated screening-level risk evaluation for groundwater and soil gas using recent data. The groundwater concentrations for the contaminants of potential concern (COPCs) are based on data from 22 monitoring wells (see **Figure 1-2**) in the West-Cap project area and in the adjacent and downgradient wells between 2005 and 2010 and are summarized in **Table 1-2**. For soil gas, data collected from seven locations (deep soil gas sampling ports in Wells WC-1, WC-6, WC-8, WC-15A, WC-16A, WC-17A, and WCSVE-1) during 2009 was used in this evaluation. In addition, soil gas data collected from WC-2 in September 1997 and WC-7 in August 2000 were used because these two locations were not sampled in 2009. For WC-2 and WC-7, data collected in summer was used as they had higher concentrations. Soil gas data from shallower depths were used where data from multiple depths were available. **Table 1-3** presents the soil gas data used in the risk evaluation.

Methodology

All chemicals detected in the groundwater and soil gas were selected as COPCs in this risk evaluation. For groundwater, the maximum detected concentrations and tap water regional screening levels (RSL) (EPA, 2010) were used as exposure point concentrations (EPC) in the calculations.

Figure 1-7 illustrates the elements of a full risk assessment. This risk evaluation is abbreviated as was done for the BHHRA because it uses risk ratio method to calculate risks. To calculate cancer risk estimates for individual COPCs, the EPC was divided by the EPA's RSL (based on carcinogenic effects and a target cancer risk of $1E-06$) and the resulting ratio was multiplied by $1E-06$. The cancer risk estimates for the individual COPCs were then summed to provide a cumulative cancer risk estimate. To obtain the hazard quotient for individual COPCs, EPC was divided by the EPA's RSL (based on noncancer effects and a hazard quotient [HQ] of 1). The HQs for the individual COPCs were summed to provide the hazard index (HI). The cumulative risk is compared against a risk management range of 10^{-6} to 10^{-4} (EPA, 1989) for carcinogens and HI is compared against a threshold HI of 1 for non-carcinogens.

For the soil gas evaluation, risks and hazards were evaluated for each location sampled. Detected concentrations from the most-recent sampling and shallowest depth were used as EPCs. Indoor air RSLs were adjusted for the soil gas evaluation by multiplying the indoor air RSL by 100 to account for attenuation from deep soil gas to indoor air (EPA, 2002). The same procedure was used to calculate risks and hazards as for groundwater with carcinogenic and non-carcinogenic ratios calculated and summed.

Current/Future Pathway Risk Summary

The potential future ELCR associated with using groundwater from the West-Cap project area for drinking water is approximately $2E-03$ (see **Table 1-4**), which exceeds EPA's point of departure for taking action ($1E-04$). The primary contributors to the risk are PCE ($1E-03$), and TCE ($5E-04$). The overall HI for drinking water is 1, which is equal to the noncancer threshold of 1. However, individual COPCs have HQs less than 1.

The highest TCE ($970 \mu\text{g/L}$) and PCE ($110 \mu\text{g/L}$) concentrations were found in WC-17A-L in January 2009.

The potential future excess lifetime cancer risks associated with indoor air pathway ranges from $3E-06$ to $1E-04$ (see **Table 1-5**), which is within or at the upper end of EPA's risk management range (10^{-6} to 10^{-4}). The primary contributor to maximum risk ($1E-04$) was TCE ($1E-04$). TCE was detected at a concentration of 58,400 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) in a soil gas sample collected from WC-7-25 in August 2000. TCE is also primary contributor to the risk in groundwater; however, the risk from a soil gas sample collected 10 years ago might not be representative of current conditions. The overall HIs for indoor air pathway are less than 1.

Uncertainties

Because there is no trend in concentrations for the main contributors over time, the maximum detected concentration in the groundwater was used to estimate risk, which is conservative and likely overestimates the risks and hazards. During generation of the tap water RSLs, it is assumed that the ingestion of water and inhalation of volatiles from water are the two primary exposure pathways. The dermal exposure route is not included (EPA, 1991), as it is considered to be of lesser potential for exposure. Omitting this exposure route may slightly underestimate the risk estimates and hazard quotients.

Indoor air RSLs were adjusted with a generic attenuation factor (AF) of 0.01 to account for attenuation from deep soil gas to indoor air. Use of this generic AF could underestimate or overestimate the risks and hazards, if the site-specific attenuation is different.

Two soil gas samples (WC-2-20 and WC-7-25) collected in 1997 and 2000, respectively, were included in the risk evaluation; however, these concentrations might not be representative of current conditions and could overestimate or underestimate the risks and hazards.

TABLE 1-1

Summary of CERCLA Milestones for Area B

Tucson International Airport Area Superfund Site—Area B

Year	Document or Milestone	Key Points
1988	Record of Decision for the TIAA	Pump-and-treat technology was selected as the remedial action for treatment of TCE to 1.5 µg/L at Area B.
1992	TI Remedial Action	Pump-and-treat system was installed at TI.
1994/1995	AANG Remedial Investigation	Investigation of all potential TCE sources at the AANG. Results identified an upgradient source for TCE-impacted groundwater, and a potential source at Site 5.
1996	ROD for AANG Site 5 Soils	SVE was selected as the remedy for Site 5 soils.
1996/1997	West-Cap RI and Phase II RI	Results indicated a TCE source near former Building A on West-Cap property.
1997	AANG Groundwater Remedial Action	Pump-and-treat system was installed at the AANG to prevent offsite migration of TCE-impacted groundwater.
1997	AANG Site 5 Remedial Action	SVE system was installed at Site 5 to remediate TCE-impacted soil.
1997	Explanation of Significant Differences	Remedial action for the AANG was modified and the federal Safe Drinking Water Act MCLs were adopted as the standards for groundwater re-injected into the regional aquifer.
1998	AANG Site 5 Closure Report	Remediation of Site 5 soils was determined to be complete and the closure recommendation was approved by EPA and ADEQ.
1998	West-Cap Groundwater Treatment Pilot Test	Pump-and-treat of TCE-impacted groundwater at West-Cap was pilot tested by the installation of a several extraction wells and a pipeline to the TI pump-and-treat system. The pilot test ran intermittently for several years.
1999	West-Cap Soil Vapor Extraction Pilot Test	A pilot-scale SVE system was implemented to address TCE-impacted soil.
2002	West Plume B RI/FS	Results identified an upper subunit TCE plume. A source of TCE was not identified.
2004	ROD Amendment	Remedial action for West-Cap was modified, and pump-and-treat was selected as the remedial action for West Plume B. RAOs for Area B were documented.
2009	ISCO Pilot Tests at 162nd Fighter Wing, West-Cap, and TI	ISCO pilot tests that evaluated the effectiveness of potassium permanganate at treating TCE were conducted at the AANG, West-Cap, and TI sites.

TABLE 1-2
 Summary Statistics for COPCs in Groundwater
 Tucson International Airport Area Superfund Site—Area B

COPCs	Number of Detections	Number of Analysis	Minimum Detected Value (µg/L)	Maximum Detected Value (µg/L)	Arithmetic Mean (µg/L)	Standard Deviation
1,1-DC	49	279	0.061	8.7	0.83	1.65
1,1,2-Trichloroethane	9	279	0.1	2.1	0.49	0.63
1,1,2-Trichloro-1,2,2- Trifluoroethane	12	279	0.11	0.62	0.35	0.17
1,2-Dichloropropane	2	279	0.62	0.66	0.64	0.03
1,3-Dichlorobenzene	1	279	0.11	0.11	0.11	0.00
1,4-Dichlorobenzene	1	279	0.1	0.1	0.10	0.00
2-Butanone, Methyl Ethyl Ketone	29	279	1.8	29	8.61	7.87
2-Hexanone	2	278	1.2	18	9.60	11.88
4-Methyl-2-Pentanone	2	278	2.2	5	3.60	1.98
Acetone	81	279	0.72	120	16.18	24.98
Benzene	22	279	0.051	1.5	0.31	0.35
Bromodichloromethane	5	279	0.051	0.13	0.09	0.03
Bromoform	6	279	0.5	1.1	0.60	0.25
Carbon Disulfide	23	279	0.071	1.6	0.58	0.38
Chlorobenzene	11	279	0.08	0.82	0.28	0.20
Chloroform	76	279	0.11	1.9	0.46	0.32
Chloromethane	12	279	0.07	0.77	0.20	0.19
CIS-1,3-Dichloropropene	4	279	0.11	0.15	0.13	0.02
CIS-1,2-Dichloroethene	13	279	0.11	7.2	1.21	1.90
Cyclohexane	2	278	0.11	0.5	0.31	0.28
Dichlorodifluoromethane	4	279	0.13	0.15	0.14	0.01
Ethylbenzene	10	279	0.015	0.38	0.21	0.13
Methyl Acetate	2	278	0.5	0.71	0.61	0.15
Methylene Chloride	32	279	0.1	2.1	0.64	0.55
Methyl Tert-Butyl Ether	2	279	0.22	0.5	0.36	0.20
Toluene	30	279	0.06	3.6	0.71	0.92
Trichlorofluoromethane	17	279	0.075	0.2	0.12	0.03
Vinyl Chloride	1	279	0.12	0.12	0.12	0.00
Trichloroethylene	215	279	0.088	970	42.17	107.90
Tetrachloroethylene	173	279	0.066	110	6.62	14.48

NOTE:

^a Summary statistics were generated using surrogate values of reported detection limit for constituents reported by the laboratory as not detectable.

TABLE 1-3
Soil Gas Data Used for Risk Evaluation
TIAA Superfund Site, West-Cap Project Area, Focused Feasibility Report, Tucson, Arizona

Analyte	Concentration																									
	WC-15A-U		WC-16A-U			WC-17A-U			WC-1-95			WC-6-90			WC-8-97			WC-SVE-1			WC-2-20		WC-7-25			
	1/21/2009		1/21/2009			1/21/2009			1/21/2009			1/21/2009			1/21/2009			1/23/2009			9/11/1997		8/23/2000			
	94-99		94-99			94-99			89.5-94.5			90-95			92-97			72-102			20		25			
Units -->	ppbv	µg/m3		ppbv	µg/m3		ppbv	µg/m3		ppbv	µg/m3		ppbv	µg/m3		ppbv	µg/m3		ppbv	µg/m3		ppbv	µg/m3			
1,1-Dichloroethane	24	97.1	U	24	97.1	U	21	85.0	U	24	97.1	U	2.3	9.3	U	23	93.1	U	3.1	12.5	U					
1,1-Dichloroethene	64	253.7		88	348.9		170	674.0		82	325.1		8.1	32.1		57	226.0		12	47.6		5863.5	23200			
1,1,1-Trichloroethane	24	131.0	U	24	131.0	U	21	114.6	U	24	131.0	U	2.3	12.5	U	23	125.5	U	3.1	16.9	U					
1,1,2-Trichloroethane	24	131.0	U	24	131.0	U	16	87.3	J	24	131.0	U	1.9	10.4	J	23	125.5	U	3.1	16.9	U					
1,1,2,2-Tetrachloroethane	24	164.8	U	24	164.8	U	21	144.2	U	24	164.8	U	2.3	15.8	U	23	157.9	U	3.1	21.3	U					
1,1,2-Trichloro-1,2,2-Trifluoroethane	63	482.8		58	444.5		120	919.7		30	229.9		7.4	56.7		100	766.4		3.8	29.1						
1,2-Dichlorobenzene	24	144.3	U	24	144.3	U	21	126.3	U	24	144.3	U	2.3	13.8	U	23	138.3	U	3.1	18.6	U					
1,2-Dichloroethane	24	97.1	U	24	97.1	U	21	85.0	U	24	97.1	U	2.3	9.3	U	23	93.1	U	3.1	12.5	U					
1,2-Dichloropropane	24	110.9	U	24	110.9	U	21	97.0	U	24	110.9	U	2.3	10.6	U	23	106.3	U	3.1	14.3	U					
1,2,4-Trichlorobenzene	24	178.1	UJ	24	178.1	UJ	21	155.8	UJ	24	178.1	UJ	2.3	17.1	UJ	23	170.7	UJ	3.1	23.0	U					
1,2-Dibromoethane	24	184.4	U	24	184.4	U	21	161.4	U	24	184.4	U	2.3	17.7	U	23	176.7	U	3.1	23.8	U					
1,2-Dichlorotetrafluoroethane	24	167.9	U	24	167.9	U	21	146.9	U	24	167.9	U	2.3	16.1	U	23	160.9	U	3.1	21.7	U					
1,3-Dichlorobenzene	24	144.3	U	24	144.3	U	21	126.3	U	24	144.3	U	2.3	13.8	U	23	138.3	U	3.1	18.6	U					
1,4-Dichlorobenzene	24	144.3	U	24	144.3	U	21	126.3	U	24	144.3	U	2.3	13.8	U	23	138.3	U	3.1	18.6	U					
Benzene	24	76.7	U	24	76.7	U	21	67.1	U	24	76.7	U	2.3	7.3	U	23	73.5	U	3.1	9.9	U					
Bromomethane	24	93.2	U	24	93.2	U	21	81.5	U	24	93.2	U	2.3	8.9	U	23	89.3	U	3.1	12.0	U					
Carbon Tetrachloride	24	151.0	U	24	151.0	U	21	132.1	U	24	151.0	U	2.3	14.5	U	23	144.7	U	3.1	19.5	U					
Chlorobenzene	24	110.5	U	24	110.5	U	21	96.7	U	24	110.5	U	2.3	10.6	U	23	105.9	U	3.1	14.3	U					
Chloroethane	24	63.3	U	24	63.3	U	21	55.4	U	24	63.3	U	2.3	6.1	U	23	60.7	U	3.1	8.2	U					
Chloroform	12	58.6	J	24	117.2	U	21	102.5	J	24	117.2	U	1.9	9.3	J	23	112.3	U	3.1	15.1	U					
Chloromethane	24	49.6	U	24	49.6	U	21	43.4	U	24	49.6	U	2.3	4.7	U	23	47.5	U	3.1	6.4	U					
Cis-1,3-Dichloropropene	24	108.9	U	24	108.9	U	21	95.3	U	24	108.9	U	2.3	10.4	U	23	104.4	U	3.1	14.1	U					
Cis-1,2-Dichloroethene	24	95.2	U	24	95.2	U	21	83.3	U	24	95.2	U	2.3	9.1	U	23	91.2	U	3.1	12.3	U					
Dichlorodifluoromethane	24	118.7	U	24	118.7	U	21	103.8	U	24	118.7	U	2.3	11.4	U	23	113.7	U	3.1	15.3	U					
Ethylbenzene	24	104.2	U	24	104.2	U	21	91.2	U	24	104.2	U	2.3	10.0	U	23	99.9	U	3.1	13.5	U					
Methylene Chloride	24	83.4	UJ	24	83.4	U	21	72.9	U	24	83.4	U	2.3	8.0	U	23	79.9	U	3.1	10.8	U					
Styrene	24	102.2	UJ	24	102.2	UJ	21	89.5	UJ	24	102.2	UJ	2.3	9.8	UJ	23	98.0	UJ	3.1	13.2	U					
Tetra,Or Perchloroethene	460	3119.9		540	3662.5		486	3296.3		380	2577.3		150	1017.4		470	3187.7		37	250.9		54.66	370	J	916	6200
Toluene	24	90.4	U	24	90.4	U	21	79.1	U	24	90.4	U	2.3	8.7	U	23	86.7	U	3.1	11.7	U					
Trans-1,2-Dichloroethene	24	95.2	U	24	95.2	U	21	83.3	U	24	95.2	U	2.3	9.1	U	23	91.2	U	3.1	12.3	U					
Trans-1,3-Dichloropropene	24	108.9	U	24	108.9	U	21	95.3	U	24	108.9	U	2.3	10.4	U	23	104.4	U	3.1	14.1	U					
Trichloroethene	3000	16121.5		3600	19345.8	J	3530	18969.6		2700	14509.3		160	859.8		3500	18808.4		270	1450.9	J	110.02	590		10889.7	58400
Trichlorofluoromethane	24	134.8	U	24	134.8	U	21	118.0	U	24	134.8	U	2.3	12.9	U	23	129.2	U	3.1	17.4	U					
Vinyl Chloride	24	61.3	U	24	61.3	U	21	53.7	U	24	61.3	U	2.3	5.9	U	23	58.8	U	3.1	7.9	U					

Notes:
µg/m3 - micrograms per cubic meter
ppbv - parts per billion by volume
U - Chemical not detected
UJ- Chemical not detected, estimated value
J - Estimated value

TABLE 1-4
Groundwater Risk Evaluation
Tucson International Airport Area Superfund Site—Area B

Contaminants of Potential Concern	Maximum Concentration (µg/L)	Tap Water Cancer RSL (µg/L)	Tap Water Noncancer RSL (µg/L)	Cancer Risk	Noncancer Hazard
1,1-DCE	8.7		3.40E+02	NA	2.56E-02
1,1,2-Trichloroethane	2.1	2.40E-01	1.50E+02	8.75E-06	1.40E-02
1,1,2-Trichloro-1,2,2-Trifluoroethane	0.62		5.90E+04	NA	1.05E-05
1,2-Dichloropropane	0.66	3.90E-01	8.30E+00	1.69E-06	7.95E-02
1,3-Dichlorobenzene	0.11	NA	NA	NA	NA
1,4-Dichlorobenzene	0.1	4.30E-01	1.00E+03	2.33E-07	1.00E-04
2-Butanone, Methyl Ethyl Ketone	29		7.10E+03	NA	4.08E-03
2-Hexanone	18		4.70E+01	NA	3.83E-01
4-Methyl-2-Pentanone	5		2.00E+03	NA	2.50E-03
Acetone	120		2.20E+04	NA	5.45E-03
Benzene	1.5	4.10E-01	4.40E+01	3.66E-06	3.41E-02
Bromodichloromethane	0.13	1.20E-01	7.30E+02	1.08E-06	1.78E-04
Bromoform	1.1	8.50E+00	7.30E+02	1.29E-07	1.51E-03
Carbon Disulfide	1.6		1.00E+03	NA	1.60E-03
Chlorobenzene	0.82		9.10E+01	NA	9.01E-03
Chloroform	1.9	1.90E-01	1.30E+02	1.00E-05	1.46E-02
Chloromethane	0.77		1.90E+02	NA	4.05E-03
Cis-1,3-Dichloropropene	0.15	4.30E-01	4.00E+01	3.49E-07	3.75E-03
Cis-1,2-Dichloroethene	7.2		3.70E+02	NA	1.95E-02
Cyclohexane	0.5		1.30E+04	NA	3.85E-05
Dichlorodifluoromethane	0.15		3.90E+02	NA	3.85E-04
Ethylbenzene	0.38	1.50E+00	1.30E+03	2.53E-07	2.92E-04
Methyl Acetate	0.71		3.70E+04	NA	1.92E-05
Methylene Chloride	2.1	4.80E+00	1.10E+03	4.38E-07	1.91E-03
Methyl Tert-Butyl Ether (Mtbe)	0.5	1.20E+01	6.30E+03	4.17E-08	7.94E-05
Toluene	3.6		2.30E+03	NA	1.57E-03
Trichlorofluoromethane	0.2		1.30E+03	NA	1.54E-04
Vinyl Chloride	0.12	1.60E-02	7.20E+01	7.50E-06	1.67E-03
Trichloroethylene	970	2.00E+00		4.85E-04	NA
Tetrachloroethylene	110	1.10E-01	2.20E+02	1.00E-03	5.00E-01
Total Cancer Risk/Hazard				2.E-03	1

NOTE:

NA = RSL not available

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TABLE 1-5
Soil Gas Risk Evaluation
TIAA Superfund Site, West-Cap Project Area, Focused Feasibility Report, Tucson, Arizona

Analyte Sample Location --> Sampling Date --> Units -->	Screening Levels ¹		Concentration		Industrial Cancer Risk	Industrial Noncancer Hazard												
	Industrial		WC-15A-U				WC-16A-U				WC-17A-U				WC-195			
	Cancer	Noncancer	1/21/2009				1/21/2009				1/21/2009				1/21/2009			
	µg/m3	µg/m3	µg/m3															
1,1-Dichloroethane	7.67E+02	NA	97.1	U			97.1	U			84.9	U			97.1	U		
1,1-Dichloroethene	NA	8.76E+04	253.7		--	2.90E-03	348.9		--	3.98E-03	674.0		--	7.69E-03	325.1		--	3.71E-03
1,1,1-Trichloroethane	NA	2.19E+06	131.0	U	--		131.0	U			114.6	U			131.0	U		
1,1,2-Trichloroethane	7.67E+01	NA	131.0	U			131.0	U			87.3	J	1.14E-06	--	131.0	U		
1,1,2,2-Tetrachloroethane	2.11E+01	NA	164.8	U			164.8	U			144.2	U			164.8	U		
1,1,2-Trichloro-1,2,2-Trifluoroethane	NA	1.31E+07	482.8			3.69E-05	444.5		--	3.39E-05	919.7		--	7.02E-05	229.9		--	1.76E-05
1,2-Dichlorobenzene	NA	8.76E+04	144.3	U			144.3	U			126.3	U			144.3	U		
1,2-Dichloroethane	4.72E+01	1.06E+06	97.1	U			97.1	U			85.0	U			97.1	U		
1,2-Dichloropropane	1.23E+02	1.75E+03	110.9	U			110.9	U			97.0	U			110.9	U		
1,2,4-Trichlorobenzene	NA	8.76E+02	178.1	UJ			178.1	UJ			155.8	UJ			178.1	UJ		
1,2-Dibromoethane	2.04E+00	3.94E+03	184.4	U			184.4	U			161.4	U			184.4	U		
1,2-Dichlorotetrafluoroethane	NA	NA	167.9	U			167.9	U			146.9	U			167.9	U		
1,3-Dichlorobenzene	NA	NA	144.3	U			144.3	U			126.3	U			144.3	U		
1,4-Dichlorobenzene	1.11E+02	3.50E+05	144.3	U			144.3	U			126.3	U			144.3	U		
Benzene	1.57E+02	1.31E+04	76.7	U			76.7	U			67.1	U			76.7	U		
Bromomethane	NA	2.19E+03	93.2	U			93.2	U			81.5	U			93.2	U		
Carbon Tetrachloride	2.04E+02	4.38E+04	151.0	U			151.0	U			132.1	U			151.0	U		
Chlorobenzene	NA	2.19E+04	110.5	U			110.5	U			96.7	U			110.5	U		
Chloroethane	NA	4.38E+06	63.3	U			63.3	U			55.4	U			63.3	U		
Chloroform	5.33E+01	4.28E+04	58.6	J	1.10E-06	1.37E-03	117.2	U			102.5	J	1.92E-06	2.40E-03	117.2	U		
Chloromethane	NA	3.94E+04	49.6	U			49.6	U			43.4	U			49.6	U		
Cis-1,3-Dichloropropene	3.07E+02	8.76E+03	108.9	U			108.9	U			95.3	U			108.9	U		
Cis-1,2-Dichloroethene	NA	NA	95.2	U			95.2	U			83.3	U			95.2	U		
Dichlorodifluoromethane	NA	8.76E+04	118.7	U			118.7	U			103.8	U			118.7	U		
Ethylbenzene	4.91E+02	4.38E+05	104.2	U			104.2	U			91.2	U			104.2	U		
Methylene Chloride	2.61E+03	4.56E+05	83.4	U			83.4	U			72.9	U			83.4	U		
Styrene	NA	4.38E+05	102.2	UJ			102.2	UJ			89.5	UJ			102.2	UJ		
Tetra,Or Perchloroethene	2.08E+02	1.19E+05	3119.9		1.50E-05	2.62E-02	3662.5		1.76E-05	3.08E-02	3296.3		1.58E-05	2.77E-02	2577.3		1.24E-05	2.17E-02
Toluene	NA	2.19E+06	90.4	U			90.4	U			79.1	U			90.4	U		
Trans-1,2-Dichloroethene	NA	2.63E+04	95.2	U			95.2	U			83.3	U			95.2	U		
Trans-1,3-Dichloropropene	3.07E+02	8.76E+03	108.9	U			108.9	U			95.3	U			108.9	U		
Trichloroethene	6.13E+02	NA	16121.5		2.63E-05	--	19345.8	J	3.16E-05	--	18969.6		3.09E-05	--	14509.3		2.37E-05	--
Trichlorofluoromethane	NA	3.07E+05	134.8	U			134.8	U			118.0	U			134.8	U		
Vinyl Chloride	2.79E+02	4.38E+04	61.3	U			61.3	U			53.7	U			61.3	U		
Total Risk/HQ					4E-05	0.03			5E-05	0.03			5E-05	0.04			4E-05	0.03

Notes:
NA - No screening level
U - Chemical not detected
UJ- Chemical not detected, estimated value
J - Estimated value
µg/m3 - micrograms per cubic meter

Notes:
¹Screening levels are calculated by multiplying EPA indoor air RSLs with 100 to adjust for attenuation from deep soil gas to indoor air.
RSL - Regional Screening Levels (EPA, 2010)
Bolded values are detected.

TABLE 1-5
Soil Gas Risk Evaluation
TIAA Superfund Site, West-Cap Project Area, Focused Feasibility Report, Tucson, Arizona

Analyte Sample Location --> Sampling Date --> Units -->	Screening Levels ¹		Concentration		Industrial Cancer Risk	Industrial Noncancer Hazard	Concentration		Industrial Cancer Risk	Industrial Noncancer Hazard	Concentration		Industrial Cancer Risk	Industrial Noncancer Hazard	Concentration		Industrial Cancer Risk	Industrial Noncancer Hazard
	Industrial		WC-6-90				WC-8-97				WC-SVE-1				WC-2-20			
	Cancer	Noncancer	1/21/2009				1/21/2009				1/23/2009				9/11/1997			
	µg/m3	µg/m3	µg/m3				µg/m3				µg/m3				µg/m3			
1,1-Dichloroethane	7.67E+02	NA	9.3	U			93.1	U			12.5	U						
1,1-Dichloroethene	NA	8.76E+04	32.1		--	3.67E-04	226.0		--	2.58E-03	47.6		--	5.43E-04	23200		--	2.65E-01
1,1,1-Trichloroethane	NA	2.19E+06	12.5	U			125.5	U			16.9	U						
1,1,2-Trichloroethane	7.67E+01	NA	10.4	J	1.35E-07	--	125.5	U			16.9	U						
1,1,2,2-Tetrachloroethane	2.11E+01	NA	15.8	U			157.9	U			21.3	U						
1,1,2-Trichloro-1,2,2-Trifluoroethane	NA	1.31E+07	56.7		--	4.33E-06	766.4		--	5.85E-05	29.1		--	2.22E-06				
1,2-Dichlorobenzene	NA	8.76E+04	13.8	U			138.3	U			18.6	U						
1,2-Dichloroethane	4.72E+01	1.06E+06	9.3	U			93.1	U			12.5	U						
1,2-Dichloropropane	1.23E+02	1.75E+03	10.6	U			106.3	U			14.3	U						
1,2,4-Trichlorobenzene	NA	8.76E+02	17.1	UJ			170.7	UJ			23.0	U						
1,2-Dibromoethane	2.04E+00	3.94E+03	17.7	U			176.7	U			23.8	U						
1,2-Dichlorotetrafluoroethane	NA	NA	16.1	U			160.9	U			21.7	U						
1,3-Dichlorobenzene	NA	NA	13.8	U			138.3	U			18.6	U						
1,4-Dichlorobenzene	1.11E+02	3.50E+05	13.8	U			138.3	U			18.6	U						
Benzene	1.57E+02	1.31E+04	7.3	U			73.5	U			9.9	U						
Bromomethane	NA	2.19E+03	8.9	U			89.3	U			12.0	U						
Carbon Tetrachloride	2.04E+02	4.38E+04	14.5	U			144.7	U			19.5	U						
Chlorobenzene	NA	2.19E+04	10.6	U			105.9	U			14.3	U						
Chloroethane	NA	4.38E+06	6.1	U			60.7	U			8.2	U						
Chloroform	5.33E+01	4.28E+04	9.3	J	1.74E-07	2.17E-04	112.3	U			15.1	U						
Chloromethane	NA	3.94E+04	4.7	U			47.5	U			6.4	U						
Cis-1,3-Dichloropropene	3.07E+02	8.76E+03	10.4	U			104.4	U			14.1	U						
Cis-1,2-Dichloroethene	NA	NA	9.1	U			91.2	U			12.3	U						
Dichlorodifluoromethane	NA	8.76E+04	11.4	U			113.7	U			15.3	U						
Ethylbenzene	4.91E+02	4.38E+05	10.0	U			99.9	U			13.5	U						
Methylene Chloride	2.61E+03	4.56E+05	8.0	U			79.9	U			10.8	U						
Styrene	NA	4.38E+05	9.8	UJ			98.0	UJ			13.2	U						
Tetra,Or Perchloroethene	2.08E+02	1.19E+05	1017.4		4.89E-06	8.55E-03	3187.7		1.53E-05	2.68E-02	250.9		1.21E-06	2.11E-03	370	J	1.78E-06	3.11E-03
Toluene	NA	2.19E+06	8.7	U			86.7	U			11.7	U						
Trans-1,2-Dichloroethene	NA	2.63E+04	9.1	U			91.2	U			12.3	U						
Trans-1,3-Dichloropropene	3.07E+02	8.76E+03	10.4	U			104.4	U			14.1	U						
Trichloroethene	6.13E+02	NA	859.8		1.40E-06	--	18808.4		3.07E-05	--	1450.9	J	2.37E-06	--	590		9.62E-07	--
Trichlorofluoromethane	NA	3.07E+05	12.9	U			129.2	U			17.4	U						
Vinyl Chloride	2.79E+02	4.38E+04	5.9	U			58.8	U			7.9	U						
					7E-06	0.01			5E-05	0.03			4E-06	0.003			3E-06	0.3

Notes:
NA - No screening level
U - Chemical not detected
UJ- Chemical not detected, estimated value
J - Estimated value
µg/m3 - micrograms per cubic meter

Notes:
¹Screening levels are calculated by multiplying EPA indoor air RSLs with 100 to ac
RSL - Regional Screening Levels (EPA, 2010)
Bolded values are detected.

TABLE 1-5
Soil Gas Risk Evaluation
TIAA Superfund Site, West-Cap Project Area, Focused Feasibility Report, Tucson, Arizona

Analyte	Screening Levels ¹		Concentration		Industrial Cancer Risk	Industrial Noncancer Hazard	Exceed Adjusted Residential RSL	Exceed Adjusted Industrial RSL
	Sample Location -->	Industrial		WC-7-25				
Sampling Date -->	Cancer	Noncancer	8/23/2000					
Units -->	µg/m3	µg/m3	µg/m3					
1,1-Dichloroethane	7.67E+02	NA						
1,1-Dichloroethene	NA	8.76E+04					Yes	No
1,1,1-Trichloroethane	NA	2.19E+06						
1,1,2-Trichloroethane	7.67E+01	NA					Yes	Yes
1,1,2,2-Tetrachloroethane	2.11E+01	NA						
1,1,2-Trichloro-1,2,2-Trifluoroethane	NA	1.31E+07					No	No
1,2-Dichlorobenzene	NA	8.76E+04						
1,2-Dichloroethane	4.72E+01	1.06E+06						
1,2-Dichloropropane	1.23E+02	1.75E+03						
1,2,4-Trichlorobenzene	NA	8.76E+02						
1,2-Dibromoethane	2.04E+00	3.94E+03						
1,2-Dichlorotetrafluoroethane	NA	NA						
1,3-Dichlorobenzene	NA	NA						
1,4-Dichlorobenzene	1.11E+02	3.50E+05						
Benzene	1.57E+02	1.31E+04						
Bromomethane	NA	2.19E+03						
Carbon Tetrachloride	2.04E+02	4.38E+04						
Chlorobenzene	NA	2.19E+04						
Chloroethane	NA	4.38E+06						
Chloroform	5.33E+01	4.28E+04					Yes	Yes
Chloromethane	NA	3.94E+04						
Cis-1,3-Dichloropropene	3.07E+02	8.76E+03						
Cis-1,2-Dichloroethene	NA	NA						
Dichlorodifluoromethane	NA	8.76E+04						
Ethylbenzene	4.91E+02	4.38E+05						
Methylene Chloride	2.61E+03	4.56E+05						
Styrene	NA	4.38E+05						
Tetra,Or Perchloroethene	2.08E+02	1.19E+05	6200		2.98E-05	5.21E-02	Yes	Yes
Toluene	NA	2.19E+06						
Trans-1,2-Dichloroethene	NA	2.63E+04						
Trans-1,3-Dichloropropene	3.07E+02	8.76E+03						
Trichloroethene	6.13E+02	NA	58400		9.53E-05	--	Yes	Yes
Trichlorofluoromethane	NA	3.07E+05						
Vinyl Chloride	2.79E+02	4.38E+04						
					1E-04	0.1		

Notes:
 NA - No screening level
 U - Chemical not detected
 UJ- Chemical not detected, estimated value
 J - Estimated value
 µg/m3 - micrograms per cubic meter

Notes:
¹Screening levels are calculated by multiplying EPA indoor air RSLs with 100 to ac
 RSL - Regional Screening Levels (EPA, 2010)
 Bolded values are detected.

Identification of Technologies

2.1 Introduction

Identification of technologies that could potentially be used at the former West-Cap facility was performed in the 2002 FS and is updated in this FFS. Alternatives for remediation were developed by assembling combinations of technologies, and the media to which they would be applied, into alternatives that address contamination on a sitewide basis. The steps of the process are briefly discussed as follows:

- Develop RAOs specifying the contaminants and media of interest, exposure pathways, and preliminary remediation goals that permit a range of treatment and containment alternatives to be developed
- Develop general response actions for each medium of interest defining containment, treatment, excavation, pumping, or other actions, singly or in combination that may be taken to satisfy the RAOs
- Identify volumes or areas of media to which general response actions might be applied, taking into account the requirements for protectiveness as identified in the RAOs, and the chemical and physical characterization of the West-Cap site
- Identify and screen the technologies applicable to each general response action to eliminate those that cannot be implemented technically
- Identify and evaluate technology process options to select a representative process for each technology type retained for consideration – although specific processes are selected for alternative development and evaluation, these processes are intended to represent the broader range of process options within a general technology type
- Assemble the selected representative technologies into alternatives representing a range of treatment and containment combinations

The development of alternatives based on remedial technologies is described in the following sections. The discussion is based on the West-Cap project area, but generally applies to other portions of Area B, as well.

2.2 Remedial Action Objectives

RAOs are narrative statements that define the extent to which sites require cleanup to meet the underlying objectives of protecting human health and the environment. RAOs reflect COCs, exposure routes and receptors, and acceptable contaminant levels (or a range of acceptable contaminant levels) for each medium. Once developed, RAOs can be expressed numerically as preliminary cleanup goals. Preliminary cleanup goals are chemical concentrations in environmental media that achieve the levels of protection specified by the RAOs. The preliminary cleanup goals consider the exposure pathways and scenarios that are

pertinent to the project areas, as described in the BHHRA (ADHS, 1996). Preliminary cleanup goals provide a basis for delineating the extent and volume of contamination that needs to be addressed and a basis for evaluating and comparing remedial alternatives. Preliminary cleanup goals are not final remediation goals or cleanup levels to be achieved by remedial action. Cleanup levels to be achieved through remedial action will be defined in the ROD Amendment for Area B.

In the 1988 ROD, developed for the regional aquifer contamination, the sole end use option for the treated water was direct drinking water use; thus, the analysis of response actions was limited by that end use. Accordingly, when the remedy was selected, a “target TCE concentration” was established at 1.5 µg/L to bring the levels of all COCs well below MCL, state action levels, and the 10⁻⁶ ECLR. EPA’s 1998 Explanation of Significant Difference (ESD) considered the appropriate cleanup goals where the treated water would not be used as drinking water supply, but would be reinjected into the aquifer; in that instance, the treatment standard was clarified to be the in situ cleanup goal of the MCL of 5 µg/L for TCE.

ROD guidance at the time that the 1988 ROD was issued did not require the identification of RAOs. However, the RAOs implicit in the 1988 ROD are the same as the RAOs for the 2004 ROD Amendment. The RAOs for the remedy are to achieve the following:

- Maintain protection of human health and the environment by reducing the risk of potential exposure to contaminants
- Expedite cleanup and restoration of the West-Cap site
- Use permanent solutions to the maximum extent practicable
- Restore contaminated groundwater to the extent practicable to support existing and future land uses
- Achieve compliance with ARARs
- Minimize untreated waste
- Cost effectively reduce contamination in groundwater to concentrations that meet the cleanup goals
- Return groundwater to its beneficial uses to the extent practicable within a timeframe that is reasonable
- Protect groundwater resources by preventing or reducing migration of groundwater contamination above MCLs

These RAOs are based on the present use of the West-Cap site, the anticipated potential for future use of the West-Cap site, and the potential for groundwater in the area to be used as a drinking water supply. These RAOs were retained during development of potential remedies for all project areas within Area B (**Section 4**).

2.2.1 Contaminants of Interest

Contaminants of interest in groundwater include VOCs, primarily TCE and PCE, and degradation products 1,1-DCE and cis-1,2-DCE. These are also referred to as the COCs. Of the four, only cis-1,2-DCE has not been detected in groundwater above its MCL. Vinyl chloride,

another potential degradation product of TCE and PCE, has only been detected in groundwater once at a concentration below its MCL and it is not considered a COC.

2.2.2 Allowable exposure/ARAR Analysis

Section 121(d) of CERCLA states that remedial actions on CERCLA sites must attain (or justify the waiver of) any federal or state environmental standards, requirements, criteria, or limitations that are determined to be legally ARAR. Applicable requirements are those cleanup standards, criteria, or limitations promulgated under federal or state law that specifically address the situation at a CERCLA site. A requirement is applicable if the jurisdictional prerequisites of the environmental standard show a direct correspondence when objectively compared with the conditions at the Site.

If a requirement is not directly legally applicable to the remedial action, the requirement is evaluated to determine whether it is relevant and appropriate. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable, address problems or situations sufficiently similar to the circumstances of the proposed response action and are well suited to the conditions of the site. The criteria for determining relevance and appropriateness are listed in Title 40, *Code of Federal Regulations* (CFR), Section 300.400(g)(2) (40 CFR 300.400[g][2]).

ARARs are divided into three categories – chemical-, location-, and action-specific requirements. Chemical-specific ARARs define the concentration levels for contaminants in the groundwater that determine whether a problem exists and help to determine the subsequent cleanup criteria. Chemical-specific ARARs also define the concentration levels required for satisfactory groundwater treatment and implementation of the end use alternatives for the treated groundwater. Location-specific ARARs relate to the geographical or physical location of the site and may limit what actions can be taken, given the specific geographic characteristics of the site. Action-specific ARARs are requirements that define acceptable treatment and disposal procedures for hazardous substances. A detailed discussion of the potential ARARs identified for the West-Cap site is provided in **Appendix A**.

The numerical values provided in the Safe Drinking Water Act (SDWA) MCLs are among the criteria that are considered relevant and appropriate to the groundwater contamination at the Site. These numerical values, or SDWA MCLs, are enforceable limits on the concentrations of certain constituents in drinking water at the tap. Because the beneficial uses of the aquifer at the Site include potential use for domestic water supply, drinking water standards, including the SDWA MCLs, are relevant and appropriate as cleanup goals for the aquifer. The presence of contaminants above MCLs has degraded the beneficial uses of the groundwater at the Site; therefore, remedial action will need to address the contamination to restore the groundwater and protect water supplies outside of the area of contamination.

The ARARs have been identified in a sequential manner. First, the ARARs that affect remedial goals, independent of the remedial alternatives, were identified. These are the chemical- and location-specific regulations and objectives that govern the release and need for remediation of specific hazardous materials and present how the physical location of the West-Cap site determines where and how facilities can be constructed and operated. Next, the action-specific ARARs are identified for each alternative. These define the performance requirements of the system and could affect cost and implementability of the alternative.

The ARARs presented in **Appendix A** were developed after examination of the extent of contamination and of the details of each remedial alternative. These ARARs are preliminary and represent the regulations that may apply to each potential option and the proposed alternative. The final ARARs identification and selection will be documented in the ROD Amendment for Area B.

2.2.3 Remediation Goals

Preliminary cleanup goals are developed on the basis of chemical-specific ARARs and/or site-specific, risk-based factors, and are designed to facilitate the development and evaluation of the remedial technologies and remedial alternatives. Preliminary cleanup goals are chemical concentrations in environmental media that achieve the levels of protection specified by the RAOs. RAOs must be translated into numerical preliminary cleanup goals to evaluate the effectiveness of an alternative in reducing risk or meeting an ARAR and to compare the costs of different alternatives. In addition, the preliminary cleanup goals provide the basis for defining areas and volumes of contaminated media for which remedial alternatives are developed.

The preliminary cleanup goals for the contaminated groundwater were developed from chemical-specific ARARs and are defined as the MCL for each COC. MCLs are concentrations that EPA has determined to be safe for drinking water and are generally relevant and appropriate for groundwater that is or that may be used as a source of drinking water. The MCLs for the primary COCs are presented in **Table 2-1**. This standard applies to both in situ groundwater and any treated water that is used for reinjection, industrial use, or irrigation. It is not anticipated that groundwater extracted during remediation will be used as drinking water.

The final cleanup goals for the selected remedial alternatives will be presented in the ROD Amendment.

TABLE 2-1
Maximum Contaminant Levels for the Primary Contaminants of Concern
Tucson International Airport Area Superfund Site—Area B

Parameter	Primary MCL (µg/L)
1,1,-DCE	7
cis-1,2-DCE	70
PCE	5
TCE	5

2.3 General Response Actions

General response actions (GRA) are basic actions that might be undertaken to remediate a site. For each GRA, several possible remedial technologies may exist, which can be further broken down into a number of process options. The following sections present GRAs that may be applicable to West-Cap.

The GRAs for this FFS include the following:

- Institutional controls (ICs)
- Monitoring
- Containment
- Extraction and treatment
- In situ treatment

As stated in **Section 1**, the purpose of this FFS is to compare the current pump-and-treat remedy to a proposed ISCO remedy. Accordingly, two remedial alternatives were developed based on the GRAs and representative technologies. The alternatives use combinations of the GRAs listed previously to meet the RAOs.

2.3.1 Institutional Controls

ICs are non-engineering methods by which access to contaminated environmental media is restricted. ICs may include restrictions or limitations on access, media use, or property use. Because of the migration of VOCs away from the former West-Cap facility, it is expected that remedial alternatives will include ICs for portions of the VOC plume outside of the treatment areas.

2.3.2 Monitoring

Monitoring consists of collecting samples of groundwater and analyzing the samples for COCs. Monitoring will be used in conjunction with an in situ or ex situ treatment technology to measure progress towards the RAOs. Within the treatment areas, monitoring will be used to measure progress of the selected remedial action. In areas of the VOC plume outside of the treatment areas, monitoring will be the only response action. Groundwater monitoring programs, consisting of a set of groundwater wells to be sampled on a routine basis, have been developed for each of the alternatives evaluated in this FFS.

2.3.3 Containment

Containment refers to minimizing the spread of groundwater contaminants. This may be accomplished using technologies such as active hydraulic gradient control using groundwater extraction wells. Other containment mechanisms, such as physical or reactive barriers, are generally not implementable at locations such as West-Cap, where the depth to groundwater is over 100 feet.

2.3.4 Extraction and Treatment

Groundwater extraction and treatment can be used in an attempt to meet groundwater cleanup standards by removing the contaminants from the groundwater using an aboveground treatment facility. Common treatment options include air stripping, which transfers contaminants from groundwater to an air stream, and granular activated carbon (GAC), which transfers contaminants from groundwater to activated carbon particles. The air stream may require additional treatment to remove contaminants, and the carbon is typically sent to a regeneration facility where contaminants are removed and destroyed, and the carbon is reused. Although air stripping has been used previously, GAC was selected for the evaluation (see **Section 3.1**) because it is generally considered more cost effective for treating

groundwater at the relatively low contaminant concentrations expected in treatment system influent.

2.3.5 In Situ Treatment

In situ treatment of groundwater entails treating the groundwater while it remains in the aquifer. Treatment can be achieved by applying physical, chemical, biological, or thermal techniques. ISCO injects oxidizing agents including liquid (e.g., permanganate, persulfate, and catalyzed hydrogen peroxide) or gaseous reagents (e.g., ozone) into the subsurface to oxidize organic constituents. Upon injection, the oxidizing agents spread into the aquifer, and, ideally, organic constituents are mineralized to carbon dioxide and inorganic salts after direct contact and reaction with the oxidant. Oxidizing agents can be delivered to the subsurface by direct-push, injection wells, or groundwater circulation wells.

2.4 Identification of Technologies Evaluated

The identified GRAs are evaluated in the following subsections. Potential technologies were identified for the GRAs, which were then developed into preliminary concepts for potential implementation. The alternatives developed, and discussed in **Section 3**, are based on combinations of applicable GRAs. Additional details regarding the implementation of the technologies are provided in the detailed analysis in **Section 3**.

2.4.1 Institutional Controls

ICs are generally used in conjunction with, or as a supplement to, active engineering measures. ICs used may include land use restrictions, such as covenants (including the use of groundwater), easements, or zoning and permitting programs; or informational devices such as deed notices, fact sheets, or the Pima County Private Well Sampling Program. It is expected that ICs will be one part of the proposed remedies.

2.4.2 Monitoring

Monitoring may be used for two primary purposes as part of a remedial alternative. The first is to monitor the effectiveness of the remediation system, which is performed through routine collection of samples from within the treatment process and from groundwater monitoring wells. The second is to monitor MNA, which is the use of natural attenuation processes to achieve site-specific remedial objectives (EPA, 1997b). Natural attenuation processes include biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants. The mechanism most likely to cause biodegradation of chlorinated hydrocarbons is reductive dechlorination. During this process, the chlorinated hydrocarbon is used as an electron acceptor, not a source of carbon, as in the case with fuel hydrocarbons. If there is not a significant amount of carbon source for biodegradation activities, the physical and geochemical processes can be the primary mechanisms for natural attenuation. These processes can also be sufficient to warrant natural attenuation as a remedial alternative if the contaminant concentrations are low, and temporal and spatial trends of the contaminant are stable.

Several previous studies conducted at the nearby WPB site indicated that groundwater containing approximately 30 µg/L of TCE is amenable to MNA (CH2M HILL, 2000; ADEQ, 2006; CH2M HILL, 2009a). Portions of the West-Cap project area share many common

characteristics with the WPB site, indicating that MNA might be able to meet the MCL for TCE within a reasonable timeframe (CH2M HILL, 2009a). MNA is used as a component of both remedial alternatives. The MNA studies are provided in Appendix B.

2.4.3 Containment

Containment of groundwater contamination could be attained through hydraulic control using extraction wells. Because containment does not treat the source area, operation of the containment system could be needed indefinitely. The groundwater extraction and treatment response action is expected to provide treatment of the source area and is, therefore, a more-sustainable alternative. Containment is not evaluated in this FFS.

2.4.4 Groundwater Extraction and Treatment

This technology uses extraction wells to remove contaminated groundwater from the subsurface and treat the groundwater with one of several available treatment technologies. Extraction of groundwater induces flow towards the extraction wells, and when properly designed and operated can create capture zones, eliminating migration of VOCs into downgradient areas. Extraction of VOCs in groundwater also treats the aquifer with the goal of meeting the preliminary cleanup goals in **Section 2.2.3**. Reinjecting the treated groundwater into the aquifer can also help control the migration of groundwater toward the extraction wells and provide clean water to flush out contaminated zones.

As proposed in Alternative 1, the treatment technology would be activated carbon, which retains certain VOCs within the carbon matrix through adsorption. The use of air stripping and carbon were both evaluated as treatment technologies in the 2002 FS, but considering the generally low VOC concentrations expected in extracted groundwater, carbon is generally more cost effective while maintaining high performance standards. Treated groundwater would be reinjected into the aquifer through a series of injection wells. Groundwater containing the highest VOC concentrations would be contained, extracted and treated, and groundwater containing lower VOC concentrations would be treated through MNA.

2.4.5 In Situ Treatment

For this GRA, ISCO was identified as the technology mostly likely to be effective given the generally aerobic nature of the aquifer. ISCO uses chemical oxidants to react with and destroy a variety of organic contaminants in groundwater (Siegrist et al., 2001). ISCO is typically implemented through the subsurface injection of chemical oxidants, including hydrogen peroxide (Fenton's reagent), permanganate as either sodium permanganate or potassium permanganate, persulfate, and ozone. In addition to being suitable for the degradation of TCE, permanganate does not require activation and is highly stable and persistent. These characteristics allow substantial subsurface treatment from fewer injection points. As proposed in Alternative 2, ISCO would be used in areas of higher VOC concentrations to reduce mass transfer into areas of low VOC concentrations, and MNA would be used to treat the downgradient areas containing lower VOC concentrations.

A second technology was evaluated for in-situ treatment at the AANG project area (see **Section 4.3**). Zero-valent iron (ZVI) is a reagent that reacts with a variety of VOCs in a set of oxidation-reduction reactions that destroy the VOCs. By injecting ZVI into the subsurface, a permeable reactive barrier (PRB) may be formed that can intercept and destroy contaminants as they move in groundwater. As proposed in Alternative A4, a PRB would be installed at the

AANG property boundary to prevent migration of VOCs to the north away from the property.

SECTION 3

Development and Screening of Alternatives— Former West-Cap Facility

Five remedial alternatives for the former West-Cap facility were identified in the 2002 FS—No action, MNA, groundwater extraction and treatment, ISCO, and air sparging. Of these, ISCO and air sparging were removed from consideration during the initial screening process because of concerns about cost effectiveness and community acceptance. No action, MNA, and groundwater extraction and treatment were retained for detailed analysis. In the 2004 ROD Amendment, groundwater extraction and treatment was selected as the remedy because it provided both short- and long-term protectiveness of human health and the environment, it complied with ARARs, it was implementable, it was acceptable to the State of Arizona and the local community, and it was considered cost effective (EPA, 2004).

As previously discussed, operational changes prompted reconsideration of the remedy for the West-Cap site and the five original alternatives were re-evaluated. The no-action alternative was not reconsidered because the 2002 FS determined that it was not protective of human health or the environment. The groundwater extraction and treatment alternative was reconsidered because it was previously selected as the remedy for the West-Cap site and some of the required infrastructure is currently in place. ISCO was reconsidered because data obtained at the West-Cap location and other areas of the Site indicated that it could be cost effective and that the community might be receptive to ISCO as a remedy. The MNA alternative was reconsidered as a component of both the groundwater extraction and treatment alternative and the ISCO alternative. The air sparging alternative was not reconsidered because it is still not considered cost effective.

The alternatives generated in the 2002 FS are listed in **Table 3-1**, along with results of the initial screening in 2002 and the results of the 2011 screening.

TABLE 3-1
Development and Screening of Alternatives
Tucson International Airport Area Superfund Site—Area B

Alternative ^a	Initial Screening Result (2002) ^a	Secondary Screening Result (2011)
No Action	Retained for detailed analysis	Removed from consideration because it is not protective
Natural Attenuation	Retained for detailed analysis	Retained as a component of other alternatives
Groundwater Extraction and Treatment	Retained for detailed analysis	Retained for detailed analysis
ISCO	Removed from consideration because of concerns about cost effectiveness and community acceptance	Retained for detailed analysis
Air Sparging	Removed from consideration because low-cost effectiveness	Not reconsidered because of low-cost effectiveness

NOTE:

^aAs described in the 2002 FS (CH2M HILL, 2002)

In the following sections, the two identified alternatives – groundwater extraction and treatment and ISCO – are further refined based on additional site characterization and treatability studies performed after development of the 2002 FS, and subjected to more detailed evaluation. The purpose of this more detailed evaluation is to provide sufficient information to allow for comparisons among the alternatives based on the standard criteria specified in the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988).

The nine CERCLA evaluation criteria include the following:

1. Overall Protection of Human Health and the Environment
2. Compliance with ARARs
3. Long-term Effectiveness and Permanence
4. Reduction of Toxicity, Mobility, or Volume through Treatment
5. Short-term Effectiveness
6. Implementability
7. Cost
8. State Acceptance
9. Community Acceptance

The National Contingency Plan (40 CFR Section 300.430[e][9][iii]) (EPA, 1990) categorizes these nine CERCLA evaluation criterion into three groups – threshold criteria, primary balancing criteria, and modifying criteria. Each type of criteria has its own weight when it is evaluated. Threshold criteria are requirements that each alternative must meet to be eligible for selection as the preferred alternative, and include overall protection of human health and the environment and compliance with ARARs (unless a waiver is obtained). Primary balancing criteria are used to weigh effectiveness and cost tradeoffs among alternatives. The primary balancing criteria include long-term effectiveness and permanence; reduction of toxicity, mobility, or volume; short-term effectiveness; implementability; and cost. The primary balancing criteria represent the main technical criteria upon which the alternatives evaluation is based. Modifying criteria include state acceptance and community acceptance,

and may be used to modify aspects of the preferred alternative when preparing the ROD. Modifying criteria are generally evaluated after public comment on the FS and the Proposed Plan. Accordingly, only the seven thresholds and primary balancing criteria are evaluated in the detailed evaluation phase.

A detailed analysis of each alternative is provided in **Sections 3.1** and **3.2**. The detailed analyses provide the basis of the comparative analysis in **Section 3.3**.

An environmental footprint analysis (GeoTrans, Inc., 2010) was performed to identify and compare the effects of each alternative on five core elements of green remediation:

- Energy use
- Air quality
- Water use and quality
- Materials and waste
- Land and ecosystems

Key findings from the report are included in the description of each alternative. The draft report is included as **Appendix C**.

3.1 Alternative 1—Groundwater Extraction and Treatment

This alternative involves the extraction, treatment, and injection of groundwater at the West-Cap site to remove VOCs from groundwater. In developing this alternative, the existing groundwater extraction system was evaluated and modified to optimize the performance of the system. Existing infrastructure was augmented with two additional extraction wells, four injection wells, and a groundwater treatment facility. The use of SVE as a supplemental technology to remove VOCs from the source zone after the source zone is dewatered by the groundwater extraction system was briefly evaluated.

The alternative also includes ICs, monitoring, and MNA. ICs such as zoning or well permit requirements; judicial consent decrees or administrative orders; and easements or covenants would be used to minimize human exposure to contaminated groundwater while the remedial action is taking place. Because the West-Cap site has been subject to remediation activities for a relatively long timeframe, it is assumed that an IC mechanism is already in place; therefore, no cost involving the implementation of IC is included for either alternative in this FFS.

3.1.1 Description

Alternative 1 consists of extraction wells, a groundwater treatment system, injection wells, and conveyance piping. Infrastructure and operations are described in the following sections.

Extraction Wells, Injection Wells, and Conveyance Piping

The area of the plume east of the Airport runway would be contained and treated by the use of two existing extraction wells, installation of two new extraction wells, and installation of four new injection wells. The extracted groundwater would be treated with liquid-phase granular activated carbon (LGAC) to remove the COCs to below their MCLs.

As described in **Section 1.2.2**, a groundwater extraction system was installed as part of a time-critical removal action in 1998. However, the original three extraction wells (WC-3U1,

WC-3U2, and WC-3L) were not adequate to contain the plume. Therefore, two additional extraction wells (WC-13B and WC-14) were installed in September 2006, to increase capture of the plume and lower the water table to enhance the potential for SVE activities. The extracted groundwater went to the TI facility for treatment and then used for industrial use. In late 2006, TI notified EPA that the volume of groundwater extracted from the West-Cap site exceeded the need for process water, and the extraction system was shut down. The TI facility ceased manufacturing operations in 2009.

This alternative includes the use of two existing extraction wells (WC-13B and WC-14) to extract water from the SGZ, USU, and LSU, and installation of two new extraction wells located near Monitoring Well A-2U to extract water from the USU (see **Figure 3-1**). The flow rate for each extraction well would be approximately 40 gpm for a total flow of 160 gpm. This flow rate was selected based on the design assumptions that were developed prior to installation of wells WC-13B and WC-14 (CH2M HILL, 2005). These four extraction wells are expected to capture the groundwater and prevent it from migrating onto the AANG property. The criteria for the new extraction wells are provided in **Table 3-2**.

TABLE 3-2
New Extraction Well Criteria
Tucson International Airport Area Superfund Site—Area B

Parameter	Description	Comments
Depth	120 feet	Extract water from the USU aquifer only
Borehole diameter	14 inches	
Casing material	8-inch nominal Schedule 80 polyvinyl chloride (PVC) blank casing and screen	
Pump	10- to 80-gpm variable frequency drive, stainless steel	

It is assumed that four injection wells would be installed on the south, east, and north sides of the source area (see **Figure 3-1**). Each injection well would receive approximately 40 gpm for a total of 160 gpm, with the flexibility to modify the injection regime to control the hydraulic gradient. The location of the injection wells was selected to assist with flushing of the source area and control of plume migration. The criteria for the new injection wells are provided in **Table 3-3**.

TABLE 3-3
New Injection Well Criteria
Tucson International Airport Area Superfund Site—Area B

Parameter	Description	Comments
Depth	150 feet	Inject water into vadose zone, shallow groundwater zone, and LSU aquifer
Borehole diameter	18 inches	
Casing material	12-inch nominal Schedule 80 PVC blank and screen	

New belowgrade conveyance piping would be installed to connect the two new extraction wells to the new treatment system. It is assumed that existing piping for WC-13B and WC-14 would be used to connect these two wells to the new treatment system. It is assumed that all new piping would be needed to connect the injection wells to the treatment system. There would be two main pipelines for the injection wells. One pipeline would connect the two injection wells north of the treatment system. The other pipeline would connect the two injection wells to the east and south of the treatment system. The location of the existing extraction wells, proposed extraction wells, proposed injection wells, existing conveyance piping, and proposed conveyance piping is shown on **Figure 3-1**. The criteria for the conveyance piping are provided in **Table 3-4**. All piping would be buried in trenches.

TABLE 3-4
Conveyance Piping Criteria
Tucson International Airport Area Superfund Site—Area B

Parameter	Description	Comments
Connect two new extraction wells to treatment system	Approximately 1,625 feet of 2-inch Schedule 40 PVC pipe	Piping would accommodate flow range of 40 to 80 gpm
Connect existing piping for WC-13B and WC-14 to treatment system	Approximately 50 feet of 2-inch schedule 40 PVC pipe	Piping would accommodate flow range of 40 to 80 gpm
Connect two new injection wells to the north of treatment system	Approximately 860 feet of 2-inch Schedule 40 PVC pipe	Piping would accommodate flow range of 40 to 80 gpm
Connect two new injection wells to the east and south of treatment system	Approximately 460 feet of 2-inch Schedule 40 PVC pipe	Piping would accommodate flow range of 40 to 80 gpm

Soil Vapor Extraction as Potential Enhancement Technology

In the 2004 ROD Amendment, the possibility of adding an SVE component to the groundwater extraction and treatment alternative was considered. The approach would be to implement SVE if the source zone was partially dewatered during groundwater extraction activities, and the dewatered source zone contained significant residual contamination (EPA, 2004). To that end, Extraction Well WC-13B, which was installed in 2006, was constructed such that SVE could be applied through the well.

The effectiveness of the proposed groundwater extraction system to meet the two criteria specified in the ROD Amendment is not known to a degree sufficient to design or evaluate the performance of a supplemental SVE system. This uncertainty arises primarily from the presence of plastic clay in the SGZ. Clay soils drain poorly and have the ability to retain moisture even when allowed to drain by gravity, so it is not clear that extracting groundwater from WC-13B will generate soil that is permeable to air. The ability of clay to transmit air is limited, and the SVE system may need to extend beyond a single well to effectively remove VOCs from the target treatment zone (TTZ) to an extent sufficient to shorten the time necessary for the groundwater extraction system to operate.

Due to these limitations and uncertainties, the addition of SVE was not developed as part of Alternative 1.

Treatment System

The treatment system would be designed to treat the 160 gpm of extracted groundwater. Descriptions for the influent water quality, infrastructure, equipment, and operation are described in the following sections.

Influent Water Quality

The two existing extraction wells would pump water primarily from the LSU aquifer. In the West-Cap project area, the LSU shows the largest areal impact from TCE, although concentrations are typically lower than those in the USU or SGZ. Data from samples collected in March 2009, before the ISCO pilot test, showed TCE concentrations of 8 µg/L in WC-13B and 0.87 µg/L in WC-14 (see **Figure 1-6**). Concentrations of TCE in the LSU have been detected as high as 240 µg/L in Monitoring Well WC-17B.

The two new extraction wells would pump water from the USU aquifer. VOCs are present in a narrow band extending through Monitoring Well A-2U onto the AANG project area to the west-northwest. Monitoring Well A-2U consistently has the highest TCE concentrations within the USU, with the highest measured concentration of 46 µg/L in February 2008.

VOC concentrations in A-2U and Extraction Wells WC-13B and WC-14 were used to estimate the VOC concentrations of influent for the treatment system. Between 2005 and 2010, two compounds have been routinely detected above laboratory reporting limits in these wells: TCE at a maximum concentration of 47 µg/L and PCE at a maximum concentration of 7.5 µg/L. Sustained pumping will likely result in lower typical influent concentrations, and a concentration of 50 µg/L total VOCs was used to estimate design parameters for the groundwater treatment system.

An ISCO pilot test was conducted for the West-Cap site in 2009. Concentrations of permanganate were monitored as part of the pilot test. Permanganate was detected in WC-13B and WC-14. For WC-13B, the concentration was 65 mg/L; no data were available for WC-14. The permanganate in WC-13B and WC-14 will decrease over time and water from the new wells, which are not expected to contain permanganate, will dilute the permanganate concentrations. Therefore, the potassium permanganate is not expected to have significant impact on the existing extraction wells, existing piping, new conveyance piping, injection wells, treatment system equipment, or the granular activated carbon. The concentration of permanganate in the influent to the treatment system should be monitored to identify any potential adverse effects on the LGAC.

Infrastructure

The new treatment system would be located at the north end of the former Building A foundation (see **Figure 3-1**). This property is currently owned by Glaz Tech, a window manufacturing company, and a lease agreement would be needed to construct and operate the treatment system. Power is not currently delivered to this building, but there are overhead power lines between the foundation and Plumer Avenue. Therefore, a transformer with breaker and meter would need to be installed to provide power for the treatment system. A security fence would be installed at the perimeter of the treatment system compound with visibility-minimizing slats. Compound lighting would be provided for security and emergency use.

A concrete pad would be installed for the control panel equipment. A canopy would be installed for protection of the control panel equipment and operator use. A separate concrete containment pad would be installed for the treatment equipment. The pad would incorporate a concrete containment berm and sump. The pad and concrete berm would be sized to contain the largest tank volume and 6 inches of rain for the surface area. A ramp would be installed within the bermed area to allow for hand-truck or forklift passage onto the pad.

Conduit would be installed in the trenches with the buried pipelines to provide power to the new extraction wells.

Equipment

The treatment system would consist of the following equipment.

- A skid-mounted LGAC package including two 5,000-pound LGAC vessels rated for 75 pounds per square inch (psi) maximum operating pressure, interior and exterior epoxy coating, piping manifold to allow for lead-lag, lag-lead, and individual vessel backwash, upper and lower manways, and the initial fill of 10,000 pounds of virgin activated carbon. The pressure drop at 200 gpm would be less than 10 psi.
- A transfer pump rated for 200 gpm at 70 feet head and two discharge pumps rated for 200 gpm at 100 feet head. The pumps would be 460-volt, three-phase, centrifugal-type, totally enclosed, fan-cooled motor, and vertical mount.
- Automated ball valves to control flow to injection wells.
- Four dual-housing bag filters constructed of stainless steel and rated at 150 psi, with a capacity of 200 gpm. Two dual-housings will be used in parallel before the LGAC and two dual-housings will be used in parallel before going to the injection wells.
- Three cross-linked polyethylene tanks colored black (approximately 5,000 gallons each). All tanks shall have an upper manway, U.S. Occupational Safety and Health Administration (OSHA)-compliant ladders, external level indicators, and seismic tie-down kits. The equalization and discharge tanks would have ultrasonic level sensors to control the speed of the transfer pump and discharge pump. The equalization and discharge tanks would also have high and low alarm float switches.
- A self-contained $\frac{3}{4}$ -horsepower submersible sump pump rated for 70 gpm at 15 feet head with a built-in on-off float switch. A high-high alarm float switch would be installed in the sump.

- The system would be controlled via programmable logic controller with an operator interface terminal using remote internet access capability (phone line to modem). Main circuit breaker operating handle will extend through the door and be pad-lockable in the OFF position. The control panel for the pumps (transfer, discharge, and groundwater extraction) would be rated for NEMA 4X. The control panel would be air conditioned with an external ultraviolet-protective window cover (lockable) over the operator interface terminal.
- The groundwater extraction pumps, transfer pump, and discharge pumps would be powered by variable frequency drives. The variable frequency drives will be housed in the control panel.
- Flow sensors and flow totalizers at the wellheads to monitor the flow for each extraction well and injection well.
- Flow sensors and flow transmitters at the equalization tank inlet and discharge tank outlet to provide flow rates to the control panel.
- Piping would be Schedule 80 PVC installed aboveground in the treatment compound, covered in 1/2-inch foam with aluminum covering to provide ultraviolet protection and to minimize freezing of water in the pipes.

Operation

It is assumed that the groundwater extraction system would have two phases of operation. Initially, the system would operate to treat the offsite plume and prevent migration to the AANG property. During the initial phase, all four extraction wells would operate at approximately 40 gpm for a total capture of 160 gpm. Based on the estimated groundwater flow rate at the West-Cap site (CH2M HILL, 2002), it is assumed that this phase would last approximately 4 years. After about 4 years of treatment, the groundwater between the source area and the new extraction wells would have been flushed several times and, therefore, the TCE concentrations in this area are expected to be below 5 µg/L.

When the concentrations of TCE are less than 5 µg/L in the treatment areas near the downgradient extraction wells (two new extraction wells and WC-14), the downgradient extraction wells would be shut off, but WC-13B would continue to operate at approximately 40 gpm to provide containment of VOCs within the source area. It is expected that, because of residual TCE mass within the fine-grained shallow groundwater zone, pumping from beneath the source area would be needed for at least 30 years (including the 4-year initial containment phase). Partial dewatering of the SGZ would result in reduced or eliminated flow of groundwater through the SGZ, and residual contamination above the lowered water table would remain untreated by the groundwater extraction and treatment system. This would lead to a rebound of VOC concentrations upon cessation of pumping and significantly extend the time required for operation of the groundwater extraction and treatment system.

Based on the estimated VOC concentrations in the influent stream, it has been estimated that the lead carbon vessel would need regenerated carbon approximately once every 5 months during the first phase of operation, and once every 18 months during the second phase. Carbon performance will be monitored by collecting samples throughout the treatment process, and adjusting the replacement schedule, as needed, based on monitoring results. It is

expected that TCE loading will be the controlling factor in determining when the carbon needs to be replaced because it is present at the highest concentration of any VOC at the West-Cap site, but the performance standard will be not to emit any contaminant above its MCL.

Monitoring and Natural Attenuation

During the first phase of the remedy, when offsite extraction wells are in operation, all groundwater monitoring wells would be sampled on a semiannual basis to monitor the effectiveness of the extraction and treatment system. Groundwater samples would be analyzed for VOCs.

During the second phase of operation, after the offsite wells have ceased operation, monitoring wells would still be sampled semiannually for VOC analysis. Selected wells would also be sampled annually for MNA parameters including sulfate, manganese, hardness, nitrate/nitrite, alkalinity, total dissolved solids, ferric/ferrous iron, methane, ethane, ethene, total organic compounds, reduction/oxidation potential, and dissolved oxygen. Results of the MNA monitoring would be used along with trends in VOC concentrations to confirm the effectiveness of the MNA portion of the remedy.

Environmental Footprint

According to the environmental footprint analysis (**Appendix C**) Alternative 1 would consume over 1×10^{11} British thermal units (Btu) of energy and over 220,000 pounds of materials, and would emit approximately 25 million pounds of carbon dioxide, 246,000 pounds of criteria air pollutants and 6,800 pounds of hazardous air pollutants over the estimated 30-year remediation period. The primary contributors to the environmental footprint of Alternative 1 are the long-term energy use of the electric motors and the GAC used in the treatment process (GeoTrans, Inc., 2010).

3.1.2 Assessment

The detailed analysis of Alternative 1 in this section provides the basis of the comparative analysis of alternatives, as summarized in **Section 3.3**. A detailed analysis provides the basis for recommendations of the preferred alternative, and the information necessary for decision makers to select an appropriate site remedy. The following text presents an analysis of Alternative 1 based on the threshold criteria and primary balancing criteria described in the introduction to **Section 3**.

Overall Protection of Human Health and Environment

Alternative 1 can protect human health and the environment, in both the short and long term, from unacceptable risks posed by TCE contamination in groundwater that may currently serve, or in the future, may serve as a source of drinking water. Under Alternative 1, the groundwater contamination source area with TCE concentrations above those that could naturally attenuate would be contained by the extraction wells and treated using LGAC, removing TCE concentrations below the MCL. Access to groundwater within most of the VOC plume is restricted because it is within the Airport property. The inclusion of supplemental IC mechanisms, such as well permit requirements and land use restrictions, in areas outside the Airport property would further prevent consumption and contact of groundwater, enhancing protection of human health and the environment.

Compliance with ARARs

Alternative 1 is expected to comply with ARARs (chemical-, location-, and action-specific). Chemical-specific ARARs (i.e., MCLs) would likely be achieved within a reasonable time except for the source area, where contaminated groundwater would be contained, but VOC concentrations would remain above MCL for an extended period of time. Alternative 1 involves pumping, treatment, and injection, as well as MNA, to meet cleanup goals (MCLs) for chlorinated solvents in groundwater.

There is some uncertainty as to whether MCLs can be achieved throughout the VOC plume, and the length of time required for this to be accomplished. Portions of the VOC plume are located outside the capture zone of the proposed extraction wells, and achieving MCLs in these areas is dependent on natural attenuation processes and on remedial actions at nearby sites. For example, continued pumping at the AANG site would draw VOCs away from the West-Cap site and could increase or decrease the rates of attenuation processes. Also, the times required for the two phases of groundwater extraction are not well defined.

Alternative 1 would meet applicable waste management requirements for investigation-derived waste generated during the drilling, installation, and development of new extraction and injection wells. Treating the contaminated water and injecting onsite would eliminate the risk of moving the water to an alternative site and alleviating the need to rely on an outside treatment facility.

Long-term Reliability and Effectiveness

Extraction, treatment, and injection for remediation of groundwater containing TCE is well established, reliable, and capable of meeting performance requirements. However, when VOCs are present primarily in fine-grained media, the rate of VOC extraction is primarily dependent on diffusion of VOCs out of the fine-grained material, reducing the effectiveness of the process. Extraction has been used at the West-Cap project area for 8 years (1998 through 2006), but concentrations near the source area remain above 100 µg/L. As previously discussed, partial dewatering of the fine-grained SGZ would reduce or eliminate movement of groundwater through the SGZ, further reducing the effectiveness of groundwater extraction. It is estimated that after about 4 years of groundwater extraction, the offsite plume concentrations will likely meet the RAOs, but the exact time for this to be achieved is uncertain.

Long-term effectiveness and permanence can be monitored through implementation of treatment monitoring and a long-term MNA program to demonstrate attainment of MCLs within the entire West-Cap project area. Contingency planning can help mitigate the impacts should non-attainment occur. The long-term reliability of ICs implemented to restrict access to contaminated groundwater is also quite high. Access to the land above most of the VOC-impacted groundwater in this portion of Area B is controlled by the Airport or the AANG. Both of these entities are aware of the VOC contamination in groundwater and are unlikely to allow the use of groundwater from contaminated areas. It is expected that the land use and controlled access will continue indefinitely. Because all of the alternatives would require ICs, they are not used as an evaluation factor for selecting the preferred alternative.

Reduction of Toxicity, Mobility, or Volume of Wastes

Alternative 1 will use LGAC to extract and remove VOCs from groundwater. This will reduce the mobility and volume of VOCs in groundwater. The estimated removal efficiency of LGAC is in excess of 99 percent when properly operated. The LGAC will be thermally regenerated at an offsite facility, thereby destroying the contamination. Within about 4 years of pumping, it is estimated that concentrations of TCE in the offsite treatment area would be below 5 µg/L. The remaining concentrations at the source area would continue to decline due to continued groundwater extraction. Although the time needed for remediation is uncertain, it is assumed that the remedial goal would be reached within 30 years.

Short-term Effectiveness

The risks posed to the workers during the installation of wells and piping work can be effectively managed through proper health and safety procedures and use of proper personal protective equipment. Furthermore, risk to the environment during the construction and operation can be minimized through proper decontamination and use of secondary containment.

Implementability

Alternative 1 is expected to be readily constructed and operated. Alternative 1 involves installation of multiple injection and extraction wells, aboveground conveyance pipelines and treatment system. Because the project area is highly developed, obstacles such as obtaining required utility clearances, implementing traffic control, and obtaining easements may also be encountered.

Under Alternative 1, coordination between EPA, ADEQ, Arizona Department of Water Resources, City of Tucson, and Tucson Electric Power would be required. EPA would also need to coordinate for the proper permits needed for extraction and injection phases of the project. However, because this technology has been used recently at the Site, approval of needed permits should not pose an issue.

Cost

A detailed cost estimate for Alternative 1 is included in **Appendix D**. The cost includes a breakdown of the estimated capital cost, annual operations and maintenance (O&M) requirement, and net present value (NPV) for a 30-year period at a discount rate of 4 percent. As previously discussed, operation of Alternative 1 would likely be required for a much longer time period due to the inefficiency of treating fine-grained material using groundwater extraction. The cost estimates have been developed based on CH2M HILL's previous experience, RS Means, EPA guidance (EPA, 1988 and 2000), and vendors' quotes. The cost estimates are intended to be order-of-magnitude estimates, with an accuracy range of +50 to -30 percent. The range applies only to the alternative under the assumptions defined in **Section 3.1.1** and **Appendix D** and does not account for changes in the scope of the alternatives. The specific details of remedial actions and cost estimates would be refined during the remedial design if selected.

The NPV of Alternative 1 is approximately \$8.4 million.

3.2 Alternative 2—In Situ Chemical Oxidation

Alternative 2 involves injection of potassium permanganate solution into the subsurface to destroy VOCs in the soil and groundwater. A pilot study and treatability evaluation were conducted in 2009 (CH2M HILL, 2008, 2009a, 2009b, and 2009c) to evaluate the effectiveness of ISCO to treat the source area at the West-Cap site. The extent of the TCE plume and conceptual approach for Alternative 2 at the West-Cap project area are shown on **Figure 3-2**. A more detailed schematic of the source zone is provided in **Figure 3-3**.

The following section describes Alternative 2, including a summary of major assumptions, previous pilot study results, and conceptual design. A detailed analysis of Alternative 2 is included in **Section 3.2.2**.

3.2.1 Description

Alternative 2 for the West-Cap project area would consist of the following components:

- Permanganate solution injected into the source area to treat residual VOCs in the deep vadose zone and shallow groundwater
- Permanganate solution injected into a portion of the downgradient plume to reduce westward plume migration
- MNA in untreated plume areas

Injection of potassium permanganate into the source area would be expected to reduce or eliminate the mass flux of VOCs out of the source area and into the downgradient plume area. Permanganate solution would also migrate out of the injection zone and into the plume area, treating VOCs away from the injection points. Injection of permanganate into the western lobe of the plume would also help treat VOCs in the plume area and is expected to reduce or eliminate migration of VOCs to the west. Smaller portions of the plume, with relatively low VOC concentrations, may not be reached by the permanganate solution, and VOC concentrations in these areas are expected to decrease due to natural attenuation processes. Implementation of ISCO is described in the following sections.

Target Treatment Zones

There are two primary treatment zones at the West-cap project area — the source zone and the western lobe of the plume. These areas are described in more detail in the following subsections.

Source Area

The source area at the West-Cap project area is defined for this FFS by the area near the north end of the foundation of the former Building A. The source area contains TCE concentrations above 100 µg/L within the SGZ and USU. For the purpose of the full-scale ISCO remedy, this area is termed the source area target treatment zone (source area TTZ). As shown on **Figure 3-3**, the source area TTZ at the West-Cap project site is approximately 100 feet (length) by 90 feet (width) by 20 feet (depth; 105 to 125 feet bgs). The average TCE concentration in the SGZ and USU of the source area TTZ is approximately 540 and 230 µg/L, respectively, based on groundwater monitoring data collected during January 2009. ISCO is expected to reduce TCE concentrations within 1 year of the injection, although the ISCO efficiency is affected by numerous factors, such as recirculation flow rates, direct contact, adsorbed or dissolved VOC

mass, advective flow, and diffusion rates. Based on migration of permanganate observed during the pilot test (CH2M HILL, 2010), it is assumed that permanganate would be distributed throughout the source area TTZ within 1 year of injection, and 2 subsequent years of monitoring would confirm the performance of the permanganate injection or identify whether additional injection would be necessary.

Once the permanganate injected into the source area is consumed, it is expected that additional reduction in VOC concentrations will result from natural attenuation processes. If post-treatment TCE concentrations remain below approximately 30 µg/L, MNA is predicted to reduce TCE concentrations to below the MCL within 10 years after the completion of source area ISCO remediation, based on the MNA study results at the nearby WPB site (CH2M HILL, 2009c). A long-term MNA monitoring program would be implemented to demonstrate the shrinking plume and achievement of the cleanup goal. If monitoring data indicate that the plume is not attenuating, additional injection of permanganate may be necessary.

Western Lobe

A secondary treatment zone, or western lobe TTZ, is located in the western lobe of the plume, near the airport runway. This area, in particular Well A-2U, has historically contained the highest concentrations of TCE outside of the source area, with a maximum concentration of 46 µg/L observed in the sample collected from Well A-2U in February 2008. This section of the plume is about 350 feet wide. Permanganate would be injected into this area to reduce the migration of VOCs to the west, beneath the airport runway and onto the AANG property. The target zone in this area is limited to the USU, which is about 7 feet thick at this location. Although concentrations of TCE in Well A-2L, which is screened in the LSU, have exceeded the MCL in the past, the concentration of TCE in this well has been below the MCL since March 2009. It is assumed that the concentration of TCE will remain below the MCL in this well in the future, and no permanganate injection into the LSU in this area is anticipated. Should TCE concentrations in the LSU in this area increase in the future, injection into the LSU may be warranted.

It is likely that the permanganate injected into the western lobe TTZ would travel downgradient to the west, and groundwater containing VOCs would move from upgradient areas. For this reason, additional injections into this area may be needed. A monitoring program would be used to determine whether additional injection is needed based on oxidant and contaminant migration in this area.

Summary of ISCO Pilot Study Results

To obtain the oxidant dosage and other field application parameters (such as oxidant distribution, injection rate, and radius of influence), an ISCO treatability study was conducted including a laboratory testing of natural oxidant demand (NOD) of potassium permanganate and a field pilot-scale ISCO injection at the source area. A summary of the treatability study components and key results (CH2M HILL, 2009b and 2009c) are described in the following paragraphs.

The measured NOD was 0.60 gram of potassium permanganate per kilogram of soil (g permanganate/kg soil) in the vadose zone, 0.13 g permanganate/kg soil in the SGZ, and 0.03 g permanganate/kg soil in the USU. These values are relatively low, suggesting that the permanganate could be relatively persistent in the subsurface. Between March 6, 2009, and

May 2, 2009, CH2M HILL conducted a pilot study at the West-Cap project area to evaluate the effectiveness of delivery of permanganate to the targeted fine-grained saturated zone (SGZ), and coarse-grained LSU (CH2M HILL, 2008 and 2009b). A summary of key pilot study results is included in **Table 3-5**.

TABLE 3-5
Summary of ISCO Pilot Study Results in the West-Cap Project Area
Tucson International Airport Area Superfund Site—Area B

Injection Period	Injection Well	Injection Depth (feet bgs)	TTZ	Pilot Study Goal	Total Potassium Permanganate Mass Injected (lbs)	Total Potassium Permanganate Volume Injected (gallons)	Injection Flowrate (gpm) ^b	Wellhead Pressure (psi)	Observed Radius of Influence (ROI) (feet) ^a
March 6 to March 31, 2009	WCSVE-01	80 to 102	SGZ and capillary fringe	Gravity flow Injection into overlying coarse-grained unit for oxidant delivery to the TTZ	12,000	51,556	5 to 15	0	21
April 1 to April 17, 2009	WC-16A	91 to 96	SGZ and capillary fringe	Pressurized Injection into overlying coarse-grained unit for oxidant delivery to the TTZ	10,000	42,907	10 to 15	15 to 45	19
April 27 to May 2, 2009	WC-17A	115 to 120	SGZ and USU	Pressurized Injection into fine-grained SGZ for oxidant delivery to the TTZ	2,000	9,349	3 to 4	20 to 45	10

NOTES:

^aObserved ROI was based on the horizontal distance between the injection well and monitoring well where permanganate was observed during the pilot study. The actual ROI is likely larger.

^bThe decreased injection rate during April 27 to May 2, 2009 may be associated with the equipment used and less mass of permanganate injected, and less permeable zone injected.

The pilot study indicated that permanganate solution can be successfully delivered to the targeted zone via injection into the overlying coarse-grained vadose zone followed by the downward infiltration, although monitoring data indicated that the distribution was uneven. Other studies at the TIAA indicated that permanganate could be persistent in the subsurface for 2 years or more, probably because of the low NOD and relatively low organic content in the aquifer at TIAA (CH2M HILL, 2009c). The injection flow rates of 10 to 15 gpm per well and a reasonable ROI in excess of 20 feet can be achieved. The pilot study also demonstrated that direct injection and delivery to the less permeable SGZ zone appeared to be feasible; however, the achievable injection flow rates and ROI would likely be less than that of the vadose zone. Direct delivery to the SGZ would require an injection-grid system with more injection points and longer injection duration than injection into the vadose zone. Considering the depth and low permeability of the SGZ (deeper than 100 feet bgs), the traditional injection-grid system would not be cost effective. Instead, Alternative 2 would involve an injection-recirculation approach with fewer injection wells, as described in the following subsections. Although the SGZ has the highest TCE concentrations at the West-Cap site, Alternative 2 proposes to inject permanganate into the more permeable vadose zone, with a hydraulic gradient generated by extracting groundwater from the SGZ and USU to promote migration of permanganate into the SGZ.

Full-Scale ISCO Conceptual Design

The conceptual designs for the two areas of permanganate injection are described in the following subsections.

Source Area TTZ

The ISCO recirculation system at the source area TTZ would consist of a network of four new 2-inch PVC injection wells and four existing wells used as extractions wells. Four new injection wells would be installed in the vadose zone screened between 90 and 100 feet bgs, as depicted in the conceptual layout (see **Figure 3-3**). Permanganate solution equivalent to one full pore volume would be injected at the source area during one single injection event. Initially, approximately 30 percent of the required oxidant mass would be injected to the injection wells without extraction, for the purpose of maximizing the horizontal ROI and minimizing vertical short circuiting. Once this mass has been injected, the remaining 70 percent of the oxidant demand would be injected under recirculation mode to promote subsurface distribution of the oxidant solution. If the extracted water at downgradient extraction wells contains relatively high permanganate concentration (i.e., greater than 1 gram per liter [g/L]), reinjection without addition of new permanganate may be considered. The dosing calculation of potassium permanganate is included in **Table 3-6**.

TABLE 3-6
Potassium Permanganate Dosing Demand for West-Cap Source Area Remediation
Tucson International Airport Area Superfund Site—Area B

Description	Value	Units or Notes
Nominal length of source area TTZ	100	feet
Nominal width of source area TTZ	90	feet
Nominal area of source area TTZ	9,000	square feet
Top of source area TTZ	105	feet bgs

TABLE 3-6
Potassium Permanganate Dosing Demand for West-Cap Source Area Remediation
Tucson International Airport Area Superfund Site—Area B

Description	Value	Units or Notes
Bottom of source area TTZ	125	feet bgs
Vertical thickness of source area TTZ	20	feet
Total volume of source area TTZ	180,000	cubic feet
Total number of injection wells	4	new vadose zone wells
Total number of extraction wells	4	existing wells
Injection ROI	15	feet
Porosity	0.3	
Direct injection pore volume (PV) coverage	31%	initial injection without circulation
Injection/circulation PV coverage	69%	injection with circulation for potassium permanganate (KP) distribution
Permanganate Demand (Chemical)		
Average TCE concentration	0.54	mg/L
Groundwater treatment volume (one PV)	54,000	cubic feet
PV	403,947	gallons
TCE mass	2	lbs
Average Stoichiometric demand	2.4	lb KP/lb TCE
		$2\text{KMnO}_4 + \text{CHCl}_3 \rightarrow 2\text{CO}_2 + 2\text{MnO}_2 + 2\text{K}^+ + 2\text{Cl}^- + \text{HCl}$
Safety factor	5	
Chemical Demand	22	lbs
Permanganate Demand (NOD):		
Measured NOD	0.0 to 0.60	grams KP per kilogram soil
Conservative NOD	0.60	grams KP per kilogram soil
Assumed soil density	110	lb/ cubic foot
Soil treatment volume	180,000	cubic feet
Soil treatment mass	19,800,000	lb
NOD	11,880	lbs KP
Safety factor	1	
Total KP Dosing Demand	11,902	lbs KP
Injection Solution Concentration	3.5	grams KP per liter
Injection Time Requirements		
Estimated injection rate	15	gpm
Number of concurrent injection points	4	
Hours of injection per day	8	hours

TABLE 3-6
Potassium Permanganate Dosing Demand for West-Cap Source Area Remediation
Tucson International Airport Area Superfund Site—Area B

Description	Value	Units or Notes
Target pore volume coverage	1	PV
Initial injection volume	126,839	gallons
Initial injection volume per well	31,710	gallons per well
Injection volume with circulation	277,108	gallons
Injection volume with circulation	69,227	gallons per well
Time to complete injection	14	Days

The ISCO injection layout would include a network of four new vadose zone injection wells placed on roughly 30-foot center (a conservative ROI of 15 feet) and existing downgradient extraction wells (three or four existing wells, WC-01 or WC-16B, WC-08, and WC-15B) to create a hydraulic gradient for recirculation and distribution of permanganate in the entire source area TTZ. Well spacing was based on results of the permanganate injection pilot test (CH2M HILL, 2009b). The extracted groundwater would be dosed with permanganate and reinjected through the injection wells.

Operation

The total injection volume would target injection of one pore volume of water (assuming porosity of 0.30) during one single injection-recirculation event. The potassium permanganate mass required (11,900 pounds) is estimated based on an average TCE concentration of 540 µg/L throughout the 180,000-cubic-foot source area TTZ and a conservative NOD of 0.60 g permanganate/kg soil.

Initially, approximately 31,700 gallons of 3.5 g/L permanganate solution would be injected into each injection well at 15 gpm (concurrent injection at four injection wells for approximately 6 to 7 days). The water source would be from existing Extraction Well WC-14, similar to the logistical setup of the permanganate injection system during the pilot study. Immediately following the first stage of injection, approximately 69,200 gallons of 3.5 g/L permanganate solution would be injected at 15 gpm per well (concurrent injection at four injection wells, approximate duration of 15 to 16 days). Groundwater from wells in and around the source area TTZ would be extracted and used as the water source for permanganate mixing. Extracting groundwater from wells near the source zone TTZ would help distribute permanganate throughout the treatment area.

Western Lobe TTZ

The permanganate injection system at the western lobe TTZ would consist of a network of three new 2-inch PVC injection wells and one existing monitoring well (A-2U) that would be used for permanganate injection. The new wells would be screened in the USU between 105 and 115 feet bgs. Sufficient permanganate solution would be injected to create a zone of permanganate across the plume in this area. The dosing calculation of permanganate is included in **Table 3-7**.

TABLE 3-7
Potassium Permanganate Dosing Demand for West-Cap Western Lobe Remediation
Tucson International Airport Area Superfund Site—Area B

Description	Value	Units or Notes
Nominal length of western lobe TTZ	350	feet
Nominal width of western lobe TTZ	100	feet
Nominal area of western lobe TTZ	35,000	square feet
Top of western lobe TTZ	105	feet bgs
Bottom of western lobe TTZ	115	feet bgs
Vertical thickness of western lobe TTZ	10	feet
Total volume of western lobe TTZ	350,000	cubic feet
Total number of injection wells	4	new and existing USU wells
Total number of extraction wells	1	
Injection ROI	50	feet
Porosity:	0.3	
Permanganate Demand (Chemical):		
Average TCE concentration	0.01	mg/L
Groundwater treatment volume (one PV)	52,500	cubic feet
PV	785,400	gallons
TCE Mass	0.06	lbs
Average Stoichiometric demand	2.4	lb KP/lb TCE
	$2\text{KMnO}_4 + \text{CHCl}_3 \rightarrow 2\text{CO}_2 + 2\text{MnO}_2 + 2\text{K}^+ + 2\text{Cl}^- + \text{HCl}$	
Safety factor	5	
Chemical demand	0.78	lbs
Permanganate Demand (NOD):		
Measured NOD	0.0 to 0.60	grams KP per kilogram soil
Conservative NOD	0.60	grams KP per kilogram soil
Assumed soil density	110	lb/ cubic foot
Soil treatment volume	350,000	cubic foot
Soil treatment mass	38,500,000	lb
NOD	23,100	Lbs KP
Safety Factor	1	
Total KP Dosing Demand	23,101	lbs KP
Injection Solution Concentration	3.5	g KP per L
Injection Time Requirements		
Estimated injection rate	15	gpm
Number of concurrent injection points	4	

TABLE 3-7

Potassium Permanganate Dosing Demand for West-Cap Western Lobe Remediation
Tucson International Airport Area Superfund Site—Area B

Description	Value	Units or Notes
Hours of injection per day	8	hours
Target PV coverage	1	PV
Injection volume	785,400	gallons
Injection volume per well	196,350	gallons per well
Time to complete injection	27	days

Operation

The total injection volume would target injection of one pore volume of water (assuming porosity of 0.30) during one single injection event. The potassium permanganate mass required (23,101 pounds) is estimated based on an average TCE concentration of 10 µg/L throughout the 350,000-cubic foot western lobe TTZ and a conservative NOD of 0.60 g permanganate/kg soil, a value derived from samples collected in the source zone. Additional samples could be collected from USU soil during installation of the injection wells to provide a more representative value of NOD in the western lobe area.

Approximately 196,350 gallons of 3.5 g/L permanganate solution would be injected into each injection well at 15 gpm (concurrent injection at four injection wells for approximately 27 days). The water source would be from existing Extraction Well WC-14, similar to the logistical setup of the permanganate injection system during the pilot study. Approximately 1,200 feet of 2-inch PVC pipe would be used to convey water from WC-14 to the permanganate mixing station. The pipe would be temporarily installed above ground. During the remedial design phase, extraction and use of groundwater near A-2U, possibly through one or more of the new injection wells, would be beneficial to assist in distributing permanganate across the plume area and drawing permanganate that may still be present near Well WC-14.

Equipment

The injection system setup would be similar to the one used during the pilot study (CH2M HILL, 2009b); a schematic is shown on **Figure 3-3**. The conceptual design of the injection and extraction system includes the following components:

- Five hundred feet of above grade PVC conveyance piping
- One 2,400-gallon storage tank for extracted water
- One 1,600-gallon mixing tank with mechanical agitator
- One 2,400-gallon injection tank
- Three secondary containment pads
- Four flow meters
- One booster pump
- Two transfer pumps with control panel
- Two bag filters
- Four submersible pumps
- One venturi

- Three transducers
- Solid permanganate powder stored in 35-gallon drums
- Pressure gauges, hoses, piping, and valves

Assumptions

- No permanent aboveground treatment facility would be required. The injection would consist of one field event of approximately 2 months. During the final design, the option of automating the recirculation system to minimize full-time O&M will be further evaluated.
- Power for operating the extraction and injection system would be provided by a portable generator, as electricity is not currently available at the mixing locations.
- It is assumed that the subsurface can accommodate the required demand of injectate, and the average injection flow rate is approximately 15 gpm per well under a wellhead pressure less than 30 psi.
- Two new nested monitoring wells (screened into SGZ and USU) would be installed immediately downgradient of the source area and across the South Plumer Avenue. One new nested monitoring well (screened in the USU and LSU) would be installed on airport property between the runway and the boundary between the airport and the AANG.
- ISCO performance monitoring would consist of semiannual sampling of 16 monitoring wells in the source area for VOCs for approximately 13 years (i.e., until TCE concentrations are below 5 µg/L during two consecutive sampling events). The 16 source area monitoring wells would include WC-01, WC-06, WC-07, WC-08, WC-13B, WC-15A, WC-15B, WC-16A, WC-16B, WC-16C, WC-17A, WC-17B, and four new nested downgradient monitoring well points. It is anticipated that many of these wells would contain permanganate after the injection/recirculation is complete, and would not be sampled. In addition, four outlying wells (A2-L, WC-9, WC-11, and SF-3) would be monitored for VOCs. Quality assurance and quality control (QA/QC) samples would be collected at a frequency of 10 percent of total samples.
- MNA performance monitoring would consist of annual sampling of two upgradient wells, one cross-gradient well, and two downgradient wells for natural attenuation and geochemical parameters, including dissolved oxygen, nitrate/nitrite, ferric/ferrous iron, dissolved manganese, sulfate, methane/ethane/ethane, alkalinity, oxidation reduction potential, total organic carbon, and pH. QA/QC samples would be collected at a frequency of 10 percent of total samples.
- NPV is calculated based on the discount rate of 4 percent.
- Five-year reviews would be required for periodic evaluation of the effectiveness of the selected remedy and recommended optimization.

Environmental Footprint

According to the environmental footprint analysis (**Appendix C**) Alternative 2 would consume over 1×10^9 Btu of energy and over 18,000 pounds of materials, and would emit over 201,000 pounds of carbon dioxide, 15,000 pounds of criteria air pollutants, and 15 pounds of hazardous air pollutants over the estimated 15-year remediation and monitoring period. The

primary contributor to the environmental footprint of Alternative 2 is the manufacture of potassium permanganate (GeoTrans, Inc., 2010).

3.2.2 Assessment

The detailed analysis of Alternative 2 in this section provides the basis of the comparative analysis of alternatives, as summarized in **Section 3.3**. A detailed analysis provides the basis for recommendations of the preferred alternative, and the information necessary for decision makers to select an appropriate site remedy. The following text presents an analysis of Alternative 2 based on the threshold criteria and primary balancing criteria described in the introduction to **Section 3**.

Overall Protection of Human Health and Environment

Alternative 2 is expected to adequately protect human health and the environment, in both the short and long term, from unacceptable risks posed by TCE contamination in groundwater that may currently serve, or in the future may serve, as a source of drinking water. Under Alternative 2, VOC concentrations within the source area TTZ are expected to be reduced to below MCL within 3 years, although concentrations could rebound if the permanganate does not contact all of the residual contamination. Injection of permanganate in the western lobe TTZ should reduce VOC concentrations in this portion of the plume, minimizing the migration of TCE to the west. The MNA component is expected to reduce VOC concentrations outside the TTZs below MCLs within approximately 13 years. The inclusion of supplemental IC mechanisms, such as well permit requirements and land use restrictions, would further prevent consumption and contact of groundwater while Alternative 2 is taking place.

Compliance with ARARs

Alternative 2 is expected to comply with ARARs (chemical-, location-, and action-specific) within a reasonable time. Alternative 2 involves a combination of ISCO and MNA to meet cleanup goals for the chlorinated solvent plume. There is some uncertainty as to the length of time required to achieve MCLs in groundwater. Achievement of MCLs in areas outside of the injection areas is dependent on movement of permanganate out of the injection areas and on natural attenuation processes. Considering the relatively low TCE concentrations outside of the TTZs (typically below 20 µg/L), it is anticipated that MNA alone would achieve the MCL for TCE within a reasonable timeframe (i.e., 13 years), assuming that no additional mass flux from the source area occurs. Consequently, treatment of the source area with ISCO to reduce the mass flux is a reasonable approach to couple with MNA.

Alternative 2 would meet applicable waste management requirements for investigation-derived waste generated during the drilling, installation, and development of new monitoring wells and injection wells. Implementation of in situ-based Alternative 2 would eliminate the need to meet National Pollutant Discharge Elimination System permit limits for treated effluent discharge and minimize managing and disposal of hazardous waste generated during the remediation process; that is, spent carbon for Alternative 1 (pump and treat). Contaminated groundwater purged from monitor wells during ISCO performance and MNA groundwater sampling would be disposed of through discharge to the Pima County sanitary sewer under permit.

Long-Term Reliability and Effectiveness

ISCO involving potassium permanganate for remediation of TCE plumes is well established, reliable, and capable of meeting performance requirements. The concept of ISCO has been successfully pilot tested at the West-Cap project area (CH2M HILL, 2008 and 2009b). Under this alternative, ISCO is expected to reduce VOC concentrations to acceptable levels for follow-on MNA within a reasonable time (about 3 years). Residual risk associated with Alternative 2 will decline as source area TCE concentrations are reduced by ISCO. However, some risk will continue to be posed by TCE in plume areas untreated by permanganate until the concentrations attenuate below MCLs. Based on attenuation rates observed at the WPB site, this is expected to occur within about 10 years after the treatment of the source area. This gives a total estimated treatment time of about 13 years.

There is some uncertainty regarding rebound of VOC concentrations after treatment and the time required to reach the preliminary cleanup goals through MNA. Additional injection of permanganate or recirculation of previously injected permanganate may be needed to completely address the VOCs within the source zone. Additional injection of permanganate may also be needed in the western lobe as additional VOCs migrate into this area. The natural attenuation rate is estimated based on a similar site (the WPB site), but results at the West-Cap project area may differ. If additional permanganate injection or recirculation is needed in the source area or if the attenuation rate is lower than expected, the treatment time may extend to 20 years or more.

Long-term effectiveness and permanence can be monitored through implementation of ISCO performance monitoring and long-term MNA program to demonstrate the TCE mass reduction in the source area and concentration decrease for the entire West-Cap project area. The long-term reliability of ICs implemented to restrict access to contaminated groundwater is also quite high. Access to the land above most of the VOC-impacted groundwater is controlled by the Airport or AANG. Both of these entities are aware of the VOC contamination in groundwater and are unlikely to allow the use of groundwater from contaminated areas. It is expected that the land use and controlled access will continue indefinitely. Both of the alternatives would require ICs, so the IC would not be a crucial factor for selecting the preferred alternative.

Reduction of Toxicity, Mobility, or Volume of Wastes

Alternative 2 relies on irreversible chemical oxidation to achieve 95 percent or higher TCE removal efficiency to reduce the concentration and mass of TCE in groundwater. Although MNA does not include active treatment, passive treatment (natural attenuation over time) would reduce the concentration and quantity of TCE in groundwater once ISCO has reduced the TCE mass flux from the source area. Based on natural attenuation rates estimated by several studies at the nearby WPB site, MNA is anticipated to attain the remediation goal within a reasonable timeframe (less than 10 to 15 years) for a TCE plume such as the one present at West-Cap (CH2M HILL, 2000 and 2009c; ADEQ, 2006).

Short-term Effectiveness

Significant effects on workers, the community, or the environment during the remediation would not be expected for Alternative 2. Implementation of the ISCO injection would take approximately 2 months. The recirculation mode would help distribute the oxidant throughout the source area TTZ. Following the completion of injection and recirculation of

potassium permanganate solution, the TCE concentration at the source area is expected to decrease in a relatively short timeframe, corresponding to the rate of distribution throughout the source area TTZ and the rapid reaction between permanganate and VOCs. The concentration of TCE in groundwater samples collected from Well WC-1, which is located at the western edge of the TTZ, decreased from 130 µg/L in January 2009 – prior to the potassium permanganate injection pilot test – to 30 µg/L in March 2011. This is the lowest measured concentration of TCE in samples from this well since the well was installed in 1997 and may indicate that the permanganate is already treating the TTZ outside of the area where permanganate has been detected.

There is an association between the presence of permanganate and elevated concentrations of metals because of the oxidizing nature of the permanganate. Of particular concern is chromium, which could be present above its MCL in groundwater near the TTZ while permanganate is present. Concentrations of chromium and other metals are expected to decline outside the area affected by the permanganate injection as the highly oxidative conditions will no longer be present. Monitoring for the presence of metals can help determine the impact of permanganate on groundwater quality. Groundwater samples collected from Wells WC-1 and WC-8, which are located on the western and northern edges of the TTZ, contained less than 10 µg/L of total and dissolved chromium. These values are below the MCL of 100 µg/L, indicating that the injection of permanganate has not resulted in elevated concentrations of chromium in groundwater, although continued monitoring would be prudent.

The risks posed to the workers during the ISCO injection work can be effectively managed through proper health and safety procedures and use of proper personal protective equipment. The risk to the environment during the ISCO injection can be minimized through secondary containment for the storage and injection tanks, and spill control using sodium thiosulfate solution as the oxidant neutralizer.

Implementability

Alternative 2 is expected to be readily constructed and operated. Alternative 2 involves installation of multiple injection wells, nested downgradient monitor wells, aboveground conveyance pipelines or hoses, and the injection system. Similar work was performed during the ISCO pilot test in 2009. Because the injection areas are located on an operating manufacturing facility and airport, with monitoring wells located within the public right-of-way, obstacles such as obtaining required utility clearances, implementing traffic controls, and obtaining easements may also be encountered.

Under Alternative 2, coordination between EPA, ADEQ, Arizona Department of Water Resources, City of Tucson, Tucson Electric Power, and the Department of Homeland Security would be required. EPA would also need to coordinate with the Tucson Airport Authority for access. EPA would need to coordinate with state and local agencies for reinjection of extracted groundwater. Considering the fact that the groundwater from Well WC-14 was used in the pilot study, gaining agency approval or permitting for the recirculation system should not be an issue.

Cost

The concept of delivery of potassium permanganate to the targeted source area zones (SGZ and USU) via injection to the overlying vadose zone followed by downward infiltration has been tested by the pilot studies. Using a combination of injection wells and extraction wells in the source area, TTZ is expected to result in a lower cost than using injection wells only. If a conventional injection grid approach were to be implemented for direct injection into the less-permeable SGZ and coarse-grained USU, the cost would be significantly higher because more injection wells and longer injection time would be required for direct injection to the SGZ (because of reduced injection flow rate).

A detailed cost estimate for Alternative 2 is included in **Appendix D**. The cost includes a breakdown of the estimated capital cost, annual O&M requirement, and NPV for a 13-year period at a discount rate of 4 percent. The cost estimates have been developed based on CH2M HILL previous experience, RS Means, EPA guidance (EPA, 1988 and 2000), and vendors' quotes. The cost estimates are intended to be order-of-magnitude estimates, with an accuracy range of +50 to -30 percent. The range applies only to the alternative under the assumptions defined in **Section 3.2.1** and **Appendix D** and does not account for changes in the scope of the alternatives. The specific details of remedial actions and cost estimates would be refined during the remedial design if selected.

The cost determined in **Appendix D** does not include the potential cost associated with additional injection of permanganate, which may be necessary if effective long-term treatment is not achieved by the single planned injection event. The cost of additional groundwater monitoring, if needed beyond the estimated 13-year period, is also not included.

The NPV of Alternative 2 is approximately \$1.5 million.

3.3 Comparative Analysis

This section provides a comparative analysis of the remedial alternatives described in **Sections 3.1** and **3.2**. The relative performance of the two alternatives is evaluated in relation to each evaluation criteria. The comparative analysis identifies the advantages and disadvantages of each alternative, relative to each other, so that key tradeoffs can be assessed during the decision-making process.

3.3.1 Overall Protection of Human Health and the Environment

Under both alternatives, human health and environment are protected for the West-Cap project area. Both alternatives provide for treatment of the area of highest TCE concentration and address migration of TCE to the west. Areas of lower TCE concentration located outside of the capture or treatment zones will attenuate over time. Some migration of VOCs outside of the treatment areas will occur under both alternatives, and this migration is accounted for and will be managed through the monitoring programs. Alternative 2 presents a potential for releases of strongly oxidizing materials into the environment. The potential for releases would be of limited duration and extent, and would be mitigated through the use of secondary containment.

3.3.2 Compliance with ARARs

Alternatives 1 and 2 would comply with ARARs, although there is some uncertainty regarding the time required to meet the cleanup goals. Extended groundwater extraction or additional injection of permanganate might be needed to fully treat the source zones. Alternative 2 is expected to meet ARARs within the property boundary in a shorter time because it would treat rather than contain the area of highest VOC concentrations.

3.3.3 Long-Term Reliability and Effectiveness

Both alternatives have been proven effective and have been implemented already at the West-Cap site. Questions about the long-term effectiveness center on the ability of groundwater extraction or a single injection of permanganate to fully treat residual contamination in the fine-grained subsurface media that is present. Because of the limited rate of diffusion of VOCs out of the fine-grained soils, continued groundwater extraction within the source zone may be required in excess of the 30 years estimated for Alternative 1. It is probable that substantial rebound of VOC concentrations would be observed upon turning off the groundwater extraction system, as residual VOCs continue to diffuse into the groundwater, and continued operation of the system would be necessary to meet the ARARs. Continuing groundwater extraction indefinitely will provide protectiveness, but is not cost effective or sustainable.

Similarly, diffusion of permanganate into the fine-grained media is a slow process and might not be completed through a single injection of permanganate. Additional injection events or recirculation of permanganate within the source area TTZ to increase the contact time between the permanganate and the fine-grained soil might be necessary to fully treat the source area TTZ.

Residual risk will continue to be posed by the contaminants until natural attenuation is complete. Alternative 2 has a shorter estimated time to achieve cleanup than Alternative 1 (about 13 to 20 years for Alternative 2 and 30 years or more for Alternative 1), although there is considerable uncertainty associated with both of these estimates.

3.3.4 Reduction of Toxicity, Mobility, or Volume of Waste

Alternative 1 would use a LGAC treatment system to remove contaminants at an efficiency of 99 percent or greater. Migration of VOCs to the west would be eliminated upon establishment of the capture zone by the extraction wells.

Alternative 2 relies on an irreversible chemical oxidation to achieve 95 percent or higher removal efficiency to reduce the concentration and quantity of VOCs in groundwater. Alternative 2 has the potential of reducing the highest VOC concentrations much faster than Alternative 1, and injection of permanganate in the western lobe of the plume will reduce the volume of VOCs migrating to the west.

Neither alternative generates hazardous waste. Nonhazardous waste includes primarily the soil cuttings generated during installation of injection and monitoring wells. Alternative 1 generates more soil than Alternative 2. Because the GAC used for Alternative 1 is regenerated, it is not considered a waste.

3.3.5 Short-term Effectiveness

Both alternatives would contain or treat the source area within a relatively short period of time. Alternative 2 could be implemented more quickly because Alternative 1 requires engineering design of the treatment system and conveyance piping. Both alternatives require installation of wells, but Alternative 1 also requires installation of subgrade conveyance piping and a permanent treatment system; whereas, Alternative 2 would use temporary abovegrade piping and rented equipment.

Because of the additional construction activities for Alternative 2 (injection events, installation of additional injection wells), slightly higher risks are posed than for Alternative 1. However, the risks to the community are still minor when proper health and safety protocol is followed.

3.3.6 Implementability

Both technologies have been executed with success at numerous other sites and also been implemented at the West-Cap as either a remedy or pilot test. Both alternatives are expected to be readily constructed and operated using reliable technologies. Alternative 1 would require design and construction work for installation of conveyance piping and the treatment system, while Alternative 2 would require minimal design calculations and would use a temporary extraction and injection system. Alternative 2 would require compliance with the Department of Homeland Security Chemical Facility Anti-Terrorism Standards because of the storage of permanganate.

3.3.7 Cost

Cost evaluations are based on engineering judgment and the alternatives are evaluated as to whether the cost is higher or lower to each other as outlined in *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988). These cost estimates are order-of-magnitude estimates and are expected to be accurate within +50 to -30 percent. Alternative 2 has a lower cost than Alternative 1, as summarized in **Table 3-8**.

Additional costs may be incurred by continuation of the groundwater extraction and treatment system beyond 30 years or by injection of additional permanganate solution, either of which could be necessary if treatment of the source area is not as effective as assumed in the descriptions of the alternatives. Costs for these potential events are not included in the cost estimates, as there is not currently a technical basis on which to form estimates.

TABLE 3-8
 Cost Comparison
Tucson International Airport Area Superfund Site—Area B

Description	Alternative 1 Groundwater Extraction, Treatment and Injection	Alternative 2 In Situ Chemical Oxidation
Total Project Duration (Years)	30	13
Capital Cost	\$2,706,000	\$394,188
Annual O&M Cost	\$352,000 (Years 1-4) \$318,500 (Years 5-30)	\$55,452
Total Periodic Cost	\$454,000	\$257,000
Total Net Present Value of Alternative	\$8,445,716	\$1,486,311

Detailed Analysis of Alternatives—Area B

Evaluations of remedial alternatives at other project areas within Area B were performed to support the development of a remedy that would provide effective management of the entire Area B, recognizing that the project areas share similar characteristics and, with the exception of the TI plume, are interrelated. Descriptions of alternatives for the individual project areas, as well as an analysis of MNA as the primary alternative for West Plume B, are presented in **Section 4.1**. **Section 4.2** presents the comparative analysis of the alternatives for all project areas based on the threshold and primary balancing criteria.

4.1 Summary of Alternatives for the West Plume B, AANG, and TI Project Areas

No alternative evaluation was performed for WPB for this report. The 2004 ROD Amendment stated that “if groundwater monitoring data and modeling suggests that the plume is attenuating, EPA will reconsider MNA” (EPA, 2004). Based on monitoring data and previous studies (CH2M HILL, 2000; ADEQ, 2006; CH2M HILL, 2009a), provided in **Appendix B**, the plume is attenuating and concentrations of TCE in all monitoring wells except one are expected to be below 5 µg/L by 2016. **Section 4.1.1** provides a description of how MNA would be implemented at WPB, as well as an evaluation of MNA using the seven-threshold and primary balancing criteria.

Detailed analyses of multiple alternatives were performed for the TI and AANG project areas. These evaluations are provided in **Appendices E and F** and are summarized in **Sections 4.1.2 and 4.1.3**.

4.1.1 West Plume B

For the detailed analysis described in this section, it is assumed that if there is no additional VOC migration into the WPB area, MNA will be an acceptable remedy for WPB. Implementation of MNA at WPB would consist of continued monitoring of VOC concentrations and other attenuation parameters in samples collected periodically from existing monitoring wells. Based on the most-recent evaluation of MNA at WPB (CH2M HILL 2009a), it is assumed that sampling for all 20 WPB monitoring wells would be performed on a semiannual basis until 2018, 2 years after the time that concentrations of TCE in all wells except one are projected to be below 5 µg/L. At that time, the monitoring program would be reduced to sampling of six wells on a semiannual basis. This reduced sampling program would be continued until 2 years after the time that concentrations of TCE in the final well are below 5 µg/L, an additional 16 years. At that time, all monitoring wells would be abandoned.

The potential implementation of MNA as a remedial alternative at WPB was evaluated against the seven threshold and primary balancing criteria for inclusion with remedial alternatives for the other project areas as presented in the following subsections.

Overall Protection of Human Health and Environment

Previous studies (CH2M HILL, 2000; ADEQ, 2006; CH2M HILL, 2009a) have demonstrated that VOC concentrations are attenuating within the WPB project area and are expected to reach MCLs by the Year 2032. Because there is no limitation on the use of groundwater within the WPB project area, some potential for exposure remains until the plume has attenuated.

Compliance with ARARs

Attenuation of VOCs over time will achieve ARARs within approximately 21 years.

Long-Term Reliability and Effectiveness

Natural attenuation is expected to be effective and reliable. Residual risk will continue to be posed by the contaminants until natural attenuation is complete.

Reduction of Toxicity, Mobility, or Volume of Waste

The toxicity and volume of VOCs in groundwater will be reduced through concentration attenuation processes. Analysis of concentration trends (CH2M HILL 2009a) has demonstrated that the plume is not migrating downgradient.

Short-Term Effectiveness

Natural attenuation is a relatively slow process and does not provide protectiveness in the short term. The lack of active remediation results in limited potential for exposure to chemical or safety hazards for site workers or the public during implementation.

Implementability

No additional actions are necessary to implement natural attenuation. Attenuation processes will continue to occur.

Cost

The cost of MNA for WPB was estimated assuming that 20 groundwater monitoring wells would be sampled for VOCs and five wells would be sampled for MNA parameters on a semiannual basis for 13 years. The cost includes a breakdown of the estimated annual monitoring, well abandonment, and NPV for a 24-year period at a discount rate of 4 percent. The cost estimates have been developed based on CH2M HILL previous experience, EPA guidance (EPA, 1988 and 2000), and vendors' quotes. The cost estimates are intended to be order-of-magnitude estimates, with an accuracy range of +50 to -30 percent. A summary of the estimated cost is provided in **Table 4-1**.

TABLE 4-1
 Cost Estimate for Monitored Natural Attenuation at West Plume B
Tucson International Airport Area Superfund Site—Area B

Description	Quantity	Unit	Unit Cost	Amount
MONITORING COSTS (2011 to 2018)				
Groundwater sampling and gauging labor	120	HR	\$110	\$13,200
Equipment (materials and rental)	2	LS	\$2,000	\$ 4,000
Project Management	20	HR	\$ 155	\$ 3,100
Reporting	60	HR	\$155	\$9,300
Laboratory Analysis – VOCs	20	EA	\$130	\$2,600
Laboratory Analysis – MNA	5	EA	\$ 300	\$1,500
Quality Control	4,100		20%	\$820
Waste Disposal	4,000	GAL	\$0.14	\$560
Annual Monitoring Cost (2011 to 2018) – Subtotal				\$35,080
Contingency	35,080		25%	\$8,770
Annual Monitoring Cost (2011 to 2018) – Total				\$43,850
MONITORING COSTS (2019-2034)				
Groundwater sampling and gauging labor	40	HR	\$110	\$4,400
Equipment (materials and rental)	2	LS	\$1,200	\$2,400
Project Management	20	HR	\$155	\$3,100
Reporting	60	HR	\$155	\$ 9,300
Laboratory Analysis – VOCs	6	EA	\$130	\$780
Laboratory Analysis – MNA	3	EA	\$300	\$900
Quality Control	1,680		20%	\$336
Waste Disposal	1,200	GAL	\$ 0.14	\$168
Annual Monitoring Cost (2019 to 2034) – Subtotal				\$21,384
Contingency	21,384		25%	\$ 5,346
Annual Monitoring Cost (2019 to 2034) – Total				\$26,730
PERIODIC COSTS				
Well Abandonment	20	EA	\$2,000	\$40,000
Periodic Cost - Subtotal				\$40,000
24-Year Net Present Value:				\$ 546,948

NOTE:

NPV was calculated using a discount rate of 4 percent.

4.1.2 Texas Instruments

As described in **Appendix E**, three alternatives for addressing the VOCs present in the deep vadose zone and groundwater at the TI site were evaluated. These include the following:

- **TI1: Pump-and-Treat (Discharge to Publicly Owned Treatment Works [POTW]).** This alternative is a modification of the existing remedy at TI. Because there is no longer an option for re-use of the groundwater, the treated water would be discharged to the POTW rather than used in the manufacturing process as it had been until 2009. Other modifications include replacing the groundwater extraction well and moving the treatment system to a more-accessible location. The current treatment system, which uses air stripping, would continue to be used with slight modifications and maintenance. This alternative would provide hydraulic control and mass removal of the TCE in groundwater.
- **TI2: Pump-and-Treat (Reinjection).** This alternative is similar to Alternative TI1, except that treated water would be reinjected into the aquifer. Two new injection wells would be installed for this purpose. As with Alternative TI1, the extraction well would be replaced and the existing treatment system would be modified slightly and moved to a more-accessible location. This alternative would provide hydraulic control and mass removal of the TCE in groundwater.
- **TI3: ISCO and MNA.** This alternative would inject potassium permanganate solution into the vadose zone and groundwater in the area beneath the former chemical storage buildings. VOCs present outside of the treated area would be expected to attenuate through natural processes.

These alternatives are developed and evaluated in more detail in **Appendix E**.

4.1.3 Arizona Air National Guard

As described in **Appendix F**, four alternatives for plume control at AANG were evaluated. These include the following:

- **Alternative AANG1: Pump-and-Treat.** This alternative is a continuation and optimization of the existing remedy at AANG. Groundwater would continue to be extracted using extraction wells screened in the USU and LSU, conveyed to a treatment system where VOCs would be removed using air stripping technology, and reinjected into the USU. This would provide hydraulic containment of the comingled VOC plume.
- **Alternative AANG2: MNA.** As previously described, this alternative uses natural attenuation processes to reduce VOC concentrations in groundwater.
- **Alternative AANG3: ISCO.** This alternative is similar to the ISCO alternative developed for the West-Cap project area, except that the permanganate would be applied to the dissolved plume area rather than to the source area. Permanganate would be injected at various locations at the AANG property to prevent migration of VOCs away from the property in concentrations that would exceed MCLs.
- **Alternative AANG4: Passive Reactive Barrier.** This alternative would use a PRB located at the northern boundary of the ANG property. ZVI would be used in the barrier to destroy

VOCs as groundwater moves through the barrier. These alternatives are developed and evaluated in more detail in **Appendix F**.

4.2 Comparative Analysis for Area B Remedial Alternatives

The remedial alternatives for each project area in Area B have been evaluated in the text or appendices of this report. **Table 4-2** provides a brief summary of the evaluations, rating each alternative against the seven threshold and primary balancing criteria. Alternatives are assigned a qualitative rating for each criteria based on whether the alternative effectively, moderately, or poorly satisfies that criteria.

The alternatives for each project area described previously were combined to form five Area B comprehensive alternatives addressing common contamination issues at all four Area B project areas. A description of each of the Area B comprehensive alternative is provided in **Section 4.2.1**, followed by a comparative analysis in **Section 4.2.2**. Because the detailed analyses of the components of each project area alternative has been described in other sections of this report, the analysis is not repeated here.

TABLE 4-2
 Summary of the Remedial Alternative Evaluation for all Area B Project Areas
Tucson International Airport Area Superfund Site—Area B

Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume	Short-term Effectiveness	Implementability	Cost
Former West-Cap Facility							
1: No Action	–	–	–	–	–	+	+
2: Groundwater Extraction and Treatment	•	•	•	•	•	+	–
3: ISCO	•	•	+	+	•	+	+
Arizona Air National Guard Project Area							
AANG1—Groundwater Extraction and Treatment	+	•	+	+	+	+	–
AANG2—MNA	•	–	+	•	–	+	+
AANG3—ISCO	+	+	+	+	+	•	+
AANG4—Permeable Reactive Barrier	•	•	+	+	•	•	–
Texas Instruments Project Area							
T11—Groundwater Extraction and Treatment (POTW Discharge)	•	+	•	+	+	+	–
T11—Groundwater Extraction and Treatment (Reinjection)	•	+	•	+	+	+	–
T13—ISCO	+	+	+	+	+	+	+
West Plume B Project Area							
WPB1—Monitored Natural Attenuation	•	•	•	•	•	+	+

Notes:

- + = Alternative effectively satisfies the criterion
- = Alternative moderately satisfies the criterion
- = Alternative poorly satisfies the criterion

4.2.1 Development of Remedial Alternatives for Area B

Common elements from the alternatives developed for each project area were used to combine them into alternatives that would provide more-comprehensive approaches for remediation at Area B. For example, all project areas except for West Plume B consider a groundwater extraction and treatment alternative, so these were combined into Alternative A2. Similarly, all project areas except for West Plume B consider an ISCO alternative, so these were combined into Alternative A3. Two additional alternatives were evaluated for the AANG project area, and these were developed into Alternatives A4 and A5. For these comprehensive alternatives, ISCO, the alternative that scored the highest in **Table 4-1**, was used for the West-Cap and TI project areas.

The alternatives developed for Area B are listed in **Table 4-3** and shown in schematic form in **Figure 4-1**. More-detailed descriptions of alternative development follow. For all alternatives except the no-action alternative, MNA is proposed for West Plume B.

TABLE 4-3
Summary of Comprehensive Remedial Alternatives for Area B
Tucson International Airport Area Superfund Site—Area B

Alternative Number	Implementation by Site			
	Arizona Air National Guard	West-Cap	Texas Instruments	West Plume B
A1	No Action	No Action	No Action	No Action
A2	Pump and Treat	Pump and Treat	Pump and Treat	Natural Attenuation
A3	ISCO	ISCO	ISCO	Natural Attenuation
A4	Permeable Reactive Barrier	ISCO	ISCO	Natural Attenuation
A5	Natural Attenuation	ISCO	ISCO	Natural Attenuation

Alternative A1—No Action

This alternative was included to provide a comparison of the other alternatives to taking no action.

Alternative A2—Pump and Treat

Under this alternative, groundwater would be extracted at the AANG, West-Cap and TI project areas. Treatment of the extracted groundwater would be accomplished using air stripping at the AANG and TI project areas, and LGAC at West-Cap. As described in **Appendix D**, Pima County discourages discharge of treated water to the POTW to minimize the volume of water passing through wastewater processing facilities. Therefore, for all three project areas, treated groundwater would be re-injected into the aquifer.

Alternative A3—In-Situ Chemical Oxidation

Under this alternative, potassium permanganate solution would be injected into the plume areas at AANG and West-Cap, and the source areas at West-Cap and TI. This type of treatment would reduce or eliminate flux of VOCs out of the source areas and reduce the migration of VOCs throughout the plume. Concentrations of VOCs in limited areas of the

plume outside of the treatment zones would be reduced through natural attenuation processes.

Alternative A4—Permeable Reactive Barrier and ISCO

This alternative is similar to Alternative A3 except that a PRB is proposed for the AANG project area. Like Alternative A3, this alternative relies on in-situ treatment of VOCs in soil and groundwater. The primary difference is that rather than treat groundwater at various points on the AANG property, a PRB would be installed near the downgradient edge of the property to prevent migration of VOCs north across Valencia Road.

Alternative A5—MNA and ISCO

For this alternative, ISCO would be used at the source areas at West-Cap and TI, but the downgradient plume areas, including the one present at the AANG project area, would be allowed to attenuate through natural processes. This alternative would not prevent VOCs from migrating north across Valencia Road.

4.2.2 Comparative Analysis of Remedial Alternatives for Area B

The comprehensive remedial alternatives developed for Area B were compared to one another using their effectiveness at meeting the seven threshold and primary balancing criteria.

Protection of Human Health and the Environment

For all of the active alternatives except for Alternative A1 (the no-action alternative), human health and the environment are protected for Area B. All of the active alternatives provide for treatment of the area of highest TCE concentration. Alternatives A2, A3, and A4 prevent migration of VOCs north across Valencia Road and into the adjacent mixed-use neighborhood. Alternative A5 (MNA at the AANG) does not prevent plume migration in this area, and therefore is somewhat less protective than the other active alternatives.

The total operating time for Alternative A2 is in excess of 30 years due to extended treatment periods for the source zones at West-Cap and TI. Alternatives A3, A4, and A5 are expected to achieve the cleanup goals within 20 years.

There is a potential for exposure to site workers by the permanganate during implementation of Alternatives A3 and A4. This potential would be of limited duration and extent and would not affect the public. The permanganate used in Alternative A3 would be injected at concentrations and volumes low enough that it is anticipated to completely degrade and/or dilute before it reaches residential properties within the West Plume B area.

Because Alternative A1 (no-action) is not protective of human health and the environment, it was eliminated from consideration under the remaining six criteria.

Compliance with ARARs

Alternative A2 would comply with the ARARs, but the timeframe to meet cleanup goals is the longest—in excess of 30 years. Alternatives A3 and A4 are expected to meet these requirements within the property boundaries of the three sites in a shorter time than the other alternatives because treatment using permanganate is quite rapid. Alternatives A3 and A4 are expected to reach these requirements throughout Area B within 13 to 20 years. Alternative A5

is expected to achieve these requirements within the site boundaries, but does not prevent potential plume migration into the West Plume B area.

Long-term Reliability and Effectiveness

For Alternative A2, there are questions about the long-term effectiveness of groundwater extraction. Alternative A2 is currently being implemented at the AANG, and if groundwater extraction continues, will be implemented for an estimated additional 20 years. At West-Cap and TI, because of the limited rate of diffusion of VOCs out of the clay, continued groundwater extraction within the source zones may be required in excess of 30 years. It is probable that substantial rebound of VOC concentrations would be observed upon turning off the groundwater extraction systems at the West-Cap and TI sites as residual VOCs continue to diffuse into the groundwater, and continued operation of the systems would be necessary to meet the cleanup goals. Continuing groundwater extraction indefinitely would provide protectiveness, but is not cost effective or sustainable.

Alternative A3 has been previously implemented and proven effective in pilot tests at the AANG, West-Cap, and TI project areas. Alternative A3 has a shorter estimated time to achieve cleanup than Alternative A2, with an estimated time of 13 to 20 years. Diffusion of permanganate into the clay is a slow process, and might not be completed through a single injection of permanganate at each location. Additional injection events or recirculation of permanganate within the source areas to increase the contact time between the permanganate and the clay might be necessary to fully treat the source areas. After treatment, residual risk will continue to be posed by the contaminants until natural attenuation is complete.

Alternative A4, which would use a PRB rather than ISCO at the AANG, is expected to permanently reduce VOCs at the northern boundary of the AANG property. The rest of the Area B is expected to meet cleanup goals within an estimated 20 years through ISCO and MNA. Water use within the areas of contamination would be restricted by the site owners to eliminate the risk of exposure to contaminated groundwater.

Alternative A5, which would use MNA rather than ISCO at the AANG, would permanently reduce VOCs in groundwater through ISCO and MNA in an estimated 20 years.

Alternatives A4 and A5 would be implemented at the AANG site in conjunction with permanganate injections at West-Cap and TI and MNA at West Plume B.

Reduction of Toxicity, Mobility, or Volume of Waste

Alternative A2 would use carbon adsorption and air stripping treatment systems to remove contaminants at an efficiency of 95 percent or greater. Migration of VOCs to the northwest would be eliminated by establishment of hydraulic capture zones by the extraction wells. Currently being implemented at the AANG, Alternative A2 would continue to decrease TCE concentrations in groundwater, as well as prevent offsite migration. Alternative A2 would contain but not treat the source areas at the West-Cap and TI sites due to the slow rate of diffusion of VOCs out of the clay, where they can be removed by the extraction system.

Alternatives A3 and A4 have the potential of reducing the highest VOC concentrations much faster than Alternative A2, since the source zones would be treated more quickly. Because the existing containment system south of Valencia Road would not be in use under either of these alternatives, offsite migration of VOCs onto the downgradient West Plume B area would be

prevented by the injection of permanganate at the leading edge of the TCE plume (Alternative A3) or through the use of a PRB (Alternative A4).

Alternative A5 would also treat the source areas quickly. However, the mobility of VOCs in groundwater would increase because the containment system at Valencia Road would be turned off and would not be replaced with another treatment or containment system.

Alternatives A4 and A5 would be implemented at the AANG site in conjunction with permanganate injections at West-Cap and TI and MNA at West Plume B.

None of the alternatives generate hazardous waste.

Short-term Effectiveness

For Alternatives A2 and A3, treatment has been at least partially implemented at the AANG, West-Cap, and TI sites. All three sites have had groundwater extraction and treatment systems in place, and all three had permanganate injections in 2009. It is anticipated that either of these alternatives could be implemented across Area B within 6 to 12 months. Hydraulic containment would be achieved shortly after implementation of Alternative A2, and treatment of the source zones at West-Cap and TI would be achieved within 3 years under Alternatives A3 and A4.

Alternative A4 would be effective in the short term if the groundwater extraction and treatment system continued to operate during design and construction of the PRB, which would take about 1 year.

Alternative A5 would be effective in the short term at all sites except the AANG site and West Plume B, because there would be no active treatment or prevention of plume migration in these areas. At West-Cap and TI, the source zones would be treated rapidly by the permanganate. At West Plume B, attenuation of VOCs would continue, and the plume is not migrating.

Implementability

Alternatives A2 and A3 are common remediation methods and have been implemented previously at Area B as either a remedy or pilot test. Both alternatives are expected to be readily constructed and operated using reliable technologies.

Alternative A2 at West-Cap would require design and construction work for installation of conveyance piping and the treatment system. Alternative A2 is currently in operation at the AANG, and was used until 2009 at TI. All necessary equipment and personnel for continued operation is readily available at these sites. The treatment system at the TI project area would be moved to a more accessible location.

Alternative A3 at West-Cap would require minimal design calculations and would use a temporary extraction and injection system. Construction associated with Alternative A3 at the AANG would require considerable coordination, space, and access permissions with AANG personnel, as the site is an operating facility. Infrastructure for implementing Alternative A3 at TI is in place, and minor additions to the pilot test currently underway would be the only requirements to implement this alternative as a remedy.

Construction associated with Alternative A4 at the AANG would require considerable coordination, space, and access permissions with AANG personnel. The implementability of this alternative at West-Cap and TI is similar to that of Alternative A3.

Construction associated with Alternative A5 at the AANG would involve the installation of several monitoring wells, but no other infrastructure. MNA analysis procedures for groundwater samples are well developed and widely available. The implementability of this alternative at West-Cap and TI is similar to that of Alternative A3.

Cost

Estimated costs for the Area B remedial alternatives are summarized in **Table 4-4**. Alternatives A3 and A5 are the most cost-effective alternatives as they provide for source area treatment and natural attenuation processes. The estimated cost of these alternatives is approximately \$6.2 million to \$7.8 million. Alternatives A4 and A5 are the least cost effective, with an estimated cost of \$19 million to \$20 million.

TABLE 4-4

Estimated Costs for Comprehensive Remedial Alternatives for Area B

TIAA Superfund Site, West-Cap Project Area, Focused Feasibility Report, Tucson, Arizona

Proposed Remedy and Estimated Cost by Site					
Alternative Number	Arizona Air National Guard	West-cap	Texas Instruments	West Plume B	TOTAL COST
A1	No Action \$0	No Action \$0	No Action \$0	No Action \$0	\$0
A2	Pump and Treat \$9,312,209	Pump and Treat \$8,445,716	Pump and Treat \$1,993,400	MNA \$546,948	\$19,499,450
A3	ISCO \$5,071,026	ISCO \$1,486,311	ISCO \$971,700	MNA \$546,948	\$7,968,317
A4	PRB \$17,771,757	ISCO \$1,486,311	ISCO \$971,700	MNA \$546,948	\$20,237,404
A5	MNA \$3,778,578	ISCO \$1,486,311	ISCO \$971,700	MNA \$546,948	\$6,474,390

NOTES:

MNA is the only proposed remedy for West Plume B.

For Alternatives A3, A4, and A5, ISCO is proposed for West-Cap and TI because it scored the highest in Table 4-2 for these locations. The difference between these three alternatives is the proposed remedy at the AANG site. Implementation at West-Cap, TI, and West Plume B is the same for these three alternatives.

Cost provided is the NPV calculated using a 4 percent discount rate for the expected lifetime of the project.

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SECTION 5

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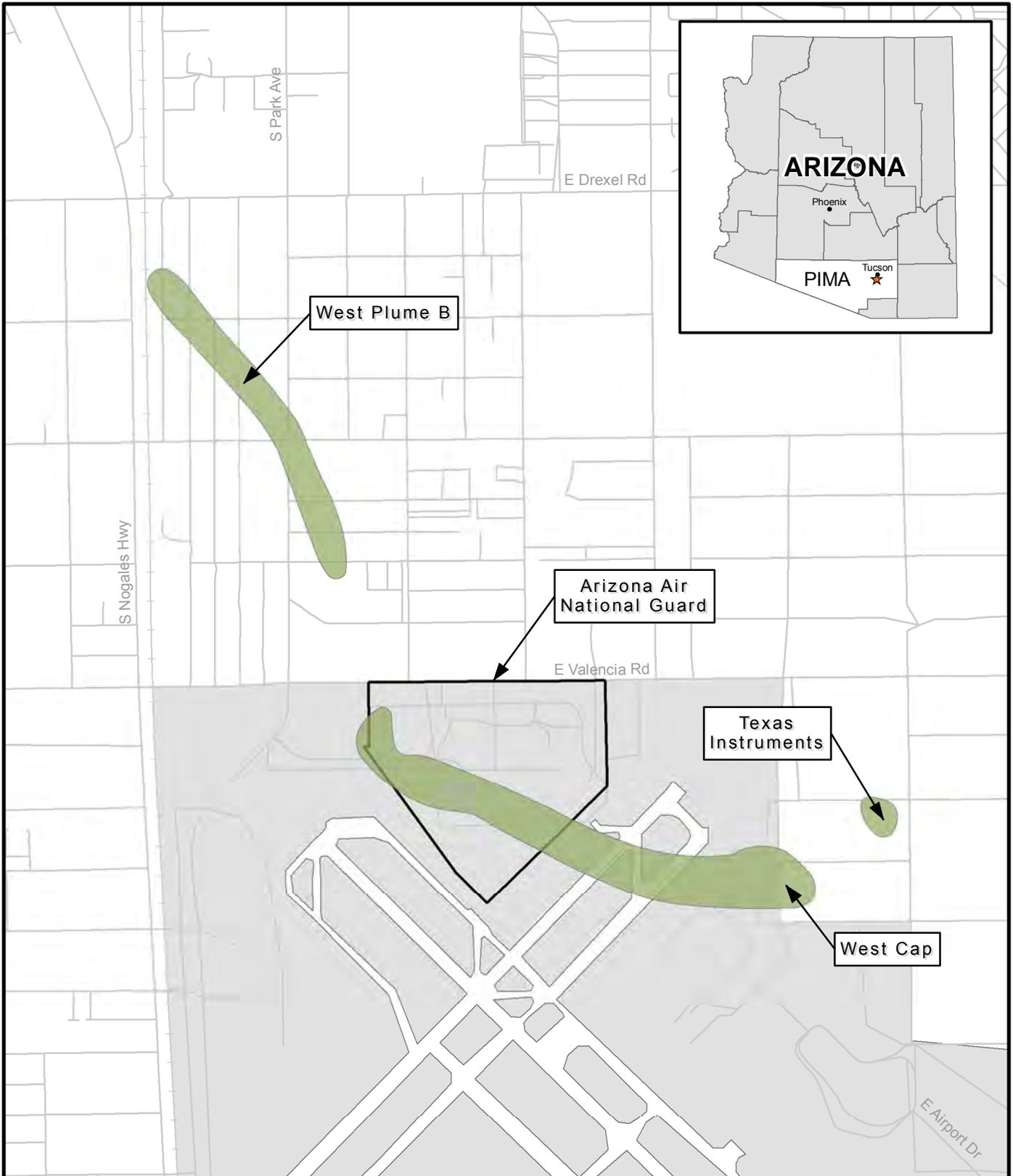
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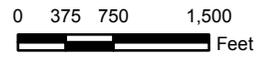
Figures

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Legend

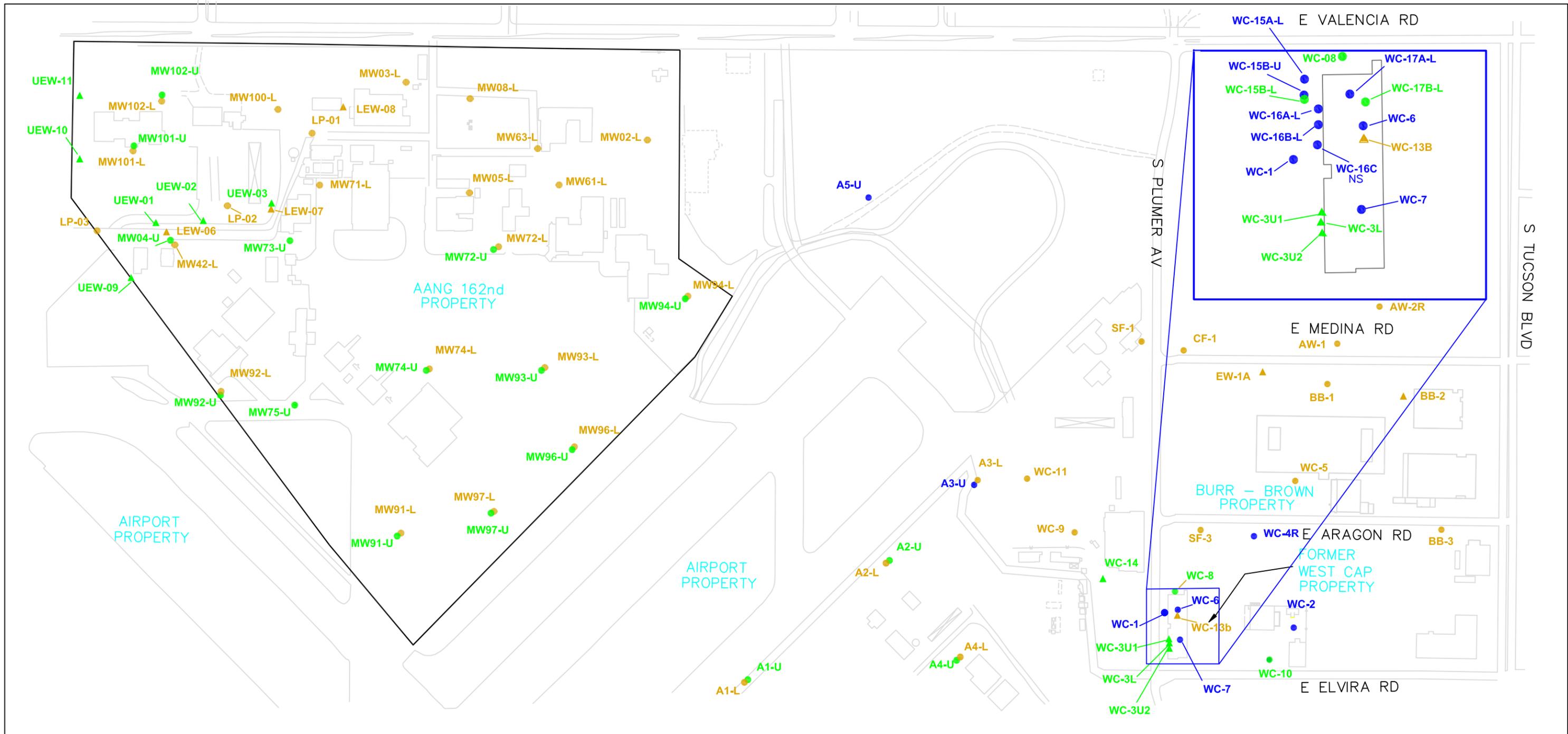
-  Road
-  Union Pacific Railroad
-  TCE Plume Concentration ≥ 5 micrograms per liter
-  Tucson International Airport



Note: Plume contours based on groundwater sampling results from February 2009.

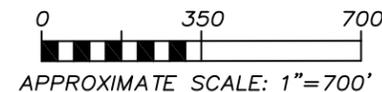
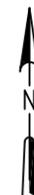
**FIGURE 1-1
Area B Site Map**

*Tucson International Airport Area
Superfund Site
Tucson, Arizona*



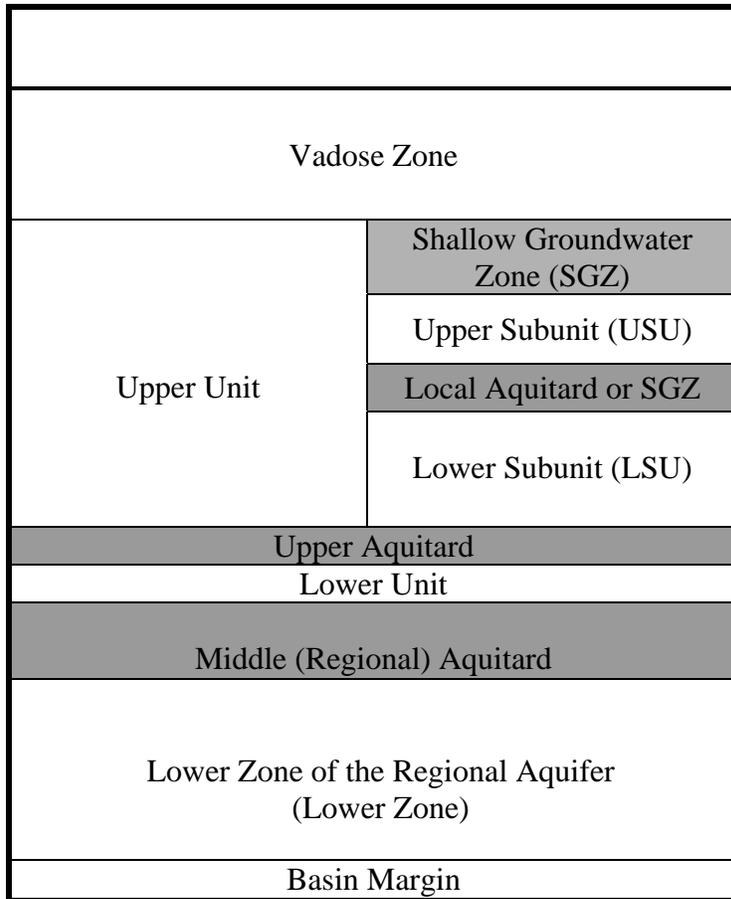
LEGEND

- SHALLOW GROUNDWATER ZONE (SGZ) MONITOR WELL
- UPPER SUBUNIT (USU) GROUNDWATER MONITOR WELL
- ▲ USU REMEDIAL EXTRACTION WELL
- LOWER SUBUNIT (LSU) GROUNDWATER MONITOR WELL
- ▲ LSU REMEDIAL EXTRACTION WELL



**FIGURE 1-2
WELL LOCATION MAP**

Tucson International Airport Area Superfund Site,
Tucson, Arizona



Modified from CH2M HILL 2002b

FIGURE 1-3
 Hydrostratigraphic Units of Area B
Tucson International Airport Area Superfund Site, Tucson, Arizona

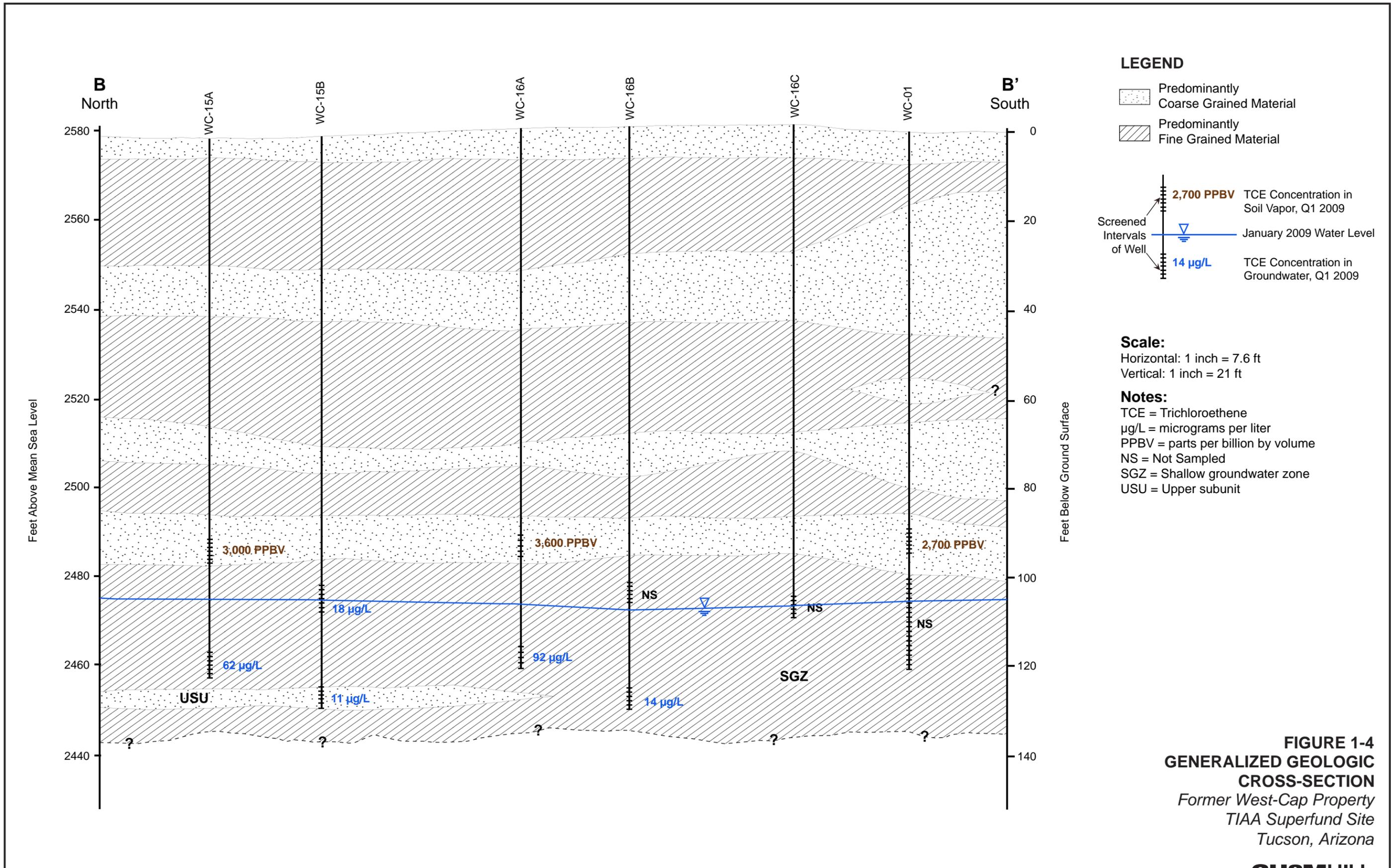
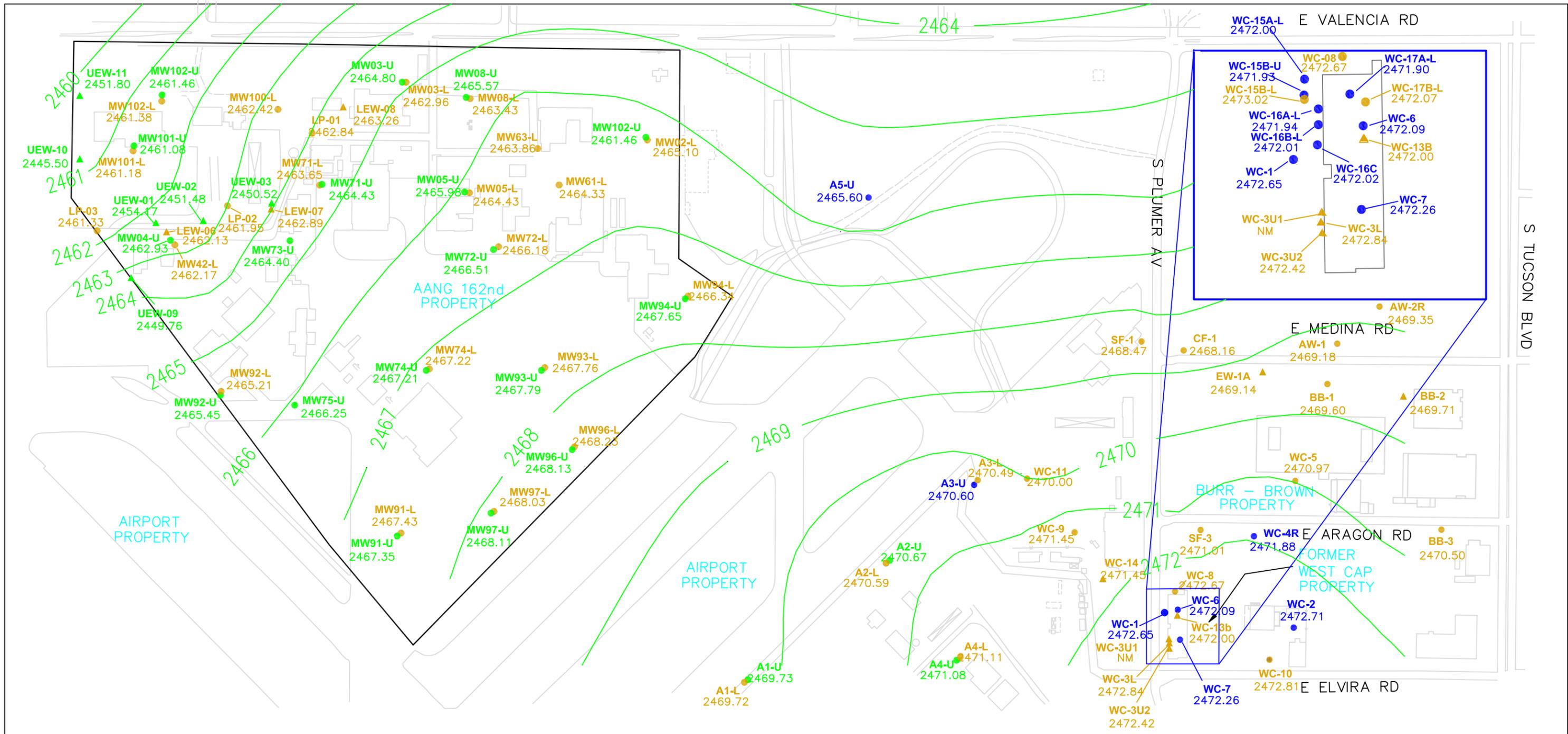


FIGURE 1-4
GENERALIZED GEOLOGIC
CROSS-SECTION
Former West-Cap Property
TIAA Superfund Site
Tucson, Arizona



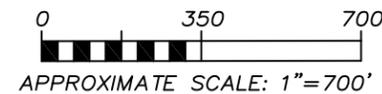
LEGEND

- SHALLOW GROUNDWATER ZONE (SGZ) MONITOR WELL
- UPPER SUBUNIT (USU) GROUNDWATER MONITOR WELL
- ▲ USU REMEDIAL EXTRACTION WELL
- LOWER SUBUNIT (LSU) GROUNDWATER MONITOR WELL
- ▲ LSU REMEDIAL EXTRACTION WELL
- 2470- GROUNDWATER CONTOUR INTERVAL

NM NOT MEASURED

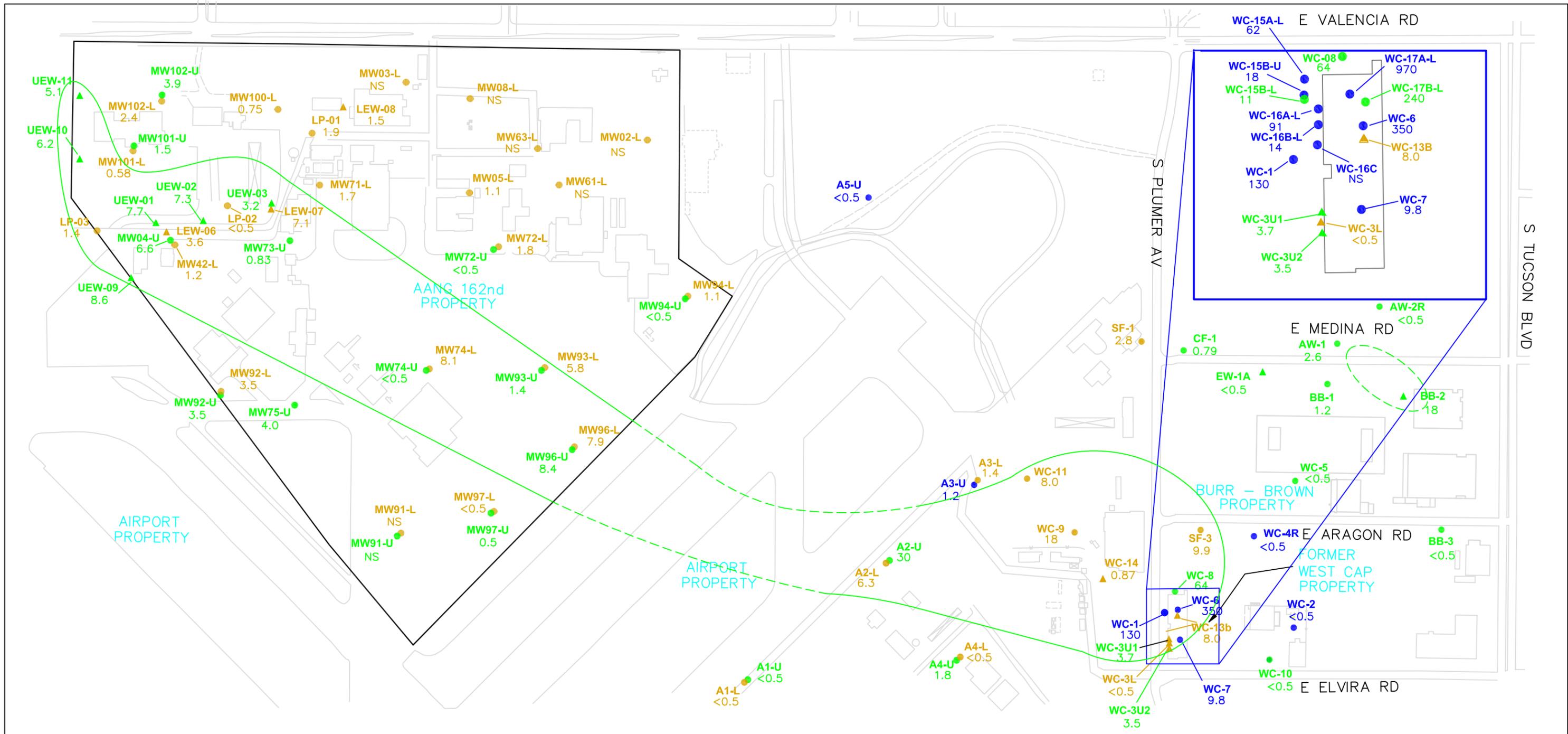
NOTES:

EXTRACTION AND INJECTION WELLS NOT USED FOR CONTOURING
 FOR PAIRED WELLS, ONLY THE UPPER PORT WAS USED FOR CONTOURING



**FIGURE 1-5
 GROUNDWATER ELEVATIONS, JANUARY -
 MARCH 2010**

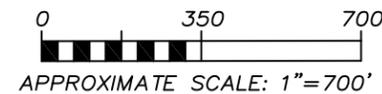
Tucson International Airport Area Superfund Site,
 Tucson, Arizona



LEGEND

- SHALLOW GROUNDWATER ZONE (SGZ) MONITOR WELL
 - UPPER SUBUNIT (USU) GROUNDWATER MONITOR WELL
 - ▲ USU REMEDIAL EXTRACTION WELL
 - LOWER SUBUNIT (LSU) GROUNDWATER MONITOR WELL
 - ▲ LSU REMEDIAL EXTRACTION WELL
 - ~ APPROXIMATE EXTENT OF GROUNDWATER CONTAINING TCE ABOVE 5 MICROGRAMS PER LITER (DASHED WHERE INFERRED)
- NS NOT SAMPLED
 - <0.5 TRICHLOROETHYLENE (TCE) CONCENTRATIONS IN MICROGRAMS PER LITER

DATA SOURCES: AANG 2009, ERROL L MONTGOMERY & ASSOCIATES 2009



**FIGURE 1-6
TCE CONCENTRATIONS IN
GROUNDWATER, JANUARY - MARCH 2009**

Tucson International Airport Area Superfund Site,
Tucson, Arizona

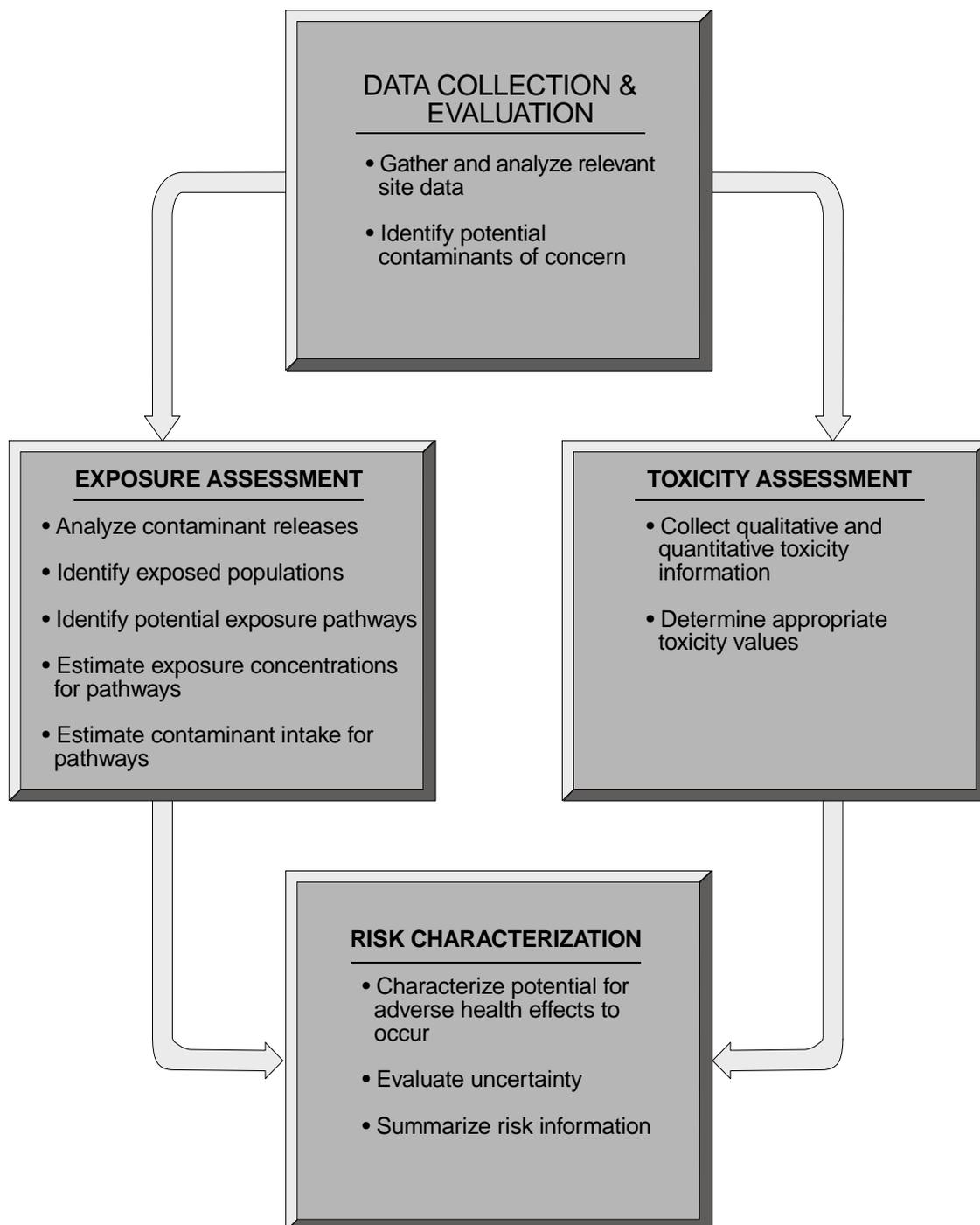
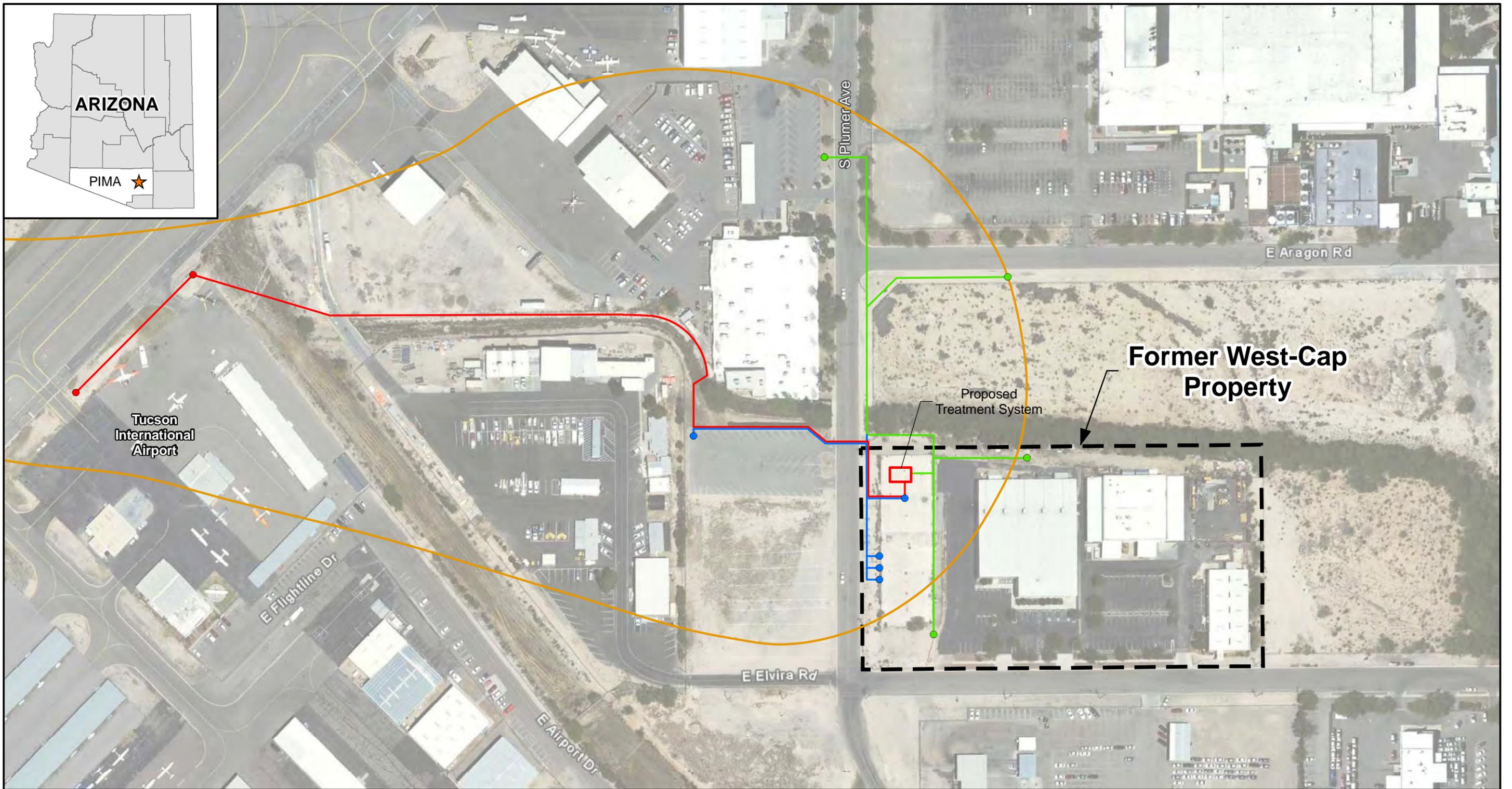
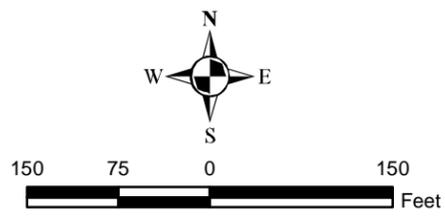


FIGURE 1-7
Elements of Risk Assessment
Tucson International Airport Area Superfund Site, Tucson, Arizona



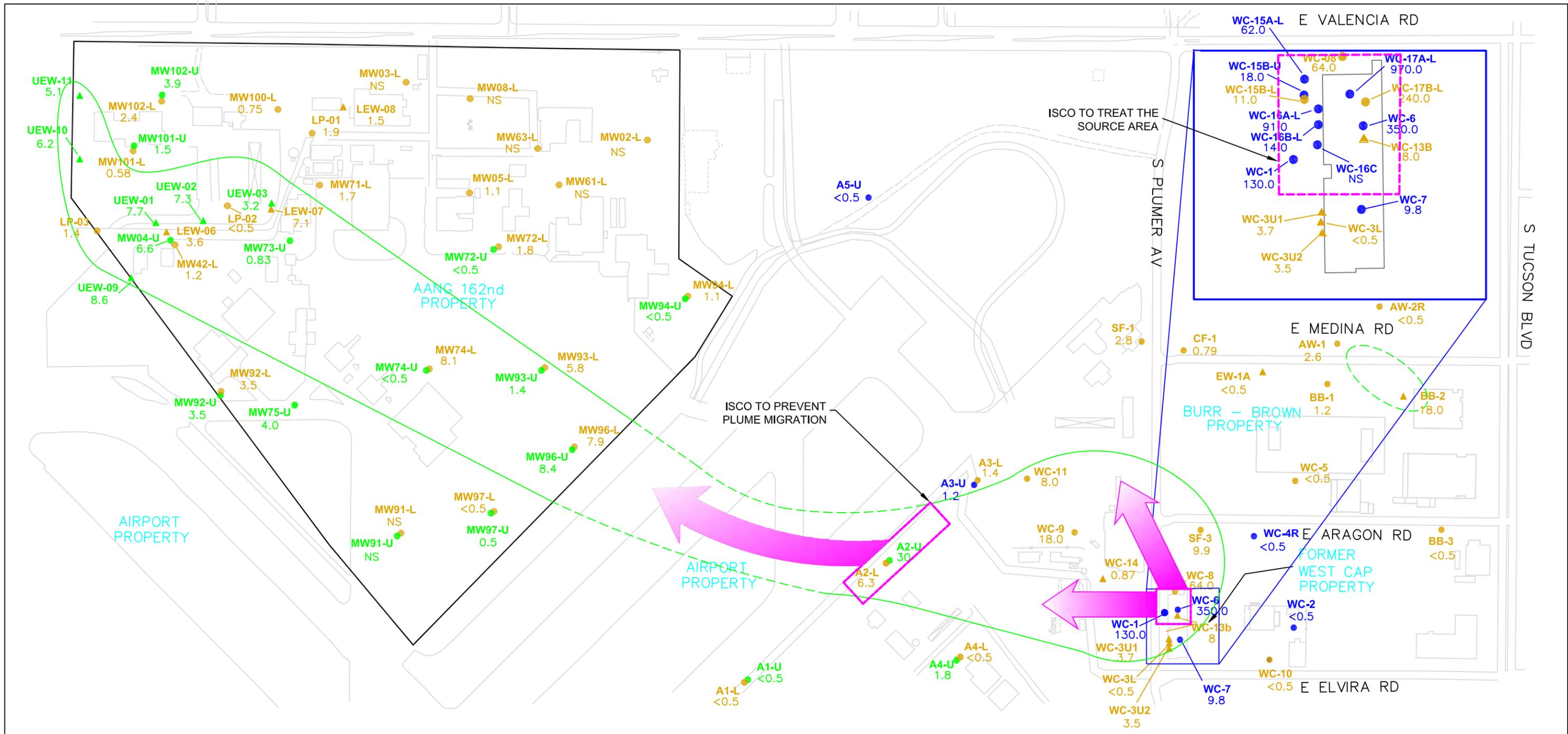
Legend

- New extraction wells, piping, and treatment system
- Existing extraction system
- New injection piping and wells
- 5 ppb TCE Contour
- Former West-Cap Property



Note:
Basemap aerial image source is Google Earth, March 2, 2008.

FIGURE 3-1
CONCEPTUAL DESIGN FOR
GROUNDWATER EXTRACTION
AND TREATMENT (ALTERNATIVE 1)
Former West-Cap Property
TIAA Superfund Site
Tucson, Arizona



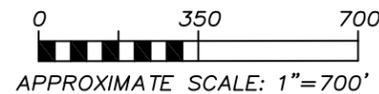
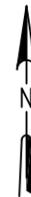
LEGEND

- SHALLOW GROUNDWATER ZONE (SGZ) MONITOR WELL
- UPPER SUBUNIT (USU) GROUNDWATER MONITOR WELL
- ▲ USU REMEDIAL EXTRACTION WELL
- LOWER SUBUNIT (LSU) GROUNDWATER MONITOR WELL
- ▲ LSU REMEDIAL EXTRACTION WELL
- <0.5 TRICHLOROETHYLENE (TCE) CONCENTRATIONS IN MICROGRAMS PER LITER (JANUARY – MARCH 2009)
- APPROXIMATE EXTENT OF GROUNDWATER CONTAINING TCE ABOVE 5 MICROGRAMS PER LITER (DASHED WHERE INFERRED)

DATA SOURCES: AANG 2009, ERROL L MONTGOMERY & ASSOCIATES 2009

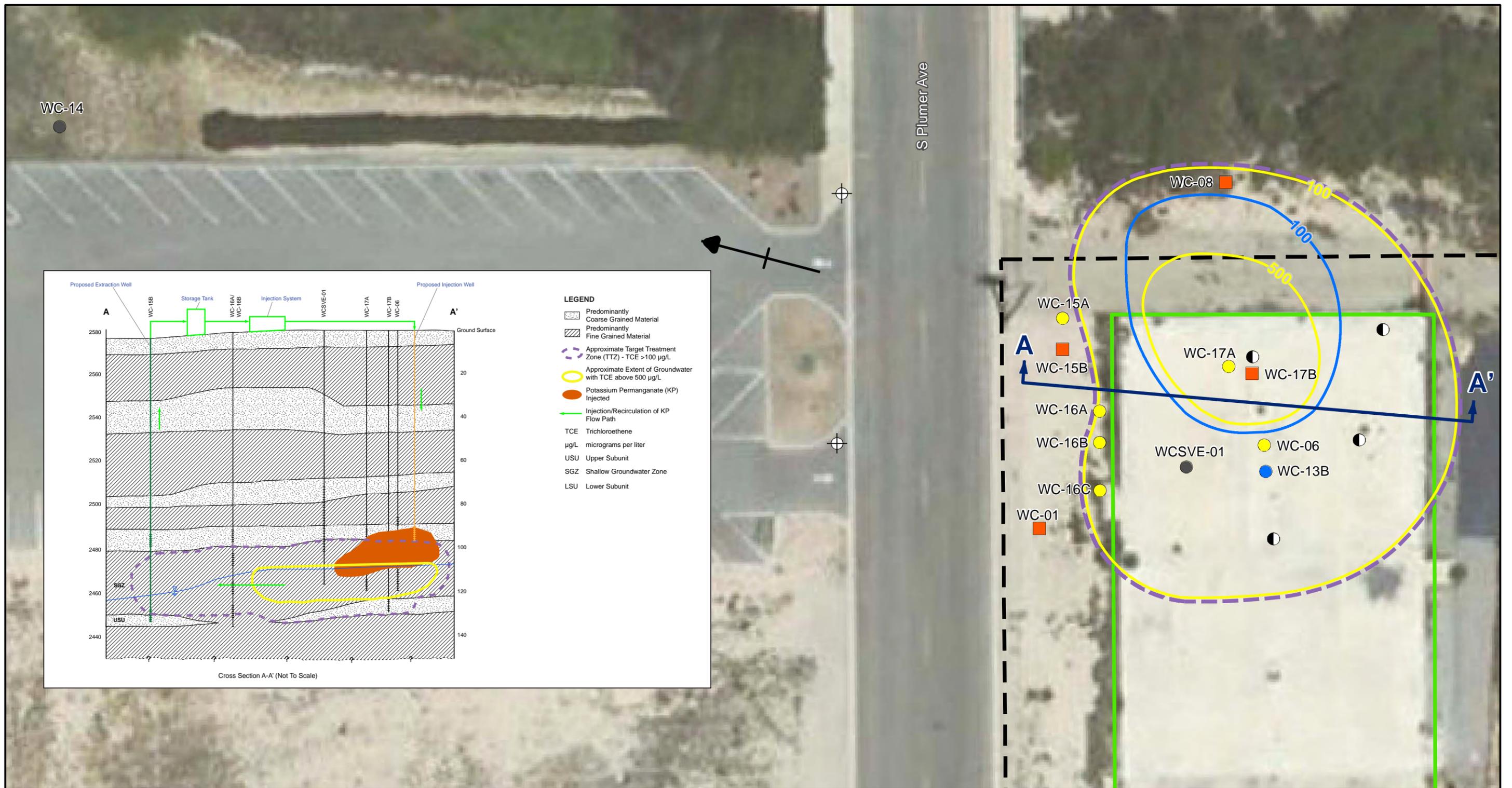
- NS NOT SAMPLED
- IN-SITU CHEMICAL OXIDATION (ISCO) INJECTION AREAS
- ← MIGRATION OF PERMANGANATE INTO PLUME AREAS

Note: 2009 data is used to show the extent of contamination prior to the ISCO pilot tests.



**FIGURE 3-2
CONCEPTUAL APPROACH FOR IN-SITU
CHEMICAL OXIDATION (ALTERNATIVE 2)**

West Cap Project Area
Tucson International Airport Area Superfund Site,
Tucson, Arizona



Legend

- Existing LSU Well
- Existing SGZ Monitoring Well
- Proposed Extraction Well
- Proposed New USU Injection Well
- ⊕ Proposed New Nested Monitoring Well (SGZ and USU)
- ↔ Cross Section
- ← Groundwater Flow Direction (Based on March 2011 Potentiometric Surface Map)
- West-Cap Building A (Pad)
- Former West-Cap Property
- 100— SGZ 100-µg/L TCE Contour Line
- 500— SGZ 500-µg/L TCE Contour Line
- 100— USU 100-µg/L TCE Contour Line
- - - Proposed Target Treatment Zone (TTZ)

Notes:
 1. bgs = below ground surface
 2. Basemap aerial image source is Google Earth, March 2, 2008.
 3. Not all wells are shown on the cross section A-A'.

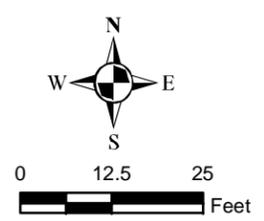


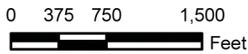
FIGURE 3-3
SOURCE ZONE IMPLEMENTATION
SCHEMATIC - ALTERNATIVE 2
Former West-Cap Property
TIAA Superfund Site
Tucson, Arizona

Permanganate Injection



Legend

-  Road
-  Railroad
-  TCE Plume Concentration ≥ 5 micrograms per liter
-  Tucson International Airport



Note: Plume contours based on groundwater sampling results from February 2009.

FIGURE 4-1
Schematic of Comprehensive Remedial Alternatives for Area B

Tucson International Airport Area Superfund Site Tucson, Arizona

