

RECORD OF DECISION AMENDMENT
TUCSON INTERNATIONAL AIRPORT AREA
SUPERFUND SITE AREA B

United States Environmental Protection Agency
Region 9
San Francisco, CA

EPA ID: AZD980737530

April 2012

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Acronyms and Abbreviations

µg/L	micrograms per liter
1,1-DCE	1,1-dichloroethene
A&Ww	Aquatic and Wildlife (warm water fishery)
A.R.S	Arizona Revised Statutes
AAC	Arizona Administrative Code
AANG	Arizona Air National Guard
ADEQ	Arizona Department of Environmental Quality
APP	Arizona Aquifer Protection
ARARs	applicable or relevant and appropriate requirements
AWQS	Aquifer Water Quality Standards
bgs	below ground surface
BHHRA	Baseline Human Health Risk Assessment for the Tucson International Airport Area Site
CAA	Clean Air Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
cis-1,2-DCE	cis-1,2-dichloroethene
COC	Contaminants of Concern
COPC	Contaminant of Potential Concern
CWA	Clean Water Act
ELCR	excess lifetime cancer risk
EPA	United States Environmental Protection Agency
EPC	exposure point concentrations
FAA	Federal Aviation Administration
GAC	granular activated carbon
GWETRS	groundwater extraction, treatment and recharge system
HBGL	Human Health-Based Guidance Levels
HI	hazard index
HQ	hazard quotient
HSWA	Hazardous and Solid Waste Amendments
ISCO	in-situ chemical oxidation
LSU	lower subunit

MCL	maximum contaminant level
MCLG	maximum contaminant level goals
MNA	monitored natural attenuation
NAAQS	National Ambient Air Quality Standards
NCP	National Contingency Plan
NHPA	National Historic Preservation Act
NPDES	National Pollutant Discharge Elimination System
NSPS	New Source Performance Standards
O&M	operation and maintenance
PCE	tetrachloroethene
PRB	permeable reactive barrier
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RI/FS	remedial investigation/feasibility study
ROD	record of decision
RSL	regional screening levels
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SGZ	shallow groundwater zones
SIP	State Implementation Plans
SRL	soil remediation level
SVE	soil vapor extraction
TBC	to be considered
TCE	trichloroethene
TI	Texas Instruments (former Burr-Brown facility)
TIAA	Tucson International Airport Area
UCAB	Unified Community Advisory Board
UIC	Criteria and standards for the Underground Injection Control
USU	upper subunit
VGAC	vapor-phase granular activated carbon
VOC	volatile organic compounds
WQARF	Water Quality Assurance Revolving fund

PART I. DECLARATION FOR THE RECORD OF DECISION AMENDMENT

1) Site Name and Location

- Tucson International Airport Area (TIAA) Superfund Site
- CERCLIS (Comprehensive Environmental Response, Compensation, and Liability Act of 1980) ID: AZD980737530
- TIAA Superfund Site Area B is the Site Name and it is collectively the groundwater project areas known as the West-Cap Site, Texas Instruments Site formerly known as Burr Brown, Arizona Air National Guard (AANG) 162nd Fighter Wing Site, and West Plume B Site
- Tucson, Arizona

2) Statement Basis and Purpose

This decision document amends the original Record of Decision (ROD) that was signed on August 22, 1988, for the TIAA Superfund Site which is a mixture of Federal Facilities, private, and Fund lead sites. The original 1988 ROD addresses groundwater contamination north of Los Reales Road in Area A and all of the contamination in Area B. This ROD Amendment presents a revised U.S. Environmental Protection Agency (EPA) Remedial Action that amends EPA's Selected Remedy for the Area B portion of the TIAA Superfund Site in accordance with the Comprehensive Environmental Response Compensation and Liability Act of 1980 as amended by the Superfund Amendments and Reauthorization Act (SARA) and to the extent practicable the National Contingency Plan (NCP). The decisions set forth in this document are based on information contained in the Administrative Record for this Site. The State of Arizona concurs with the selected remedy.

3) Assessment of the Site

The original response action for the Site included the pumping and treating of contaminated groundwater and was successful in containing the groundwater and inhibiting the migration of contaminated groundwater to other areas. However, the response action was not effective in treating the source areas of contamination in a timely manner. Source areas with residual contamination mass have persisted in the groundwater at the Site and contamination levels in groundwater remain above clean-up standards.

The response actions selected in this ROD Amendment are necessary to protect human health from actual or threatened releases of hazardous substances in the environment.

4) Description of the Revised Remedy

The main components of the original 1988 remedy, which applied to all of Area B, included:

- Groundwater pumping from extraction wells;
- Air stripping and Granular Activated Carbon for treatment of contaminated groundwater;

- Beneficial use of treated groundwater either through use of treated water in industrial operations, irrigation, or reinjection into the aquifer; and
- Groundwater Monitoring.

The revised remedy replaces the original remedy in TIAA Superfund Site Area B (groundwater extraction and treatment) with:

- In-Situ Chemical Oxidation (ISCO) using potassium permanganate injected in source areas of contamination and other strategic locations described in the Decision Summary as residual volatile organic compound (VOC) areas at the West-Cap Site, Texas Instruments (TI) Site, and Arizona Air National Guard (AANG) Site;
- Monitored Natural Attenuation (MNA) at the West Plume B;
- Groundwater Monitoring; and
- Institutional Controls.

5) Statutory Determinations

The revised remedy is protective of human health and the environment, complies with federal and state requirements that are applicable or relevant and appropriate to the remedial action, is cost-effective, and utilizes permanent solutions and alternative treatment (or resource recovery) technologies to the maximum extent practicable. The revised remedy satisfies the statutory preference for treatment as a principal element of the remedy as it uses potassium permanganate that permanently and significantly reduces the toxicity, mobility, or volume of the hazardous substances.

Because this remedy will result in hazardous substances, pollutants, or contaminants remaining on-Site above levels that allow for unlimited use and unrestricted exposure, the statutory review cycle triggered by the original remedial action will continue to ensure that the remedy is protective of human health and the environment. The next Five-Year Review for the Site is required in 2013.

6) ROD Data Certification Checklist

The following information is included in the Decision Summary section of this Record of Decision. Additional information can be found in the Administrative Record file for this Site.

- Chemicals of concern and their respective concentrations
- Baseline risk represented by the chemicals of concern
- Cleanup levels established for chemicals of concern and the basis for these levels
- How source materials constituting principal threats are addressed
- Current and reasonably anticipated future land use assumptions and current and potential future beneficial uses of ground water used in the baseline risk assessment and ROD

- Potential land and ground-water use that will be available at the Site as a result of the Selected Remedy
- Estimated capital, annual operation and maintenance (O&M), and total present worth costs, discount rate, and the number of years over which the remedy cost estimates are projected
- Key factor(s) that led to selecting the remedy (i.e., describe how the Selected Remedy provides the best balance of tradeoffs with respect to the balancing and modifying criteria, highlighting criteria key to the decision)

7) Authorizing Signature

Claire Noubadene acting for

4/20/2012

Clancy Tenley, Assistant Director

Date

Superfund Division

Partnerships, Land Revitalization, and Clean Up Branch

U.S. Environmental Protection Agency, Region 9

PART II: DECISION SUMMARY

This Decision Summary provides a description of the TIAA Superfund Site and the analyses that led to the amendment of the selected remedy for the Site. It includes background information about the Site, the nature and extent of contamination found at the Site, the assessment of human health and environmental risks posed by the contaminants at the Site, and the identification and evaluation of remedial action alternatives for the Site.

1) Site Name, Location, and Brief Description

In 1981, volatile organic compounds (VOCs) were detected in City of Tucson drinking water wells in the vicinity of the Tucson Airport that resulted in the establishment of the Tucson International Airport Area (TIAA) Superfund Site (Figure 1). For the purpose of investigating and remediating groundwater contamination, EPA divided this Site into two geographic areas: (1) TIAA Superfund Site Area A, which comprises the main groundwater contamination plume located to the west of the Airport, and (2) TIAA Superfund Site Area B, which includes the West Plume B, Arizona Air National Guard, Texas Instruments and former West-Cap project areas, located to the north and west of the airport (Figure 2). This ROD Amendment is restricted to TIAA Superfund Site Area B. EPA is the lead agency for TIAA Superfund Site Area B with the Arizona Department of Environmental Quality (ADEQ) in the support role. The CERCLIS ID is AZD980737530.

2) Site History and Enforcement Activities

In 1981, VOCs, including trichloroethene (TCE), which had been 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 in the proposed TIAA Site area. In September 1983, EPA placed the TIAA Site on the National Priorities List.

In 1985, the U.S. Air Force adopted a remedy to address the groundwater contamination associated with Air Force Plant 44, which is located south of Los Reales Road. Three years later, in August 1988, EPA signed a Record of Decision (ROD) identifying groundwater extraction and treatment as the remedy to address the groundwater contamination for the balance of the TIAA Superfund Site, which includes both Area A and Area B. The 1988 ROD explained that the assumptions made regarding Area B were preliminary and were subject to further investigation (Table 1). The ROD indicated that the ground water extraction and treatment remedy for Area B could require some modification as additional information was gathered as the same level of protection of human health and the environment and the same level of compliance with applicable or relevant and appropriate requirements (ARARs) as the remedy selected in the 1988 ROD. Remedial Investigations for Area B were not completed.

The major CERCLA milestones for the Area B portion of the TIAA Superfund Site work are summarized below in Table 1.

TABLE 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 Superfund Site	Pump-and-treat technology was selected as the remedial action for treatment of TCE to 1.5 micrograms per liter (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 confirmed source at Site 5.
1996	ROD for AANG Site 5 Soils	Soil vapor extraction (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 Arizona Department of Environment Quality (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. Source of contamination identified south of Los Reales at the AANG. No sources were identified within West Plume B.
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.
2009-2012	ISCO (in-situ chemical oxidation) Pilot Tests at 162 nd 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.

FIGURE 1
 Map of Tucson International Airport Area Superfund Site
Tucson International Airport Area Superfund Site—Area B

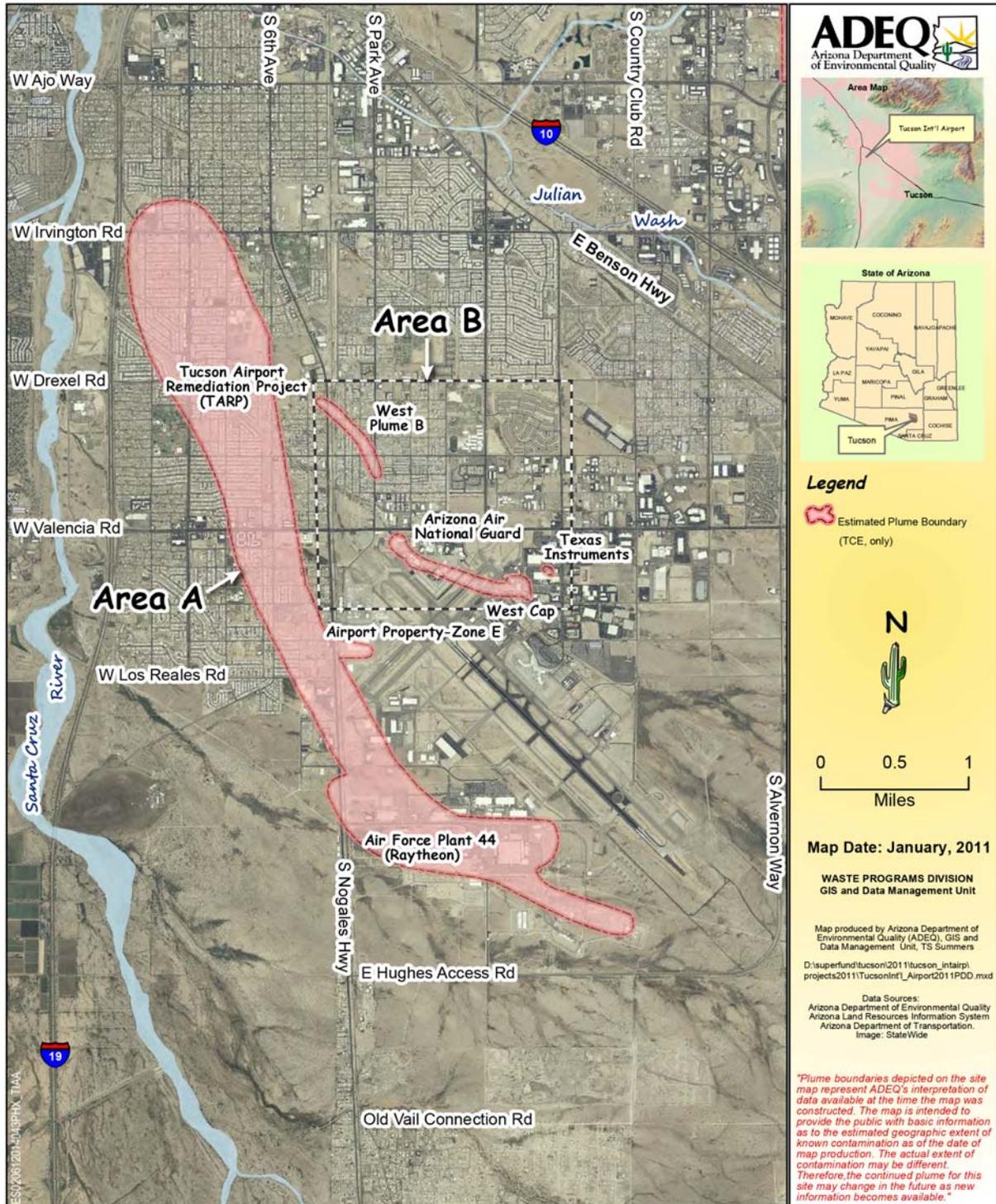
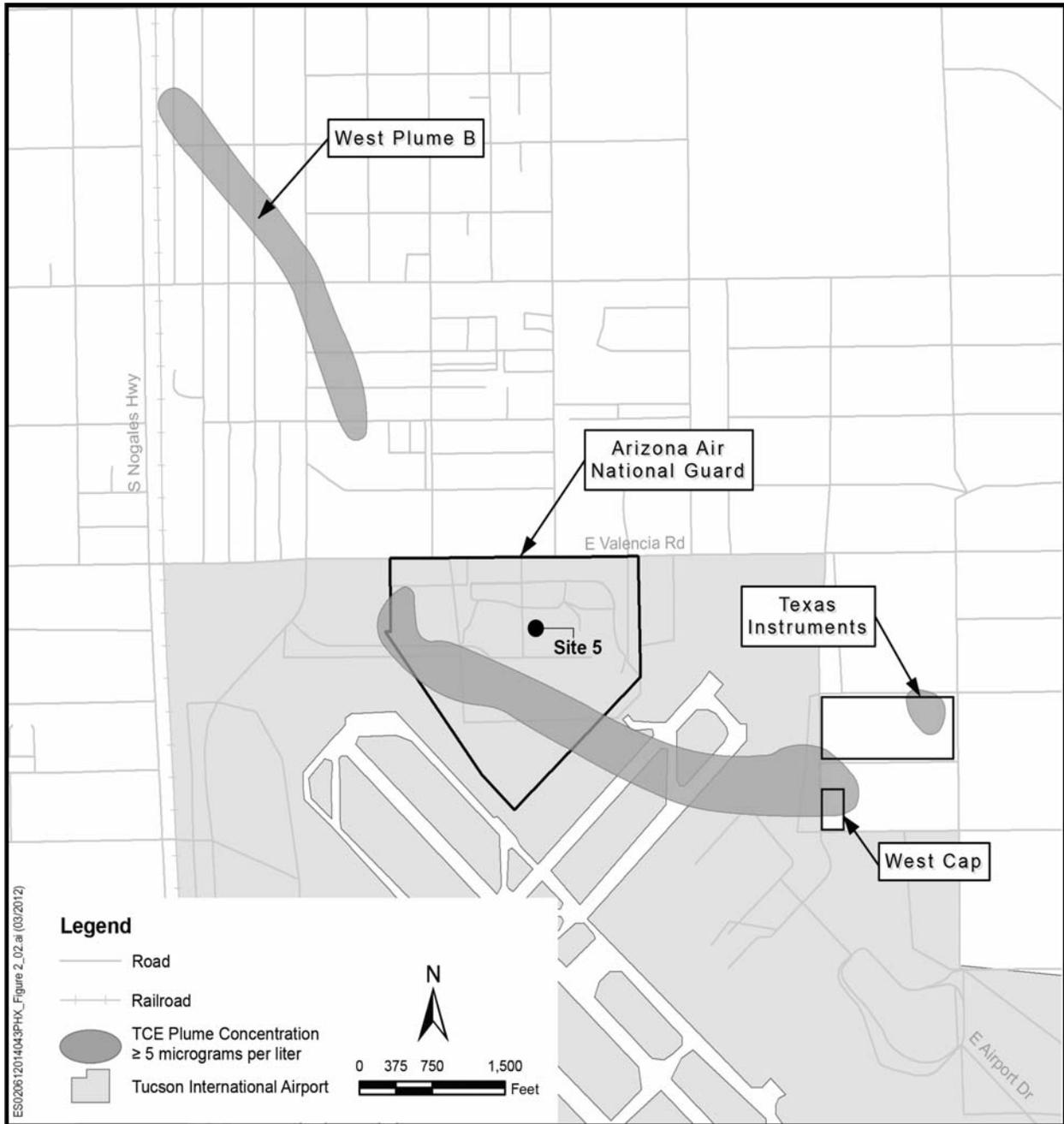


FIGURE 2
Map of Area B of the TIAA Superfund Site
Tucson International Airport Area Superfund Site—Area B



The history of the individual Sites within the TIAA Superfund Site Area B are as follows:

- **West Plume B:** This site includes elevated levels of VOCs in the groundwater and is considered to be the result of past migration of VOCs downgradient from the Arizona Air National Guard property. Operation of a groundwater extraction and treatment system at the Arizona Air National Guard has stopped this continued migration from the property and separated the Arizona Air National Guard and West Plume B plumes. No active treatment has taken place at the West Plume B Site. Remediation of upgradient Sites has removed the input of VOCs to the West Plume B area and VOC concentrations have been decreasing for almost 10 years due to natural attenuation. In 2004, a ROD Amendment for TIAA Superfund Site Area B was issued which recognized that MNA was a potential remedy for West Plume B and required more data to be collected. This ROD Amendment identifies MNA as the final remedy for the West Plume B Site.
- **Arizona Air National Guard 162nd Fighter Wing:** The base became operational in 1956. The property is currently used to provide aircraft training to fighter pilots from around the world. Operations also include aircraft and ground vehicle maintenance. Remedial investigations performed in 1987 identified TCE-impacted groundwater at the West Base Parking Lot, the Old Wash Rack Area A (also known as Site 5), and near the edges of the Aircraft Parking Area. A source of VOC contamination was identified at Site 5. These investigations were unable to determine potential historical contamination impacts at other locations. An extended soil vapor extraction (SVE) pilot test was conducted at Site 5 between April and November 1997. Results of soil gas samples collected after operations of the vapor extraction system indicated that VOC levels in soil gas were reduced to concentrations below the target cleanup goal, and Site 5 was closed in October 1998.

A Federal Facilities Agreement with EPA, the Arizona Department of Environmental Quality, and the National Guard Bureau was signed in 1994. The groundwater extraction, treatment, and recharge system (GWETRS) was installed at the Arizona Air National Guard (AANG) property in May 1997 to capture and treat elevated levels of the TCE in groundwater and to prevent offsite migration. Groundwater is removed from up to 11 extraction wells, treated with an air stripping system, and re-injected into the vadose zone (the soil layer above the saturated groundwater zone). The air stripping system transfers the VOCs from the groundwater as a vapor and treats the vapor with a carbon adsorption vessel that removes the TCE before discharging the vapor into the atmosphere.

An in-situ chemical oxidation pilot test was initiated in 2009 to evaluate the effectiveness of potassium permanganate in mitigating TCE in groundwater. The results of the pilot test between 2009 and 2012 indicated that the permanganate effectively mitigated TCE in groundwater, as TCE concentrations decreased in both the upper and lower subunits of the pilot test area. Continued monitoring will be necessary to assess the long-term performance of in-situ chemical oxidation.

- **Texas Instruments (TI):** The TI Site, formerly operated by Burr-Brown Corporation, operated a microchip manufacturing facility between 1969 and 2009. The presence of VOCs in soil and groundwater beneath the manufacturing facility has been attributed to past operational and disposal practices, particularly those related to former chemical storage areas. A consent decree between EPA and Burr Brown Corporation for the obligations of the response action was entered in 1990. A groundwater extraction and treatment system operated at the Texas Instruments (TI) Site between 1992 and 2009. A pilot test using permanganate was initiated in 2009, and the results between 2009 and 2012 indicated the successful delivery and the oxidation of VOCs in the target zone.
- **West-Cap:** From the early 1960s to the late 1980s the former West-Cap property, located adjacent to the Tucson International Airport, was occupied by the West-Cap of Arizona Corporation, which used solvents during manufacturing of small film capacitors and magnets. It is believed that West-Cap disposed of solvents into floor drains, which subsequently leaked into the soil. The West-Cap of Arizona Corporation dissolved through bankruptcy.

In early 1998, EPA initiated a time critical removal action for the remediation of the groundwater plume below the West-Cap project area, as the plume was migrating off-site. Contaminated groundwater was extracted and pumped to the treatment system at the Texas Instruments property. Groundwater extraction was discontinued because the existing system was not designed to treat the additional volume and increases in concentrations of contamination that resulted from the installation of additional extraction wells at West-Cap. The use of permanganate to break down TCE in groundwater was tested beginning in 2009 and the results between 2009 and 2012 indicated the successful delivery of potassium permanganate and the oxidation of the contaminants of concern (COCs) in the target zone.

3) Community Participation

A 30-day public comment period was held from October 26, 2011, to November 30, 2011. At an October 19, 2011 public meeting, EPA discussed the proposed changes to the selected remedy for portions of TIAA Superfund Site Area B from pump and treat to in-situ chemical oxidation with the members of the Unified Community Advisory Board (UCAB) for the TIAA Superfund Site on October 19, 2011. A draft of the Proposed Plan document was also distributed to the UCAB. An announcement of the Proposed Plan was printed in the Arizona Daily Star on October 18, 2011, and a Spanish language version was printed in the La Estrella on October 21, 2011. There were 1,251 copies of the Proposed Plan mailed out to the community and interested parties of the TIAA Superfund Site.

Copies of the Focused Feasibility Study for TIAA Superfund Site Area B, as well as the Proposed Plan, were made available at the El Pueblo Public Library located at 101 W. Irvington Road in Tucson, Arizona and the U.S. EPA Region 9 Records Center located at 95 Hawthorne Street in San Francisco, California. Electronic copies of the Proposed Plan and the Focused Feasibility Study were posted on the EPA website for the TIAA Superfund Site: www.epa.gov/region9/tucsonairport.

The Public Meeting for the Proposed Plan was held on November 16, 2011, at the office of the Arizona Department of Environmental Quality Southern Regional Office at 400 West Congress Street, Tucson, Arizona. Four comments were received on the Proposed Plan. The comments and EPA's responses are presented in a Responsiveness Summary attached to this ROD amendment.

4) Scope and Role of Response Action

The response action presented in this ROD amendment is an amendment to the Area B portion of the selected remedy described in the 1988 TIAA Superfund Site-Wide ROD and also replaces portions of the 2004 TIAA Superfund Site ROD Amendment, which identified that more analysis was needed for the determination of an MNA remedy for the West Plume B Site. The basis for this action is the existing pump and treat remedy was not effective in treating the source areas in groundwater. This proposed action will be the final action for Area B. The goals of this action are to address the residual VOC contamination that exists in the groundwater and minimize migration of contaminants in groundwater away from industrial areas. The selected remedy replaces the existing remedy with in-situ chemical oxidation using potassium permanganate to treat VOCs and also selects monitored natural attenuation for West Plume B.

5) Site Characteristics

A summary of site characteristics is presented below.

- **Physical Characteristics:** Based on historical data, the total length of the axis of the Area B Site as it is currently understood is over 2 miles long. It is located from West-Cap Site near the intersection of Plumer Avenue and Elvira Street to just south of East Drexel Avenue. The known width of the Area B plume is less than 1,000 feet at its widest point and more often interpreted to be 400 feet wide.
- **Site Hydrogeology:** The Tucson Basin is described as saturated alluvial sediments that compose a single regional aquifer system and all aquifers are considered to be drinking water aquifers in the State of Arizona. 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 is divided here 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. 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.

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 are present 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.

Regional groundwater movement is generally from southeast to northwest across Area B. 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:** Various remedial investigations and actions have been performed since 1982 to establish the Contaminants of Concern (COC) for the Site (Table 2) and their distribution within Area B. The 2004 ROD Amendment listed TCE, tetrachloroethene (PCE), 1,1-dichloroethene (1,1-DCE), cis-1,2-dichloroethene (cis-1,2-DCE), and vinyl chloride as the Contaminants of Concern. Only TCE and PCE routinely exceed Maximum Contaminant Levels at the Site (Table 3). The presence of PCE is generally limited to a small area near the former West-Cap facility. TCE and PCE are industrial solvents previously used by entities in the vicinity of the TIAA Superfund Site.

TABLE 2
 Maximum Contaminant Levels are clean up 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
Vinyl Chloride	2

TABLE 3
Summary Statistics for VOCs in Groundwater
Tucson International Airport Area Superfund Site—Area B

Compound	Number of Detections	Number of Analysis	Minimum Detected Value (µg/L)	Maximum Detected Value (µg/L)	Arithmetic Mean (µg/L)
1,1-DCE	49	279	0.061	8.7	0.83
1,1,2-Trichloroethane	9	279	0.1	2.1	0.49
1,1,2-Trichloro-1,2,2-Trifluoroethane	12	279	0.11	0.62	0.35
1,2-Dichloropropane	2	279	0.62	0.66	0.64
1,3-Dichlorobenzene	1	279	0.11	0.11	0.11
1,4-Dichlorobenzene	1	279	0.1	0.1	0.10
2-Butanone, Methyl Ethyl Ketone	29	279	1.8	29	8.61
2-Hexanone	2	278	1.2	18	9.60
4-Methyl-2-Pentanone	2	278	2.2	5	3.60
Acetone	81	279	0.72	120	16.18

Important characteristics of contaminant distribution in TIAA Superfund Site Area B are summarized as follows. A map showing the distribution of TCE in groundwater in February 2009 is shown on Figure 3.

- West Plume B:** The VOC plume at West Plume B is shrinking in area and has no further input of VOCs. The plume is approximately 2,000 feet in length, is located to the northwest of the Arizona Air National Guard Site, and is located at a depth of approximately 85 to 135 feet below ground surface. Concentrations of TCE have been less than 20 µg/L since 2002, and the most recent sampling confirms the maximum TCE concentration in West Plume B to be 8 µg/L. In addition, concentrations have been steadily decreasing without treatment. The attenuation mechanisms observed and confirmed by EPA to be occurring at West Plume B include hydrodynamic dispersion, sorption, and biodegradation. Together, these mechanisms are decreasing 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, but is likely occurring based on collected data. The presence of compounds such as 1,1-DCE and cis-1,2-DCE, which are products of biological reductive dechlorination, indicate that some biological degradation is occurring. A copy of the Technical Memorandum supporting Monitoring Natural Attenuation for West Plume B is included in the Appendix A of this document.

- **Arizona Air National Guard:** The existing groundwater extraction and treatment has been successful in capturing and containing VOC contamination to the area south of Valencia Road. The VOCs in groundwater at this Site are confined to the property at a depth of approximately 90 to 120 feet bgs. Concentrations of TCE at the Arizona Air National Guard Site are below 10 µg/L but this is under conditions associated with the operation of the groundwater extraction system. A rebound test is needed to evaluate the effectiveness of the groundwater extraction system in removing contaminants. The majority of the Site 5 soil contamination has been treated by the SVE system.
- **West-Cap:** Residual VOCs that are located in a deep clay layer (about 100 feet bgs) at the former West-Cap facility continue to contribute to a groundwater plume that extends approximately 500 feet to the north and at least 2,500 feet to the west. The depth of this plume is approximately 110 to 140 feet bgs. Prior to the permanganate pilot test, the maximum concentrations of TCE were 790 µg/L in the clay layer directly underneath the West-Cap property and less than 30 µg/L to the west of the property.
- **Texas Instruments:** Residual VOCs are found in a deep clay layer at the Site, which contributes to a groundwater plume that has remained on-site and was previously contained but not effectively treated by the groundwater extraction and treatment system. Prior to the permanganate pilot test, the groundwater plume extended less than 400 feet from the former chemical storage areas, at a depth of approximately 110 to 130 feet bgs. Concentrations of TCE have been below 10 µg/L since 2001 in all wells except Extraction Well BB-2, which rebounded up to 76 µg/L when the groundwater extraction system was turned off. This well currently contains permanganate from the permanganate pilot test and is not sampled for VOC analysis but surrounding wells are showing trends of decreasing concentrations of contaminations.

6) Current and Future Site and Resource Use

The land use in Area B is currently commercial/light industrial near West-Cap and Texas Instruments, an active military base at the Arizona Air National Guard, and mostly residential with some light commercial activity in West Plume B (Figure 4). The Site overlies the Tucson groundwater basin, which provides up to 80% of the municipal drinking water for over 1 million residents of the City of Tucson and surrounding communities. In addition to the municipal supply of drinking water, there are private wells found throughout the area in and near the City of Tucson. The anticipated future land use is the same as the current use as the location of the Tucson Airport and the Arizona Air National Guard base is not likely to be moved.

FIGURE 3
TCE Concentrations in Groundwater, January-March 2009
Tucson International Airport Area Superfund Site—Area B

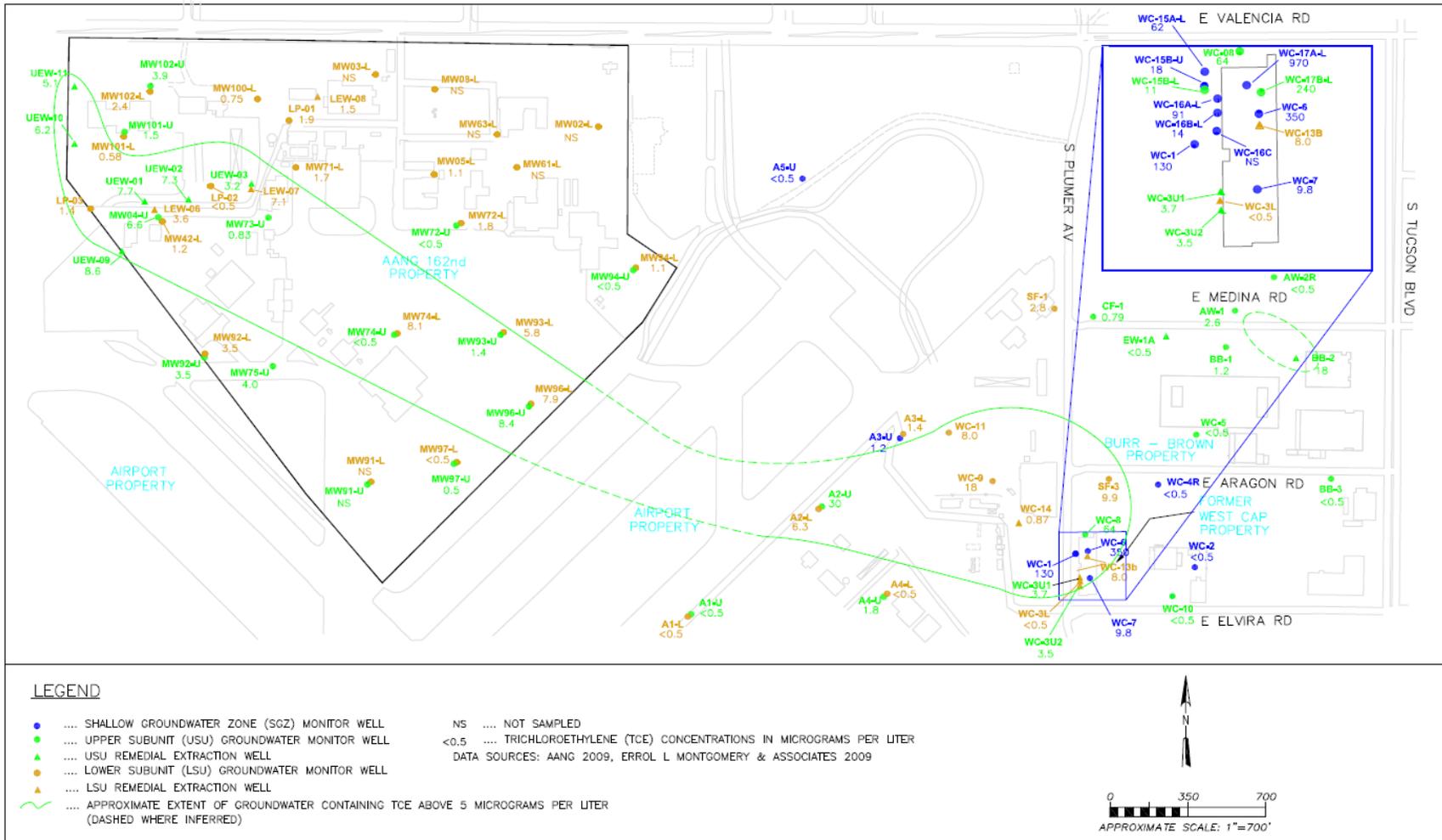
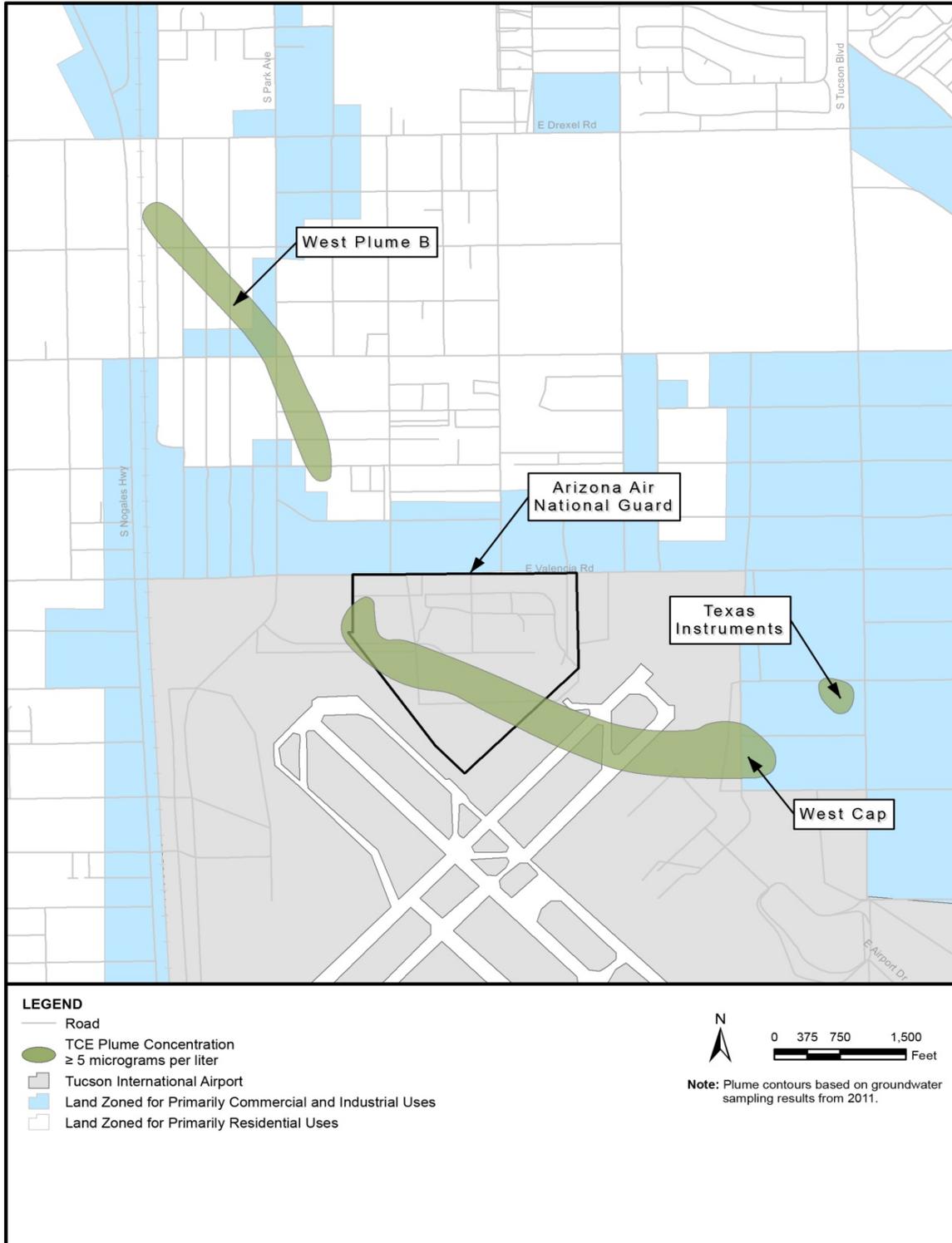


FIGURE 4
General Land Use Zoning Classifications
Tucson International Airport Area Superfund Site—Area B



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7) Summary of Site Risks

The summary of Site risks for soil and groundwater is based on the *Baseline Human Health Risk Assessment for the Tucson International Airport Area Site* (BHHRA; Arizona Department of Health Services [ADHS], 1996), but has been updated based on recent contaminant concentration data in groundwater. 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 off-Site 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 Nogales Highway (west), including the West-Cap property.

There is no new data that would change the previous studies that evaluated the risk for surface soil under current and future residential scenarios. The previous results showed excess lifetime cancer risk (ELCR) less than EPA’s risk management range of 10^{-6} (1E-06) - 10^{-4} (1E-04).

An updated screening-level risk evaluation for groundwater was performed in the 2011 TIAA Superfund Site Area B Focused Feasibility Study using the latest groundwater monitoring data at West-Cap for current and future residential scenarios (Table 4). All chemicals detected in the groundwater were defined as contaminants of potential concern (COPCs). 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. The highest TCE (970 µg/L) and PCE (110 µg/L) concentrations were found at the West-Cap site in January 2009. The ELCR for groundwater exceeded EPA’s risk management range of 10^{-6} to 10^{-4} . The potential future ELCR associated with using groundwater from the West-Cap project area for drinking water is approximately 2E-03 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 action level for clean up in these areas are MCLs for drinking water. This document relies on the 1996 Risk Assessment for conclusions for inhalation/absorption risk.

TABLE 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

TABLE 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
1,4-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 = not available

The cancer risk estimates for the individual COPCs were then summed to provide a cumulative cancer risk estimate. The Hazard Quotient (HQ) for individual COPCs was calculated taking the EPC and dividing it by the EPA's RSL. 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. The overall HI for drinking water is 1, which is equal to the non-cancer threshold of 1. However, individual COPCs have HQs

less than 1. Based on the most recent data, the Site is not within EPA’s acceptable risk range for Superfund Sites and remedial action is required.

8) Remedial Action Objectives

The Remedial Action Objectives in the 2004 ROD Amendment have been combined into the following three objectives:

- Reduce the risk of potential exposure to contaminants.
- Restore contaminated groundwater to support existing and future uses, i.e. drinking water.
- Prevent or reduce migration of groundwater contamination above maximum contaminant levels.

9) Description of Alternatives

Below is a list of alternatives evaluated in this revised remedy with the exception of the selection of MNA for West Plume B. In the 2004 ROD Amendment, it was stated that MNA could be the selected remedy for West Plume B if the data supported it. The Technical Memorandum supporting the selection of MNA for West Plume B is attached as an Appendix A to this document.

EPA evaluated 5 alternatives in this revised remedy:

Alternative 1: No Further Action

Alternative 2: Groundwater Extraction and Treatment in West-Cap, Texas Instruments, Arizona Air National Guard and MNA in West Plume B

Alternative 3: In-Situ Chemical Oxidation (ISCO) at West-Cap, Texas Instruments, Arizona Air National Guard, and MNA in West Plume B (EPA’s Preferred Alternative)

Alternative 4: ISCO at West-Cap, Texas Instruments, Permeable Reactive Barrier in Arizona Air National Guard, and MNA in West Plume B

Alternative 5: ISCO at West-Cap and Texas Instruments and MNA in Arizona Air National Guard and West Plume B

Alternative 1: No Further Action

EPA is required to consider the no further action alternative. Under this alternative, no additional treatment would be implemented, and monitoring would cease. The estimated cost for this alternative is \$0, and this alternative would never achieve RAOs.

Alternative 2: Groundwater Extraction and Treatment in West-Cap, Texas Instruments, Arizona Air National Guard and MNA in West Plume B

This alternative involves the extraction, treatment, and injection of groundwater at the West-Cap, Texas Instruments, and Arizona Air National Guard Sites to remove VOCs. Groundwater extraction would target the source areas at the West-Cap and Texas Instruments

Sites. Groundwater extraction and treatment would prevent migration of contamination north of Valencia Road at the Arizona Air National Guard Site.

Treatment of extracted groundwater at the Arizona Air National Guard and Texas Instruments Sites would be accomplished by upgrading the existing air stripping systems present at those locations, and a new liquid-phase granular-activated carbon treatment system would be constructed at the former West-Cap facility. Treated water would be re-injected back into the aquifer. Concentrations of VOCs at the West Plume B Site have been decreasing through natural attenuation, and no groundwater extraction is proposed for this area. MNA would be used to remediate the groundwater in the West Plume B area. The MNA in West Plume B is discussed in further detail in the common elements of the alternatives in this section. The estimated cost for this alternative is \$19 million and estimated time to achieve RAOs is in excess of 30 years.

Alternative 3: ISCO at West-Cap, Texas Instruments, Arizona Air National Guard, and MNA in West Plume B (EPA's Preferred Alternative)

Alternative 3 involves ISCO through the injection of potassium permanganate solution into VOC source areas in the groundwater plume at the West-Cap Site and the Texas Instruments Site and injection into the residual VOC areas in the groundwater plume at the Arizona Air National Guard Site. Specifics of the residual plume areas at Arizona Air National Guard will be better defined through the rebound test that will commence after the cessation of the active groundwater extraction system. The groundwater extraction system will be used as a contingency during the test for rebound on the Arizona Air National Guard portion of the Site but will be discontinued when full scale ISCO implementation is in place. The trigger for operating the groundwater extraction system would be the observation of 10 ppb TCE in any of the monitoring wells identified in Appendix B of this document during the rebound test.

At the Area B Sites, potassium permanganate has been successfully tested and is proposed for continued use for ISCO. The injected permanganate solution has been shown to break down the VOCs in place. The pilot studies of ISCO did result in minor increases in by-products resulting from the higher oxidation states affecting the minerals in the source areas. However, the slight increases in these by-products (chromium, selenium) were reduced to normal levels outside of the areas of treatment where normal oxidation levels in the subsurface are found. Treatment of the residual VOCs in the source areas and residual VOC areas would prevent further contamination of the aquifer and allow for plume reduction through an enhanced attenuation processes.

The use of ISCO with permanganate was considered during development of the 2004 ROD Amendment. At the time, it was not considered a cost-effective alternative, as injection methods had not been developed. The permanganate injection pilot tests conducted in 2009 demonstrated that permanganate can be effectively delivered to the target treatment zones. The estimated cost for this alternative is \$7.4 million. The cost estimates for this remedy assumes a single injection event after completion of Remedial Design. If multiple injections are needed, it is expected that the cost estimates would increase by less than 25%. The estimated time to achieve RAOs is 13-20 years.

Monitored natural attenuation would be used to manage the VOCs remaining in the West Plume B.

Alternative 4: ISCO at West-Cap and Texas Instruments, Permeable Reactive Barrier at Arizona Air National Guard, and MNA at West Plume B

Alternative 4 is similar to Alternative 3 with ISCO accomplished by injecting permanganate solution into the subsurface at the West-Cap and Texas Instruments areas. However, Alternative 4 involves the installation of a subsurface permeable reactive barrier to prevent off-Site plume migration at the Arizona Air National Guard property. The permeable reactive barrier would be constructed to allow groundwater to flow through, but would contain zero-valent iron, which destroys TCE and PCE contaminants as contamination flows through the barrier. MNA would be used to manage the VOCs present in the West Plume B area as in Alternatives 2 and 3. The estimated cost for this alternative is \$19 million and estimated time to achieve RAOs is 20 years.

Alternative 5: ISCO at West-Cap and Texas Instruments and MNA at Arizona Air National Guard and West Plume B

Alternative 5 is similar to Alternative 3, as it involves ISCO with injection of potassium permanganate solution into the subsurface at the West-Cap and Texas Instruments areas and MNA to address VOCs in the West Plume B area. However, under Alternative 5, no active treatment would take place at the Arizona Air National Guard Site and groundwater in this area would be allowed to remediate through natural attenuation processes. This alternative would not prevent migration of the VOC plume from the Arizona Air National Guard property north of Valencia Road. The estimated cost for this alternative is \$6 million and estimate time to achieve RAOs is 13-20 years.

Common Elements: With the exception of the “No Action” alternative, all of the alternatives evaluated at the four different project areas (West-Cap, Texas Instruments, Arizona Air National Guard, and West Plume B) include common components combined in various ways. All of the alternatives include active treatment of VOCs in source areas and residual zones. Attenuation parameters outside of the treatment zones would be monitored to ensure the effectiveness of the remedy. All active alternatives are expected to attain the Remedial Action Objectives.

The active alternatives also include institutional controls to limit or prevent public access to areas where treatment of residual VOCs will be ongoing, such as industrial property, the Tucson International Airport property, or the Arizona Air National Guard property. Consistent with expectations set out in the Superfund regulations, none of the remedies rely exclusively on institutional controls to achieve protectiveness.

Finally, other than “No Further Action,” all of the alternatives evaluated here contain MNA for West Plume B. This is consistent with the 2004 ROD Amendment, which proposed that West Plume B be changed to MNA if sufficient data is collected and the analysis supported the remedy change. The analysis for MNA for West Plume B is included in an appendix to this ROD Amendment.

10) Comparative Analysis of Alternatives

EPA evaluates each of the alternatives based on nine standard criteria. The first two criteria are *threshold criteria*: overall protection of human health and the environment, and compliance with federal and state ARARs. The next five criteria are *balancing criteria* and include long-term effectiveness and permanence; reductions in toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost. The final two criteria are *modifying criteria* and include state and community acceptance, which were evaluated after the close of the public comment period on the proposed remedy. Figure 5 illustrates how each alternative compares to the threshold and balancing criteria.

Threshold Criteria

- *Overall Protection of Human Health and Environment*: Each of the five alternatives evaluated here are protective of human health and environment with the exception of Alternative 1, the “No Further Action” alternative. Without some form of treatment in source areas, there would be an unacceptable level of risk remaining at the Site. The other four alternatives provide for treatment of the areas of highest concentration of TCE.
- *Compliance with ARARs*: ARARs can be chemical specific, action specific, or location specific. The 5 µg/L MCL for TCE is a relevant and appropriate chemical-specific requirement. The “No Further Action” Alternative does not comply with ARARs because it would leave concentrations of TCE at the Site above the MCL. Alternatives 2-5 will reduce the TCE concentrations below the MCL, and will comply with ARARs. Alternative 2 is essentially the existing remedy which has air and water discharges that result from groundwater extraction and treatment would need to meet the additional ARARs associated with these activities. Alternatives 3-5 are all remedies are essentially the same remedy with respect to ARARs. In each of these remedies, there are no surface discharges so the MCL is the relevant and appropriate requirement.

Balancing Criteria

- *Long-term effectiveness and permanence*: Alternative 1 will not be effective in the long term for restoring ground water to its beneficial use. For Alternative 2, there are questions about the long-term effectiveness of groundwater extraction. Alternative 2 is currently being implemented at the AANG, and if groundwater extraction continues, will be implemented for an estimated additional 20 years. At the West-Cap and TI Sites, because of the limited rate of diffusion of VOCs out of the source areas, continued groundwater extraction 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 sustainable.

FIGURE 5

Nine Criteria Analysis (excluding State and Community Acceptance)
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							
WC1—No Action	—	—	—	—	—	●	●
WC2—Groundwater Extraction and Treatment	●	●	○	○	○	●	—
WC3—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 (Sewer-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

Alternative 3 has been previously implemented and proven effective in pilot tests at the AANG, West-Cap, and TI project areas. Alternative 3 has a shorter estimated time to achieve cleanup than Alternative 2, with an estimated time of 13 to 20 years. Diffusion of permanganate into the source areas is a difficult and time-consuming process, and might not be completed through a single injection 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 enhanced attenuation is complete.

Alternative 4, which would use a Permeable Reactive Barrier rather than ISCO at the AANG, is expected to permanently reduce VOCs at the northern boundary of the AANG property. However, there have been no pilot studies using a Permeable Reactive Barrier at the TIAA Superfund Site and therefore its effectiveness is questionable. The rest of the Area B is expected to meet cleanup goals within an estimated 20 years through ISCO and MNA.

Alternative 5, which would use MNA rather than ISCO at the AANG, will permanently reduce VOCs in groundwater through ISCO at West-Cap and Texas Instruments Sites. But MNA on AANG property may result in VOCs increasing north of Valencia Road, which would decrease the long-term effectiveness.

- *Reduction in toxicity, mobility, or volume through treatment:* Alternative 1 would not result in reduction of toxicity as there is no treatment. Alternative 2, Groundwater Extraction and Treatment would use carbon adsorption and air stripping treatment systems to remove contaminants at an efficiency of 95 percent or greater. The migration of VOCs to the northwest would be eliminated by establishing hydraulic capture zones through the operation of the extraction wells. Groundwater extraction and treatment is currently being implemented at the AANG. Alternative 2 would continue to decrease TCE concentrations in groundwater, as well as prevent offsite migration. However, Alternative 2 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 source areas.

Alternatives 3 and 4 have the potential of reducing the highest VOC concentrations much faster than Alternative 2, since the source zones and residual treatment areas 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 3) or through the use of a permeable reactive barrier (PRB) (Alternative 4).

Alternative 5 would also treat the source areas at West-Cap and Texas Instruments. However, the mobility of VOCs in groundwater north of Valencia would increase because the containment system on AANG would be turned off and would not be replaced with another treatment or containment system.

None of the alternatives generate hazardous waste.

- *Short-Term Effectiveness:* Alternate 1 is no further action which is not effective in the short term. For Alternatives 2 and 3, 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 2, and treatment of the source zones at West-Cap and TI would be achieved multiple injections over a span of ten years under Alternatives 3 and 4.

Alternative 4 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 5 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 Texas Instruments, the source zones would be treated rapidly by the permanganate. At West Plume B, attenuation of VOCs would continue because the plume is not migrating.

There is a potential for exposure to Site workers by the permanganate during implementation of Alternatives 3, 4 and 5. This potential would be of limited duration and extent and would not affect the public. The permanganate used in these alternatives is anticipated to completely degrade and/or dilute before it reaches groundwater underneath residential properties within the West Plume B area.

In addition to the period of time needed to implement the remedy, short-term effectiveness criteria is used to evaluate the risks to workers and community during the construction and implementation of the remedy. Short-term risks to workers associated with normal construction hazards and potential contact with contaminated water in Alternatives 2 through 5 would be eliminated through appropriate controls and adherence to proper health and safety protocols. Due to the limited potential for exposure to contaminated groundwater, no risk to residents is expected during implementation of any of the alternatives.

- *Implementability:* Alternative 1 is no further action and there is no implementation. Alternatives 2 and 3 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 2 at West-Cap would require design and construction work for installation of conveyance piping and the treatment system. Alternative 2 is currently in operation at the AANG, and was used until 2009 at Texas Instruments. All necessary equipment and personnel for continued operation is readily available at these Sites. The treatment system at the Texas Instruments project area would be moved to a more accessible location.

Alternative 3 at West-Cap would require minimal design calculations and would use existing wells for the injection system. Construction associated with Alternative 3 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 3 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 4 with the PRB would require considerable coordination, space, and access permissions with AANG personnel. The implementability of this alternative is uncertain because no pilot tests have been performed at the TIAA Superfund Site.

Construction associated with Alternative 5 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.

- *Cost:* EPA compares each alternative based on upfront capital cost, annual operation and maintenance cost, and overall present value cost, which is a measure of the total future project cost over a 30-year timeframe. There is no cost for Alternative 1. Estimated costs for the Area B remedial alternatives are summarized in Table 5. Alternatives 3 and 5 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 2 and 4 are the least cost effective, with an estimated cost of \$19 million to \$20 million. The following table summarizes the estimated costs of the remedy alternatives for each Site.
- *State Acceptance:* The Arizona Department of Environmental Quality submitted comments to the EPA on the Proposed Plan in a letter dated November 28, 2011 supporting EPA's revised remedy for Area B of the TIAA Superfund Site. ADEQ also provided concurrence of this Record of Decision Amendment in a letter dated April 6, 2012 (Appendix C).
- *Community Acceptance:* There were two comments from the community submitted on the Proposed Plan. One verbal comment supporting EPA's proposed remedy was delivered at the Public Meeting for the Proposed Plan. A written comment letter did not specifically support it but did not raise any objections or concerns with the revised remedy. All of the comments are included in Part 3 Responsiveness Summary of this ROD Amendment along with EPA responses to the comments.

11) Principal Threat Waste

The NCP establishes an expectation that EPA will use treatment to address the principal threats posed by a Site wherever practicable. The principal threat concept is applied to the characterization of source materials at a Superfund Site. Contaminated groundwater generally is not considered to be a source material, thus no principal threat waste exists in Area B of the TIAA Superfund Site.

TABLE 5
Remedy Alternatives and Estimated Cost by Site
Tucson International Airport Area Superfund Site—Area B

Alternative Number	Arizona Air National Guard	West-cap	Texas Instruments	West Plume B	Total Cost
Alternative 2	Groundwater Extraction and Treatment	Groundwater Extraction and Treatment	Groundwater Extraction and Treatment	Monitored Natural Attenuation	
Estimated Capital	\$350,350	\$1,630,000	\$522,300	\$0	\$2,502,650
Annual Operation and Maintenance	\$620,150	\$322,967	\$85,100	\$26,370	\$1,054,587
Total Cost (Net Present Value)	\$8,513,386	\$8,445,716	\$1,993,400	\$546,948	\$19,499,450
Alternative 3	In-Situ Chemical Oxidation	In-Situ Chemical Oxidation	In-Situ Chemical Oxidation	Monitored Natural Attenuation	
Estimated Capital	\$2,074,800	\$394,188	\$422,500	\$0	\$2,891,488
Annual Operation and Maintenance	\$499,200	\$55,452	\$55,000	\$26,370	\$636,022
Total Cost (Net Present Value)	\$4,963,358	\$1,486,311	\$971,700	\$546,948	\$7,968,317
Alternative 4	Passive Reactive Barrier	In-Situ Chemical Oxidation	In-Situ Chemical Oxidation	Monitored Natural Attenuation	
Estimated Capital	\$11,861,850	\$394,188	\$422,500	\$0	\$12,678,538
Annual Operation and Maintenance	\$406,667	\$55,452	\$55,000	\$26,370	\$543,489
Total Cost (Net Present Value)	\$17,232,445	\$1,486,311	\$971,700	\$546,948	\$20,237,404
Alternative 5	Monitored Natural Attenuation	Monitored Natural Attenuation	Monitored Natural Attenuation	Monitored Natural Attenuation	
Estimated Capital	\$310,310	\$394,188	\$422,500	\$0	\$1,126,998
Annual Operation and Maintenance	\$240,000	\$55,452	\$55,000	\$26,370	\$376,822
Total Cost (Net Present Value)	\$3,469,431	\$1,486,311	\$971,700	\$546,948	\$6,474,390

Note: Alternative 1 (No Action) is not included in this analysis because there is no cost associated with this Alternative and it does not meet the threshold criteria.

12) Selected Remedy

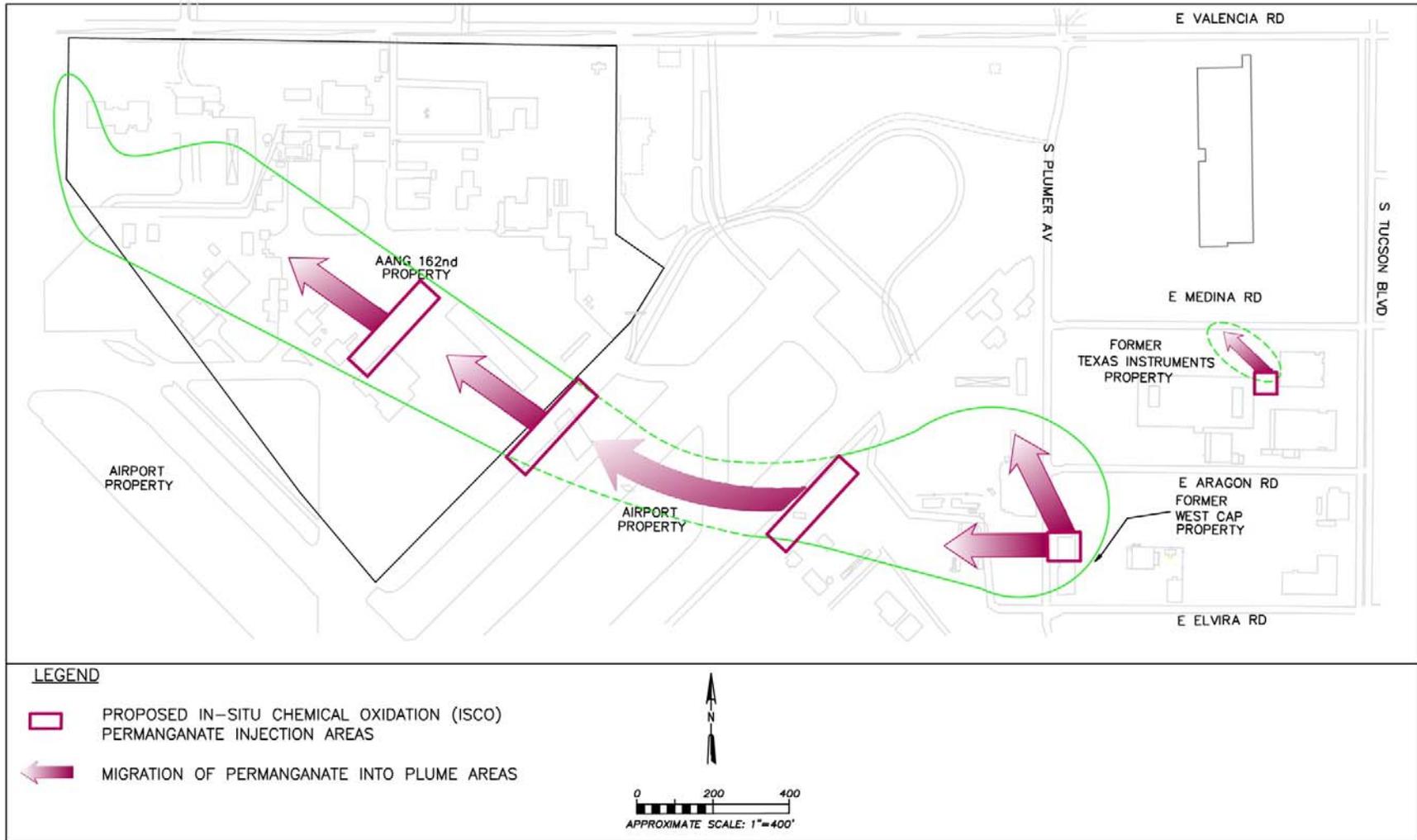
EPA's selected remedy is Alternative 3, permanganate injection at the AANG, West-Cap, and TI Sites and MNA at West Plume B (Figure 6). Based on information currently available, the EPA believes the selected remedy meets the threshold criteria and provides the best balance of tradeoffs among the other alternatives with respect to the balancing and modifying criteria. The EPA expects the selected remedy to satisfy the following statutory requirements of CERCLA §121(b): (1) be protective of human health and the environment; (2) comply with ARARs; (3) be cost-effective; (4) utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable; and (5) satisfy the preference for treatment as a principal element.

Alternative 3 was selected because it is expected to achieve substantial environmental and human health risk reduction and comply with ARARs. The combination of treating the residual VOCs with potassium permanganate at the Site and safe management of remaining off-Site material using cost-effective enhanced attenuation reduces environmental and human health risk sooner than the other alternatives. Alternative 3 also meets the statutory preference for the selection of a remedy that involves treatment as a principal element because ISCO, through the use of potassium permanganate, would treat the residual VOCs present in the source areas.

Based on information currently available, EPA also believes the selected remedy provides the best balance of tradeoffs among the other alternatives with respect to the balancing and modifying criteria. The pilot studies at the Sites have shown that ISCO, through the use of potassium permanganate, is effective in reducing the toxicity of the contaminants of concern in a timely manner in the Sites in Area B of the TIAA Superfund Site.

The selected remedy uses ISCO as a permanent solution and alternative treatment technologies to the maximum extent practicable. Potassium permanganate will be applied to the known source areas of contamination and the residual VOC areas. The residual VOC areas will be identified through additional data collection, including the performance of a rebound test and the installation of additional wells. A rebound test is performed by turning off the existing groundwater extraction treatment system and monitoring the ground water as it returns to natural equilibrium. The rebound test is expected to take place over a period of six months to a year and will assist in identifying strategic VOC residual areas to be considered in Remedial Design to maximize the remediation efforts. The groundwater extraction system will remain as a contingency in the event that higher than expected residual VOC contamination is encountered during the rebound test. In Appendix B there is a list of wells that will be monitored during the rebound test that will be used to trigger the contingency of restarting the GWETRS. If any of the wells listed in Appendix B exceed 10 µg/L or ppb of TCE, then the GWETRS shall operate until the ISCO remedy is operational and functional. After the rebound test on AANG property, the ISCO remedy will be designed to ensure the RAOs are met.

FIGURE 6
Conceptual Design of the Selected Remedy
Tucson International Airport Area Superfund Site—Area B



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EPA believes the selected remedy is more cost effective than all of the other alternatives except the “No Further Action” Alternative, which does not meet the Threshold Criteria and Alternative 5, which includes MNA at AANG. EPA is concerned that MNA at the AANG will result in plume migration, which then will affect the remediation at West Plume B. This alternative may not be effective in the long term and is not cost effective as it is likely to create additional work in the future. EPA believes the balance of slight increase in cost of the selected remedy over Alternative 5 is needed to assure the remedy is protective.

13) Statutory Determinations

This section provides a brief description of how the selected remedy satisfies the CERCLA statutory requirements. Under CERCLA § 121 and the NCP § 300.430(f)(5)(ii), the lead agency must select remedies that are protective of human health and the environment, comply with ARARs (unless a statutory waiver is justified), and are cost-effective. EPA also must use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. In addition, CERCLA includes a preference for remedies that employ treatment that permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants, or contaminants as a principal element, and a bias against off-Site disposal of untreated wastes.

Protection of Human Health and Environment

The exposure of the public to contaminated groundwater through public water supplies or private water wells is the potential risk. The Selected Remedy will be protective of human health by reducing the COCs in groundwater through ISCO treatment and MNA at West Plume B to below drinking water standards. The remedy will not have detrimental cross-media impacts such as air emissions or surface water discharges.

Compliance with Applicable or Relevant and Appropriate Requirements

The NCP § 300.430(f)(5)(ii)(B) and (C) require that a ROD describe the federal and state ARARs that the selected remedy will attain, and that any ARARs the remedy will not meet, the waiver invoked, and the justification for any waivers. All federal and state ARARs will be met upon completion of the Selected Remedy and no ARARs are being waived.

Section 121 (e) of CERCLA, U.S.C. § 9621(e), states that no federal, state, or local permit is required for remedial actions conducted entirely on-Site. Therefore, actions conducted entirely on-Site must meet only the substantive, not the administrative, requirements of the ARARs. Any action conducted off-Site is subject to the full requirements of federal, state, and local regulations.

The most significant ARARs are discussed below.

- Chemical-Specific ARARs

The major statutes and regulations that contribute to the list of potential chemical-specific ARARs are the Clean Water Act (CWA), the Safe Drinking Water Act (SDWA), the Arizona Water Quality Standards (A.A.C Title 18, Chapter 11), and the Arizona Soil Remediation Levels (A.A.C, Title 18, Chapter 7). If an Arizona Water Quality Standard (AWQS) does not

exist for a specific compound, the ADEQ Human Health-Based Guidance Levels for Contaminants in Drinking Water (HBGL) are To Be Considered (TBC) standards. The chemical-specific ARARs that have been evaluated are those that affect groundwater and vadose zone remedial goals.

MCLs are applicable to the quality of drinking water at the tap pursuant to the SDWA and are ARARs for treated groundwater when the end use is for purposes of human consumption. Pursuant to 40 Code of Federal Regulations (CFR) § 300.430(e)(2)(i)(B), MCLs and non-zero maximum contaminant level goals (MCLG) are relevant and appropriate as in situ aquifer standards for groundwater that is or may be used for drinking water. The MCLs are presented in Table 2. The State of Arizona has adopted the federal MCLs by reference as stated in A.A.C§§18-4-108 and 109.

TABLE 6
Chemical-Specific Groundwater ARARs and TBCs for Area B of the Tucson International Airport Superfund Site
(Concentrations in µg/L)
TIAA Superfund Site, Area B Project Area, Tucson, Arizona

Parameter	Applicable or Relevant and Appropriate				To Be Considered
	Primary MCL ^a	MCLG ^b	A&Ww ^c Acute	A&Ww ^c Chronic	HBGL ^d for Water
Organics					
1,1-Dichloroethene	7	7	15,000	950	0.06
cis-1,2-Dichloroethene	70	70	-	-	
Tetrachloroethene (PCE)	5	-	6,500	680	0.7
Trichloroethene (TCE)	5	-	20,000	1,300	3.2

Notes:

The Arizona AWQS for 1,1-dichloroethene, cis-1,2-dichloroethene, PCE and TCE, are identical to the federal MCLs

^a MCL = Maximum Contaminant Level.

^b MCLG = Maximum Contaminant Level Goal

^c A&Ww = Aquatic and Wildlife (warm water fishery).

^d HBGL = Human Health-Based Guidance Levels are only applicable in the absence of an MCL or AWQS (March 1991 Update).

There are four contaminants identified as COCs for this Site. The MCL for the most prevalent contaminant in the shallow groundwater zone, TCE, is 5 micrograms per liter (µg/L). The MCLs for other contaminants of concern in the shallow groundwater zone are set forth in Table 6.

The Arizona Aquifer Water Quality Standards (AWQS) AAC §R18-11-401 et seq., are standards developed to protect groundwater by preventing discharges of pollutants above certain concentrations to aquifers that endanger human health, or that impair the uses of the aquifer. The AWQS applied to aquifers classified as sources of drinking water for the primary contaminants of concern are currently identical to the federal SDWA MCLs. At this Site, all aquifers are identified as drinking water aquifers. As is the case with MCLs, the

AWQs are relevant and appropriate as in situ aquifer cleanup standards for groundwater that may be used for drinking water at the Site.

Groundwater from CERCLA actions may be treated as non-Resource Conservation and Recovery Act (RCRA) waste if the waste contains chemicals in concentrations below health-based levels (i.e., MCLs) selected by EPA Region IX as set forth in Table 6 or exhibits no hazardous characteristics.

- Location-Specific ARARs

The Location-Specific ARARs for the Site are listed in Table 7. Location-specific ARARs differ from Chemical-Specific or Action-Specific ARARs in that they are not closely related to the characteristics of the wastes at the Site or to the specific remedial alternative under consideration. Location-Specific ARARs are concerned with the area in which the Site is located. Actions may be required to preserve or protect aspects of the environment or cultural resources of the area that could be threatened by the existence of the Site or by the remedial actions to be undertaken at the Site.

- Action-Specific ARARs

The Action-Specific ARARs for this Site are listed in Table 8. The RCRA is a federal statute passed in 1976 to meet three goals: the protection of human health and the environment; the reduction of waste and the conservation of energy and natural resources; and the elimination of the generation of hazardous waste as expeditiously as possible. The Hazardous and Solid Waste Amendments of 1984 significantly expanded the scope of RCRA by adding new corrective action requirements, land disposal restrictions, and technical requirements. Substantive RCRA requirements are applicable to response actions at CERCLA Sites if contaminants are characterized as hazardous waste.

Untreated groundwater at the Site containing VOCs is not a listed waste. The groundwater is not a characteristic waste because the contaminants in the groundwater are below the levels established for the characteristic of toxicity. Consequently, the RCRA requirements triggered by the hazardous nature of waste are not applicable and not relevant and appropriate with respect to the groundwater.

Because the untreated groundwater is not a RCRA hazardous waste, the groundwater that has been treated to health-based standard (i.e., MCLs) would not be a RCRA hazardous waste, and the RCRA requirements again would not be triggered.

TABLE 7
 Location-Specific ARARs for VOC-Contaminated Shallow Groundwater
TIAA Superfund Site, Area B Project Area, , Tucson, Arizona

Source	Standard, Requirement, Criteria, or Limitation	Applicable or Relevant and Appropriate	Description of Standard, Requirement, Criteria, or Limitation	Manner in Which ARAR Applies to Alternative
Archaeological Discoveries, Historic Preservation	41 Arizona Revised Statutes ("A.R.S.") §§ 841, 843 – 845, and substantive portions of 865	Applicable	Preserves archaeological artifacts and remains.	If any archaeological artifacts, human remains, or funerary objects are discovered during construction, excavation or other onsite activities, the activity must cease temporarily to allow for investigation and preservation of such artifacts, remains, or objects in accordance with these procedures.
National Historic Preservation Act	16 CFR Part 470	Applicable	Requirements for identification and preservation of historic or cultural resources.	If any archaeological artifacts, human remains, or funerary objects are discovered during construction, excavation or other onsite activities, the activity must cease temporarily to allow for investigation and preservation of such artifacts, remains or objects in accordance with these procedures.

TABLE 8
 Action-Specific ARARs for VOC-Contaminated Shallow Groundwater
TIAA Superfund Site, Area B Project Area, , Tucson, Arizona

Source	Standard, Requirement, Criteria, or Limitation	Applicable or Relevant and Appropriate	Description of Standard, Requirement, Criteria, or Limitation	Manner in Which ARAR Applies to Alternative
Clean Water Act §402, 33 U.S.C. §1342	AZPDES General Permit AZG2008-001 (Discharge requirements for Discharges of Storm Water from with Construction Activities)	Applicable to construction activities affecting more than 1 acre; relevant and appropriate to such activities affecting less than 1 acre	Discharges of stormwater associated with construction activity from soil disturbance of more than five acres is regulated as industrial activity.	The substantive portions of the general permit are action-specific ARARs for activities associated with construction of the groundwater system.
40 CFR Section 262.11; (Arizona Administrative Code) AAC § R18-8-262	40 CFR Section 262.11 and AAC § R18-8-262	Applicable	Regulation of waste from construction & operation of remedial action requires waste generators to determine whether wastes are hazardous wastes and establishes procedures for such determinations.	These requirements are applicable to management of waste materials generated as a result of construction of the selected remedial action or operation of any groundwater treatment units.
40 CFR § 144.12 – 144.16	40 CFR § 144.12 - 144.16	Applicable	Criteria and standards for the Underground Injection Control (UIC) Program. These criteria include current and future use, yield and water quality characteristics and regulate the reinjection of groundwater.	These criteria are applicable for determining exempt aquifers. Injection wells will comply with these design, construction, operation and maintenance requirements.
Safe Drinking Water Act, 42 U.S.C. §300f <i>et seq.</i>	40 CFR 144.24(a), 146	Applicable	Establishes criteria for determining exempt aquifers, including current and future use, yield and water quality.	Applies to design, construction, operation and maintenance of Class V injection wells, if selected to return treated groundwater to the aquifer.

The RCRA program is a delegable program: a state may manage the program in lieu of the EPA if the state statutes and regulations are equivalent to or more stringent than the federal statutes and regulations. In some cases, the applicable or relevant and appropriate RCRA requirement will be cited as state law and in other cases as federal law. The substantive requirements of RCRA's regulations found in 40 CFR Part 264, as incorporated into or modified by AAC R18-8-264, may be relevant and appropriate to the storage and disposal of hazardous wastes generated on-Site, such as waste generated during field operations. This includes requirements for container storage, secondary containment, and leak detection. Any off-Site storage of hazardous wastes would be subject to administrative requirements as well. Any off-Site disposal of hazardous waste must be met, and this includes requirements for notification, disposal methods, and transport.

Federal regulations that govern underground injection programs are found in 40 CFR §144.12 and §144.13. According to these regulations, no injection operation can allow movement of contaminants into underground sources of drinking water, which may result in violations of MCLs or adversely affect health. Injection of oxidants is allowed as part of a CERCLA corrective action as its goal is to restore contaminated water to MCLs.

The substantive requirements of the Arizona Aquifer Protection (APP) Permits (ARS §49-241, et seq. and AAC §R18-9-101 et seq.) will be relevant and appropriate to injection onsite. The APP program requires that any discharges to the aquifer must not cause or contribute to a violation of AWQS.

Arizona's state Superfund program, known as the Water Quality Assurance Revolving Fund (WQARF), provides for cleanup of hazardous substances in groundwater. (ARS § 49-281 et seq.) Section 49-282.06 of WQARF, requires groundwater remedial actions to assure the protection of public health, welfare, and the environment; to manage and cleanup hazardous substances, to the extent practicable, so as to allow for the maximum beneficial uses of the waters of the state; and to be reasonable, necessary, cost effective, and technically feasible. These criteria are very similar to criteria applicable to response actions under CERCLA and the NCP. Those authorities require that remediations be protective of human health and the environment, meet ARARs, and consider advancing numerous other factors, including: long-term permanence; the reduction of toxicity, mobility or volume; implementability; and cost effectiveness. In addition, the NCP requires that groundwater remedial actions generally attain federal MCLs and non-zero MGCLs where relevant and appropriate; the NCP also requires remedial alternatives to take into account the expectation that the remedial action will return groundwater to its beneficial uses wherever practicable within a reasonable timeframe for the site circumstances. The WQARF provisions do not appear to be more stringent than those in the NCP and therefore are not ARARs. Any remedy that EPA selects will meet the WQARF statutory criteria by meeting the NCP requirements.

Cost Effectiveness

A cost-effective remedy is defined as one in which "costs are proportional to its overall effectiveness" (40 C.F.R. § 300.430(f)(1)(ii)(D)). Assessing cost-effectiveness involves comparing costs to overall effectiveness, which is determined by evaluating the following three of the five balancing criteria: 1) longer-term effectiveness and permanence; 2) reduction in toxicity, mobility and volume through treatment; and 3) short-term effectiveness.

The selected remedy is cost effective. Although Alternative 5 met the threshold criteria and was slightly less expensive, the selected remedy suggests higher levels of long term effectiveness and permanence, demonstrated higher levels in reduction of toxicity and mobility through treatment, and is considered as having higher levels of long-term effectiveness than the other Alternatives.

Utilization of Permanent Solutions and Alternative Treatment Technologies

EPA has determined that the selected remedy represents the maximum extent to which permanent solutions and treatment technologies can be used in a practicable manner in Area B of the TIAA Superfund Site. Of those alternatives that are protective of human health and the environment and comply with ARARs, EPA has determined that the selected remedy provides the best balance in terms of the five criteria, while also considering the statutory preference for treatment as a principal element, bias against off-Site treatment and disposal, and considering state and community acceptance. All of the ISCO remediation will take place at the Site. The selected remedy treats the groundwater contaminants in-situ and will result in a permanent cleanup of groundwater. The groundwater will be treated in-situ, thereby avoiding the water chemistry issues and complications that arise when groundwater is extracted and treated. There will be no ancillary environmental concerns that can be associated with the operations or any discharges from a treatment plant.

Preference for Treatment as a Principal Element

EPA has determined that the selected remedy meets the statutory preference for treatment as a principal element. The contamination is not highly toxic when compared to the EPA standard definition of principal threat waste. Furthermore, the selected remedy uses ISCO in known source areas which meets the preference for treatment as a principal element.

Five-Year Review Requirements

The NCP §300.430(f)(4)(ii) requires a five-year review if a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining on-site above levels that allow for unlimited use and unrestricted exposure. Because this remedy will result in contaminants remaining on-Site and the future property use will be limited, EPA will conduct the required statutory five-year reviews to ensure that the remedy is, and will continue to be, protective of human health and the environment. The first Five year Review for Area B of TIAA Superfund Site will occur in the year 2013.

Documentation of Significant Change

The Proposed Plan for amending the TIAA Superfund Site ROD was released for public comment in October 2011. The Proposed Plan identified ISCO at West-Cap, TI, and AANG and MNA at West Plume B as the preferred alternative for groundwater remediation. EPA reviewed all written and verbal comments submitted during the public comment period. It was determined that no significant changes to the remedy, as originally identified in the Proposed Plan, were necessary or appropriate.

PART III: RESPONSIVENESS SUMMARY

This Responsiveness Summary provides EPA's response to written and oral comments received from the public and governmental agencies on EPA's October 2011 Proposed Plan for the TIAA Superfund Site ROD Amendment for Area B.

On October 15, 2011, the Proposed Plan was mailed to the persons and organizations on the TIAA Superfund Site mailing list, including local residents. The Proposed Plan summarized EPA's proposed amended remedy for the Site and invited citizens to attend a November 16, 2011, public meeting in Tucson at which EPA presented the proposed amended remedy and received one oral public comment. In addition to the public meeting, there was a 30-day comment period on the proposed amended remedy from October 26 to November 30, 2011. During the public comment period EPA received one written comment letter from an individual member of the public, one comment letter from the contractors representing the Arizona Air National Guard, and one comment letter from the Arizona Department of Environmental Quality. A transcript of the public meeting and copies of the written comments are included in the Administrative Record for this ROD Amendment.

The comments received during the public comment period show that the public and the State supports efforts to clean up groundwater at the Site.

COMMENTS ON EPA'S PREFERRED ALTERNATIVE

- 1. Comment:** One commenter suggested that although the community may not fully understand the details of the clean up process, there is a cooperative relationship with EPA and the Unified Community Advisory Board (UCAB) and he supports the selection of the Preferred Alternative.

EPA Response: EPA fully appreciates the long standing support of the community and the UCAB for the clean-up activities at the Tucson International Airport Area Superfund Site.

- 2. Comment:** One commenter proposed that a specific innovative low cost air stripper be considered for implementation in the remediation operations.

EPA Response: EPA supports the use of innovative technologies when applicable, but the proposed use of wellhead treatment is not relevant to the Preferred Alternatives identified in the Proposed Plan.

- 3. Comment:** Environmental Resources Management, on behalf of the AANG, provided a letter that provided several editorial comments on the Proposed Plan document.

EPA Response: EPA appreciates the efforts by the contractors of AANG to review and propose edits to the Proposed Plan document. The document was already printed and distributed to the public before these comments were received. The Proposed Plan document went to the printer on October 24, 2011 and the comment letter from the AANG contractor was dated November 3, 2011.

- 4. Comment:** Several of the AANG comments on the Proposed Plan note it is written in a manner to imply that all of the contamination at West Plume B originates from AANG. It was proposed that references should be added that some of the contamination in West Plume B comes from West-Cap.

EPA Response: The 2002 Remedial Investigation Report for West Plume B states that the contamination from West Plume B originates from AANG property. The Proposed Plan as written is consistent with this determination. It has also been generally accepted that there is a commingled plume on AANG Property. The issues of allocation of responsibility do not factor into the selection of the remedy and these comments are not relevant.

5. **Comment:** The AANG commented that there should be some reference to the recent EPA revisions to the toxicity evaluation of TCE.

EPA Response: There has not been any change in the MCL for TCE at this time. The MCL is the ARAR used to develop the clean-up standards. Any future changes to the MCL for TCE and other COCs will be evaluated during future Five-Year Reviews.

6. **Comment:** The AANG commented that there should be discussion of whether injections are planned between project Sites (particularly between AANG and West-Cap properties), as this would account for a large portion of the defined plume and contaminated media.

EPA Response: EPA considered including specific injection locations in the figures and the discussion in the Proposed Plan, but decided it would be premature and misleading to try to identify specific locations for the injection of potassium permanganate. Data collected through the addition of two monitoring wells and the rebound test on the AANG property will be used to determine the most strategic locations for the implementation of the ISCO remedy.

7. **Comment:** The AANG commented that the conditions for shut down of the existing pump and treat system should be identified in the discussion of the Preferred Remedy.

EPA Response: EPA considers discussions for the details regarding the shut-down of the pump and treat system to be too detailed for the purposes of the Proposed Plan. The discussions in the selected remedy in the ROD Amendment do provide more details on the shutdown of the pump and treat system in relation to the rebound test, which will be used to identify strategic locations for ISCO treatment of residual VOC areas at the Site.

8. **Comment:** The Arizona Department of Environmental Quality supports the selection of ISCO at West-Cap, Texas Instruments, and AANG with MNA at West Plume B as the selected remedy.

EPA Response: EPA appreciates the support and high level of cooperation of the Arizona Department of Environmental Quality in the remediation efforts at the TIAA Superfund Site.

9. **Comment:** ADEQ believes there are data gaps that need to be closed before implementation of the selected remedy that include a rebound test on AANG and the installation of additional monitoring wells. ADEQ is currently using EPA grant money to install additional wells to obtain any missing data.

EPA Response: EPA agrees that certain data gaps need to be resolved and supports ADEQ using the EPA grant money to install the monitoring wells.

Appendix A
Monitored Natural Attenuation Technical
Memorandum

Evaluation of Monitored Natural Attenuation within Area B of the Tucson International Airport Area Superfund Site

PREPARED FOR: Martin Zeleznik/USEPA
PREPARED BY: CH2M HILL
DATE: September 14, 2011

1.0 Introduction

This memorandum evaluates whether using Monitored Natural Attenuation (MNA) is a viable alternative for remediation within Area B of the Tucson International Airport Area (TIAA) Superfund Site. Area B includes multiple plumes of trichloroethene (TCE) groundwater contamination; the plumes of contamination are managed as the West Plume B (WPB), Arizona Air National Guard (AANG), West Cap, and Texas Instruments project areas (Figure 1). The focus of this evaluation will be the WPB area because contaminant concentrations are relatively low and no active remediation has been implemented in this area. A more limited qualitative analysis of whether MNA could be a feasible alternative for AANG, West Cap and Texas Instruments project areas will also be discussed in the conclusions.

This MNA assessment was conducted within the framework outlined in the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (the Technical Protocol) (United States Environmental Protection Agency (USEPA), 1998). The basis for this analysis consists of the review of data presented in two previous MNA evaluations conducted in 2000 and 2006, as well as review of additional site data collected since the previous evaluations were conducted. This information was used to identify and quantify attenuation mechanisms taking place in the WPB area according to methods proposed in the Technical Protocol. If review of available data indicates insufficient information is available to quantify specific attenuation mechanisms, data gaps and methods of obtaining the missing information are identified.

This technical memorandum includes:

- 1.0 Introduction, which presents the purpose and organization of the memorandum.
- 2.0 Site Hydrogeology, which presents a brief description of hydrogeological conditions at the site.
- 3.0 Previous MNA Evaluations, which summarizes the findings presented in previous MNA evaluations conducted in 2000 and 2006.

- 4.0 New Site Data, which presents new data collected between 2006 and 2009 and compares the new TCE concentration trends and distribution to those presented in the 2006 MNA evaluation.
- 5.0 Attenuation Mechanisms, which identifies mechanisms responsible for the observed attenuation within WPB, and their relative significance compared to one another.
- 6.0 Quantification of Attenuation Mechanisms, which presents mathematical methods used to estimate the effect each attenuation mechanism has on the overall attenuation of the WPB contamination plume.
- 7.0 Enhanced Attenuation, which presents methods of enhanced attenuation (EA) which can be used in conjunction with MNA to achieve site remedial goals.
- 8.0 Conclusions, which summarizes the findings of this MNA evaluation.
- 9.0 References, which presents the cited references.

2.0 Site Hydrogeology

In the vicinity of the TIAA Site, the regional aquifer system is hydrogeologically complex due to lateral and vertical stratigraphic changes. This technical memorandum focuses on the Upper Unit of the aquifer, where VOC contamination has been observed. A complete description of the hydrogeology of the TIAA site is provided in the *Feasibility Study of Former West-Cap Property and West Plume B with Supplemental West-Cap Remedial Investigation Results* (CH2M HILL 2002).

Within Area B, the Upper Unit occurs between approximately 85 and 145 feet bgs, and contains one or two coarse-grained layers (subunits) in some areas of the Site, or consists 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 are termed Shallow Groundwater Zones (SGZs) when saturated. SGZs occur within the Upper Unit where unconfined saturated silt- and clay-rich sediments exist above or within 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.

The water table occurs about 110 feet below ground surface (bgs). Groundwater in Area B generally flows from southeast to northwest. The West Cap and Texas Instruments project areas appear to have distinct source zones, while the WPB and AANG project areas do not. These source areas are 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.

3.0 Previous MNA Evaluations

Previous MNA evaluations related to TCE groundwater contamination in the WPB project area of the TIAA Superfund Site were conducted by CH2M HILL in 2000 and by the

Arizona Department of Environmental Quality (ADEQ) in 2006. These evaluations are discussed below.

2000 MNA Evaluation

CH2M HILL conducted an evaluation of the potential use of MNA as a remedial treatment for the WPB area in 2000. The evaluation was based on data collected from fourteen monitoring wells in the WPB area (WPB-1 through WPB-14); the locations of these wells are presented in Figure 2. Historical groundwater sampling results from these monitoring wells were reviewed to evaluate temporal and spatial changes in TCE concentrations. MNA screening parameters including total petroleum hydrocarbons (TPH), oxidation-reduction potential (ORP), dissolved oxygen, pH, total organic carbon (TOC), methane, sulfate, and nitrate concentrations were measured to compare observed values in the WPB area to those values known to be conducive to biodegradation of TCE. The results of this evaluation are summarized below; the complete report is presented in *Using Monitored Natural Attenuation as a Potential Remedial Alternative for West Plume B* (CH2M HILL, 2000).

Three mechanisms for the biodegradation of chlorinated aliphatic hydrocarbons were presented, including reductive dechlorination, direct oxidation, and co-metabolism. Based on the chemical and physical properties of chlorinated hydrocarbons, reductive dechlorination was reported as the mechanism most likely to cause the biodegradation of TCE. However, reductive chlorination takes place in anaerobic conditions (e.g., dissolved oxygen concentration less than 1 milligram per liter (mg/L)), and the dissolved oxygen concentrations measured in monitoring wells studied in this evaluation ranged from 1.53 to 9.88 mg/L. Based on the observed dissolved oxygen concentrations, the WPB area was reported “not likely to support reductive chlorination on a widespread basis.”

Despite the reportedly aerobic conditions observed in samples collected during this study, breakdown products of TCE, including primarily cis-1,2-dichloroethene (cis-1,2-DCE) and, to a lesser extent vinyl chloride, were detected in monitoring wells WPB-5, WPB-6, and WPB-8. The detections of these compounds provided evidence that the anaerobic biodegradation of TCE by reductive dechlorination was occurring in some areas. One hypothesis presented to explain a mechanism which could create the conditions necessary for the anaerobic degradation of TCE was the presence of underground storage tanks (USTs) in the WPB area which may have leaked petroleum hydrocarbons to the subsurface, resulting in the consumption of oxygen through the direct oxidation of petroleum hydrocarbons.

TCE concentrations in the WPB area were observed to be decreasing over time and down-gradient of the suspected source. Based on this information, CH2M HILL reported that further evaluation could be carried out to quantify the mobility of the contaminant to more accurately assess how dispersion, dilution, and adsorption affect MNA at the site.

The evaluation concluded that biological degradation was likely not occurring to a great enough extent to degrade all TCE by reductive dechlorination. It was concluded, however, that physical and geochemical processes may reduce TCE concentrations to less than the maximum contaminant levels (MCLs), and that MNA should be retained as a potentially viable remedial alternative for further evaluation in the future Feasibility Study process.

2006 MNA Evaluation

ADEQ conducted an evaluation of the potential use of MNA as a remedial treatment for the WPB area in 2006. The evaluation was based on review of (1) sources of TCE contamination, (2) extent and degree of TCE contamination, (3) mass attenuation of TCE contamination, (4) TCE attenuation mechanisms, and (5) TCE risk management in the West Plume B area. The results of this evaluation are summarized below; the complete report is presented in *Monitored Natural Attenuation (MNA) Technical Memorandum, West Plume B – TIAA CERCLA Site* (ADEQ, 2006).

Sources of TCE contamination were evaluated for Area B of the TIAA Superfund Site, including the WPB, AANG, West Cap, and Texas Instruments project areas. No sources of TCE were identified in the WPB area. Sources of TCE contamination were identified at project areas south of Valencia Road (hydraulically upgradient of WPB); however, ADEQ reported that the AANG operates a groundwater pump, treat, and injection system to contain TCE contamination south of Valencia Road.

TCE distribution plumes were presented for 1999, 2002, 2004, and 2005 for TCE concentration contours of 5, 10, and 20 parts per billion (ppb). Based on the change in distribution of the TCE concentration contours over time, the extent and degree of TCE contamination was reported to be “steadily decreasing due to attenuation.” Concentration trend analysis was also performed for each monitoring well in the WPB project area; this concentration trend analysis showed that TCE concentrations in “nearly all monitor wells have declined steadily between 1999 and 2005.” ADEQ reported that the head of the TCE plume is not advancing and concentrations in the central and tail of the plume are decreasing. ADEQ projected TCE concentrations in the WPB project area should be below the MCL for TCE (5 ppb) in approximately 10 years if capture of sources south of Valencia Road continues through the ongoing operation of the AANG treatment system.

ADEQ reported that the mass of dissolved-phase TCE decreased 42% from 1.6 kg in 1999 to 0.9 kg in 2005. Based on the assumption that the fraction of organic carbon (F_{oc}) in soil at the site is 0.001, the total mass of TCE (including sorbed-phase TCE) was estimated to be 1.2 kg in 2005.

The relative importance of TCE attenuation mechanisms (e.g., advection, dispersion, retardation, biodegradation) was not quantified in the evaluation. ADEQ reported that previous groundwater flow and contaminant transport modeling conducted for WPB, which assumed source control south of Valencia Road, no contaminant retardation or degradation, and transport by advection and dispersion, predicted TCE plume attenuation in 30 to 60 years. Based on the information presented above, ADEQ also reported that attenuation is occurring significantly faster than previously predicted through modeling. Attenuation mechanisms were reportedly a combination of (1) dilution due to diffusion and dispersion, (2) retardation due to sorption and diffusion into dead-end pore spaces, and (3) anaerobic biodegradation. Similar to the 2000 MNA evaluation, the detection of TCE breakdown products was presented as evidence of anaerobic biodegradation as cis-1,2-DCE was detected in monitoring wells WPB-8 and PW-002. WPB-8 was reported to exhibit detectable levels of cis-1,2-DCE in the previous MNA evaluation (CH2M HILL, 2000); however, the detection of TCE breakdown products in monitoring well PW-002 provided

new information not available in 2000 which indicated more widespread anaerobic biodegradation of TCE than previously observed.

ADEQ reported that risk management for the WPB project area includes coordination with the Arizona Department of Water Resources (ADWR) and private well owners on issues such as the installation of new wells, the monitoring of active private wells, reporting analytical groundwater sampling results to well owners, and providing municipal water supply to well owners whose wells have been impacted by contamination associated with WPB. These actions were recommended to continue until all portions of the aquifer in the vicinity of WPB exhibit chlorinated hydrocarbon concentrations below drinking water standards.

Based on the information summarized above, ADEQ recommended that MNA be the selected remedy for the WPB project area. ADEQ recommended continued monitoring of existing wells and the installation of one additional groundwater monitoring well in the southern portion of the site to confirm the plume between AANG and WPB was discontinuous. ADEQ also recommended that the AANG install additional groundwater monitoring wells west of the AANG property to confirm containment and capture of TCE south of Valencia Road. Continued risk management and communication with private well owners was recommended. ADEQ also recommended that if any localized hotspots of TCE contamination persist longer than expected, treatment of these areas with potassium permanganate *in-situ* oxidation may be performed in order to reduce exposure risk and remediation timeframes. Review of the MNA remedy was recommended to occur once every 5 years to verify protectiveness.

4.0 New Site Data

The MNA evaluations described in Section 3 included data from 1998 through 2005. On June 22, 2009, ADEQ provided CH2M HILL with groundwater sampling data for 173 monitoring wells within Area B, including the WPB, AANG, West Cap, and Texas Instruments project areas. The locations of each of the 173 monitoring wells included in the database are presented in Figure 2. The data included groundwater samples collected from February 1997 through March 2009. This database of analytical results was used to evaluate changes in the extent and degree of TCE contamination in the WPB project area which have occurred since the previous MNA evaluation was conducted, and also to review the behavior of TCE concentration trends among WPB monitoring wells over the entire period of record. The results of these evaluations are presented below.

As stated in the Technical Protocol, the definition of monitored natural attenuation includes:

"...a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil and ground water."
(USEPA, 1998)

Pump and treat groundwater remediation systems have been operated at the AANG, West Cap, and Texas Instrument project areas for the majority of the period for which analytical data are available for these sites. This human influence on the reduction of mass, toxicity, mobility, volume, and concentration of contamination at these project areas makes

evaluation of the mechanisms and performance of MNA as a stand-alone remedy at these sites problematic. MNA is best evaluated under more steady-state conditions and over long periods of time. The conditions at AANG, West Cap, and Texas Instruments have been transient due to various active remediation efforts in operation. Therefore, the new site data has been used in this evaluation to assess possible mechanisms responsible for the observed attenuation at the WPB project area only, where no active remediation has taken place. Conclusions regarding the applicability of MNA at WPB will be evaluated to determine if the findings from WPB apply to other project areas within Area B. As stated in the Technical Protocol and the *Technical and Regulatory Guidance, Enhanced Attenuation: Chlorinated Organics* (Interstate Technology Regulatory Counsel (ITRC), 2008), when MNA is not an appropriate stand-alone remedy, successful application of MNA can be performed in conjunction with active remedies such as source control. The application of MNA in conjunction with active remedies is discussed further in Section 7.

Extent and Degree of TCE Contamination at WPB

The extent and degree of TCE contamination at WPB was evaluated graphically with TCE concentration contours of 5, 10, and 20 micrograms per liter ($\mu\text{g}/\text{L}$) for the years 1999, 2004, and 2009 to determine how the spatial distribution and magnitude of TCE concentrations has changed through time (Figures 3 through 5). Comparison of Figures 3 through 5 shows that the magnitude of TCE concentrations in WPB has decreased between 1999 and 2009. The overall findings from TCE concentration contour plots from 1999 through 2009 indicate that the TCE plume is not advancing, the size of the plume is reducing slowly, but more importantly the magnitude of TCE concentrations is decreasing towards the MCL of $5 \mu\text{g}/\text{L}$. These findings are consistent with the TCE plume distributions presented in the 2006 MNA evaluation. The decreasing concentration trends graphically presented in Figures 3 through 5 are evaluated in more depth in the Concentration Trends in WPB Monitoring Wells section below.

Concentration Trends in WPB Monitoring Wells

The TCE concentration trends were evaluated for wells in the WPB project area. Duplicate samples were not considered in the concentration trend evaluation, and in instances of non-detect results, a value of one half the reporting limit was used.

Figures 6 and 7 present TCE concentrations for groundwater samples collected from wells in the southern and central portions of the WPB project area, respectively. All wells in these areas show decreasing or stable concentration trends below the MCL of $5 \mu\text{g}/\text{L}$. The new data for the period between 2006 and 2009 indicate no change from conditions previously reported by ADEQ in 2006. Because all groundwater samples collected from these wells have exhibited TCE concentrations below $5 \mu\text{g}/\text{L}$ since at least February 2003, no further concentration trend analysis was performed for these locations.

Figure 8 presents TCE concentrations for groundwater samples collected from wells in the northern portion of the of WPB project area. Monitoring well WPB-19 exhibited an increasing concentration trend from June 2004 through November 2005 when the maximum concentration of $5.1 \mu\text{g}/\text{L}$ was measured; since November 2005, WPB-19 has shown a decreasing concentration trend with all subsequent samples exhibiting TCE concentrations below the MCL of $5 \mu\text{g}/\text{L}$. All other wells presented in Figure 8 have exhibited stable

concentration trends below the MCL. The new data for the period between 2006 and 2009 did provide additional information on the concentration trend of WPB-19. At the time of the previous MNA evaluation, this monitoring well was exhibiting an increasing concentration trend with the most recent sample result equal to the MCL. Because this monitoring well is located in the northern portion of WPB, the concentration trend could be interpreted as the migration of WPB in the direction of groundwater flow to the northwest. However, seven consecutive samples collected subsequent to the 2006 MNA evaluation indicate that TCE concentrations in WPB-19 are both decreasing and have been below the MCL since at least February 2006. Because groundwater samples collected from these wells have consistently exhibited TCE concentrations below 5 µg/L, no further concentration trend analysis was performed for these locations.

Figure 9 presents TCE concentrations for groundwater samples collected from wells located in the zone of highest TCE concentrations in the WPB project area. Groundwater samples collected from these wells consistently exhibit TCE concentrations above 5 µg/L. Monitoring wells WPB-05, WPB-08 and WPB-11 have exhibited decreasing concentration trends since at least August 2000. Monitoring well PW-002 exhibited an increasing concentration trend from February 1997 to November 2000 after which time this well has exhibited a decreasing concentration trend. The new data for the period between 2006 and 2009 indicate the decreasing concentration trends (for all wells shown in Figure 9) previously reported by ADEQ in 2006 have persisted in the approximately three year period since the 2006 MNA evaluation. Projections regarding the attenuation rates in these wells which consistently exhibit TCE concentrations above the MCL will be discussed in Section 6.

The concentration trends of monitoring wells with fewer than three reported samples were not presented in Figures 6 through 10. This included monitoring well WPB-14 which was sampled once on August 2, 2006 and exhibited a TCE concentration of 4.7 µg/L, and monitoring well PW-021 which was sampled once on February 5, 2004 and exhibited a non-detect TCE result of less than 0.5 µg/L. In addition, monitoring wells MWAFF-01 through MWAFF-03 were each sampled on two occasions (August 2007 and February 2009). Both samples from monitoring well MWAFF-01 contained less than or equal to 1.5 µg/L on both occasions. Samples collected from monitoring well MWAFF-02 contained 6.3 µg/L TCE in August 2007 and 6.7 µg/L in February 2009. Samples collected from monitoring well MWAFF-03 contained 7.6 µg/L TCE in August 2007 and 10 µg/L in February 2009.

The concentration trend analysis discussed above was made based on data collected over a time period when the water table elevation did not change significantly in WPB. Substantial increases in groundwater table elevation, while not anticipated, could lead to changes in concentration trends due to mobilization of contaminants historically located in the vadose zone.

Evidence of TCE Biodegradation

As presented in Section 3, both the 2000 and 2006 MNA evaluations reported detections of cis-1,2-DCE and/or vinyl chloride as evidence that anaerobic biodegradation of TCE was occurring within the WPB project area. Among the new data reviewed for WPB and Area B from 2006 to 2009, continued detections of cis-1,2-DCE continue to support the hypothesis that biodegradation of TCE is occurring despite the generally aerobic groundwater conditions present in the area. Among samples collected from February 2006 through March

2009, the TCE breakdown product cis-1,2-DCE was detected in 3 monitoring wells within the WPB project area (MWAFF-03, PW-002, and WPB-08). The 2000 and 2006 MNA evaluations previously reported the detection of TCE breakdown products in monitoring wells PW-002 and WPB-08; however the detection of cis-1,2-DCE in monitoring well MWAFF-03 provides evidence of a larger spatial distribution of locations where biodegradation of TCE is occurring than was previously reported.

Vinyl chloride was detected on one occasion between 1997 and 2009 in wells WPB-06, WPB-08 and WPB-10. The limited detections of vinyl chloride suggest that once this compound is formed, it is rapidly oxidized in the aerobic aquifer to form carbon dioxide, water and chloride ions.

5.0 Attenuation Mechanisms

As described in Section 1.3 of the Technical Protocol, several lines of evidence can be used to demonstrate attenuation of chlorinated aliphatic hydrocarbons, and include the following:

- Demonstrating clear and meaningful decreasing concentration trends over time at appropriate sampling locations; this trend shall not be the result of contaminant migration.
- Indirectly demonstrate the types of attenuation processes active in a study area, and determine the rate at which such processes will lower contamination levels to the remediation goals.

The distribution and concentration trend evaluations discussed in the first bullet above were provided in the 2006 MNA evaluation for the WPB project area; additional concentration trend information gathered from data collected between 2006 and 2009 was presented in Section 4. Section 5 of this MNA evaluation expands upon information previously reported in the 2000 and 2006 MNA evaluations to demonstrate what mechanisms are responsible for the attenuation observed in the WPB project area. This information will be used in the context of the second bullet above to support any estimates made regarding the rate at which attenuation processes at WPB will lower contamination levels to the remediation goals at the site.

Attenuation mechanisms of chlorinated aliphatic hydrocarbons include destructive and non-destructive processes which result in the decrease in concentration of a contaminant in groundwater. Destructive attenuation mechanisms include biodegradation and abiotic chemical reactions such as hydrolysis. Non-destructive mechanisms include hydrodynamic dispersion, sorption, volatilization, and dilution due to groundwater recharge. Each of these mechanisms is discussed in further detail below to determine what primary mechanisms are responsible for the attenuation observed in the WPB area. Following the initial discussion of each mechanism, methods used in the quantification of attenuation mechanisms are presented.

Hydrodynamic Dispersion

Hydrodynamic dispersion is the combination of molecular diffusion and mechanical dispersion. Molecular diffusion is the movement of molecules from areas of high

concentration to areas of low concentration, and is driven by concentration gradients. Mechanical dispersion is the result of phenomena associated with the advective flow of water through porous media. Variability in pore sizes, variability in the length and direction of groundwater flow paths at the pore scale, and variability of the speed of groundwater flow through a single pore (i.e., flow rate in center of pore versus flow rate at edge of pore) are all contributing factors to the mechanical dispersion which occurs when water flows through porous media. The consequence of hydrodynamic dispersion on a contamination plume is that over time the plume spreads out in space and concentrations within the plume decrease.

While molecular diffusion can be a significant driver for the movement of contaminants from relatively high permeability materials such as sands and gravels into lower permeability materials such as silts and clays, the relative contribution of molecular diffusion to hydrodynamic dispersion compared to the contribution from mechanical dispersion is often insignificant and frequently neglected (Fetter, 1999). One situation where molecular diffusion would play a significant role in hydrodynamic dispersion would be in the case where no groundwater flow is occurring. In such a scenario, no mechanical dispersion would take place and molecular diffusion would be the sole mechanism contributing to hydrodynamic dispersion. However, this is not the case at WPB or in Area B; therefore attenuation due to hydrodynamic dispersion within WPB and Area B is assumed to be dominated by mechanical dispersion rather than molecular diffusion.

The relative importance of mechanical dispersion can be further evaluated by analyzing mechanical dispersion in three dimensions. The effects of longitudinal mechanical dispersion (i.e., the degree of mechanical dispersion which takes place in the direction parallel to groundwater flow) is significantly greater than the effects of transverse mechanical dispersion (i.e., the degree of mechanical dispersion which takes place in directions perpendicular to groundwater flow). Transverse mechanical dispersion results only from the divergence of groundwater flow paths at the pore scale. Longitudinal mechanical dispersion, on the other hand, occurs as a result of additional mechanisms such as variations in pore size and variations in the velocity of groundwater flow through a pore (i.e., flow rate in center of pore versus flow rate at edge of pore) (USEPA, 1998).

Based on the information above, hydrodynamic dispersion is considered to be a significant mechanism in the attenuation observed at WPB. Mechanical dispersion is considered to play a much more important role than molecular diffusion in this process. Furthermore, the effects of longitudinal mechanical dispersion are expected to result in more significant attenuation than those of transverse mechanical dispersion. Methods used to approximate the magnitude of hydrodynamic dispersion are presented in Section 6.

Sorption

Sorption is a reversible process in which dissolved-phase chemicals partition from groundwater and adhere to the surfaces of aquifer matrix particles such as clay particles or organic carbon material. Sorption can play a significant role in attenuation for several reasons. When sorption takes place, the contaminant is no longer in the groundwater dissolved-phase thus temporarily reducing the concentration of the contaminant in groundwater. The ongoing cycle of sorption and desorption also results in the slowing down of the transport of a contaminant through porous media compared to the

groundwater flow rate through the same porous media, a phenomena known as retardation. Various intra-molecular forces and other mechanisms drive sorption; however, hydrophobic bonding is a critical driving force in the sorption of chlorinated compounds (Devinny *et al.*, 1990). The F_{oc} in the aquifer matrix has a significant influence on the amount of sorption that takes place. Previous soil samples collected from the WPB area have been analyzed for F_{oc} , and indicate that sorption is an attenuation mechanism which should be considered in the MNA evaluation for WPB and Area B. These results are discussed further in Section 6.

Volatilization

At the interface between a body of water and air, the concentration of a chemical in the water is proportional to the concentration of that chemical in the air above. This relationship is given by Henry's Law:

$$C_a = HC_w,$$

where,

C_a = The concentration of a given chemical in air

C_w = The concentration of a given chemical in water

H = Henry's Law Constant, specific to each chemical of interest

While volatilization of chlorinated aliphatic hydrocarbons does occur from groundwater contamination plumes, and this volatilization does result in the removal of contaminant mass from the plume, several factors combine to limit the amount of mass that is removed from the dissolved-phase plume and transferred into soil vapor. These factors include (1) the relatively small surface area over which chemical exchange can take place in the subsurface, (2) the limited movement of soil vapor in the subsurface, and (3) the fact that TCE and other chlorinated aliphatic hydrocarbons exhibit low Henry's Law constants due to their physical and chemical properties (USEPA, 1998). The Technical Protocol states that the effect of volatilization on contaminant mass reduction from a contamination plume can be neglected for most compounds. Based on this information, volatilization is not believed to be a primary attenuation mechanism in WPB or in Area B of the TIAA Superfund Site.

Dilution

Dilution of a contamination plume can occur through the recharge of groundwater from precipitation percolating through the vadose zone to the aquifer below, and from recharge by surface water bodies such as lakes or streams. There are no lakes or perennial streams in the vicinity of WPB or any other project area within Area B. The AANG operates a groundwater pump, treat, and injection system south (hydraulically up-gradient) of WPB. While upgradient re-injection of groundwater which is also extracted from an upgradient location does not fit the traditional definition of dilution (i.e., by rainfall or surface water bodies), it is possible that the AANG treatment system could have a net diluting effect on the southern portion of the WPB TCE plume. In addition, Tucson receives approximately 12 inches of precipitation annually. The majority of precipitation in the vicinity of Area B falls on paved asphalt and concrete surfaces as well as building roofs. Stormwater runoff flows to ephemeral washes which flow out of Area B. Unpaved surfaces in Area B contain

vegetation which intercepts some percentage of precipitation and releases it back into the atmosphere through evapotranspiration. While some small amount of contamination plume dilution due to aquifer recharge is expected to occur at WPB and in Area B, the amount of plume dilution due to groundwater recharge is inherently difficult to estimate. Methods used to quantify attenuation mechanisms are largely unable to separate out the effects of plume dilution from more significant mechanisms such as hydrodynamic dispersion; consequently, the net effect of mechanisms such as hydrodynamic dispersion and dilution are typically calculated together. Such methods are presented in Section 6.

Biodegradation

Biodegradation represents a significant mechanism involved in the attenuation of many forms of subsurface contamination. The process of biodegradation involves the consumption (or breakdown) of contaminants such as TCE during metabolic processes of microorganisms present in soil and groundwater. Specific metabolic processes depend on conditions such as the presence or absence of oxygen. As presented in Section 3, the process most likely to lead to the biodegradation of TCE in groundwater is reductive dechlorination, which takes place in anaerobic conditions. While groundwater in WPB and Area B exhibit levels of dissolved oxygen which largely indicate aerobic groundwater, evidence of reductive dechlorination is observed by the detection of TCE breakdown products such as cis-1,2-DCE in groundwater samples collected from these areas. Based on the detection of TCE breakdown products within WPB, biodegradation is considered to be a potentially significant attenuation mechanism for this area.

Abiotic Chemical Reaction

Abiotic destructive chemical reactions are not thought to contribute significantly to the attenuation of TCE in groundwater. The half life of TCE in the vadose and saturated zones has been reported to be approximately 274 years (ADEQ, 1996). As a result, while it is recognized that this attenuation mechanism does account for a small decrease in TCE concentrations within WPB, the magnitude of abiotic chemical reaction compared to others attenuation mechanisms discussed above is small. Therefore, this attenuation mechanism can be neglected and is not included in the attenuation mechanism calculations presented in Section 6.

6.0 Quantification of Attenuation Mechanisms

Several methods were used to quantify the attenuation observed at WPB. These methods included the application of a curve-fitting model to data collected from monitoring wells which exhibit TCE concentrations above the MCL, and the use of mathematical methods for estimating the magnitude of select attenuation mechanisms described previously in Section 5 of this memorandum. The basis for these methods and calculations used in this Technical Memorandum were Appendices B and C of the Technical Protocol which provide guidance on applicable models and techniques which can be used in attenuation-related calculations. These analyses are presented below.

Overall Attenuation Rate

Figure 10 presents the projected attenuation of TCE in monitoring wells which consistently exhibit TCE at concentrations above the MCL. The attenuation projections are based on an exponential decay model of the form:

$$C = C_o e^{-kt},$$

where,

C = TCE concentration at time t

C_o = Initial TCE concentration

e = an irrational numerical constant approximately equal to 2.71828

k = overall attenuation rate

t = time

Based on the projected attenuations for each well shown in Figure 10, TCE concentrations in monitoring wells WPB-11 and WPB-08 are predicted to be less than 5µg/L between 2014 and 2016. The projected attenuation of TCE to concentrations below 5µg/L in monitoring well WPB-05 is predicted to have occurred in the past (in 2008). In fact, the first sample collected from WPB-05 which exhibited a TCE concentration less than 5µg/L was collected in February 2008. Since that time, two samples collected in July 2008 and February 2009 have exhibited TCE concentrations of 5.2 and 5.5µg/L, respectively; however, TCE concentrations in this well are expected to continue to decrease and stabilize at concentrations below 5µg/L in the near future. The projected attenuation of TCE to concentrations below 5µg/L in monitoring well PW-002 is predicted to occur in approximately 2032.

These projected attenuation periods are similar to those forecast by ADEQ in the 2006 MNA evaluation which appear to have been estimated using the same exponential decay function described above. TCE concentrations below 5µg/L were predicted by ADEQ to occur in monitoring well WPB-05 in 2008. Attenuation timeframes for WPB-11 and WPB-08 were predicted by ADEQ to occur several years after the 2014 - 2016 timeframe described above; the reduction in the predicted attenuation timeframe for WPB-11 and WPB-08 can be attributed to the relatively lower concentrations of TCE observed in these wells in samples collected between 2006 and 2009. No attenuation timeframe was proposed by ADEQ in 2006 for PW-002, so no comparison can be made for that well.

The attenuation projections described above are based on the measured TCE concentrations in groundwater samples collected from WPB. Decreases in TCE concentrations in these groundwater samples can be attributed to all applicable attenuation mechanisms described in Section 5. In other words, the curves shown in Figure 10 represent the combined effect of hydrodynamic dispersion, biodegradation, sorption, dilution from groundwater recharge, and all other acting attenuation mechanisms. In some cases, it is very difficult or impossible to accurately separate these mechanisms from one another and quantitatively predict their individual effect on a contamination plume. In other cases, it is possible to isolate the contribution of one mechanism over another. These methods are summarized below.

Biodegradation vs. Other Attenuation Mechanisms

As presented in Appendix C of the Technical Protocol, attenuation due to biodegradation can be separated out from attenuation due to other mechanisms if data for a suitable tracer compound are available. Tracer compounds suitable for this purpose include compounds with measurable concentrations which are resistant to biodegradation. The best tracer compounds will have physical properties such as a Henry's Law constant and a soil sorption coefficient which are the same as the contaminant of interest. In addition, when possible, it is recommended to use multiple tracers to compare results for consistency (USEPA, 1998). The Technical Protocol recommends selection of suitable tracer compounds for this purpose on a site by site basis with choices based on site-specific conditions. A suitable tracer has not been identified for the West Plume B.

Sorption

Several mathematical relationships describing the behavior of organic chemicals with regard to sorption are given in Appendix B of the Technical Protocol. The distribution coefficient, K_d , represents the distribution of an organic compound between the phase sorbed to the aquifer matrix and the phase dissolved in groundwater:

$$K_d = \frac{C_a}{C_l}$$

where,

K_d = Distribution coefficient (milliliters per gram (mL/g))

C_a = Sorbed concentration (mass contaminant in micrograms per mass of soil in grams)

C_l = Dissolved concentration (mass of contaminant in micrograms per volume of solution in milliliters)

The distribution coefficient can also be related to organic content of soil, as:

$$K_{oc} = \frac{K_d}{F_{oc}}$$

where,

K_{oc} = Soil Sorption coefficient

K_d = Distribution coefficient

F_{oc} = Fraction total organic carbon

The soil sorption coefficient (K_{oc}) is chemical specific, and the soil sorption coefficient for TCE is reported in literature between 87 and 150 mL/g (Knox *et al.*, 1993; Jeng *et al.*, 1992; Howard, 1990; USEPA, 1998). The fraction total organic carbon in soil at WPB was previously reported in the 2000 MNA evaluation as 0.0006. Assuming a K_{oc} value of the average of 87 and 150 mL/g (118.5 mL/g), the distribution coefficient can be calculated:

$$K_d = K_{oc} \times F_{oc} = 118.5 \times 0.0006 = 0.0711 \text{ mL/g}$$

Using the original equation for the distribution coefficient from above:

$$K_d = \frac{C_a}{C_l} = \frac{0.0711}{1} = 0.0711$$

This is to say that based on the measured fraction of organic carbon in soil at WPB, and based on the values of K_{oc} reported in literature, out of every 1.0711 micrograms TCE in the WPB groundwater contamination plume, approximately 1 microgram will be dissolved in groundwater and approximately 0.0711 micrograms will be sorbed to the aquifer matrix. In other words, 6.6% of TCE in the WPB groundwater contamination plume is in a non-aqueous phase due to sorption; this results in the lower observed groundwater concentrations than would be present if sorption were not active.

Sorption also affects the speed with which a compound can flow through the aquifer matrix, with sorption resulting in the net reduction in transport velocity, also referred to as retardation. The retarded contaminant transport velocity can be calculated based on the distribution coefficient; this velocity is always lower than the advective velocity of groundwater through the aquifer matrix.

7.0 Enhanced Attenuation

EA is a plume remediation strategy to achieve groundwater remediation goals by providing a “bridge” between MNA and aggressive source zone or dissolved-phase treatment (ITRC, 2008). Treatment of project areas within Area B which exhibit ongoing sources of TCE to groundwater may require a more aggressive remedial treatment, rather than using MNA as a stand-alone remedy. At the same time, aggressive treatment methods such as pump and treat systems may not necessarily be appropriate in some of these areas. EA strategies such as MNA with source zone control are being studied to determine if EA may be the preferred remedial alternative at the other project areas within Area B.

The primary method of enhancing attenuation that has been evaluated at Area B is using in-situ chemical oxidation (ISCO) to control source areas or reduce VOC concentrations in dissolved plume areas. As reported in *In-Situ Chemical Oxidation Pilot Test, Former West-Cap Property, Tucson International Airport Area Superfund Site* (CH2M HILL, 2009), a pilot test was conducted between March 6, 2009 and May 4, 2009 at the West Cap project area using potassium permanganate (KP) injection as a method of source control for TCE contamination at that site. The ISCO process involves the delivery of KP to the zone of contamination where it oxidizes residual TCE, producing inert compounds. Similar ISCO pilot tests using KP injection are being planned, performed, or have been recently performed at other project areas within Area B, including the Texas Instruments and AANG project areas. Ongoing groundwater monitoring results will be used to evaluate the effect of KP injection on TCE concentration in groundwater. If ISCO is demonstrated to be an effective treatment of TCE source zones within Area B, continued ISCO treatment may be selected as an EA method for source zone control to be used in conjunction with MNA to reach remedial goals of Area B of the TIAA Superfund Site.

Enhancement Implementation

As discussed in the technical and regulatory guidance for EA (ITRC, 2008), remediation of a contaminated site is an iterative process whereby the methods of remediation may change over time due to changes in site conditions. In order to evaluate these changes in remedial strategy over time, a decision sequence can be performed to evaluate when MNA is a suitable stand-alone remedy, when EA should be considered, and what conditions would justify the transition from one treatment method to another. This decision sequence is presented in the Expanded MNA/EA Decision Flowchart (Figure 2-1, ITRC, 2008). In this decision sequence, site data are used to evaluate risk, system performance, remediation timeframe, and cost-benefit relationships to determine whether MNA alone is an appropriate remedial alternative. If the answer is no, then enhancements can be evaluated by stating the project goals, identifying technologies available to (1) increase attenuation or (2) reduce loading, and consider options available to meet the project goals. After implementing an enhancement, plume stability is evaluated through time and decision sequences are repeated (i.e., annually) to evaluate changes that justify transition from one remedial strategy to another.

The first step in implementing EA is to provide source area treatment. The current and planned ISCO pilot tests are intended to decrease the VOC loading from the source zone, although ISCO will likely be scaled up to a full-scale remedy before it can be considered a remedial enhancement. Once the enhancements have been implemented, data obtained through routine monitoring can be used to answer questions in the Decision Flowchart, and continue the iterative process. Questions in the Decision Flowchart include:

- Are the risks acceptable?
- Is the plume stable or shrinking?
- Are conditions sustainable?
- Is the remediation time frame acceptable?
- Are the cost-benefits acceptable? (ITRC, 2008)

Evaluation of these questions can help determine whether additional enhancement is required.

8.0 Conclusions

CH2M HILL conducted an evaluation to determine whether MNA is an appropriate remedial alternative for the treatment of TCE groundwater contamination found within Area B of the TIAA Superfund Site. The WPB project area was the primary focus of this evaluation based on the fact that active remediation techniques (such as pump and treat) have not taken place at the WPB project area. This allowed a clear evaluation of the effectiveness of MNA as a stand-alone remedy, and the specific mechanisms responsible for the attenuation observed in this area could also be identified. Conclusions drawn regarding the use of MNA at WPB were then considered in the context of other Area B project areas, including the AANG, Texas Instruments, and West Cap project areas, particularly in conjunction with attenuation enhancements such as ISCO.

Mechanisms identified that play an important role in the attenuation of TCE contamination within the WPB project area include hydrodynamic dispersion, sorption, and biodegradation. Of the mechanisms which contribute to hydrodynamic dispersion, longitudinal mechanical dispersion is the most influential mechanism, with transverse mechanical dispersion and molecular diffusion playing much less significant roles. Additional attenuation mechanisms which are thought to contribute on a very limited basis to the attenuation of WPB include dilution due to groundwater recharge, volatilization, and abiotic chemical reactions.

Based on the cumulative effect each of the attenuation mechanisms listed above have on TCE concentrations in groundwater, projections were made to predict the timeframe needed for MNA to achieve the remediation goal of lowering TCE concentrations below the MCL of 5 µg/L throughout the entire WPB project area. The data indicate that all but one monitoring well in the WPB area are expected to exhibit TCE concentrations below 5 µg/L by 2016, with one monitoring well (PW-002) expected to take until 2032. An alternate well head treatment method may be an alternative for this well if it remains in active use.

The time frames to reach the cleanup appear reasonable with respect to changes in current and foreseeable end use of the groundwater. Although the final remedial goal is to restore the aquifer to drinking water quality there appears to be no current or short-term end use that is limited by implementing an MNA strategy. However, it is always recommended that a regular review of changes in user needs along with the monitoring of remedial progress be established.

Overall, MNA appears to be an appropriate remedial alternative for the WPB project area because:

- The VOC plume in groundwater is shrinking over time, and is not migrating downgradient;
- There is no continuing source of VOCs to the WPB plume;
- Attenuation mechanisms have been identified; and
- The site is expected to meet remediation goals within a reasonable time frame.

Likewise, EA appears to be an appropriate remedial alternative for the lower concentration portion of the plumes in the West Cap, AANG and Texas Instruments project areas provided that certain criteria are met. For example, based on analogy with WPB, MNA is likely feasible for portions of the other TCE plumes that are below approximately 30 µg/L (the initial concentrations observed at WPB), while the higher concentration zones would remain under an active remedy until they reached the necessary threshold. It is recommended that if this strategy is pursued, a more quantitative evaluation be focused on each area to identify potential local conditions that may inhibit attenuation.

9.0 References

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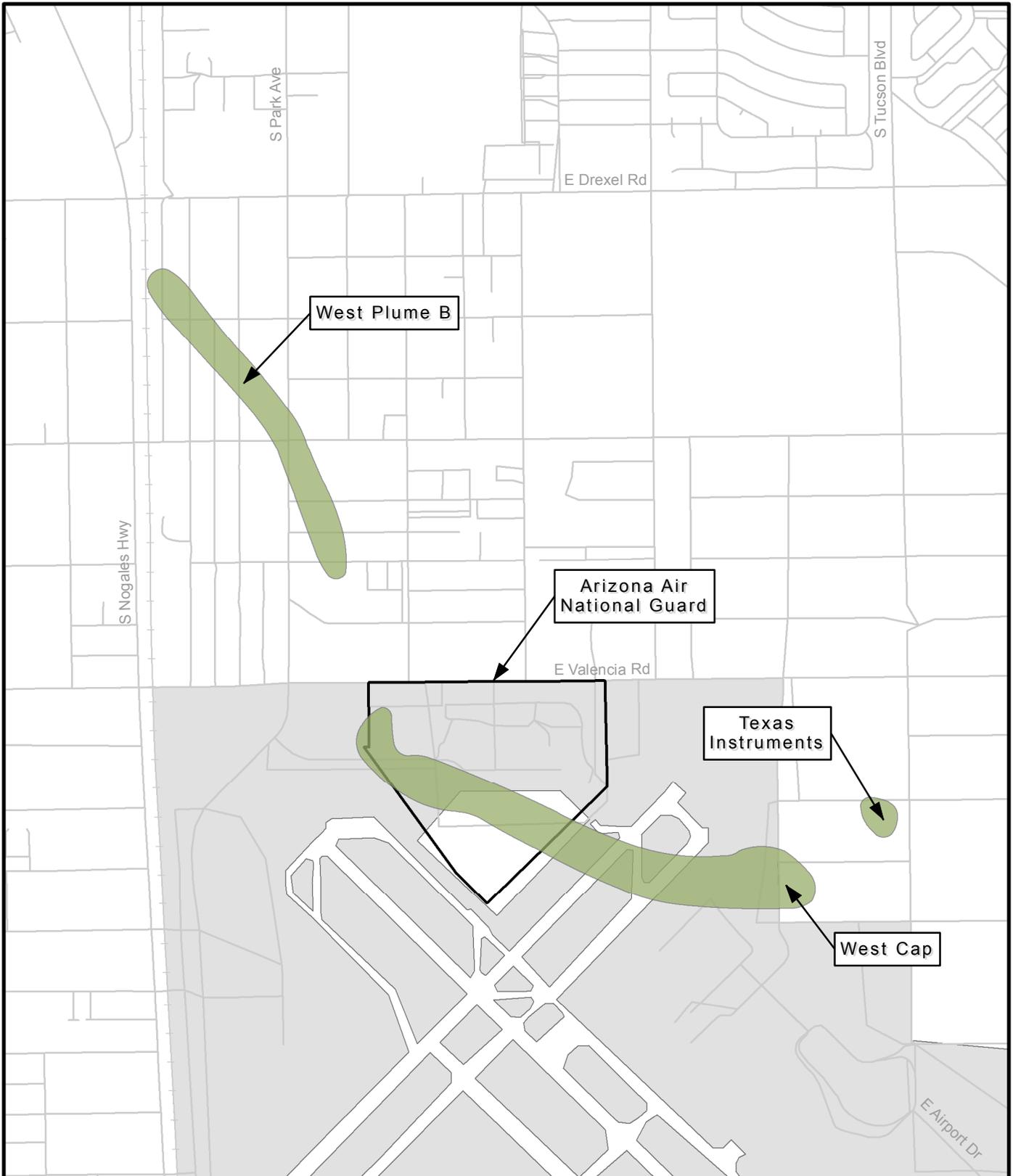
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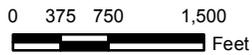
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Figures



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
Site Location Map and
Project Areas

Area B
TIAA Superfund Site
Tucson, Arizona



Legend

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

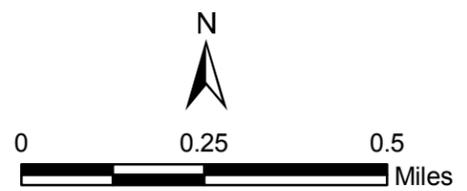
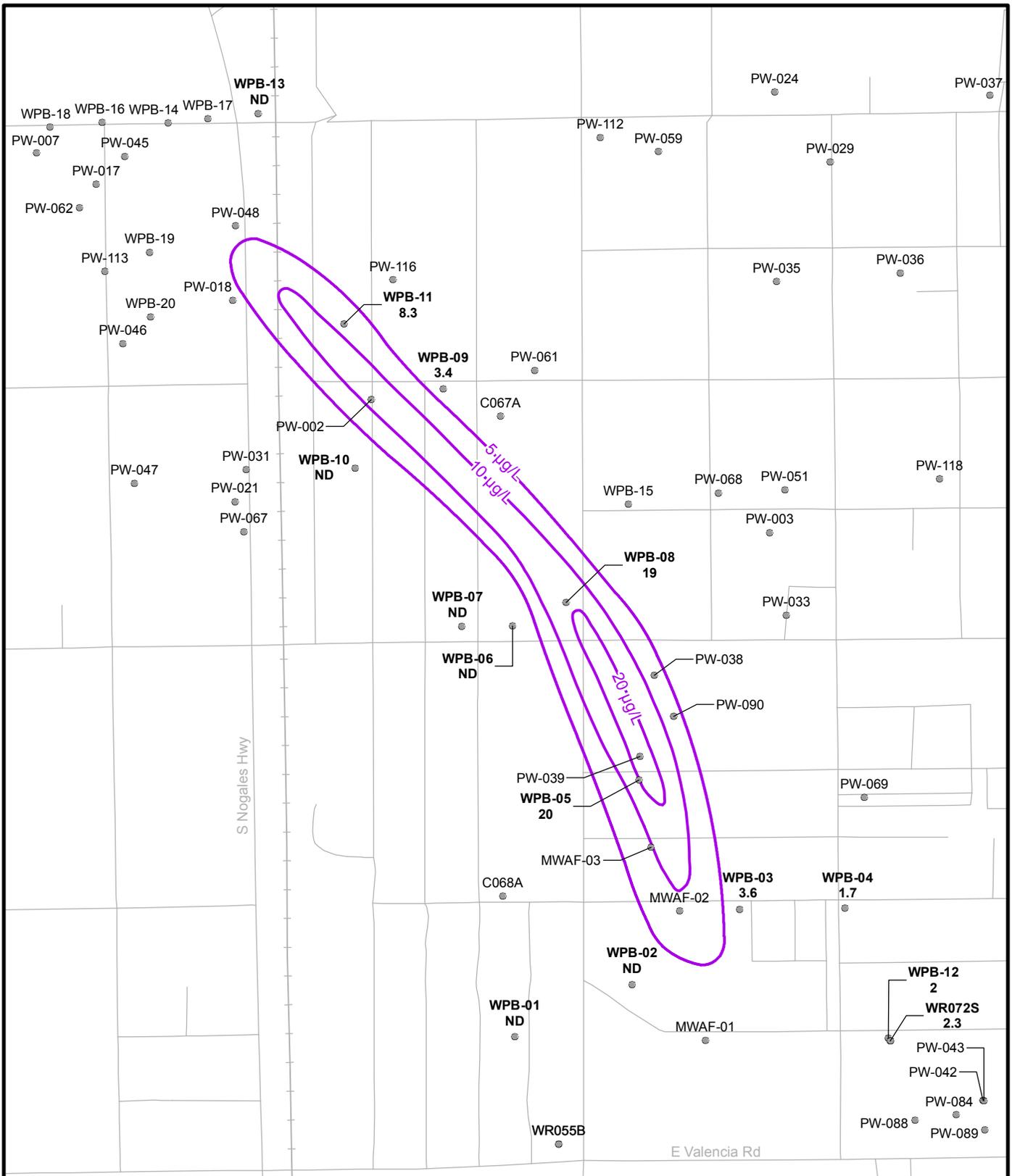


FIGURE 2
Groundwater Monitoring Well Locations
 Area B
 TIAA Superfund Site
 Tucson, Arizona



Legend

- Area B Well
- Road
- +— Union Pacific Railroad
- Trichloroethene Plume
- WPB-03—Monitoring Well ID
- 3.6—Trichloroethene Concentration

Notes: All concentrations in micrograms per liter (µg/L).
 ND = Not Detected

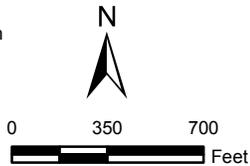


FIGURE 3
West Plume B, August 1999
Trichloroethene Plume

Area B
TIAA Superfund Site
Tucson, Arizona

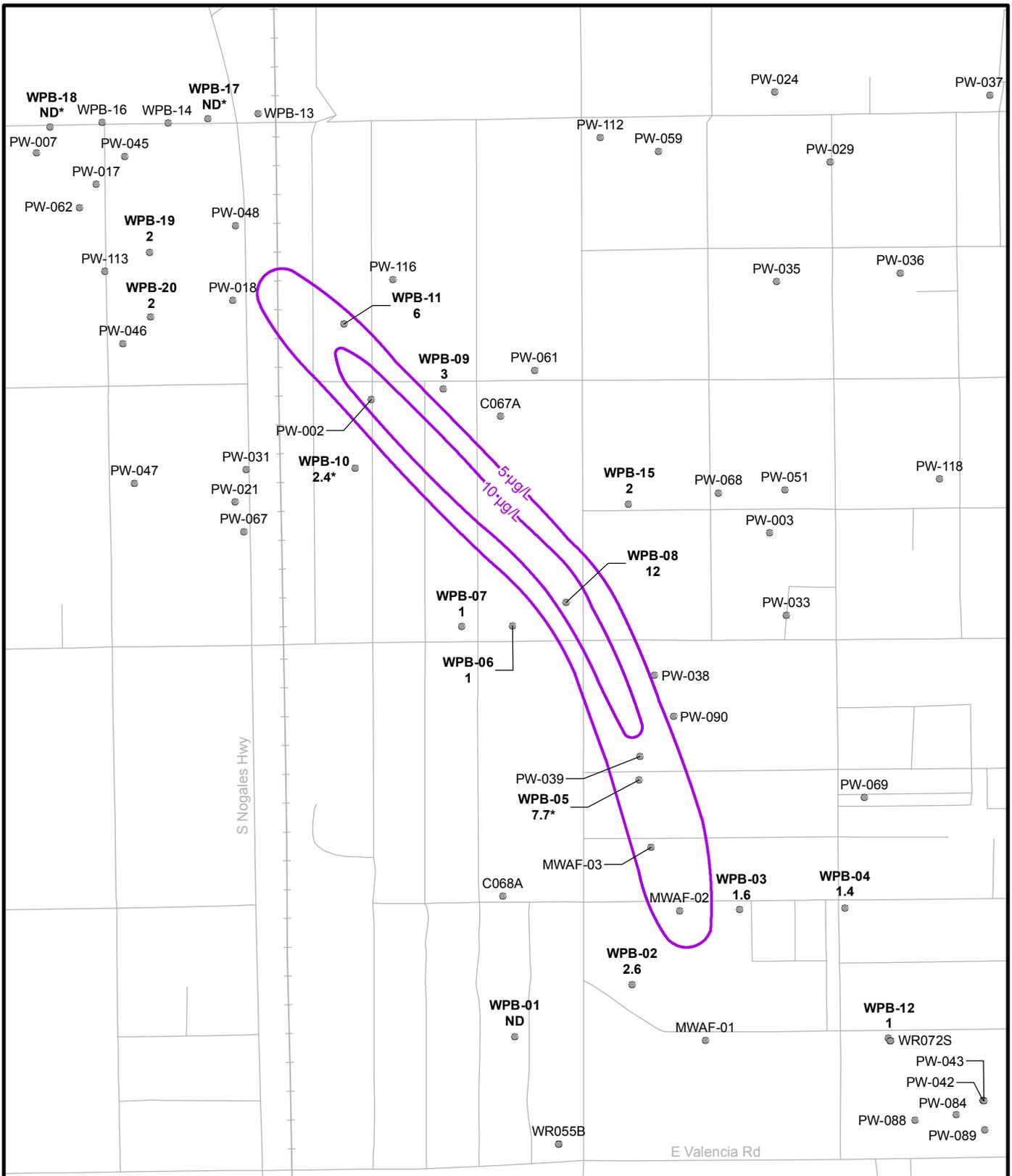
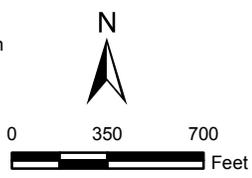


FIGURE 4
West Plume B, August 2004
Trichloroethene Plume

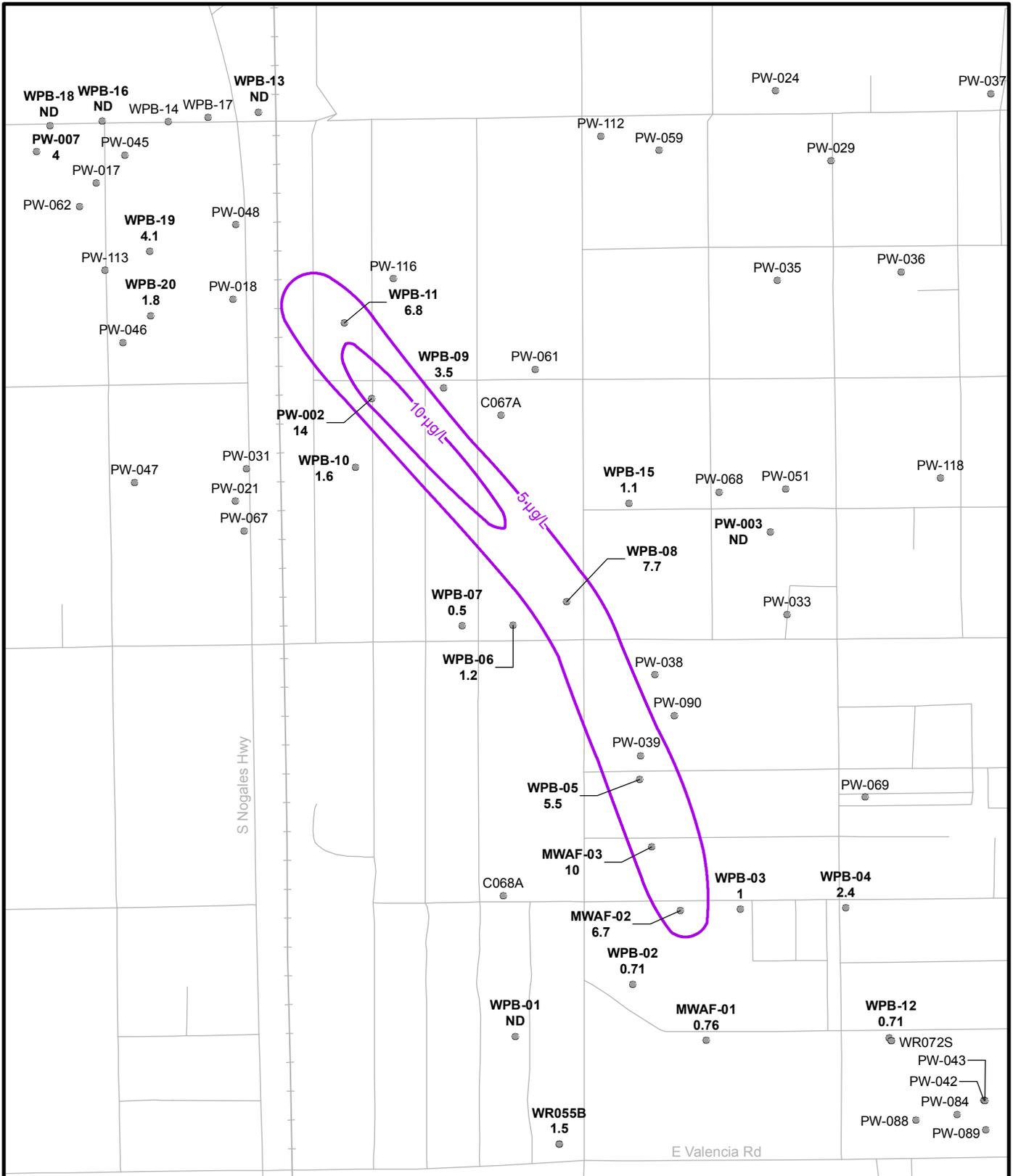
*Area B
 TIAA Superfund Site
 Tucson, Arizona*

Legend

- Area B Well WPB-03—Monitoring Well ID
- Road 1.6—Trichloroethene Concentration
- +— Union Pacific Railroad
- Trichloroethene Plume



Notes: All concentrations in micrograms per liter (µg/L).
 * Results from sample collected in September 2004.
 ND = Not Detected



Legend

- Area B Well
- Road
- +— Union Pacific Railroad
- Trichloroethene Plume
- WPB-03—Monitoring Well ID
- 1 — Trichloroethene Concentration

Notes: All concentrations in micrograms per liter (µg/L).
 ND = Not Detected

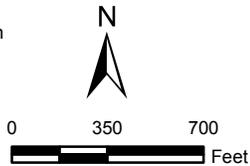


FIGURE 5
West Plume B, February 2009
Trichloroethene Plume

Area B
TIAA Superfund Site
Tucson, Arizona

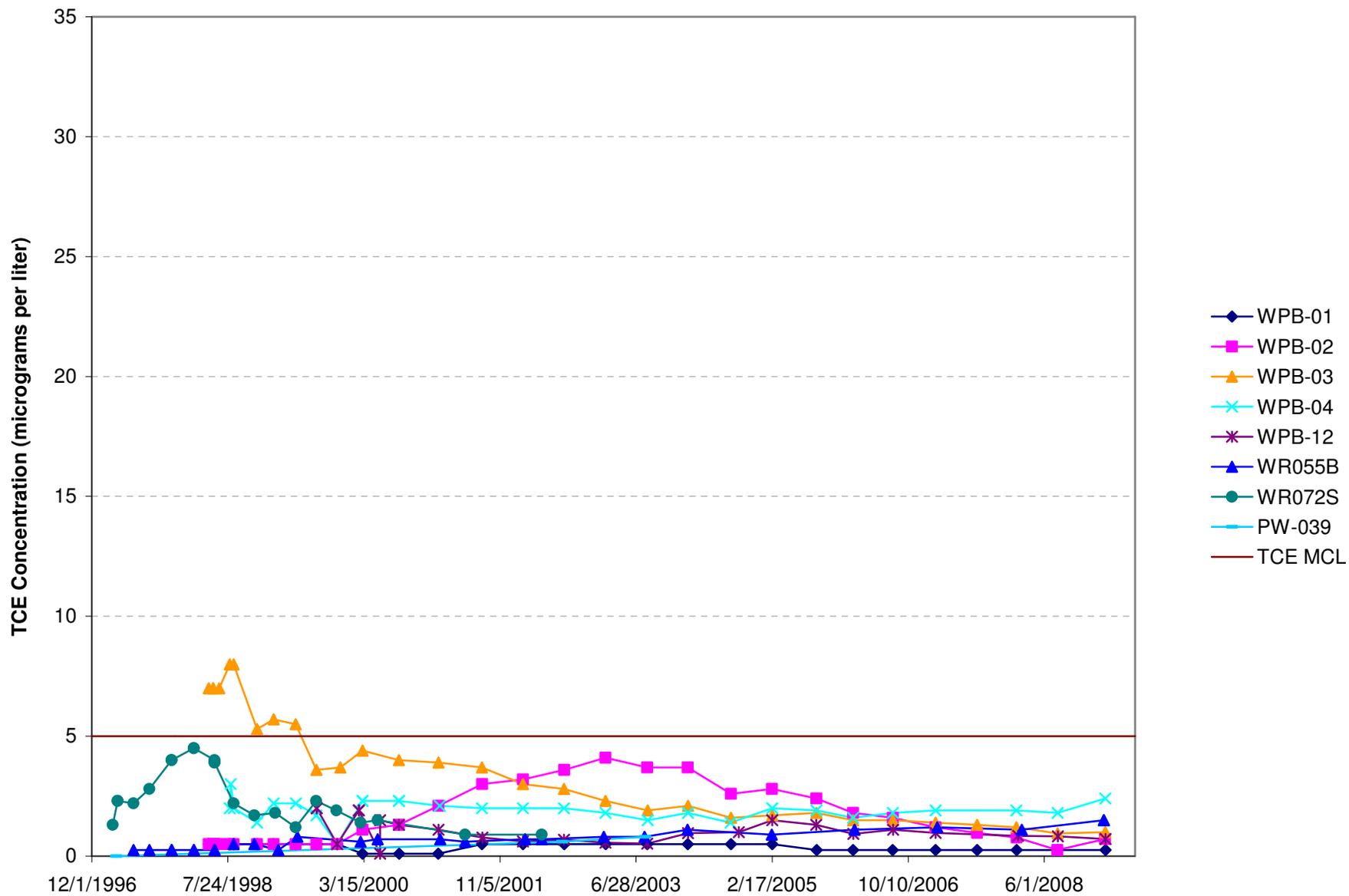


FIGURE 6
TCE CONCENTRATION VS TIME
SOUTHERN PORTION OF WEST PLUME B
West Plume B
TIAA Superfund Site, Tucson, Arizona

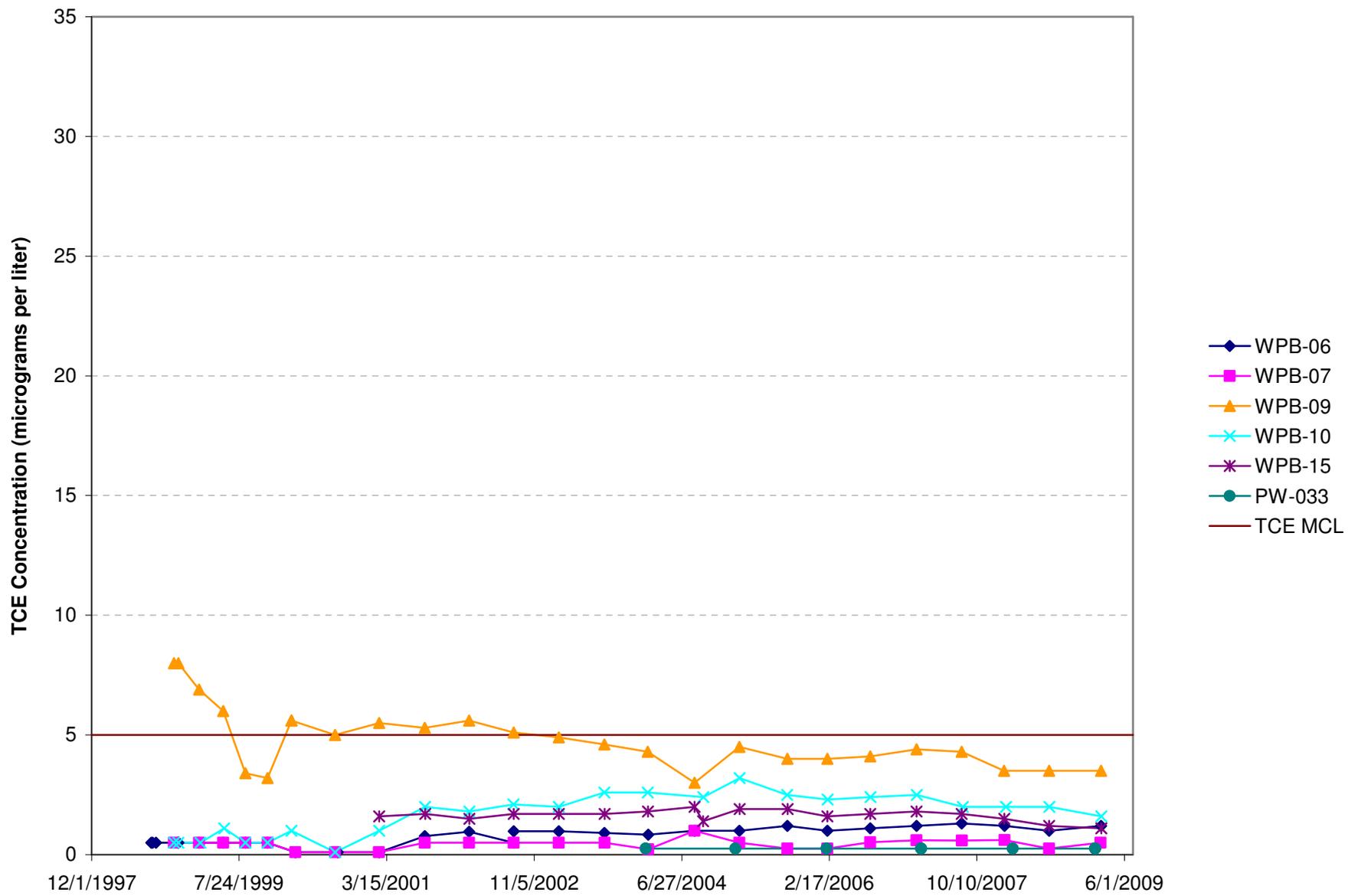


FIGURE 7
TCE CONCENTRATION VS TIME
CENTRAL PORTION OF WEST PLUME B
West Plume B
TIAA Superfund Site, Tucson, Arizona

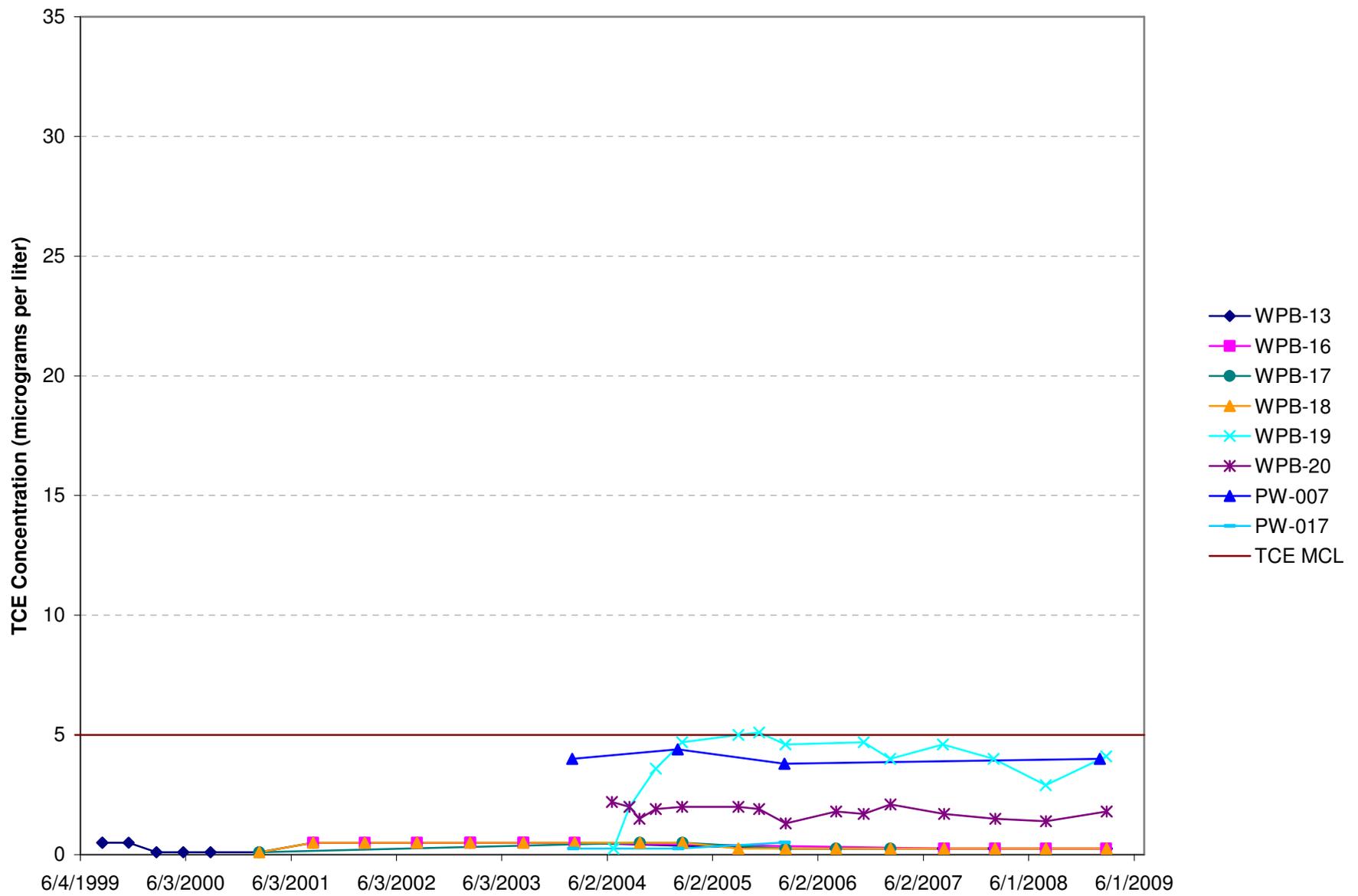


FIGURE 8
TCE CONCENTRATION VS TIME
NORTHERN PORTION OF WEST PLUME B
West Plume B
TIAA Superfund Site, Tucson, Arizona

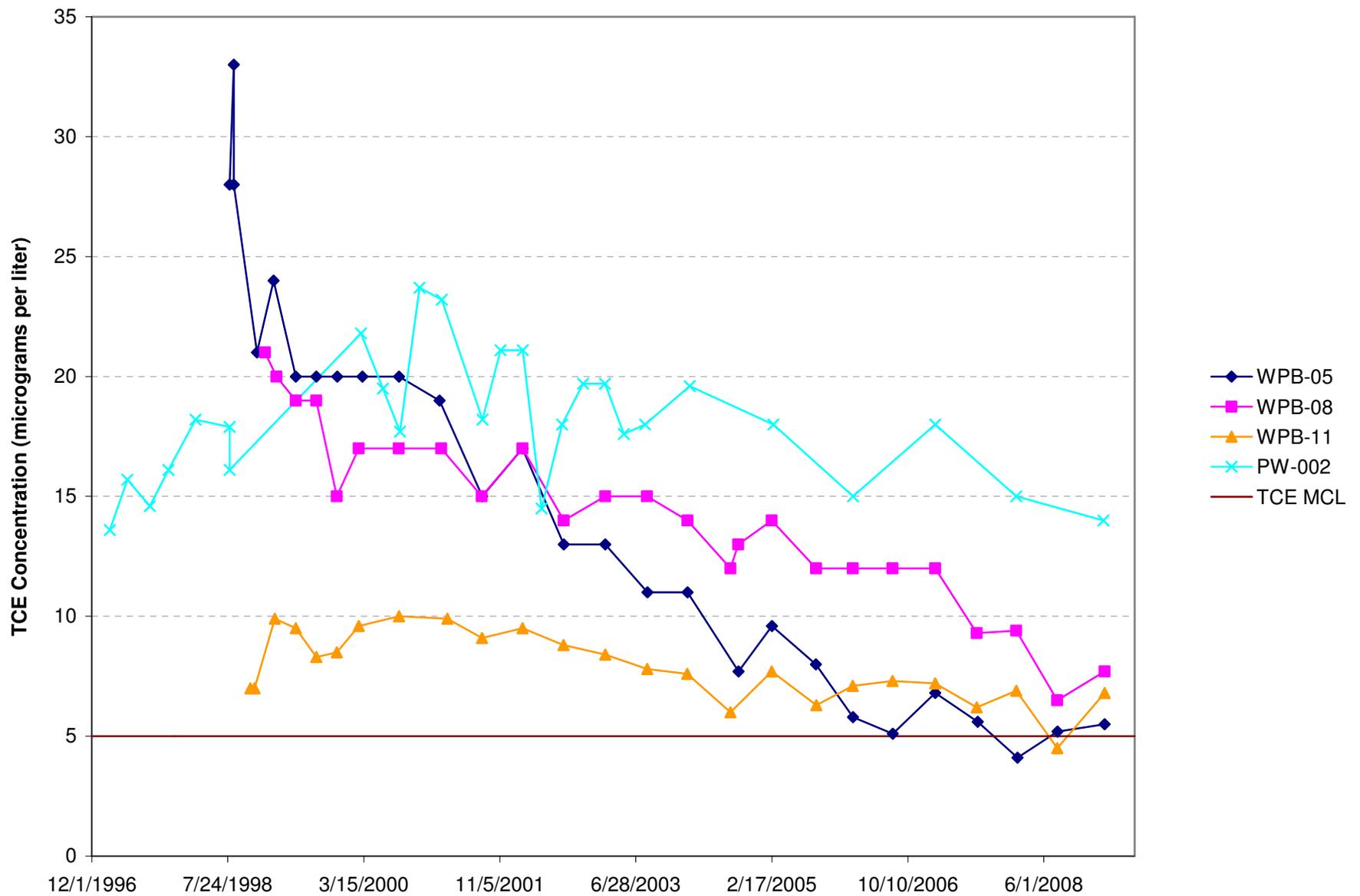


FIGURE 9
TCE CONCENTRATION VS TIME
IN-PLUME PORTION OF WEST PLUME B
West Plume B
TIAA Superfund Site, Tucson, Arizona

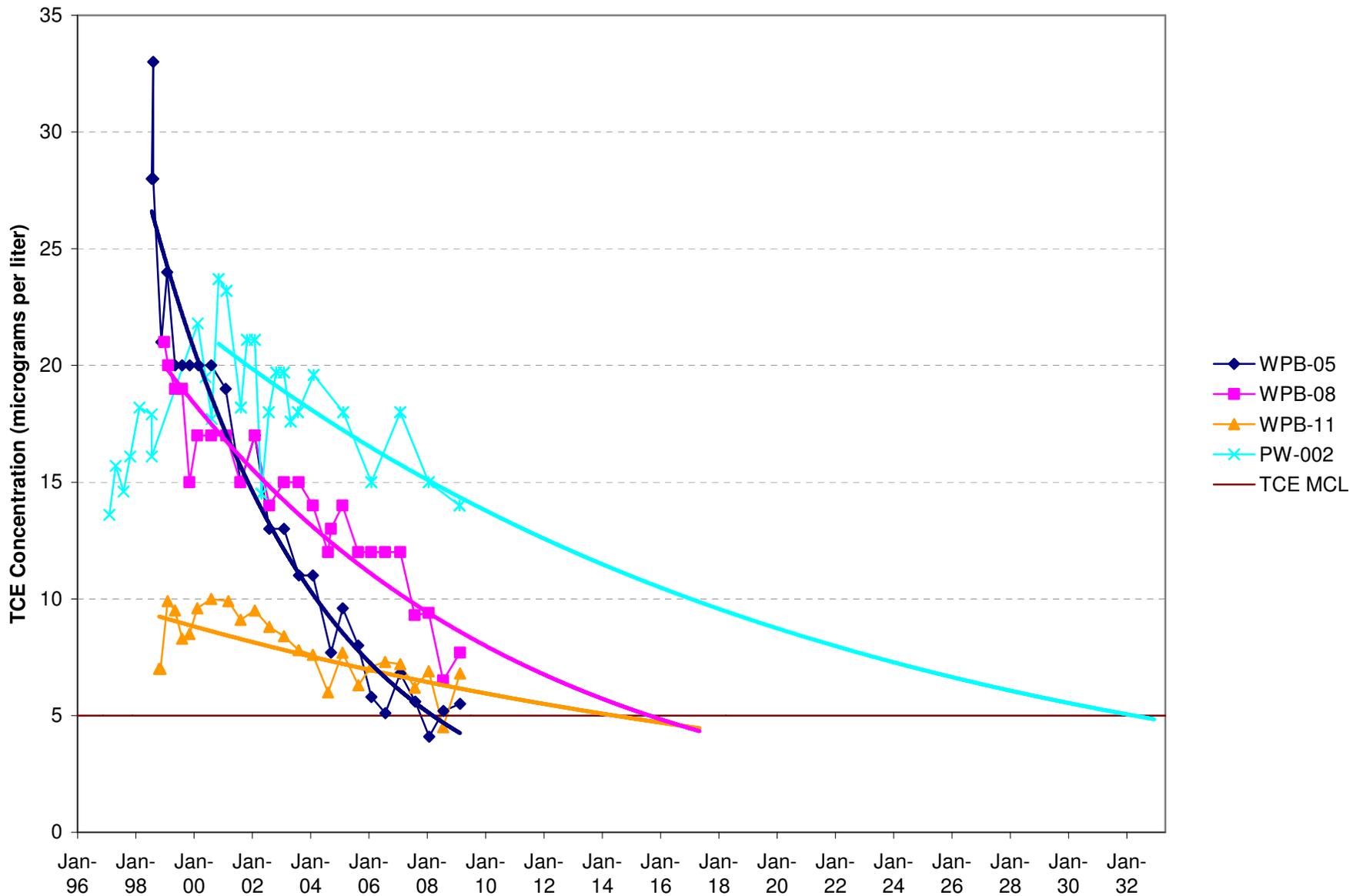


FIGURE 10
TCE ATTENUATION FORECAST
West Plume B
TIAA Superfund Site, Tucson, Arizona

Appendix B
Contingency Plan for Rebound Test on the
162nd Fighter Wing Arizona Air National Guard
Property, Tucson, Arizona

APPENDIX B

**CONTINGENCY PLAN FOR REBOUND TEST ON THE 162ND FIGHTER WING
ARIZONA AIR NATIONAL GUARD PROPERTY, TUCSON, ARIZONA**

A contingency plan is needed for the rebound test in the event that unanticipated increases of concentrations of contamination occur near the northern boundary of the Arizona Air National Guard property. To ensure that high levels of contamination do not migrate off AANG property, if any of the wells listed below shows analytical results greater than **10 micrograms per liter (µg/L) or parts per billion (ppb)** for trichloroethene (TCE), then the AANG will need to restart and operate the GWETRS until the ISCO remedy can be designed and installed.

- LP01
- MW05-L
- MW05-U
- MW100-L
- MW100-U
- MW101-L
- MW101-U
- MW102-L
- MW102-U
- MW104-L
- MW104-U
- WPB-02
- WPB-03
- WPB-04
- WPB-12
- MW-AF01
- MW-AF02
- MW-AF03

Appendix C
Letter of Concurrence from the Arizona
Department of Environmental Quality



Janice K. Brewer
Governor

ARIZONA DEPARTMENT
OF
ENVIRONMENTAL QUALITY

1110 West Washington Street • Phoenix, Arizona 85007
(602) 771-2300 • www.azdeq.gov



Henry R. Darwin
Director

SROSPU12, 039

April 6, 2012

Mr. Martin Zeleznik
Remedial Project Manager
U.S. Environmental Protection Agency, Region 9
Mail Code SFD-6-2
75 Hawthorne Street
San Francisco, California 94105-3901

Re: **Tucson International Airport Area Superfund Site, Tucson, Arizona:** ADEQ
Concurrence on the *Record of Decision Amendment, Tucson International Airport Area
Superfund Site Area B*

Dear Martin:

The Arizona Department of Environmental Quality (ADEQ) has reviewed the Area B Record of Decision (ROD) Amendment, dated March 2012, and hereby concurs with the ROD Amendment. If you have any questions, I can be reached at 520-628-6740.

Sincerely,

Marc E. Herman
Project Manager
Superfund Programs Unit

cc: William Ellett / ADEQ-SRO (reading file)
Craig Kafura / ADEQ-SRO (email)

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