National Aeronautics and
Space Administration
Armstrong Flight Research Center
Edwards Air Force Base, California

Environmental Restoration Program

Second Five-Year Review Report

Operable Unit 6

Final

September 2016

DEPARTMENT OF THE AIR FORCE
AIR FORCE CIVIL ENGINEER CENTER
INSTALLATION SUPPORT TEAM
EDWARDS AIR FORCE BASE, CALIFORNIA

20 September 2016

MEMORANDUM FOR DISTRIBUTION

FROM: AFCEC/CZO-West
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Edwards AFB, CA 93524-8400

SUBJECT: Final Second Five-Year Review Report, National Aeronautics and Space Administration, Armstrong Flight Research Center, Operable Unit 6, Edwards Air Force Base, CA

1. Transmitted herein is the subject document, a Secondary Document under the 1990 Edwards Federal Facility Agreement (FFA). This document is part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedial Action Phase for Operable Unit (OU) 6.

2. The subject document presents the Second Five-Year Review for OU 6 and was prepared in accordance with the Comprehensive Five-Year Review Guidance and the 2016 Five-Year Review Recommended Template.

3. If you have any questions or comments, please call me at (661) 277-1469 or Tom Merendini at (661) 277-1414.

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ENVIRONMENTAL RESTORATION PROGRAM

SECOND FIVE-YEAR REVIEW REPORT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ARMSTRONG FLIGHT RESEARCH CENTER
OPERABLE UNIT 6

EDWARDS AIR FORCE BASE
CALIFORNIA

FINAL

SEPTEMBER 2016

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ARMSTRONG FLIGHT RESEARCH CENTER
SAFETY, HEALTH, AND ENVIRONMENTAL OFFICE
EDWARDS AIR FORCE BASE, CA 93523-0273

and the

UNITED STATES AIR FORCE CIVIL ENGINEER CENTER
ENVIRONMENTAL RESTORATION PROGRAM
INSTALLATION SUPPORT TEAM-WEST (AFCEC/CZOW)
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SECOND FIVE-YEAR REVIEW REPORT FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ARMSTRONG FLIGHT RESEARCH CENTER
OPERABLE UNIT 6
EDWARDS AIR FORCE BASE
CALIFORNIA

September 2016

Prepared by:
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Approved by: Date:

Suzanne W. Bilbrey 13 Sep 16

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Director, Environmental Management Directorate

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LIST OF ABBREVIATIONS AND ACRONYMS

μg/L	micrograms per liter
AECOM	AECOM Technical Services, Inc.
AFB	Air Force Base
AFCEC/CZOW	Air Force Civil Engineer Center/Environmental Restoration Program Installation Support Team - West
AFCEC/CZRW	Air Force Civil Engineer Center/ Restoration Program Management Office - West
AFRC	Armstrong Flight Research Center
ARAR	applicable or relevant and appropriate requirement
BG	background
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
CRWQCB	California Regional Water Quality Control Board
CT	carbon tetrachloride
DCA	dichloroethane
Development One	Development One, Inc.
DTSC	Department of Toxic Substances Control
DWNL	drinking water notification level
e.g.	*exempli gratia*, for example
Earth Tech	Earth Tech, Inc.
ERP	Environmental Restoration Program
FFA	Federal Facility Agreement
FYR	Five-Year Review
FYRR	Five-Year Review Report
GIS	geographic information system
HHRA	human health risk assessment
i.e.	*id est*, that is
IC	institutional control
IDP	Installation Development Plan
ISCO	*in situ* chemical oxidation
Jacobs	Jacobs Engineering, Inc.
LUC	land use control
MCL	Maximum Contaminant Level
mg/L	milligrams per liter
MIBK	4-methyl-2-pentanone
MP	Master Plan
NASA	National Aeronautics and Space Administration
NCP	National Contingency Plan
NDMA	N-nitrosodimethylamine

LIST OF ABBREVIATIONS AND ACRONYMS *(Continued)*

NPL	National Priorities List
OU	Operable Unit
PFC	perfluorinated compound
PME	performance monitoring event
RA	remedial action
RAB	Restoration Advisory Board
RAO	remedial action objective
RAWP	Remedial Action Work Plan
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
RPM	remedial project manager
RPGMR	Remedy Performance and Groundwater Monitoring Report
SEMS	Superfund Enterprise Management System
SI	site investigation
TCE	trichloroethene
U.S.	United States
USAF	United States Air Force
USEPA	United States Environmental Protection Agency
UU/UE	unlimited use and unrestricted exposure
VIP	vapor intrusion pathway
VOC	volatile organic compound

1.0 INTRODUCTION

The purpose of a Five-Year Review (FYR) is to evaluate the implementation and performance of a remedy in order to determine if the remedy is, and will continue to be, protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in five-year review reports such as this one. In addition, FYR reports identify issues found during the review and document recommendations to address them.

The United States (U.S.) Air Force (USAF) prepared this five-year review pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 121, consistent with the National Contingency Plan (NCP)(40 CFR Section 300.430(f)(4)(ii)), and with consideration to U.S. Environmental Protection Agency (USEPA) policy. The triggering action for this statutory review is the USEPA non-concurrence letter issued in response to the previous (First) FYR, dated 30 September 2011. Therefore, the reporting period for this (Second) FYR is October 2011 to September 2016. This FYR has been prepared due to the fact that contaminants remain at the site above levels that allow for unlimited use and unrestricted exposure.

Edwards Air Force Base (AFB) (the site) (Figure 1) consists of ten operable units (OUs) defined by administrative boundaries as shown on Figure 2; however, only OU 6 (consisting of the National Aeronautics and Space Administration [NASA] Armstrong Flight Research Center [AFRC]) is addressed in this FYR. The remaining OUs are addressed under separate Records of Decision (RODs) and separate FYRs. The OU 6 ROD documented a final remedial action (RA) approach to remediate groundwater impacted by various chlorinated and aromatic hydrocarbons, and includes the following components: land use controls (LUCs), *in situ* chemical oxidation (ISCO), bioremediation, groundwater monitoring, and FYRs. Although OU 6 is defined by an administrative boundary (the extent of which is based on the NASA lease boundary), the remedy selected in the OU 6 ROD addresses only the OU 6 groundwater contamination plume originating in OU 6. The plume boundary, as currently known, is shown on Figure 3. Each contaminant source originating outside of the OU 6 administrative boundary will be managed under the OU/Site associated with that source.

The OU 6 FYR effort was led by the USAF, the responsible party and lead agency; support was provided by AECOM Technical Services, Inc. (AECOM). NASA was the funding entity. The USEPA has an oversight role for the cleanup. In addition to the USEPA, the regulatory agencies include the California Department of Toxic Substances Control (DTSC) and the California Regional Water Quality Control Board (CRWQCB). FYR participants included the USAF, USEPA, DTSC, and CRWQCB Remedial Project Managers (RPMs); a USAF community involvement coordinator and a geographic information system (GIS) manager; a NASA AFRC site manager and personnel; and AECOM program, project, and deputy project managers and hydrologist and risk assessors. The FYR began in September 2015, and this report was prepared in accordance with the *Comprehensive Five-Year Review Guidance* (USEPA 2001) and with supplemental guidance documents *Recommended Evaluation of Institutional Controls* (USEPA 2011) and *Assessing Protectiveness at Sites for Vapor Intrusion* (USEPA 2012) and the *Five-Year Review Recommended Template* (USEPA 2016). A completed FYR summary form is provided as Section 1.2.

1.1 BACKGROUND

Edwards AFB is located in the Southern California counties of Kern, Los Angeles, and San Bernardino, approximately 2 miles east of the city of Rosamond (Figure 1). NASA AFRC is a tenant organization at Edwards AFB; the 838-acre leased facility is designated as Environmental Restoration Program (ERP) OU 6, and is located in the north-central portion of the Base on the main flightline, wholly within Kern County.

OU 6 is located on the northwestern edge of Rogers Dry Lake in generally flat, but gently sloping terrain toward the lakebed to the east. Subsurface materials consist of granitic bedrock overlain by a relatively thin layer of unconsolidated alluvial and lakebed deposits. The alluvial layer consists of sandy sediments that appear to have been derived from granitic bedrock outcrops. The bedrock at OU 6 is generally competent, except for surface weathering and localized fracturing.

Due to the near surface occurrence of bedrock, the saturated zone in the main OU 6 area lies almost entirely within fractures in the granitic bedrock. As the alluvial layer thickness increases on the lakebed, groundwater occurs increasingly in unconsolidated material. Groundwater depth ranges from approximately 10 feet below ground surface (bgs) in the western portion of the OU to 26 feet bgs in the eastern portion of the OU, with an estimated shallow groundwater flow direction to the east (toward the lakebed) at velocities ranging from approximately 30 to 240 feet per year (Figure 4).

Site use involving potentially hazardous substances began in 1946, and investigations and studies at OU 6 began in 1988. An overview of the investigation activities conducted up to the First FYR is presented in Table 1. The findings related to the historical studies identified 20 potentially-contaminated areas. Of these 20 areas and as documented in the ROD (USAF 2006), 5 sites within the NASA AFRC boundary (Sites N1, N2, N3, N4 and N7) are considered to be the original source areas of the OU 6 chlorinated and aromatic hydrocarbon commingled groundwater plume (Figure 5). Historical use has been industrial, and it is not anticipated that the site will be used for residential purposes. Historical activities that resulted in contamination at OU 6 involved drum and underground tank storage of fuels and solvents and the use of coating-related materials (paints, thinners, strippers, and plating materials) during aircraft operation and maintenance.

Although OU 6 groundwater has been impacted by chlorinated and aromatic hydrocarbons, a decision of No Action for soil based on human health and ecological risk assessments was documented in the ROD (USAF 2006). Site history, contamination history at each of Sites N1, N2, N3, N4, and N7, National Priorities List (NPL) information, physical characteristics of the site, land and resource use details, and historical contaminant volume estimates are provided in the Feasibility Study and the ROD (Earth Tech, Inc. [Earth Tech] 2004 and USAF 2006, respectively). The latest detailed groundwater monitoring results and data analysis are presented in the *2015 Remedy Performance and Groundwater Monitoring Report* (RPGMR) (AECOM 2016c).

To facilitate the investigation of wastes and implementation of response actions under the ERP, Edwards AFB was divided into 10 OUs defined by lease boundaries (where applicable), geographic location, similarities in contaminant types and distribution, and/or hydrologic setting. The locations of these OUs and their status in the CERCLA process are presented on Figure 2. Of the other OUs not covered in this FYR, Site 25 (within OU 8) warrants consideration as the OU 6 RA progresses. A volatile organic compound (VOC) plume associated with Site 25 is present upgradient (west) of the OU 6 plume (AECOM 2016a) (Figure 6). A feasibility study presenting remedial alternatives to address the Site 25 plume is scheduled for submittal in 2016, with remedy selection documented in the ROD scheduled for submittal in 2019. As additional RODs are signed for Edwards AFB OUs, the Air Force will begin concurrently documenting FYRs, as appropriate.

1.2 FIVE-YEAR REVIEW SUMMARY FORM

A completed FYR summary form is provided below.

Five-Year Review Summary Form

SITE IDENTIFICATION		
Site name: Edwards Air Force Base		
EPA ID: CA1570024504		
Region: 9	**State:** CA	**City/County:** Near Lancaster/Kern

SITE STATUS	
NPL Status: Final	
Multiple OUs? Yes	**Has the site achieved construction completion:** No

REVIEW STATUS
Lead agency: Other Federal Agency, United States Air Force
Author name: Paul Schiff
Author affiliation: United States Air Force Civil Engineer Center Installation Support Team - West
Review period: 9/25/2015 to 8/1/2016*
Date(s) of site inspection: 2/17/2016
Type of review: Statutory
Review number: 2
Triggering action date: 9/30/2011
Due date: 9/30/2016

* Per the *Five-Year Review Recommended Template* (USEPA 2016), The "Review period" is intended to correspond to the start and end dates associated with the preparation of this FYR report.

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2.0 REMEDIAL ACTION SUMMARY

2.1 BASIS FOR TAKING ACTION

Historical chemical usage within OU 6 resulted in a groundwater plume that encompasses multiple source areas. Locations of former releases to the environment within OU 6 have been designated as Sites N1, N2, N3, N4, and N7. The location and nature of these releases contributed to a single commingled VOC groundwater plume that encompasses all of the source areas, and extends from the Site N3 area in the west, and to the east beneath Sites N1, N2, N4, and N7 and Rogers Dry Lake (Figure 5).

Risk assessments (Earth Tech 2003) performed prior to the signing of the ROD indicated that groundwater is the medium of concern and the exposure pathways that need to be prevented and/or minimized are groundwater ingestion, dermal contact, and inhalation of groundwater vapors. Though the inhalation pathway includes direct inhalation of vapors from groundwater and indirect inhalation within buildings through the vapor intrusion pathway (VIP), the selected remedy was designed to be protective of direct inhalation only as the risk assessment indicated no unacceptable VIP risk requiring action. Groundwater at OU 6 is not currently used for drinking water; thus, potential risks associated with the ingestion of contaminants of concern (COCs) in groundwater are reduced by the lack of complete exposure pathways for current land use scenarios (Figure 7). However, concentrations detected in groundwater exceed maximum contaminant levels (MCLs), and exceeding MCLs in groundwater is also considered to represent risk for actual or potential drinking water. The COCs identified in the ROD are listed in Table 2. Although there are no current impacts to humans and the resources that humans use, nor are there impacts to the environment anticipated, an RA was warranted in order to prevent future human exposure to groundwater contaminant concentrations exceeding regulatory thresholds and to restore the groundwater to its designated beneficial use as drinking water.

2.2 INITIAL RESPONSE

Potential release locations were initially identified in 1988 and, following Edwards AFB's listing on the NPL on 30 August 1990, the USAF entered into a Federal Facility Agreement (FFA) with the USEPA, California DTSC, and CRWQCB in October 1990. The FFA established the process for involving federal and state regulatory agencies and the public in the Edwards AFB remedial response process. It provided a procedural framework for developing, implementing, and monitoring response actions at Edwards AFB in accordance with CERCLA, the Superfund Amendments and Reauthorization Act, the NCP, pertinent provisions of the Resource Conservation and Recovery Act (RCRA), and applicable state laws (Earth Tech 2000b). Remedial investigations at OU 6 were performed until 1998, and pilot and treatability studies were performed between 1992 and 2005. The Feasibility Study (Earth Tech 2004) for OU 6 was completed in August 2004 and made available for review. The Proposed Plan (Earth Tech 2005) for OU 6 was presented to the public in April 2005. The RA at OU 6 began in May 2005 (prior to the signing of the ROD [USAF 2006] in September 2006), and included baseline groundwater monitoring followed by ISCO implementation at Sites N3 and N7. Aircraft-related operations have not been interrupted throughout the CERCLA process, and are expected to continue indefinitely.

2.3 REMEDY SELECTION

As the decision document associated with OU 6, the ROD (USAF 2006) provided the remedy selection with the final version that was signed on 28 September 2006. The remedial action objectives (RAOs) as presented in the ROD include:

- Restoration of groundwater to its designated beneficial use as drinking water; and
- Prevention of exposure of human receptors to contaminated groundwater until groundwater contaminant concentrations are below MCLs.

The RAOs will be met through the implementation of four RA components:

- <u>LUCs</u>: Implement, monitor, maintain, enforce, and report LUCs on groundwater in accordance with the *Installation Development Plan* (IDP) (Jacobs Engineering Group Inc. [Jacobs] 2015) and the NASA AFRC Master Plan (MP) (Development One, Inc. [Development One] 2009)
- <u>ISCO</u>: Treatment of high concentration portions of the chlorinated hydrocarbon (primarily trichloroethene [TCE]) plume via ISCO (Sites N3 and N7 areas)
- <u>Bioremediation</u>: Treatment of high concentration portions of the aromatic hydrocarbon plume (primarily benzene) via enhanced natural attenuation (bioremediation) (Site N3 area)
- <u>Groundwater Monitoring</u>: Demonstrate if natural attenuation is occurring in the low concentration areas of the groundwater plume (plume containment) through periodic groundwater monitoring (Sites N1 and N4 areas), and document the reduction in contaminant levels throughout the plume (Sites N1, N2, N3, N4, and N7 areas)

The areas in which the various RA components were targeted for implementation are shown on Figure 5.

COCs and cleanup goals (MCLs) were identified in the ROD (USAF 2006), and include 17 VOCs. These COCs, along with their respective historical concentration ranges present at OU 6 and their respective cleanup goals, are presented in Table 2.

2.3.1 Land Use Controls

The RA includes LUC implementation during the remediation of contaminated groundwater to restrict residential development (including child development centers, kindergarten through 12^{th} grade schools, play areas, and hospitals) where contamination is at levels that do not allow for unlimited use and unrestricted exposure, and to maintain worker safety. Once cleanup levels for groundwater are achieved and indicate that the site is available for unlimited use and unrestricted exposure, LUCs will no longer be maintained, monitored, reported, or enforced. LUCs involving restrictions on residential use were developed to prevent and/or minimize ingestion and dermal contact with groundwater, and direct inhalation of groundwater vapors. LUCs were not specified for the indirect inhalation of groundwater vapors through the VIP into buildings because the risk assessment indicated no unacceptable VIP risk for the current industrial use, and the residential scenario was not evaluated.

The complete narrative of LUCs as specified in the ROD is attached as Appendix A.

Key LUC components are listed below:

- Annotating the residential development restrictions in the Base IDP (Jacobs 2015) and NASA AFRC MP (Development One 2009).
- Prohibiting residential development in designated areas set forth in the IDP and MP.
- Review and approval procedures for any construction and ground-disturbing activities within the OU 6 LUC boundary, including construction and dig permits.
- Notifications to state and federal agencies prior to changes in land use or property transfers.
- LUC monitoring and reporting.

NASA AFRC is a secured facility within a military base. LUCs such as the security gate house and fencing shown on Figure 5 are intrinsic to the NASA AFRC operations.

Until OU 6 is remediated to concentrations appropriate for unlimited use and unrestricted exposure, the Base IDP (Jacobs 2015) will reflect the restrictions on development and land use. Upon completion of RA, the Base IDP will be updated to modify the site-specific use restrictions as appropriate. The Base IDP provides links or references to GIS-based maps and associated databases for all of the sites and groundwater contaminant plumes where LUCs are in effect. These GIS-based maps and associated databases and metadata are the primary management tool for implementing, documenting, and managing LUCs, and are web accessible via Webmap to allow Base personnel to view them. Chemical data from soil and groundwater sampling locations are entered into the GIS as they are submitted by contractors. Boundary layers indicating the extent of restricted areas are generated by the GIS. Specific information contained within the GIS includes:

- A statement that restrictions are required because of the presence of pollutants or contaminants;
- The current land use of the site;
- The geographic control boundaries; and
- The land use restrictions.

The footprints of the areas impacted with COCs are periodically updated in the database from ERP documents. LUC boundaries are based on contamination boundaries, which are updated on a regular basis when new data are available. Restrictions required by the ROD for each layer are either entered into the GIS or referenced by hyperlink to the ROD. Included information describes the required restrictions (such as restrictions on excavation and groundwater use or engineering controls on residential structures), generally allowed uses where applicable, and any specifically required inspections or monitoring (Earth Tech 2007).

2.3.2 *IN SITU* CHEMICAL OXIDATION

The RA includes ISCO of contaminants in the groundwater plume areas with the highest contaminant concentrations. ISCO involves the addition of oxidation reagents directly into the subsurface to destroy organic contaminants; organic contaminants are transformed into constituents such as water and carbon dioxide. A total of 22 existing wells were originally identified for use as injection points for the chemical oxidation reagent (sodium permanganate) at Sites N3 and N7. The injection time intervals, number of events, and RA duration were to be determined based upon field conditions, and the design has been modified as data were compiled.

An example of changing conditions in the field included identification of a high concentration area at Site N4. As previously stated, the RA documented in the ROD includes ISCO treatment in groundwater plume areas with the highest contaminant concentrations. Site N4 was not identified as a high contaminant concentration area in the ROD based on available groundwater data and subsequent design documents defining high contaminant concentration areas as areas with TCE concentrations exceeding 300 micrograms per liter (μg/L). Samples collected from Site N4 groundwater monitoring wells installed post-ROD indicated the presence of TCE exceeding 300 μg/L and therefore ISCO was implemented at Site N4 in 2010.

2.3.3 BIOREMEDIATION

Bioremediation is a process in which microbes break down hydrocarbons to produce carbon dioxide, water, and, in the case of chlorinated contaminants (e.g., TCE, 1,2-dichloroethane [DCA], carbon tetrachloride [CT]), inorganic salts. Because previous studies have shown that sodium permanganate solution used for ISCO is not effective at treating aromatic hydrocarbons (benzene) and some ethanes (1,2-DCA), portions of the plume impacted by these contaminants will be treated by bioremediation following the completion of the ISCO portion of the RA. Limited-scale bioremediation using a food-grade oxygen-release compound will be employed at some Site N3 wells to accelerate the biodegradation of aromatic hydrocarbons.

2.3.4 GROUNDWATER MONITORING

The RA includes groundwater monitoring to track treatment performance in the high-concentration plume areas and to demonstrate the effectiveness of natural attenuation in the low-concentration plume areas. Wells within and outside the plume are monitored to establish that treatment is occurring, and to ensure that plume behavior does not change in unexpected ways that might threaten the regional groundwater subbasin. Following the ISCO and bioremediation portions of the RA, groundwater monitoring will continue to be employed in order to verify plume containment and document achievement of the cleanup standards and compliance with applicable or relevant and appropriate requirements (ARARs).

2.4 STATUS OF IMPLEMENTATION

The RA has been implemented as presented in the *Remedial Action Work Plan* (*RAWP*) (Earth Tech 2008) and *RAWP Addendum* (AECOM 2010). Summaries of the activities are presented in Table 3 and in the following sections.

2.4.1 LAND USE CONTROLS/INSTITUTIONAL CONTROLS SUMMARY TABLE

The USAF and NASA AFRC are responsible for implementing LUCs. NASA AFRC is a secured facility within a military base. LUCs such as the security gate house and fencing shown on Figure 5 are intrinsic to the NASA AFRC operations, and were in place when the ROD was signed. Due to the mobile nature of the ISCO treatment systems, lack of a permanent treatment compound, and potential impact to mission-critical activities such as aircraft movement, permanent treatment-related signage and fencing are not used. RA activities occur within the NASA AFRC secured area (security fencing is maintained and patrolled by NASA AFRC as part of daily mission activities) or the secured area maintained by Edwards AFB flightline management.

Because the Base IDP provides links to GIS-based maps and associated databases, the Base IDP was annotated to include LUCs specified in the ROD by entering information into the GIS. In 2006, land use restrictions required by the ROD were entered into the GIS by referencing pertinent sections of the ROD via hyperlink. Additionally, the GIS was updated with the geographic control boundary established in the ROD. The LUC boundary is based on the contamination boundaries that are updated as new data are available. The current LUC boundary at OU 6 is the OU 6 plume boundary based on 2015 data and is shown on Figures 5 and 8. The Base conducts annual LUC inspections and provides LUC reports (Calendar Years 2011 to 2015) to the USEPA (Region IX), California DTSC, and CRWQCB (United States Air Force Civil Engineer Center, Environmental Restoration Program, Installation Support Team-West [AFCEC/CZOW] 2014, 2015, and 2016) and Appendix A . An institutional control summary table is included below as recommended in the *Five-Year Review Recommended Template* (USEPA 2016).

INSTITUTIONAL CONTROL SUMMARY TABLE

Media, engineered controls, and areas that do not support UU/UE based on current conditions	ICs Needed	ICs Called for in the Decision Documents	Impacted Parcel(s)	IC Objective	Title of IC Instrument Implemented and Date (or planned)
Groundwater	Yes	Yes	Operable Unit 6	Restrict residential development (including child development centers, kindergarten through 12th grade [K-12] schools, play areas, and hospitals) where contamination is at levels that do not allow for UU/UE and to maintain worker safety.	Record of Decision (USAF 2006)

Notes:

IC institutional control
UU/UE unlimited use and unrestricted exposure

2.4.2 REMEDIAL ACTION WELL INSTALLATION

Three groundwater monitoring wells (N3-MW27, N3-MW28, and N3-MW29) were installed to aid in addressing the Risk Assessment key issue identified in the *First Five-Year Review Report* (*First FYRR*) (AECOM 2011c). In August 2012, well N3-MW27 was installed northwest of Building 4806 and in April 2015, well N3-MW29 was installed northeast of Building 4806. These two wells were intended to provide data to delineate the VOC concentrations south of Site N3, provide monitoring points to aid in determining the extent of the plumes relative to Building 4806, and provide data for a VIP investigation at Buildings 4806 and 4807 (AECOM 2016c). In April 2015, groundwater monitoring well N3-MW28 was installed south of Building 4800 to provide a monitoring point to aid in determining the extent of the commingled VOC plumes relative to that building.

Lack of full characterization of the OU 6 commingled plume in the areas of Sites N1 and N4 was identified as an issue in the *First FYRR*, and was described as the Plume Characterization key issue in subsequent documents. In August 2012, well N4-MW14 was installed to further delineate the downgradient portion of the commingled VOC plumes south/southwest of the Site N4 area. In September and October 2013, 18 monitoring wells (6 wells each at 3 well cluster locations) were installed (under a Site 25-related investigation) on the Rogers Dry Lake lakebed to depths ranging from 45 to 450 feet bgs, extending vertically through the alluvial sediments and weathered bedrock, and into competent bedrock (AECOM 2016a). Although not installed as part of the OU 6 RA, the laboratory analytical data from the groundwater samples collected from these 18 monitoring wells were used to identify locations for the installation of eight additional groundwater monitoring wells (Figure 6) at Sites N1 (wells N1-MW12 and N1-MW13) and N4 (wells N4-MW15 through N4-MW20); these wells were installed in April 2015 to address the Plume Characterization key issue. These newly-installed wells were sampled during the reporting period and the results indicate that the plume is not fully characterized and long-term protectiveness undetermined. Results indicate that the plume extends over a thousand feet beyond the 2010 interpreted plume extent reported in the First FYR (Figure 9). Because the laboratory analytical results indicated the presence of TCE in the groundwater samples collected from all of the Site N1 and N4 wells installed in 2015, an additional plume characterization effort (including utilizing direct-push technology to obtain groundwater samples) is planned for calendar year 2017, as discussed in Section 6.1.

RA activities must be coordinated to minimize impact to mission-critical activities. The majority of the commingled plume is inaccessible to ISCO and groundwater monitoring due to its location below aircraft taxiways and ramps. The LUC boundary indicated on Figure 5 coincides with the current commingled OU 6 plume boundary as understood based on the June to July 2015 monitoring results, and presents the extent to which the commingled plume is overlain by mission-critical aircraft taxiways and ramps.

2.4.3 *IN SITU* CHEMICAL OXIDATION

No injection activities were performed during the reporting period. ISCO activities were discontinued in the Site N4 area (downgradient plume area) in order to minimize the introduction of additional variables that may alter site characteristics and complicate or impede plume delineation and fate and transport modeling efforts. Groundwater sampling data collected prior to 2015 indicated the continued presence of permanganate in the Site N3 and N7 treatment areas; therefore, additional injection events were unnecessary. Due to the absence of permanganate in a majority of the injection wells during the 2015 (fifth) performance monitoring event (PME) (based on field observations) and the rebounding VOC concentrations (based on laboratory analytical results), ISCO activities are scheduled to resume in 2017 at Sites N3 and N7. RPGMRs will present any ISCO activities performed during the reporting period for which they are submitted and will assess occurrences of dichloroethene or vinyl chloride as potential intermediate degradation compounds.

2.4.4 BIOREMEDIATION

Aerobic bioremediation will be implemented at OU 6 to enhance the natural attenuation of aromatic hydrocarbons by deploying oxygen release compound filter socks following the completion of all ISCO injection events. ISCO can result in the transformation of organic compounds into daughter products that are more biodegradable than the parent compounds. However, native microbes may be negatively impacted by exposure to chemical reagents with contaminant biotransformation rates limited until aquifer conditions return to pre-ISCO treatment conditions (Earth Tech 2008). For these reasons, bioremediation will be implemented only after no evidence of residual permanganate exists and post-treatment performance groundwater sample analytical results indicate that TCE concentrations are below the cleanup level (5 μg/L). Bioremediation was not implemented during this reporting period and will be implemented following the completion of the ISCO portion of the RA, which is likely after the next FYR period. No impacts to the RA or protectiveness due to delayed bioremediation implementation are anticipated. Once bioremediation activities are implemented, RPGMRs will present any bioremediation activities performed during the reporting period for which they are submitted and will assess enhanced natural attenuation parameters.

2.4.5 GROUNDWATER MONITORING

Groundwater monitoring was performed to establish baseline concentrations, and to allow for the comparison of contaminant concentrations in groundwater to previous results to evaluate ISCO performance in the high-concentration portions of the plume as well as plume stability in the low-concentration portions of the plume. Two monitoring events were performed prior to the signing of the ROD, three monitoring events were performed subsequent to ROD finalization during the previous reporting period (First FYR), and three monitoring events were performed during the current reporting period. The results of these events are presented in the RPGMRs for 2011 to 2012 and 2015 (AECOM 2012 and 2016c, respectively). Future RPGMRs will present any ISCO and bioremediation activities performed during the reporting period for which they are submitted and will assess the performance of these activities.

2.5 OPERATION AND MAINTENANCE

The ISCO approach does not include traditional operation and maintenance tasks. Instead, the RA primarily consists of implementing LUCs and a series of injection and monitoring events using mobile equipment. Well maintenance was performed during the reporting period and included plant root removal from well N4-MW03 as well as well covers replacements and repairs.

3.0 PROGRESS SINCE LAST REVIEW

The *First FYRR* was submitted to FFA partners as a revised draft final in August 2011. Following regulatory FFA partner review of the revised draft final *First FYRR*, the USEPA issued a letter in September 2011 expressing the concern that the available data were insufficient to determine that the current OU 6 remedy is protective. The 2011 letter indicated that the USEPA could not concur with the protectiveness determination as presented in the *First FYRR*, and such a protectiveness determination would be deferred pending additional (2012 to 2013) site investigation. A final version of the *First FYRR* was not prepared; the *Addendum to the First Five-Year Review Report* (*First FYRR Addendum*) (AECOM 2016b and Appendix B) was prepared providing both the results of the additional (2012 to 2013) site investigation, as well as an updated human health risk assessment (HHRA) based on the 2012 to 2013 supplemental data, including consideration of the VIP under the industrial and residential scenario (AECOM 2016e). Demolition of Buildings 4806 and 4807 was delayed, and continued occupation of those buildings warranted performing an additional VIP sampling event during the 2016 winter season (AECOM 2016d and Appendix C) as recommended by RPM comments generated from reviews of the *First FYRR Addendum*. Because the conclusions and protectiveness statements provided in the early versions of the *First FYRR Addendum* required further verification due to the change in site conditions, the *First FYRR Addendum* was finalized as a summary report with a recommendation to perform an additional VIP winter sampling event. RPM review comments on the draft *First FYRR Addendum* and responses to those comments are included in Appendix B. Responses to RPM review comments that apply to the content of this document have been integrated herein as indicated in Appendix D.

3.1 PREVIOUS PROTECTIVENESS STATEMENT

The protectiveness statements outlined in the *First FYRR* were as follows:

> The remedy is expected to be protective of human health and the environment in the long term upon attainment of groundwater cleanup goals, which are expected to require more than 100 years to achieve, through a combination of *in situ* treatment (chemical oxidation and bioremediation) and natural attenuation. Exposure pathways that could result in unacceptable risks in the short term are being controlled through institutional controls that are preventing exposure to, and the ingestion of, contaminated groundwater. All current threats at the site have been addressed by the implementation of LUCs.

Long-term protectiveness of the remedy will be verified by evaluating the future residential indoor air risk and, if applicable, modifying the LUC boundary to restrict residential development in areas with unacceptable indoor air risk. Long-term protectiveness will also be verified by installing and sampling additional groundwater monitoring wells, and modeling subsurface conditions to fully delineate the commingled plume.

The remedy is protective in the short term because unacceptable risks are being controlled through LUCs. Short-term protectiveness of the remedy will be verified by evaluating changes to the VIP protocol and assessing those changes as applicable to OU 6 site conditions. The evaluation may result in collection and analysis of SV samples from beneath building foundations to evaluate vapor intrusion risk for industrial users.

3.2 STATUS OF PREVIOUS FIVE-YEAR REVIEW RECOMMENDATIONS

During the technical assessment performed as part of the previous FYR, issues were identified that warranted consideration to determine if they may impact current or future protectiveness. The current status of the recommendations related to those considerations are presented in the following subsections and summarized in Table 4.

3.2.1 SITE 25 UPGRADIENT GROUNDWATER CONTAMINATION

Groundwater monitoring of the Site 25 VOC plume west of OU 6 was recommended during the previous FYR. Because the Site 25 plume has not clearly commingled with the OU 6 plume (Figure 6), Site 25 groundwater monitoring is managed as a separate project with remedy selection to be made under a separate ROD scheduled for submittal in 2019. Current protectiveness of the OU 6 remedy has not been affected by the Site 25 plume. However, the final remedy selected for Site 25 may affect the OU 6 plume.

3.2.2 PLUME DELINEATION DATA GAP

The installation of additional monitoring wells was recommended during the previous FYR to completely delineate the leading edge of the plume and to monitor and predict cleanup progress. The new wells were installed and TCE was detected above the MCL in the groundwater samples collected from the furthest downgradient wells, located at the leading edge of the plume on Rogers Dry Lake (AECOM 2016c) (Figure 6). The data indicated that the plume extends beyond the monitored area and a data gap still exists and; therefore, long-term protectiveness cannot currently be evaluated. Because exposure pathways that could result in unacceptable risks in the short term are being controlled through institutional controls, current protectiveness has not been affected.

To further address the apparent gaps in groundwater plume data, a series of direct-push boreholes will be advanced, grab groundwater samples will be collected, and additional wells will be installed on Rogers Dry Lake (Figure 10). The RPMs will be consulted prior to the selection of sampling and well installation locations. If the recommended site characterization indicates that the plume is migrating significantly toward the groundwater subbasin and drinking water supply wells, future protectiveness could be threatened.

3.2.3 Vapor Intrusion Pathway Risk Assessment

Because methodologies for determining risk to indoor air from subsurface contaminants was revised since the ROD was signed, an evaluation of the updated VIP guidance methodologies as they related to site conditions was recommended during the previous FYR. An assessment, using current methodologies and including ethylbenzene and naphthalene (Section 3.2.4), of the VIP at three OU 6 buildings and an updated HHRA for the groundwater plume were performed in 2013 and documented in the *First FYRR Addendum* (Appendix B). No unacceptable risks from groundwater contamination to the building occupants were identified. An additional VIP sampling event was conducted in February 2016, is documented in the *Vapor Intrusion Investigation Report Addendum* included as Appendix C, and is further discussed in Section 5.2.

3.2.4 Naphthalene and Ethylbenzene Risk in Groundwater

Because naphthalene and ethylbenzene were re-classified as carcinogens since the signing of the ROD, it was recommended that the residential health risk at OU 6 be re-assessed. An update to the 2003 baseline HHRA (Earth Tech 2003) was performed and included in the *First FYRR Addendum* (Appendix B). The update did not result in recommendations for changes to the RAOs, COCs, or cleanup goals selected in the ROD (USAF 2006) because 1) the re-assessment using current toxicity values, risk assessment methodologies, and chemical concentrations resulted in decreased cancer risk values at a majority of the sites; 2) the increases in non-cancer hazard indices were attributable to TCE (which was already identified as a COC in the ROD); and 3) LUCs prevent residential exposure.

3.2.5 REMEDY OPERATION AND MAINTENANCE

Continued revision of the LUC boundary in the GIS as necessary based on the most recent, vetted, and available sampling results was recommended, as was the continued adherence to review and approval procedures for construction and ground-disturbing activities. These activities continued during the reporting period, and include LUC boundary updates as determined by the estimated areal extents of the benzene, CT, and TCE groundwater plumes.

Continued well maintenance was recommended, including well completion repairs and well labeling with identification tags. Well maintenance activities performed during the reporting period included well cover replacements and repairs, and the removal of plant roots from a well screen.

Continued ISCO in the areas with the highest VOC concentrations at Sites N3, N4, and N7, and groundwater monitoring for n-nitrosodimethylamine (NDMA), metals (including total and hexavalent chromium), and VOCs was recommended. Although groundwater monitoring activities were performed during the reporting period, ISCO-related activities were not performed (as discussed in Section 2.4.3).

The inclusion of a tracer in the reagent during future ISCO injections was recommended to evaluate whether injections into fractures with limited volume causes plume expansion. As documented in the *RAWP Addendum* (AECOM 2013b), a teleconference was held with representatives from the USEPA, USAF, and NASA, and included discussion of the potential for injection of ISCO reagents at Site N3 to cause benzene to migrate under occupied buildings, possibly completing the VIP. *In lieu* of including a tracer in the reagent during future injection events, the USAF and NASA agreed that, should pressurized ISCO injection be employed, only wells greater than 100 feet from occupied buildings will be utilized. Pressures will be monitored within observation wells located between injection points and occupied buildings to monitor for indications of plume displacement/mobilization. The next treatment event will be performed at Sites N3 and N7 in calendar year 2017.

3.2.6 SHUTDOWN OF ENVIRONMENTAL RESTORATION PROGRAM INFORMATION EXCHANGE WEBSITE

The USAF discontinued the ERP information exchange web page (BSX), which was used to obtain and exchange critical information. In 2012, an information exchange was established on Facebook social media to provide reports to stakeholders and announcements at: www.facebook.com/RAB.Edwards.

3.2.7 PLUME BOUNDARIES AND *IN SITU* CHEMICAL OXIDATION IMPLEMENTATION

Although plume boundaries were established at Sites N3 and N7 (based on site boundaries and the extents of benzene and TCE concentrations detected above MCLs in groundwater) to allow for consistent contaminant mass estimates, Site N4 was not included as an area with high VOC concentrations, and implementing ISCO in the area was not originally anticipated. Establishing an artificial plume boundary to support ISCO treatment in the Site N4 area was recommended during the previous FYR to facilitate removal estimates in that treatment area. However, a Site N4 boundary will not be established until plume delineation has been completed.

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4.0 FIVE-YEAR REVIEW PROCESS

4.1 COMMUNITY NOTIFICATION, INVOLVEMENT, AND SITE INTERVIEWS

The Community Involvement Plan (USAF 2014) for Edwards AFB provides a framework for making information fully and readily available to on- and off-Base communities, establishes two-way communication between Edwards AFB and the public, responds to community concerns and needs that may arise during Base cleanup efforts, and fulfills the Department of Defense and Air Force objective of "maximum disclosure with minimum delay." The Restoration Advisory Board (RAB) was established in January 1995 to promote community awareness. OU 6 RA status updates are provided to the RAB on a semiannual basis.

The community was notified of the initiation of the FYR process during the 19 May 2016 RAB meeting, and an update will be provided during the November 2016 RAB meeting. An announcement was published in the May 2016 edition of the "Armstrong X-Press" newsletter, and provided contact information available to address questions and/or comments. A summary of the results is planned to be published in the October 2016 edition. Additionally, notification to the community that the Second FYR for the OU 6 remedy is underway was published in the *Antelope Valley Press* newspaper in June 2016, with a final notice to be provided in October 2016 announcing the availability of the final report. The final version of the *Second FYR Report* (this document) will be placed in the public repositories located at the Edwards AFB Library on the Base; the Kern County Public Library in Rosamond, California; and the Los Angeles County Public Library in Lancaster, California.

During the FYR process, interviews were conducted to document any perceived problems or successes with the remedy that has been implemented to date. The results of these interviews are summarized below.

Interviews were conducted via emails initiated by Ms. Kimberly Coleman (AECOM) between 21 April 2016 and 9 May 2016 and sent to the following individuals:

- Ms. Julie Bond, Code XV, NASA AFRC;
- Ms. Gemma Flores, Architect, NASA AFRC;
- Mr. Daniel Mullen, Energy and Water Conservation Program Manager, NASA AFRC;

- Mr. Bruce Lewis, RPM, California DTSC;
- Ms. Christina Guerra, RPM, CRWQCB Lahontan Region; and
- Mr. Kevin Mayer, RPM, USEPA.

The emails written to the individuals listed above included questions associated with the following areas of interest:

- Access to information and community concerns;
- Changes in site conditions that may impact remedy protectiveness;
- LUC violations; and
- Community concerns regarding protectiveness.

Detailed questions, responses, and additional information are presented on the interview record forms included as Appendix E.

All of the respondents indicated that they had access to the information. They also indicated that they were not aware of any LUC violations or community concerns regarding protectiveness. Interviewed site personnel noted that they were not aware of any changes in site conditions that may impact protectiveness. However, the RPMs identified potential impacts to protectiveness. Ms. Guerra indicated that the contaminant plume has not been fully characterized, and requested that ISCO be resumed concurrent to plume delineation efforts. Mr. Lewis and Mr. Mayer identified the proximity of the Site 25 VOC plume (upgradient of the OU 6 plume) as a potential impact to future OU 6 RA protectiveness and the RPMs have indicated a preference for restarting the Site 25 groundwater extraction and treatment system (see comments and responses provided in Appendix J).

In addition to the standard questions, one respondent, Ms. Flores, was asked for input regarding the Edwards AFB MP (Development One 2009) update frequency, and how the document addresses new construction as it relates to vapor intrusion. Ms. Flores was also questioned regarding how intrusive activities, land use, and potable water well installations are addressed in the plan.

During the interview process, although not presented with the standard questions, Mr. Phil Saxton, a Civil Engineering Project Programmer with the 412th Test Wing, Environmental Management

Directorate, was asked to provide his understanding of the Base's potable well installation review and approval process. The questions and Ms. Flores' and Mr. Saxton's responses are detailed in Appendix E.

4.2 DATA REVIEW

This FYR included a review of relevant documents as presented in Table 5. ARARs, as listed in the ROD, were also reviewed (Appendix F).

This section provides a review of dig permits as they relate to the LUC remedy component. Because the groundwater monitoring component of the RA was implemented in part to evaluate the performance of the ISCO RA component, a review of groundwater monitoring data is also presented.

4.2.1 LAND USE CONTROL DATA REVIEW

The LUC remedy component includes approval procedures for all construction and ground-disturbing activities (including construction and dig permits) within the OU 6 LUC boundary (as defined by the OU 6 plume boundary). The LUC boundary is revised in the GIS as necessary based on the most recent, vetted, and available groundwater sampling results. The LUC boundary was most recently revised to coincide with the 1-μg/L benzene, the 0.5-μg/L CT, and the 5-μg/L TCE isoconcentration contours based on the June to July 2015 monitoring results (Figure 6). Benzene, CT, and TCE concentrations are used because, based on MCL exceedances, these plumes exhibit the largest aerial extent.

4.2.1.1 Calendar Year 2011

Mission-related excavation activities occurred in 2011 as documented in the 2011-2013 annual LUC report (AFCEC/CZOW 2014 and Appendix A). Of the five mission-related excavations conducted in 2011, one task occurred within the LUC boundary (as defined by the 2010 LUC boundary). Various manholes were excavated throughout OU 6 to a depth of 12 feet bgs and groundwater was encountered. Appropriate personal protective equipment was worn. The mission-related excavation activities did not impact the remedy. No remedy-related excavation activities were performed.

4.2.1.2 Calendar Year 2012

Both mission-related and remedy-related excavation activities occurred in 2012 as documented in the 2011-2013 annual LUC report (AFCEC/CZOW 2014 and Appendix A). Of the 25 mission-related excavations conducted in 2012, three occurred within the LUC boundary (as defined by the 2010 LUC boundary), none exceeded a depth of 4 feet, and none encountered groundwater. Remedy-related activities included the installation of wells N3-MW27 and N4-MW14 as discussed in the RPGMR (AECOM 2012).

4.2.1.3 Calendar Year 2013

Mission-related excavation activities occurred in 2013 as documented in the *Annual LUC Reports – 2011 - 2013* (AFCEC/CZOW 2014 and Appendix A). Of the 31 mission-related excavations conducted in 2013, eight occurred within the LUC boundary (as defined by the 2012 LUC boundary), none exceeded a depth of 12 feet, and none encountered groundwater. No remedy-related excavation activities were performed.

4.2.1.4 Calendar Year 2014

Mission-related excavation activities occurred in 2014 as documented in the *Annual LUC Report - 2014* (AFCEC/CZOW 2015 and Appendix A). Of the 15 mission-related excavations conducted in 2014, four occurred within the LUC boundary (as defined by the 2012 LUC boundary), none exceeded a depth of 12 feet, and none encountered groundwater. No remedy-related excavation activities were performed.

4.2.1.5 Calendar Year 2015

Both mission-related and remedy-related excavation activities occurred in 2015 as documented in the *Annual LUC Report - 2015* (AFCEC/CZOW 2016 and Appendix A). Of the 21 mission-related excavations conducted in 2015, four occurred within the LUC boundary (as defined by the 2012 LUC boundary), none exceeded a depth of 8 feet, and none encountered groundwater. Remedy-related activities in 2015 included the installation of wells N1-MW12, N1-MW13, N3-MW28, N3-MW29, and N4-MW15 through N4-MW20, as discussed in the 2015 RPGMR (AECOM 2016c). Excavation activities performed since the completion of the March 2013 VIP investigation at Buildings 4806 and

4807 did not result in new preferential pathways, impact the VIP, or otherwise invalidate the VIP investigation results or conclusions.

4.2.2 REVIEW OF 2015 CONTAMINANT OF CONCERN MONITORING RESULTS

The most recent monitoring results (June to July 2015) within the reporting period indicate that, of the 17 VOCs identified in the ROD as COCs for OU 6 (Table 2), 13 were detected in the groundwater samples collected. Of the COCs detected, 12 were detected at concentrations exceeding their respective cleanup goals (MCLs). A comparison of the maximum organic analyte concentrations detected in groundwater during the June to July 2015 monitoring event to cleanup goals is presented in the 2015 RPGMR (AECOM 2016c). Concentration trends for TCE, benzene, CT (the primary COCs used to track plume configuration variations), NDMA, and inorganic analytes are discussed in the following subsections. Trend graphs for noteworthy wells and analytes are presented in Appendix G.

4.2.2.1 TCE Analytical Results

Site N1

Well N1-MW08 is located at the northeast leading edge of the plume. TCE was detected at only trace concentrations in the samples collected between 2000 and 2006. TCE concentrations in the samples collected from this well between 2007 and 2015 have ranged from 1.2 to 1.9 μg/L, with the exception of the TCE concentration detected in the sample collected in 2011, which was 10 μg/L. The TCE concentration of 1.2 μg/L detected in the 2015 sample is consistent with historical concentration ranges, and indicates that the 2011 result may be an anomaly. The 2.2-μg/L TCE concentration detected in the sample collected in 2015 from well N1-MW12 (located within 60 feet of well N1-MW08) is consistent with historical concentration ranges detected in the samples collected from well N1-MW08.

Site N3

The 2015 plume delineation shown on Figures 6 and 10 represent the data collected during the subject document's reporting period for the fifth PME. The most significant change in plume delineation from the ROD (2003 data) to the 2015 PME is in the Site N1 and Site N4 areas (Figure 9). The plume boundaries were extended in these areas after submittal of the ROD based on groundwater analytical data obtained from the wells installed in 2004, 2009, 2010, and 2015.

The highest TCE concentration identified during the 2015 PME was 83,000 μg/L, which was detected in the sample collected from well N3-MW22. This well was installed in 2008 and the 2015 concentration is equal to the highest historical TCE concentration detected at OU 6, which is an increase from below the reporting limit in 2010, 25,000 μg/L detected in 2011, and 66,000 μg/L detected in 2012. The development log for the N3-MW22 well installation noted the presence of permanganate (purple water), indicating that the well had been installed within the treatment zone of an earlier (March 2008) ISCO injection event. TCE was not detected above the reporting limit in the groundwater samples collected from well N3-MW22 in 2008 and 2010, which occurred after the March 2008 ISCO injection event and prior to the August 2010 ISCO injection event. The lack of permanganate observed in the well following the 2010 ISCO event indicate that the 2010 ISCO event treatment area did not extend to well N3-MW22 in 2010.

Wells N3-MW07, N3-MW15, and N3-MW21 are within 20 feet of well N3-MW22 (Figure 11), and were used as injection points during both the 2008 and 2010 ISCO events. Wells N3-MW07 and N3-MW15 received similar reagent volumes of 4-percent sodium permanganate solution during the two ISCO events; however, well N3-MW21 accepted more than twice the reagent volume during the 2008 ISCO event compared to the 2010 ISCO event. It appears that the larger reagent volume injected during the 2008 ISCO event increased the well N3-MW21 treatment area to include well N3-MW22. TCE concentration rebounding was not observed at well N3-MW22 until the 2011 (third) PME, which occurred approximately 30 months after the 2008 ISCO event.

Wells N3-MW05, N3-MW07, N3-MW12, N3-MW15, and N3-MW21 were used as Site N3 injection points in 2008 and 2010. TCE concentration rebounding at the injection points ranged from less than 14 months to greater than 60 months. As of 2015, evidence of permanganate (purple water) persisted at wells N3-MW07 and N3-MW12, and TCE concentrations at these wells were below reporting limits. The TCE concentration was below the reporting limit in the sample collected from well N3-MW05 in 2011 and evidence of permanganate was present; however, no evidence of permanganate was apparent in 2012 and TCE concentration rebounding occurred less than 14 months after the 2011 PME. The TCE concentration in the sample collected in 2012 from well N3-MW15 was below the reporting limit and increased to 15,000 μg/L in the sample collected from that well in 2015, less than 38 months later. A light brown tint was noted on the 2015 sampling log for N3-MW15. Partial TCE concentration rebounding occurred at well N3-MW21 in 2010 (less than 21 months after the 2008 ISCO event), and additional rebounding occurred in 2011. No evidence of permanganate was observed at well N3-MW21 in 2011, 2012, or 2015.

Based upon interpreted TCE plume extents from 2012 (AECOM 2012) and 2015 (Figure 9), significant changes are apparent. An increase in TCE concentration in the 2015 sample collected from well N3-MW15 warranted an expansion of the 5,000-μg/L concentration contour in that area (Figure 11). During the 2015 PME, TCE was detected above the reporting limit at well N3-MW15 for the first time since the August 2010 ISCO event. The historical high TCE concentration of 45,000 μg/L at well N3-MW15 was detected in the sample collected in 2002 (the first sample collected after installation). The TCE concentrations detected in the samples collected from newly-installed wells N3-MW27 and N3-MW29 resulted in the extrapolation of the 5-μg/L concentration contour beneath Building 4806 (Figure 11).

Because of the proximity of wells N3-MW04, N3-MW20, N3-NW07, and N3-NW08 to occupied Buildings 4806, 4807, and 4808 at Site N3, they were included in the 2015 PME to support vapor intrusion investigation activities. Additionally, wells N3-MW27, N3-MW28, and N3-MW29 were installed adjacent to Buildings 4806, 4800, and 4806, respectively. TCE was detected at a concentration of 0.18 μg/L (estimated value) in the sample collected from well N3-MW04, and below the reporting limit in the samples collected from wells N3-MW20 and N3-NW07. An increase in TCE concentration from 3.4 μg/L in 2012 to 5.5 μg/L in the 2015 sample collected from well N3-NW08 warranted an expansion of the 5-μg/L concentration contour in that area (Figure 11). The TCE concentrations of 18 (estimated value) and 7.9 μg/L detected in the samples collected from newly-installed wells N3-MW27 and N3-MW29 resulted in the extension of the 5-μg/L concentration contour below the north corner of Building 4806. The TCE concentration of 30 μg/L detected in the sample collected from well N3-MW28 supports the interpreted location of the 5- and 50-μg/L concentration contours relative to Building 4800 (Figure 6), as previously reported using 2012 sampling data.

Site N4

Laboratory analytical results from the 2015 PME indicate a persistence of TCE in the Site N4 area at wells N4-MW04 through N4-MW06 and N4-MW08 through N4-MW13, and the presence of TCE in newly-installed wells N4-MW14 through N4-MW20. TCE concentrations in the samples collected from wells N4-MW12 and N4-MW13, at the previously-assumed plume leading edge, have not exhibited any clear trends. The results for the groundwater samples collected from wells N1-MW13, N4-MW19, and N4-MW20 indicate that VOCs are present, and have not been delineated to the east (Figure 6).

Wells N4-MW07, N4-MW08, and N4-MW09 were used as injection points in August 2010 and monitoring points during the 2015 PME. TCE concentrations were reduced following ISCO treatment; however, TCE concentrations rebounded in less than 59 months. Although indications of the presence of permanganate were reported on the sampling purge logs generated for well N4-MW07 during the 2011 and 2012 PMEs, the presence of permanganate was not noted on the sampling purge logs for any of the Site N4 wells sampled in 2015. ISCO treatment did not reduce the TCE concentrations at wells N4-MW08 or N4-MW09. Well N4-MW06, located at the previously-assumed leading edge of the TCE plume, has not been used as an injection point, and has a comprehensive sampling history since the signing of the ROD. TCE concentrations in the groundwater samples collected from well N4-MW06 increased from 2005 until 2010 (Appendix G); the TCE concentrations at N4-MW06 were possibly influenced by ISCO injection at adjacent well N4-MW08.

Site N7

The wells nearest to former Building 4810 (one of the buildings included in the 2013 vapor intrusion investigation activities) included in the 2015 PME were wells N7-MW07 and N7-MW10. The 2015 TCE concentration detected in the sample collected from well N7-MW07 was 21 μg/L, which decreased from the 30-μg/L concentration detected in 2002. The TCE concentration detected in the sample collected from well N7-MW10 was 46 μg/L (an increase from the concentration in 2012). Although Building 4810 was demolished in September 2014, a replacement building is planned. Results of the 2015 PME indicate that the plume does not extend beneath the former or planned building footprints.

Wells N7-MW10 and N7-MW11 were used as injection points in August 2010, and monitoring points during the 2015 PME. Although evidence of permanganate was present during the 2011 PME, discolored water was not apparent in these two wells during the 2015 event. TCE concentration rebounding occurred at wells N7-MW10 and N7-MW11 by the 2011 PME.

4.2.2.2 Benzene Analytical Results

The OU 6 benzene plume is limited to the Site N3 area, which was previously used as a gas station and the former location of underground storage tanks. Benzene concentration trends are monitored throughout the RA to evaluate if and where aerobic bioremediation of benzene will be required. Clear trends were only identified at well N3-MW15, where benzene concentrations have been decreasing since 2007, and N3-MW12, where benzene concentrations have been decreasing since 2010.

The highest benzene concentration identified during the 2015 PME was 7,900 μg/L, and was detected in the sample collected from well N3-MW14. This concentration is below the highest historical OU 6 concentration of 19,000 μg/L, which was detected in a sample collected from this well in 2002.

Because of the proximity of wells N3-MW04, N3-MW20, N3-NW07, and N3-NW08 to occupied Buildings 4806, 4807, and 4808 at Site N3, they were included in the 2015 PME to support vapor intrusion investigation activities (Figure 12). Additionally, wells N3-MW27, N3-MW28, and N3-MW29 were installed adjacent to Buildings 4806, 4800, and 4806, respectively. In 2015, benzene was not detected above the reporting limit in the samples collected from wells N3-MW04, N3-MW28, N3-NW07, and N3-NW08. Benzene was detected at concentrations of 600 μg/L in the sample collected from well N3-MW20, 18 μg/L (estimated value) in the sample collected from well N3-MW27, and 0.54 μg/L (estimated value) in the sample collected from well N3-MW29. The benzene isoconcentration contours interpreted from 2015 sampling data collected from the newly-installed wells confirm the 2012 benzene isoconcentration contours, which indicate that the benzene plume extends below the north corner of Building 4806 and does not extend to the Building 4800 footprint.

4.2.2.3 Carbon Tetrachloride Analytical Results

Interpretations of 2015 CT concentrations and isoconcentration contours indicate that CT is present in two distinct areas within OU 6: Sites N3 and N4 (Figures 13 and 14). The highest CT concentrations detected during the 2015 PME were in the samples collected from wells N3-MW05, N3-MW15, N3-MW21, and N3-MW22, which were 970, 1,100, 860, and 7,400 μg/L, respectively. Wells N3-MW15, N3-MW21, and N3-MW22 were also the locations where the highest TCE concentrations were detected during that timeframe, indicating that the TCE and CT likely originated from the same sources. The sources of CT at Site N3 and other solvent-related COCs such as TCE are likely former drum storage and drum dispensary areas. The drum dispensaries were described in the *Expanded Source Investigation/RCRA Facility Assessment* (The Earth Technology Corporation 1993) as 55-gallon spigot-fitted drums positioned on their sides on metal racks containing solvents such as mineral spirits. One of the drum dispensaries was located at the present location of well N3-MW05, which is one of the Site N3 wells with relatively high CT concentrations. Additionally, this drum dispensary area was located immediately adjacent to the drainage ditch that defines the northern and western Site N3 boundary.

The sources of CT at Site N4 were likely spills from former drum dispensaries to a drainage ditch located at Site N3, with an outfall in the area of monitoring well N4-MW06, which is at the estimated center of the southern CT plume (distinct from the Site N3 CT plume). At well N4-MW06, CT concentrations increased from 59 μg/L in 2005 to 210 μg/L in 2012, and decreased to 120 μg/L in 2015 (Appendix G). CT concentrations in the Site N4 area in 2015 ranged from 0.65 μg/L in the sample collected from well N4-MW10 to 330 μg/L in the sample collected from well N4-MW09.

Although CT was not previously identified in the samples collected from Site N7 area wells since trace concentrations were initially detected in 2001, CT concentrations of 1.6 and 0.25 μg/L (estimated value) were detected in the samples collected from wells N7-MW02 and N7-MW04, respectively, in 2015. The limited number of and low concentration detections in the Site N7 area indicate that Site N7 is not a contributing source of CT in Site N4 groundwater.

The highest CT concentration identified during the 2015 PME was 7,400 μg/L, which was detected in the sample collected from well N3-MW22. CT was also detected at a concentration of 7,500 μg/L in the sample collected from this well in 2011. These concentrations represent the highest historical CT concentrations detected in OU 6 groundwater since 2002 (7,000 μg/L in the sample collected from well N3-MW15).

4.2.3 NDMA ANALYTICAL RESULTS

The highest NDMA concentrations identified since 2010 have been detected in the samples collected from wells N3-MW06, N3-MW07, and N3-MW23. The NDMA concentrations during the 2015 PME were 0.017 μg/L, below the reporting limit, and 0.1 μg/L in the samples collected from wells N3-MW06, N3-MW07, and N3-MW23, respectively. Although well N3-MW07 is located within the Site N3 solvent plume source area, there is no evidence of historical use or storage of NDMA. Wells N3-MW06 and N3-MW23 are located near the flightline, where long-term aircraft storage was common and a more likely NDMA source location.

4.2.4 OTHER INORGANIC ANALYTICAL RESULTS

Metals analyses are included in the groundwater sampling program to monitor for trace metals that may be present in the ISCO reagent. A total of 23 metals (including both total and hexavalent chromium) were detected in the groundwater samples collected during the 2015 PME. Aluminum, arsenic, hexavalent chromium, total chromium, lead, and nickel were detected at concentrations that exceeded respective drinking water notification levels (DWNLs) or MCLs. Of the metals that exceeded regulatory thresholds, only total chromium and manganese also exceeded the OU 1 background (BG) concentration (Earth Tech 2001a) (BG inorganic levels have not been established for OU 6; therefore, BG levels established at adjacent OU 1 are used for comparison). A comparison of the maximum inorganic analyte concentrations detected in groundwater during the 2015 PME to OU 1 BGs, MCLs, and DWNLs is presented in the 2015 RPGMR (AECOM 2016c).

4.2.5 CHROMIUM AS A BYPRODUCT OF *IN SITU* CHEMICAL OXIDATION

Permanganate used as the ISCO reagent has the potential to convert naturally-occurring trivalent chromium to hexavalent chromium, which is a carcinogen. However, treatability studies performed at Site N7 using permanganate indicated that hexavalent chromium was transitional and returned to the trivalent form in groundwater once oxidation conditions degraded (within approximately five years of introducing permanganate into OU 6 groundwater).

During the 2015 PME, hexavalent chromium was detected in 18 samples collected from 15 wells at concentrations ranging from 0.00027 milligrams per liter (mg/L) (estimated value) in the sample collected from well N3-MW06 to 0.23 mg/L in the sample collected from well N7-MW11. During the

2015 PME, total chromium was detected in 23 samples collected from 20 wells at concentrations ranging from 0.0012 mg/L (estimated value) in the sample collected from well N3-MW16 to 38 mg/L in the sample collected from well N3-MW07.

During the reporting period, hexavalent chromium concentrations were detected above 0.01 mg/L, exceeding the current MCL (California Department of Public Health 2014) in the samples collected from wells N3-MW15 and N4-MW07 (both of which were used as injection points in 2010), and wells N7-MW02 and N7-MW11 (the latter was used as an injection point in 2008 and 2010). Hexavalent chromium concentrations remain elevated compared to pre-injection levels (2010) in the samples collected from wells N3-MW15 and N7-MW11; however, a downward concentration trend is evident at well N7-MW11. Hexavalent chromium concentrations have decreased to pre-injection levels in the sample collected from well N7-MW02. A hexavalent chromium concentration trend cannot be interpreted at well N4-MW07 due to limited analytical data (only one groundwater sample has been analyzed for hexavalent chromium following the 2010 ISCO event due to permanganate interference). Total chromium concentrations were detected above the 0.05-mg/L MCL in the samples collected from wells N3-MW12 (used as an injection point in 2010), N3-MW07, and N7-MW11 (the latter two wells were used as injection points in 2008 and 2010). Total chromium concentrations remain elevated compared to pre-injection levels (2010) in the samples collected from these three wells; however, a downward concentration trend is evident at well N7-MW11.

4.3 SITE INSPECTION

Site N3 (Buildings 4806, 4807, and 4808), Site N7, and the Environmental Management office (for GIS review) were visited on 17 February 2016 to assess the protectiveness of the remedy. Mr. Tom Merendini (AFCEC/CZOW), Mr. Julio Barrios (412 CEG/CEVA), Mr. Kevin Mayer (USEPA), Mr. Bruce Lewis (DTSC), Mr. Alonzo Poach (CRWQCB), Ms. Kimberly Coleman (AECOM), and Mr. Oscar Perez (Helios Resources, Ltd.) attended the inspection. The completed FYR Site Inspection Checklist and the results of the June 2016 well inspection are presented in Appendix H along with photographs taken during the site inspection (representative of current site conditions) supplemented by additional well head photographs representing typical well maintenance issues encountered during the June 2016 inspection.

Location 1 (Site N3 and Buildings 4806, 4807, and 4808) – After signing in and receiving NASA AFRC escorted badges, Mr. Perez (NASA AFRC contractor) drove the group to Site N3. Ms. Coleman (Air Force and NASA AFRC contractor) briefly described the site history, including the former location of the sources of groundwater contamination. Wells within the TCE, CT, and benzene high-concentration areas were located. Site features, including AFRC security fencing and a drainage ditch running along the western site boundary and outfalling at Site N4 on Rogers Dry Lake, were noted. Mr. Poach noted a damaged well cover at well N3-MW24.

The group then toured Buildings 4806, 4807, and 4808, located at Site N3. Ms. Coleman and Mr. Poach identified several sub-slab sampling wells associated with the VIP investigations conducted in 2013 and 2016 at Buildings 4806 and 4807. The locations of the indoor air and sub-slab sampling locations in which the highest VOC concentrations were detected were noted. Building 4806 is used for aircraft ground equipment vehicle maintenance; a sweeper located in the building was photographed. Ms. Coleman noted that the project team attempted to remove any indoor VOC sources prior to sampling; however, vehicles were present at various times during indoor air sampling. The uncertainties associated with indoor VOC sources, such as running vehicles, are discussed in the *Vapor Intrusion Investigation Report Addendum* included as Appendix C.

Location 2 (Site N7 and former location of Building 4810) – Between Sites N3 and N7, the inspection group observed various segments of the drainage ditch that runs along the western edge of Site N3 and outfalls at Site N4. The former location of Building 4810 (one of buildings included in the 2013 VIP investigations) was evident from asphalt patching. At Site N7, Ms. Coleman described the site history, including the locations of the former sources of groundwater contamination and the nature of the contamination. Wells within the areas with the highest groundwater TCE concentrations were located. Site features, including AFRC security fencing along Rogers Dry Lake, were also noted. As part of the flightline, Rogers Dry Lake is a controlled movement area and could not be accessed by the inspection team. From Site N7, Ms. Coleman identified the approximate location of Site N4 on the lakebed.

Location 3 (Environmental Management office on Rosamond Boulevard) – Because the GIS is the primary management tool for implementing, documenting, and managing LUCs, a review of the GIS was included during the inspection process, and Mr. Julio Barrios (412 CEG/CEVA) presented an overview of the GIS to the inspection team. OU 6 information was accessed via Webmap so that the inspection team could verify that land use restrictions are described in the GIS, and that a full description of the restrictions are available through GIS via hyperlink to the ROD. Additionally, the GIS includes updated (2015) groundwater COC concentration data, groundwater elevation data, and groundwater well locations. At the time of the site inspection, the LUC boundary had not been updated with plume shape files generated from 2015 data, as the plume shapes had yet to be fully vetted by the finalization of the 2015 RPGMR. Following the inspection, Ms. Coleman contacted Mr. Barrios on 12 May 2016 and verified that the LUC boundary had been updated in the GIS on 5 May 2016.

Monitoring Well Network Inspection - Inspection of the monitoring well network was performed in June 2016 and the results are presented in Appendix H. Issues noted during previous groundwater sampling efforts include broken bolts, cracked well covers, and plant roots in a well screen. The addition of a formal inspection sheet (Appendix I) to sampling field forms to be populated during groundwater monitoring events is recommended in Section 6.2.3.

5.0 TECHNICAL ASSESSMENT

The technical assessment portion of the FYR should provide the answers to the following three questions:

- Question A: Is the remedy functioning as intended by the decision documents?
- Question B: Are the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of the remedy still valid?
- Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

The appropriate information is presented in the following subsections in accordance with the *Comprehensive Five-Year Review Guidance* (USEPA 2001), and with supplemental guidance documents *Recommended Evaluation of Institutional Controls* (USEPA 2011) and *Assessing Protectiveness at Sites for Vapor Intrusion* (USEPA 2012).

5.1 QUESTION A: IS THE REMEDY FUNCTIONING AS INTENDED BY THE DECISION DOCUMENTS?

This section addresses whether remedy components, as implemented, will maintain the effectiveness of the remedy, and is organized in accordance with the *Five-Year Review Recommended Template* (USEPA 2016). ISCO and groundwater monitoring remedy components are discussed in Sections 5.1.1 and 5.1.2. An evaluation of the LUC remedy component performance is included in Section 5.1.3. The bioremediation remedy component has not been implemented, and is therefore not discussed.

5.1.1 REMEDIAL ACTION PERFORMANCE

This section addresses whether the ISCO and groundwater remedy components continue to operate and function as designed, whether cleanup levels are being achieved, and if opportunities exist to improve performance and/or reduce costs.

5.1.1.1 *In Situ* Chemical Oxidation

The ISCO remedy component continues to function as designed. Deviation from the planned implementation schedule is discussed in Section 5.1.2. During the First FYR period, ISCO was implemented at high COC concentration areas as planned. Results from the groundwater monitoring conducted during the current (Second) FYR period agree with anticipated performance trends observed during pre-RA treatability studies, i.e., permanganate persists in treated wells and the COC concentrations eventually rebound as observable permanganate concentrations decline, resulting in the need for subsequent treatment events.

As further discussed in Sections 6.2.2, opportunities to improve the efficiency of the ISCO component may exist in the form of employing a stronger oxidant than permanganate to improve the rate of CT concentration reduction. Additionally, gradual release of reagent may be employed instead of pressurized injection.

5.1.1.2 Groundwater Monitoring

The groundwater monitoring component was designed to track treatment performance in the areas with the highest COC concentrations and to demonstrate the effectiveness of natural attenuation in the areas of the plume where COC concentrations were lower. The groundwater monitoring component is not functioning as designed. This reporting period (Second FYR) represents Years 6 through 10 of implementation, and per the ROD, the groundwater monitoring component was to be implemented biennially. However, based on the rebound of COC concentrations within the ISCO treatment areas observed between the 2012 and 2015 PMEs, annual groundwater monitoring is recommended to better target and plan the next treatment/injection event. The groundwater monitoring component is also not functioning as intended, as the natural attenuation effectiveness has not been demonstrated in the low concentration areas. At the time of remedy selection, groundwater analytical data indicated that downgradient areas (Sites N1 and N4) of the commingled plume had reached steady-state conditions, with dilution and dispersion occurring at the leading edge of the plume as represented by the 2003 contour line indicated on Figure 9. However, data collected from the groundwater monitoring wells installed since 2012 indicate that the plume leading edge has not been fully delineated in the Site N4 area, and that the plume extends at least several thousand feet to the east of the 2003 delineation.

The groundwater monitoring component provides the mechanism for evaluating if cleanup levels are being achieved. Seventeen COCs and cleanup goals (MCLs) were identified in the ROD (USAF 2006). These COCs, along with their respective historical concentration ranges in OU 6 groundwater and their respective cleanup goals, are presented in Table 2. During the 2015 PME, 13 of the 17 COCs were detected above their respective reporting limits in the groundwater samples collected, and 12 of the

13 COCs were detected above their respective MCLs. CT and TCE concentrations detected in the sample collected from well N3-MW22 during the 2015 PME are the historical maximum concentrations for those COCs. Details regarding the benzene, chromium, CT, NDMA, and TCE concentrations and their trends are included in the 2015 RPGMR (AECOM 2016c).

Per the ROD, if any unexpected behavior was observed during groundwater monitoring, the FYR would include a contingency plan to capture anomalous migration of contaminants. To address the COC concentration data gaps in the area east of Site N4 on Rogers Dry Lake, additional step-out boreholes (Figure 10) will be advanced to facilitate groundwater sampling and monitoring wells will be installed for plume delineation, which will provide greater accuracy in plume estimation. The estimates will provide the basis for more reliable contaminant mass/volume calculations that may yield a better understanding of remedy progress. If upon completion of plume delineation the plume is determined to be migrating, containment in the form of ISCO treatment at the leading edge could be implemented.

The TCE plume has not been fully delineated and long-term protectiveness has not been determined; the current estimate indicates that the plume extends eastward into the Rogers Dry Lake area. The Base-wide conceptual site model further predicts that the plume could follow a path that extends further eastward before starting a northerly course, based partially on west-to-east-oriented bedrock high, which directs groundwater flow east and then north (AECOM 2011b).

The estimated distance from the leading edge of the OU 6 TCE plume to the North Edwards production wells is approximately 26,400 feet (Figure 8). Based on the shallow groundwater elevations observed (including at the lakebed wells), the groundwater gradient over a 7,100-foot distance along the western portion of the groundwater pathway is 0.006 feet per foot. The hydraulic conductivity of the weathered bedrock from the two lakebed cluster aquifer performance tests conducted in 2014 (AECOM 2016a) ranged between 1.32 to 5.9 feet per day (recovery phase results), with an assumed porosity of 15 percent. Using these parameters to estimate groundwater flow velocity, assuming no adsorption and constant aquifer hydraulic conductivity, porosity, and gradient along the entire flow pathway, the estimated travel time between OU 6 and North Edwards wells ranges between 306 and 1,369 years.

Protectiveness of the remedy could be impacted by the installation of production wells (intended to extract groundwater for beneficial uses) in the downgradient contaminant plume flow path. However, a rigorous review process exists for determining new production well locations at Edwards AFB, and approval to install production wells in an area potentially impacted by the groundwater contaminant plume is unlikely. Mr. Phil Saxton, a staff member of the Edwards AFB Civil Engineering Department, provided a detailed description of the approval process during the FYR interview (Appendix E).

As further discussed in Section 6.2.3, an opportunity to improve the efficiency of the groundwater monitoring component may exist in the form of well condition inspections to document required well maintenance.

5.1.2 SYSTEMS OPERATIONS

This section addresses whether large variances in implementation costs could indicate a potential remedy problem. Cost analyses provided in the 2011 to 2012 and 2015 RPGMRs (AECOM 2012 and 2016c, respectively) indicate that costs variances were due to the differences in the scheduling of field tasks and the addition of unanticipated tasks. ISCO was not performed during the reporting period, and is an example of a field task scheduling difference. As discussed in Section 2.4.3, although an ISCO event was anticipated during the reporting period, groundwater sampling data collected prior to 2015 indicated the continued presence of permanganate in the Site N3 and N7 treatment areas; therefore, additional injection events up to 2015 were unnecessary. Examples of unanticipated tasks include tasks recommended in the *First FYRR* (AECOM 2011c), and principally include multiple vapor intrusion sampling events. Results of the vapor intrusion investigations do not indicate a potential remedy problem, as further discussed in Section 5.2.

5.1.3 IMPLEMENTATION OF INDUSTRIAL CONTROLS AND OTHER MEASURES

LUCs have been successfully employed as expected at OU 6 during the reporting period. The LUC remedy component includes approval procedures for all construction and ground-disturbing activities within the OU 6 LUC boundary (Figure 5), including construction and dig permits. The LUC boundary is revised in the GIS as necessary based on the most recent, vetted, and available sampling results. The benzene, CT, and TCE concentrations detected in groundwater are used to define the LUC boundary because, based on MCL exceedances, these plumes exhibit the largest aerial extent. Proper personal protective equipment was used by field personnel during any excavations that were performed within the LUC boundary that may result in exposure of personnel to contaminated groundwater. The GIS was updated based on the June to July 2015 monitoring results, which resulted in revising the LUC boundary by expanding the OU 6 plume boundary to the east, encroaching upon Rogers Dry Lake as represented by the 5-µg/L TCE concentration contour shown on Figure 6.

LUCs such as the security gate house and fencing are intrinsic to the NASA AFRC operations, were in place when the ROD was signed, and were maintained and consistent with the ROD at the time of the site inspection. RA activities occur within the NASA AFRC secured area or the secured area maintained by Edwards AFB flightline management.

5.2 QUESTION B: ARE THE EXPOSURE ASSUMPTIONS, TOXICITY DATA, CLEANUP LEVELS, AND RAOS USED AT THE TIME OF THE REMEDY STILL VALID?

Per guidance, the validity of assumptions on which the remedy was selected was evaluated as indicated below.

5.2.1 CHANGES IN STANDARDS AND TBCS

ARARs were reviewed as part of the FYR, and are presented in Appendix F. As indicated in Table F-1 in Appendix F, a State primary MCL for hexavalent chromium was established during the reporting period. The impact of this change to remedy protectiveness is discussed below.

Effective July 2014, the State of California designated hexavalent chromium as a regulated drinking water contaminant, with a MCL of 0.010 mg/L. As discussed in Section 4.2.5, permanganate used as the ISCO reagent has the potential to convert naturally-occurring trivalent chromium to hexavalent chromium. Hexavalent chromium has been included in the monitoring program since remedy implementation, and the groundwater sampling results indicate that hexavalent chromium is transitional and returns to the trivalent form in groundwater once oxidation conditions degrade. There has been no impact to the monitoring program over the past 5 years, because the analytical method used for hexavalent chromium has a method detection limit of 0.010 mg/L. The promulgation of an MCL for hexavalent chromium is not expected to impact remedy protectiveness because hexavalent chromium analysis is already included under the groundwater monitoring remedy component with a detection limit equal to the MCL, LUCs are in place preventing groundwater exposure, and hexavalent chromium formation is temporary.

5.2.2 CHANGES IN TOXICITY AND OTHER CONTAMINANT CHARACTERISTICS; RISK ASSESSMENT METHODS; AND EXPOSURE PATHWAYS

The baseline (2003) HHRA (Earth Tech 2003) presented the results of the potential risk from groundwater VOCs that might migrate through the vadose zone and into buildings routinely occupied by indoor workers. The results of those assessments indicated that the risks were all within or less than the generally acceptable cancer risk range of 1 x 10^{-4} to 1 x 10^{-6} and less than a Hazard Index of 1. Therefore, cleanup levels to protect receptors from the potential VIP were not established in the ROD. However, since the toxicity criteria and methods by which some of the VOCs were evaluated for the VIP assessment have changed since the baseline HHRA, a re-evaluation of the risks via the VIP was warranted, and thus, the 2013 and 2016 vapor intrusion investigations were conducted. Additionally, changes in the extent of benzene in relation to the occupied buildings (representing a potential change in the exposure pathway) necessitated the collection and inclusion of building sub-slab soil gas and indoor air data during the re-assessment. Results of the 2013 VI investigation are presented in the Final *Vapor Intrusion Investigation Report* dated June 2016 that is included as Attachment B to Appendix C (the Final *Human Health Risk Assessment Addendum*) of the *Addendum to First Five-Year Review Report* (Appendix B of this *Second Five-Year Review Report*). Results of the 2016 VI investigation are presented in the *Vapor Intrusion Investigation Report Addendum* (Appendix C of this *Second Five-Year Review Report*).

Since the baseline HHRA was performed (Earth Tech 2003), the USEPA updated the toxicity criteria for some chemicals as reflected in its Integrated Risk Information System database. Additionally, exposure parameters such as body weight assumptions have increased for adults (from 70 to 80 kilograms) which results in a net decrease in risk for adult exposure to all compounds. Table 6 presents the latest toxicity criteria and revision dates for VIP-related chemicals. Updates were made to the toxicity criteria since the baseline HHRA for 2-butanone, 4-methyl-2-pentanone (MIBK), benzene, cyclohexane, isopropanol, n-hexane, and tetrahydrofuran. The toxicity values for four compounds (2-butanone, MIBK, benzene, and n-hexane) have become less stringent since the baseline HHRA was performed. Although the toxicity criteria for isopropanol and tetrahydrofuran have been updated (the most recent toxicity values for all the chemicals, including isopropyl alcohol and tetrahydrofuran, were used in the 2013 and 2016 VIP assessments) their toxicity values were not used in the baseline HHRA; therefore, there is no comparison to be made. The toxicity criteria for cyclohexane has become more stringent; the non-cancer reference concentration decreased by approximately 5-fold, which increased its potential toxic effect by 3-fold. These changes in toxicity criteria since the baseline HHRA was performed were accounted for during the 2013 and 2016 vapor intrusion evaluations discussed below.

Sub-slab soil gas and indoor air samples were collected in three buildings in 2013 and two buildings in 2016 at OU 6. Additionally, outdoor air samples were collected outside of each building. Per the *Vapor Intrusion Sampling Plan and Risk Assessment Work Plan* (AECOM 2013a), risks and hazards were calculated using both DTSC-developed toxicity values and USAF-preferred toxicity values for comparison purposes. Using both approaches, the results indicated that all of the cancer risks from VIP-related chemicals for the industrial scenario were less than 1 x 10^{-4} (the highest cancer risk was 4 x 10^{-6}), and the non-cancer Hazard Quotients were less than 1 (Table 7). The USEPA has provided FYR guidance for interpreting these risk results within the CERCLA framework (USEPA 2001):

> *Generally, your human health determination should be based on whether the cancer risk could now be greater than 10^{-4} and/or the hazard index could be greater than 1 for non-carcinogenic effects.*

Thus, based on the 2013 and 2016 VIP investigations, the OU 6 remedy is protective of vapor intrusion for the current industrial worker as well as the hypothetical future resident, given the continued implementation of LUCs prohibiting residential development for the foreseeable future.

Updating the vapor intrusion assessment using current methodologies and toxicity data did not result in any recommendations for changes to the RAOs, COCs, or cleanup goals selected in the ROD (USAF 2006).

5.2.3 Expected Progress Towards Meeting RAOs

Minimal active progress was made toward meeting the first RAO, restoration of groundwater to its designated beneficial use as drinking water. No ISCO injection tasks were performed due to the persistence of permanganate in groundwater, which was observed during the 2012 PME. The second RAO, prevention of exposure of human receptors to contaminated groundwater until groundwater contaminant concentrations are below MCLs, was met during the reporting period.

5.3 QUESTION C: HAS ANY OTHER INFORMATION COME TO LIGHT THAT COULD CALL INTO QUESTION THE PROTECTIVENESS OF THE REMEDY?

The following subsections present additional information that was considered during the FYR when determining the protectiveness of the remedy.

5.3.1 SITE 25

Site 25 in OU 8 warrants consideration as the OU 6 RA progresses. A VOC plume associated with Site 25 is present upgradient (west) of the OU 6 plume (Figure 6). The remedy selected in the OU 6 ROD addresses the OU 6 groundwater plume (as defined by the OU 6 plume boundary presented on Figure 3) originating from OU 6 and does not include plumes originating from outside the OU 6 boundary. Because the Site 25 plume has not commingled with the OU 6 groundwater plume (Figure 6), the current protectiveness of the OU 6 plume remedy has not been affected.

Site 25 is managed as a separate project under CERCLA, with remedy selection to be made under a separate ROD scheduled for submittal in 2019. The effect of the Site 25 plume on future OU 6 remedy protectiveness is dependent upon the remedy selected for Site 25. Site 25 activities that will be conducted prior to remedy selection in 2019 are described below.

Remedial alternatives for the Site 25 plume are currently being evaluated. Under the Site 25 program, a risk based screening level for TCE of 170 μg/L for groundwater under the industrial use exposure scenario has been developed. This concentration was back-calculated using the Johnson and Ettinger model, corresponds to 1×10^{-6} cancer risk, and will be used as a trigger for identifying potential vapor intrusion impacts associated with that site. A VIP investigation associated with the Site 25 plume was conducted from August 2012 through August 2013 at Buildings 4824 and 4870. The results of the investigation indicated that the indoor air cancer risks were below 1×10^{-6} and indoor air hazards were below 1. Groundwater monitoring data gathered in 2014 indicated that no NASA buildings (other than the previously-investigated Buildings 4824 and 4870) are located within the 100-μg/L TCE contour from Site 25. Four NASA buildings (4828, 4832, 4857, and 4876) are located between the 5- and 100-μg/L TCE concentration contours at Site 25. If necessary, groundwater monitoring wells will be installed upgradient of the existing buildings. Future buildings will be evaluated for VIP barriers prior to construction.

Groundwater monitoring associated with the Site 25 plume will be performed annually. Additionally, annual evaluations of potential impacts to NASA buildings based on groundwater monitoring data will be performed, and groundwater monitoring wells will be installed as necessary. Annual building occupancy evaluations, a building construction evaluation, and surveys will be performed at buildings within the 170-µg/L Site 25 TCE contour. If building surveys indicate the potential for increased vapor intrusion risks (based on discussions with regulatory agencies), a VIP-related sampling program will be conducted and, if unacceptable indoor air risks are encountered, seasonal variations will be evaluated and/or mitigation measures will be implemented. Groundwater models will be used to project which buildings are potential candidates for monitoring well installation and/or vapor intrusion sampling.

5.3.2 OTHER POTENTIAL IMPACTS TO PROTECTIVENESS

No complete pathways to potential human receptors were identified, and no ecological targets were identified during previous risk assessments. No new pathways or receptors were identified during the FYR, and no weather-related events have affected the protectiveness of the remedy. No natural disasters have impacted protectiveness, and no new circumstances or information have been identified that affect the assumed protectiveness of the remedy.

Perfluorinated compounds (PFCs), a sub-set of perfluoroalkyl and polyfluoroalkyl substances, are persistent degradation-resistant organic compounds identified as "emerging contaminants" and present in aqueous film-forming foam formerly used for fire suppression at Edwards AFB (including OU 6). Although regulatory thresholds for PFCs have not been established, investigation activities have been initiated and site inspections (SIs) were performed in March 2016 (Oneida Total Integrated Enterprises 2016) to gather further information regarding aqueous film-forming foam use areas identified during preliminary assessments (CH2M Hill 2015). Data gathered during the SIs will be used to develop a work plan for the field investigation (tentatively scheduled for late 2016) which will include soil and groundwater sampling. The details of the recommended field investigation, including proposed schedule, will be provided under the Basewide PFC investigation program.

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6.0 ISSUES/RECOMMENDATIONS

During the technical assessment, issues were identified that warranted consideration to determine if they may impact current or future protectiveness, those issues, and the recommended actions for addressing them, are presented in the following subsections. The USAF and NASA will be responsible for any follow-up actions, with regulatory oversight by the USEPA, DTSC, and CRWQCB.

6.1 ISSUES AND RECOMMENDATIONS IDENTIFIED IN THE FIVE-YEAR REVIEW AFFECTING PROTECTIVENESS

The issue/recommendation included in the table below affects future protectiveness, and should be tracked in the Superfund Enterprise Management System (SEMS).

<table>
<tr><td rowspan="3">OU(s): 6</td><td colspan="4">Issue Category: Remedy Performance</td></tr>
<tr><td colspan="4">Issue: Plume delineation data gap at the leading edge.</td></tr>
<tr><td colspan="4">Recommendation: Additional delineation of the plume should be performed at the leading edge on Rogers Dry Lake and additional groundwater monitoring wells installed. The new wells should be sampled annually to evaluate concentration trends, to evaluate whether the plume is expanding, shrinking, or stable, to monitor cleanup progress, and to possibly provide in situ chemical oxidation injection locations should leading edge treatment be required.</td></tr>
<tr><td>Affect Current Protectiveness</td><td>Affect Future Protectiveness</td><td>Party Responsible</td><td>Oversight Party</td><td>Milestone Date</td></tr>
<tr><td>No</td><td>Yes</td><td>Federal Facility</td><td>EPA/State</td><td>9/30/2021</td></tr>
</table>

6.1.1 PLUME DELINEATION DATA GAP AT THE LEADING EDGE

TCE has been detected in groundwater samples collected from the eastern-most (downgradient) OU 6 wells N1-MW13 and N4-MW20, indicating that the plume extends beyond the monitored area and a data gap exists (AECOM 2016c). Because exposure pathways that could result in unacceptable risks in the short-term are being controlled through institutional controls, current protectiveness has not been affected. However, additional groundwater sampling points are planned to further delineate the leading edge of the plume. Additionally, continued ISCO treatment in the Site N4 area will likely be required to reduce the TCE concentrations. If ISCO treatment is unsuccessful in reducing TCE concentrations at Site N4, and if the planned plume delineation activities result in data that indicate that the plume is migrating significantly toward the groundwater subbasin and drinking water supply wells, future protectiveness could be threatened. The conceptual site model should be updated as delineation investigation data become available.

6.1.2 Site 25 Groundwater Plume

Although Site 25 has the potential to affect future OU 6 remedy protectiveness, it was not included in the above table in Section 6.1, as it will be tracked in SEMS under a separate OU and ROD.

As discussed in Section 5.3.1, current protectiveness of the OU 6 remedy has not been affected by the Site 25 plume, because the Site 25 plume has not clearly commingled with the OU 6 plume (Figure 6), and a VIP investigation performed at two NASA buildings in OU 6 and located above the Site 25 plume (AECOM 2014) indicated no unacceptable risks (attributable to the VIP from groundwater contamination) to the building occupants. However, the final remedy selected for Site 25 in the 2019 ROD may affect the OU 6 plume. Prior to the Site 25 remedy selection in the ROD scheduled for 2019, the following tasks are recommended under the Site 25 CERCLA program for areas upgradient and generally west of the vapor intrusion differentiation boundary indicated on Figure 6: annual groundwater monitoring of the Site 25 VOC plume, well installations (as necessary), and annual evaluations of potential impacts to NASA buildings based on groundwater monitoring data, building occupancy evaluations, and building construction evaluations. If building surveys indicate the potential for increased vapor intrusion risks (based on discussions with regulatory agencies), a VIP-related sampling program should be conducted and, if unacceptable indoor air risks are encountered, seasonal variations should be evaluated and/or mitigation measures should be implemented.

6.2 OTHER FINDINGS

The following subsections present recommendations that were identified during the Second FYR and may improve performance of the remedy, reduce costs, improve the management of operation and maintenance, or accelerate site close-out, but do not affect current and/or future protectiveness.

6.2.1 LAND USE CONTROL REMEDY COMPONENT RECOMMENDATIONS

Continued revision of the LUC boundary in the GIS as necessary based on the most recent, vetted, and available sampling results is recommended, as is the continued adherence to review and approval procedures for construction and ground-disturbing activities. Future revisions of the LUC boundary should include a buffer zone to account for uncertainties in plume delineations. Annual LUC reports should be expanded to include a discussion of changes in site conditions (as they relate to new construction or intrusive activities) that might complete the VIP in occupied buildings downgradient and generally east of the vapor intrusion differentiation boundary indicated on Figure 6 or otherwise result in exposure of site workers to plume contaminants. The reports should provide appropriate recommendations as they relate to such conditions.

6.2.2 *IN SITU* CHEMICAL OXIDATION REMEDY COMPONENT RECOMMENDATIONS

A discussion of the recommendations related to the ISCO remedy component is provided in the following subsections.

6.2.2.1 Carbon Tetrachloride Treatment

Based on the treatability study results, permanganate was the selected ISCO reagent for the OU 6 RA. However, since CT is a significant component of the commingled plume in the Site N4 area and CT treatment requires a stronger oxidant, to improve RA performance, Fenton's reagent or persulfate will likely be employed for CT treatment. The unconsolidated materials of the aquifer in the Site N4 and lakebed areas should allow for more substantial dispersion of the Fenton's reagent or persulfate than was encountered during the treatability studies conducted in the fractured bedrock aquifer of the Site N3 and N7 areas. To avoid introducing an additional variable into the plume delineation process, ISCO treatment at Site N4 is not recommended until leading edge plume characterization is complete.

6.2.2.2 *In Situ* Chemical Oxidation Injection

Continued ISCO in the areas with the highest VOC concentrations is recommended. Based on the persistence of permanganate observed in the wells used for injection and the TCE concentration rebound timeframes (both timeframes ranged from less than 14 months to greater than 60 months), ISCO should be employed at three-year intervals. An injection event is planned for 2017.

Re-development and/or acid de-scaling of potential injection wells as necessary to ensure effective delivery of reagent in future injection events is recommended.

An opportunity to improve the efficiency of the ISCO component may exist through the deployment of time-release delivery mechanisms such as Sustained Oxidation and Controlled Oxidant Release Encapsulants. This approach involves coating oxidant crystalline particles with a food-grade paraffin wax, providing long-term oxidant release through passive oxidant delivery via advection and concentration-gradient diffusion. A comprehensive technology assessment of the encapsulate technology and other promising ISCO technologies and delivery systems will be developed before the next round of injections scheduled for 2017. The technology assessment (with regulatory input) will make recommendations for the 2017 treatment event, including treatment locations, application, and reagent type and volumes.

6.2.2.3 Plume Displacement

Evidence for the area influenced by pressurized ISCO was exhibited in two ways, 1) groundwater mounding and surfacing observed at monitoring wells (up to 30 feet from an injection well), and 2) purple or pink water observed in monitoring wells during subsequent groundwater sampling events (up to 50 feet from an injection well). Although gravity-fed injection or passive deployment will be the selected method for future ISCO events, if pressurized injection is considered, to prevent displacement of contaminated groundwater and potential impact to site workers via the VIP, it should not be employed closer than 100 feet (a conservative figure based on the 50-foot maximum radius of influence observed during previous injection events) from occupied buildings. The application of pressurized injection and injection locations relative to occupied building should be further evaluated in the recommended comprehensive technology assessment.

6.2.2.4 Plume Boundaries and *In Situ* Chemical Oxidation Implementation

After the VOC plume has been completely delineated, an artificial boundary of the plume, as it relates to Site N4, should be established to support contaminant mass estimation and ISCO treatment implementation.

6.2.3 GROUNDWATER MONITORING REMEDY COMPONENT RECOMMENDATIONS

Continued well maintenance is recommended, including well completion repairs and well labeling with identification tags. Annual groundwater monitoring for NDMA, metals (including total and hexavalent chromium), potential intermediate ISCO degradation compounds and VOCs is recommended. Well maintenance forms (Appendix I), which should indicate the condition of each well as well as recommendations for any repairs or maintenance, should be filled out during each groundwater monitoring event. The lids of the wellhead protective casings should be labeled using integral stampings or fitted with traffic-resistant well identification tags.

Remedy performance and groundwater monitoring reports should include discussion of changes in site conditions (as they relate to COC concentrations and plume delineation and impact to remedy protectiveness) that might complete the VIP in occupied buildings downgradient and generally east of the vapor intrusion differentiation boundary indicated on Figure 6. The reports should provide appropriate recommendations as they relate to such conditions.

6.2.4 HEXAVALENT CHROMIUM AS A CONTAMINANT OF CONCERN

Hexavalent chromium was not identified as a COC in the ROD. The inclusion of the compound as a COC in future documents would be characterized as "non-significant" or "minor" based on guidance for addressing post-ROD changes (USEPA 1999) since chromium and hexavalent chromium are, and will continue to be, included in the analytical program for OU 6 wells used as injection points. This change does not 1) significantly alter the scope of the remedy, 2) alter the performance of the RA to raise concerns about the protectiveness or long-term effectiveness of the remedy, or 3) significantly impact anticipated costs. Because permanganate has the potential to convert naturally-occurring trivalent chromium to hexavalent chromium, it is recommended that hexavalent chromium be identified as a COC in future work plans as well as in monitoring and FYR reports.

The monitoring program should continue to include total and hexavalent chromium analyses for groundwater samples collected from the monitoring wells utilized as injection points. This will provide the data necessary to estimate and document the oxidation state transition times from hexavalent to trivalent chromium.

7.0 PROTECTIVENESS STATEMENT

Protectiveness Statement	
Operable Unit:	*Protectiveness Determination:*
6	**Protective**

Protectiveness Statement:

The remedy identified in the Edwards Air Force Base Operable Unit 6 Record of Decision protects human health and the environment in the short-term, in the area impacted by the Operable Unit 6 contamination, because exposure pathways that could result in unacceptable risks are being controlled through institutional controls that are preventing exposure to, and the ingestion of, contamination in groundwater. In order for the remedy to be protective of groundwater resources and occupied buildings above or near the shallow groundwater plume in the long-term, the Operable Unit 6 groundwater contaminant plume will be completely delineated and changes in site conditions will be tracked and evaluated in annual land use control reports and remedy performance and groundwater monitoring reports.

The remedy for the Operable Unit 6 contamination is expected to be protective of human health and the environment upon completion. In the interim, remedial activities completed to date have adequately addressed all exposure pathways that could result in unacceptable risks. Other areas within the Operable Unit 6 administrative (lease) boundary are impacted by groundwater contamination from Site 25. Site 25 is undergoing a remedy selection process. Recommendations have been provided in this report to address protectiveness to areas within the Operable Unit 6 administrative boundary impacted by the Site 25 groundwater contamination.

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8.0 NEXT REVIEW

The next five-year review report for OU 6 is required five years from the completion date of this review.

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9.0 REFERENCES

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TABLES

TABLE 1. CHRONOLOGY OF SITE EVENTS

Date(s)	Site/Area	Event	Reference
1946 - Present	OU 6	Use, management, and disposal of hazardous substances/waste related to aircraft operations, testing, and maintenance.	Earth Tech 2000b
1988 – 1998	OU 6	Initial identification of contamination and remedial investigations.	Earth Tech 2000b
8/1990	OU 6	NPL listing.	Earth Tech 2000b
10/1990	Edwards AFB	entered into a FFA with the USEPA, California DTSC, and CRWQCB	Earth Tech 2000b
5/1992 – 2/1997	N3	GW extraction TS using a recovery trench.	RESNA 1992
1995 – 2004	OU 6	GW monitoring program.	Earth Tech 2004
5/1997 – 6/1997	N3	Dual extraction air sparging PS.	Rust 1997b
6/1997	N2	Dual extraction air sparging PS.	Rust 1997a
7/1997	N7	GW extraction PS.	Rust 1997c
10/1998 – 6/2001	N3	Dual extraction TS.	Earth Tech 2001b
11/1998 – 6/1999	N2	SV extraction and air sparging TS.	Earth Tech 2000a
10/1998 – 4/1999	N7	Dual extraction TS.	Earth Tech 2001c
8/2000	N7	Potassium permanganate ISCO TS.	Earth Tech 2004
6/2002 – 5/2003	N3	Fenton-based reagent and persulfate ISCO TS.	Earth Tech 2008
8/2004	OU 6	Feasibility Study complete.	Earth Tech 2004
4/2005	OU 6	Proposed Plan presented.	Earth Tech 2005
2/2008 – 5/2010	OU 6	RA design.	Earth Tech 2008 and AECOM 2010
5/2005 – 10/2006	N3 and N7	RA Pre-ROD (Phase I) implementation.	Earth Tech 2008
6/2005 – 7/2005	N3 and N7	Sodium permanganate ISCO TS.	Earth Tech 2008
4/2005 - 12/2006	OU 6	Proposed Plan public comment period and ROD signed.	Earth Tech 2005 and USAF 2006
10/2007 – 10/2008	N3 and N7	RA Post-ROD (Phase II) implementation through 2008.	Earth Tech 2009
9/2008 – 10/2010	N3 and N7	RA Post-ROD (Phase II) implementation through October 2010.	AECOM 2011a
3/2011 – 4/2011	OU 6	GW monitoring event.	AECOM 2012
5/2012 – 6/2012	OU 6	GW monitoring event.	AECOM 2012
6/2012 – 8/2013	N3 and N7	VIP investigation at Buildings 4806, 4807, and 4810.	AECOM 2016e
4/2015 – 7/2015	N1, N3, and N4	Installation of 10 GW monitoring wells.	Pending
6/2015 – 7/2015	OU 6	GW monitoring event.	AECOM 2016c
2/2016	N3	VIP investigation at Buildings 4806 and 4807.	AECOM 2016d

Notes:

AECOM AECOM Technical Services, Inc.
AFB Air Force Base
CRWQCB California Regional Water Quality Control Board
DTSC Department of Toxic Substances Control
Earth Tech Earth Tech, Inc.
FFA Federal Facility Agreement
GW groundwater
ISCO *in situ* chemical oxidation
NPL National Priorities List
OU operable unit
PS pilot study
RA remedial action
ROD Record of Decision
Rust Rust Environment & Infrastructure
SV soil vapor
TS treatability study
USAF United States Air Force
USEPA United States Environmental Protection Agency
VIP vapor intrusion pathway

TABLE 2. CONTAMINANTS OF CONCERN

COC	Historical COC Concentration[a] Minimum	Date	Maximum	Date	2015 Maximum Concentration	Cleanup Goal[b]
benzene	0.12	3/2001	19,000	7/2002	7,900	1
carbon tetrachloride	0.17	9/2001	7,400	7/2015	7,400	0.5
chloroform	0.12	9/2001	3,200	6/2002	1,300	80
1,2-dibromoethane[c]	0.55	9/2008	220	3/2002	8.5	0.05
1,1-dichloroethane	0.1	3/2001	100	6/2003	ND	5
1,2-dichloroethane	0.16	6/2010	310	7/2002	86	0.5
cis-1,2-dichloroethene	0.12	7/2015	14,000	6/2010	9,900	6
trans-1,2-dichloroethene	0.11	7/2015	42	5/2005	16	10
1,2-dichloropropane	0.17	9/2001	55	6/2003	ND	5
ethylbenzene	0.1	7/2015	2,100	3/2002	1,100	300
methylene chloride	0.2	9/2000	65,000	3/2011	ND	5
1,1,2,2-tetrachloroethane	1.7	4/2004	430	4/2004	25	1
toluene	0.13	9/2001	34,000	3/2002	2,800	150
1,1,2-trichloroethane	0.14	9/2000	54	9/2001	ND	5
trichloroethene	0.2	4/2004	83,000	7/2015	83,000	5
vinyl chloride	0.07	9/2003	200	6/2003	0.48	0.5
total xylenes	0.18	7/2015	7,300	6/2010	5,800	1,750

Notes:

All concentrations are presented in micrograms per liter.
Results do not include grab groundwater samples.
[a] Minimum and maximum concentrations detected during all sampling events.
[b] Cleanup goals are based upon Maximum Contaminant Levels (California Department of Public Health 2014).
[c] 1,2-dibromoethane is also known as ethylene dibromide.
COC contaminant of concern
ND not detected

TABLE 3. SUMMARY OF REMEDIAL ACTION ACTIVITIES

	Event	Date	Task	Documentation
	LUCs	September 2006 - Present	Enforcement of LUCs and Annual LUC reporting (Calendar Years 2007 to 2015)	95 ABW/EM 2008, 2009, 2010, and 2011 AFCEC/CZOW 2014, 2015, 2016
Phase I	Pre-ROD baseline monitoring	May 2005	Sampling of 39 wells	Appendix A of the *RAWP* (Earth Tech 2008)
Phase I	Pre-ROD injection event	June - July 2005	Injection at 12 wells	
Phase I	Pre-ROD well installation	September 2005	Installation of 2 wells	
Phase I	Pre-ROD performance monitoring	August - October 2006	Sampling of 36 wells	
Phase II	Baseline monitoring	October - November 2007	Sampling of 38 wells	IRACR for Phase II Injection Event I of III (Earth Tech 2009)
Phase II	Injection Event I	March 2008	Injection at 21 wells	
Phase II	Injection well installation	August and December 2008	Installation of 7 wells (4 wells [August] and 3 wells [December])	
Phase II	First performance monitoring	September - October 2008	Sampling of 46 wells	
Phase II	Injection well installation	September 2009	Installation of 3 wells	IRACR for Phase II Injection Event II of III (AECOM 2011a)
Phase II	Monitoring well installation	May 2010	Installation of 6 wells	
Phase II	Second performance monitoring	June - July 2010	Sampling of 46 wells	
Phase II	Injection Event II	August 2010	Injection at 10 wells	
Current Reporting Period	Third performance monitoring	March - April 2011	Sampling of 62 wells	RPGMR - 2011-2012 (AECOM 2012)
Current Reporting Period	Fourth performance monitoring	May - June 2012	Sampling of 59 wells	
Current Reporting Period	Monitoring well installation	August 2012	Installation of 2 wells	
Current Reporting Period	Vapor intrusion pathway investigation	March - August 2013	Soil vapor and indoor air sampling at Buildings 4806, 4807, and 4810	Vapor Intrusion Investigation Report (AECOM 2016e)
Current Reporting Period	Site 25 monitoring well sampling	November 2013 and March 2014	Sampling of 18 Site 25 monitoring wells on Rogers Dry Lake	Site 25 Remedial Investigation Report Addendum No. 2 (AECOM 2016a)
Current Reporting Period	Monitoring well installation	April 2015	Installation of 10 wells	Pending groundwater investigation report.
Current Reporting Period	Fifth performance monitoring	June - July 2015	Sampling of 72 wells	RPGMR - 2015 (AECOM 2016c)

TABLE 3. SUMMARY OF REMEDIAL ACTION ACTIVITIES
(Page 2 of 2)

	Event	Date	Task	Documentation
Current Reporting Period	Vapor intrusion pathway investigation	February 2016	Soil vapor and indoor air sampling at Buildings 4806 and 4807	Vapor Intrusion Investigation Report Addendum (AECOM 2016d)

Notes:

All injections utilized sodium permanganate solution.
First performance monitoring event is documented in the *IRACR for Phase II, Injection Event I of III* and the *IRACR for Phase II, Injection Event II of III*.

95 ABW/EM	95th Air Base Wing, Environmental Management Directorate
AECOM	AECOM Technical Services, Inc.
AFCEC/CZOW	Air Force Civil Engineer Center, Environmental Restoration Program Installation Support Team – West
Earth Tech	Earth Tech, Inc.
IRACR	Interim Remedial Action Completion Report
LUC	land use control
RPGMR	Remedy Performance and Groundwater Monitoring Report
RAWP	Remedial Action Work Plan
ROD	Record of Decision

TABLE 4. STATUS OF RECOMMENDATIONS FROM THE FIRST FIVE-YEAR REVIEW
(Page 1 of 3)

Issue	Recommendations	Current Status	Current Implementation Status Description
Site 25 upgradient groundwater contamination	Semiannual monitoring of the Site 25 plume will continue under a separate project. Data will be used to estimate the plume extent, capture, and migration characteristics.	Ongoing	Monitoring of the Site 25 plume will continue under a separate project and data will be used to estimate the plume extent, capture, and migration characteristics. Additionally, under the Site 25 project, a VIP investigation was performed at two buildings at OU 6 and no significant risks were identified.
Plume delineation data gap at the leading edge	Additional monitoring wells will be installed and modeling performed to completely delineate the leading edge of the plume and monitor and predict cleanup progress. Additional ISCO treatment may be required at the leading edge. Recommended future step-out monitoring wells include locations south of existing monitoring wells N4-MW04, N4-MW05, N4-MW11, N4-MW12, N4-MW13, and N7-MW13. Other recommended monitoring wells include locations west of N1-MW08 and N1-MW10.	10 monitoring wells installed 2015. Additional delineation effort scheduled for 2017	New groundwater monitoring wells were installed, and TCE was detected in groundwater samples collected from the furthest downgradient wells. The data indicated that the plume extends beyond the monitored area and a data gap still exists. To further address the apparent gaps in groundwater plume data, a series of direct-push boreholes will be advanced, grab groundwater samples will be collected, and additional wells will be installed on Rogers Dry Lake.
Changes in vapor intrusion pathway risk assessments	Methodologies for determining risk to indoor air from subsurface contaminants has been revised since the ROD was signed. An evaluation of the updated VIP guidance methodologies as they relate to site conditions will be performed. The evaluation may result in a field investigation.	Complete	Updated VIP guidance methodologies were employed to perform a risk assessment of the VIP at three OU 6 buildings in 2013 and 2016. An updated HHRA for the groundwater plume was performed during the assessment. No unacceptable risks from groundwater contamination to building occupants were identified.
Determine risk associated with naphthalene and ethylbenzene	Because of changes in the toxicity criteria (e.g., naphthalene and ethylbenzene), recalculate the residential health risk and assess the need to take additional action to meet RAOs.	Complete	An updated HHRA for the groundwater plume was performed. No additional action to meet RAOs was recommended.

TABLE 4. STATUS OF RECOMMENDATIONS FROM THE FIRST FIVE-YEAR REVIEW
(Page 2 of 3)

Issue	Recommendations	Current Status	Current Implementation Status Description
Remedy operation and maintenance	Update LUC boundary in the GIS as necessary. Continue adherence to review and approve procedures for construction and ground-disturbing activities. Perform well maintenance, including well completion repairs and well labeling with identification tags. Continue ISCO in the areas with the highest VOC concentrations at Sites N3, N4, and N7 and groundwater monitoring for NDMA, metals (including total and hexavalent chromium), and VOCs are recommended. Conduct tracer testing with ISCO injections.	Ongoing	Continued revision of the LUC boundary in the GIS continued during the reporting period and included LUC boundary updates as determined by the estimated areal extents of the benzene, CT, and TCE groundwater plumes. Well maintenance was performed during the reporting period. Although groundwater monitoring activities were performed during the reporting period, ISCO-related activities were not. The next injection event will be performed at Sites N3 and N7 in 2017. Redevelopment of wells critical for use as active injection points which do not readily accept reagent will be performed, as necessary. Fenton's reagent or persulfate treatment will be employed for CT treatment as necessary. *In lieu* of including a tracer in the reagent during future injection events, the USAF and NASA agreed that, should pressurized ISCO injection be employed, only wells greater than 100 feet from occupied buildings will be utilized.
Shutdown of ERP information exchange website	Re-establish an ERP information exchange website.	Complete	In 2012, an information exchange was established on Facebook social media to provide reports to stakeholders and announcements at: www.facebook.com/RAB.Edwards.

TABLE 4. STATUS OF RECOMMENDATIONS FROM THE FIRST FIVE-YEAR REVIEW
(Page 3 of 3)

Issue	Recommendations	Current Status	Current Implementation Status Description
Plume boundaries and ISCO implementation	Establishing an artificial plume boundary to support mass removal estimates and ISCO treatment in the Site N4 area was recommended as during the first five-year review.	2021	A Site N4 artificial plume boundary will be established following complete groundwater contaminant plume delineation.

Notes:

CT carbon tetrachloride
e.g. *exempli gratia,* for example
ERP Environmental Restoration Program
GIS geographic information system
HHRA human health risk assessment
ISCO *in situ* chemical oxidation
LUC land use control
NASA National Aeronautics and Space Administration
NDMA N-nitrosodimethylamine
OU Operable Unit
RAO remedial action objective
ROD Record of Decision
TCE trichloroethene
VIP vapor intrusion pathway
VOC volatile organic compound

TABLE 5. DOCUMENTS REVIEWED
(Page 1 of 2)

Document	Reference	Purpose of Document	Use During the Five-Year Review
Feasibility Study	Earth Tech 2004	Analysis of alternatives for the remedial approach	RA approach, plume configurations, and mass/volume calculations
Record of Decision	USAF 2006	Documentation of remedial decision	Goals of the remedy, site background, basis for action, cleanup levels, and ARARs
Remedial Action Work Plan	Earth Tech 2008	RA design	Modifications to the RA for comparison to original assumptions
Remedial Action Work Plan Addendum	AECOM 2010		
Basewide LUC Implementation Plan	Earth Tech 2007	Basewide LUC implementation	LUC implementation
Annual LUC Report	95 ABW/EM 2008	LUC status documentation	Status of LUCs for 2007 Calendar Year
	95 ABW/EM 2009		Status of LUCs for 2008 Calendar Year
	95 ABW/EM 2010		Status of LUCs for 2009 Calendar Year
	95 ABW/EM 2011		Status of LUCs for 2010 Calendar Year
	AFCEC/CZOW 2014		Status of LUCs for 2011 through 2013 Calendar Years
	AFCEC/CZOW 2015		Status of LUCs for 2014 Calendar Year
	AFCEC/CZOW 2016		Status of LUCs for 2015 Calendar Year
Interim Remedial Action Completion Report, Injection Event I of III	Earth Tech 2009	RA design, construction, and functionality of the RA, and documentation of progress to completion	History of the RA, plume status, and performance versus expectations information
Interim Remedial Action Completion Report, Injection Event II of III	AECOM 2011a		
RPGMR - 2011-2012	AECOM 2012	Monitoring well installation and sampling documentation	Plume status and performance versus expectations information
Vapor Intrusion Investigation Report	AECOM 2016e	Risk assessment and documentation of soil vapor and indoor air sampling at Buildings 4806, 4807, and 4810	Risk assessment
Addendum to First Five-Year Review Report	AECOM 2016b	Acknowledgement of issues affecting protectiveness at OU 6	Assessment of the status of issues affecting protectiveness

TABLE 5. DOCUMENTS REVIEWED
(Page 2 of 2)

Document	Reference	Purpose of Document	Use During the Five-Year Review
Site 25 VIP Investigation Report - Buildings 4824 and 4870	AECOM 2014	Risk assessment related to Site 25 and documentation of soil vapor and indoor air sampling at Buildings 4824 and 4870	Risk assessment
Site 25 Remedial Investigation Report Addendum No. 2	AECOM 2016a	Groundwater investigation related to Site 25	Plume status on Rogers Dry Lake
RPGMR - 2015	AECOM 2016c	Monitoring well installation and sampling documentation	Plume status and performance versus expectations information
Vapor Intrusion Investigation Report Addendum	AECOM 2016d	Risk assessment and documentation of soil vapor and indoor air sampling at Buildings 4806 and 4807	Risk assessment

Notes:

95 ABW/EM	95th Air Base Wing, Environmental Management Directorate
AECOM	AECOM Technical Services, Inc.
AFCEC/CZOW	Air Force Civil Engineer Center, Environmental Restoration Program Installation Support Team – West
ARAR	applicable or relevant and appropriate requirement
Earth Tech	Earth Tech, Inc.
LUC	land use control
No.	number
OU	operable unit
RA	remedial action
RPGMR	Remedy Performance and Groundwater Monitoring Report
USAF	United States Air Force
VIP	vapor intrusion pathway

TABLE 6. TOXICITY CRITERIA FOR VAPOR INTRUSION PATHWAY-RELATED CHEMICALS

Analyte	EPA-Recommended Cancer IUR ($\mu g/m^3$)$^{-1}$	EPA-Recommended Cancer IUR Date Revised	EPA-Recommended Non-cancer RfC (mg/m^3)	EPA-Recommended Non-cancer RfC Date Revised	OEHHA IUR ($\mu g/m^3$)$^{-1}$	OEHHA IUR Date Revised	OEHHA RfC (mg/m^3)	OEHHA RfC Date Revised
1,2,4-trimethylbenzene	---	---	---	---	---	---	---	---
2-butanone (MEK)	---	---	5.0E+00	**9/26/2003**	---	---	---	---
4-ethyltoluene	---	---	---	---	---	---	---	---
4-methyl-2-pentanone (MIBK)	---	---	3.0E+00	**4/25/2003**	---	---	---	---
acetone	---	---	3.1E+01[(1)]	---	---	---	---	---
benzene	7.8E-06	1/19/2000	3.0E-02	**4/17/2003**	2.9E-05	1984	3.0E-03	**2014**
carbon disulfide	---	---	7.0E-01	8/1/1995	---	---	8.0E-01[(3)]	**2008**
cyclohexane	---	---	6.0E+00	**9/11/2003**	---	---	---	---
dichlorodifluoromethane	---	---	1.0E+01[(2)]	---	---	---	---	---
ethanol	---	---	---	---	---	---	---	---
ethylbenzene	---	---	1.0E+00	3/1/1991	2.5E-06	**2007**	2.0E+00	**2008**
isopropanol	---	---	2.0E-01[(2)]	**9/16/2014**	---	---	---	---
isopropylbenzene (cumene)	---	---	4.0E-01	8/1/1997	---	---	---	---
n-heptane	---	---	---	---	---	---	---	---
n-hexane	---	---	7.0E-01	**12/23/2005**	---	---	---	---
naphthalene	3.4E-05[(4)]	---	3.0E-03	9/17/1998	3.4E-05	**2009**	9.0E-03	**2008**
p-isopropyltoluene	---	---	---	---	---	---	---	---
styrene	---	---	1.0E+00	11/1/1992	---	---	9.0E-01	**2008**
tetrahydrofuran	---	---	2.0E+00	**2/21/2012**	---	---	---	---
xylenes	---	---	1.0E-01	2/21/2003	---	---	---	---

Notes:

Dates for criteria adopted since the Operable Unit 6 Baseline *Human Health Risk Assessment* (AECOM 2003) are shown in bold.

(1) ATSDR as listed in USEPA RSLs

(2) PPRTV as listed in USEPA RSLs

(3) HERO recommends use of IRIS values in lieu of the OEHHA toxicity criteria.

(4) Value from OEHHA but has been adopted by the USEPA for use in RSLs.

--- not applicable

($\mu g/m^3$)$^{-1}$ per micrograms per cubic meter

IRIS Integrated Risk Information System

IUR inhalation unit risk

mg/m^3 milligrams per cubic meter

OEHHA Office of Environmental Health Hazard Assessment

RfC reference concentration

TABLE 7. MAXIMUM CUMULATIVE INDOOR AIR RISK FROM VAPOR INTRUSION PATHWAY-RELATED CHEMICALS

		Cancer Risk		Non-cancer Hazard	
Building	Event	USAF/CERCLA Approach	DTSC-Preferred Approach	USAF/CERCLA Approach	DTSC-Preferred Approach
4806	March 2013	1E-06	4E-06	0.02	0.1
	August 2013	1E-06	2E-06	0.04	0.08
	February 2016	3E-07	1E-06	0.01	0.04
4807	March 2013	---	---	<0.01	<0.01
	August 2013	8E-07	3E-06	<0.01	0.09
	February 2016	4E-07	2E-06	<0.01	0.05
Maximum per approach:		1E-06	4E-06	0.04	0.1

Notes:

Results for the March and August 2013 vapor intrusion investigation at Building 4810 are not included as the building was demolished in September 2014.

--- No vapor intrusion pathway-related cancer risk identified.
CERCLA Comprehensive Environmental Response, Compensation, and Liability Act
DTSC Department of Toxic Substances Control
USAF United States Air Force

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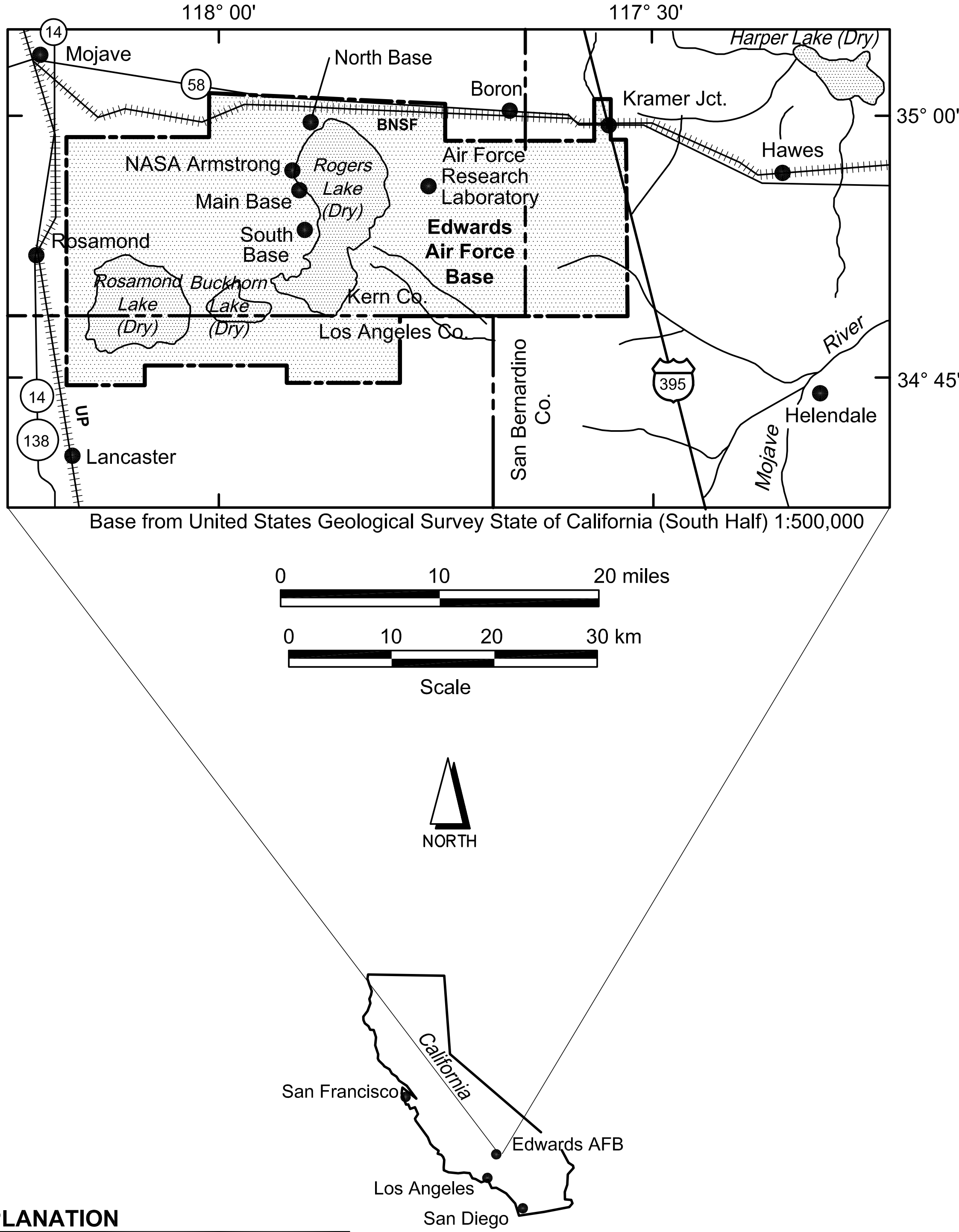
FIGURES



EXPLANATION

AFB = AIR FORCE BASE
BNSF = BURLINGTON NORTHERN SANTA FE
Co. = COUNTY
Jct. = JUNCTION
NASA = NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
UP = UNION PACIFIC
= COUNTY LINE
= RAILROAD
(58) = STATE HIGHWAY
(395) = INTERSTATE HIGHWAY

Edwards Air Force Base Location Map		
Date 09-2016	Second Five-Year Review Report	Figure
Project No. 60444679	Operable Unit 6 Edwards AFB	1

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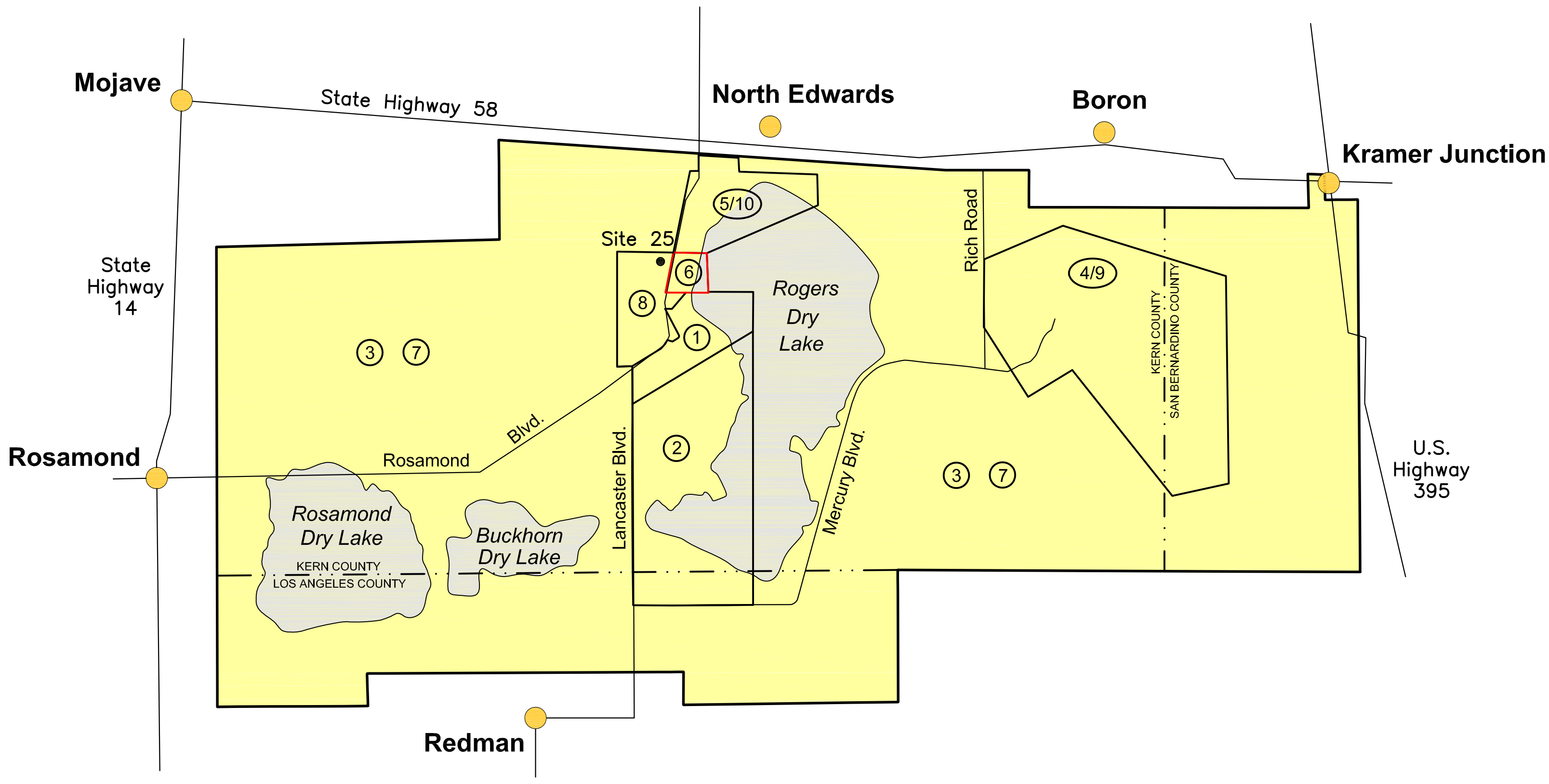

Operable Units

①/⑧ **Main Base Flightline/Northwest Main Base**	(actual or *planned* date of ROD)
-all sites	*2020*
② **South Base**	
-Sites 5, 14, 29, 69, 76, 78, 79, 86, 96, 417	2009
③ **Basewide Water Wells**	
-all sites	2003
(4/9) **AFRL and AFRL-East**	
-South AFRL (Sites 37, 120, 133, 321)	2007
-AFRL soil and debris sites	2008
-AFRL Arroyos (Sites 36, 162, and 461)	*2016*
-Northeast AFRL (Sites/AOCs 115, 116, 118, 177/325, 318, and 178)	*2018*
-Mars Blvd. (Sites 27, 125, 127, 167, 333)	*2018*
(5/10) **North Base**	
-all sites	*2019*
⑥ **NASA Armstrong**	
-Sites N2, N3, N7	2006
⑦ **Basewide Miscellaneous**	
-CWM Sites 442 and 426	2009
-non-CWM Site 3	2012
-non-CWM Sites	*2020*
⑧ **Northwest Main Base**	
-Site 25	*2019*

NORTH

0 5 Miles

NOTES

1. PLANNED DATES IN ITALICS.
2. DATA PROJECTED IN NAD 83 CA STATE PLANE ZONE 5 US SURVEY FEET.

ABBREVIATIONS

~	APPROXIMATELY
AFRL	AIR FORCE RESEARCH LABORATORY
AOC	AREA OF CONCERN
BLVD.	BOULEVARD
CWM	CHEMICAL WARFARE MATERIEL
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ROD	RECORD OF DECISION

Operable Unit Location Map

Date 09-2016	Second Five-Year Review Report	Figure
Project No. 60444679	Operable Unit 6 Edwards AFB	2

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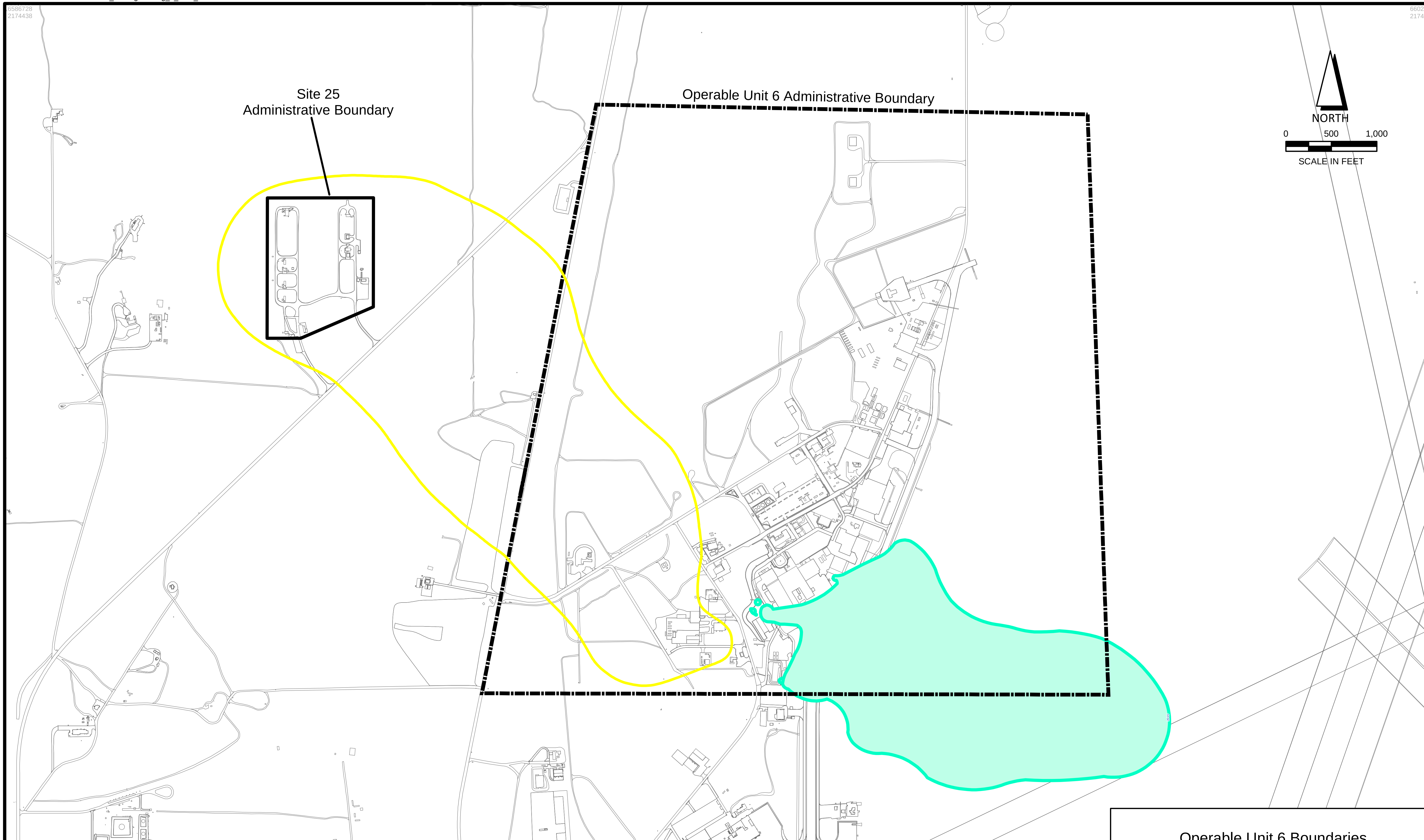

EXPLANATION

OPERABLE UNIT 6 PLUME BOUNDARY AND CURRENT LAND USE CONTROL BOUNDARY

OPERABLE UNIT 6 PLUME AREA AND THE SUBJECT OF THE OPERABLE UNIT 6 REMEDIAL ACTION

SITE 25 PLUME BOUNDARY

Operable Unit 6 Boundaries

Date 09-2016	Second Five-Year Review Report	Figure
Project No. 60444679	Operable Unit 6 Edwards AFB	3

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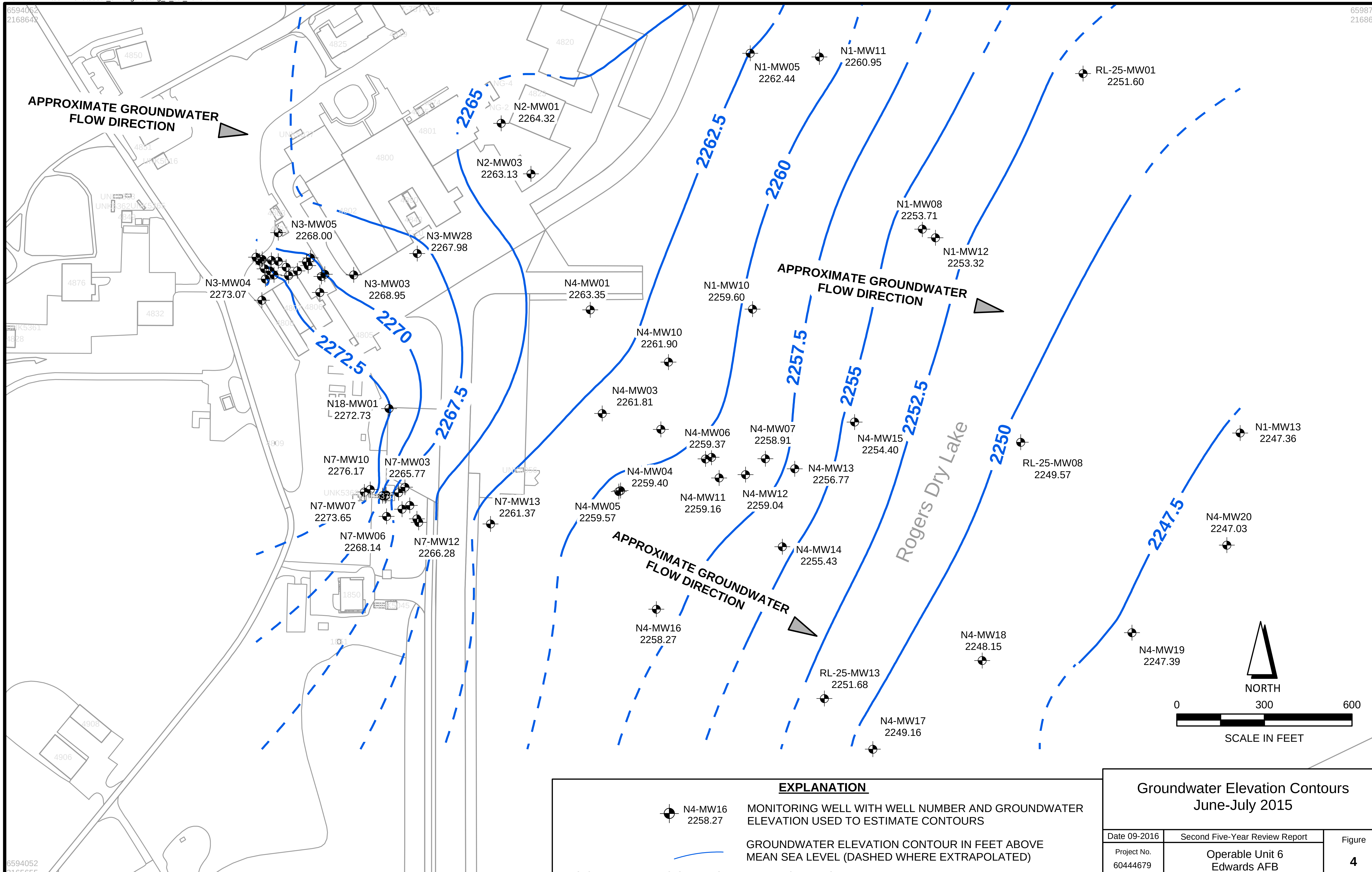

EXPLANATION

N4-MW16 2258.27 — MONITORING WELL WITH WELL NUMBER AND GROUNDWATER ELEVATION USED TO ESTIMATE CONTOURS

GROUNDWATER ELEVATION CONTOUR IN FEET ABOVE MEAN SEA LEVEL (DASHED WHERE EXTRAPOLATED)

GROUNDWATER ELEVATIONS ARE PRESENTED IN FEET ABOVE MEAN SEA LEVEL.

Groundwater Elevation Contours
June-July 2015

Date 09-2016	Second Five-Year Review Report	Figure
Project No. 60444679	Operable Unit 6 Edwards AFB	4

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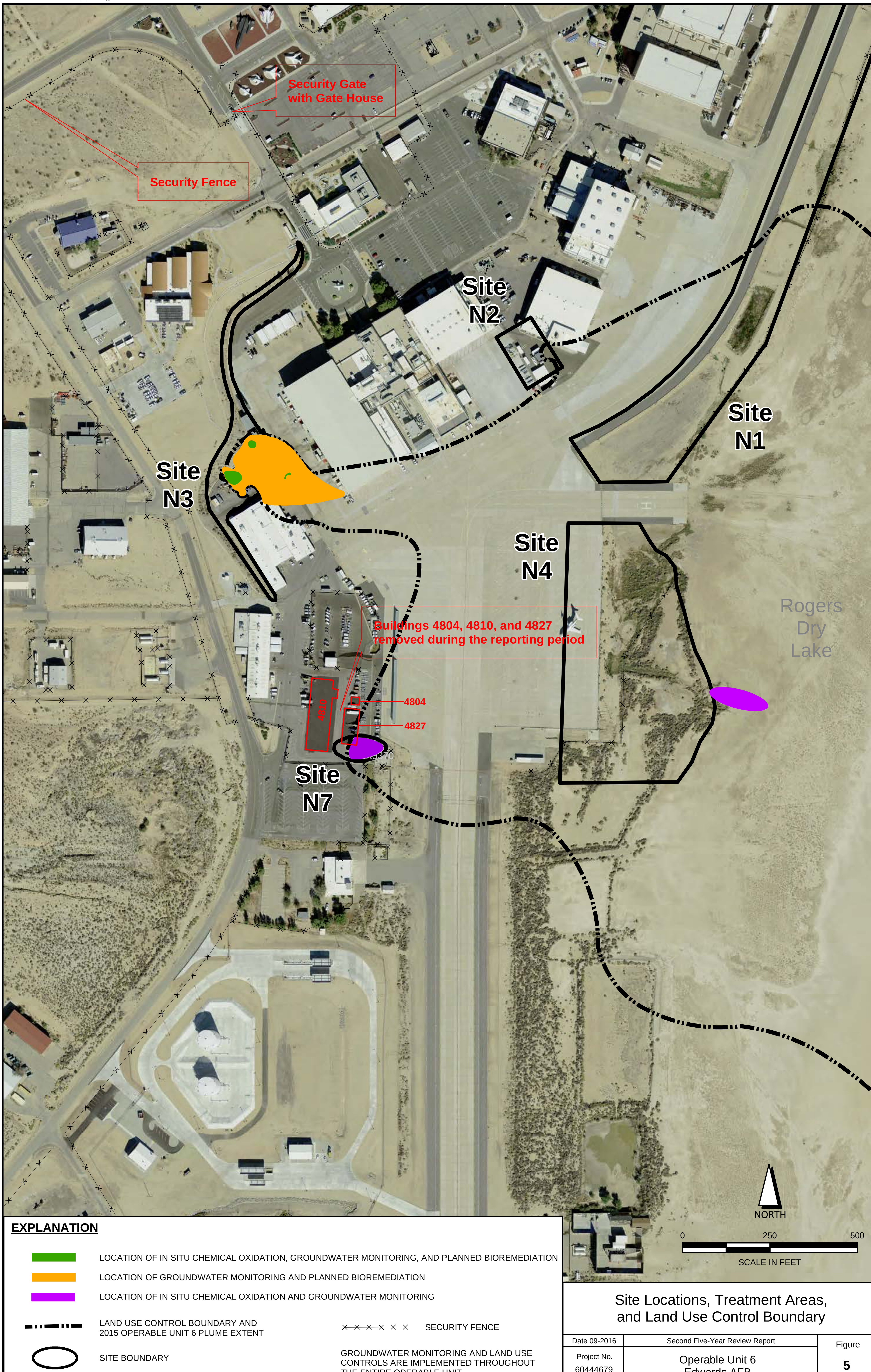

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EXPLANATION

N4-MW10 46	OU 6 MONITORING WELL LOCATION (USED FOR INJECTION IN AUGUST 2010) AND TCE CONCENTRATION
N4-MW16 370	MONITORING WELL LOCATION AND TCE CONCENTRATION
25-EW01 67	SITE 25 EXTRACTION WELL LOCATION AND TCE CONCENTRATION
(green)	BUILDING INCLUDED IN VAPOR INTRUSION PATHWAY INVESTIGATION
(blue)	OCCUPIED BUILDING LOCATED BETWEEN THE 5- AND 100-UG/L GROUNDWATER TCE CONCENTRATION CONTOURS AT SITE 25
50	GROUNDWATER TCE CONCENTRATION CONTOUR (INTERVALS = 5, 50, 100, AND 500 FOR OU 6 AND 5, 10, 100, 1,000, 5,000, AND 10,000 FOR SITE 25 [SITE 25 CONTOURS AS PRESENTED IN THE SITE 25 FEASIBILITY STUDY]); ALL CONCENTRATIONS PRESENTED IN UG/L
	DIFFERENTIATION BOUNDARY BETWEEN OU 6 AREA OF VAPOR INTRUSION RESPONSIBILITY AND SITE 25 AREA OF VAPOR INTRUSION RESPONSIBILITY

< INDICATES THAT TCE WAS BELOW THE REPORTING LIMIT SHOWN.
UG/L MICROGRAMS PER LITER
OU OPERABLE UNIT
TCE TRICHLOROETHENE

N4-MW01* - TCE CONCENTRATION AT THIS WELL WAS BELOW 5 UG/L AND SURROUNDING TCE CONCENTRATIONS EXCEEDED 10 UG/L.

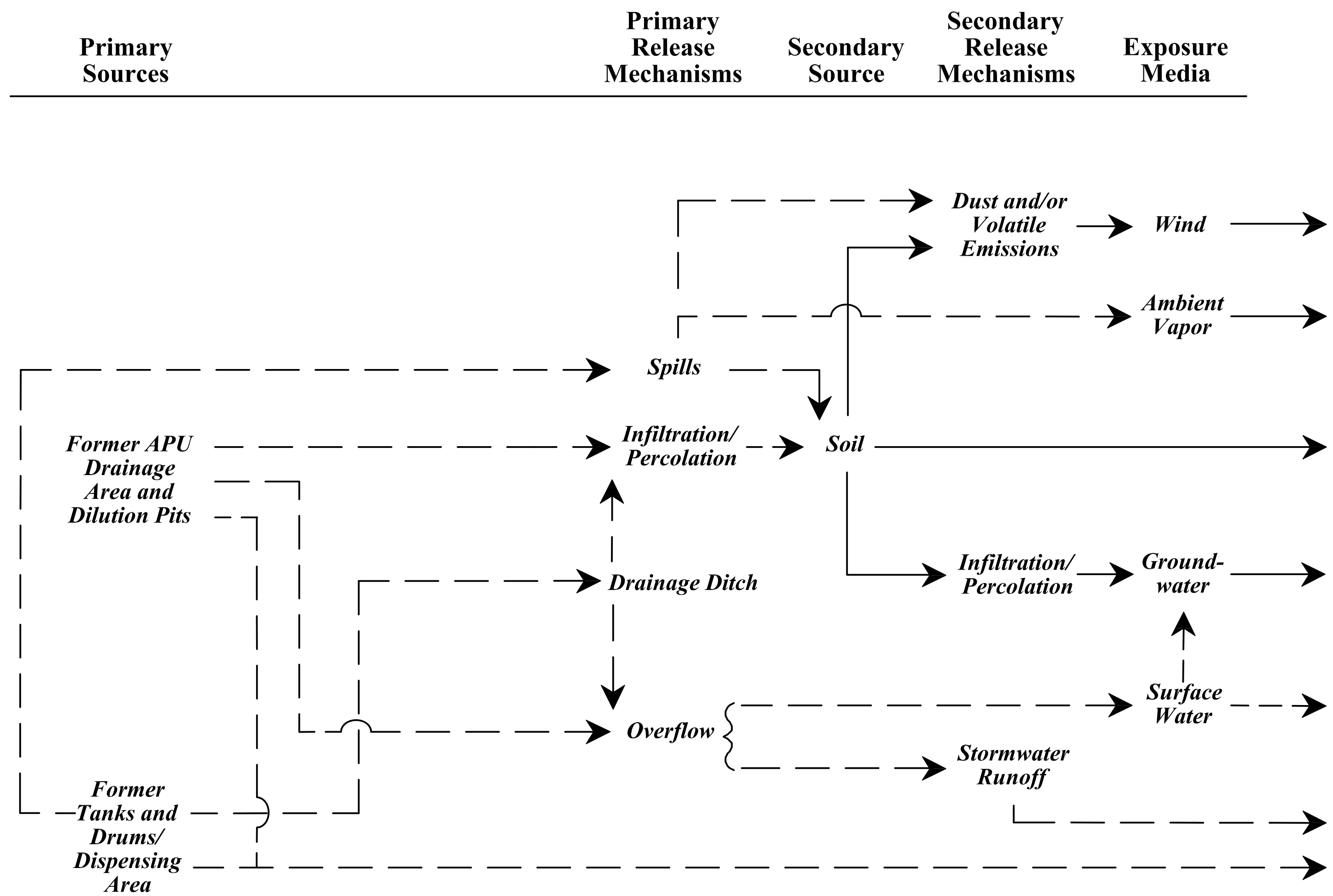
CURRENT DATA TOOK PRIORITY OVER HISTORICAL DATA IN ESTIMATING CONTOURS.

MOST RECENT SAMPLING DATES ARE PRESENTED FOR OU 6 WELLS NOT SAMPLED DURING THE JUNE-JULY 2015 EVENT AND FOR SITE 25 WELLS NOT SAMPLED DURING THE AUGUST-SEPTEMBER 2014 EVENT.

SCREEN INTERVALS ARE PRESENTED IN FEET BELOW GROUND SURFACE.

TCE Groundwater Concentration Contours - June-July 2015

Date 09-2016	Second Five-Year Review Report	Figure
Project No. 60444679	Operable Unit 6 Edwards AFB	6



		Receptor						
	Human						Ecological	
Exposure Route	Current Industrial	Future Industrial	Future Construction	Future Res/Sens	Risk Mgt. Decisions/RA		Terrestrial	Aquatic
Inhalation	Yes[1]	Yes[2]	Yes[2]	Yes[2]	a		No[3]	No[3]
Inhalation	No[4]	No[4]	No[4]	No[4]			No[4]	No[4]
Ingestion	Yes[1]	Yes[2]	Yes[2]	Yes[2]	a		No[3]	No[3]
Dermal Contact	Yes[1]	Yes[2]	Yes[2]	Yes[2]	a		No[3]	No[3]
Ingestion	No[3]	No[3]	No[3]	Yes[2]	b		No[3]	No[3]
Inhalation-Amb	No[3]	No[3]	No[3]	Yes[2]	b		No[3]	No[3]
Inhalation-VIP	Yes[1]	Yes[2]	Yes[2]	Yes[2]			No[3]	No[3]
Dermal Contact	No[3]	No[3]	No[3]	Yes[2]	b		No[3]	No[3]
Ingestion	No[4]	No[4]	No[4]	No[4]			No[4]	No[4]
Inhalation	No[4]	No[4]	No[4]	No[4]			No[4]	No[4]
Dermal Contact	No[4]	No[4]	No[4]	No[4]			No[4]	No[4]
Ingestion	No[4]	No[4]	No[4]	No[4]			No[4]	No[4]
Inhalation	No[4]	No[4]	No[4]	No[4]			No[4]	No[4]
Dermal Contact	No[4]	No[4]	No[4]	No[4]			No[4]	No[4]

EXPLANATION

YELLOW HIGHLIGHTS INDICATE PATHWAY RETAINED FOR A CERCLA RESPONSE

GRAY SHADING INDICATES PATHWAYS NOT RETAINED EITHER BECAUSE PATHWAY DOES NOT EXIST OR RISKS ARE WITHIN ACCEPTABLE LIMITS

— — → PATHWAY NO LONGER EXISTS

ABBREVIATIONS

Amb	AMBIENT AIR
APU	AUXILIARY PROPULSION UNIT
CERCLA	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT
DIR	DIRECT
MGT.	MANAGEMENT
PAH	POLYCYCLIC AROMATIC HYDROCARBON
RA	REMEDIAL ACTION
RES/SENS	RESIDENTIAL/SENSITIVE USE
VIP	VAPOR INSTRUSION PATHWAY

NOTES

CURRENT AND FUTURE, AS USED IN THIS FIGURE, ARE DEFINED RELATIVE TO THE POINT AT WHICH THE RECORD OF DECISION WAS SIGNED.

[1] COMPLETE PATHWAY
[2] POTENTIAL PATHWAY, CURRENTLY INCOMPLETE
[3] INCOMPLETE PATHWAY, LAND USE CONTROLS IN PLACE
[4] INCOMPLETE, NOT APPLICABLE BECAUSE PATHWAY NO LONGER EXISTS

RISK MGT. DECISIONS/RA:

a. ORGANIC LEAD AND PAH RISK DRIVERS FOR SOIL. ORGANIC LEAD DETECTIONS WERE SUSPECT; ELIMINATED AS A RISK DRIVER. PAHS DETECTED IN SHALLOW SOIL SAMPLES COLLECTED BENEATH ASPHALT; PAHS LIKELY ASSOCIATED WITH ASPHALT; PAHS NOT PART OF ORIGINAL CERCLA RELEASE.

b. ADDRESSED BY RA: TREATMENT, LAND USE CONTROL.

Operable Unit 6 Exposure Pathways

Date 09-2016	Second Five-Year Review Report	Figure
Project No. 60444679	Operable Unit 6 Edwards AFB	7

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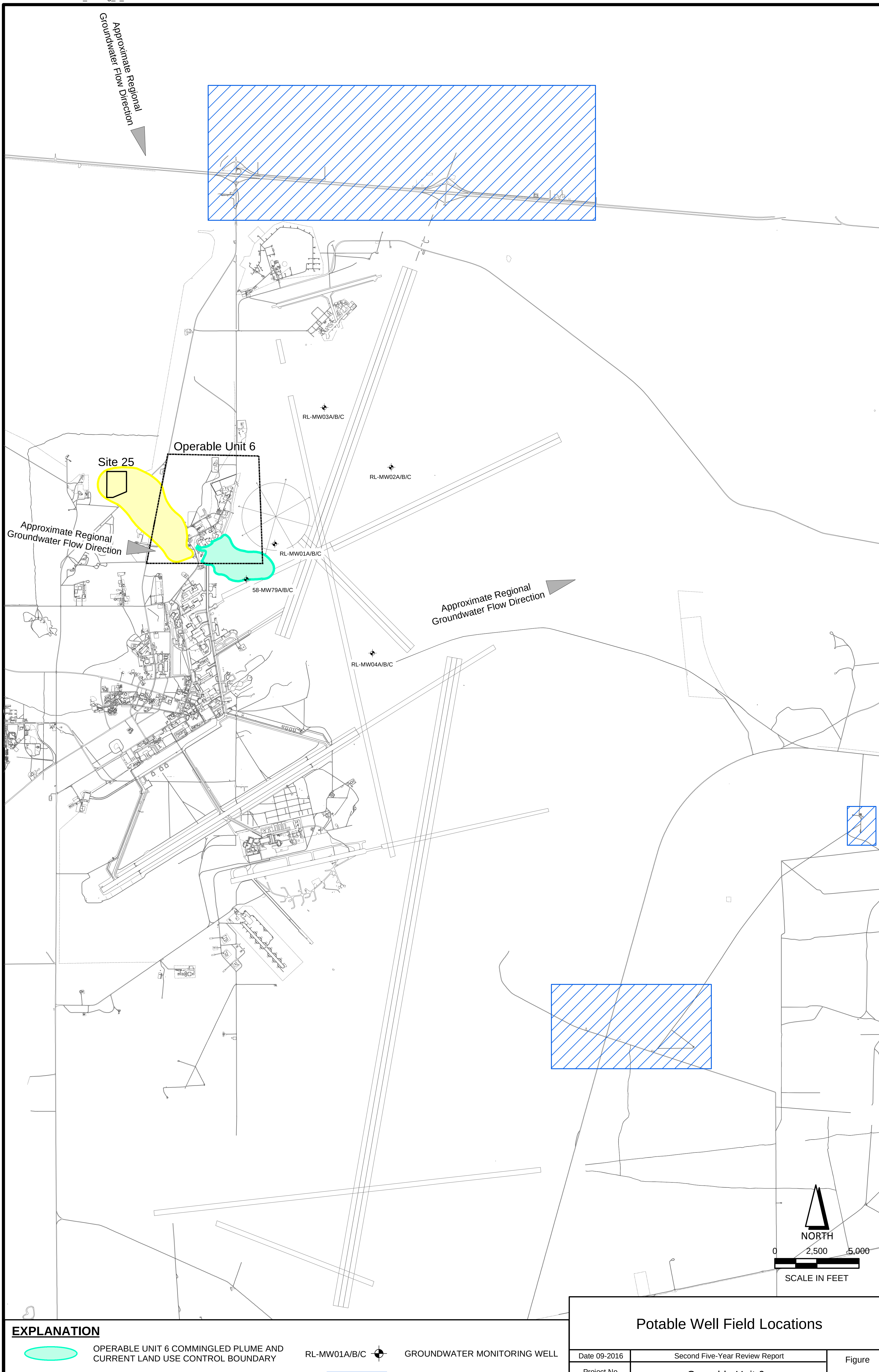

EXPLANATION

OPERABLE UNIT 6 COMMINGLED PLUME AND CURRENT LAND USE CONTROL BOUNDARY	RL-MW01A/B/C GROUNDWATER MONITORING WELL
SITE 25 TRICHLOROETHENE PLUME	POTABLE WELL FIELD

Potable Well Field Locations

Date 09-2016	Second Five-Year Review Report	Figure
Project No. 60444679	Operable Unit 6 Edwards AFB	8

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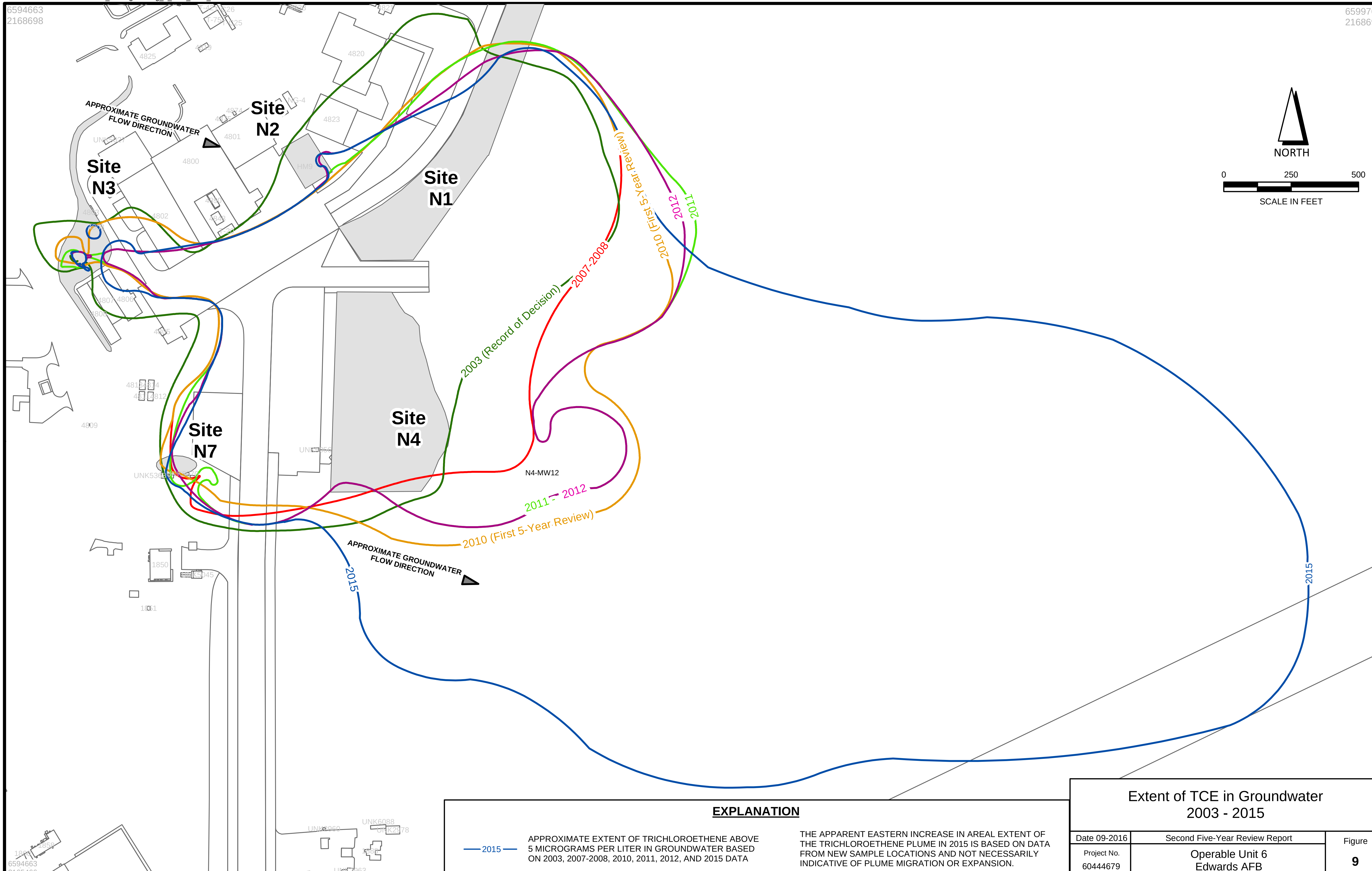

EXPLANATION

2015 — APPROXIMATE EXTENT OF TRICHLOROETHENE ABOVE 5 MICROGRAMS PER LITER IN GROUNDWATER BASED ON 2003, 2007-2008, 2010, 2011, 2012, AND 2015 DATA

THE APPARENT EASTERN INCREASE IN AREAL EXTENT OF THE TRICHLOROETHENE PLUME IN 2015 IS BASED ON DATA FROM NEW SAMPLE LOCATIONS AND NOT NECESSARILY INDICATIVE OF PLUME MIGRATION OR EXPANSION.

Extent of TCE in Groundwater 2003 - 2015

Date 09-2016	Second Five-Year Review Report	Figure
Project No. 60444679	Operable Unit 6 Edwards AFB	9

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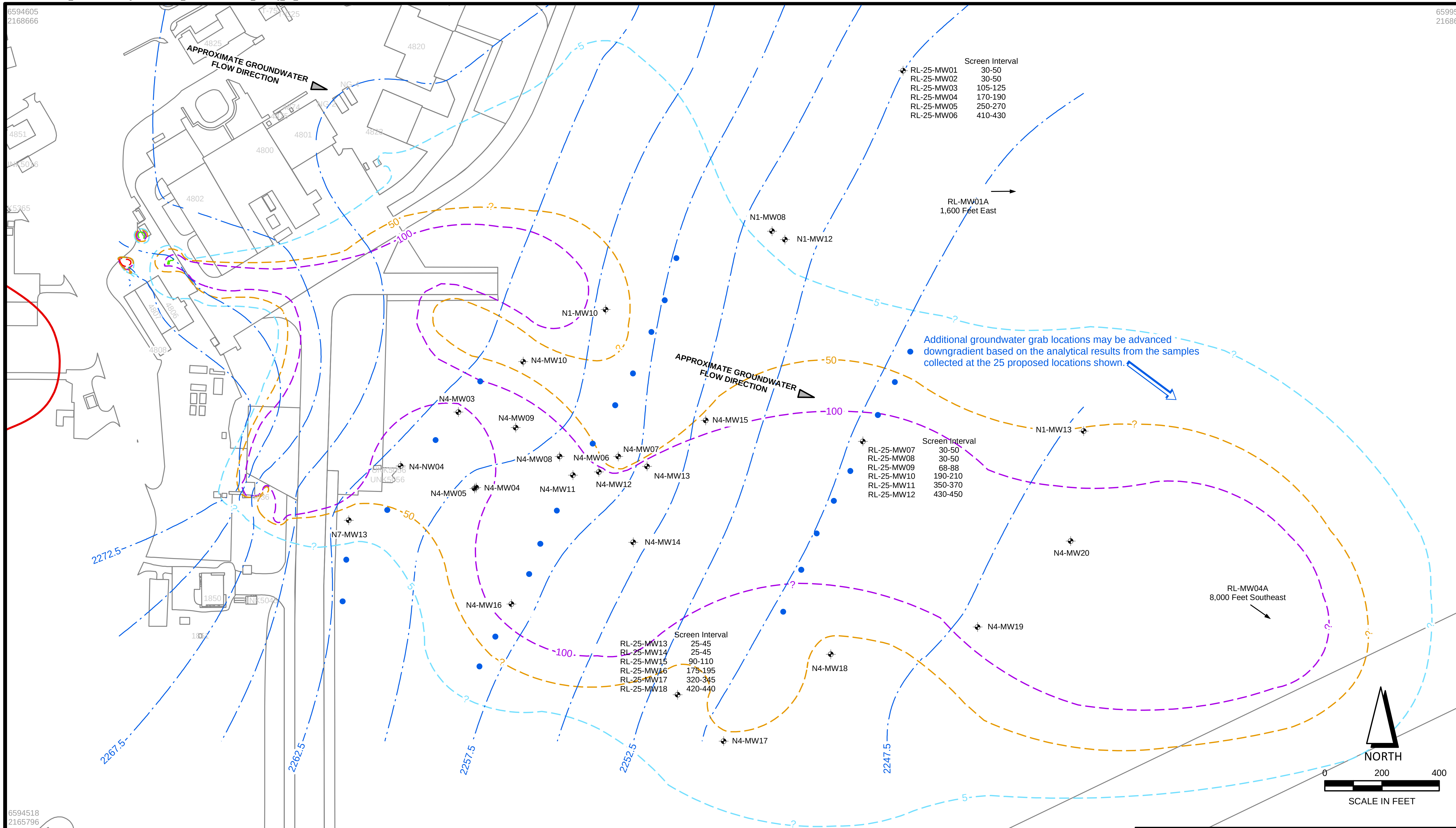

EXPLANATION

N4-MW16 MONITORING WELL LOCATION

PROPOSED DIRECT PUSH GROUNDWATER SAMPLE LOCATION

GROUNDWATER ELEVATION CONTOUR IN FEET ABOVE MEAN SEA LEVEL

APPROXIMATE EXTENT OF SITE 25 TRICHLOROETHENE (TCE) PLUME

50 GROUNDWATER TCE CONCENTRATION CONTOUR (INTERVALS = 5, 50, 100, 500) ALL CONCENTRATIONS PRESENTED IN MICROGRAMS PER LITER (UG/L)

SCREEN INTERVALS ARE PRESENTED IN FEET BELOW GROUND SURFACE.

Proposed Groundwater Sample Locations

Date 09-2016	Second Five-Year Review Report	Figure
Project No. 60444679	Operable Unit 6 Edwards AFB	10

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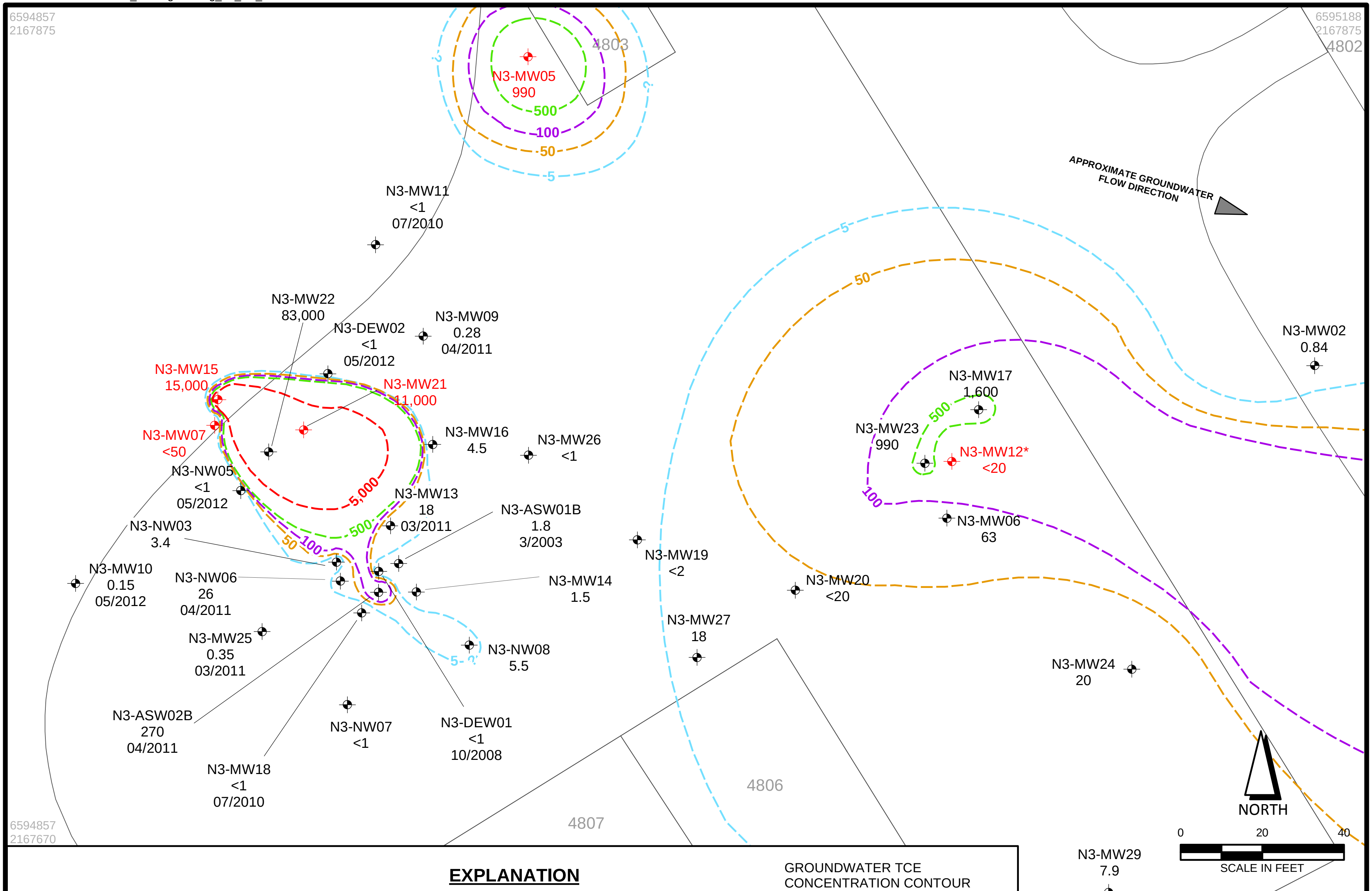

EXPLANATION

N3-MW23 990 — MONITORING WELL LOCATION AND TCE CONCENTRATION

N3-MW15 15,000 — MONITORING WELL LOCATION (USED FOR INJECTION IN AUGUST 2010) AND TCE CONCENTRATION

"<" INDICATES THAT TRICHLOROETHENE (TCE) WAS BELOW THE REPORTING LIMIT SHOWN.

N3-MW12* - TCE CONCENTRATION AT THIS WELL WAS BELOW THE REPORTING LIMIT AND SURROUNDING TCE CONCENTRATIONS EXCEEDED 100 UG/L.

50 — GROUNDWATER TCE CONCENTRATION CONTOUR (INTERVALS = 5, 50, 100, 500, 5,000); ALL CONCENTRATIONS PRESENTED IN MICROGRAMS PER LITER

MOST RECENT SAMPLING DATES ARE PRESENTED FOR WELLS NOT SAMPLED DURING THE JUNE-JULY 2015 EVENT.

Site N3
TCE Groundwater Concentration Contours - June-July 2015

Date 09-2016	Second Five-Year Review Report	Figure
Project No. 60444679	Operable Unit 6 Edwards AFB	11

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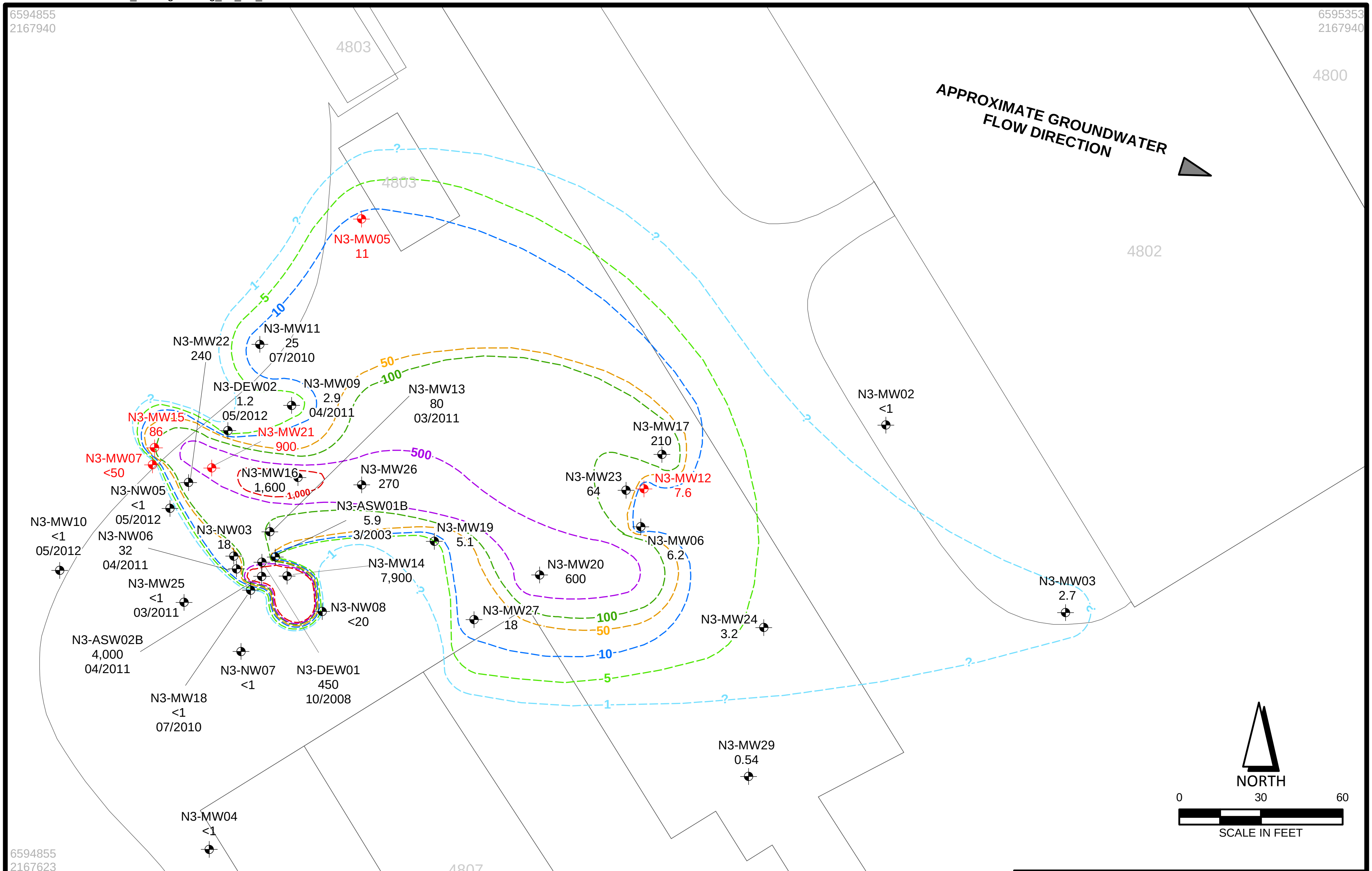

EXPLANATION

N3-MW22 240	MONITORING WELL LOCATION AND BENZENE CONCENTRATION
N3-MW15 86	MONITORING WELL LOCATION (USED FOR INJECTION IN AUGUST 2010) AND BENZENE CONCENTRATION

"<" INDICATES THAT BENZENE WAS BELOW THE REPORTING LIMIT SHOWN.

MOST RECENT SAMPLING DATES ARE PRESENTED FOR WELLS NOT SAMPLED DURING THE JUNE-JULY 2015 EVENT.

50 — GROUNDWATER BENZENE CONCENTRATION CONTOUR (INTERVALS = 1, 5, 10, 50, 100, 500, 1,000, 5,000); ALL CONCENTRATIONS PRESENTED IN MICROGRAMS PER LITER

Site N3 Benzene Groundwater Concentration Contours June-July 2015

Date 09-2016	Second Five-Year Review Report	Figure
Project No. 60444679	Operable Unit 6 Edwards AFB	12

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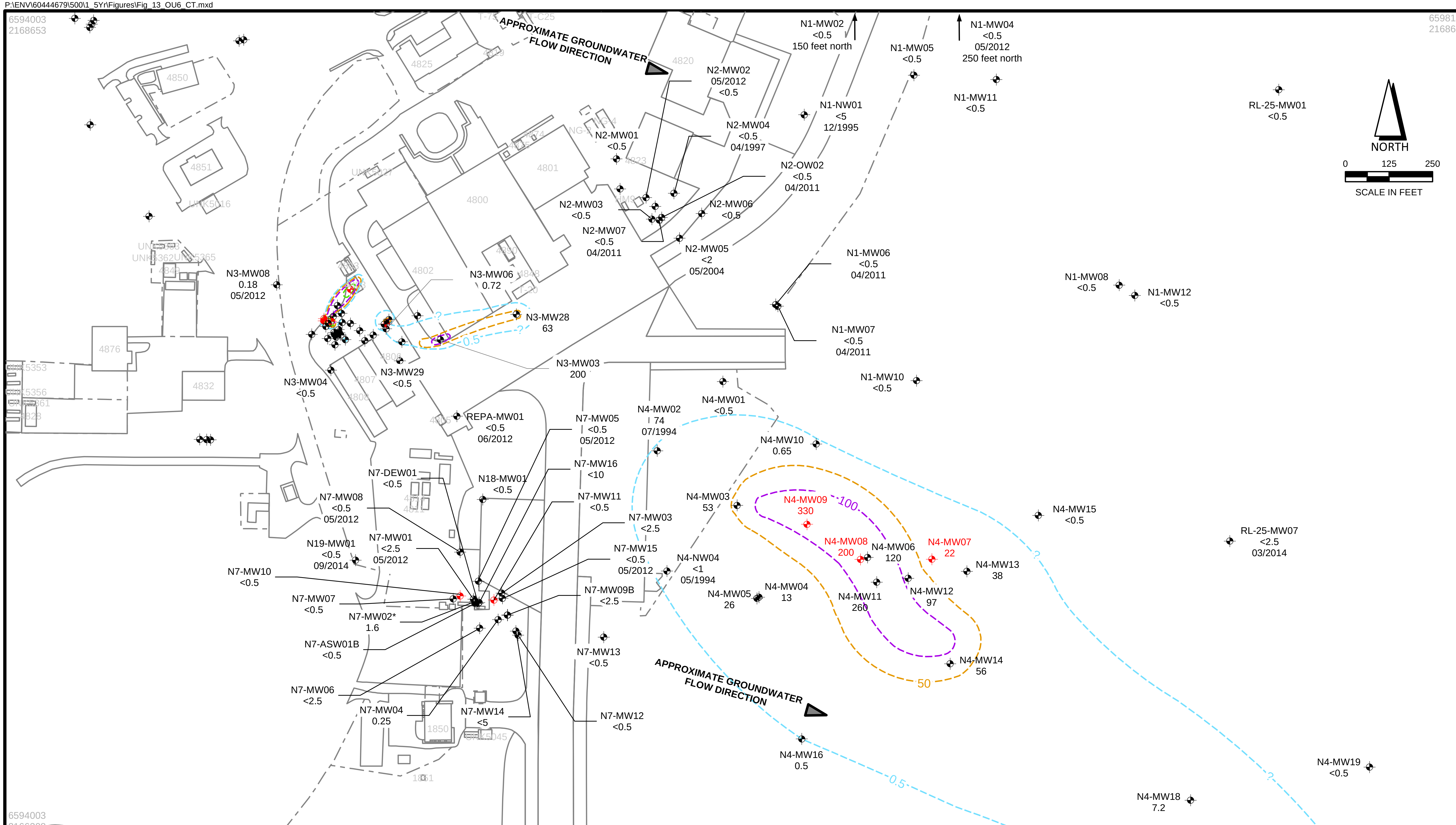

EXPLANATION

N4-MW05 26 — MONITORING WELL LOCATION AND CT CONCENTRATION

N4-MW09 330 — MONITORING WELL LOCATION (USED FOR INJECTION IN AUGUST 2010) AND CT CONCENTRATION

"<" INDICATES THAT CARBON TETRACHLORIDE (CT) WAS BELOW THE REPORTING LIMIT SHOWN.

N7-MW02* - CT CONCENTRATION AT THIS WELL WAS ABOVE 0.5 UG/L AND SURROUNDING CT CONCENTRATIONS WERE BELOW.

-- 50 -- GROUNDWATER CT CONCENTRATION CONTOUR (INTERVALS = 0.5, 50, 100, 500, 1,000); ALL CONCENTRATIONS PRESENTED IN MICROGRAMS PER LITER (UG/L)

CURRENT DATA TOOK PRIORITY OVER HISTORICAL DATA IN ESTIMATING CONTOURS.

MOST RECENT SAMPLING DATES ARE PRESENTED FOR WELLS NOT SAMPLED DURING THE JUNE-JULY 2015 EVENT.

CT Groundwater Concentration Contours - June-July 2015

Date 09-2016	Second Five-Year Review Report	Figure
Project No. 60444679	Operable Unit 6 Edwards AFB	13

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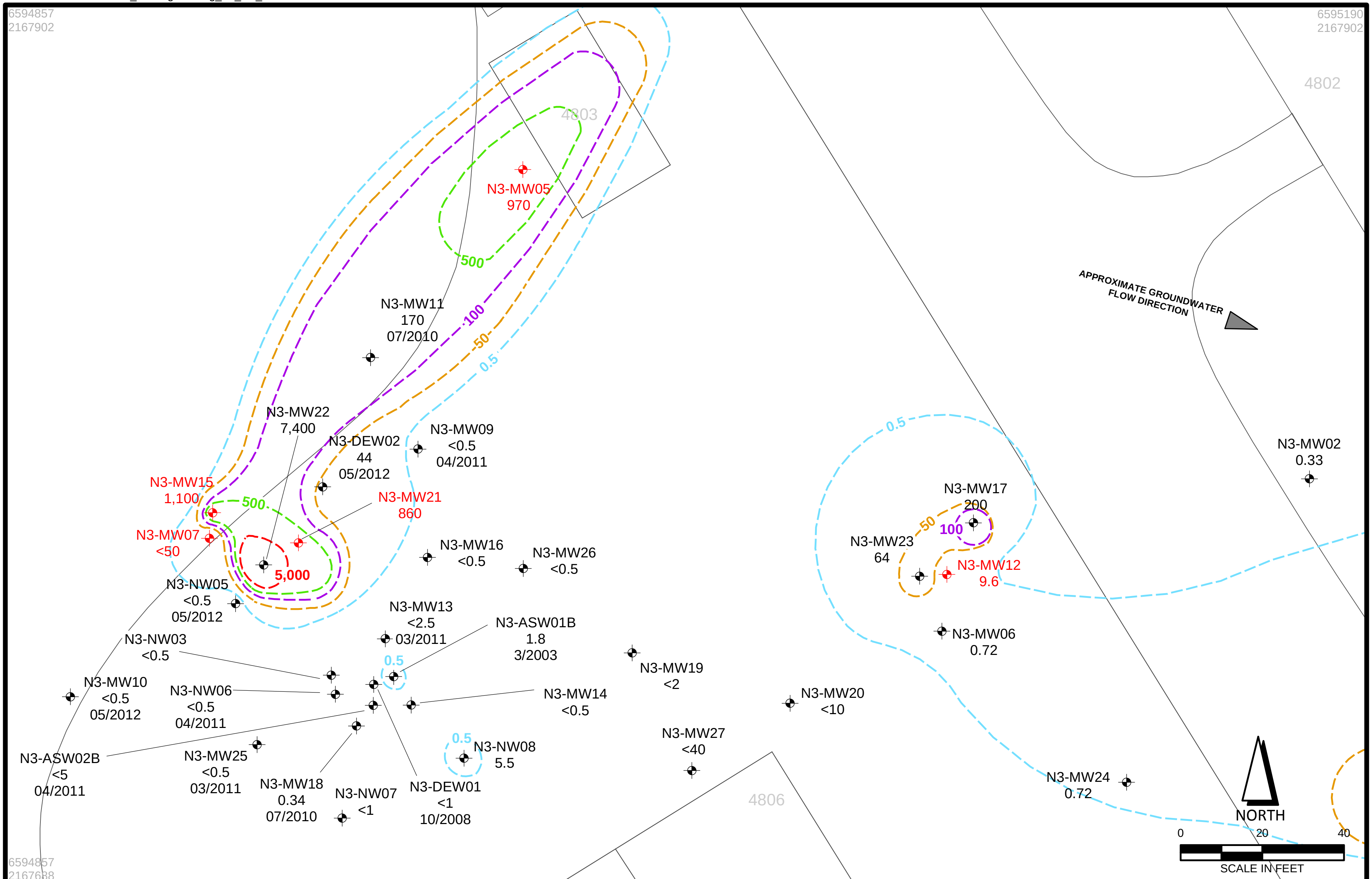

EXPLANATION

N3-MW22 7,400 — MONITORING WELL LOCATION AND CT CONCENTRATION

N3-MW15 1,100 — MONITORING WELL LOCATION (USED FOR INJECTION IN AUGUST 2010) AND CT CONCENTRATION

"<" INDICATES THAT CARBON TETRACHLORIDE (CT) WAS BELOW THE REPORTING LIMIT SHOWN.

MOST RECENT SAMPLING DATES ARE PRESENTED FOR WELLS NOT SAMPLED DURING THE JUNE-JULY 2015 EVENT.

--50-- GROUNDWATER CT CONCENTRATION CONTOUR (INTERVALS = 0.5, 50, 100, 500, 5,000); ALL CONCENTRATIONS PRESENTED IN MICROGRAMS PER LITER

Site N3
CT Groundwater Concentration Contours - June-July 2015

Date 09-2016	Second Five-Year Review Report	Figure
Project No. 60444679	Operable Unit 6 Edwards AFB	14

APPENDIX A

LAND USE CONTROL EXCERPT FROM ROD AND 2011 TO 2015 ANNUAL LUC REPORTS

2.12 SELECTED REMEDY

2.12.1 SUMMARY OF THE RATIONALE FOR THE SELECTED REMEDY

The selected remedy for soil is No Action.

Alternative 4, the selected remedy for the groundwater, utilizes chemical oxidation treatment at the areas of highest contaminant concentrations, enhanced natural attenuation of aromatic hydrocarbons, hydrologic control (the natural aquifer characteristics that resulted in the steady-state condition of the plume), LUCs to maintain incomplete exposure pathways, and groundwater monitoring to address and monitor treatment performance.

The selected remedy is the most cost-effective and implementable remedial alternative for groundwater at OU6 that includes treatment and does not impact mission-critical activities. It will achieve compliance with ARARs and applies treatment as the primary component to degrade VOCs in groundwater for a significantly lower cost than Alternative 3.

2.12.2 DESCRIPTION OF THE SELECTED REMEDY

The selected remedy for soil is No Action.

The selected remedy for groundwater will include multiple components, some based on other alternatives. These components are LUCs, groundwater monitoring, *in situ* chemical oxidation, and 5-year reviews.

2.12.2.1 LUCs

The Air Force is committed to implement, monitor, maintain, and enforce remedies that protect human health and the environment in accordance with CERCLA and the NCP. DFRC is a tenant of Edwards AFB. The use of OU6 is restricted to research, development, and aerospace testing purposes. The 95th Air Base Wing, Environmental Restoration Branch (95 ABW/CEVR) works closely with NASA DFRC on all environmental issues and acts as a conduit to the USEPA and the State and will be involved in LUC implementation.

Implementation

The selected remedy requires LUCs to be in place during remediation of contaminated groundwater within the OU6 plume area where contaminant levels do not allow for unlimited use and unrestricted exposure. Figure 2-15 depicts the boundary of groundwater contamination requiring LUCs. The Air Force's commitment to include more specific LUC maps in the GP and NASA DFRC MP is discussed below.

LUC measures to be used at OU6 are in accordance with specific provisions of 22 California Code of Regulations (CCR) Section 67391.1 that were determined by the Air Force to currently be relevant and appropriate requirements. Subsections (a), (b), and (e)(2) of 22 CCR Section 67391.1 provide that if a remedy at property owned by the federal government will result in levels of hazardous substances remaining on property at levels not suitable for unlimited use and unrestricted exposure, and it is not feasible to record a land use covenant (as is the case with the OU6 sites subject to LUCs), then the ROD is to clearly define and include limitations on land use and other IC mechanisms to ensure that future land use will be compatible with the levels of hazardous substances remaining on the property. These limitations and mechanisms are more specifically set forth in this section of the ROD, to include annotating the residential development restrictions in the GP and MP, and continuing to follow the review and approval procedures for any construction and ground-disturbing activities within the OU6 LUC boundary.

The following LUCs apply to groundwater industrial controls for OU6. The objectives are to restrict residential development (including child development centers, kindergarten through 12th grade [K-12] schools, play areas, and hospitals) where contamination is at levels that do not allow for unlimited use and unrestricted exposure and to maintain worker safety. These goals will be achieved through the following:

- Annotating the residential development restrictions in the GP and MP
- Prohibiting residential development in designated areas set forth in the GP and MP
- Continuing administrative measures (described in the following paragraph)

EXPLANATION

-·-·-·-·- LAND USE CONTROL BOUNDARY

Operable Unit 6
Land Use Control Boundary

Date 09-2006 Project No. 54212	**Operable Unit 6** **Record of Decision** **Edwards AFB**	Figure **2-15**

These LUCs are accomplished by a prohibition on residential development in designated areas set forth in the GP and MP, and administrative measures. The administrative measures are the NASA DFRC Work Request procedures, the NASA DFRC Facilities Engineering Digging Permit procedures, and the Environmental Impact Assessment Process (EIAP). The EIAP, Work Request, and Facilities Engineering Digging Permit procedures restrict development during the interim period before remedial actions are implemented. A Facilities Engineering Digging Permit is required for any project that involves any mechanical soil excavation, such as digging trenches for underground lines or excavating soil for building foundations. The permit lists the DFRC Safety, Health, and Environmental Office and other support offices that review the excavation plans for approval. If constraints involving soil disturbance or worker safety exist at the excavation area, the permit describes the appropriate procedures that will prevent unknowing exposure to groundwater contamination and measures the workers must implement before the start of excavation.

The Air Force and/or NASA DFRC will implement the following measures at all sites with LUCs.

- Include in the GP and MP any specific restrictions required at each site, a statement that restrictions are required because of the presence of pollutants or contaminants, the current land users and uses of the site, the geographic control boundaries, and the objectives of the land use restrictions. Unless a site is cleaned up to levels appropriate for unlimited use and unrestricted exposure, the GP and MP will reflect the prohibitions on residential development (including child development centers, K-12 schools, play areas, and hospitals). Upon completion of a remedial action at a site, the GP and MP will be updated to modify the site-specific use restrictions as appropriate. The section describing the specific restrictions will also refer the reader to the Base Environmental Office or NASA DFRC Safety, Health, and Environmental Office, if more information is needed. The GP and MP will each contain a map depicting the geographic boundaries of all OU6 sites where LUCs are in effect.
- While LUCs are in place, maintain administrative control of the integrity of current and future remedial or monitoring systems and maintain existing administrative controls (presented in the subsequent section). LUCs will remain in place as long as groundwater contamination concentrations remain above levels allowing for unlimited use and unrestricted exposure. Neither the Air Force nor NASA DFRC will modify or terminate LUCs, implement actions, or modify land use without USEPA and California DTSC approval. The Air Force shall seek prior concurrence before any anticipated action (by the Air Force or NASA DFRC) that may disrupt the effectiveness of the LUCs or any action that may alter or negate the need for LUCs.
- Whenever the Air Force transfers real property that is subject to ICs and resource use restrictions to another federal agency, the transfer documents shall require that the federal transferee include the ICs, and applicable resource use restrictions in its resource use plan or equivalent resource use mechanism. The Air Force shall advise the recipient federal agency of all obligations contained in the ROD, including the obligation that a State Land Use Covenant

will be executed and recorded pursuant to 22 CCR Section 67391.1 in the event the federal agency transfers the property to a non-federal entity.

- Whenever the Air Force proposes to transfer real property subject to resource use restrictions and ICs to a non-federal entity, it will provide information to that entity in the draft deed and transfer documents regarding necessary resource use restrictions and ICs, including the obligation that a State Land Use Covenant will be executed and recorded pursuant to 22 CCR Section 67391.1. The signed deed will include ICs and resource restrictions equivalent to those contained in the State Land Use Covenant and this ROD.
- The Air Force will provide notice to USEPA and the State at least 6 months prior to any transfer or sale of OU6 so that USEPA and the State can be involved in discussions to ensure that appropriate provisions are included in the transfer terms or conveyance documents to maintain effective ICs. If it is not possible for the facility to notify USEPA and the State at least 6 months prior to any transfer or sale, then the facility will notify USEPA and the State as soon as possible but no later than 60 days prior to the transfer or sale of any property subject to ICs. In addition to the land transfer notice and discussion provisions above, the Air Force further agrees to provide USEPA and the State with similar notice, within the same time frames, as federal-to-federal transfer of property. The Air Force shall provide a copy of the executed deed or transfer assembly to USEPA and the State.
- NASA DFRC will notify the Air Force and the Air Force will notify the USEPA and the State at least 30 days in advance of any proposed land use changes that are inconsistent with LUC objectives or the selected remedy and any changes to the GP or MP that would affect the LUCs.
- NASA DFRC will notify the Air Force and the Air Force will notify the USEPA and the State as soon as practicable, but no longer than 10 days after discovery of any activity that is inconsistent with LUC objectives or use restrictions, or any action that may interfere with the effectiveness of LUCs, as well as provide the USEPA and the State within 10 days of notification of the breach with a tentative plan (including a timeline of proposed actions and delivery dates) regarding how the Air Force and NASA DFRC will address the breach or with a description of how the breach has been addressed.
- Address as soon as practicable any activity that is inconsistent with LUC objectives or use restrictions or any other action that may interfere with the effectiveness of LUCs, but in no case will the process be initiated later than 30 days after the Air Force and NASA DFRC becomes aware of the breach.
- NASA DFRC shall conduct periodic monitoring and take prompt action to restore, repair, or correct any LUC deficiencies or failures identified. A different monitoring schedule may be agreed upon according to the schedule provisions of the FFA, if all parties agree and if the change reasonably reflects the risk presented by the site.

It is understood that the Air Force is responsible for remedy implementation and ensuring integrity of the remedy. NASA DFRC, with oversight by the Air Force, is responsible for implementing (to the degree controls are not already in place), monitoring, maintaining, and enforcing the identified controls. If NASA DFRC and the Air Force determine that it cannot meet specific LUC requirements, it is understood that the remedy may be reconsidered and that additional measures may be required to ensure the protection of human health and the environment.

In addition, to assure the USEPA and the State and the public that the Air Force will fully comply with and be accountable for the performance measures identified herein, NASA DFRC will supply information to the Air Force for, and the Air Force will timely submit to USEPA and California DTSC, an annual monitoring report on the status of LUCs and/or other remedial actions, including the operation and maintenance and monitoring thereof, and how any LUC deficiencies or inconsistent uses have been addressed. The report also will be filed in the information repositories. The report would not be subject to approval and/or revision by USEPA and the State. The annual monitoring reports will be used in preparation of the 5-year reviews to evaluate the effectiveness of the remedy and will verify that state and local agencies were notified of the use restrictions and controls affecting the property and that the use of the property has conformed to such restrictions and controls.

Availability of the Edwards AFB General Plan, NASA DFRC Master Plan, and Existing Administrative Procedures

The first step in restricting specific types of development at a site is to revise the GP and MP to place constraints ensuring that these sites are never used for residential development (including child development centers, K-12 schools, play areas, and hospitals). The GP resides in the office of the Base community planner, and the MP is available at the NASA DFRC Facilities Planning Office. Accordingly, the GP and MP will be revised to include residential development prohibitions and any specific restrictions required at each site, a statement that restrictions are required because of the presence of pollutants or contaminants, the current land users and uses of the site, the geographic control boundaries, and the objectives of the land use restrictions.

All proposed construction requires approval of the appropriate NASA DFRC office to ensure compliance with the GP and MP.

Form DFRC 8-0053, Facilities Work Request, must be submitted and approved before the start of any building project at NASA DFRC. Approval of the Work Request involves the comparison of the building site with the constraints in the MP. The Work Request serves as the document for communicating any construction constraints to the appropriate offices. Any constraints at the site result in the disapproval of the form unless the requester makes appropriate modifications to the building plans. The DFRC Facilities Engineering and Asset Management Office (CODE F) is responsible for the final approval of proposed building projects through the Configuration Control Board review process.

NASA DFRC will also use form DFRC 8-0808, Facilities Engineering Digging Permit, to enforce the groundwater LUCs, as previously discussed. The requester submits the Facilities Engineering Digging Permit to the Facilities Office, CODE F, for any project that involves any mechanical soil excavation, and it is circulated to appropriate offices for review of needed safety procedures. The DFRC Facilities Engineering and Asset Management Office (CODE F) is responsible for the final approval of excavation projects through the permit review process.

Both the Work Request and Facilities Engineering Digging Permit are subject to an EIAP review conducted pursuant to the National Environmental Policy Act, as promulgated for NASA in 14 Code of Federal Regulations (CFR) Part 1216 Subpart 1216.3. The EIAP analysis is initiated when a proponent of a proposed action fills out a form DFRC 8-0039, Request for Environmental Impact Analysis. A proponent of an action is required to submit the Work Request and/or Facilities Engineering Digging Permit with the form DFRC 8-0039 to the Safety, Health, and Environmental Office so that the appropriate environmental analysis of the proposed action and alternatives to the proposed action is accomplished prior to any construction activities. The NASA DFRC environmental staff (air, water, cultural and natural resources, restoration, and others) and the community planner review DFRC forms 8-0039 that involve facilities construction. Major new construction may result in a determination that a formal publicized Environmental Assessment is necessary. The EIAP process works to ensure proposed construction sites are reviewed in accordance with the MP. The process also ensures that all environmental factors, as well as the Base's ROD LUCs, are considered in siting construction projects.

Cleanup Levels

Based on the current industrial land use and the reasonably foreseeable future long-term land use that is projected to be industrial, potential risks associated with COCs in groundwater are mitigated by the lack of complete exposure pathways. However, should the groundwater at OU6 ever be used for beneficial purposes, ingestion of the water from this aquifer would pose a potential risk to human health because

2011 TO 2015 ANNUAL LUC REPORTS

DEPARTMENT OF THE AIR FORCE
AIR FORCE CIVIL ENGINEER CENTER
INSTALLATION SUPPORT TEAM
EDWARDS AIR FORCE BASE, CALIFORNIA

29 May 2014

MEMORANDUM FOR RECORD

Mr. Ai Duong
AFCEC/CZO-West
12 Laboratory Road, Building 4231
Edwards AFB, CA 93524

Mr. James Ricks
U.S. Environmental Protection Agency, Region IX
75 Hawthorne Street, SFB-8-1
San Francisco, California 94105

SUBJECT: Edwards Air Force Base OU 6 NASA Armstrong Flight Research Center Annual Land Use Control Report - 2013

Dear Mr. Ricks:

For your information and in accordance with Section 2.12.2.1 of the Record of Decision for Edwards Air Force Base (AFB) OU 6 NASA Dryden Flight Research Center (DFRC) (Air Force 2006), the land use controls (LUCs) discussed below were carried out at OU 6, NASA Armstrong Flight Research Center (AFRC) (formerly NASA DFRC) for the Calendar Year 2013.

The Edwards AFB Geographic Information System (GIS) is the primary management tool for implementing, documenting, and managing OU 6 LUCs. The LUC boundary is revised in the GIS as necessary based on the most-recent, vetted, and available sampling results. The LUC boundary was revised during the review period to coincide with the 1- microgram per liter (μg/L) benzene, 0.5-μg/L carbon tetrachloride (CT), and 5-μg/L trichloroethene (TCE) isoconcentration contours based on the 2012 monitoring results (documented in the *Remedy Performance and Groundwater Monitoring Report, 2011-2012*) by Mr. Julio Barrios on 11 February 2013.

The LUC remedy component includes approval procedures for any construction and ground-disturbing activities within the OU 6 LUC boundary (as represented by the benzene, CT, and TCE commingled plume boundary documented in the *Remedy Performance and Groundwater Monitoring Report, 2011-2012*), including construction and dig permits. Dig permit data for excavations occurring within this review period are tabulated in Table 1. Whether excavations are within the LUC boundary, the purpose/objectives for each of the excavations, and the excavation depths are provided. Dig permit data for previous reporting periods are also included in Table 1 in response to Remedial Project Manager request for more detailed LUC Reports.

Thirty-one excavation activities were performed in 2013 (Table 1). Eleven excavations occurred within or near the LUC boundary and personal protective equipment (PPE) was employed during the efforts. None of the excavation activities impacted the remedy.

Please call Mr. Tom Merendini at (661) 277-1414 if you have any questions or require additional information.

AI DUONG
Remedial Project Manager

Mr. Joe Healy, U.S. EPA, Region IX
Mr. Kevin Depies, California DTSC Office of Military Facilities
Mr. Bruce Lewis, California DTSC Office of Military Facilities
Ms. Christina Velasquez, California RWQCB, Lahontan Region

TABLE 1. 2011-2013 NASA ARMSTRONG EXCAVATION ACTIVITIES

Date Required	Inside LUC boundary (Yes/No)	Location	Type of Project	Excavation Depth (feet)	PPE Required (Yes/No)
1/10/2011	No	SE Corner CITC NE to Lilly Ave.	Install new 12" PVC Fire Water Line	800	Yes
3/15/2011	No	CITC Project DFRC	Dig for Fire Water Line	Unknown	No
5/16/2011	No	B703 SW	Install (3) New Bollards to Protect New Air Conditioner	Unknown	No
6/16/2011	No	Near Existing Pad	Extend Existing Concert Pan to Accommodate new High Voltage Safety Clearance Requirements	10	No
11/21/2011	Yes	Multiple Locations Center Wide	Install underground sewer Mains and manholes	12'	Yes
1/11/2012	No	Multiple Center Locations (Buildings 4824, 4825,4853,4887,4871,4882)	Place and Drive Ground Rods – 10' Long At Fuel Tanks	10'	No
1/23/2012	No	Multiple Center Locations (Buildings 4824, 4825,4853,4887,4871,4882)	Place and Drive Ground Rods – 10' Long At Fuel Tanks	10	No
4/9/2012	No	NE Corner of DAOF	Dig a 24" x 48" post hole for 15' H post	Unknown	N/A
5/3/2012	No	Building 4825 by Fuel Tank	Install Ground Rod – ¾ " x 10' Long	10'	No
5/11/2012	No	Building 4811	Facilities Support Center	Unknown	No
5/15/2012	No	Various	(Repair Flight Lines Roads and Ramps Project)	Unknown	No
5/30/2012	No	Various	(Repair Flight Lines Roads and Ramps Project)	Unknown	No
6/4/2012	Yes	SUB 13, HM12, and M1	Soil Grading Work - Repair Grounding	Min. 6"	Yes
7/30/2012	No	Various	(Repair Flight Lines Roads and Ramps Project)	Unknown	No
8/6/2012	No	Various	(Repair Flight Lines Roads and Ramps Project)	Unknown	No
8/15/2012	No	Various	(Repair Flight Lines Roads and Ramps Project)	Unknown	No
8/27/2012	Yes	Sub 13, HM12, and M1	Repair Grounding, Substation 13, HM12, and M1	3 to 4	Yes
9/4/2012	Yes	Lakebed and North Side of Building 4806	Install Groundwater Monitoring Wells	40'	Yes
9/4/2012	No	Various	(Repair Flight Lines Roads and Ramps Project)	Unknown	No
9/17/2012	No	Various	(Repair Flight Lines Roads And Ramps Project)	Unknown	No
10/1/2012	No	Lilly and Walker Ave.	Installation of Fire Line (Repair Flight Lines Roads and Ramps Project)	Unknown	No
10/1/2012	No	N & S side Lilly and Walker Ave.	Fire Line Repairs, (Repair Flightline Project)	Unknown	No
10/18/2012	No	Media Hill	Irrigation PVC Pipe Repair	Unknown	No
10/22/2012	No	Building 4850	Irrigation Pipe Install	Unknown	No
10/22/2012	Yes	Swann Ave.	Irrigation Pipe	12"	Yes
11/5/2012	No	McKay Ave.	Curb, Gutter and Asphalt Work at Mckay Avene (Repair Flight Lines Roads and Ramps Project)	Unknown	No
11/5/2012	No	Curbs and Gutters along McKay Ave.	Repair Flightline Roads and Ramps Project	Unknown	No

DEPARTMENT OF THE AIR FORCE
AIR FORCE CIVIL ENGINEER CENTER
INSTALLATION SUPPORT TEAM
EDWARDS AIR FORCE BASE, CALIFORNIA

31 July 2015

MEMORANDUM FOR RECORD

Mr. Ai Duong
AFCEC/CZO-West
120 N. Rosamond Boulevard, Suite A
Edwards AFB, CA 93524-8400

SUBJECT: Edwards Air Force Base OU 6 NASA Armstrong Flight Research Center Annual Land Use Control Report - 2014

Dear Mr. Mayer:

For your information and in accordance with Section 2.12.2.1 of the Record of Decision for Edwards Air Force Base (AFB) OU 6 NASA Dryden Flight Research Center (DFRC) (Air Force 2006), the land use controls (LUCs) listed below were carried out at OU 6, NASA Armstrong Flight Research Center (AFRC) (formerly NASA DFRC) for the Calendar Year 2014.

The Edwards AFB Geographic Information System (GIS) is the primary management tool for implementing, documenting, and managing OU 6 LUCs. The LUC boundary is revised in the GIS as necessary based on the most-recent, vetted, and available sampling results. The current LUC boundary coincides with the 1- microgram per liter (µg/L) benzene, 0.5-µg/L carbon tetrachloride (CT), and 5-µg/L trichloroethene (TCE) isoconcentration contours based on the most-recent monitoring results (documented in the *Remedy Performance and Groundwater Monitoring Report, 2011-2012*).

The LUC remedy component includes approval procedures for any construction and ground-disturbing activities within the OU 6 LUC boundary (as represented by the benzene, CT, and TCE commingled plume boundary documented in the *Remedy Performance and Groundwater Monitoring Report, 2011-2012*), including construction and dig permits. Dig permit data for excavations occurring within this review period are tabulated in Table 1. Whether excavations are within the LUC boundary, the purpose/objectives for each of the excavations, and the excavation depths are provided.

Fifteen excavation activities were performed in 2014 (Table 1). Four excavations occurred within the LUC boundary and personal protective equipment (PPE) was employed when appropriate during the efforts. None of the excavation activities impacted the remedy.

Please call Mr. Tom Merendini at (661) 277-1414 if you have any questions or require additional information.

AI DUONG
Remedial Project Manager

Mr. Kevin Mayer, U.S. EPA, Region IX
Mr. Kevin Depies, California DTSC Office of Military Facilities
Mr. Bruce Lewis, California DTSC Office of Military Facilities
Ms. Christina Guerra, California RWQCB, Lahontan Region

TABLE 1. 2014 NASA ARMSTRONG EXCAVATION ACTIVITIES

Date Required	Inside LUC boundary (Yes/No)	Location	Type of Project	Excavation Depth	PPE Required (Yes/No)
1/22/2014	No	North side of Lilly Avenue	Trenching for Ductwork Install – Repair EDS	3’6.5” for Trench, 12’4” for Electrical Manholes	No
1/24/2014	No	Northwest corner of B4840	Relocate/Anchor Office Trailer to New Location	Unknown	No
2/3/2014	Yes	Centerwide	Trenching/Potholing – Centerwide Fire Main Repair	10-12’	Yes
2/6/2014	No	Substation 24 – B4850	Trenching/Potholing – Repair EDS	Approx. 5’	No
2/18/2014	Yes	Near B4837, B4823, B4838A, B4840, NB107, B4826,	Dig Holes/Pour Concrete/Set Posts - Sign Installation	1’	Yes
2/20/2014	No	Substation 5	Trenching/Potholing – Repair EDS	Unknown	No
3/6/2014	No	Substation 15	Potholing/Digging – Repair EDS	Unknown	No
6/9/2014	No	NB103, NB108, B4852	Trenching/Potholing - Fire Main Repair	Unknown	No
6/18/2014	No	Substation 5 to B4871	Trenching/Potholing – Repair EDS	Unknown	No
7/28/2014	Yes	B4810, 4804, 4827	Excavating – Wet Utility Capping	10-12”	No
8/6/2014	No	South of Lilly Avenue, B4824, 4870	Trenching/Potholing – Centerwide Fire Main Repair	Unknown	No
8/11/2014	No	TCCON Pad	Trenching/Potholing - Repair EDS	Unknown	No
9/22/2014	Yes	Aircraft Ramp Pad	Trenching/Potholing – Power and Communication for Video Cameras	3’	Yes
10/22/2014	No	B700 – LOX Tank	Digging/Excavating – LOX Storage Upgrades	1.5’	No
12/1/2014	No		Trenching/Potholing - Repair EDS	Unknown	No

TABLE 1. 2011-2013 NASA ARMSTRONG EXCAVATION ACTIVITIES

11/15/2012	No	Near Building 4839	Replace-Install Signage, Static Display	Unknown	No
11/19/2012	No	Building 4825 Eastside Loading Area	Repair Flightline Roads	Unknown	No
12/10/2012	No	Grading Around Building 4876	Grade Area For Environmental Controls For Records Storage	2’	No
1/22/2013	No	North Edwards AFB	Boring for Soils Investigation (Project - Electronic Manhole)	10’	No
1/22/2013	Yes	Centerwide	Potholing, Trenching, Pipe Install (Centerwide Fire Mains Repair)	10-12’	Yes
3/4/2013	Yes	EAFB/NASA – Sub 13	Cut, Break, Remove Concrete Pads. Dirt Backfill	Only deep enough to remove asphalt	Yes
3/11/2013	No	Building 703	Potholing and Excavation for New Slab	54”	No
3/11/2013	Yes	Centerwide	Potholing and Trenching	Unknown	Yes
4/1/2013	No	Multiple Locations Inside Building 4800	Trenching and Excavation (Repair Sewer Project)	Unknown	No
5/13/2013	No	EAFB/NASA DFRC-Sub 24	Underground Trenching/Conduit	Approx. 5’	No
5/15/2013	No	DFRC-Shuttle Area	Potholing/Trenching	Approx. 5’	No
5/28/2013	Yes	Building 4801 Ramp Area	Potholing, Trenching, Pipe Install	Approx. 5’	Yes
5/28/2013	No	Tanks to Gray Avenue	Potholing, Trenching, Pipe Install	Approx. 5’	No
5/29/2013	No	DFRC-Sub 9	Hand Excavation for Footings	Unknown	No
6/17/2013	Yes	Adjacent to Building 4810	Potholing, Trenching, and Excavation	10-12’	Yes
6/17/2013	No	Center Gas Station (West of Swann Ave.)	Drilling	20-33’	No
6/21/2013	Yes	Building 4800 Exterior to Sewer Line Mains	Potholing, Trenching, and Excavation	Approx. 5’	Yes
6/24/2013	No	Buildings 4847, 4822, E Side of 4840, Parking Lot 1, and Building 4830	Potholing, Trenching, Hot Tapping	Approx. 5’	No
6/24/2013	No	DFRC - Centerwide (West End)	Potholing and Excavation	Approx. 5’	No
7/8/2013	Yes	Adjacent to Building 4801	Potholing, Trenching, and Excavation	Unknown	Yes
7/22/2013	Yes	DFRC – Centerwide (Hydrant Leg)	Potholing, Trenching, and Excavation	Approx. 5’	Yes
7/23/2013	No	Lilly Ave. North of HL10 Static Display	Potholing and Excavation (Repair Water Line)	Unknown	No
8/15/2013	No	DFRC - Area A Ramp	Potholing, Trenching, and Excavation	Unknown	No
8/19/2013	No	DFRC - Adjacent to Building 4840	Potholing, Trenching, and Excavation	Unknown	No
9/11/2013	No	Building 703	Excavation (Airborne Science lab Remodel)	Unknown	No

TABLE 1. 2011-2013 NASA ARMSTRONG EXCAVATION ACTIVITIES

9/16/2013	No	DFRC – NE Side of Building 4840	Potholing, Trenching, and Excavation (Repair Sewer System)	Unknown	No
9/17/2013	No	Various Location	Excavation (PIV Valve)	Unknown	No
11/12/2013	No	DFRC – Southside Building 4826	Potholing, Trenching, and Excavation	Unknown	No
11/13/2013	No	DFRC – LOX Servicing Area	Potholing, Trenching, and Excavation	3'	No
11/19/2013	No	DFRC – Sub 23	Dig Footings for Concrete Slabs	Unknown	No
11/25/2013	No	DFRC – Buildings 4870 and 4824	Potholing, Trenching, and Excavation (Repair Fire Mains)	Approx. 5'	No
11/25/2013	Close Proximity	DFRC-Adjacent to Buildings 4806, 4807, 4808, 4809	Potholing, Trenching, and Excavation (Repair Fire Mains)	Approx. 5'	Yes
12/17/2013	Close Proximity	DFRC-NB82, Sub 2	Underground Trenching for Conduit	Approx. 5'	Yes
12/17/2013	Near Plume	NB82, Sub 2	Underground Trenching for Conduit	5'	Yes

DEPARTMENT OF THE AIR FORCE
AIR FORCE CIVIL ENGINEER CENTER
INSTALLATION SUPPORT TEAM
EDWARDS AIR FORCE BASE, CALIFORNIA

16 May 2016

MEMORANDUM FOR RECORD

Mr. Ai Duong
AFCEC/CZO-West
120 N. Rosamond Boulevard, Suite A
Edwards AFB, CA 93524-8400

Mr. Kevin Mayer
U.S. Environmental Protection Agency, Region IX
75 Hawthorne Street, SFB-8-1
San Francisco, California 94105

SUBJECT: Edwards Air Force Base OU 6 NASA Armstrong Flight Research Center Annual Land Use Control Report - 2015

Dear Mr. Mayer:

For your information and in accordance with Section 2.12.2.1 of the Record of Decision for Edwards Air Force Base (AFB) OU 6 NASA Dryden Flight Research Center (DFRC) (Air Force 2006), the land use controls (LUCs) listed below were carried out at OU 6, NASA Armstrong Flight Research Center (AFRC) (formerly NASA DFRC) for the Calendar Year 2015.

The Edwards AFB Geographic Information System (GIS) is the primary management tool for implementing, documenting, and managing OU 6 LUCs. The LUC boundary is revised in the GIS as necessary based on the most-recent, vetted, and available sampling results. The LUC boundary was revised to coincide with the 1- microgram per liter (μg/L) benzene, 0.5-μg/L carbon tetrachloride (CT), and 5-μg/L trichloroethene (TCE) isoconcentration contours based on the 2015 monitoring results (documented in the *Remedy Performance and Groundwater Monitoring Report, 2015*) by Mr. Julio Barrios on 5 May 2016.

The LUC remedy component includes approval procedures for any construction and ground-disturbing activities within the OU 6 LUC boundary, including construction and dig permits. Dig permit data for excavations occurring within this review period are tabulated in Table 1. Whether excavations are within the LUC boundary, the purpose/objectives for each of the excavations, and the excavation depths are provided.

Twenty two excavation activities were performed in 2015 (Table 1). Five excavations occurred within the LUC boundary and personal protective equipment (PPE) was employed when appropriate during the efforts. Excavation activities included installation of monitoring wells in support of the remedy. None of the remaining excavations impacted the remedy.

Please call Ms. Kimberly Coleman at (530) 344-0711 or Mr. Tom Merendini at (661) 277-1414 if you have any questions or require additional information.

AI DUONG
Remedial Project Manager

Mr. Kevin Mayer, U.S. EPA, Region IX
Mr. Kevin Depies, California DTSC Office of Military Facilities
Mr. Bruce Lewis, California DTSC Office of Military Facilities
Ms. Christina Guerra, California RWQCB, Lahontan Region

2015 NASA ARMSTRONG EXCAVATION ACTIVITIES

Date Required	Inside LUC boundary (Yes/No)	Location	Type of Project	Excavation Depth (feet)	PPE Required (Yes/No)
1/19/2015	no	Centerwide	FY14 Repair Aircraft Hangar Fire Protection System (RAHFPS)	6	no
1/20/2015	yes	Centerwide	FY14 RAHFPS	6	yes
3/9/2015	no	Centerwide	FY12 CoF repair primary distribution system – phase 8	6	no
4/13/2015	yes	Building 4810	Asphalt patching	<4	yes
4/13/2015	yes	Site N3	Installation of 2 ground monitoring wells	30-37	yes
4/16/2015	yes	Adjacent to Building 4811	Repair erosion and correct surface drainage	4	yes
5/25/2015	no	Building 4876 area	CCR 368 – construct warehouse fencing	<4	no
6/1/2015	no	Centerwide	FY14 RAHFPS	6	no
6/22/2015	no	Centerwide	Gas metering project	5	no
6/22/2015	no	Sub 3	Repair substation 3	5 inches	no
6/29/2015	no	Building 4847	Firemain leak repair	6 to 8	no
7/2/2015	no	Building 4837	Firemain leak repair	6 to 8	no
8/9/2015	no	Building 4847	Install 2 new bollards at west side fire hydrant near fence line	0.5 to 3	no
8/20/2015	no	Area A	Demo shuttle support facilities – Phase 2	4 to 6	no
8/24/2015	yes	Building 4823	Metal awning repair	2	yes
9/8/2015	no	Centerwide	Repair Centerwide Firemains – Phase 2 – Trailer installation	5	no
9/8/2015	no	Building 4824	Utility trenching	5	no
9/14/2015	no	Centerwide	Repair Centerwide Firemains – Phase 2	6 to 8	no
9/28/2015	no	Building 4882 Area 12	Demo Phase 2 / demo gate	<4	no
10/15/2015	no	Building 4853	Fire tanks fire water valve replacement	6	no
10/21/2015	no	North of Fuel Farm	FY14 Demo Shuttle support facilities	4 to 6	no
unknown	no	Centerwide	Fire hydrant replacement (1, 31, 32, 33)	6 to 8	no

APPENDIX B

ADDENDUM TO THE FIRST FIVE-YEAR REVIEW REPORT (ON CD)

National Aeronautics and Space Administration
Armstrong Flight Research Center
Edwards Air Force Base, California

Environmental Restoration Program

Addendum to First Five-Year Review Report

Operable Unit 6

Final

April 2016

ENVIRONMENTAL RESTORATION PROGRAM

ADDENDUM TO FIRST FIVE-YEAR REVIEW REPORT NATIONAL AERONAUTICS AND SPACE ADMINISTRATION ARMSTRONG FLIGHT RESEARCH CENTER OPERABLE UNIT 6

EDWARDS AIR FORCE BASE
CALIFORNIA

FINAL

APRIL 2016

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ARMSTRONG FLIGHT RESEARCH CENTER
SAFETY, HEALTH, AND ENVIRONMENTAL OFFICE
EDWARDS AIR FORCE BASE, CA 93523-0273

and the

UNITED STATES AIR FORCE CIVIL ENGINEER CENTER
ENVIRONMENTAL RESTORATION PROGRAM
INSTALLATION SUPPORT TEAM-WEST (AFCEC/CZOW)
EDWARDS AIR FORCE BASE, CA 93524-8400

and

RESTORATION PROGRAM MANAGEMENT OFFICE-WEST (AFCEC/CZRW)
JOINT BASE SAN ANTONIO-LACKLAND, TX 78236-9853

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LIST OF ABBREVIATIONS AND ACRONYMS

μg/L	micrograms per liter
AECOM	AECOM Technical Services, Inc.
AFB	Air Force Base
AFCEC	Air Force Civil Engineer Center (formerly Air Force Center for Engineering and the Environment)
AFCEC/CZOW	Air Force Civil Engineer Center, Environmental Restoration Program Installation Support Team-West
AFCEC/CZRW	Air Force Civil Engineer Center, Restoration Program Management Office-West
AF	Air Force
CA	California
COC	chemical of concern
CT	carbon tetrachloride
DTSC	Department of Toxic Substances Control
FFA	Federal Facility Agreement
FYRR	Five-Year Review Report
HHRA	human health risk assessment
i.e.	*id est*, that is
ISCO	*in situ* chemical oxidation
LUC	land use control
MCL	Maximum Contaminant Level
OU	Operable Unit
RA	remedial action
RAO	remedial action objective
ROD	Record of Decision
RPGMR	Remedy Performance and Groundwater Monitoring Report
RPM	remedial project manager
SV	soil vapor
TCE	trichloroethene
TX	Texas
U.S.	United States
USAF	United States Air Force
USEPA	United States Environmental Protection Agency
VIP	vapor intrusion pathway
VOC	volatile organic compound

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EXECUTIVE SUMMARY

Addendum to the First Five-Year Review Report for
Operable Unit 6, Edwards Air Force Base
Kern County, California

A Five-Year Review Addendum is generally completed for remedies where the protectiveness determination is deferred until further information is obtained. This document provides information regarding progress since the First Five-Year Review and protectiveness determinations for the Operable Unit (OU) 6, Edwards Air Force Base remedy where the statement was deferred in the September 2011 First Five-Year Review as indicated by United States Environmental Protection Agency (USEPA) in their summary:

> A five year review of [the OU 6] remedy was submitted in September 2011. USEPA deferred the Five-Year Review Protectiveness Statement until the Air Force provides some additional data and analysis in a Five-Year Review Report Addendum expected in 2014. Critical sampling of the vapor intrusion pathway is currently underway and a new risk assessment is planned for late 2014.

This Addendum updates the Issues/Recommendations relating to the Protectiveness Statement for OU 6 by incorporating the 2012-2013 data into the Summary Form (USEPA 2011) tabular format to track issues, recommendations and protectiveness statements that are consistent with five-year review Superfund Enterprise Management System (formerly the Comprehensive Environmental Response, Compensation, and Liability Information System) data entry requirements to facilitate accurate USEPA data entry.

Issues/Recommendations

Issues and Recommendations Identified in the Addendum to Five-Year Review:

OU(s): OU 6	Issue Category: Changed Site Conditions			
	Issue: Plume stability at the leading edge has not yet been demonstrated.			
	Recommendation: Sample groundwater annually to evaluate concentration trends to enable stability assessment in the Second Five-Year Review.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
No	Yes	Federal Facility	EPA/State	09/28/2016

OU(s): OU 6	Issue Category: Remedy Performance			
	Issue: Plume delineation data gap investigation may identify the need for additional in situ chemical oxidation injections and/or locations to optimize remedy performance.			
	Recommendation: Install additional monitoring wells to facilitate assessment of treatment approach in the Second Five-Year Review.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
No	Yes	Federal Facility	EPA/State	09/28/2021*

* Initial investigation to be completed Spring 2015; contingent follow-on investigation and interpretation to be completed 09/28/2021.

Protectiveness Statement for OU 6

The supplemental Addendum data from 2012-2013, will be used to assess the OU 6 remedy protectiveness in the Second Five-Year Review Report.

1.0 INTRODUCTION

This *Addendum to First Five-Year Review Report* (*FYRR*) was prepared in accordance with the *Five-Year Review Addendum Sample* (United States Environmental Protection Agency [USEPA] 2008) to address the remedial action (RA) at Operable Unit (OU) 6, Armstrong Flight Research Center, Edwards Air Force Base, California where regulatory partner concurrence on the protectiveness determination was deferred (see Appendix A) in September 2011 until further information was obtained. The trigger date for the OU 6 RA (28 September 2006) corresponds to the remedy initiation that occurred with the signing of the Record of Decision (ROD) (United States Air Force [USAF] 2006). This *Addendum to First FYRR* provides the information regarding progress since the five-year review (the review period extending from 2006 to 2011) as presented in the *First FYRR* (AECOM Technical Services, Inc. [AECOM] 2011). The protectiveness statements outlined in the *First FYRR* (Appendix B) were as follows:

> The remedy is expected to be protective of human health and the environment in the long term upon attainment of groundwater cleanup goals, which are expected to require more than 100 years to achieve, through a combination of *in situ* treatment (chemical oxidation and bioremediation) and natural attenuation. Exposure pathways that could result in unacceptable risks in the short term are being controlled through institutional controls that are preventing exposure to, and the ingestion of, contaminated groundwater. All current threats at the site have been addressed by the implementation of land use controls (LUCs).
>
> Long-term protectiveness of the remedy will be verified by evaluating the future residential indoor air risk and, if applicable, modifying the LUC boundary to restrict residential development in areas with unacceptable indoor air risk. Long-term protectiveness will also be verified by installing and sampling additional groundwater monitoring wells, and modeling subsurface conditions to fully delineate the commingled plume.
>
> The remedy is protective in the short term because unacceptable risks are being controlled through LUCs. Short-term protectiveness of the remedy will be verified by evaluating changes to the vapor intrusion pathway (VIP) protocol and assessing those changes as applicable to OU 6 site conditions. The evaluation may result in collection and analysis of soil vapor (SV) samples from beneath building foundations to evaluate vapor intrusion risk for industrial users.

The *First FYRR* was submitted to the Federal Facility Agreement (FFA) partners as a revised draft final in August 2011. Following regulatory FFA partner review of the revised draft final *First FYRR*, the USEPA issued a letter (Appendix A) in September 2011 expressing the concern that the available data were insufficient to determine that the current OU 6 remedy is protective. The 2011 letter indicated that the USEPA could not concur with the protectiveness determination as presented in the *First FYRR* and such a protectiveness determination would be deferred pending additional (2012-2013) site investigation. A final version of the *First FYRR* was not prepared; this Addendum instead provides both the results of the additional (2012-2013) site investigation, as well as an updated human health risk assessment (Appendix C) based on the 2012-2013 supplemental data, including consideration of the vapor intrusion pathway. Remedial project manager (RPM) comments on the revised draft final *First FYRR* and responses to those comments are included in Appendix A. Responses to RPM review comments that apply to the content of this Addendum have been integrated herein.

2.0 PROGRESS SINCE THE FIVE-YEAR REVIEW COMPLETION

After the *First FYRR* of the OU 6 remedy was submitted to FFA partners in September 2011, the USEPA deferred the five-year review protectiveness statement until the Air Force provided this additional data and analysis in a FYRR Addendum. The additional investigation priorities were related to risk assessment and plume characterization and were considered at the RPM meeting held on 5 October 2011 (AECOM 2013b). During this meeting, the following key action items were discussed:

1. Risk Assessment Key Action Items

- Vapor emanating from volatile organic compound (VOC) plumes in groundwater may impact indoor air quality and result in chemical exposure to building occupants; therefore, assessment of the VIP is warranted and should be considered the highest priority (per 5 October 2011 meeting agreements). The VIP assessment results were to be presented in this First FYRR Addendum.
- Additional data were available for assessing risk, and assessment methodologies were modified since previous efforts. An updated assessment of site risks based upon the most recent data was warranted. The updated risk assessment results were to be presented in this First FYRR Addendum.

Due to a delay in demolition of two buildings and to confirm seasonal variations, an additional VIP sampling event was performed in February 2016. The results of the 2016 VIP Investigation will be presented in the Second FYRR. This Addendum includes a discussion of the VIP up through the 2013 VIP Investigation (Section 2.1.2.1)

2. Plume Characterization Key Action Items

- The VOC plumes required further delineation to close data gaps at the leading edge of the trichloroethene (TCE) plume (Sites N1 and N4). The vertical and lateral extents of the plumes were to be investigated and the results presented in a Groundwater Investigation Report, subsequent annual Remedy Performance and Groundwater Monitoring Reports (RPGMRs), and the Second FYRR scheduled for September 2016.
- Plume stability had not been established; therefore, annual groundwater monitoring was warranted to assess plume movement. The plume stability assessment results were to be presented in the Second FYRR scheduled for September 2016.

Though the Plume Characterization Key Action Items are dynamic and the status update will be included the Second FYRR in September 2016, this Addendum includes a discussion of the plume delineation based on the most recent data available (up through 2012) (Section 2.1.1.3).

This Addendum expands the five-year review to include a summary of the 2013 VIP investigation and to provide the details of the updated human health risk assessment (HHRA). RA progress for the 2011 to 2016 review period will be presented in the Second FYRR.

2.1 TECHNICAL ASSESSMENT OF LATEST GROUNDWATER PLUME DELINEATION AND HEATH RISK ASSESSMENT ACTIVITIES

Per guidance (USEPA 2001), the technical assessment portion of the five-year review should provide the answers to three questions:

Question A: Is the remedy functioning as intended by the decision documents?
Question B: Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives (RAOs) used at the time of the remedy still valid?
Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

The appropriate information, beyond that presented in the *First FYRR* (AECOM 2011), is presented in the following subsections.

2.1.1 QUESTION A: IS THE REMEDY FUNCTIONING AS INTENDED BY THE DECISION DOCUMENTS?

Although the RA is functioning as intended, plume characteristics should be further investigated to properly plan and document future RA activities and progress.

2.1.1.1 Plume Boundaries and *In Situ* Chemical Oxidation Implementation

Artificial plume boundaries were established at Sites N3 and N7 (based on benzene and TCE concentrations above Maximum Contaminant Levels [MCLs] in groundwater) to allow for consistent future contaminant mass estimates. These artificial plume boundaries allow for evaluation of contaminant mass removal despite changes in the plume footprint. As Site N4 was not previously identified as an area of high VOC concentrations in groundwater, *in situ* chemical oxidation (ISCO) implementation in the area was not originally anticipated. The remedy identified for Sites N3 and N7 in the ROD (USAF 2006) included application of ISCO. Establishing an artificial plume boundary for Site N4 is recommended as part of the next five-year review to initiate removal estimates in that treatment area.

Although areas of increasing concentrations and possible plume instability were not necessarily anticipated, they are not unusual occurrences when plume delineation is ongoing. Contaminant mass estimates will be updated as new wells are installed, data are compiled, and plume extent estimates are updated. Treatment areas will be selected based on the latest available data to ensure efficient RA progress. Areas of possible plume instability and expansion were identified at the downgradient edge of the commingled plume after initial RA design and implementation. Therefore, possible plume expansion and instability is an indication of incomplete contamination delineation as opposed to failure or shortcoming of the ISCO component of the remedy for plumes identified in the ROD.

Localized effects of pressurized injections in the form of groundwater mounding and surfacing have been observed up to 30 feet away from injection points during field implementation. Based on this observation the recommendation that ISCO injections be conducted only at wells greater than 100 feet from occupied buildings to avoid displacing/mobilizing the plumes under buildings and possibly completing the VIP has been made in Section 3.2.3. To evaluate if ISCO injections have affected plume stability at the downgradient edge, concentration trends in downgradient wells in relation to Site N7 injection events were evaluated. Site N7 injection events in relation to downgradient monitoring wells were evaluated due to the proximity of the site to downgradient areas and the availability of long-term data as a result of early ISCO implementation (in 2000) at the site. Trend graphs of TCE concentrations in groundwater were generated for wells in the Site N7 and downgradient edge areas (Appendix D) and notated with the timing of Site N7 injections. The locations of wells for which trend graphs were generated are shown on Figure D-1 provided in Appendix D. As further discussed in Section 2.1.1.2, of the leading edge wells with an adequate number of data points, only monitoring well N4-MW06 demonstrates a clear trend of increasing TCE concentrations indicating possible plume movement. As shown on Figure D-1, monitoring well N4-MW06 is located over 1,000 feet away and cross-gradient of the Site N7 treatment area. Given the distance from the Site N7 treatment area and that permanganate has not been observed in monitoring well N4-MW06, it is unlikely that increasing TCE concentrations at this well are a result of injections at Site N7. A closer evaluation of the trend graph indicates that the TCE concentration trend for well N4-MW06 may be becoming asymptotic or leveling off. If this trend is further defined or confirmed during the 2015 and 2016 groundwater monitoring events then it should be determined if there were any site activities that could have caused the increase in TCE concentrations from 2006 to 2010. For example, was an unusually large volume of surface water discharged to the South Retention Pond (Site N4) during this timeframe? It is also noted, that when the Site N4 TCE high concentration area or hotspot is overlain on an aerial photograph (Figure D-1), the hotspot appears to align with an outflow point from the Retention Pond.

2.1.1.2 Groundwater Monitoring

Per the *Groundwater Investigation Work Plan* (AECOM 2015), additional monitoring wells were installed east, southeast, and south of Site N4 in Spring 2015. Samples from these wells provided data for greater accuracy in plume extent estimation. The estimates will provide the basis for more certain contaminant mass/volume calculations that are expected to yield a better understanding of RA progress and cleanup timeframe assessment in the Second FYRR.

2.1.1.3 Groundwater Monitoring Data Review

The groundwater monitoring component of the RA was implemented to evaluate the performance of the ISCO RA component and to track changes in plume characteristics. Though plumes are dynamic and a status update based on the 2015 groundwater sampling event will be included in the Second FYRR in September 2016, the following subsections include a discussion of the plume delineation based on data available up through 2012. Figure 1 is provided as an update to Figure 6-3 of the *First FYRR* to present the difference in plume estimates between 2010 and 2012. Figures 2, 3, and 4 show groundwater TCE, benzene, and carbon tetrachloride (CT) plume estimates, respectively, based on data collected since the first five-year review reporting period, including preliminary data.

<u>TCE in Groundwater</u>

TCE concentrations detected in samples collected from wells installed at OU 6 since 2009 indicate that the commingled plume extends further downgradient than the plume delineation based on previous monitoring events. TCE concentrations in groundwater in 2012 were 110 micrograms per liter (μg/L) at N1-MW10, less than 1 μg/L at N4-MW07, 580 μg/L at N4-MW11, 160 μg/L at N4-MW12, and 150 μg/L at N4-MW13. Trend graphs for wells with an adequate number of data points are included on Figure 2, and indicate that the extent of leading edge plume instability appears to be limited to the southern portion of Site N1 and the northern portion of Site N4 as indicated by increasing TCE concentrations at monitoring well N4-MW06. TCE concentrations in samples collected from monitoring well N4-MW06 have consistently increased since its initial sampling in 2005.

Since the review period, 18 groundwater monitoring wells (RL-25-MW01 to RL-25-MW18) associated with Site 25 (OU 8) were installed in April through September 2013 on the lakebed east and southeast of OU 6 and groundwater samples were collected from those wells and well N4-MW14. Figure 2 presents the locations of these wells and an updated plume configuration estimate based on data collected since those data shown on Figure 6-4 of the *First FYRR*. The laboratory analytical results for those groundwater samples indicated the presence of TCE at 12 of the 18 wells and at well N4-MW14. The horizontal extent of the plume remains unclear to the east, southeast, and south of Site N4 and additional wells were installed in Spring 2015 to close these data gaps. The rationale for the additional well locations is provided in the Revised Final *Groundwater Investigation Work Plan* (AECOM 2015). Site 25 lakebed results (Figure 2) agree with the results of previous investigations regarding vertical contaminant gradient and extent. Site 25 lakebed results indicate that the highest TCE concentrations occur at the water table. This finding is consistent with previous investigations conducted in upgradient areas. As further discussed and illustrated in the Revised Final *Groundwater Investigation Work Plan* (AECOM 2015), packer testing performed at Site N1 indicated a vertical concentration gradient with the highest TCE concentrations present at the water table. Plume characterization extent findings will be updated during the second five-year review period and in future five-year review periods.

<u>Benzene in Groundwater</u>

Figure 3 presents an updated benzene plume configuration estimate based on data collected in 2012. Since the review period covered by the September 2011 *First FYRR*, well N3-MW24 (located downgradient of well N3-MW20) was sampled in 2012 for the first time. Well N3-MW24 groundwater sampling results in 2012 indicate that the benzene plume extends farther downgradient than shown on Figure 3-7 of the *First FYRR*. As well N3-MW24 was not previously sampled, adequate data are not yet available to determine if benzene concentrations detected in this well indicate plume instability. Installation of a monitoring well (proposed well N3-MW29, Figure 3) downgradient of well N3-MW24 occurred in Spring 2015 to further delineate the benzene plume (AECOM 2015).

<u>Carbon Tetrachloride in Groundwater</u>

CT concentration contouring (AECOM 2012) indicates that CT is present in two distinct areas within OU 6, Sites N3 and N4 (Figure 4). This observation was further confirmed by the 2014 sampling data collected as part of the Site 25 investigation effort. CT was detected at a concentration of 60 µg/L at well N4-MW14 and was not detected above the reporting limit at wells RL-25-MW01 to RL-25-MW18 on Rogers Dry Lake (Figure 4). The sources of CT (and other solvent-related chemicals of concern [COCs] such as TCE) are likely former drum storage and drum dispensary areas at Site N3. One of the drum dispensaries was located at the present location of well N3-MW05, which is one of the Site N3 wells with relatively high CT concentrations. Additionally, this drum dispensary area was located immediately upgradient from the drainage ditch which defines the northern and western Site N3 boundary. The outfall of the drainage ditch is the Southern Retention Pond identified as Site N4, indicating that the sources of CT at Site N4 are the former drum storage and drum dispensary areas at Site N3. CT has not been detected in samples collected from Site N7 area wells since trace concentrations were detected in 2001, further indicating that the former Site N3 drum storage and drum dispensary areas are the likely source of CT in Site N4 groundwater.

The CT concentration contour estimates (Figure 4) in the Site N4 area potentially impact future ISCO implementation. ISCO treatment of CT requires a strong oxidant such as Fenton's reagent or persulfate. ISCO treatability studies using permanganate, Fenton's reagent, and persulfate were performed at Sites N3 and N7. Based on the results of these studies, permanganate was selected as the oxidant for the RA, primarily due to the difficulties dispersing Fenton's reagent and persulfate into the fractured bedrock aquifer of Sites N3 and N7. However, due to its location on the lakebed, Site N4's groundwater contamination is located in unconsolidated material and may be more amenable to Fenton's reagent or persulfate treatment. Further evaluation and recommendations regarding employing Fenton's reagent or persulfate treatment at Site N4 are anticipated to be included in the RPGMRs and Second FYRR as part of the plume characterization and containment periodic (five-year) evaluation.

2.1.2 QUESTION B: ARE THE EXPOSURE ASSUMPTIONS, TOXICITY DATA, CLEANUP LEVELS, AND RAOS USED AT THE TIME OF THE REMEDY STILL VALID?

Per guidance, the validity of assumptions on which the RA was selected was evaluated in the *First FYRR* (AECOM 2011). As a result of the evaluation, changes in risk parameters (contaminants characteristics, risk assessment methods, and exposure pathways) and the nature and extent of COCs and other contaminants were identified as requiring further assessment. In support of a protectiveness determination, risk parameters (in the form of an update to the baseline HHRA [Earth Tech, Inc. 2003]) and the nature and extent of COCs and other contaminants were re-examined since the completion of the September 2011 *First FYRR* as summarized in the following subsections.

2.1.2.1 Changes in Toxicity and Other Contaminant Characteristics

Guidance indicates that a review should be performed of toxicity criteria used for determining cleanup levels as part of the five-year review process.

At least two key changes in toxicity criteria (for example, new USEPA Integrated Risk Information System non-cancer toxicity criteria not released until 2010 and 2011 for CT and TCE, respectively) resulted in updates to the HHRA since it was completed in 2003. Using the latest toxicity criteria, the HHRA Addendum (Appendix C), with consideration of 2012 groundwater and 2013 indoor air contaminant concentrations and exposure pathways, presents a comprehensive update to the groundwater risk assessment for the industrial inhalation (via the VIP) and for residential ingestion, inhalation (direct via groundwater use and indirect via the VIP), and dermal exposure routes. Direct groundwater exposure pathways for all receptors (see Figure 1 of Appendix C) remain incomplete due to the implementation of LUCs as part of the RA. The following components comprise the updated HHRA (Appendix C):

- Identification of contaminants of potential concern in groundwater
- Determination of hypothetical direct contact groundwater-related cancer risks and non-cancer hazards
- Determination of VIP-related cancer risks and non-cancer hazards for Buildings 4806, 4807, and 4810

Based on maximum reported 2012 groundwater concentrations at each OU 6 source area, the updated human health risk screening for dermal, ingestion, and direct inhalation exposure routes under the hypothetical future residential scenario indicated that the total hypothetical future tapwater-derived cancer risks decreased since those presented in the baseline HHRA at Sites N1, N2, N3, and N7 and slightly increased at Site N4. The increased risk at Site N4 is partially due to an increase in TCE concentration. That increase in concentration is due to more extensive plume delineation in the Site N4 area and not to a new or continued release. With the exception of Site N2, the non-cancer hazards at OU 6 increased due to the inclusion of TCE in the re-assessed hazard based on USEPA release of non-cancer toxicity values in 2011. Changes in TCE concentrations and toxicity values are the primary contributing factors to the slight cancer risk increase at Site N4 and the non-cancer hazard increases at Sites N1, N3, N4, and N7. Since the OU 6 remedy includes LUCs prohibiting residential redevelopment and use of the groundwater for drinking, no actual residential exposures are occurring. TCE is identified as a COC in the ROD with a cleanup goal of 5 μg/L. Additionally, the LUCs at OU 6 preventing residential development will continue into the foreseeable future at this active military installation.

Given that 1) the re-assessment using current toxicity values, risk assessment methodologies, and chemical concentrations resulted in decreased cancer risk values at a majority of the sites, 2) the increases in non-cancer hazard indices are attributable to TCE (which is already identified as a COC in the ROD), and 3) LUCs are in place preventing residential exposure, the remedy remains protective consistent with USEPA Five-Year Review guidance for interpreting these risk results within the CERCLA framework (USEPA 2001):

> Generally, your human health determination should be based on whether the cancer risk could now be greater than 10^{-4} and/or the hazard index could be greater than 1 for non-carcinogenic effects.

The baseline (2003) HHRA presented the results of the potential risk from groundwater VOCs that might migrate through the vadose zone and into buildings routinely occupied by indoor workers. The results of those assessments indicated that the risks were all within or less than the generally acceptable cancer risk range of 1×10^{-4} to 1×10^{-6} and a Hazard Index of 1. Therefore, cleanup levels to protect receptors from the potential VIP were not established in the ROD. However, since the toxicity criteria by which some of the VOCs were evaluated for the VIP assessment have changed since the baseline HHRA, re-evaluation of risks via the VIP was warranted, thus the 2013 vapor intrusion investigation was conducted. Additionally, changes in the nature and extent of benzene in relation to occupied buildings, necessitated the collection and inclusion of building sub-slab soil gas and indoor air data in the reassessment as presented in the HHRA Addendum (Appendix C).

Sub-slab soil gas and indoor air samples were collected in three buildings in 2013. Additionally outdoor air samples were collected at each building. The results indicated that all of the cancer risks for VIP-related chemicals for the industrial scenario were less than 1×10^{-4} (the highest cancer risk was 5×10^{-6}) and the non-cancer hazards were less than 1. When the 2013 indoor air data were assessed with future hypothetical residential exposure assumptions, the estimated VIP-related risk results for the residential scenario were (as expected) slightly higher than the industrial scenario risks (the highest cancer risk was 2 x 10^{-5}), however all cancer risks were still below 1 x 10^{-4}. None of the non-cancer hazards for the residential scenario exceeded 1 (Appendix C, Table 6). The USEPA has provided Five-Year Review guidance for interpreting these risk results within the CERCLA framework (USEPA 2001):

> Generally, your human health determination should be based on whether the cancer risk could now be greater than 10^{-4} and/or the hazard index could be greater than 1 for non-carcinogenic effects.

Thus based on the 2013 VIP investigation, the OU 6 remedy is protective of vapor intrusion for both the current industrial worker as well as the hypothetical future resident given the continued implementation of LUCs prohibiting residential development for the foreseeable future. Due to a delay in the demolition of two buildings and to confirm seasonal variations, an additional VIP investigation was performed in February 2016. The findings of the 2016 VIP investigation will be documented in the Second FYRR.

Per the *Vapor Intrusion Sampling Plan and Risk Assessment Work Plan* (AECOM 2013a) risks and hazards were calculated using both Department of Toxic Substances Control (DTSC)-developed toxicity values and USAF-preferred toxicity values for comparison purposes. While the risks and hazards calculated using the DTSC-preferred toxicity values were slightly higher or the same as those calculated using the USAF-preferred toxicity values, the risks were less than 1 x 10^{-4}. The non-cancer hazard calculated using the DTSC-preferred toxicity values exceeded 1 at 1 of 13 sampling locations during 1 of the 2 seasonal events. The current assessment of the VIP with USAF-preferred toxicity values estimated that cancer risks were below 1 x10^{-4} and non-cancer hazards less than 1, similar to the findings presented in the ROD and based on the baseline (2003) HHRA. Updating the HHRA using current methodologies and toxicity data did not result in recommendations for changes to the RAOs, COCs, or cleanup goals selected in the ROD (USAF 2006).

2.1.2.2 VOCs in Groundwater

As summarized in Section 2.1.1.3 and presented in the *RPGMR, 2011 - 2012* (AECOM 2012), groundwater monitoring was performed since the *First FYRR*. Although no new groundwater sources were identified, plume delineation data gaps exist. As further discussed in Section 3, those data gaps do not impact the current protectiveness of the RA and additional groundwater investigation activities are planned.

2.1.3 QUESTION C: HAS ANY OTHER INFORMATION COME TO LIGHT THAT COULD CALL INTO QUESTION THE PROTECTIVENESS OF THE REMEDY?

No additional information, beyond that presented in the *First FYRR* (AECOM 2011), has come to light that could call into question the protectiveness of the remedy.

2.1.4 TECHNICAL ASSESSMENT SUMMARY

The results of the updated HHRA indicate that changes in contaminant concentrations, risk assessment methodologies, and toxicity criteria since the signing of the ROD have not impacted remedy protectiveness.

Two factors have affected the previous understanding of the plume nature and extent, causing difficulties in the estimation of timeframes for the achievement of RAOs. The downgradient TCE extent is unknown and plume stability/expansion cannot be assessed due to insufficient data in the downgradient portion of the plume.

Based on the information presented in the *First FYRR* and this Addendum, the remedy is functioning as intended by the decision documents.

3.0 ISSUES AND RECOMMENDATIONS

3.1 ISSUES

During the technical assessment in the five-year review, issues were identified that warranted consideration to determine if they may impact current or future protectiveness. Those considerations are discussed in the followings subsections.

3.1.1 LEADING EDGE DATA GAP

Based on data collected since the five-year review reporting period, TCE has been detected in groundwater samples collected from wells N4-MW14 and RL-25-MW01 to RL-25-MW18 on Rogers Dry Lake installed under the Site 25 investigation efforts (Figure 2). To further address the apparent gaps in groundwater plume data, additional well installations were proposed in the area of Site N4 and on Rogers Dry Lake as presented in the Revised Final *Groundwater Investigation Work Plan* (AECOM 2015).

Data collected since the five-year review reporting period indicate that the plume extends beyond the monitored area and that a data gap exists. Because exposure pathways that could result in unacceptable risks in the short term are being controlled through institutional controls, short-term protectiveness has not been affected. The ISCO RA component was implemented at Site N4 during the Phase II, Injection Event II implementation in August 2010. ISCO treatment in the Site N4 area using a strong oxidant such as Fenton's reagent or persulfate will likely be required to reduce CT and TCE concentrations. If ISCO treatment is unsuccessful in reducing VOC concentrations at Site N4 and if the recommended Site N1 and Site N4 characterization indicates that the plume is migrating significantly toward the groundwater subbasin drinking water supply wells, future protectiveness could be threatened.

The issues related to plume leading edge characteristics and treatment do not affect short-term protectiveness; however, they may affect long-term/future protectiveness. Updates will be provided in the Second FYRR (September 2016) to track progress toward verification of long-term protectiveness.

3.1.2 Changes in Toxicity Criteria and Risk Assessment Methodologies

To account for changes in site-specific human health risk, toxicity criteria, and regulatory guidance since the signing of the ROD, an assessment of the VIP at three OU 6 buildings and an updated HHRA for the groundwater plume (Appendix C) were performed. Changes in toxicity criteria, risk assessment methodologies, and contaminant concentrations did not impact remedy protectiveness.

3.2 RECOMMENDATIONS AND FOLLOW-UP ACTIONS

The issues described in Section 3.1.1, potentially affecting short-term and/or long-term remedy protectiveness, warrant follow-up actions as presented in Table 1. The USAF and National Aeronautics and Space Administration will be responsible for any follow-up actions, with the regulatory oversight by the USEPA, DTSC, and California Regional Water Quality Control Board. Table 2 presents a summary of anticipated RA activities, related document submittals through 2016, and follow-up actions.

3.2.1 Issues Warranting Follow-up Actions

The issue described in Section 3.1.1 warranting follow-up action is presented as Specific Issues 1 and 2 in Table 1 and discussed below.

Specific Issue 1: To close the leading edge data gaps, optimize remedy performance by identifying potential ISCO injection candidate locations, monitor cleanup progress, and verify future protectiveness (to be reassessed in the Second FYRR), installation and sampling of monitoring wells is recommended. Step-out monitoring wells should include locations south of existing monitoring wells N4-MW04, N4-MW05, N4-MW11, N4-MW12, N4-MW13, and N7-MW13. Other recommended monitoring well locations include east of N1-MW08, N1-MW10, N1-MW11, and N4-MW13.

Specific Issue 2: Because plume stability at the leading edge has not been demonstrated, groundwater monitoring of the OU 6 plume is recommended to evaluate concentration trends to determine whether the leading edge is expanding, shrinking, or stable.

3.2.2 ANTICIPATED REMEDIAL ACTION ACTIVITIES IN THE NEXT FIVE YEARS

The *Remedial Action Work Plan Addendum* (AECOM 2013b) presented a schedule and pathway for program documents detailing the investigative and analytical work efforts addressing issues identified above. Action items were divided into three main categories: Risk Assessment, Plume Characterization, and Ongoing RA. Table 2 presents the RA activities based on the schedule outlined in the *Remedial Action Work Plan Addendum* (AECOM 2013b). Figure 5 presents the relationship of program tasks to each other and approximate document submittal timing through the Second FYRR.

3.2.3 ADDITIONAL REMEDIAL ACTION IMPLEMENTATION RECOMMENDATIONS

During the review period, TCE and benzene were used to define the LUC boundary because these two COCs were believed to be present at concentrations above their respective MCLs over a larger area than the other detected chemicals; however, a comparison of Figures 2 and 4, indicates that the CT plume maybe larger northeast of Site N4 than the TCE plume. Data from the proposed monitoring wells (specifically proposed well N4-MW15) in conjunction with the Site 25 investigation data may indicate that the TCE plume extends further to the northeast of Site N4. However, as a precaution, it is recommended that the LUC boundary be modified to include the CT plume as well as the TCE and benzene plumes (AECOM 2012).

Artificial plume boundaries were established at Sites N3 and N7 to allow for consistent future contaminant mass estimates. To initiate removal estimates and allow for consistent future contaminant mass estimates an artificial plume boundary for Site N4 is recommended as part of the next five-year review.

ISCO injections should be conducted only at wells greater than 100 feet from occupied buildings to avoid displacing/mobilizing the plumes under buildings and possibly completing the VIP. Pressures should be monitored in observation wells located between injection points and occupied buildings as an indication of plume displacement/mobilization (AECOM 2013b). Redevelopment of wells critical for use as active injection points, which do not readily accept reagent is recommended. Further evaluation and recommendations regarding employing Fenton's reagent or persulfate treatment at Site N4 to treat CT should be included in the RPGMRs and Second FYRR as part of the plume characterization and containment evaluation (AECOM 2012).

A delay in the demolition of two OU 6 buildings and the need to confirm seasonal variances to ensure that the indoor air risk is still in the protective range for the site workers under the industrial land use scenario warranted an additional winter sampling event. The additional VIP investigation was conducted in February 2016 and will be documented in the Second FYRR.

4.0 PROTECTIVENESS STATEMENT

The supplemental Addendum data from 2012-2013, will be used to assess the OU 6 remedy protectiveness in the Second FYRR.

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5.0 NEXT FIVE-YEAR REVIEW

The next five-year review will be completed in 2016, 10 years after the signing of the ROD.

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6.0 REFERENCES

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——— 2013a. *Environmental Restoration Program*, *Vapor Intrusion Sampling Plan and Risk Assessment Work Plan, National Aeronautics and Space Administration, Dryden Flight Research Center, Operable Unit 6, Edwards Air Force Base, California, Final*. Prepared for 412 TW/CEV, Edwards AFB, CA; NASA DFRC, Edwards AFB, CA; and AFCEC/CZRW, San Antonio, TX. Sacramento, CA. March.

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LIST OF FIGURES

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EXPLANATION

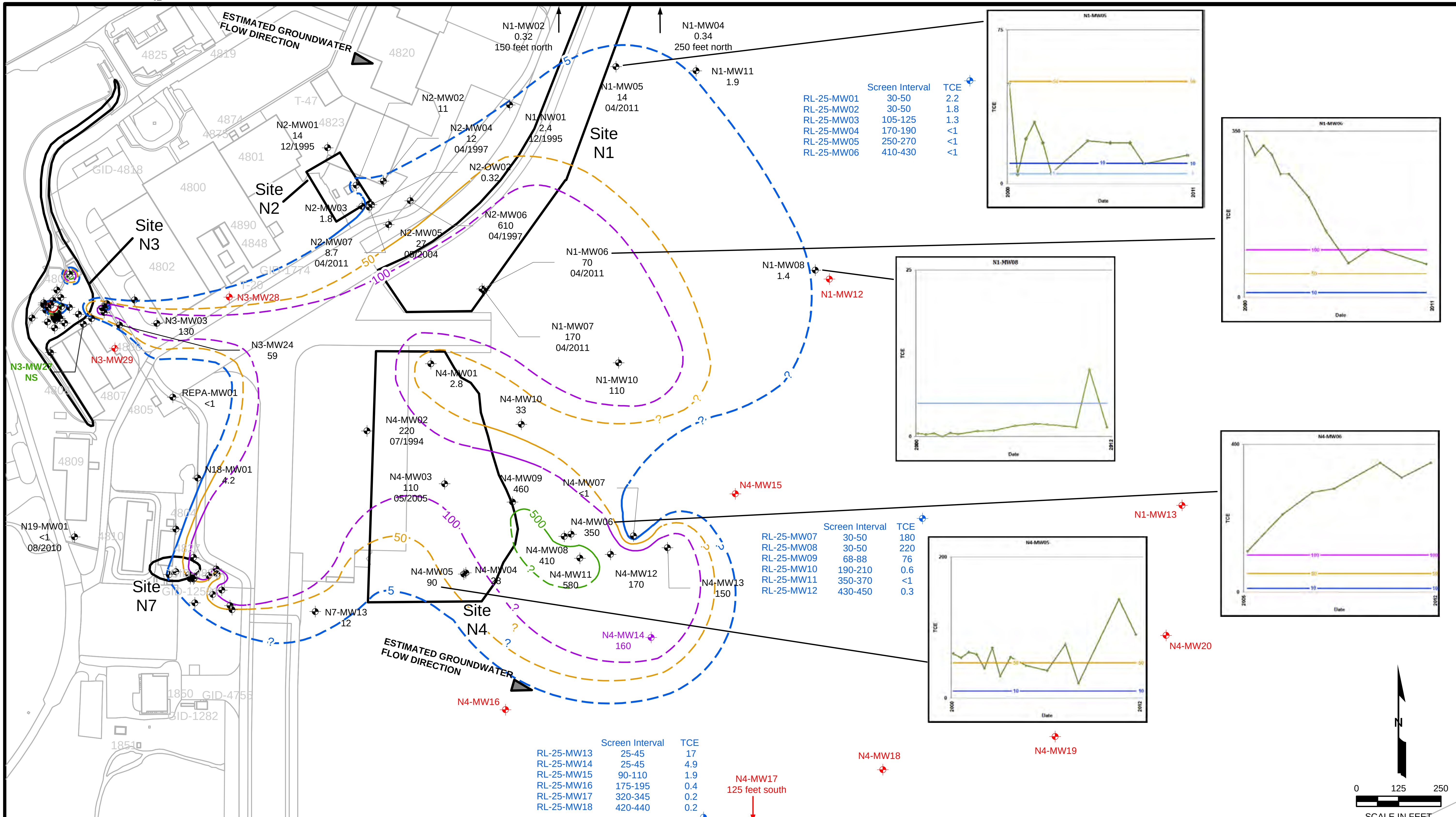
- ESTIMATED TCE PLUME EXTENT BASED ON 2010 DATA (5 ug/L) PER THE INTERIM REMEDIAL ACTION COMPLETION REPORT (AECOM 2011)
- ESTIMATED TCE PLUME AREA EXCEEDING 5 ug/L IN BOTH 2010 AND 2012
- ESTIMATED TCE PLUME EXTENT BASED ON 2012 DATA (5 ug/L) PER THE REMEDY PERFORMANCE AND GROUNDWATER MONITORING REPORT (AECOM 2012)
- ESTIMATED TCE PLUME AREA EXCEEDING 5 ug/L BASED ON 2014 RESULTS FROM WELL N4-MW14

ug/L MICROGRAMS PER LITER
TCE TRICHLOROETHENE

Approximate Extent of TCE in Groundwater

Date 04-2015	Addendum to First Five-Year Review Report	Figure
Project No. 60318504	**Operable Unit 6 Edwards AFB**	**1**

P:\ENV\EAFB\60277061\7.0\7.2\5YRRA\Fig_2.mxd



EXPLANATION

N4-MW18 — PROPOSED MONITORING WELL

N7-MW04 76 — MONITORING WELL AND 2012 TCE CONCENTRATION

N4-MW14 160 — MONITORING WELL SAMPLED IN MARCH 2014 AND TCE CONCENTRATION

N3-MW27 NS — MONITORING WELL INSTALLED IN AUGUST 2012 - NOT SAMPLED

RL-25-MW01 — MONITORING WELL, SCREEN INTERVAL IN FEET BELOW GROUND SURFACE, AND TCE CONCENTRATION FROM MARCH 2014 18 WELLS INSTALLED AS PART OF THE SITE 25 INVESTIGATION

"<" INDICATES THAT TRICHLOROETHENE (TCE) WAS BELOW THE REPORTING LIMIT SHOWN.

MOST RECENT SAMPLING DATES ARE PRESENTED FOR WELLS NOT SAMPLED DURING THE 2012 EVENT. COMPREHENSIVE 2012 DATA, INCLUDING THOSE FOR SITE N3, ARE PRESENTED IN THE REMEDY PERFORMANCE AND GROUNDWATER MONITORING REPORT (AECOM 2012).

GROUNDWATER TCE CONCENTRATION CONTOUR (INTERVALS = 5, 50, 100, 500) ALL CONCENTRATIONS PRESENTED

-- 50 -- IN MICROGRAMS PER LITER. THE ESTIMATED CONTOURS ARE BASED ON 2012 MONITORING RESULTS, DASHES INDICATE CONTOUR IS INFERRED.

TCE Groundwater Concentration Contours May - June 2012 and Proposed Well Locations

Date 04-2015	Addendum to First Five-Year Review Report	Figure
Project No. 60318504	Operable Unit 6 Edwards AFB	2

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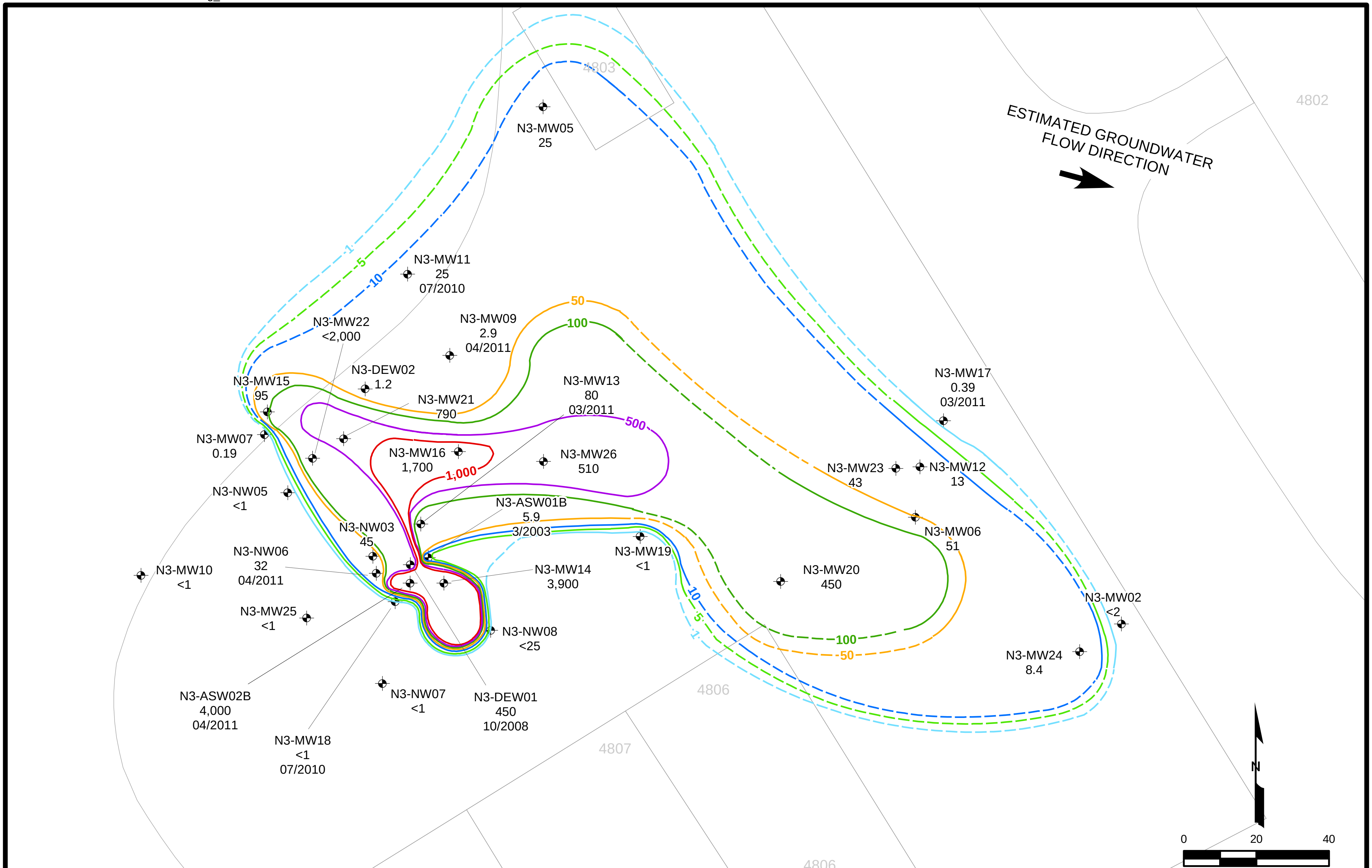

EXPLANATION

N3-MW14 3,900 — MONITORING WELL AND BENZENE CONCENTRATION

N3-MW29 — PROPOSED MONITORING WELL

"<" INDICATES THAT BENZENE WAS BELOW THE REPORTING LIMIT SHOWN.

MOST RECENT PREVIOUS SAMPLING DATES ARE PRESENTED FOR WELLS NOT SAMPLED DURING THE 2012 EVENT.

50 — GROUNDWATER BENZENE CONCENTRATION CONTOUR (INTERVALS = 1, 5, 10, 50, 100, 500, 1,000) ALL CONCENTRATIONS PRESENTED IN MICROGRAMS PER LITER. THE ESTIMATED CONTOURS ARE BASED ON 2012 MONITORING RESULTS, DASHES INDICATE CONTOUR IS INFERRED.

Site N3
Benzene Groundwater Concentration Contours - May-June 2012

Date 04-2015	Addendum to First Five-Year Review Report	Figure
Project No. 60318504	**Operable Unit 6 Edwards AFB**	**3**

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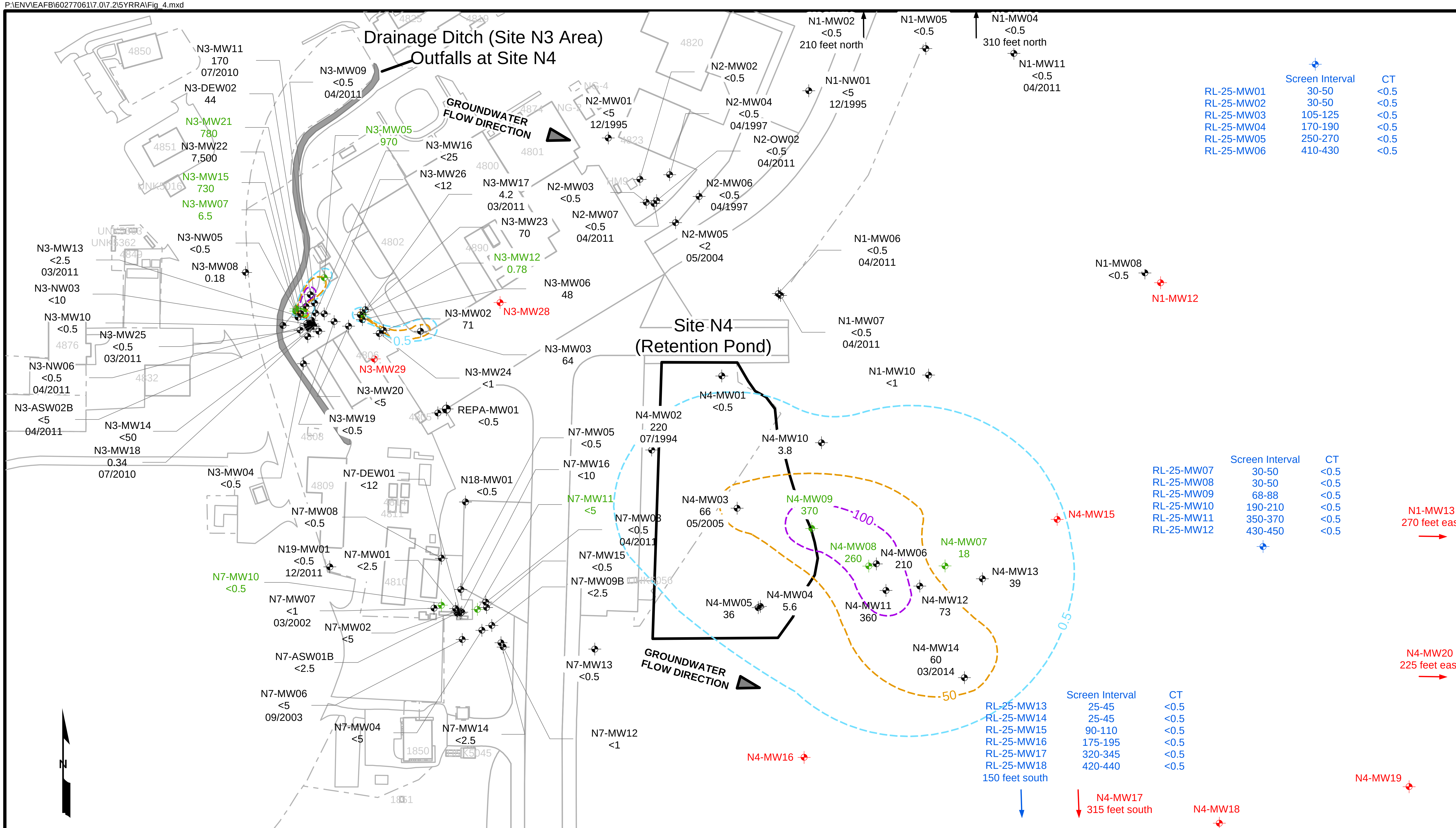


EXPLANATION

N3-MW23 46 — MONITORING WELL AND CT CONCENTRATION

N3-MW07 4.4 — MONITORING WELL (USED FOR INJECTION IN AUGUST 2010) AND CT CONCENTRATION

N3-MW29 — PROPOSED MONITORING WELL LOCATION

RL-25-MW01 — MONITORING WELL, SCREEN INTERVAL IN FEET BELOW GROUND SURFACE, AND CT CONCENTRATION FROM MARCH 2014 18 WELLS INSTALLED AS PART OF THE SITE 25 INVESTIGATION

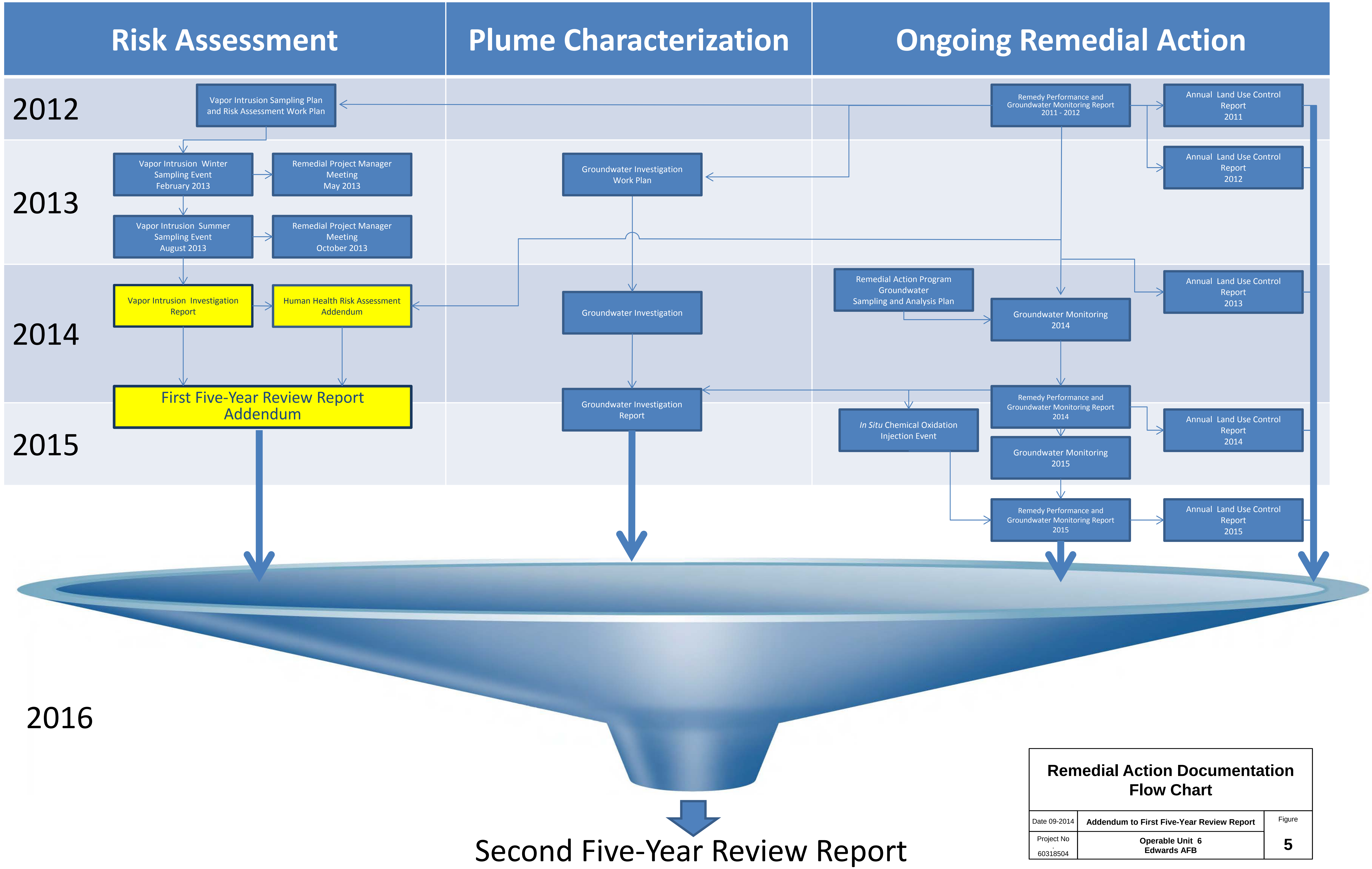
"<" INDICATES THAT CARBON TETRACHLORIDE (CT) WAS BELOW THE REPORTING LIMIT SHOWN.

MOST RECENT SAMPLING DATES ARE PRESENTED FOR WELLS NOT SAMPLED DURING THE MAY-JUNE 2012 EVENT.

-- 50 -- GROUNDWATER CT CONCENTRATION CONTOUR (INTERVALS = 0.5, 50, 100, 500, 1,000) ALL CONCENTRATIONS PRESENTED IN MICROGRAMS PER LITER

CT Groundwater Concentration Contours - May-June 2012

Date 04-2015	Addendum to First Five-Year Review Report	Figure
Project No. 60318504	Operable Unit 6 Edwards AFB	4



Remedial Action Documentation Flow Chart

Date 09-2014	Addendum to First Five-Year Review Report	Figure
Project No. 60318504	Operable Unit 6 Edwards AFB	5

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TABLE 1. RECOMMENDATIONS AND FOLLOW-UP ACTIONS

Specific Issue	Recommendations and Follow-up Actions	Anticipated Completion	Affects Protectiveness (Yes/No) Current	Affects Protectiveness (Yes/No) Future
1.) Remedy Performance: Plume delineation data gap at the leading edge	Additional monitoring wells were installed to further delineate the leading edge of the plume, monitor cleanup progress, and to possibly provide *in situ* chemical oxidation injection locations should leading edge treatment be required. Recommended future locations of step-out monitoring wells include locations south of existing monitoring wells N4-MW04, N4-MW05, N4-MW11, N4-MW12, N4-MW13, and N7-MW13. Other recommended monitoring well locations include locations east of N1-MW08, N1-MW10, N1-MW11, and N4-MW13. Data from groundwater samples to be collected from proposed monitoring wells (which were installed in Spring 2015) will be used to optimize remedy performance as necessary. Protectiveness will be reassessed in the Second FYRR.	Initial investigation completed Spring 2015. Contingent follow-on investigation to be proposed by September 2016	No	Yes

TABLE 2. SUMMARY OF ANTICIPATED REMEDIAL ACTION ACTIVITIES IN THE NEXT FIVE YEARS

Activity	Event	Date	Task	Documentation	Projected Document Submittal Date
Risk Assessment	VIP field investigation	2/2013 to 8/2013	Vapor and air sampling at 3 buildings	Vapor Intrusion Investigation Report	9/2014 (AECOM 2014)
		2/2016	Vapor and air sampling at 2 buildings	Second Five-Year Review Report	9/2016
	HHRA update	3/2014 to 5/2014	Update of HHRA using latest groundwater/vapor data/methodology	Human Health Risk Assessment Addendum (Appendix C to this Addendum)	9/2014
Plume Character-ization	Monitoring well installation	9/2012	Installation of 2 wells	RPGMR 2011-2012	10/2012 (AECOM 2012)
	Monitoring well installation	4/2015	Installation of 10 wells *	Groundwater Investigation Work Plan (AECOM 2015)/RPGMR	Second Quarter 2016
Ongoing Remedial Action	LUCs	On-going	Enforcement of LUCs	Annual LUC Reports	Annually in February
	Groundwater Monitoring 2011-2012	3/2011 to 6/2012	Sampling of 59 wells	RPGMR 2011-2012	10/2012 (AECOM 2012)
	Groundwater Monitoring 2015	5/2015	TBD	RPGMR 2015	Second Quarter 2016
	Groundwater Monitoring 2016	10/2016	TBD	RPGMR 2016	First Quarter 2017

Notes:

*Well locations are shown on Figure 2 and presented in the Revised Final Groundwater Investigation Work Plan (AECOM 2015).

AECOM AECOM Technical Services, Inc.
HHRA human health risk assessment
LUC land use control
RPGMR Remedy Performance and Groundwater Monitoring Report
TBD to be determined
VIP vapor intrusion pathway

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APPENDIX A
NON-CONCURRENCE LETTER AND RESPONSE/
RESPONSES TO REGULATORY COMMENTS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

30 September 2011

Robert W. Wood
Chief, Environmental Management
95 ABW/CEV
5 East Popson Avenue, Bldg. 2650A
Edwards Air Force Base, California 93524-8060

Re: U.S. Environmental Protection Agency (EPA) - EPA Non-Concurrence on the Edwards AFB Draft Final First Five-Year Review Report, NASA Dryden Flight Research Center, Operable Unit 6 (OU 6), Edwards Air Force Base, California, dated August 2011.

Dear Mr. Wood:

The U.S. Environmental Protection Agency (EPA) has reviewed the Air Force's *Draft Final First Five-Year Review Report, NASA Dryden Flight Research Center, Operable Unit 6 (OU 6),* Edwards Air Force Base, California dated August 2011. As explained during the July 2011 teleconference re "*EPA Technical Response to the Air Force Response to Comments (RTCs) on the subject Draft Final Five-Year Review Report*," EPA does not concur with the Air Force's protectiveness determination for Operable Unit 6. EPA has found that a protectiveness determination for the remedy cannot be made at this time until further information is obtained. The State of California, Department of Toxic Substances Control (DTSC) supports EPA's position and informed the Air Force of its decision to non-concur on the protectiveness statement for the subject Draft Final Five Year Review Report (via a letter dated 2 September 2011 to Mr. Ai Duong, Chief, Environmental Restoration Branch, Edwards AFB from Mr. Kevin Depies, RPM, DTSC).

Technical Assessment of the OU 6 Remedy - Protectiveness Statement:

Based upon EPA's technical assessment, the subject Draft Final Five-Year Review Report fails to provide sufficient information to make a protectiveness determination that the remedy at OU 6 is expected to be protective of human health and the environment. Accordingly, and consistent with EPA's 2001 Comprehensive Five-Year Review Guidance, EPA will defer a protectiveness determination for the groundwater remedy until additional information (as described below) has been submitted by the Air Force and reviewed by EPA. It is EPA's expectation that the actions necessary to obtain the additional information should take place within two years from the date of this letter. Upon review of the information, EPA will make a final protectiveness determination.

Data acquisition follow-up actions would include but not limited to additional studies, further analyses and clarifications, and/or additional data collection. This will be one of the major agenda items for the Edwards AFB RPM Meeting re *Five Year Review Administrative Deferment Requirements and Processes* on 5 and 6 October in Oakland, i.e., the development of an *RA Work Plan Addendum* with specific milestones for completing this Five Year Review Report.

Summary of Technical Assessment of Remedy

The major technical deficiencies involve:

1. Contaminant Concentrations: The subject document reflects the lack of knowledge about the extent of constituents (benzene, naphthalene and ethylbenzene) and contaminant levels under and in the vicinity of worker-occupied buildings. It is important that the Air Force use the appropriate toxicity values for a revised VIP risk analysis for current and future workers who may potentially be exposed to VOCs in occupied buildings; and

2) Plume Characterization: Incomplete plume delineation resulting in an inability to conclude that the leading edge of the TCE plume is stable given the increasing contaminant concentrations at monitoring wells in the area.

Technical Assessment of Remedy – Major Issues

1. Vapor Intrusion Pathway (VIP) Risk

The most significant technical issue informing the assessment of the remedy Protectiveness Deferred is the Vapor Intrusion Pathway (VIP) Risk; specifically, changes in both exposure pathways and in VOC concentrations, as well as changes in toxicity criteria.

Three buildings at OU 6 are currently occupied by workers: Buildings 4806**;** 4807 and 4810. There is a concern for the potential vapor intrusion pathway for current or future worker exposure in these buildings. Based on recent groundwater monitoring data, high concentration areas of the benzene plume have migrated beneath Building 4806, while Buildings 4807 and 4810 are in close proximity to migrating plume. Prior to 2010 there were no wells near this building.

Recommended Action: The detection of benzene concentration increases in groundwater and lack of knowledge about the extent and contaminant levels under worker-occupied buildings will require collection of additional information via a Vapor Intrusion Pathway (VIP) Risk Assessment. This additional information is essential in order to make a determination whether the remedy is protective for current or future workers who may potentially be exposed to VOCs in occupied buildings via a preferential vapor intrusion pathway.

A risk assessment for the vapor intrusion pathway must be conducted including both subslab and indoor air sampling. Indoor air sampling must be performed as soon as possible to evaluate risk to workers and additional groundwater monitoring to determine preferential pathway potential. Sampling indoor will help demonstrate if there is a complete pathway and/or potential current exposure.

Also, the Air Force shall use the more conservative State toxicity values within the revised risk assessment for the vapor intrusion pathway. The State of California OEHHA toxicity value is different from EPA's by a factor of 4. Thus, the Agency's industrial indoor air screening value at 10^{-6} is 1.6 ug/m^3, the State's would be 0.4 ug/m^3. In addition, when performing the VIP risk assessment, the Air Force must use 10^{-6} as the point of departure for evaluating risk in terms of the area of risk for both the industrial scenario and for a future residential scenario, and as the trigger for developing action levels within the risk management range.

2. Plume Delineation and Updates of Groundwater Contaminant Concentration Contours.

Another significant technical issue that resulted in non-concurrence involves the delineation and routine updates of the critical groundwater contaminant concentration contours that impact ISCO applications as well as the above-discussed VIP concerns. For example, due to the lack of delineation of the extent of the TCE plume to the east, southeast and south of the N4 area, it cannot be concluded that the leading edge plume is stable given the increasing TCE concentrations at monitoring wells in the area.

Recommended Action: Due to the lack of delineation of the extent of the TCE plume, it cannot be concluded that the leading edge of the plume is behaving as predicted and relied upon in the ROD. The Air Force shall, consistent with the ROD (See Section 2.12.2.2 ": Groundwater Monitoring"), provide sufficient and timely groundwater monitoring data to demonstrate that the current observed plume behavior is consistent with the assumptions of the groundwater monitoring model, then EPA is unable to determine plume stability and/or shrinkage. It should be noted that the ROD requires the Air Force "to verify performance against the modeling predictions, and to ensure that that plume behavior does not change in any unexpected ways that might threaten the regional aquifer." However, should the groundwater monitoring data reveal variance between the assumptions of the model and the expected plume behavior, then the ROD requires the Air Force to submit "a contingency plan to capture anomalous migration of contaminants" (Record of Decision, NASA *Dryden Flight Research Center, Operable Unit 6 (OU 6), Edwards Air Force Base, California, 2006 September, page 2-62).*

Given the increasing contaminant concentrations at monitoring wells in the area, additional wells must be installed to delineate the plume and additional samples must be collected from wells installed in 2010 in order to determine whether the full extent of the TCE plume has been successfully delineated. Based on these results, a contingency plan may be required.

Summary of Technical Assessment of Remedy Performance and Actions Necessary for Final Protectiveness Determination

In sum, EPA has concluded that insufficient data regarding the TCE groundwater plume and the potential vapor intrusion issues present significant uncertainty in the assessment of threats to human health. Accordingly, the Agency has changed the Human Health Environmental Indicator (EI) determination from "Current Human Exposures Controlled" to "Insufficient Data to Determine Human Exposure Control Status."

In addition, EPA is contemplating the need to change the EI for groundwater to a similar non-protectiveness status due to insufficient data to confirm that the TCE contaminated groundwater plume has stabilized, and whether the *in situ* chemical oxidation (ISCO) component of the OU 6 remedy is performing as expected.

As an aid in further preparation for completing this Five Year Review Report, attached please find EPA's general and specific technical comments on the subject Draft Final Five-Year Review report, including additional information and recommendations relative to obtaining EPA concurrence on a final protectiveness determination.

EPA reaffirms its commitment to working in partnership with the Department of the Air Force to expeditiously facilitate the cleanup at Edwards AFB in a manner that is protective of human health and the environment.

Should you have any concerns or require additional information or clarification regarding the Agency's comments, please contact Loren Henning, Chief, Air Force and DOE Section, Superfund Division at 415-972- 3164.

Sincerely,

Michael M. Montgomery
Assistant Director
Federal Facilities and Site Cleanup Branch

Attachments: EPA Comments on Draft Final Five-Year Review Report

cc:

Ai Duong, RPM, EAFB
Dan Medina, AFCEE
Kevin Depies, DTSC RPM
Tim Post, RWQCB RPM
John Steude, RWQCB
Thelma Estrada, EPA ORC

U.S. Environmental Protection Agency
Review of the Responses to Comments
Draft Final First Five-Year Review Report and Redline Version, Operable Unit 6,
Edwards Air Force Base, California, August 2011

NEW GENERAL COMMENTS

1. A number of revisions were made to the text of the revised Draft Final First Five-Year Review (5-Year Review that are not accounted for in the redline/strike-out version of the text. For example, some deletions that have been made do not appear as redline/strike-out text. Additionally, the responses should indicate exactly where the incorporated changes have been made to the text so that original comments can be evaluated, however in many cases the locations of the revision is too general or not provided at all. For future deliverables, please include all deleted text in strike-out form. Additionally, please include the specific location of revisions in the comment responses.

2. Text in Sections 6 and 7 (e.g., the redline text at the bottom of page 7-7) states that the extent of the Site N4 plume has not been delineated in the "northern portion of Site N4," but based on the dashed lines on figures depicting the extent of the plume, the extent of the plume east, southeast, and south of Site N4 has not been delineated. Please revise references to the need to delineate the plume in the "northern portion of Site N4" to state that the plume needs to be delineated to the east, southeast, and south of Site N4.

3. Changes in toxicity values and/or changes in the classification of certain chemicals of concern (COCs) as carcinogens and noncarcinogens, as well as changes to the Johnson and Ettinger (J&E) model, have occurred since 2002 at the time the human health risk assessment (HHRA) for Operable Unit (OU) 6 was prepared by Earth Tech (2003) yet the risk calculations were not updated. Further, the vapor intrusion pathway was only evaluated for four of the six sites where buildings are present, but Sites N4 and N14, where buildings are not currently present, were not evaluated. For transparency and in order to evaluate the cumulative impact of multiple variables on risk and the protectiveness of the remedy, the risk calculations should be updated. Please re-calculate risk using: 1) recent groundwater monitoring data for detected chemicals, 2) revised toxicity values for chemicals previously evaluated, 3) the J&E model to evaluate the vapor intrusion pathway for sites N4 and N14 where buildings are not currently present, and 4) incorporate changes to the J&E model that have been made since 2002. Please also include in the risk calculations chemicals that have been reclassified as carcinogens and non-carcinogens.

4. The 5-Year Review states that OU 6 cleanup levels are based on promulgated standards -- Maximum Contaminant Levels (MCLs) – and because MCLs have not changed, no additional cleanup goals have been developed. However, while there is no MCL for naphthalene, the Department of Toxic Substances Control (DTSC) has reclassified naphthalene as a carcinogen in 2002 (DTSC, 2004) and therefore, a cleanup goal and remedial action objective (RAO) should be developed. In the absence of an MCL for naphthalene, a risk-based tap-water value should be developed to ensure that the remedy is protective for all groundwater risk drivers. Please develop a remedial goal (RG) for naphthalene or provide additional information to support why a RG does not need to be developed for a new risk driver in groundwater.

NEW SPECIFIC COMMENTS

1. **Section 1.1, Basis, Purpose, and Authority, Page 1-1:** The first paragraph should include the trigger date (i.e., date that the Record of Decision [ROD] was signed, September 28, 2006). The Content Checklist For Five-Year Review Reports in the Comprehensive Five-Year Review Guidance, EPA/540/R-01/007, June 2001 (the Guidance), states that the trigger date should be included in the Introduction. Please include the trigger date in the first paragraph of Section 1.1.

2. **Section 3.3, History of Contamination, Pages 3-5 through 3-20:** The text does not explain how contamination was discovered at each site. Section III in Appendix E of the Guidance indicates that this section should explain how contamination was discovered. Please revise the text for each site to explain briefly how contamination was discovered at each site.

3. **Section 4.2, Remedy Implementation, Pages 4-6 through 4-12:** The text should include a discussion about the performance of each remedy component or state where this information can be found in the 5-Year Review. Please revise the text to discuss the performance of each remedy component or state where this information can be found.

4. **Section 4.3, Operation and Maintenance, Page 4-12:** The text states that the "remedial approach does not include traditional operation and maintenance [O&M] tasks," but this is incorrect. For example, maintaining the Mobile Treatment Unit, maintaining monitoring wells, fixing the damaged well completions identified during the Site Inspection, and replacing missing well tags is considered O&M. Also, based on Section 7.1.2, some wells did not accept the target 57 gallons of sodium permanganate; redeveloping these wells is considered O&M. Please delete or revise the quoted statement to reflect O&M activities relevant to the OU 6 remedy that may include maintaining the Mobile Treatment Unit and monitoring wells, fixing damaged well completions, replacing missing well tags, and redeveloping wells.

5. **Section 7.2.2, Changes in Exposure Pathways, Page 7-9, lines 19-26; Section 7.2.5.1, Changes in VOC Concentrations, Page 7-18; and Section 8.3, Changes in Vapor Intrusion Pathway Risk Assessment:** The text does not explain increased concentrations in the vicinity of worker-occupied buildings. For example, benzene concentrations in the vicinity of Building 4806 appear to have increased based on a comparison of Figures 3-6 and 3-7. The 2002/2003 Risk Assessment did not consider the higher concentrations in the vicinity of this building because additional benzene contamination was discovered when well N3-MW20 was installed; this should be discussed in the text. The text should also discuss uncertainties associated with delineation of the extent of contamination, since there are no wells to determine if

benzene plumes with high concentrations are present beneath Buildings 4806 and 4807. Please revise the text in this section to discuss contaminant concentration changes/trends in the vicinity of worker-occupied buildings. Also, please revise the text to discuss uncertainties associated with delineation of the extent of contamination near these buildings.

6. **Section 7.2.3, Changes in Toxicity and Other Contaminant Characteristics, Page 7-15:** The text acknowledges that naphthalene and ethylbenzene now are considered carcinogens, but the text does not discuss the concentrations of these contaminants in the vicinity of worker-occupied buildings. Please revise the text to discuss the concentrations of naphthalene and ethylbenzene in the vicinity of worker-occupied buildings.

7. **Section 7.2.3 Changes in Toxicity and Other Contaminant Characteristics, Pages 7-13 and 7-14:** The following comments apply to Section 7.2.3:
   a. The point of departure for evaluation cancer risk is 10-6. Results of the risk assessment from vapor intrusion indicate that risks were within or less than the cancer risk range of 10-4 to 10-6 and Hazard Index of 1. For this reason, cleanup levels to protect receptors exposed to chemicals through the vapor intrusion pathway were not established. Please use 10-6 as the point of departure for evaluating risk, not the risk management range, and as the trigger for developing cleanup levels.
   b. This section states that "since concentrations of groundwater VOCs [volatile organic compounds] were present at the site in excess of MCLs, and those groundwater VOCs did not lead to "unacceptable indoor air risks, it is reasonable to conclude that MCLs were also protective of the groundwater-to-indoor air pathway." This conclusion is based on 2002 toxicity criteria used to evaluate the vapor intrusion pathway and may not be valid since some VOCs (e.g., naphthalene and ethylbenzene) have been reclassified as carcinogens and were not previously evaluated as such. Please revise the risk assessment using the updated toxicity values and recent groundwater monitoring data to demonstrate whether or not the chemicals that have now been classified as carcinogens contribute significantly to overall cancer risk (e.g., less than 1 x 10-6); otherwise cleanup goals should be developed for these chemicals.

8. **Section 7.2.4 Changes in Risk Assessment Methods, Pages 7-14 and 7-15:** The potential for migration of VOCs into buildings was not evaluated at Sites N4 and N14; however, VOCs are present in soil, groundwater, or both. According to this section, the vapor intrusion pathway was assessed at sites with VOCs in soil, soil vapor, or groundwater for sites that were, or could be occupied on a routine basis, which included four of the six sites. Current guidance (e.g., DTSC, 2005) requires that future development of a site assume the presence of buildings. Please evaluate the vapor intrusion pathway in the risk assessment for Sites N4 and N14 to determine if vapor intrusion is a future potential exposure pathway of concern.

Additionally, the last sentence at the bottom of Page 7-15 is incomplete. Please add text related to the lack of soil vapor data to the last sentence of this section.

9. **Table 7-3, Changes in Toxicity Criteria Used to Assess the VIP at OU6, Page 7-23:** This table indicates that naphthalene is "no longer considered a non-carcinogen;" however, this is incorrect. Toxicity values for noncarcinogenic effects are available for the oral and the inhalation exposure routes while a toxicity value is also available to evaluate naphthalene for carcinogenic effects by the inhalation exposure route. Please update the table to indicate that naphthalene has been classified as a carcinogen and indicate the availability of an inhalation unit risk factor for this compound.

   Also, three of the entries in the "Change in Risk" column appear to belong in the "Factor" column and it appears that the change in risk for these analytes is missing. Please review and correct the entries in the "Change in Risk" column and the "Factor" column.

10. **Section 8.3, Issues:** This section should include the need for well redevelopment based on the fact that a number of wells were not able to accept the target 57 gallons of sodium permanganate. Please acknowledge this issue in Section 8.3 and include a recommendation and follow-up action in Section 9.

11. **Section 8.4.1, Naphthalene and Ethylbenzene in Groundwater, Page 8-3:** This section indicates that the Air Force would determine if sufficient analytical data are available to characterize current concentrations of naphthalene and ethylbenzene in groundwater but it is unclear why an updated risk assessment was not performed. Section 7.2.3 (Page 7-13, last paragraph) states that "groundwater monitoring data collected within the last 2 to 3 years are available to support this assessment." Please update the risk assessment using the more recent available groundwater data or provide justification to support the decision not to update the risk assessment.

COMMENTS ON RESPONSES TO COMMENTS (RTCs)

Response to General Comment (GC) 1b: The response only partially addresses the original comment. Although the response provides some additional detail for why N3-MW15 and N3-MW21; as well as N4-MW07, N4-MW08, and N4-MW09 were selected for injection during the Phase II Injection Event II, the revised text does not provide any detail about any other injection sites that were or were not included in the Phase II Injection Event II. Additionally the revisions made to the tables in Section 6 make it difficult to differentiate Phase II Injections Events as the Tables only refer to Phase I Injection Event (Table 6-4) and Phase II Injection Event I (Table 6-5 and 6-6) when the text also discusses Phase II Injection Event II. Please revise the text to provide additional details about all the injection sites for Phase II Injection Event II. Also, please revise the and tables to be consistent in presenting the different phases and events for injection.

Response to GC 2: The response partially addresses the comment. According to the 5-Year Review Summary Form, the review period for this 5-Year Review was "11/2/2010 to

8/22/2011;" therefore, it is unclear why the data and information from monitoring after the August 2010 injection event are not included in this 5-Year Review. Additionally documents are referenced in this 5-Year Review that have reporting periods as late as October 2010, therefore this response is inconsistent with other sections of the document. Please include the requested information/data from the post-August 2010 injection event or explain why this data cannot be included.

Also, the Land Use Control (LUC) boundaries should be representative of the most protective conditions (i.e., data through the entire reporting period should be utilized) and it is unclear if the use of June-July 2010 monitoring results are the most up-to-date values for drafting the LUC boundaries. Please use the most protective data available for constructing the LUC boundaries.

Response to GC 4: The response addresses the comment, but was not fully incorporated into the text. Specifically, the work plan mentioned in the comment was not included in Section 9. Please revise Table 9-1 to include the work plan that will include the proposed well locations.

Response to GC 5: The response addresses the comment, but due to the lack of delineation of the extent of the plume to the east, southeast and south of the N4 area, it cannot be concluded that the "leading edge plume instability appears limited to the southern portion of Site N1 and the northern portion of Site N4 as indicated by increasing TCE [trichlorethene] concentrations at monitoring well N4-MW06." Installation of additional wells to delineate the plume (i.e., resolve the lines that are dashed on Figure 3-5) and collection of additional samples from wells installed in 2010 may indicate that there are other areas where the plume is migrating. Please revise the response and text to acknowledge that plume instability cannot be fully assessed because wells installed in 2010 have not been sampled a sufficient number of times to evaluate whether the plume is stable and because the full extent of the TCE plume has not been delineated.

Response to GC 6: The response partially addresses the comment. Based on data from well N3-MW20, Building 4806 is now in close proximity to high concentration areas of the benzene plume. Since there are no wells within, south or east of Building 4806, the concentration of benzene beneath this building is unknown (as acknowledged by the dashed lines on Figure 3-7). Therefore it is unclear if there is an ongoing concern for the vapor intrusion pathway for current or future worker exposure. It appears that additional groundwater monitoring wells and/or subslab and indoor air sampling is necessary to evaluate the risk to workers in this building. Please provide data to support that the remedy is protective for current or future workers who may potentially be exposed to (VOCs in occupied buildings through the vapor intrusion pathway or discuss how and when this data can be obtained.

Response to GC 8: The response partially addresses the comment, i.e. the response indicates that the intent of the In Situ Chemical Oxidation (ISCO) component of the Remedial Action (RA) is to address hot spot remediation only; however, it is not clear if increasing concentrations and an expansion of the plume was an anticipated outcome. Additionally the comment does not address the evaluation of mass destruction given an expanding plume with increasing concentrations. Please discuss whether increasing concentrations and an expansion of the plume was an anticipated outcome and clarify how mass destruction can be evaluated when a plume is expanding and concentrations are increasing.

Response to GC 9: The response partially addresses the comment. It is difficult to assess whether or not cleanup will be achieved via the selected remedy as the concentrations of COCs are increasing and the plume appears to be migrating in some locations. Please revise the 5-Year Review to discuss whether or not cleanup can be achieved within the expected timeframe given the increasing concentrations and expansion of the plume.

Response to GC 10: The response does not specifically address the comment. There is a concern that RAOs and LUCs may not be protective with the increasing concentrations of TCE in N3-MW15, which result in the potential for exposure to VOCs in occupied buildings through the vapor intrusion pathway. Please discuss the protectiveness of the RAOs and LUCs with respect to potential vapor intrusion into buildings located above the groundwater plume.

Also, the response and revised Section 6.5.2.3 are misleading when the text states, "TCE concentrations increased in samples collected from two wells during that timeframe [2003 to 2010]" because this does not acknowledge that TCE concentrations also increased in seven additional wells between 2008 and 2010 (See Table 6-6). These seven wells were either not sampled in 2003 or were installed after 2003. It is important to consider the increased concentrations in these wells (N3-MW03, N3-MW21, N4-MW06, N7-DEW01, N7-MW02, N7-MW15 and N7-MW16) in order to understand the performance of the remedy. Please revise the text to discuss the increases in TCE concentrations in these wells and whether the remedy is performing as intended in the vicinity of these wells.

Response to Specific Comment (SC) 8: The response addresses the comment, but incorrectly references Tables 6-3 and 6-6. Please revise the response to reference the correct tables.

Response to SC 17: The response partially addresses the comment. Although the response states that no new wells are needed to address the benzene plume, new wells are needed in the vicinity of worker-occupied Buildings 4806 and 4807 to delineate the extent of the high concentration benzene plume and to evaluate whether the benzene plume extends beneath these buildings. Please revise the text of the 5-Year Review to include installation of additional monitoring wells to delineate the extent of the benzene plume in the vicinity of Buildings 4806 and 4807.

Response to SC 20: The response only partially addresses the comment as it indicates that a citation will be provided; however, the reference to "supplemental risk assessments" was deleted and was not shown in strike-out in the revised draft final version. Due to this deletion the requested citation was not provided. Please retain the reference to "supplemental risk assessments" and provide a citation.

Response to SC 22: The response does not address the comment. Although the cleanup goals for groundwater are based on MCLs, the absence of an MCL does not preclude the need to develop a cleanup goal for naphthalene, particularly since naphthalene was classified as a carcinogen in 2005 and a cleanup level had not been previously developed. The response indicates that if there is sufficient data to re-evaluate risk for those chemicals with toxicity values that have changed since 2002, the new "information would be used as part of the next 5-Year

Review as the basis for considering if a new RAO is required." If this information is currently available, please re-calculate risk and new RAOs, as applicable, for the 2011 5-Year Review Report.

Response to SC 24: The response does not address the comment as it does not include a discussion of how benzene may impact risk calculations. Please include a discussion of benzene's impact on risk calculations in the response.

Response to SC 27: The comment requested revisions to Section 7.4 that have not been made. Please provide the requested revisions from the original comment, including deleting or changing the word "inadequate" in the last sentence of Section 7.4.

REFERENCES

California Department of Toxic Substances Control (DTSC). 2004. Air Toxics Hot Spots: Adoption of a Unit Risk Value for Naphthalene. http://www.oehha.ca.gov/air/hot_spots/naphth.html#naphth Accessed on September 12, 2011.

DTSC. 2005. Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air. Interim Final. February.

Earth Tech, Inc. 2003. Environmental Restoration Program, Human Health Risk Assessment, NASA Dryden, Operable Unit 6. Prepared for Air Force Flight Test Center/Environmental Restoration Division, Edwards AFB, CA; and AFCEE/ERD, Brooks City Base, TX. San Jose, CA. March.

Lead RPM Joseph Healy
Technical Review Comments on:
***Draft Final First Five-Year Review Report*; and**
***Redline Version, Operable Unit 6*; and**
Air Force Responses to Regulatory Comments

GENERAL COMMENTS

A. The general topics you listed in Section 9 for the next steps to be conducted during the next five years seem to be acceptable, although they are not clearly and concisely described by their titles and by the table entries. They are also inadequately described in their temporal and strategic relationships with each other. Thus, in addition to there being insufficient data and analysis for EPA to concur on protectiveness for some current and potential future risk pathways, there is also insufficient clarity in your presentation of next steps that would address current data gaps, data insufficiencies, and the resolution of currently unacceptable uncertainties in the location of current and potential future risks. Add about 3-5 pages of additional explanatory text to Section 9 in order to correct this fatal flaw. Most of my remaining comments on your responses to my previous comments will provide you with specific improvements to include or summarize within the requested expansion and improvement of Section 9.

B. The report has many instances of inconsistencies that are exacerbated by further inconsistencies within your responses to my comments. I did not have time to review other regulatory comments and your responses to those comments. Thus, I do not know if this is simply a quality control problem in addressing comments that may have conflicts with other reviewers' comments, or if this a problem of misunderstanding and/or not appreciating EPA guidance that has been explained and observed for other operable units at Edwards AFB and at most NPL Sites, nationally. Some of my specific comments will point out some examples.

C. This red-line version of the report is particularly unclear on some key issues. I could not tell how you intend to resolve EPA's need understand the 10^{-6} point of departure for the vapor intrusion pathway in terms of the area of risk at that point of departure for both the industrial scenario and for a future residential scenario. Directly related to this area of potential concern would be the delineation and routine updates of the critical groundwater contaminant concentration contours (not only for ISCO applications, but also potentially for VIP concerns). I also could not tell how you intend to resolve the State's need to understand the effect of using the more conservative State toxicity values within a revised risk assessment for the vapor intrusion pathway. Resolution of these issues will be key to eventually obtaining a protectiveness determination from EPA.

D. The most effective and efficient way to address the above general concerns, would be to produce an RA Work Plan Addendum as soon as possible. In addition to providing necessary updates from where the original RA Work Plan left off, it should provide the details for your commitments from Section 9 of this Five Year Review Report.

E. As you consider the above General Comments while reading through my following Specific Comments, you could use this general comment as an example of the type of summary text that could clarify the scope and relationships of Table 9-2 entries within the larger context of continued OU6 remedy implementation during the next five years (see example table entries immediately following this paragraph). Depending on how you choose to respond to my specific comments, you could end up with a different list or different combination of scopes than what I present below in my "Example Deliverables Schedule for Table 9-2." Scope items listed beneath some of the deliverables could either be listed with the document title in the table or footnoted to the bottom of the table. The footnotes at the bottom of the table could alternatively contain a reference to a sub-section within Section 9 (or elsewhere in the five year review report) that contains further clarification or explanation of the scope (e.g., comprising part or most of the 3-5 pages of additional clarification that I ask for in my General Comment A above).

EXAMPLE DELIVERABLES SCHEDULE FOR TABLE 9-2

2012 DELIVERABLES

RA Work Plan Addendum (2012-2016) [*Draft in Winter 2012*]

including but not limited to:

. Updated plans for ISCO events and new locations
. SAP for ISCO Injection Fluid Tracer Study (expedited to coincide with April 2012 start)
. SAP for Groundwater Monitoring and Data Gaps Study
. Scope and Methods for VIP Risk Assessment
. Annotated Gantt Chart Schedule
. Conditional SAP for Limited VIP Field Investigation

Annual Groundwater Monitoring Report (AGWMR) [*Final in Spring 2012*]

including but not limited to:

. Discussion of updated plume concentration contour map and trend analysis
. Evaluation of plume stability (including rate of shrinkage or migration relative to GW flow rate)
. Recommendations for update of LUC compliance boundaries (link to Annual LUC Rpt)
. Recommendations relevant to next ISCO injection event

Annual LUC Status Report [*Final in early Summer 2012*]

including but not limited to:

. Any changes to the LUC compliance boundaries based on just-released AGWMR (linked)
. Any relevant enforcements or changes to site conditions or land use

Revised VIP Risk Assessment and Risk Mgmt. Eval. Report [*Draft in Summer 2012*]

including but not limited to:

. Assess risk with current media concentrations for all COCs and using State toxicity values
. Calculation of GW Vapor Compliance Levels using 2007 South AFRL ROD approach
. Map showing areas exceeding 10-6 point of departure for industrial and residential scenarios
. Map also shows building occupation status, MCL plume boundary, and GW hot spot areas
. Discussion of general Risk Management options relative to current and long-term protectiveness

2013 DELIVERABLES

IRACR for Phase II Injection III of III [*Final in Spring 2013*]

including but not limited to:

. An Appendix with the 2013 **AGWMR** (see 2012 version for minimum contents)
. A discussion of and conclusions for leading **edge data gaps study**.
. An Appendix with the **ISCO Injection Fluid Tracer Study Report**

Annual LUC Status Report [*Final in early Summer 2013*]

including standard contents (see 2012 version) and link to above 2013 IRACR's AGWMR

Groundwater Modeling Report [*Draft in Summer 2013*]

including but not limited to:
. Discussion of projected plume stability (horizontal and vertical)
. Revised recommendation for scheduling Enhanced Natural Attenuation component of remedy
. Discussion of effects of ISCO injection fluids (linked to **ISCO Injection Fluid Tracer Study Rpt.)**

Addendum to the First Five Year Review Report (AGWMR) [*Draft in Summer 2013*]
including but not limited to:
. Summary of and conclusions for all reports produced due to 2011 EPA Deferral Letter
. Presentation of new versions of Tables 9-1 and 9-2 (e.g., recommendations and next steps)
. A Revised Protectiveness Statement based on newer information
. Discussion of possible need for more immediate actions to ensure protectiveness

2014 DELIVERABLES

Annual Groundwater Monitoring Report (AGWMR) [*Final in Spring 2014*]
(See 2012 version for minimum contents)

Annual LUC Status Report [*Final in early Summer 2014*]
(See 2012 version for minimum contents)

2015 DELIVERABLES

Annual Groundwater Monitoring Report (AGWMR) [*final in Spring 2015*]
(see 2012 version for minimum contents)

Annual LUC Status Report [*Final in early Summer 2015*]
(see 2012 version for minimum contents)

2016 DELIVERABLES

IRACR for Injection IV [*Final in Spring 2016*]
including but not limited to:
. An Appendix with the 2016 **AGWMR** (see 2012 version for minimum contents)
. A discussion of and conclusions for leading edge data gaps study

Annual LUC Status Report [*Final in early Summer 2016*]
including standard contents (see 2012 version) and link to above 2016 IRACR's AGWMR

SPECIFIC COMMENTS

Note: *I have organized my new specific comments into sub-sections based on Deliverables I think you need to produce. Some of these might overlap with deliverables you have already listed in Section 9, although I prefer the more descriptive titles that I use below.*

1. Remedial Action Work Plan Addendum

[1a] Your response to my previous Specific Comment 20: You promised to add "An RAWP addenda" to Table 9-2. However, I did not see this document listed. Addenda is the plural of addendum and perhaps you meant to include several different addenda due to project phasing?

[1b] Your response to my previous Specific Comment 20: You did not answer whether you agree about explaining the schedules, including the SAPs, and O&M plans within the Addendum.

[1c] I strongly recommend that you take the following approach to using an RA Work Plan Addendum. If you prepare an RA Work Plan Addendum on an expedited schedule and obtain regulator buy-in on expedited review times, we will be able to resolve some potentially very critical issues as soon as possible (e.g., possible current VIP exposure in occupied buildings). If you include descriptions in the RA Work Plan Addendum of all the sampling, studies, and evaluations needed for this Five Year Review, in addition to descriptions of the normal extension or expansion of remedy implementation already required by the ROD (e.g., ISCO injections, IRACRs, normal groundwater monitoring and modeling, LUC boundaries and LUC reporting), you will probably have the most effective and efficient vehicle for communicating with and obtaining concurrence from the regulators.

[1d] I think Table 9-2 could include some bullets under the title of this document and then provide further clarification of the overall scope within the requested few extra pages for Section 9 (See my General Comments above). Some of the bullets or additional explanation of the scope could cover some of the documents I list below, and possibly remove the need for listing some of them separately in Table 9-2 (See various individual comments below).

[1e] <u>Your response to my previous Specific Comment 12</u>: If for Section 9 there is not a simple brief explanation of what might cause you to collect soil vapor data (trigger conditions within your risk evaluation), at least list this as one of the parts of your RA Work Plan. Ideally you would determine the need early in the evaluation process so that the data can be expeditiously obtained and discussed in the risk assessment report.

[1f] <u>Your response to my previous Specific Comment 18</u>: You are correct. Thank you for providing estimated dates by Quarter and Year. My newer understanding from the EPA Region 9 Five Year Review expert has clarified what EPA needs since we are now going to defer our protectiveness determination. Because you did not answer or discuss why you would not provide a Gantt Chart schedule and describe the linkages or strategy for document preparation, review, and support for follow-on or concurrent documentation, I need to ask for it again. Of course the simplest way to provide this schedule, in case you can not do it for Section 9, would be to provide it as part of the overall RA Work Plan Addendum's estimated schedule. The work plans for other OUs have provided these kinds of details. EPA Region 9 needs them so that we can report progress and milestones to Congress within our CERCLIS database. We will determine our CERCLIS milestone dates by considering the estimated schedule you provide us.

[1g] <u>Your response to my previous Specific Comment 18</u>: As you can see by the titles of some of the ten documents I have listed and used to organize these specific comments on your Five Year Review Report, there are some primary documents under the FFA. Others might be considered as secondary documents under the FFA. Regardless of how you title them or how you want to interpret the FFA, nearly all of these documents will be critical during the next five years in providing the necessary information for EPA to make a protectiveness determination. Thus, they are likely "key" documents and deserve, at least, a joint discussion of appropriate draft, review, (plus draft final, review for some), and final dates. EPA would like the parties to discuss these dates in early October 2011.

2. Sampling and Analysis Plan for Injection Fluid Tracer Study

[2a] Perhaps you will only need to modify some DQOs to an already existing SAP for groundwater monitoring. I think you might be better off with a specific addendum to another SAP or a stand-alone work plan for this tracer study if you do not intend to follow the RA Work Plan Approach that I strongly recommend above.

[2b] Indicate within a schedule presented in Section 9 when this draft deliverable will be submitted to the regulators.

[2c] Discuss the timing strategy of the SAP and the tracer study within the overall schedule of the next five years. A Gantt chart showing linkages of all key projects for OU 6 is strongly recommended in my general comments and this document is a perfect example illustrating the need for such a master schedule and discussion of its strategy.

3. Sampling and Analysis Plan for Additional Investigation of Vapor Intrusion

[3a] <u>Your response to my previous Specific Comment 12</u>: You state that your evaluation of VIP guidance documents as they related to site conditions may lead to a field investigation. Can you provide an idea of what might lead or trigger you to collect soil vapor data. Is this an early step in the process of assessing the VIP risk? Is it similar in concept to the South AFRL ROD's tiered levels of sampling (e.g., first use groundwater data, then soil vapor data, and then indoor air data according to a decision tree logic)?

[3b] Ideally, this SAP would be part of the RA Work Plan Addendum (e.g., an appendix). However, you might find a quicker way to take some samples by modifying an already existing work plan for another OU that needs to take some indoor or sub-slab samples. Time will likely be of the essence, so please plan to have a SAP ready to go, even if it is a conditional SAP that you later might determine you don't need to activate. The RA Work Plan should explain what would trigger you to activate such sampling.

[3c] If you are not going to use the RA Work Plan Addendum approach I recommend, you may have to list this SAP in Table 9-2 because it could be an essential document in support of resolving part of the VIP Risk Assessment.

4. Revised VIP Risk Assessment and Risk Management Evaluation Report

[4a] <u>Your response to my previous Specific Comment 2</u>: You state that "... the reassessment of the VIP to verify protectiveness is included as a recommendation (Section 9.0)." However, in Section 9 you say you will report on a VIP evaluation. You must clarify what you mean by these terms. EPA expects you to conduct a risk assessment using the new methodologies that you have been using for the other Edwards OUs. This risk assessment will need to include both the residential and the industrial scenario, conservative toxicity values per the State's needs, all

COCs including the newly identified ones, and show on a map where the 10^{-6} point of departure would be for both the industrial and the residential scenario. A separate risk management section can be added to this Risk Assessment Report or can be placed in a separate report (e.g., a letter report or the Addendum to the Five Year Review Report). Presumably the risk management section would offer recommendations for next steps, especially if some of the next steps might involve minor or major changes to the 2006 selected remedy.

[4b] Your response to my previous Specific Comment 3: You state that the VIP will need to be reconsidered in the Next Five Year Review. You need to be more specific. Prior to the completion of the Next Five Year Review, you need to specifically determine whether or not the MCL plume boundary used for the groundwater LUC that currently prohibits residential uses and sensitive uses (e.g., daycares) would conveniently and fortuitously be eligible to serve as a boundary for a vapor intrusion LUC that would prohibit residential and sensitive uses. If so, this could provide a very simple and efficient alternative for consideration in the event that the Risk Assessment determines risk greater than the 10^{-6} point of departure for the VIP. The simplest way to show this would be on a map showing the MCL plume area and VIP risk contour, especially if the VIP risk contour for potential future residences is based on a groundwater concentration developed by similar methodologies to those in the 2007 South AFRL ROD. EPA is looking for a clear commitment that you will consider this as part of your risk evaluation activities to be required by Section 9 of this Five Year Review.

[4c] Your response to my previous Specific Comment 4: Your reasoning appears overly simplistic. The whole point of the requirement to conduct the risk assessment as I describe in the preceding comments, is to verify whether your belief is still correct. If so, then we will likely not see calculated risks above the 10^{-6} point of departure.

[4d] Your response to my previous Specific Comment 4: How the Air Force or NASA voluntarily controls or plans to control land use outside of CERCLA (i.e., not required by a CERCLA ROD) is not relevant to whether the Air Force must conduct a risk assessment and determine protectiveness of the current ROD selected remedy. Your risk assessment must be conducted and must determine the risk for current and future uses that are not restricted. Only in this way can we then ask the next question about whether current responses required by the ROD are providing adequate and desired protection of human health. Thus, residential and sensitive uses must be assessed. In addition, this is especially important since you once had sensitive uses at this industrial site and you currently do not know for sure that the ROD's prohibition of such uses within the MCL plume area is protective enough. If the VIP risk assessment determines risk above the point of departure occurs outside the MCL plume area (e.g., shallow groundwater concentrations lower than MCLs and yet potentially capable of causing indoor air risk above the point of departure), the FFA parties must consider whether additional response actions are necessary. Thus, your risk assessment must be conducted in a manner that, at least, will answer this point of departure question.

[4e] Your response to my previous Specific Comments 9 and 10: If it turns out that you actually do have some occupied industrial buildings that were occupied at the time of the ROD and that were or are located above groundwater concentrations that presented or present a vapor risk of concern, you may need to provide additional clarification for those industrial receptors. I believe the State and TechLaw are looking at this question in detail within their comments. I note that this is a most critical point to resolve as soon as possible. It may cause you to want to consider speeding up any associated field work that might be necessary to help resolve this question and the magnitude of exposure that has occurred or is continuing to occur.

[4f] Your response to my previous Specific Comment 11: Your response is completely unacceptable, especially if you understand the final sentence of your response within CERCLA.

First, you did not answer my question about the use of groundwater concentrations as a method in the 2007 South AFRL ROD. In fact, that ROD provides for a conservative vapor LUC at a site that could easily make the case for a lower likelihood than OU 6 of no future residential development. I would expect you to make at least a similar conservative risk management approach for OU 6, which is located much closer to development and higher densities of industrial workers and potential residential and sensitive uses than is the remote Air Force Research Lab addressed by the 2007 South AFRL ROD.

Second, EPA HQ is quite clear in their IC Checklist language and other policies that you must specifically determine the levels of residual contamination that are safe for unrestricted use and unlimited exposure. You cannot avoid this by simply assuming that "residential development is not anticipated" especially when contamination could remain at the site for more than 100 years into the future. You would at least need to couple your assumption with a discussion of the degree of certainty you have in your anticipation and with a discussion of the level of residual risk, if your assumption did not hold up in the future.

Third, you have already had a daycare facility at this industrial site in the past. As you have stated elsewhere in the Five Year Review Report, you did not intend the groundwater LUC prohibiting residential and sensitive uses to also prevent exposure to the vapor intrusion pathway. You cannot simply assume that future managers or owners of this property will not consider a similar sensitive use at some point in the future.

Thus, for all of these reasons, you absolutely must assess the residential VIP risk and evaluate current risk management effects on the protectiveness of this OU 6 remedy for such potential future uses.

[4g] Your response to my previous Specific Comment 13: Simply because you state you are concerned about the future residential scenario for VIP by including it in the CSM figure, does not mean that you don't have to justify why you are concerned and explain what you will do about your concern. I think your response is vague, confusing, and maybe even evasive. I think you need to explain what you are doing or going to be doing and why within Section 7.2.4. The current end of the second paragraph is incorrect and inappropriate as a conclusion.

5. Annual Groundwater Monitoring Report

[5a] Your response to my previous Specific Comment 19: I think the lack of basic evaluation details in past reports on monitoring results for this operable unit have contributing to the problems many newcomers have experienced when they join the team, especially as reviewers. The most recent example is the EPA Region 9 Five Year Review Expert. He would strongly support an insistence by EPA that you conduct frequent groundwater monitoring until plume stability or rate of migration are clearly determined. In EPA's experience, most sites that do routine or long-term groundwater monitoring report their results along with some basic evaluation of the meaning of the results (e.g., updated plume maps and/or trend analysis). It is not clear to EPA where and how you intend to provide this type of information. Thus, I think you should indicate the document that will serve the function of providing this critical analysis. Most other OUs at Edwards use Annual Monitoring Reports and I believe they all are required to provide this information.

[5b] Your response to my previous Specific Comment 19: Your answer is too vague. Why do you not agree? Under what circumstances do you think it is "appropriate" to evaluate groundwater monitoring data? Wouldn't you need to do this to determine whether you need to periodically update the groundwater LUC compliance boundary, which is based on the extent of the MCL plumes? What about during this next five years when you are trying to answer some fundamental questions and data gaps about your plume and its stability?

6. Annual LUC Monitoring Report

[6a] I would think this is already a specified ROD Requirement based on the required IC Checklist language that I believe you included in the 2006 ROD. If so, I do not think it necessarily belongs in this section unless there is some particular issue or new feature that you are now recommending or identifying as a requirement to be associated with this Annual LUC Report. Thus, please consider shortening your list in Table 9-2. You could easily mention this as one of the features in the RA Work Plan Addendum if you want to continue its visibility in this Five Year Review Report.

[6b] How will this report be linked to the report that provides updated MCL plume maps, which I believe is the basis for determining the area in which the groundwater LUCs apply?

7. Interim Remedial Action Completion Report (IRACR)

[7a] I would think this is already a specified RA Work Plan Requirement since you had already been producing these for ISCO injection events according to the original RA Work Plan. If so, I do not think it necessarily belongs in this section unless there is some particular issue or new feature that you are now recommending or identifying as a requirement to be associated with these IRACRs. Thus, please consider shortening your list in Table 9-2. You could easily mention this as one of the features in the RA Work Plan Addendum if you want to continue its visibility in this Five Year Review Report.

[7b] If these IRACRs are intended to also report on particular issues identified in this Five Year Review Report (e.g., groundwater migration issues related to protectiveness, data gap of the leading edge, or the issue about potential plume expansion effects from injection fluids), then you must identify that briefly in the table for the specific IRACR and also provide a bit more clarification in a table footnote or within some of the additional text I have requested for Section 9.

[7c] Normally, IRACRs would be very similar to a functionally equivalent of the interim RA Reports that EPA uses to document completion of discrete phases of remedy construction or implementation. I had thought these were primarily focused on the ISCO injection events and how well the events succeeded in reducing the groundwater concentrations in high concentration areas. If you are also intending to use these for data gap reporting and plume migration tracking (e.g., updating groundwater LUC boundaries), you need to briefly explain that in this section.

[7d] My strong preference would be for you to rely on the Annual Groundwater Monitoring Reports (a standard feature in most groundwater response sites and in most of the other Operable Units at Edwards AFB) for the reporting of issue resolutions for data gap reporting and plume migration tracking (e.g., updating groundwater LUC boundaries). See Annual Groundwater Monitoring Report comments (item 5) above.

8. ISCO Injection Fluid Tracer Study Report

[8a] Presumably, this report would explain the results of the tracer study that I believe you are going to do to resolve an issue identified by TechLaw, Inc. in other comments. I did not review your responses to those comments. Perhaps there is a better title for this study and possibly you have already intended to report the results in an existing report (e.g., an IRACR). Somewhere in Table 9-2, either as a separate report or as a descriptive bullet to an existing report, it needs to be obvious to the reader where you will report the results of this study that is intended to resolve a specific issue.

[8b] Indicate within a schedule presented in Section 9 when this draft deliverable will be submitted to the regulators.

[8c] Discuss the timing strategy of the SAP and the tracer study results within the overall schedule of the next five years. A Gantt chart showing linkages of all key projects for OU 6 is strongly recommended.

9. Groundwater Modeling Report

[9a] Will this report be coordinated with modeling of the Site 25 groundwater plume?

[9b] Does this report need to feed into the resolution of a particular issue specifically identified for this Five Year Review Report or is it simply an activity you periodically conduct as part of your long-term groundwater restoration projects? If it is the latter, perhaps it does not need to be in the Table 9-2 list and can instead be explained as one of the components under the RA Work Plan Addendum umbrella (I made a similar observation about the Annual LUC Monitoring Report - item 6 above).

[9c] Depending on the timing of this report, you might want to delay it so that it can incorporate any relevant conclusions from the ISCO Injection Fluids Tracer Study, the report for which perhaps could be placed in an appendix to this modeling report. The modeling report could then be titled "Groundwater Modeling and ISCO Injection Fluid Tracer Study Report" and you might save time and money in the process.

10. Addendum to the First Five Year Review Report

[10a] The exact title of this document probably depends on further discussion among the FFA parties concerning EPA guidance appropriate to a Five Year Review for which EPA defers a protectiveness determination. Functionally, there needs to be some type of formal documentation during this next five year review period that summarizes the conclusions of the required next steps identified at the time of the deferral. My understanding is that it would ideally provide the protectiveness determination and/or identify next steps necessary to further clarify or refine any remaining protectiveness issues at that time. For example, if the VIP risk assessment report finds that a currently occupied building has a level of risk that the FFA parties agree needs to be addressed, this Addendum to the Five Year review Report would identify the next steps recommend to resolve that risk (e.g., removal action, building closure or mitigation, potential ROD amendment etc.).

[10b] Ideally, this Addendum would be issued as soon as possible within the first few years of this next five year review. This would allow time to begin implementing any important next steps identified to obtain full protection of human health and the environment as specified in the ROD. It is important to remember that the second Five Year Review Report will be due in September of 2016, regardless of when the deferred protectiveness statement is issued by EPA.

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS 95TH AIR BASE WING (AFMC)
EDWARDS AIR FORCE BASE CALIFORNIA

16 NOV 11

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Mr. Michael M. Montgomery
Federal Facilities and Site Cleanup Branch
USEPA, Region 9
75 Hawthorn Street
San Francisco, California 94105

Dear Mr. Montgomery

This letter is in response to your 30 September 2011 memo non-concurring with the Draft Final First Five-Year Review Report, NASA Dryden Flight Research Center, Operable Unit 6 (OU 6), dated August 2011. The Air Force has determined that we concur in principle with your suggestions regarding the path forward. Specifically, we concur that additional characterization of soil vapor levels are required to ascertain the level of protectiveness of the selected remedy as it relates to vapor intrusion into buildings located on OU-6. Furthermore, we concur that additional characterization is required to determine the extent of migration of the groundwater plume at the site and that doing so would likely involve the installation of additional groundwater wells in OU-6. As a result, we concur that because of these data gaps we will defer protectiveness determination because more information is needed to make a protectiveness determination with respect to human health risk.

You also stated it is your expectation that the actions necessary to obtain the additional information should take place within two years from the date of your letter and upon review of the information; you will make a final protectiveness determination. While we share your desire to ascertain protectiveness as quickly as possible, we must state that because of uncertainties with respect to both the procurement process and, more importantly, the predictable and prompt availability of adequate funds due to the federal budgetary process, that such a timeframe may not be attainable. Nevertheless, the project team has already developed "target dates" to address these two issues. The vapor intrusion study and reports will be complete by September 2014. The additional groundwater analysis will be completed and submitted with the next five-year review report due in September 2016.

In my discussions with AFCEE, your office and the State of California regarding the use of the State of California Office of Environmental Health Hazard Assessment toxicity values, and using 10^{-6} excess cancer risk as a point of departure for evaluating risk I find that our agencies are quite polarized in the interpretation of the regulations and the policy that should be followed. Colonel Gregory Schwab, the 95th Air Base Wing Commander, will be sending a letter to Mr. Terry

Edwards, the AFCEE Director, illustrating our concerns at Edwards AFB and recommending these important risk assessment issues be resolved without initiating the formal dispute resolution process. It is our hope that Mr. Edwards, who will be the AFCEE member of the Dispute Resolution Committee, will try to find a position on the risk assessment process that all the remedial project managers can agree on.

If you have any further questions or concerns, my point of contact with respect to these matters is Mr. Ai Duong, who can be reached at (661) 277-1474 or via e-mail at ai.duong@edwards.af.mil.

Sincerely

ROBERT W. WOOD, NH-IV
Chief, Environmental Management

cc:
Loren Henning, EPA
Joseph Healy, EPA
Thelma Estrada, EPA ORC
Kevin Depies, DTSC
Tim Post, RWQCB
Dan Medina, AFCEE/ERC
Thomas Rudolph, AFLOA JACE-FSC

Responses to comments that do not directly apply to this Addendum to the First Five-Year Review Report are presented as proposed text and are written in a manner that could be directly implemented into a final version of the *First Five-Year Review Report*. That proposed text may be implemented in some form in the Second FYRR if it directly applies to the content of that document.

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Review of the Responses to Comments for
Draft Final First Five-Year Review Report and Redline Version,
Operable Unit 6, Edwards Air Force Base, California, August 2011

Responses to comments are shown below in blue text. Where excerpts from the text of the report, or proposed text, are included in the response, the text is shown in purple. In addition to new comments on the revised draft final version (redline version), the USEPA submitted comments on the Air Force's response to comments received on the previous draft final version. The initial comments and responses are shown in gray for reference.

NEW GENERAL COMMENTS

1. A number of revisions were made to the text of the revised Draft Final First Five-Year Review (5-Year Review that are not accounted for in the redline/strike-out version of the text. For example, some deletions that have been made do not appear as redline/strike-out text. Additionally, the responses should indicate exactly where the incorporated changes have been made to the text so that original comments can be evaluated, however in many cases the locations of the revision is too general or not provided at all. For future deliverables, please include all deleted text in strike-out form. Additionally, please include the specific location of revisions in the comment responses.

Response: Presentation of redline/strike-out text in the Revised Draft Final *First Five-Year Review Report* (AECOM 2011) was complicated by multiple revisions to multiple document versions by multiple reviewers. The volume of redline/strike-outs created an illegible and unstable document. Where applicable, a description of the change locations has been included in the comment response.

2. Text in Sections 6 and 7 (e.g., the redline text at the bottom of page 7-7) states that the extent of the Site N4 plume has not been delineated in the "northern portion of Site N4," but based on the dashed lines on figures depicting the extent of the plume, the extent of the plume east, southeast, and south of Site N4 has not been delineated. Please revise references to the need to delineate the plume in the "northern portion of Site N4" to state that the plume needs to be delineated to the east, southeast, and south of Site N4.

Response: Section 2.1.1.3 of the *Addendum to First Five-Year Review Report (FYRR)* includes the following text: Since the review period, 18 groundwater monitoring wells (RL-25-MW01 to RL-25-MW18) associated with Site 25 (OU 8) were installed in April through September 2013 on the lakebed east and southeast of OU 6 and groundwater samples were collected from those wells and well N4-MW14. Figure 2 presents the locations of these wells and an updated plume configuration estimate based on data collected since those data shown on Figure 6-4 of the *First FYRR*. The preliminary (i.e., not yet validated or reported) laboratory analytical results for those groundwater samples indicated the presence of TCE at 12 of the 18 wells and at well N4-MW14. The extent of the plume remains unclear to the east, southeast, and south of Site N4 and more wells will be installed to close these data gaps (AECOM 2014a). Plume characterization extent findings will be updated during the second five-year review period and in future five-year review periods.

Since the comment only partially applies to the content of the *Addendum to First FYRR*, if applicable, text similar to the following may be included in the Second FYRR to address the comment: As discussed in Section 6.4.2.4, since remedy implementation, an area of relatively high TCE concentrations (ranging from 21 to 560 μg/L [Figure 3-5]) exists in the Site N4 area. Recent groundwater monitoring results indicate that the OU 6 commingled plume is not delineated in the lakebed areas of Sites N1 and N4 and that these areas of the commingled plume extend further downgradient than originally defined in the ROD. Trend graphs for leading edge wells with an adequate number of data points (Figure 6-4), indicate that leading edge plume instability exists in the Site N4 area as indicated by increasing TCE concentrations at monitoring well N4-MW06. TCE concentrations in samples collected from monitoring well N4-MW06 have consistently increased since its initial sampling in 2005. Per the ROD, if any unexpected behavior was observed during the groundwater monitoring, the five-year review would include a contingency plan to capture anomalous migration of contaminants. To address this possible plume expansion in the vicinity of monitoring well N4-MW06, the ISCO RA component was implemented at Site N4 in August 2010.

Section 2.1.1.2 of the *Addendum to First FYRR* includes the following text: Per the *Groundwater Investigation Work Plan* (AECOM 2014a), additional monitoring wells will be installed east, southeast, and south of Site N4. Samples from the proposed wells will provide data for complete delineation of the leading edge of the plume allowing for greater accuracy in plume extent estimation. The estimates will provide the basis for more certain contaminant mass/volume calculations that are expected to yield a better understanding of RA progress and cleanup timeframe assessment.

3. Changes in toxicity values and/or changes in the classification of certain chemicals of concern (COCs) as carcinogens and noncarcinogens, as well as changes to the Johnson and Ettinger (J&E) model, have occurred since 2002 at the time the human health risk assessment (HHRA) for Operable Unit (OU) 6 was prepared by Earth Tech (2003) yet the risk calculations were not updated. Further, the vapor intrusion pathway was only evaluated for four of the six sites where buildings are present, but Sites N4 and N14, where buildings are not currently present, were not evaluated. For transparency and in order to evaluate the cumulative impact of multiple variables on risk and the protectiveness of the remedy, the risk calculations should be updated. Please re-calculate risk using: 1) recent groundwater monitoring data for detected chemicals, 2) revised toxicity values for chemicals previously evaluated, 3) the J&E model to evaluate the vapor intrusion pathway for sites N4 and N14 where buildings are not currently present, and 4) incorporate changes to the J&E model that have been made since 2002. Please also include in the risk calculations chemicals that have been reclassified as carcinogens and non-carcinogens.

Response: Risk calculations have been updated based on Items 1 through 4 listed in the comment and are included in the human health risk assessment (HHRA) Addendum included as Appendix C to this document. Site N4 falls within the leading edge of the plume and therefore is a part of the updated evaluation. AOC N14 was not re-evaluated for reasons described in the *Vapor Intrusion Sampling Plan and Risk Assessment Work Plan* (AECOM 2013a): "The sixth site, AOC N14 was identified as "no action required" in the ROD and is over a half mile (approximately 3,375 ft) north of the current estimated groundwater plume extents (Figure 4).

As described in Section I.3.1, four VOCs (methylene chloride, naphthalene, 1,2,3-trichlorobenzene, and xylenes) were detected in soil. The age of the samples (16 years), the low contaminant concentrations and volatility in soil, and frequency of detection support the conclusion that the VOCs in soil at AOC N14 do not present a risk to future indoor air receptors via the VIP. For these reasons, AOC N14 will not be included further in the assessment."

Since the comment does not entirely apply to the content of the *Addendum to First FYRR*, if applicable, text similar to the following may be included in the Second FYRR to address the comment: As a result, the VIP was evaluated at only four of the six sites. In the two that were not evaluated (Sites N4 and N14), VOCs were present in soil, groundwater, or both. However, since no buildings were present at either site, the VIP was not evaluated in 2003. Because the RA addresses the plume as a whole, the risks calculations were updated for the entire commingled plume and not on a site-by-site basis in 2014 using current models and guidance. Site N4 is within the commingled plume boundary and included in the 2014 updated risk evaluation (Appendix C). Area of Concern (AOC) N14 was not re-evaluated for reasons described in the *Vapor Intrusion Sampling Plan and Risk Assessment Work Plan* (AECOM 2013a), principally because AOC N14 was identified as "no action required" in the ROD (USAF 2006) and is over a half mile (approximately 3,375 ft) north of the current estimated groundwater plume extents (Figure 4 of the *Vapor Intrusion Sampling Plan and Risk Assessment Work Plan* [AECOM 2013a]). Four VOCs (methylene chloride, naphthalene, 1,2,3-trichlorobenzene, and xylenes) were detected in soil. The age of the samples (16 years), the low contaminant concentrations and volatility in soil, and frequency of detection support the conclusion that the VOCs in soil at AOC N14 do not present a risk to future indoor air receptors via the VIP. For these reasons, AOC N14 was not included in the updated assessment.

4. The 5-Year Review states that OU 6 cleanup levels are based on promulgated standards -- Maximum Contaminant Levels (MCLs) – and because MCLs have not changed, no additional cleanup goals have been developed. However, while there is no MCL for naphthalene, the Department of Toxic Substances Control (DTSC) has reclassified naphthalene as a carcinogen in 2002 (DTSC, 2004) and therefore, a cleanup goal and remedial action objective (RAO) should be developed. In the absence of an MCL for naphthalene, a risk-based tap-water value should be developed to ensure that the remedy is protective for all groundwater risk drivers. Please develop a remedial goal (RG) for naphthalene or provide additional information to support why a RG does not need to be developed for a new risk driver in groundwater.

Response: A cleanup goal for naphthalene is not recommended in the *Addendum to First FYRR* as the updated HHRA (Appendix C) using the latest groundwater, air, and vapor data and the latest risk assessment methodologies and toxicity criteria indicated that the current groundwater contaminant concentrations and proposed cleanup goals will result in generally acceptable risks, no additional response action beyond the current remedy is needed. No additional or revised cleanup goals are proposed. This is consistent with the USEPA 2001 *Comprehensive Five-Year Review Guidance*: "If the estimated risk has increased, then you should determine whether the new estimated risk is acceptable. In most cases, you should base this determination on whether the risk is within or below the generally acceptable risk range of 10^{-4} to 10^{-6} for carcinogenic risk and the hazard index is below 1 for non-carcinogenic effects. If the estimated risk is not protective, you should determine what actions need to be taken to achieve an acceptable level of risk."

NEW SPECIFIC COMMENTS

1. **Section 1.1, Basis, Purpose, and Authority, Page 1-1:** The first paragraph should include the trigger date (i.e., date that the Record of Decision [ROD] was signed, September 28, 2006). The Content Checklist For Five-Year Review Reports in the Comprehensive Five-Year Review Guidance, EPA/540/R-01/007, June 2001 (the Guidance), states that the trigger date should be included in the Introduction. Please include the trigger date in the first paragraph of Section 1.1.

   Response: The following text is included in Section 1.0 of the *Addendum to First FYRR*: The trigger date for the OU 6 RA (28 September 2006) corresponds to the remedy initiation that occurred with the signing of the Record of Decision (ROD) (United States Air Force [USAF] 2006).

2. **Section 3.3, History of Contamination, Pages 3-5 through 3-20:** The text does not explain how contamination was discovered at each site. Section III in Appendix E of the Guidance indicates that this section should explain how contamination was discovered. Please revise the text for each site to explain briefly how contamination was discovered at each site.

   Response: Since the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, text similar to the following may be included in the Second FYRR to address the comment: Contamination was discovered at each site during soil gas, soil, and groundwater sampling activities (Earth Tech, Inc. [Earth Tech] 2004).

3. **Section 4.2, Remedy Implementation, Pages 4-6 through 4-12:** The text should include a discussion about the performance of each remedy component or state where this information can be found in the 5-Year Review. Please revise the text to discuss the performance of each remedy component or state where this information can be found.

   Response: If, in the Second FYRR, the remedy components are introduced in one section and discussed in a separate section, a reference will be provided to the section presenting the discussion.

4. **Section 4.3, Operation and Maintenance, Page 4-12:** The text states that the "remedial approach does not include traditional operation and maintenance [O&M] tasks," but this is incorrect. For example, maintaining the Mobile Treatment Unit, maintaining monitoring wells, fixing the damaged well completions identified during the Site Inspection, and replacing missing well tags is considered O&M. Also, based on Section 7.1.2, some wells did not accept the target 57 gallons of sodium permanganate; redeveloping these wells is considered O&M. Please delete or revise the quoted statement to reflect O&M activities relevant to the OU 6 remedy that may include maintaining the Mobile Treatment Unit and monitoring wells, fixing damaged well completions, replacing missing well tags, and redeveloping wells.

Response: Characterizing the approach as not including traditional system O&M activities is correct. The same mobile treatment unit may not be used for each injection event and events are not regularly implemented; so, maintenance of the treatment unit does not apply to the remedial action. The listed tasks are not "operation". The text of the Revised Draft Final First Five-Year Review Report reflected maintenance activities relevant to the OU 6 remedy.

NASA has implemented a maintenance program for the monitoring well field. The program includes replacing low-flow dedicated pumps and well completions based on damages noted during the 2011 site inspection and during groundwater sampling and injection events. The program also includes a survey of the well field to develop recommendations for abandonment and repairs.

If applicable, text will be included in the Second FYRR to partially address the comment by clarifying these points: Well maintenance activities within the review period included installing low-flow dedicated and affixing brass identification tags to frequently sampled Sites N2, N3, N4, and N7 monitoring wells.

If applicable, text similar to the following may be included in the Second FYRR to partially address the comment:

Continued well maintenance is recommended including pump replacement, well completion repairs and well labeling with identification tags.

The following text is included in Section 3.2.3 of the *Addendum to First FYRR*:

ISCO injections should be conducted only at wells greater than 100 feet from occupied buildings to avoid displacing/mobilizing the plumes under buildings and possibly completing the VIP. Pressures should be monitored in observation wells located between injection points and occupied buildings as an indication of plume displacement/mobilization (AECOM 2013b). Redevelopment of wells critical for use as active injection points, which do not readily accept reagent is recommended. Further evaluation and recommendations regarding employing Fenton's reagent or persulfate treatment at Site N4 to treat CT should be included in the RPGMRs and Second FYRR as part of the plume characterization and containment evaluation (AECOM 2012).

Table 1 in the *Addendum to First FYRR* presents follow-up actions updated from the *First FYRR*. If applicable, text similar to the following may be included in the Second FYRR to partially address the comment:

A maintenance program for the RA is recommended. The program should include replacement of low-flow dedicated pumps and repair of well completions based on damages identified during the 2011 site inspection and during groundwater sampling and injection events. The program should also include a survey of the well field to identify wells for abandonment and/or repairs. Specific recommendations for well maintenance and redevelopment should also be included in annual RPGMRs.

The following text is included in Section 3.2.3 of the *Addendum to First FYRR*:

During the review period, TCE and benzene were used to define the LUC boundary because these two COCs were believed to be present at concentrations above their respective MCLs over a larger area than the other detected chemicals; however, as previously noted, recent CT plume extent estimates indicate that the CT plume is larger at Site N4 than the TCE plume. Therefore, it is recommended that the LUC boundary be modified to include the CT plume as well as the TCE and benzene plumes (AECOM 2012).

Note regarding inclusion of Tracer Studies: In previous program documents and comment responses, the Air Force and NASA had agreed to include a Tracer Study as part of the remedy implementation; however during the 12 March 2013 Technical Working Group Teleconference, the RPMs agreed that a Tracer Study would not be conducted. The discussion is documented in Table 3-2 of the *Remedial Action Work Plan Addendum* (AECOM 2013b). References to conducting a tracer study are not present in the *Addendum to First FYRR*. The following text is included in Section 3.2.3 of the *Addendum to First FYRR*:

ISCO injections should be conducted only at wells greater than 100 feet from occupied buildings to avoid displacing/mobilizing the plumes under buildings and possibly completing the VIP. Pressures should be monitored in observation wells located between injection points and occupied buildings as an indication of plume displacement/mobilization (AECOM 2013b).

5. **Section 7.2.2, Changes in Exposure Pathways, Page 7-9, lines 19-26; Section 7.2.5.1, Changes in VOC Concentrations, Page 7-18; and Section 8.3, Changes in Vapor Intrusion Pathway Risk Assessment:** The text does not explain increased concentrations in the vicinity of worker-occupied buildings. For example, benzene concentrations in the vicinity of Building 4806 appear to have increased based on a comparison of Figures 3-6 and 3-7. The 2002/2003 Risk Assessment did not consider the higher concentrations in the vicinity of this building because additional benzene contamination was discovered when well N3-MW20 was installed; this should be discussed in the text. The text should also discuss uncertainties associated with delineation of the extent of contamination, since there are no wells to determine if benzene plumes with high concentrations are present beneath Buildings 4806 and 4807. Please revise the text in this section to discuss contaminant concentration changes/trends in the vicinity of worker-occupied buildings. Also, please revise the text to discuss uncertainties associated with delineation of the extent of contamination near these buildings.

A Groundwater Investigation effort is scheduled for completion by December 2014 and includes well installations near occupied Building 4806 and the hanger Building 4802. The results of the investigation will be documented in an investigation report to support the Second Five Year Review scheduled for 2016. The *Groundwater Investigation Work Plan* (AECOM 2014a) contains the following passages:

Current data indicate that the benzene plume extends laterally beneath the north corner of Building 4806 and that the TCE plume does not extend beneath Building 4806 (Figures 7, 8, 9, and 12 <of the *Groundwater Investigation Work Plan*>). Buildings 4806 and 4807 (Figures 12 and 14 <of the *Groundwater Investigation Work Plan*>) are the subject of the current vapor intrusion investigation, which consists of sub-slab vapor and indoor air sampling. Proposed well N3-MW29 will provide a monitoring point to aid in determining whether the benzene and TCE plumes extend beneath the subject buildings and will provide a future monitoring point after the vapor intrusion investigation is concluded.

The TCE plume is estimated to extend laterally beneath the southern corners of Buildings 4800 and 4802 (Figure 6 <of the *Groundwater Investigation Work Plan*>). These buildings are occupied but were not included in the initial phase of the vapor intrusion investigation due, in part, to their up crossgradient locations relative to known source areas and the resulting estimated low TCE concentrations and lack of benzene in groundwater beneath the buildings (Figures 6 and 12 <of the *Groundwater Investigation Work Plan*>). Proposed well N3-MW28 will provide a monitoring point to help refine plume extents and help determine whether the plumes extend laterally beneath the buildings.

Since the comment does not entirely apply to the content of the *Addendum to First FYRR*, if applicable, paragraphs similar to the following may be included in the Second FYRR to address the comment: For example, 2010 benzene concentrations detected in monitoring well N3-MW20 indicate that the benzene plume extends laterally beneath the north corner of Building 4806. The 2003 benzene plume delineation evaluated in the baseline HHRA did not extend beneath Building 4806. As there are no monitoring wells within, south, or east of Building 4806, the extent of benzene beneath Building 4806 is uncertain.

The results of the information obtained to address these issues identified two changes in the physical and chemical setting of the sites covered in the ROD. 1) Buildings 4886 and 4889 at Site N3 formerly housed a boiler used for heating purposes and electric switching equipment, respectively, were demolished and the structures removed and 2) COCs detected in monitoring wells installed post-ROD have increased the possibility of completed COC exposure routes via the VIP into occupied buildings (particularly Building 4806).

The removal of Buildings 4886 and 4889 did not result in any significant changes to the exposure pathways previously identified for the site. Though not a ROD requirement, the current Base GP (Edwards AFB 2009) continues to indicate that OU 6 will be used for industrial purposes only and the NASA DFRC MP (Development One 2009) indicates that office activity will be relocated to areas outside the portions of OU 6 where groundwater is impacted or anticipated to be impacted in the future.

Although not strictly related to changes in site use, the position of the constituents in the plumes have changed in the 10 years since the ROD was signed. These changes were discussed in Section 3.3. While concentrations of plume constituents have decreased in some areas, they have increased in others. Although some of these increases have resulted in higher groundwater concentrations near some buildings to levels that are higher than have been detected in the past, they have not resulted in higher concentrations than have been detected historically at this OU. The implication of these changes as they pertain to this five-year review is evaluated in more detail in Section 7.2.5. Plume extent and contamination trends are uncertain near occupied Buildings 4800, 4802, and 4806. Two monitoring wells included in the Groundwater Investigation scheduled for completion December 2014 were located to obtain data to further determine plume extent and contamination trends near these occupied buildings.

Exposure pathways at Sites N2, N3, and N7 are depicted on Figures 7-1, 7-2, and 7-3, respectively. These figures have been updated from those presented in the ROD and include footnotes for complete and potentially complete pathways to explain either why they are not being addressed as part of the RA because of risk management decisions or indicate the remedial actions that have been implemented in accordance with the ROD. Groundwater impacts are being addressed by the selected remedy through treatment and LUCs, but No Further Action was selected for soil at Sites N2, N3, and N7 because soil contaminants were limited in occurrence and extent and contaminants identified as risk drivers were likely not associated with Air Force/NASA AFRC use of the site. Exposures to COCs from soil as a secondary source via inhalation of windborne dust and volatile emissions, and ingestion and dermal contact were considered to be complete pathways for current industrial receptors and potentially complete pathways for future construction workers. However, the recommended remedy for soil at these sites was No Action because contaminants were limited in occurrence and extent and contaminants identified as risk drivers were likely not associated with Air Force/NASA AFRC use of the site. Organic lead was initially identified as a risk driver at Sites N2 and N3; however, the validity of organic lead results was suspect and organic lead was eliminated from further consideration as a risk driver. Polycyclic aromatic hydrocarbons (PAHs) were a risk driver for all three sites. PAHs were detected in shallow soil samples beneath asphalt pavement. PAHs are a common component of asphalt, and given the shallowness of the soil samples in which the PAHs were detected, it is likely that the PAHs were associated with the asphalt. Therefore, the PAHs did not appear to be a part of the original CERCLA release.

Other than the two items identified above (Buildings 4886 and 4889 demolitions and COCs detected in post-ROD installed monitoring wells indicating the increased possibility of completed COC exposure routes via the VIP into occupied buildings), conditions at the sites addressed in the OU 6 ROD are essentially unchanged since the signing of the ROD, and no change is anticipated. The proposed relocation of office activity to areas outside the groundwater plume are expected to reduce the potential exposure to site-related chemicals, but are not a ROD requirement and will not significantly change exposure pathways for either human or ecological receptors.

The following text is included in Section 2.1.2.1 of the *Addendum to First FYRR*:

Guidance indicates that a review should be performed of toxicity criteria used for determining cleanup levels as part of the five-year review process.

At least two key changes in toxicity criteria (for example, new USEPA Integrated Risk Information System non-cancer toxicity criteria not released until 2010 and 2011 for CT and TCE, respectively) resulted in updates to the HHRA since it was completed in 2003. Using the latest toxicity criteria, the HHRA Addendum (Appendix C), with consideration of current (2012 groundwater and 2013 indoor air) contaminant concentrations and exposure pathways, presents a comprehensive update to the groundwater risk assessment for the industrial inhalation (via the VIP) and for residential ingestion, inhalation (direct via groundwater use and indirect via the VIP), and dermal exposure routes.

6. **Section 7.2.3, Changes in Toxicity and Other Contaminant Characteristics, Page 7-15:** The text acknowledges that naphthalene and ethylbenzene now are considered carcinogens, but the text does not discuss the concentrations of these contaminants in the vicinity of worker-occupied buildings. Please revise the text to discuss the concentrations of naphthalene and ethylbenzene in the vicinity of worker-occupied buildings.

Response: The updated HHRA included as Appendix C of the *Addendum to First FYRR* and the *Vapor Intrusion Investigation Report* (AECOM 2014b) contain discussions of the risk represented by carcinogens to worker-occupied buildings.

7. **Section 7.2.3 Changes in Toxicity and Other Contaminant Characteristics, Pages 7-13 and 7-14:** The following comments apply to Section 7.2.3:

a. The point of departure for evaluation cancer risk is 10-6. Results of the risk assessment from vapor intrusion indicate that risks were within or less than the cancer risk range of 10-4 to 10-6 and Hazard Index of 1. For this reason, cleanup levels to protect receptors exposed to chemicals through the vapor intrusion pathway were not established. Please use 10-6 as the point of departure for evaluating risk, not the risk management range, and as the trigger for developing cleanup levels.

b. This section states that "since concentrations of groundwater VOCs [volatile organic compounds] were present at the site in excess of MCLs, and those groundwater VOCs did not lead to "unacceptable indoor air risks, it is reasonable to conclude that MCLs were also protective of the groundwater-to-indoor air pathway." This conclusion is based on 2002 toxicity criteria used to evaluate the vapor intrusion pathway and may not be valid since some VOCs (e.g., naphthalene and ethylbenzene) have been reclassified as carcinogens and were not previously evaluated as such. Please revise the risk assessment using the updated toxicity values and recent groundwater monitoring data to demonstrate whether or not the chemicals that have now been classified as carcinogens contribute significantly to overall cancer risk (e.g., less than 1 x 10-6); otherwise cleanup goals should be developed for these chemicals.

Response: Section 2.1.2 of the *Addendum to First FYRR* includes a discussion of the results of the vapor intrusion investigation and the updated HHRA. The risk re-evaluations used the latest environmental data, risk assessment methodologies, and toxicity criteria. Please refer to the response to New General Comment 4 regarding point of departure.

8. **Section 7.2.4 Changes in Risk Assessment Methods, Pages 7-14 and 7-15:** The potential for migration of VOCs into buildings was not evaluated at Sites N4 and N14; however, VOCs are present in soil, groundwater, or both. According to this section, the vapor intrusion pathway was assessed at sites with VOCs in soil, soil vapor, or groundwater for sites that were, or could be occupied on a routine basis, which included four of the six sites. Current guidance (e.g., DTSC, 2005) requires that future development of a site assume the presence of buildings. Please evaluate the vapor intrusion pathway in the risk assessment for Sites N4 and N14 to determine if vapor intrusion is a future potential exposure pathway of concern.

Additionally, the last sentence at the bottom of Page 7-15 is incomplete. Please add text related to the lack of soil vapor data to the last sentence of this section.

Response: Please see response to New General Comment 3. Since the comment does not entirely apply to the content of the *Addendum to First FYRR*, if applicable, paragraphs similar to the following may be included in the Second FYRR to address the comment: The OU 6 baseline HHRA (Earth Tech 2003) evaluated both direct and indirect exposure scenarios to site-related soil and groundwater chemicals. In general, the direct exposure pathways were assessed using risk based chemical screening levels. However, since screening levels were not available for the VIP from the subsurface into indoor air, one of the major indirect pathways, the HHRA used the J&E vapor intrusion model. The vapor intrusion model has not changed however, other aspects of the assessment of the VIP have changed since the HHRA was completed and the ROD was signed. The ROD was based on an HHRA in accordance with the HHRA work plan (Earth Tech 2001a). However, the DTSC (DTSC 2005) and the USEPA (USEPA 2002) have modified guidance for assessing the VIP. The major differences between the approach used in the HHRA and current guidance are summarized below.

During the 2003 OU 6 HHRA, the VIP was assessed on a site-by-site basis and only at sites with VOCs in soil, soil vapor (SV), or groundwater, and for sites with buildings that were, or could be, occupied on a routine basis (in accordance with the HHRA Work Plan). As a result, the VIP was evaluated at only four of the six sites. In the two that were not evaluated (Sites N4 and N14), VOCs were present in soil, groundwater, or both. However, since no buildings were present at either site, the VIP was not evaluated in 2003. Because the RA addresses the plume as a whole, the risks calculations were updated for the entire commingled plume and not on a site-by-site basis in 2014 using current models and guidance. Site N4 is within the commingled plume boundary and included in the 2014 updated risk evaluation (Appendix C).

Area of Concern (AOC) N14 was not re-evaluated for reasons described in the *Vapor Intrusion Sampling Plan and Risk Assessment Work Plan* (AECOM 2013a), principally because AOC N14 was identified as “no action required” in the ROD (USAF 2006) and is over a half mile (approximately 3,375 ft) north of the current estimated groundwater plume extents (Figure 4 of the *Vapor Intrusion Sampling Plan and Risk Assessment Work Plan*. Four VOCs (methylene chloride, naphthalene, 1,2,3-trichlorobenzene, and xylenes) were detected in soil. The age of the samples (16 years), the low contaminant concentrations and volatility in soil, and frequency of detection support the conclusion that the VOCs in soil at AOC N14 do not present a risk to future indoor air receptors via the VIP. For these reasons, AOC N14 was not included in the updated assessment.

9. **Table 7-3, Changes in Toxicity Criteria Used to Assess the VIP at OU6, Page 7-23:** This table indicates that naphthalene is “no longer considered a non-carcinogen;” however, this is incorrect. Toxicity values for noncarcinogenic effects are available for the oral and the inhalation exposure routes while a toxicity value is also available to evaluate naphthalene for carcinogenic effects by the inhalation exposure route. Please update the table to indicate that naphthalene has been classified as a carcinogen and indicate the availability of an inhalation unit risk factor for this compound.

Also, three of the entries in the “Change in Risk” column appear to belong in the “Factor” column and it appears that the change in risk for these analytes is missing. Please review and correct the entries in the “Change in Risk” column and the “Factor” column.

Response: An updated HHRA was performed and is included as Appendix C of the *Addendum to First FYRR*. Section 2.1.2 includes the associated data and findings.

10. **Section 8.3, Issues:** This section should include the need for well redevelopment based on the fact that a number of wells were not able to accept the target 57 gallons of sodium permanganate. Please acknowledge this issue in Section 8.3 and include a recommendation and follow-up action in Section 9.

Response: Please see response to Specific Comment 4.

11. **Section 8.4.1, Naphthalene and Ethylbenzene in Groundwater, Page 8-3:** This section indicates that the Air Force would determine if sufficient analytical data are available to characterize current concentrations of naphthalene and ethylbenzene in groundwater but it is unclear why an updated risk assessment was not performed. Section 7.2.3 (Page 7-13, last paragraph) states that "groundwater monitoring data collected within the last 2 to 3 years are available to support this assessment." Please update the risk assessment using the more recent available groundwater data or provide justification to support the decision not to update the risk assessment.

Response: The HHRA was updated with the most-recent groundwater monitoring data (including results for ethylbenzene and naphthalene) and is included as Appendix C of the *Addendum to First FYRR*.

COMMENTS ON RESPONSES TO COMMENTS RECEIVED ON THE DRAFT FINAL DOCUMENT

Initial General Comment 1: The information presented in the text, tables, and figures of the Draft Final First Five-Year Review Report, OU6, NASA DFRC, Edwards Air Force Base, California, dated June 2011 (Five-Year Review) is not consistent. For example,

a. Lines 24-26 on Page 4-5 indicate that injection was completed at 12 wells as part of the pre-Record of Decision (ROD) injection event. Similarly, Section 4.3.2.1 (Phase I Injection Event) indicates that injection was completed at 12 wells. However, Table 4-1 (Summary of Remedial Action Activities) indicates that injection was completed at 13 wells as part of the pre-ROD injection event.
b. Lines 3-6 on Page 6-7 state that, "A comparison of TCE results from the 2008 to 2010 monitoring events indicated an increase in TCE concentrations at wells N3-MW07, N3-MW12, N3-MW15, N3-MW21, N7-MW10, and N7-MWl1, and therefore these wells were selected for injection during Injection Event II." However, Table 6-7 (TCE Concentration Variations) indicates an increase in TCE concentrations at wells N3-MW03, N3-MW12, N3-MW16, N3-MW21, N3-NW03, N4-MW06, N7-DEW01, N7-MW02, N7-MW03, N7-MW04, N7-MWl0, N7-MW11, N7-MW 15, and N7-MW16. Please revise the Five-Year Review to clarify why the increases in TCE concentrations at wells N3-MW03, N3-MWl6, N3-NW03, N4-MW06, M7-DEW01, N7-MW02, N7-MW03, N7-MW04, N7-MW15, and N7-MW16 are not discussed in Section 6-7 and clarify why injections during Injection Event II did not occur at these wells.
c. Lines 8-10 on Page 7-13 state that, "No complete pathways to potential human receptors were identified and no ecological targets were identified during the previous risk assessments. No new

pathways or receptors were identified during the five-year review and no weather-related events have affected the protectiveness of the remedy." Similarly, Lines 15-16 on Page 8-1 states that no exposure pathways exist. However, Figures 7-1 (Site N2 - Exposure Pathways) and 7-3 (Site N7 - Exposure Pathways) show complete pathways for the current industrial worker exposure route for groundwater inhalation.

Please revise the Five-Year Review to ensure information is consistently presented.

Initial Response to General Comment 1:

a. Section 4.0 text and Tables 4-1 and 4-2 have been reviewed and revised to ensure that the number of injection wells used during each injection event have been accurately and consistently reported.

b. The reference text has been revised as follows:
"The greatest increases in TCE concentrations were observed at wells N3-MW15 and N3-MW21 and therefore, these wells were among the wells selected for injection during Phase II Injection Event II (August 2010). Results from the 2008 and 2010 monitoring events showed continued increase in TCE concentrations at well N4-MW06 (Figure 6-2), which indicates possible plume instability in the vicinity of this well. Wells N4-MW07, N4-MW08, and N4-MW09 were selected for injection during Phase II Injection Event II to address increasing TCE concentrations near well N4-MW06."

c. Figures 7-1 to 7-3 have been revised to clearly indicate which exposure pathways are being addressed by the remedy. The document has been revised to consistently present that complete exposure pathways are controlled through institutional controls that are preventing exposure to, and the ingestion of, contaminated groundwater.

Response to General Comment 1b Response: The response only partially addresses the original comment. Although the response provides some additional detail for why N3-MW15 and N3-MW21; as well as N4-MW07, N4-MW08, and N4-MW09 were selected for injection during the Phase II Injection Event II, the revised text does not provide any detail about any other injection sites that were or were not included in the Phase II Injection Event II. Additionally the revisions made to the tables in Section 6 make it difficult to differentiate Phase II Injections Events as the Tables only refer to Phase I Injection Event (Table 6-4) and Phase II Injection Event I (Table 6-5 and 6-6) when the text also discusses Phase II Injection Event II. Please revise the text to provide additional details about all the injection sites for Phase II Injection Event II. Also, please revise the and tables to be consistent in presenting the different phases and events for injection.

Response: Each concentration comparison table included notes for the phase included within that table, there is no inconsistency in that regard. The injection sites used during each event were clearly presented in Table 4-2. If applicable in the Second FYRR where high concentration target areas are defined, a sentence similar to the following may be included: Injection locations for each event are presented in Table 4-2.

Section 6.0 is the Data Review and performance sampling data for the Phase II Injection Event II was not available during the reporting period. Although it is beyond the intent and scope of the *Addendum to First FYRR*, the comment will be addressed in the Second FYRR if applicable.

Initial General Comment 2: Page 6-7 indicates that performance monitoring results associated with the Phase II - Injection Event II (i.e., June-July 2010) were not available within this review period; however, Table 6-3 includes TCE Concentrations from several wells sampled during the June-July 2010 performance monitoring event. As such, it is unclear if the information presented in the Five-Year Review is up-to-date. For example, it is unclear if the land use control (LUC) boundary, presented in Figure 4-1 (Land Control Boundary), represents the 5-μg/L isoconcentration contour from the June-July 2010 monitoring event. Please ensure that the final Five-Year Review includes information from reports that are submitted in late 2010/early 2011.

Initial Response General Comment 2: Phase II Injection Event II occurred in August 2010 not June-July 2010. Figure 4-1 (now Figure 4-2 due to document reorganization) includes the LUC boundary based on the June-July 2010 monitoring results. The following note has been added to the figure: "Land use control boundary based on 2010 contaminant concentrations".

Response to General Comment 2 Response: The response partially addresses the comment. According to the 5-Year Review Summary Form, the review period for this 5-Year Review was "11/2/2010 to 8/22/2011;" therefore, it is unclear why the data and information from monitoring after the August 2010 injection event are not included in this 5-Year Review. Additionally documents are referenced in this 5-Year Review that have reporting periods as late as October 2010, therefore this response is inconsistent with other sections of the document. Please include the requested information/data from the post-August 2010 injection event or explain why this data cannot be included.

Also, the Land Use Control (LUC) boundaries should be representative of the most protective conditions (i.e., data through the entire reporting period should be utilized) and it is unclear if the use of June-July 2010 monitoring results are the most up-to-date values for drafting the LUC boundaries. Please use the most protective data available for constructing the LUC boundaries.

Response: The "11/2/2010 to 8/22/2011" period is correct. The November date represents the contract start date for performing the review. The August date represents the last date on which the interviews were conducted. During the 6 October 2010 Remedial Project Manager (RPM) meeting held in Lake Tahoe, the RPMs agreed to use the June/July 2010 data as the most-recent data in the First Five-Year Review Report. The relevant excerpt from the meeting minutes is as follows: "Mr. Healy further indicated that the best available information available at the time of the review should be used (all agreed the June/July 2010 groundwater sampling data would be used as the most-recent data in the 5-Year Review Report as the data from the planned December 2010 sampling event would not be available in time to include in the report)." Although planned for December 2010, the post August 2010 injection event sampling did not occur until March/April 2011. Taking into account time needed for laboratory analysis, data validation, and data management, the March/April 2011 data was not available until August 2011. Therefore, statements such as the following, included in Section 3.3 of the Revised Draft Final Five-Year Review, "The 2010 delineation is presented because it is based on the most recent data available within this review period" are accurate. However, for clarity, in appropriate places within the *Addendum to First FYRR*, "review period" has been replaced with "reporting period". March/April 2011 data evaluation as well as updated LUC boundaries are included in the *Remedy Performance and Groundwater Monitoring Report, 2011-2012* (AECOM 2012) and Figures 2 through 4 the *Addendum to First FYRR* include the 2012 data (the most-recent groundwater data available during *Addendum to First FYRR* preparation).

Initial General Comment 4: Based on Figures 2-1 (TCE Groundwater Concentration Contours - 2010) and 6-2 (Approximate Extent of TCE in Groundwater), it does not appear that the current extent of groundwater contamination at OU6 is sufficiently delineated. For example, no monitoring wells exist north of N3-MW03, N2-MW07, N1-MW05 or N1-MW11; west of N1-MW11, N1-MW08, N1-MWl0, or N4-MW13; or south of N7-MWl3, N4-MW05, N4-MW04, N4-MW11, N4-MW12, or N4-MW13. In addition, the Implementation of the Remedy subsection of Section XI (Overall Observations) of Appendix C (Site Inspection Report) indicates that groundwater sampling of newly installed wells along the plume's leading edge indicate that the plume is larger than predicted. While additional monitoring wells are proposed to delineate the leading edge of the groundwater plume, additional step-out monitoring wells may be necessary to address data gaps associated with the current extent of the plume. Sufficient wells should be installed to fully delineate the extent of the plume and monitor plume expansion or migration. Please revise the Five-Year Review to recommend additional monitoring wells to determine the current extent of the groundwater plume so that data from existing monitoring wells and proposed leading edge monitoring wells can be used to determine how fast the groundwater plume is expanding.

Initial Response: North of N3-MW03 = critical hanger 4802 Section 6.4.3 "Recommendations" has been added to the document and includes:
"Installation of monitoring wells downgradient of Sites N1, N4, and N7 (locations to be presented in a future work plan), and groundwater modeling is recommended in Section 9.0 to delineate the plume's downgradient extent and to determine future compliance as it relates to the possible migration of the plume toward the groundwater subbasin (location indicated on Figure 6-3)."

Additionally, Section 9.0 has been revised to include the following "Recommendations and Follow-up Actions":
"Additional monitoring wells will be installed and modeling performed to completely delineate the leading edge of the plume and monitor cleanup progress. Additional ISCO treatment may be required at the leading edge. Recommended future locations of step-out monitoring wells include locations south of existing monitoring wells N4-MW04, N4-MW05, N4-MW11, N4-MW12, N4-MW13, and N7-MW13, Other recommended monitoring well locations include locations west of N1-MW08 and N1-MW10."

Response to General Comment 4 Response: The response addresses the comment, but was not fully incorporated into the text. Specifically, the work plan mentioned in the comment was not included in Section 9. Please revise Table 9-1 to include the work plan that will include the proposed well locations.

Response: Table 2 of the *Addendum to First FYRR* includes a reference to the *Groundwater Investigation Work Plan* (AECOM 2014a).

Initial General Comment 5: The potential expansion of the groundwater plume is not discussed with sufficient detail. Based on the Implementation of the Remedy subsection of Section XI (Overall Observations) of Appendix C (Site Inspection Report), groundwater sampling of newly installed wells along the plume's leading edge indicate that the plume is larger than predicted. Similarly, Section 6.4 (Data Review) indicates that the plume configuration along the east/southeastern leading edge indicates a change has occurred. As such, it is unclear if the groundwater plume is expanding as a result of ISCO injections due to the limited volume of-the bedrock fractures. Including a tracer in future ISCO injections would help evaluate whether the injections are causing plume expansion. If additional ISCO injections are conducted, please recommend including a tracer in the injectant to help evaluate whether the groundwater plume is expanding.

Initial Response: Section *6.4.2.6 "Leading Edge TCE Concentration Variations"* has been added to the document and includes:
"TCE concentrations detected in samples collected from wells installed at OU 6 since 2009 (N1-MW10 [110 μg/L], N4-MW07 [<1 μg/L], N4-MW11 [580 μg/L], N4-MW12 [160 μg/L], and N4-MW13 [150 μg/L]) indicate that the commingled plume extends further downgradient than the plume delineation based on previous monitoring events. Well locations and associated 2003 and 2010 TCE concentrations are shown on Figures 3-4 and 3-5, respectively. Figure 6-3 presents the extent of the TCE plume delineated in 2003 (at the time of remedy development in the FS [Earth Tech 2004]), in 2004 as presented in the ROD (Earth Tech 2006), and in 2010. The area in blue indicates the change in estimated plume configuration along the east/southeastern leading edge as a result of TCE concentrations detected in newly installed wells N1-MW10, N4-MW07, N4-MW11, N4-MW12, and N4-MW13. Trend graphs for wells with an adequate number of data points during the review period are included on Figure 6-4, and indicated that the leading edge of the plume is exhibiting instability as indicated by increasing TCE concentrations at monitoring wells including N4-MW06. TCE concentrations in samples collected from monitoring well N4-MW06 have consistently increased between 2005 and 2010. Additionally, analytical results from the 2010 monitoring event indicated that an area of relatively high TCE concentrations, ranging from 21 to 560 μg/L (Figure3-5), exists in the Site N4 area. To address this high concentration area and apparent plume instability in the vicinity of monitoring well N4-MW06, Site N4 area injection wells (N4-MW07, N4-MW08, and N4-MW09) were included in the Phase II Injection Event II."

Section 6.4.3 "Recommendations" has been added to the document and includes:
"Inclusion of a tracer in future ISCO injections is recommended to evaluate whether injections are displacing the plume."

Response to General Comment 5 Response: The response addresses the comment, but due to the lack of delineation of the extent of the plume to the east, southeast and south of the N4 area, it cannot be concluded that the "leading edge plume instability appears limited to the southern portion of Site N1 and the northern portion of Site N4 as indicated by increasing TCE [trichlorethene] concentrations at monitoring well N4-MW06." Installation of additional wells to delineate the plume (i.e., resolve the lines that are dashed on Figure 3-5) and collection of additional samples from wells installed in 2010 may indicate that there are other areas where the plume is migrating. Please revise the response and text to acknowledge that plume instability cannot be fully assessed because wells installed in 2010 have not been sampled a sufficient number of times to evaluate whether the plume is stable and because the full extent of the TCE plume has not been delineated.

Response: Agreed. Plume stability cannot be fully assessed until an adequate number of wells have been installed to delineate the plume's leading edge and an adequate number of sampling events conducted to determine if the plume is stable. During the October 2011 Technical RPM meeting, the RPMs agreed that plume delineation would be a milestone for the Second Five-Year Review Report scheduled for September 2016 and is not the focus of this Addendum. This was documented in the *Remedial Action Work Plan Addendum* (AECOM 2013b). A *Groundwater Investigation Work Plan* (AECOM 2014a) has been prepared proposing the installation of 10 groundwater monitoring to further evaluate plume extent. The well placements proposed in the Groundwater Investigation Work Plan are currently being re-evaluated due the preliminary results from the Site 25 Remedial Investigation effort indicating that contamination associated with OU 6 may extend beyond the eastern-most well locations proposed in the *Work Plan*. Well installation is scheduled for completion December 2014. It is unknown if the extent of the plume will be determined with the 10 well installations and more may be required.

The following text is included in Section 2.1.1.3 of the *Addendum to First FYRR*: TCE concentrations detected in samples collected from wells installed at OU 6 since 2009 indicate that the commingled plume extends further downgradient than the plume delineation based on previous monitoring events. TCE concentrations in groundwater in 2012 were 110 micrograms per liter (μg/L) at N1-MW10, less than 1 μg/L at N4-MW07, 580 μg/L at N4-MW11, 160 μg/L at N4-MW12, and 150 μg/L at N4-MW13.

Since the review period, 18 groundwater monitoring wells (RL-25-MW01 to RL-25-MW18) associated with Site 25 (OU 8) were installed in April through September 2013 on the lakebed east and southeast of OU 6 and groundwater samples were collected from those wells and well N4-MW14. Figure 2 presents the locations of these wells and an updated plume configuration estimate based on data collected since those data shown on Figure 6-4 of the *First FYRR*. The preliminary (i.e., not yet validated or reported) laboratory analytical results for those groundwater samples indicated the presence of TCE at 12 of the 18 wells and at well N4-MW14. The extent of the plume remains unclear to the east, southeast, and south of Site N4 and more wells will be installed to close these data gaps (AECOM 2014a). Plume characterization extent findings will be updated during the second five-year review period and in future five-year review periods.

Since the entire comment does not specifically apply to the content of the *Addendum to First FYRR*, if applicable, text similar to the following may be included in the Second FYRR to further address the comment: Well locations and associated 2003 and 2010 TCE concentrations are shown on Figures 3-4 and 3-5, respectively. Figure 6-3 presents the extent of the TCE plume delineated in 2003 (at the time of remedy development in the FS [Earth Tech 2004]), in 2004 as presented in the ROD (USAF 2006), and in 2010 (latest data available during the reporting period [November 2010 through August 2011]). The area in blue indicates the change in estimated plume configuration along the east/southeastern leading edge as a result of TCE concentrations detected in newly installed wells N1-MW10, N4-MW07, N4-MW11, N4-MW12, and N4-MW13. As indicated in Section 1.2, though the Plume Characterization Key Action Item is not expected to be complete until the Second FYRR in September 2016, this document includes a discussion of the plume delineation based on the most-recent data available. Figures showing groundwater TCE and benzene plume estimates based on data collected since the five-year review reporting period, including preliminary data, are included in Appendix E. Figure E-1 in Appendix E is provided as an update to Figure 6-3 to present the difference in plume estimates between 2010 and 2012. Trend graphs for wells with an adequate number of data points during the review period are included on Figure 6-4, and indicated that the leading edge of the plume is exhibiting instability as indicated by increasing TCE concentrations at monitoring wells including N4-MW06. TCE concentrations in samples collected from monitoring well N4-MW06 have consistently increased between 2005 and 2010. Additionally, analytical results from the 2010 monitoring event indicated that an area of relatively high TCE concentrations, ranging from 21 to 560 μg/L (Figure 3-5), exists in the Site N4 area. To address this high concentration area and apparent plume instability in the vicinity of monitoring well N4-MW06, Site N4 area injection wells (N4-MW07, N4-MW08, and N4-MW09) were included in the Phase II Injection Event II. Though performance monitoring results associated with the Phase II Injection Event II were not available within the reporting period (November 2010 through August 2011), continued sodium permanganate solution injections at the Site N4 area will likely be required.

Initial General Comment 6: Occupied buildings have not been distinguished from unoccupied buildings in the Five-Year Review. As a result, it is unclear if occupied buildings are located above the groundwater plume. Further, it is unclear if workers have been relocated to areas outside the portions of OU6 where groundwater is impacted or anticipated to be impacted in the future, as indicated in Lines 7-9 on Page 7-5. Please revise Figure 2-1 (TCE Groundwater Concentration Contours - 2010) to indicate which buildings are occupied relative to monitoring wells and the groundwater plume. If occupied buildings exist above the groundwater plume, please provide monitoring well or soil vapor data to substantiate that the inhalation exposure pathway is not important for current or future workers.

Initial Response: Due to security concerns it was agreed at the 20 July 2011 RPM technical meeting that a figure indicating occupied buildings need not be presented. The relevant text in Section 7.2.5.1 has been revised to discuss building occupancy and includes:

"These changes in groundwater concentrations imply that the location of the plumes relative to buildings currently occupied on a routine basis may have also changed. This issue was brought up during a review of a draft version of this report where a concern for the health of current indoor workers was raised. To address this concern, a list of routinely occupied buildings over and adjacent to groundwater plumes was generated. These plumes are presented on Figures 3-5 and 3-7 showing the current extent of TCE and benzene at OU6. These chemicals were selected since they represent the primary constituents of the impacted groundwater and the primary risk drivers previously identified for the VIP. These figures represent the most current information of the extent of groundwater impact as of 2010. Six buildings were identified above or near these plumes; Buildings 4803, 4805, 4806, 4807, 4810, and 4827. Of these, only three buildings were identified as being occupied on a routine basis; Buildings 4806, 4807, and 4810. Site personnel familiar with the activity patterns for this OU verified that these buildings were occupied daily throughout the work week. Occupancy at a lower frequency would make it highly unlikely that exposure would lead to adverse health effects; especially considering the fact that these buildings are located only on the margins of the plumes."

Response to General Comment 6 Response: The response partially addresses the comment. Based on data from well N3-MW20, Building 4806 is now in close proximity to high concentration areas of the benzene plume. Since there are no wells within, south or east of Building 4806, the concentration of benzene beneath this building is unknown (as acknowledged by the dashed lines on Figure 3-7). Therefore it is unclear if there is an ongoing concern for the vapor intrusion pathway for current or future worker exposure. It appears that additional groundwater monitoring wells and/or subslab and indoor air sampling is necessary to evaluate the risk to workers in this building. Please provide data to support that the remedy is protective for current or future workers who may potentially be exposed to VOCs in occupied buildings through the vapor intrusion pathway or discuss how and when this data can be obtained.

Response: Please see response to New Specific Comment 5.

Initial General Comment 8: Section 7.1.3 (In Situ Chemical Oxidation and Groundwater Monitoring Remedial Action Component Performance) and Table 7-2 (Plume Mass and Volume Summary) present conflicting information. For example, Lines 15-16 on Page 7-3 indicate that the ISCO RA appears to be functioning as anticipated (implying reductions in mass and contaminant concentrations); however, Table 7-2 indicates that the OU6 plume mass and volume are increasing. Similarly, Lines 14-15 and Table 7-2 indicate that mass destruction is occurring while Table 6-3 (TCE Concentration Variations) indicates that concentrations are increasing and new hot spot areas exist which implies that the OU6 plume is expanding and mass is increasing. As such, it is unclear if the ISCO RA is functioning as anticipated and mass destruction is occurring. Please revise the Five-Year Review to clarify how the ISCO RA is functioning as anticipated when concentrations are increasing and new hot spot areas imply that the OU6 plume is expanding. Further, please clarify how mass destruction can be evaluated when the OU6 plume is expanding and concentrations are increasing.

Initial Response: Sections 6 and 7 have been amended to reiterate that ISCO component of the RA is intended to only treat the areas of highest contaminant concentrations and that the wells in those area show nearly 100% reduction in TCE concentrations since 2003.

Response to General Comment 8 Response: The response partially addresses the comment, i.e. the response indicates that the intent of the In Situ Chemical Oxidation (ISCO) component of the Remedial Action (RA) is to address hot spot remediation only; however, it is not clear if increasing concentrations and an expansion of the plume was an anticipated outcome. Additionally the comment does not address the evaluation of mass destruction given an expanding plume with increasing concentrations. Please discuss whether increasing concentrations and an expansion of the plume was an anticipated outcome and clarify how mass destruction can be evaluated when a plume is expanding and concentrations are increasing.

Response: The following text is included in Section 2.1.1.1 of the *Addendum to First FYRR*: Artificial plume boundaries were established at Sites N3 and N7 (based on benzene and TCE concentrations above Maximum Contaminant Levels [MCLs] in groundwater) to allow for consistent future contaminant mass estimates. These artificial plume boundaries allow for evaluation of contaminant mass removal despite changes in the plume footprint. As Site N4 was not previously identified as an area of high VOC concentrations in groundwater, *in situ* chemical oxidation (ISCO) implementation in the area was not originally anticipated. The remedy identified for Sites N3 and N7 in the ROD (USAF 2006) included application of ISCO. Establishing an artificial plume boundary for Site N4 is recommended as part of the next five-year review to initiate removal estimates in that treatment area.

Although areas of increasing concentrations and possible plume instability were not necessarily anticipated, they are not unusual occurrences when plume delineation is ongoing. Contaminant mass estimates will be updated as new wells are installed, data are compiled, and plume extent estimates are updated. Treatment areas will be selected based on the latest available data to ensure efficient RA progress. Areas of possible plume instability and expansion were identified at the downgradient edge of the commingled plume after initial RA design and implementation. Therefore, possible plume expansion and instability is an indication of incomplete contamination delineation as opposed to failure or shortcoming of the ISCO component of the remedy for plumes identified in the ROD.

Initial General Comment 9: Section 7.1. (Question A: Is the Remedy functioning as Intended by the Decision Documents?) does not assess several aspects of the remedy implementation, as outlined in Sections 4.1.2 through 4.3 of the Comprehensive Five-Year Review Guidance, EPA 540-R-01-007, dated June 2001 (the Guidance). The following aspects of the remedy implementation are not assessed consistently:

Question A: Is the remedy functioning as intended by the decision documents?

a. Remedial Action Performance
b. Costs of System Operations
c. Monitoring Activities
d. Opportunities for Optimization
e. Early Indicators of Potential Remedy Problems

Please revise to include an assessment of these aspects of the remedy implementation.

Initial Response: The Question A elements are addressed as follows:

a. Remedial Action Performance – Currently addressed in Section 7.1.3.
b. Costs of System Operations – Currently addressed in Section 7.1 with reference to Section 4.3.3.
c. Monitoring Activities – The text has been revised to mention performance monitoring data as the vehicle for evaluating RA performance.
d. Opportunities for Optimization - An opportunity for optimization is currently presented in Section 7.1.
e. Early Indicators of Potential Remedy Problems – The last sentence of Section 7.1 has been revised to clarify that it is an early indicator of a potential problem. Elevated TCE concentrations at Site N4 are possible early indicators of plume instability (a potential problem) as further discussed in Section 7.1.4.

Response to General Comment 9 Response: The response partially addresses the comment. It is difficult to assess whether or not cleanup will be achieved via the selected remedy as the concentrations of COCs are increasing and the plume appears to be migrating in some locations. Please revise the 5-Year Review to discuss whether or not cleanup can be achieved within the expected timeframe given the increasing concentrations and expansion of the plume.

Response: Section 2.1.1.2 of the *Addendum to First FYRR* includes a mention of the impact of plume expansion on the expected cleanup timeframe as follows: Per the *Groundwater Investigation Work Plan* (AECOM 2014a), additional monitoring wells will be installed east, southeast, and south of Site N4. Samples from the proposed wells will provide data for complete delineation of the leading edge of the plume allowing for greater accuracy in plume extent estimation. The estimates will provide the basis for more certain contaminant mass/volume calculations that are expected to yield a better understanding of RA progress and cleanup timeframe assessment.

Initial General Comment 10: Due to the increased concentrations of TCE and benzene and the potential for vapor intrusion, it is unclear if RAOs presented in Section 4.1 (Remedy Selection) and LUCs presented in Section 4.1.1 (Land Use Controls) are protective. For example, Table 6-3 (TCE Concentration Variations) indicates that TCE concentrations have increased from a maximum concentration of 2,000 μg/L during the 2008 monitoring event to a maximum concentration of 20,000 μg/L during the 2010 monitoring event. Further, Table 9-1 (Recommendations and Follow-Up Actions) indicates that the methodologies for determining risk to indoor air from subsurface contaminants have been revised since the ROD was signed and an evaluation of the updated vapor intrusion pathway guidance methodologies as they relate to site conditions is necessary. Please revise the Five-Year Review to clarify how the RAOs and LUCs presented in Sections 4.1 and 4.1.1 are protective.

Initial Response: Section 6.4.2.3 Overall TCE Concentration Variations (2003 to 2010) has been added to the document and includes: The data collected during the 2003 monitoring event were the basis for the remedies developed in the FS (Earth Tech, 2004) and the final remedy selection in the ROD (Earth Tech, 2006) and the data collected during the 2010 monitoring event represent the most-recent results available within this five-year review period. Comparing the TCE data from the 2003 and 2010 monitoring events provides a means of evaluating the overall performance of the remedy. Of the 23 wells sampled during both of the 2003 and 2010 monitoring events, 20 wells exhibited an overall decrease in TCE concentrations and 18 of those wells showed significant (greater than 50 percent) decreases (Table 6-7). TCE concentrations increased in samples collected from two wells during that timeframe, N3-MW15 and N1-MW08, and were not detected in the samples from well REPA-MW01. The increase at well N1-MW08 is not statistically significant because of the relatively low TCE concentrations detected in both samples, less than 1.5 μg/L (which is below the 5-μg/L cleanup goal [MCL]). The increase in TCE concentrations detected in samples from well N3-MW15 (from 4,600 μg/L in 2003 to 20,000 μg/L in 2010) may be attributable to rebounding as this well was treated with a Fenton-based reagent in 2003 as part of an ISCO treatability study. The 2010 concentration is a significant decrease from the historical high TCE concentration (45,000 μg/L) at N3-MW15, detected in 2002.

The 2003 groundwater monitoring data for samples collected from wells N3-DEW02, N3-MW06, N3-MW07, N3-MW15, and N3-NW05 at Site N3 and wells N7-MW01 and N7-MW12 at Site N7 indicated that the wells were located in the areas of highest TCE concentrations at the respective sites. Trend graphs for TCE concentrations for these wells and N7-MW02, a deep well near N7-MW01, are presented in Appendix A. The percent decrease in TCE concentrations from the 2003 to 2010 timeframe were at, or near, 100 percent at these wells with the exception of N3-MW15 (Table 6-7). As described above, the TCE concentrations in samples collected from N3-MW15 have likely rebounded from reductions realized during a previous treatability study. The significant decreases in TCE at the highest concentration area wells indicate that the ISCO component of the RA is progressing successfully.

Table 3-1 in Section 3.3 indicates a decreasing trend in concentrations of 15 of the 17 COCs, including TCE and further indicates that the ISCO component of the RA is progressing successfully.

Response to General Comment 10 Response: The response does not specifically address the comment. There is a concern that RAOs and LUCs may not be protective with the increasing concentrations of TCE in N3-MW15, which result in the potential for exposure to VOCs in occupied buildings through the vapor intrusion pathway. Please discuss the protectiveness of the RAOs and LUCs with respect to potential vapor intrusion into buildings located above the groundwater plume.

Also, the response and revised Section 6.5.2.3 are misleading when the text states, "TCE concentrations increased in samples collected from two wells during that timeframe [2003 to 2010]" because this does not acknowledge that TCE concentrations also increased in seven additional wells between 2008 and 2010 (See Table 6-6). These seven wells were either not sampled in 2003 or were installed after 2003. It is important to consider the increased concentrations in these wells (N3-MW03, N3-MW21, N4-MW06, N7-DEW01, N7-MW02, N7-MW15 and N7-MW16) in order to understand the performance of the remedy. Please revise the text to discuss the increases in TCE concentrations in these wells and whether the remedy is performing as intended in the vicinity of these wells.

Response: Please see response to New General Comment 4 regarding the update to the HHRA.

Regarding the increases in TCE concentrations within the 2003 to 2010 timeframe, the wells noted in the comment were discussed in the 2008 to 2010 comparison. Because the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, text similar to the following may be included in the Second FYRR to address the comment: The data collected during the 2008 and 2010 monitoring events represent site conditions following the Phase II Injection Event I (March 2008). The 2008 and 2010 monitoring events followed the Phase II Injection Event I by 6 and 27 months, respectively. Comparing the TCE data from the 2008 and 2010 monitoring events provides a means of evaluating the long-term performance of the Phase II Injection Event I. Of the 34 wells sampled during both the 2008 and 2010 monitoring events, results from 5 of the wells showed reductions in TCE concentrations (Table 6-6) while 15 wells (N3-MW03, N3-MW07, N3-MW12, N3-MW15, N3-MW16, N3-MW21, N3-NW03, N4-MW06, N7-DEW01, N7-MW02, N7-MW03, N7-MW10, N7-MW11, N7-MW15, and N7-MW16) showed an increase in TCE concentrations. These increases in TCE concentrations may be the result of untreated groundwater moving into the treatment zone and further indicates that rebound occurred within 27 months following Phase II Injection Event I. The greatest increases in TCE concentrations were observed at wells N3-MW15 and N3-MW21 and therefore, these wells were among the wells selected for injection during Phase II Injection Event II (August 2010). Wells N3-MW07 and N3-MW12 were also selected for injection during the August 2010 event. The remaining eleven wells with increased TCE concentrations were not utilized as injection points in August 2010 because they were either not suitable injection wells, were utilized as monitoring points, or were located outside of the treatment area.

Initial Specific Comment 8: Table 6-3, TCE Concentration Variations, Page 6-5. The TCE concentration variations between 2003 and 2007 have not been presented in Table 6-3. While the approximate decrease between 2003 and 2010 is presented, the approximate decrease between 2003 and 2007 has not. Please revise Table 6-3 to provide the approximate decrease between 2003 and 2007.

Initial Response: Table 6-3 has been added and presents the TCE concentration variances between the 2003 and 2007 sampling events. Table 6-6 has been added and presents the TCE concentration variances between the 2003 and 2010 sampling events.

Response to Specific Comment 8 Response: The response addresses the comment, but incorrectly references Tables 6-3 and 6-6. Please revise the response to reference the correct tables.

Response: Because the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, tables will be included in the Second FYRR to present the TCE concentration variances between the 2003 and 2007 sampling events and TCE concentration variances between the 2003 and 2010 sampling events and proper references applied.

Initial Specific Comment 17: Section 7.1.3, In Situ Chemical Oxidation and Groundwater Monitoring Remedial Action Component Performance, Page 7-3. Lines 19-23 indicate that benzene concentrations have significantly increased since 2003; however, the cause of this increase has not been discussed. As such, it is unclear if the increased concentrations are associated with a new spill or contaminant migration. Further, it is unclear if additional wells are needed to monitor areas with increasing benzene concentrations. Please revise Section 7.1.3 to discuss the cause of increased benzene concentrations and clarify whether additional monitoring wells are necessary to monitoring potential migration.

Initial Response: The text has been revised to indicate that the elevated benzene concentrations were detected in new wells and that additional releases or migration are not occurring. Additionally, the text indicates that no new wells are warranted based upon the benzene detections. Section 7.1.3 (renamed "Bioremediation" due to report reorganization) has been revised to include the following discussion:
"The delineated benzene mass has increased by 954% since 2003 (Table 7-2). Because ISCO is not expected to address the presence of aromatic hydrocarbons (such as benzene), and because the bioremediation remedy component to address benzene has not yet been implemented, the increase in benzene mass is not an indication of remedy failure. The increase in mass is not a result of an ongoing source, but a result of further delineation of the benzene plume. The estimated benzene plume configuration was extended to the south due to benzene concentrations detected in well N3-MW20, installed in July 2004 (Section 6.4.2.6). Additionally, a review of Table 3-1 in Section 3.3, indicates a decreasing trend in benzene concentrations. The highest historical benzene concentration at OU6 (19,000 μg/L) was detected in the sample collected from monitoring well N3-MW14 in 2002. The maximum benzene concentration detected in the most-recent groundwater sampling event (2010) was also collected from monitoring well N3-MW14 and was 7,000 μg/L.

The bioremediation component to address benzene and other aromatic hydrocarbons will be implemented after the completion of the ISCO component (Earth Tech, 2008) and outside the five-review period presented in this report. Further delineation of the benzene plume may be warranted prior to or during bioremediation implementation."

Response to Specific Comment 17 Response: The response partially addresses the comment. Although the response states that no new wells are needed to address the benzene plume, new wells are needed in the vicinity of worker-occupied Buildings 4806 and 4807 to delineate the extent of the high concentration benzene plume and to evaluate whether the benzene plume extends beneath these buildings. Please revise the text of the 5-Year Review to include installation of additional monitoring wells to delineate the extent of the benzene plume in the vicinity of Buildings 4806 and 4807.

Response: Per the *Groundwater Investigation Work Plan* (AECOM 2014a) a well will be installed on the northeast side of Building 4806 to aid in delineation of the benzene plume.

The following text is included in Section 2.1.1.3 of the *Addendum to First FYRR*: Figure 3 presents an updated benzene plume configuration estimate based on data collected in 2012. Since the review period covered by the September 2011 *First FYRR*, well N3-MW24 (located downgradient of well N3-MW20) was sampled in 2012 for the first time. Well N3-MW24 groundwater sampling results in 2012 indicate that the benzene plume extends farther downgradient than shown on Figure 3-7 of the *First FYRR*. As well N3-MW24 was not previously sampled, adequate data are not yet available to determine if benzene concentrations detected in this well indicate plume instability. Installation of a monitoring well (proposed well N3-MW29, Figure 3) downgradient of well N3-MW24 is planned by December 2014 to further delineate the benzene plume (AECOM 2014a).

Because the comment does not entirely apply to the content of the *Addendum to First FYRR*, if applicable, the Second FYRR may include text similar to the following to fully address the comment: For example, 2010 benzene concentrations detected in monitoring well N3-MW20 indicate that the benzene plume extends laterally beneath the north corner of Building 4806. This monitoring well was installed in 2004 and the impact the detected benzene concentrations had on defining the benzene plume relative to Building 4806 is evident when comparing the 2003 benzene plume depicted on Figure 3-6 to the 2010 benzene plume shown on Figure 3-7. As shown on Figure 3-6, the 2003 benzene plume delineation evaluated in the HHRA did not extend beneath Building 4806. As there are no monitoring wells within, south, or east of Building 4806, the extent of benzene beneath Building 4806 is uncertain.

Initial Specific Comment 20: Section 7.2.2, Changes in Exposure Pathways, Page 7-5. The first paragraph on page 7-5 indicates that while Buildings 4886 and 4889 were removed from Site N3, and that other buildings remain at the site; however, this section states that office activity at these other buildings will be relocated to areas outside the portions of OU6 where groundwater is impacted or anticipated to be impacted in the future. There is an immediate concern that this area may present a potential vapor intrusion risk due to high levels of TCE detected at the site at concentrations that may be indicative of DNAPL [see Table 6-2 (Maximum Organic Analyte Concentrations Detected in Groundwater Compared to Cleanup Goals - Second Performance Monitoring Event - June-July 2010), where the maximum concentration of TCE at 20,000 μg/L exceeds 1 percent of TCE solubility]. Since the relocation of office activity is only proposed and no date was specified, there is a concern that there is current ongoing exposure of workers as a result of vapor intrusion from high concentration groundwater. To ensure protection of current workers, clarification is warranted regarding the location of existing and occupied buildings relative to the TCE plume, otherwise current worker safety must be demonstrated with indoor air monitoring. Please provide a list of all buildings in OU6, indicating whether they are occupied and the type of activities that occur in these buildings. Also, please provide a figure that depicts occupied buildings and with the 2010 TCE and benzene plume concentration contours. Finally, please include vapor monitoring in the recommendations or provide a date when office workers will be relocated.

Further, the third paragraph on Page 7-5 references results of the OU6 HHRA performed by Earth Tech in 2003 and the predictive ecological risk assessment performed by Tetra Tech in 2003; however, supplemental risk assessments are also mentioned but the specific documents were not cited in the text. To promote clarity in this section, please include the citations for the supplemental risk assessments.

Initial Response: Please see response to General Comment 6. Supplemental risk assessment references have been added.

Response to Specific Comment 20 Response: The response only partially addresses the comment as it indicates that a citation will be provided; however, the reference to "supplemental risk assessments" was deleted and was not shown in strike-out in the revised draft final version. Due to this deletion the requested citation was not provided. Please retain the reference to "supplemental risk assessments" and provide a citation.

Response: Text no longer exists due to change made to universally incorporate DTSC Specific Comment 9.

Initial Specific Comment 22: Section 7.2.3, Changes in Toxicity and Other Contaminant Characteristics, Page 7-10. The third paragraph states that the "cancer risk associated with groundwater in the Site N3 area increased from 0.628 to 1.18" due to the reclassification of naphthalene as a carcinogen in 2005 and concludes that since a cleanup level for naphthalene was not proposed in the ROD, it is unlikely that this change in toxicity would have dictated a cleanup level as no MCL has been promulgated. The basis for this conclusion is unsupported as the absence of a promulgated MCL does not preclude the need to develop a cleanup goal for naphthalene. In the absence of an MCL for naphthalene, a risk-based tap-water value should be developed to ensure that the remedy is protective for all groundwater risk drivers. Please provide additional information to support why a cleanup goal does not need to be developed for a new risk driver in groundwater, otherwise naphthalene should be included as a final groundwater chemical of concern that should be addressed by the remedy.

Initial Response: In Section 7.2.3, naphthalene is discussed in the second full paragraph on page 7-10. The discussion in this section indicates that if the current Regional Screening Level (the equivalent of the PRGs that were used to calculate the risks presented in the report) were used to calculate groundwater risk from the maximum detected groundwater concentration, the potential cancer risk would have increased as specified in the comment. However, the subject of Section 7.2.3 was to assess the effects, if any, that changes in toxicity criteria would have if cleanup levels were determined today. The discussion indicates that even though there have been changes in the toxicity criteria for naphthalene, these changes would not have been reflected in revised cleanup goals since these goals were based on MCLs (which are not available for naphthalene) rather than risk.

As discussed in the 20 July RPM meeting, we will check to see if we have enough current data to re-assess risk for those groundwater chemicals whose toxicity criteria have changed – including naphthalene. This information will be used as part of the next five-year review as the basis for considering if a new RAO is required.

Response to Specific Comment 22 Response: The response does not address the comment. Although the cleanup goals for groundwater are based on MCLs, the absence of an MCL does not preclude the need to develop a cleanup goal for naphthalene, particularly since naphthalene was classified as a carcinogen in 2005 and a cleanup level had not been previously developed. The response indicates that if there is sufficient data to re-evaluate risk for those chemicals with toxicity values that have changed since 2002, the new "information would be used as part of the next 5-Year Review as the basis for considering if a new RAO is required." If this information is currently available, please re-calculate risk and new RAOs, as applicable, for the 2011 5-Year Review Report.

Response: Please see response to New General Comment 4.

Initial Specific Comment 24: Section 7.2.4, Changes in Risk Assessment, Page 7-11. This section concludes that the total cancer risks and HIs) for Sites N2, N3, and N7 were significantly below 1×10^{-6} and an HI of 1 for the vapor intrusion pathway and that it is "unlikely that repeating the VIP assessments at these sites using current methodology would alter the conclusions;" however, the basis of this conclusion is not supported. The risks were calculated in 2003 yet the groundwater data presented in Table 6-2 (Maximum Organic Analyte Concentrations Detected in Groundwater Compared to Cleanup Goals - Second Performance Monitoring Event - June-July 2010) indicate significant increases in the TCE concentrations, indicating that the risk has also increased. As a result, it appears that the EPCs used in 2003 may not be representative and that the risks based on 2010 data would be higher. In addition, the text also states that benzene concentrations have increased. The Five-Year Review should provide supporting information to discuss how recent data would impact the 2003 risk calculations to support such a conclusion.

Initial Response: The maximum detected TCE concentration listed for the entire OU in Table 6-3 (20,000 μg/L) is for a well in Site N3. The maximum groundwater TCE concentration used for the HHRA in 2003 was 65,000 μg/L (also from Site N3); which was the highest level detected at OU 6 in 2003. Therefore, the results presented in Table 6-3 indicate a significant reduction in TCE groundwater concentrations used to calculate groundwater and VIP risk.

The cancer risk and non-cancer hazard for the VIP at Site N3 presented in the HHRA were 9E-09 and $<$0.001, respectively. Given the reduction in TCE (the primary risk driver) at this site, these risks can be expected to be lower today than they were calculated in 2003. The risks and hazards for sites N2 and N7 were approximately 8.8E-11 and 6.3E-11, and 0.001 and less than 0.001, respectively. However, since these risks were also driven almost entirely by TCE, and since TCE has generally decreased over time (as shown in Table 3-1 of the report) it is reasonable to conclude that the low risks reported in 2003 have probably decreased to even lower levels – as the report states.

The report has been revised to include graphs showing changes in groundwater VOC concentrations over time. These graphs support the general decreases in VOC levels at OU6.

Response to Specific Comment 24 Response: The response does not address the comment as it does not include a discussion of how benzene may impact risk calculations. Please include a discussion of benzene's impact on risk calculations in the response.

Response: The report has been revised as the *Addendum to First FYRR* and includes an update to the HHRA which assessed all of the VOCs detected in groundwater during the 2012 groundwater monitoring event, including benzene. Benzene is specifically discussed as a risk driver in the updated HHRA.

Initial Specific Comment 27: Section 7.4, Summary of Technical Assessment, Page 7-14. This section concludes that there is "no information that indicates that the protectiveness of the remedy is inadequate" but the word "inadequate" should not be used to describe protectiveness. The remedy is either protective, protectiveness is undetermined, or the remedy is not protective. Please revise the quoted statement to state whether the remedy is protective, protectiveness is undetermined, or it is unprotective. Also, the last sentence on Page 7-13 indicates that there is information that is "possibly affecting the protectiveness of the remedy." Further, the top of Page 7-12 indicates that if "the use of DTSC or USEPA guidance methodologies for determining risk to indoor air from subsurface contaminants may yield different results." Based on these statements, the conclusion in Section 7.4 should provide additional information to demonstrate that there is no other information that indicates that the protectiveness of the remedy is inadequate. For example, clarify what part of the remedy may protect human receptors despite the uncertainties associated with the historical risk results relative to new guidance and toxicity information.

Initial Response: Section 7.4 has been revised to clarify that part of the remedy may protect human receptors despite the uncertainties associated with the historical risk results relative to new guidance and toxicity information.

Response to Specific Comment 27 Response: The comment requested revisions to Section 7.4 that have not been made. Please provide the requested revisions from the original comment, including deleting or changing the word "inadequate" in the last sentence of Section 7.4.

Response: The sentence: "No additional information, beyond that presented in the *First FYRR* (AECOM 2011), has come to light that could call into question the protectiveness of the remedy." is used in Section 2.1.3 of the *Addendum to First FYRR*. This replacement sentence is derived from the Comprehensive Five-Year Review Guidance, EPA 540-R-01-007, dated June 2001 and is appropriate. The comment-referenced sentences that indicated that there is information that is "possibly affecting the protectiveness of the remedy." and "the use of DTSC or USEPA guidance methodologies for determining risk to indoor air from subsurface contaminants may yield different results." have not been included in the *Addendum to First FYRR*.

Lead RPM Joseph Healy
Technical Review Comments on:
Draft Final First Five-Year Review Report*; and *Redline Version, Operable Unit 6*; and *Air Force Responses to Regulatory Comments

This set of comments is included at the end of the USEPA non-concurrence letter included in Appendix I of the First Five-Year Review Addendum. The Air Force and NASA produced the *Remedial Action Work Plan Addendum* (AECOM 2013b) as a response to Mr. Healy's comments

References

AECOM Technical Services, Inc. (AECOM) 2011. *Environmental Restoration Program, First Five-Year Review Report, NASA Dryden Flight Research Center, Operable Unit 6, Edwards Air Force Base, California, Revised Draft Final.* Prepared for 95th Air Base Wing, Environmental Management, Edwards Air Force Base (AFB), California (CA), National Aeronautics and Space Administration (NASA) Dryden Flight Research Center (DFRC), Safety, Health, and Environmental Office, Edwards AFB, CA, and Air Force Center for Engineering and the Environment, Environmental Programs Execution – West, San Antonio, Texas (TX). Sacramento, CA. August.

——— 2012. *Environmental Restoration Program, Remedy Performance and Groundwater Monitoring Report, 2011 - 2012, NASA Dryden Flight Research Center, Operable Unit 6, Edwards Air Force Base, California, Final.* Prepared for 412th Test Wing, Environmental Management (412 TW/CEV), Edwards AFB, CA, NASA DFRC, Safety, Health, and Environmental Office, Edwards AFB, CA, and the Air Force Civil Engineer Center, Environmental Center of Excellence - West (AFCEC/CZRW). Sacramento, CA. October.

——— 2013a. Environmental Restoration Program, *Vapor Intrusion Sampling Plan and Risk Assessment Work Plan, National Aeronautics and Space Administration, Dryden Flight Research Center, Operable Unit 6, Edwards Air Force Base, California, Final*. Prepared for 412 TW/CEV, Edwards AFB, CA; NASA DFRC, Edwards AFB, CA; and AFCEC/CZRW, San Antonio, TX. Sacramento, CA. March.

——— 2013b. Environmental Restoration Program, *Remedial Action Work Plan Addendum, National Aeronautics and Space Administration, Dryden Flight Research Center, Operable Unit 6, Edwards Air Force Base, California, Final*. Prepared for 412 TW/CEV, Edwards AFB, CA; NASA DFRC, Edwards AFB, CA; and AFCEC/CZRW, San Antonio, TX. Sacramento, CA. April.

——— 2014a. Environmental Restoration Program, *Groundwater Investigation Work Plan, Uniform Federal Policy – Quality Assurance Project Plan, National Aeronautics and Space Administration, Dryden Flight Research Center, Operable Unit 6, Edwards Air Force Base, California, Final*. Prepared for NASA DFRC, Edwards AFB, CA; and AFCEC/CZ, San Antonio, TX. Sacramento, CA. January.

———. 2014b. *Environmental Restoration Program, Vapor Intrusion Investigation Report, National Aeronautics and Space Administration, Armstrong Flight Research Center, Operable Unit 6, Edwards Air Force Base, California, Draft*. Prepared for NASA Armstrong Flight Research Center, Edwards AFB, CA; AFCEC/CZRW; Lackland AFB, TX, and AFCEC/Environmental Restoration Operations Division-West (CZOW), Edwards AFB, CA. Sacramento, CA. April.

RESPONSES TO COMMENTS

Environmental Restoration Program
First Five-Year Review Report
Operable Unit 6
Edwards Air Force Base, California
Revised Draft Final, August 2011

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Kevin Depies (DTSC)	General Comment 1	Based on the information provided in the Review, DTSC cannot concur with the Review that the remedy is protective of human health and the environment. DTSC, the U. S. Environmental Protection Agency (EPA), and the Lahontan Regional Water Quality Control Board (RWQCB) met with the Air Force on 20 July 2011 to discuss the Draft Review and believed we had developed a path forward to develop a Final Review that adequately demonstrates remedy protectiveness. However, the Draft Final Review contains disputable language on how the Air Force believes risk should be managed, what is considered 'acceptable', 'generally acceptable', and 'unacceptable' risk, and how toxicity criteria should be applied to calculate risk levels. As previously conveyed to the Air Force in letters and meetings, DTSC disagrees (please see General Comments 5 and 6 below) with how the Air Force is applying these concepts to site evaluations, remedy determination, and cleanup at EAFB. Also, the Draft Final Review introduces ambiguity (please see General Comment 3) as to whether an updated human health risk assessment (HHRA) is needed to demonstrate protectiveness. Because of the risk management and toxicity criteria issues, and the ambiguity on the need to update the HHRA, the Review does not provide a substantive basis that the remedy is protective. For DTSC to concur with the protectiveness determination, the Review needs to clearly address the following: A. Address the current risk to occupants of buildings located in source areas and above groundwater	A1.) The VIP was assessed using current sampling and assessment methodologies in 2013 and the results are presented in the *Human Health Risk Assessment (HHRA) Addendum* and the *Vapor Intrusion Investigation Report* (included as appendices to the *Addendum to First Five-Year Review Report* [*FYRR*]). Additionally, the *Vapor Intrusion Investigation Report* was submitted for regulatory review on 30 April 2014. A2.) The re-assessment included in Appendix C used the latest toxicity values and classifications for naphthalene and ethylbenzene. A3.) The re-assessment included in Appendix C used the latest toxicity values and presents risk results for both CERCLA-preferred and DTSC-preferred toxicity values. B.) See response to General Comment A. The *Remedial Action Work Plan Addendum* (AECOM 2013b) presented a path for the program documents that will detail the investigative and analytical work efforts to be performed as a result of the First Five-Year Review. Additionally, Tables 1 and 2 of the *Addendum to First FYRR* provide anticipated completion dates for follow up actions, a summary of anticipated remedial action activities and related document submittals for the next 5 years.

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		plumes. This can be achieved by updating the HHRA with the following three actions. 1) Reassess the Vapor Intrusion Pathway (VIP) using current sampling and assessment methodology. 2) Factor in ethylbenzene and naphthalene which, since the ROD, have been determined by the State of California to be carcinogens. 3) Factor in any new toxicity criteria which have changed since the HHRA was last completed and apply these toxicity criteria in accordance with State of California procedures. B. Assess potential future building occupant risk in accordance with the three actions described in General Comment 1.A. Determine (within a specified time period) if the groundwater remedy is meeting the groundwater protection Remedial Action Objective. Based on the information provided, the Review does not effectively demonstrate that the implemented remedy will clean up the groundwater contamination, or if the plume is stable and thus if monitored natural attenuation will be effective. This is addressed further in Specific Comments 18, 19, and 20 below.	
Kevin Depies (DTSC)	General Comment 2	DTSC will work with the EPA, RWQCB, and Air Force to develop a mutually agreed-upon schedule to address the protectiveness deficiencies. DTSC assumes that the Air Force will develop a workplan of action and proposes it be distributed by next year so that fieldwork	See response to DTSC General Comment 1. In addition to the *Remedial Action Work Plan Addendum* (AECOM 2013b), the Air Force and NASA prepared and finalized, with regulatory concurrence, the *Vapor Intrusion*

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		and a remedy protectiveness assessment can be completed by 2013. DTSC considers this timeline achievable and adequate for assessing worker protectiveness since the Air Force has already implemented a "non-CERCLA" plan to relocate workers from potentially impacted buildings. DTSC anticipates the workplan will describe in detail how the VIP will be assessed, how the human health risk assessment will be updated, and how/when the groundwater remedy will be determined to be effective at cleaning up the groundwater.	*Sampling Plan and Risk Assessment Work Plan* (AECOM 2013a) in support of the 2013 vapor intrusion field effort.
Kevin Depies (DTSC)	General Comment 3	The Draft Final Review discusses how methodology and evaluation procedures for assessing the VIP have changed since the ROD was signed. This is consistent with DTSC's requests in comments on the Draft Review. However, based on various unsupported reasoning (see our GC 4 below), statements are made that the Air Force doesn't believe revaluating the VIP will result in a need to alter the remedy nor support a finding that the remedy is not protective. Yet, as a "non-CERCLA" action and supported by DTSC, the Air Force is relocating current building occupants to areas less-likely impacted by subsurface VOCs. Also, when discussing the need for a new VIP assessment, the text in several sections implies it "may" or "might" be needed or performed. Based on the high concentrations of VOCs in shallow groundwater, and the lack of soil gas and/or indoor air sampling at several locations of where elevated VOCs are known or suspected to be present, DTSC believes current and future occupants of buildings in VOC source areas and above the VOC groundwater plume are at	See response to DTSC General Comment 1.

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		elevated risk of exposure to VOCs. DTSC request that the Review provide a clear, definitive discussion and recommendation for a revised VIP assessment at OU 6.	
Kevin Depies (DTSC)	General Comment 4	Not expected by DTSC, the Draft Final Review contains updated HHRA risk levels for various pathways and remedy protectiveness assessments based on these updated risk levels. DTSC does not agree with the methodology used to develop the updated risk levels as the Review states that the risk calculations are based on the Air Force's toxicity criteria hierarchy which is not accepted by the State of California for hazardous waste sites. Furthermore, supporting documentation on risk evaluation procedures is not provided. More important, these assessments in the Review introduce confusion as to whether the VIP needs to be reassessed and the HHRA updated. DTSC believes these new risk and remedy protectiveness discussions (examples are the 3rd paragraph in Section 7.2.3, the 2nd paragraph in Section 7.2.5.1, the 4th paragraph in Section 7.2.5.3, Table 7-3, the penultimate paragraph in Section 7.2.5, and the 2nd paragraph in Section 8.4.2) provide no value to the Review and recommend they be deleted. Also please remember that the updated risk evaluation (which is expected in the updated HHRA) is based on cumulative risk.	See response to DTSC General Comment 1. The results of the Vapor Intrusion Investigation and the updated human health risk assessment were used to compose the risk-related summary sections of the *Addendum to First FYRR*.
Kevin Depies (DTSC)	General Comment 5	Intermittently throughout the Review are general statements comparing site risk to 'acceptable', 'generally acceptable', and 'unacceptable' risk levels and/or direct comparisons to a 10^{-4} or 10^{-6} risk level. Please note that DTSC evaluates risk, determines a remedy, and evaluates a remedy protectiveness based on the following	See response to DTSC General Comment 1. Because an update to the HHRA was performed, risk-related sections were revised considerably and this comment was accounted for in the revised text. Per the USEPA 2001 *Comprehensive Five-Year Review*

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		approach: Generally, cumulative site risk below 10^{-6} does not require remedial action while cumulative risk above 10^{-4} usually does require action. The range between 10^{-4} and 10^{-6} is considered the risk management range and the need for remediation at sites falling within this range is generally a risk management decision determined by various considerations such as uncertainty or site-specific conditions. For non-carcinogens, DTSC (and U.S. EPA) has established for regulatory purposes that, when the total hazard index for an exposed individual or group of individuals exceeds 1, there may be concern for potential non-cancer effects, such as respiratory illnesses (U.S. EPA's *Role of Baseline Risk Assessment in Superfund Remedy Selection Decisions* (OSWER Directive 9355.0-30, 22 April 1991)). DTSCs approach is consistent with the U.S. EPA's Risk Management Rules of Thumb which are stated as: "In the absence of ARARs for chemicals that pose carcinogenic risks, preliminary remediation goals generally should be established at concentrations that achieve 10^{-6} excess cancer risk, modifying as appropriate based on exposure, uncertainty, and technical feasibility factors", and "The Agency has expressed a preference for cleanups achieving the more protective end of the risk range (i.e., 10^{-6})." (OSWER 9355.0-69, Aug 1997). DTSC expects that the remedy protectiveness will be made by the Federal Facility Agreement-signatories using the above guidance when the aforementioned VIP	*Guidance*, the new estimated risk should be evaluated to determine if it is acceptable. The guidance defines acceptable risk as "within or below the generally acceptable risk range of 10^{-4} to 10^{-6} for carcinogenic risk and the hazard index is below 1 for non-carcinogenic effects." Section 2.1.2 risk discussions in the First Five-Year Review Addendum are consistent with the USEPA 2001 Guidance. Additionally, the Guidance equates protectiveness with the generally acceptable risk range based on the following: "Protectiveness is generally defined in the National Contingency Plan (NCP) by the risk range and the hazard index (HI)." And "If the estimated risk has increased, then you should determine whether the new estimated risk is acceptable. In most cases, you should base this determination on whether the risk is within or below the generally acceptable risk range of 10^{-4} to 10^{-6} for carcinogenic risk and the hazard index is below 1 for non-carcinogenic effects. If the estimated risk is not protective, you should determine what actions need to be taken to achieve an acceptable level of risk."

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		assessment is complete and the HHRA updated as described in General Comment 1 above.	
Kevin Depies (DTSC)	General Comment 6	Related to General Comment 1 above, for DTSC to assess the remedy protectiveness, the pending updated HHRA will need to be consistent with DTSC's procedures for determining risk at California Hazardous Waste Sites. As stressed in recent DTSC comment letters on various EAFB primary documents, to calculate environmental human health risk DTSC utilizes the most health protective toxicity criteria derived from the California/OEHHA (Office of Environmental Health Hazard Assessment) and US EPA/IRIS databases. In the Draft Final Review, the Air Force added discussions of the change in risk at OU 6 based on a risk screening process that is not consistent with DTSCs approach. DTSC cannot concur with the Review's remedy protectiveness statements without an HHRA evaluation completed in accordance with DTSC policy.	The HHRA was updated using toxicity criteria derived from the OEHHA and US EPA/IRIS databases and included as Appendix C of this document. Protectiveness statements in this document were generated with consideration to the updated HHRA.
Kevin Depies (DTSC)	General Comment 7	Since the ROD, the Air Force has implemented in-situ chemical oxidation (ISCO) at source areas and a monitoring program to assess the success of the ISCO and the monitored natural attenuation (MNA) component for the groundwater remedy. Based on the information provided in the review, a determination of the remedy effectiveness cannot be made at this time primarily because the groundwater contaminant plumes are significantly larger than previously estimated in the ROD, the downgradient extent of the plumes continues to be unknown, and contaminant concentration trends at	Progress has been made in gathering data and performing the assessments necessary to determine remedy effectiveness as proposed in the *Remedial Action Work Plan Addendum* (AECOM 2013b). Tables 1 and 2 of the *Addendum to First FYRR* provide anticipated completion dates for follow-up actions, a summary of anticipated remedial action activities and related document submittals for the next 5 years. See responses to DTSC General Comments 1 and 8 and

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		key plume locations (generally at the downgradient portion of the plumes) are unknown. Less critical, but also resulting in uncertainty, is the viability of the ISCO remedy component as discussed in Specific Comments 5, 6 and 7, below. While not critical to current occupant protectiveness, these uncertainties provide additional support for DTSC being unable to concur with the remedy effectiveness as identified in General Comment 1 above.	Specific Comments 5, 6, 7, and 19.
Kevin Depies (DTSC)	General Comment 8	The remedial approach described is incomplete as it says, in summary ISCO will be applied to treat the halogenated VOCs, then bioremediation will be applied to treat the aromatic VOCs; and monitoring will be done to assess the these activities and the nature and extent of the groundwater contamination. In Section 6 or 7, please add a discussion that includes the specific goals/objectives that are to be met for each component of the groundwater remedial action. For example, what are the criteria for stopping the ISCO and initiation the bioremediation? How and when will plume stability be determined?	The *Revised Draft Final First FYRR* text contained the requested information in Section 4.0 as the section focuses on remedy implementation and appears to be a more appropriate location than Section 6.0 or 7.0 for addressing the comment. Examples are included below: Section 4.1.3 of the *Revised Draft Final First FYRR* contained the following: "Because previous studies have shown that sodium permanganate solution used for ISCO is not effective at treating aromatic hydrocarbons (benzene) and some ethanes (1,2-DCA), portions of the plume impacted by these contaminants will be treated by bioremediation following the completion of the ISCO portion of the RA". Section 4.1.4 of the *Revised Draft Final First FYRR* contained the following: "Following ISCO and bioremediation portions of the RA, monitoring will continue to be employed to verify plume containment and document achievement of the cleanup standards and compliance with applicable or relevant and appropriate requirement (ARARs)."

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			Section 4.2.4 of the *Revised Draft Final First FYRR* contained the following: "Bioremediation was not implemented during this review period and will be implemented following the completion of the ISCO portion of the RA, likely after the next five-year review period." Because the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, the above information may be included in later sections of the Second FYRR. Additionally, if applicable, text similar to the following may be included in the Second FYRR to further address the comment: "Once cleanup levels for groundwater are achieved and indicate that the site is available for unlimited use and unrestricted exposure, LUCs will no longer be maintained, monitored, reported, or enforced." "The contaminant concentration data suggest that ISCO should be employed in treatment areas until halogenated VOC concentrations remain below respective cleanup goals for at least 2 years following an injection event." "As shown on Figure 4-1, the ISCO component of the RA selected in the ROD was to be implemented at Sites N3 and N7, which represented the highest concentration areas of the commingled chlorinated hydrocarbon plume. The RAWP further defined the high concentration areas as areas with TCE concentrations above 300 μg/L. At the time Phase II Injection Event I (March 2008) was implemented, TCE concentrations above 300 μg/L were limited to the

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			Sites N3 and N7 areas." The following is an excerpt from the *Addendum to First FYRR* Section 2.0 providing information regarding plume stability: "Plume stability had not been established; therefore, annual groundwater monitoring was warranted to assess plume movement. The plume stability assessment results will be presented in annual RPGMRs and in the Second FYRR scheduled for September 2016." The following is an excerpt from the *Addendum to First FYRR* Section 2.1.1.3: "The extent of the plume remains unclear to the east, southeast, and south of Site N4 and more wells will be installed to close these data gaps (AECOM 2014a). Plume characterization extent findings will be updated during the second five-year review period and in future five-year review periods." Table 1 of the *Addendum to First FYRR* indicates that for "Plume stability at the leading edge" (Specific Issue 1), the anticipated completion date is "Ongoing", which is appropriate given that sampling data will be needed to access concentration trends in newly installed wells and wells planned for installation by December 2014.
Kevin Depies (DTSC)	Specific Comment 1	Section 3.3, 1st Paragraph, 3rd Sentence. Contrary to what is stated, the No Action decision was not selected simply because soil contaminant concentrations were within "USEPA's acceptable risk range". There were a	Because the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, a sentence similar to the following may be included in the Second FYRR to address the comment: "As documented in the ROD (USAF

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		variety of factors that went into the No Action decision. Either provide a full accounting of the factors, or delete this sentence.	2006), a decision of No Action was selected for the soils due to the limited occurrence and extent."
Kevin Depies (DTSC)	Specific Comment 2	Section 3.3.2, Last Paragraph. The Draft Review contained a discussion on cis-1,2-DCE trends at Site N2 which is not in the Draft Final Review. Please explain/justify the removal of this discussion or add it back to the Review. Also, it is unclear from the text if there are any other Compounds of Concern (COCs) present in groundwater related to Site N2. If there are additional COCs present, then add discussion of the trends of these COCs to Section 3.3.2.	*Cis*-1,2-DCE has not been detected above the MCL in groundwater samples collected from Site N2 wells since 1999; thus, it does not warrant discussion. Therefore, the referenced sentence contained in the draft final document version was revised in the revised draft final version (August 2011) by removal of identifying *cis*-1,2-DCE as exceeding MCLs in groundwater at Site N2. Because the comment does not entirely apply to the content of the *Addendum to First FYRR*, if applicable, a sentence similar to the following may be included in the Second FYRR to further address the comment: "Of the 17 COCs listed in Table 3-1, only TCE concentrations attributable to on-site sources exceeded the 5-μg/L cleanup goal (MCL) in groundwater at Site N2."
Kevin Depies (DTSC)	Specific Comment 3	Figure 3-7. The benzene plume configuration indicates a benzene source somewhere in the vicinity or upgradient of Building 4803. Please identify the source and source location. Also, please add a discussion on the Air Force's confidence in contour placement in this area and estimate/speculate on potential maximum benzene concentrations in groundwater in this area.	No evidence of a source upgradient of Building 4803 has been identified during any investigations. The former drum dispensing area at the location of well N3-MW05 is the only potential source identified in that area. Well N3-MW08 is located upgradient of Building 4803 and well N3-MW05. Benzene has never been detected in this well.
Kevin Depies (DTSC)	Specific Comment 4	Figure 3-7. Benzene contours north of well N3-MW05 and south of N3-MW20 are poorly defined. Determining these horizontal extents is critical from both a groundwater remedy component and assessing the potential risk to current and future occupants of	See response to DTSC Specific Comment 3 regarding benzene in the vicinity of well N3-MW05. The *Addendum to First FYRR* includes the latest benzene contours available (2012) on Figure 3 and the following text

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		overlying buildings 4803, 4858, 4806 and 4807. This concern is factored into our General Comments above.	in Section 2.1.1.3: "Figure 3 presents an updated benzene plume configuration estimate based on data collected in 2012. Since the review period covered by the September 2011 *First FYRR*, well N3-MW24 (located downgradient of well N3-MW20) was sampled in 2012 for the first time. Well N3-MW24 groundwater sampling results in 2012 indicate that the benzene plume extends farther downgradient than shown on Figure 3-7 of the *First FYRR*. As well N3-MW24 was not previously sampled, adequate data are not yet available to determine if benzene concentrations detected in this well indicate plume instability. Installation of a monitoring well (proposed well N3-MW29, Figure 3) downgradient of well N3-MW24 is planned by December 2014 to further delineate the benzene plume (AECOM 2014a)."
Kevin Depies (DTSC)	Specific Comment 5	Section 4.2.4. The Review states aerobic bioremediation to enhance the natural attenuation of aromatic hydrocarbons will be implemented only after no evidence of residual permanganate exists and post-treatment performance groundwater sample analytical results indicate TCE concentrations are below the cleanup level (5 µg/L). This is based on, in part, that native microbes may be negatively impacted by exposure to the ISCO chemical reagent. Literature indicates permanganate has a minimally negative impact on microbe populations. The use of ISCO alone to remediate TCE to 5 µg/L is often unsuccessful or cost prohibitive as increasing amounts of reagent is required to achieve the desired effect due to the random nature of the reactions. Delaying implementation of in situ bioremediation until after the next five year review	Although the negative impact of ISCO to the implementation of the bioremediation phase may be characterized as "minimal", there is not a compelling reason to disregard that impact and to alter the planned remedial action approach. See Water Board Specific Comment 3. Additionally, elevated benzene concentrations were detected in new wells and additional delineation may be required prior to the bioremediation phase. Because the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, text similar to the following may be included in the Second FYRR to further address the comment: "The bioremediation component to address benzene and other aromatic hydrocarbons will be implemented after the completion of the ISCO component (Earth Tech 2008) and outside the five-year review period presented in this report.

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		seems unwarranted. Recent Performance Monitoring results should be reviewed and a plan to implement the bioremediation phase of the remedy as soon as conditions allow should be developed. Additionally, anaerobic in situ bioremediation should be evaluated as an alternative to ISCO for areas where concentrations of TCE remain above the remedial goal. Anaerobic bioremediation could be implemented prior to aerobic bioremediation as a cost effective method to reach remedial goals.	Well N3-MW20 may be a candidate for early bioremediation implementation as ISCO treatment has not been implemented at this location due to limited TCE concentrations (below reporting limits) in samples collected since 2008."
Kevin Depies (DTSC)	Specific Comment 6	Section 6.4.2.2. The Review discusses results of the 34 wells sampled during both the 2008 and 2010 monitoring events, and shows that TCE concentrations decreased in five wells while TCE concentrations increased in 15 wells. The analysis suggests the TCE concentration increases may be due to untreated (upgradient) groundwater migrating into the aquifer treatment zone and further indicates that rebound occurred within 27 months following Phase II Injection Event I. The report should discuss the potential this may have on the projected remedial action success.	Because the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, text similar to the following may be included in the Second FYRR to further address the comment: "The TCE concentration increases within treatment areas during this timeframe (27 months) are not indicators that the remedy is not performing as intended and will be accounted for when selecting future injection locations. TCE concentration increases within treatment areas are expected following treatment, have been observed in previous treatability studies, and are a function of treating small high concentration areas within a larger plume area. Concentration decreases are generally observed immediately following treatment for at least 6 months (see "Monitoring Events 2007 and 2008 Comparison" discussion and Table 6-5). However, within approximately 2 years of treatment some concentration increases are observed. Generally concentrations do not increase above pre-treatment concentration levels. Wells with rebounded concentrations are targeted for re-injection. Wells with rebounded concentrations above pre-treatment levels are targeted for

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			re-injection and the areas within the vicinities of the wells are considered for additional well installations. The contaminant concentration data suggest that ISCO should be employed in treatment areas until halogenated VOC concentrations remain below respective cleanup goals for at least 2 years following an injection event."
Kevin Depies (DTSC)	Specific Comment 7	Section 6.4.2.3. This Section discusses overall TCE concentration variations from 2003 to 2010. The Review states cis-1,2-DCE and total xylenes were detected at historical maximum concentrations during the 2010 sampling event. It further notes cis-1,2-DCE is a TCE biodegradation breakdown product of TCE; and the decrease in TCE concentrations are accompanied by corresponding increasing cis-1,2-DCE concentrations. DTSC notes that vinyl chloride was not detected during the 2010 Performance Monitoring event, indicating a possible stall in the degradation of TCE to ethene at cis-1,2-DCE. The Review should note this as an uncertainty and recommend an evaluation of the stalling of TCE degradation be done as part of the Remedial Action.	Because the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, text similar to the following may be included in the Second FYRR to address the comment: "Because permanganate readily oxidizes *cis*-1,2-DCE, this trend is unlikely to be the result of the Phase II Injection Event I. The formation of *cis*-1,2-DCE may be the result of co-metabolic biodegradation of TCE along with benzene, toluene, and xylene (which are also present in groundwater samples collected from well N3-MW21). Continued application of permanganate at well N3-MW21 is recommended to treat TCE and *cis*-1,2-DCE."
Kevin Depies (DTSC)	Specific Comment 8	Section 6.4.2.4. With the exception of a single well (N1-MW08), no actual "leading edge" wells are included in this section titled "Leading Edge TCE Concentration Variations". Accordingly, we recommend it be re-titled "TCE Concentration Trends/Variations", or alternately insert a discussion of how leading edge TCE concentration variations cannot be assessed at this time as not enough data are yet available to complete this assessment.	Because the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, the comment will be addressed in the Second FYRR. An example of the implementation would be to retitle the subject section as something similar to: "TCE Concentration Variations Near the Leading Edge" and include a discussion of the limitations of data available using the current well network.
Kevin	Specific	Section 7.2.2, 4th Paragraph, (Page 7-12), 5th Sentence.	Because the comment does not apply to the content of the

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Depies (DTSC)	Comment 9	Delete the statement *"risk assessment process used was conservative in nature"* as the HHRA was in general accordance with CERCLA risk assessment procedures which are not universally categorized as "conservative". Note also, numerous variables which could be construed as "conservative" or "not conservative" were factored into the HHRA and so DTSC does not consider the HHRA as "conservative" as stated in the Review.	*Addendum to First FYRR*, if applicable, text similar to the following may be included in the Second FYRR to address the comment: "However, the recommended remedy for soil at these sites was No Action because contaminants were limited in occurrence and extent and contaminants identified as risk drivers were likely not associated with Air Force/NASA AFRC use of the site."
Kevin Depies (DTSC)	Specific Comment 10	Section 7.2.3. This section appears to be collection of somewhat related issues, but it is unclear on what is trying to be conveyed. Various statements appear to be randomly made and are hard to follow and/or are insufficiently unsupported. We recommend reformatting and adding introductory and concluding paragraphs for clarity. Also, we recommend you stay consistent with the section title and simply discuss the toxicity (and other contaminant characteristic) changes and then maybe point the reader to the other sections where the remedy protectiveness was (or will be) assessed based on the changes.	The comment was accounted for in the development of Section 2.1.2.1 of the *Addendum to First FYRR*. Section 2.1.2.1 was developed to remain relevant to the updated risk assessment approach. The effect "Changes in Toxicity and Other Contaminant Characteristic have on remedy protectiveness in this section is consistent with the USEPA 2001 *Comprehensive Five-Year Review Guidance*. Guidance states: **Changes in Toxicity and Other Contaminant Characteristics** *Discuss the following:* • Whether toxicity factors for contaminants of concern at the site have changed in a way that could affect the protectiveness of the remedy • Whether other contaminant characteristics have changed in a way that could affect the protectiveness of the remedy
Kevin Depies (DTSC)	Specific Comment 11	Section 7.2.3, 1st Paragraph, Last Sentence. Please either delete or explain the relevance of this sentence.	Subject sentence is not included in the *Addendum to First FYRR*.

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Kevin Depies (DTSC)	Specific Comment 12	Section 7.2.3, Last Paragraph, 3rd Sentence. This sentence is inaccurate and should be deleted as several additional factors were part of the remedy determination for soil.	Subject sentence is not included in the *Addendum to First FYRR*.
Kevin Depies (DTSC)	Specific Comment 13	Section 7.2.4, 1st Paragraph, 4th Sentence. Clarify what is meant by *"Although the current version of this model is still used"*.	Because the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, text similar to the following may be included in the Second FYRR to address the comment: "The vapor intrusion model has not changed however, other aspects of the assessment of the VIP have changed since the HHRA was completed and the ROD was signed."
Kevin Depies (DTSC)	Specific Comment 14	Section 7.2.4, 1st Paragraph, 5th Sentence. This sentence as written is unclear and doesn't add value to the discussion We think your point is that the ROD was based on an HHRA process described in the 2001 workplan and that the process has changed to such a level warranting a reassessment. Suggest changing the 5th and 6th sentences to "The ROD was based on an HHRA in accordance with the HHRA Workplan (reference the workplan here). However, DTSC and EPA have since significantly modified guidance for assessing the VIP. Edwards AFB is currently…"	Because the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, text similar to the following may be included in the Second FYRR to address the comment: "The ROD was based on an HHRA in accordance with the HHRA work plan (Earth Tech 2001a). However, the DTSC (DTSC 2005) and the USEPA (USEPA 2002) have modified guidance for assessing the VIP."

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Kevin Depies (DTSC)	Specific Comment 15	Section 7.2.5.1, 3rd Paragraph, 1st Sentence. Due to the uncertainty of the placement of benzene groundwater contours as discussed in Specific Comment 4, DTSC does not concur with the Air Force's conclusion that the groundwater VOCs do not present a threat to indoor worker's health in overlying buildings 4803, 4858, 4806 and 4807 and instead consider this assessment "inconclusive". Please convey this in the Review.	The HHRA was updated and included as Appendix C of the *Addendum to First FYRR*. Because an update to the HHRA was performed the subject section was revised considerably to remain relevant to the updated risk assessment approach and this comment was accounted for in the revised text. Information in the revised section includes results of the VIP investigation at Buildings 4806 and 4807. Buildings 4803 and 4858 are not routinely occupied as detailed in Appendix A of the *Vapor Intrusion Sampling Plan and Risk Assessment Work Plan* (AECOM 2013a). The referenced sentence no longer exists.
Kevin Depies (DTSC)	Specific Comment 16	Section 7.2.5.2, 2nd Sentence. Recommend adding "in SVE wells" between *"…sampling ports" and "installed to…"*.	Because the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, text similar to the following may be included in the Second FYRR to address the comment: "Soil gas samples were collected in 1998 and 1999 from sampling ports in soil vapor extraction wells installed to monitor the progress of the groundwater treatment systems operating at Sites N2, N3, and N7."
Kevin Depies (DTSC)	Specific Comment 17	Section 7.2.5.2, 6th Sentence. Please change *"required"* to "recommended".	Because the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, it will be included in the Second FYRR.
Kevin Depies (DTSC)	Specific Comment 18	Section 7.4, Last Full Paragraph, 2nd Sentence. The statement about not being able to make accurate predictions for achieving RAOs is weakly supported. Rather than simply state that the evaluation of meeting RAOs cannot be made at this time due to data gaps,	The subject sentence was revised in the *Addendum to First FYRR* Section 2.1.4 to read: "The downgradient TCE extent is unknown and plume stability/expansion cannot be assessed due to insufficient data in the downgradient portion of the plume."

Reviewer	Comment #	Comment	Response
		instead state that it is because the downgradient TCE extent is unknown and plume stability/expansion cannot be assessed due to insufficient data in the downgradient portion of the plume.	
Kevin Depies (DTSC)	Specific Comment 19	Section 8.2. This section notes that there is a “leading edge data gap”, but does not emphasize the impact this has on remedy effectiveness and instead simply notes that estimation of timeframes to achieve RAOs is ‘difficult’. Five years subsequent to the ROD and the Air Force is uncertain if the remedy will effectively meet the RAOs because the downgradient contamination extent has not been determined and data have not been acquired to assess TCE concentration trends in the downgradient region of the plume. Specify that a plume stabilization assessment and protectiveness determination will be performed and identify relevant workplans, fieldwork, and reports that will be produced to assess and report this assessment/determination.	Well installations are discussed in Section 2.1.1.2 of the *Addendum to First FYRR* and a reference to the well installation work plan is included in that section. The following text is included in Section 3.1.1 of the *Addendum to First FYRR*: " Based on preliminary data collected since the five-year review reporting period, TCE has been detected in groundwater samples collected from wells N4-MW14 and RL-25-MW01 to RL-25-MW18 on Rogers Dry Lake installed under the Site 25 investigation efforts (Figure 2). To further address the apparent gaps in groundwater plume data, additional well installations are proposed in the area of Site N4 and on Rogers Dry Lake as presented in the *Groundwater Investigation Work Plan* (AECOM 2014a). However, data generated during the Site 25 investigation may warrant a revision of the proposed well locations. RPMs will be consulted prior to alterations to the proposed well locations." Table 2 of the *Addendum to First FYRR* identifies tasks and documentation occurring over the next 5 years.
Kevin Depies (DTSC)	Specific Comment 20	Section 8.5 and Table 9-2. Consistent with Specific Comment 19, add the components (e.g., workplan, fieldwork and reports) of the plume extent and stabilization determination assessment which are required to determine remedy effectiveness.	See response to DTSC Specific Comment 19.
John Steude (CRWQCB)	General Comment 1	Water Board staff finds that the short-term protectiveness of the remedy is inconclusive at this point due to the VIP	See response to DTSC General Comments 1 and 8 and DTSC Specific Comment 19.

Reviewer	Comment #	Comment	Response
		and HHRA issues. Water Board staff finds the long-term protectiveness of the remedy is inconclusive due to contaminant data recently obtained from new wells that has substantially increased the size of the plume known at the time of the Record of Decision (ROD). At this time, there has not been enough trend data generated to determine conclusively whether or not the plume is migrating.	
John Steude (CRWQCB)	General Comment 2	The In Situ Chemical Oxidation (ISCO) remedy in the source areas appears to be working successfully since tricloroethene (TCE) mass has reportedly been reduced by 37 and 72 percent at Sites N3 and N7, respectively. Comparison of TCE concentrations over time, as reported in Table 6-7, indicate that ISCO has been effective where applied and high concentrations of TCE can be reduced or eliminated within a fairly short time period. Water Board staff commends the Air Force for adding ISCO treatment at Site N4 to remediate the high concentrations of TCE found at that location. Water Board staff recommends that ISCO continue during the next five year period.	The ISCO remedy is scheduled to continue with the next injection event scheduled for Calendar Year 2015.
John Steude (CRWQCB)	Specific Comment 1	Page ES-7, paragraph 4. This paragraph states that long-term protectiveness will also be verified by installing and sampling additional groundwater monitoring wells, and modeling subsurface conditions to fully delineate the commingled plume. Please add that trend data will also be analyzed to determine whether or not the plume is migrating.	The subject sentence is included in Section 4.0 of the *Addendum to First FYRR* and reads: "Contaminant concentrations will be reported, and apparent trends will be evaluated, under the monitoring program to assess plume stability."

Reviewer	Comment #	Comment	Response
John Steude (CRWQCB)	Specific Comment 2	Page ES-7, paragraph 5. This paragraph states that VIP evaluation may result in collection and analysis of soil vapor samples from beneath building foundations to evaluate vapor intrusion risk for industrial users. Please add that indoor air and ambient air samples may be collected and analyzed during the evaluation.	The VIP was assessed using current sampling and assessment methodology in 2013 and included soil vapor and ambient air sampling. The results are presented in the *VI Investigation Report* (AECOM 2014b). The subject sentence is included in Section 4.0 of the *Addendum to First FYRR* and reads: "The evaluation included collection and analysis of SV samples from beneath building foundations and indoor and outdoor air samples to evaluate vapor intrusion risk for industrial users."
John Steude (CRWQCB)	Specific Comment 3	Page 4-11, Section 4.2.4. Water Board staff agrees that ISCO treatment can be detrimental to microbes as long as the oxidant is present and that ISCO treatment should continue until it is no longer producing significant results before switching to bioremediation. The timing of switching from ISCO to bioremediation should be carefully considered keeping in mind that ISCO was only intended for high concentration areas with TCE concentrations greater than 300 μg/L pursuant to the Remedial Action Work Plan. The ISCO treatments clearly should continue where significant percentages of TCE are being destroyed with each treatment event. However, in the case of Site N3 where bioremediation will not be implemented until ISCO is complete, it may not be recommended to continue treatments until the TCE cleanup goal is reached if successive treatments do not produce improved results. At some point of diminishing return, it may be more practical to switch to	See response to DTSC General Comment 8 and DTSC Specific Comment 5. Regarding measures to improve/accelerate ISCO treatment, the following text applies to Section.3.2.3 of the *Addendum to First FYRR*: "ISCO injections should be conducted only at wells greater than 100 feet from occupied buildings to avoid displacing/mobilizing the plumes under buildings and possibly completing the VIP. Pressures should be monitored in observation wells located between injection points and occupied buildings as an indication of plume displacement/mobilization (AECOM 2013b). Redevelopment of wells critical for use as active injection points, which do not readily accept reagent is recommended. Further evaluation and recommendations regarding employing Fenton's reagent or persulfate

Reviewer	Comment #	Comment	Response
		bioremediation to start addressing the benzene plume at Site N3. Please provide a plan to address the timing of when to switch from ISCO to bioremediation treatment at Site N3. Please include any measures that may be taken to accelerate the ISCO treatment process (e.g., pressurized injections, additional injection locations) at Site N3 to expedite the timing of switching to bioremediation to treat the contaminants not affected by ISCO (e.g., benzene).	treatment at Site N4 to treat CT should be included in the RPGMRs and Second FYRR as part of the plume characterization and containment evaluation (AECOM 2012)."
John Steude (CRWQCB)	Specific Comment 4	Table 6-7. This table provides significant evidence supporting the success of ISCO treatments. Please present the data in the table in a graphical format on a map to allow the reader easy evaluation of where success has specifically occurred and where rebound has occurred.	Please refer to Figures B-1 through B-4 in Appendix B of the Revised Draft Final *First FYRR* for figures depicting the differences between 2003 and 2010 concentration contours in treatment areas. Additionally, Figure 3-3 provides a graphical comparison of the 2003 and 2010 overall plume shapes.
John Steude (CRWQCB)	Specific Comment 5	Section 6.4.3. For the limited number of wells where some rebound is exhibited (e.g., N3-MW15), Water Board staff recommends that an evaluation be conducted to determine whether or not the incidents of rebound could be reduced or eliminated by adding ISCO treatment to a location upgradient of the area where rebound occurs. Please include other recommendations that may be able to reduce or eliminate rebound and provide the results of such an evaluation. This information could be included in a contingency plan.	Because the comment does not apply to the content of the *Addendum to First FYRR*, if applicable, text similar to the following may be included in the Second FYRR to address the comment: "The TCE concentration increases within treatment areas during this timeframe (*27* months) are not indicators that the remedy is not performing as intended and will be accounted for when selecting future injection locations. TCE concentration increases within treatment areas are expected following treatment, have been observed in previous treatability studies, and are a function of treating small high concentration areas within a larger plume area. Concentration decreases are generally observed immediately following treatment for at least *6* months (see "Monitoring Events 2007 and 2008 Comparison" discussion and Table 6-

Reviewer	Comment #	Comment	Response
			5). However, within approximately 2 years of treatment some concentration increases are observed. Generally concentrations do not increase above pre-treatment concentration levels. Wells with rebounded concentrations are targeted for re-injection. Wells with rebounded concentrations above pre-treatment levels are targeted for re-injection and the areas within the vicinities of the wells are considered for additional well installations." Since submittal of the revised draft final *First Five-Year Report* in August 2011 for which this set of comments was generated, a revised RAWP Addendum has been prepared and finalized. The *Remedial Action Work Plan Addendum* (AECOM 2013b) presented a path for the program documents that will detail the investigative and analytical work efforts to be performed as a result of the First Five-Year Review. The document specified that the Remedy Performance and Groundwater Monitoring Reports (RPGMRs) would: include "…recommendations for future ISCO events." A recommendation to include adding ISCO treatment to a location upgradient of the area where rebound occurs will be included in the next RPGMR.
John Steude (CRWQCB)	Specific Comment 6	Sections 9.0 and 10.0. Table 9-1 indicates that future protectiveness is affected by multiple issues including the Site 25 plume, leading edge delineation, naphthalene and ethylbenzene risk, and vapor intrusion pathway risk assessments. In contrast, Section 10.0 states that the remedy is expected to be protective of human health and the environment in the long term upon attainment of groundwater cleanup goals, which are expected to require more than 100 years to achieve, through a	The Protectiveness Statement was revised taking into consideration the 2013 VIP investigation results and updated human health risk assessment (Appendix C of the *Addendum to First FYRR*) as well as guidance for constructing the Protectiveness Statement provided in the USEPA. 2001 *Comprehensive Five-Year Review Guidance*.

Reviewer	Comment #	Comment	Response
		combination of in situ treatment (chemical oxidation and bioremediation) and natural attenuation. Water Board staff finds that Section 9.0 correctly points to the uncertainty and inconclusive evidence regarding long term protectiveness. The lack of trend analysis data for the recently installed wells that redefined the location of the leading edge adds to the uncertainty of the long term protectiveness with regards to groundwater. Please change Section 10.0 to state that the future protectiveness is inconclusive at this time and measures are being taken to resolve the protectiveness issues identified in Table 9-1. Also, please indicate whether or not the estimate of more than 100 years to achieve Remedial Action Objectives (RAOs) has taken into account contaminant mass reduction in the high concentration areas. Please discuss the effect of successful elimination of contaminant mass in high concentration areas to substantially reduce the estimate of at least 100 years to achieve RAOs.	
John Steude (CRWQCB)	Specific Comment 7	Section 10.0, second paragraph. This paragraph states that groundwater monitoring and modeling will be conducted to fully delineate the commingled plume. Please add that trend analysis will be conducted to determine if any plume migration is occurring over time.	Section 4.0 of the *Addendum to First FYRR* includes the following text: "Long-term protectiveness of the remedy was verified by evaluating the future residential indoor air risk; modifying the LUC boundary to restrict residential development is not necessary. Long-term protectiveness will be further verified by installing and sampling additional groundwater monitoring wells to fully delineate the commingled plume. Contaminant concentrations will be reported, and apparent trends will be evaluated, under the monitoring program to assess plume stability."
John Steude	Specific	Section 10.0, last paragraph. This paragraph states that	The Air Force and NASA performed a vapor intrusion

RESPONSES TO COMMENTS

Environmental Restoration Program
First Five-Year Review Report
Operable Unit 6
Edwards Air Force Base, California
Revised Draft Final, August 2011

Reviewer	Comment #	Comment	Response
(CRWQCB)	Comment 8	the remedy is protective in the short term and that this protectiveness will be verified by evaluation of changes to VIP protocol and assessing those changes as applicable to OU 6. Water Board staff finds that the outstanding VIP and HHRA issues and lack of data render the short term protectiveness of the remedy to be inconclusive until verified. Please consider changing this paragraph to state that the short term protectiveness of the remedy is inconclusive until verified.	investigation at Buildings 4806, 4807, and 4810 in 2013 to determine if the VIP is complete as discussed in Section 2.1.2 and the updated HHRA (Appendix C of the *Addendum to First FYRR*). The protectiveness statement was revised with consideration to the results of the VIP investigation and HHRA update.
John Steude (CRWQCB)	Specific Comment 9	Section 10.0, last sentence. This sentence states that a vapor intrusion pathway assessment may result in collection and analysis of soil vapor samples from beneath building foundations. Please add that the evaluation may also result in collection and analysis of indoor air and ambient air outside of the buildings.	The subject text has been revised as presented in Section 4.0 of the *Addendum to First FYRR* to read: "The evaluation included collection and analysis of SV samples from beneath building foundations and indoor and outdoor air samples to evaluate vapor intrusion risk for industrial users."

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APPENDIX B
REVISED DRAFT FINAL FIRST FIVE-YEAR REVIEW REPORT
(ON CD)

National Aeronautics and Space Administration Dryden Flight Research Center Edwards Air Force Base, California

Environmental Restoration Program

First Five-Year Review Report Operable Unit 6

REVISED DRAFT FINAL

August 2011

ENVIRONMENTAL RESTORATION PROGRAM

FIRST FIVE-YEAR REVIEW REPORT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
DRYDEN FLIGHT RESEARCH CENTER
OPERABLE UNIT 6

EDWARDS AIR FORCE BASE
CALIFORNIA

REVISED DRAFT FINAL

AUGUST 2011

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ENVIRONMENTAL PROGRAMS EXECUTION – WEST (AFCEE/EXW)
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AUTHORIZING SIGNATURE

____ Date_______________

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Commander, 95th Air Base Wing
Edwards Air Force Base, California

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LIST OF ABBREVIATIONS AND ACRONYMS

<	less than
$(mg/kg\text{-}day)^{-1}$	reciprocal milligrams per kilogram-day
µg/L	micrograms per liter
95 ABW/CEV	95th Air Base Wing, Environmental Management
95 ABW/EM	95th Air Base Wing, Environmental Management Directorate (previously referred to as 95th Air Base Wing, Environmental Management Office)
AECOM	AECOM Technical Services, Inc.
AFB	Air Force Base
AFCEE/ERD	Air Force Center for Environmental Excellence, Environmental Restoration Division
AFCEE/EXE	Air Force Center for Engineering and the Environment, Execution Branch for Restoration Program
AFCEE/EXW	Air Force Center for Engineering and the Environment, Environmental Programs Execution – West (previously referred to as Air Force Center for Engineering and the Environment, Execution Branch for Restoration Program)
AFCEE/ISM	Air Force Center for Environmental Excellence, Installation Support, Air Force Materiel Command
AFRL	Air Force Research Laboratory
AOC	Area of Concern
APU	Auxiliary Propulsion Unit
ARAR	applicable or relevant and appropriate requirement
ATF	Aeronautical Tracking Facility
Ave.	avenue
Bldg.	building
Blvd.	boulevard
BTEX	benzene, toluene, ethylbenzene, and total xylenes
C	carcinogen
CA	California
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CG	cleanup goal
COC	contaminant of concern
CRWQCB	California Regional Water Quality Control Board
CITC	Consolidated Information Technology Center
CT	carbon tetrachloride
CWM	chemical warfare materiel
DAOF	Dryden Aircraft Operations Facility
DCA	dichloroethane
DCE	dichloroethene
Development One	Development One, Inc.
DFRC	Dryden Flight Research Center
Dir	direct
DTSC	Department of Toxic Substances Control

LIST OF ABBREVIATIONS AND ACRONYMS *(Continued)*

Earth Tech	Earth Tech, Inc.
e.g.	*exempli gratia*, for example
ERP	Environmental Restoration Program
ESI/RFA	Expanded Source Investigation/RCRA Facility Assessment
etc.	*et cetera*, and so forth
FFA	Federal Facility Agreement
FS	Feasibility Study
ft	feet
FY	fiscal year
GETS	groundwater extraction and treatment system
GIS	geographic information system
GP	General Plan
gpm	gallons per minute
GW	groundwater
HHRA	human health risk assessment
HI	hazard index
i.e.	*id est*, that is
IRACR	Interim Remedial Action Completion Report
ISCO	*in situ* chemical oxidation
IUR	inhalation unit risk
J&E	Johnson and Ettinger
Ja	detected above the detection limit but less than the reporting limit, considered quantitatively uncertain
JP-4	jet fuel number 4
LRO	Long-Range Optics
LUC	land use control
MCL	Maximum Contaminant Level
Mgt.	management
MP	Master Plan
NA	not available
NASA	National Aeronautics and Space Administration
NC	noncarcinogen
NCP	National Contingency Plan
ND	not detected
NDMA	N-nitrosodimethylamine
No.	number
NPL	National Priorities List
OU	Operable Unit
OU6	Operable Unit 6
PAH	polycyclic aromatic hydrocarbon
POL	petroleum oil and lubricants
PPE	personal protective equipment

LIST OF ABBREVIATIONS AND ACRONYMS *(Continued)*

PRG	Preliminary Remediation Goal
PS	pilot study
RA	remedial action
RAB	Restoration Advisory Board
RAO	remedial action objective
RAWP	Remedial Action Work Plan
RCRA	Resource Conservation and Recovery Act
Res/Sens	residential/sensitive use
ROD	Record of Decision
RPM	remedial project manager
RSL	Regional Screening Level
Rust	Rust Environment & Infrastructure
SARA	Superfund Amendments and Reauthorization Act
SH	Safety Health
SV	soil vapor
TBD	to be determined
TCE	trichloroethene
TS	treatability study
TX	Texas
U.S.	United States
USEPA	United States Environmental Protection Agency
UST	underground storage tank
VIP	vapor intrusion pathway
VOC	volatile organic compound
X	times

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EXECUTIVE SUMMARY

National Aeronautics and Space Administration (NASA) Dryden Flight Research Center (DFRC), a tenant organization at Edwards Air Force Base (AFB), is designated Environmental Restoration Program Operable Unit 6 (OU6) and is located in the north-central portion of the Base on the main flightline, which is wholly within Kern County. The responsible party and lead agency for OU6 activities is the United States Air Force. NASA is the funding entity. United States Environmental Protection Agency (USEPA) has an oversight role for the cleanup. In addition to the USEPA, the regulatory agencies include the California Department of Toxic Substances Control (DTSC) and the California Regional Water Quality Control Board (CRWQCB).

NASA DFRC has leased a portion of the Edwards AFB flightline since 1946 to support Space Shuttle, flight testing, and aeronautical research operations. During that time, workers performed test, evaluation, and maintenance activities involving toxic and hazardous materials. These materials often spilled and soaked into the ground or were disposed of inappropriately. Current use and disposal of these materials are strictly regulated to prevent releases to the environment. However, the following two past practices most likely resulted in releases to the environment at OU6: drum and underground tank storage of fuels and solvents, and use of coating-related materials (paints, thinners, strippers, and plating materials) in aircraft operation and maintenance.

Locations of former releases to the environment have been designated as Sites N1, N2, N3, N4, and N7 in OU6. The location and nature of these releases contributed to a commingled groundwater plume that emanates from the Site N3 area in the west, extends downgradient to the east to include Sites N1, N2, N4, and N7, and eventually reaches Rogers Dry Lake (Figure ES-1). The groundwater plume consists of the following contaminants of concern (COCs): chlorinated hydrocarbons (principally trichloroethene [TCE], a solvent used in aeronautical operations) and aromatic hydrocarbons (including benzene, toluene, ethylbenzene and xylenes [BTEX] typically found in petroleum products). Groundwater COCs are present at levels representing potential risk to human health and the environment. Contaminants in soil are not present at levels representing a risk to human health and the environment.

Sites N2, N3, and N7 are considered to be the primary source areas, with Sites N3 and N7 containing the highest contaminant concentrations. Site N3 formerly consisted of a gas station with underground storage tanks and drum storage areas, and contributed TCE and BTEX to the commingled groundwater plume. Former drum storage and waste disposal activities at Sites N2 and N7 contributed TCE and other chlorinated solvents to the groundwater plume. The portion of the groundwater plume beneath Site N3 is located within fractured bedrock. As the plume extends east towards Roger Dry

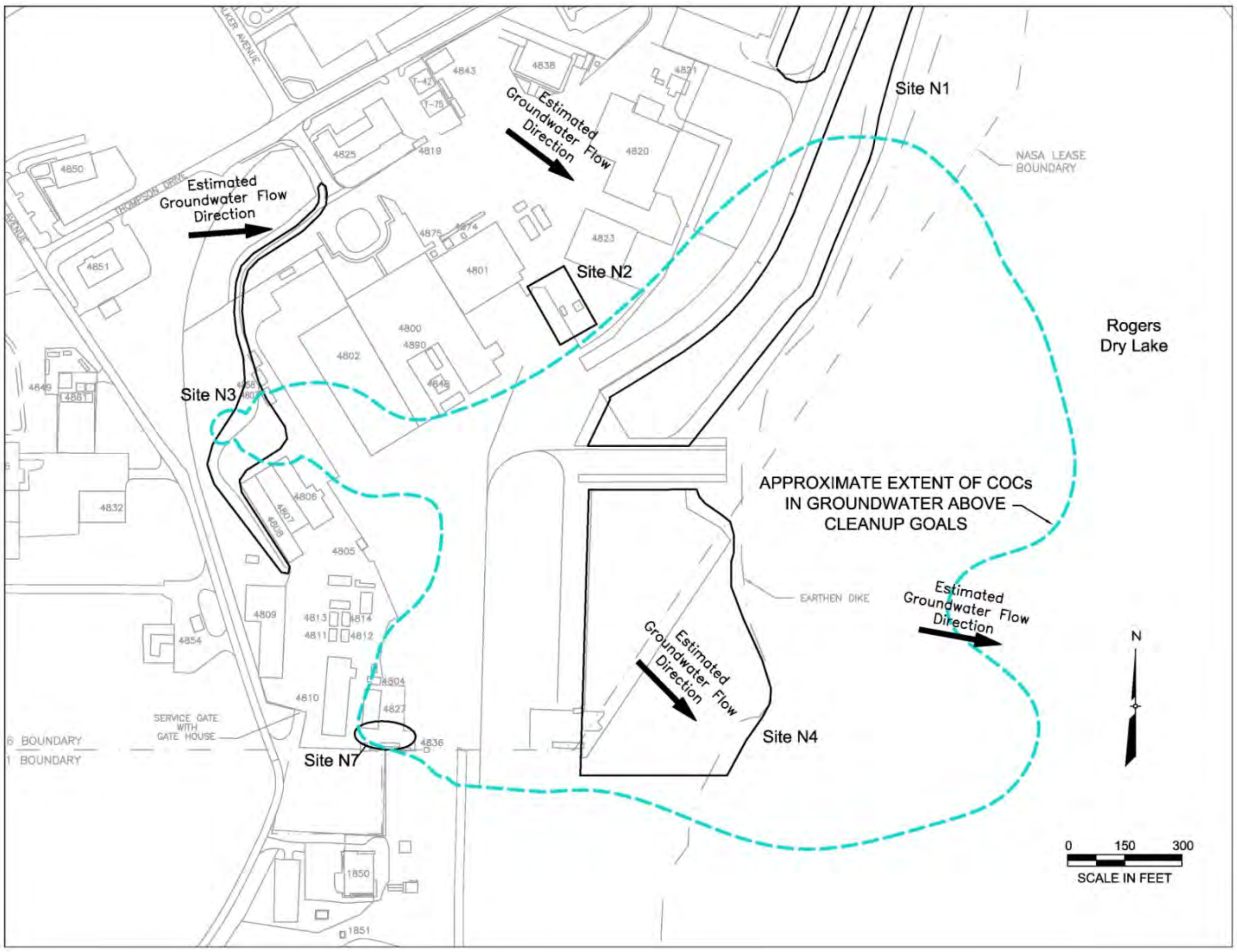

Figure ES-1.

Lake, the groundwater plume enters alluvial lakebed sediments in the areas of Sites N1 and N4. Sites N1 and N4 consist of a series of topographic depressions along the lakebed boundary and were used to manage surface water runoff originating from NASA DFRC. Historically, the lowest contaminant concentrations within the OU6 plume were located beneath Sites N1 and N4, likely due to the diluted nature of Sites N1 and N4 contaminant sources (surface water runoff).

The plume shape is narrower at Sites N3 and N7, where releases occurred in smaller areas. Since, contaminated groundwater at Sites N3 and N7 is in bedrock, the plume geometry is controlled by fractures. As the plume reaches Sites N1 and N4 it enters sediments that allow more lateral dispersion. In addition, the Sites N1 and N4 sources are more diffuse, covering larger areas.

A remedial investigation was conducted at OU6, in which over 10 years of groundwater contaminant concentration data were collected that indicated that the plume had reached steady-state conditions - the rate of advance approximately equaled the rate of attenuation; thus, no further migration of groundwater contaminants was anticipated. Based on the understanding of the extent and nature of contamination derived from the remedial investigation, the Air Force (the lead agency) and NASA, with the approval of the USEPA, Region IX and concurrence of the California DTSC and the CRWQCB, Lahontan Region, signed a Record of Decision (ROD) and agreed to a final remedial action approach to remediate the impacted OU6 groundwater with the following remedial action objectives (RAOs):

- The restoration of groundwater to its designated beneficial use as drinking water
- The prevention of exposure of human receptors to contaminated groundwater until groundwater contaminant concentrations are below Maximum Contaminant Levels (MCLs)

The exposure pathways that need to be prevented and/or minimized are groundwater ingestion and dermal contact, and inhalation of groundwater vapors. Though the inhalation pathway includes direct inhalation and inhalation through the vapor intrusion pathway (VIP) into buildings, the selected remedy was designed to be protective of direct inhalation only as the risk assessment showed no unacceptable VIP risk requiring action.

The main components of the selected remedy include:

- Land Use Controls (LUCs): Implement, monitor, maintain, enforce, and report LUCs on groundwater in accordance with the Base General Plan and NASA DFRC Master Plan
- *In Situ* Chemical Oxidation (ISCO): Treatment of high concentration portions of the chlorinated hydrocarbon (primarily TCE) plume via ISCO (Sites N3 and N7 areas)
- Bioremediation: Treatment of high concentration portions of the aromatic hydrocarbon plume (primarily benzene) via enhanced natural attenuation (bioremediation) (Site N3 area)
- Groundwater Monitoring: Demonstrate the effectiveness of natural attenuation in low concentration areas of the groundwater plume (plume containment) through periodic groundwater monitoring (Sites N1 and N4 areas), and document reduction in contaminant levels throughout the plume (Sites N1, N2, N3, N4, and N7 areas)

■ <u>Five-Year Reviews</u>: Conduct five-year reviews to evaluate the effectiveness of the selected remedy and monitor the status of the RAOs

The areas in which the various RA components were targeted for implementation per the 2006 OU6 ROD are shown on Figure ES-2.

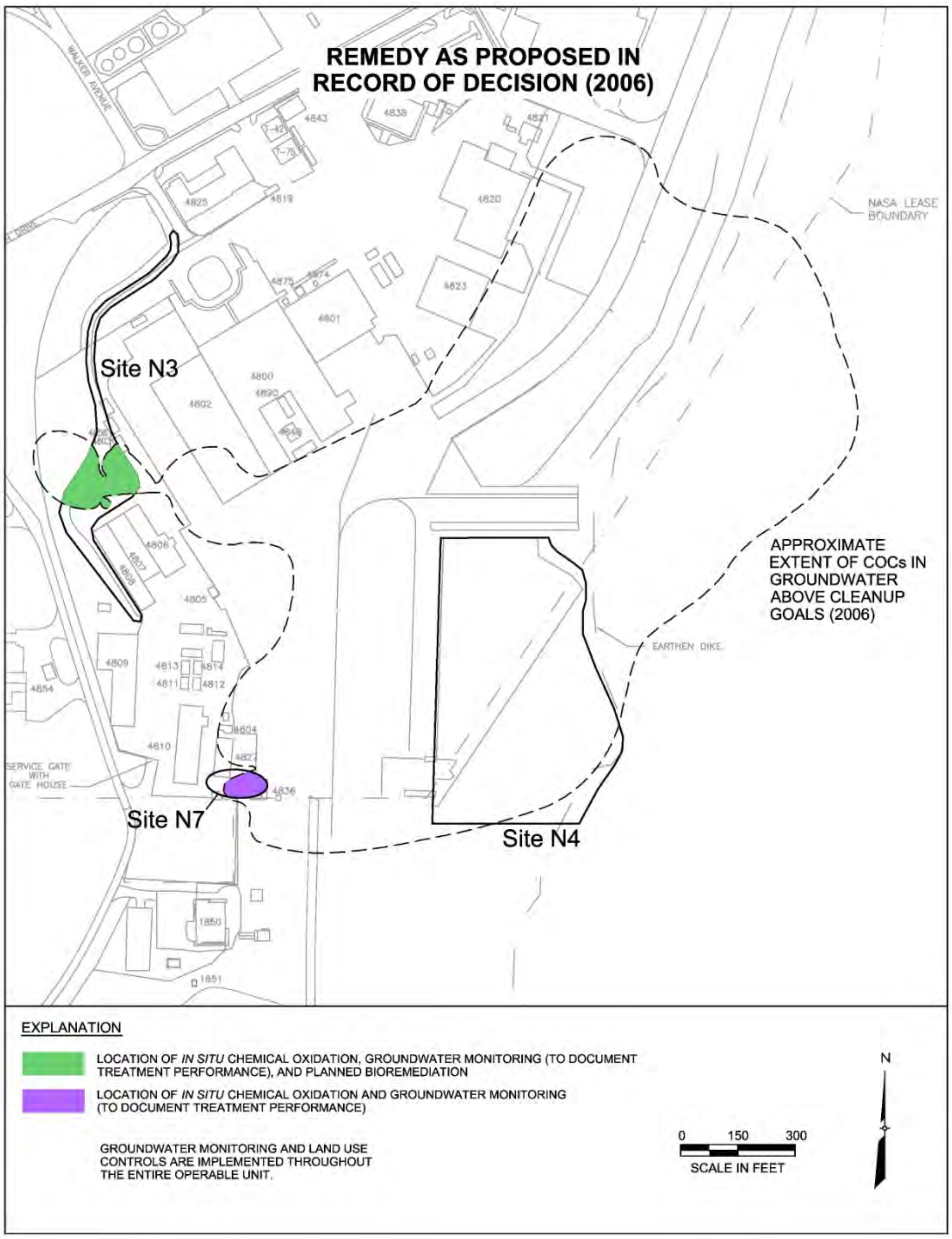

Figure ES-2

This report documents the first five-year review performed to evaluate the effectiveness of the selected remedy. The purpose of a five-year review is to determine whether the remedy at a site is protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in Five-Year Review Reports. In addition, Five-Year Review Reports identify issues found during the review, if any, and identify recommendations to address them. The triggering action for a five-year review is remedy initiation. This Five-Year Review Report was prepared to coincide with the five-year anniversary of the remedy initiation, which occurred with the signing of the ROD on 28 September 2006. The following three questions are considered when assessing the protectiveness of the selected remedy:

Question A: Is the remedy functioning as intended by the decision documents?
Question B: Are the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of the remedy still valid?
Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

With regards to Question A, the data review indicates that with the newly defined LUC boundary, the LUC component of the remedy continues to function as intended. LUCs will continue to be in place until contaminants at the site are at or below levels that allow for unlimited use and unrestricted exposure. LUCs are expected to be required for at least 100 years. The ISCO component has been implemented in accordance with the ROD, with adjustments to the schedule and injection/monitoring operations based upon changing conditions encountered during field implementation. Changing conditions in the field included identification of a high concentration area at Site N4 (discussed below) resulting in ISCO implementation in this area in addition to Sites N3 and N7 (Figure ES-3). Repeated ISCO injections (from 2003 to 2010) at Sites N3 and N7 have resulted in TCE mass reductions by 37 and 72 percent, respectively. Site N4 TCE mass reduction quantities are not available as ISCO implementation has occurred relatively recently in 2010. ISCO injections are expected to continue at least through the next 5 years to further reduce TCE mass. The bioremediation component will not be implemented to address the aromatic hydrocarbons (primarily benzene) until ISCO is complete. Implementation of the groundwater monitoring component of the remedy unexpectedly revealed a high concentration area of TCE at Site N4 as well as a plume delineation data gap in the areas of Sites N1 and N4. Because groundwater monitoring is used to verify that contaminants at the site are at or below levels allowing for unlimited use and unrestricted exposure, as with the LUC component, the groundwater monitoring component is expected to continue for at least 100 years.

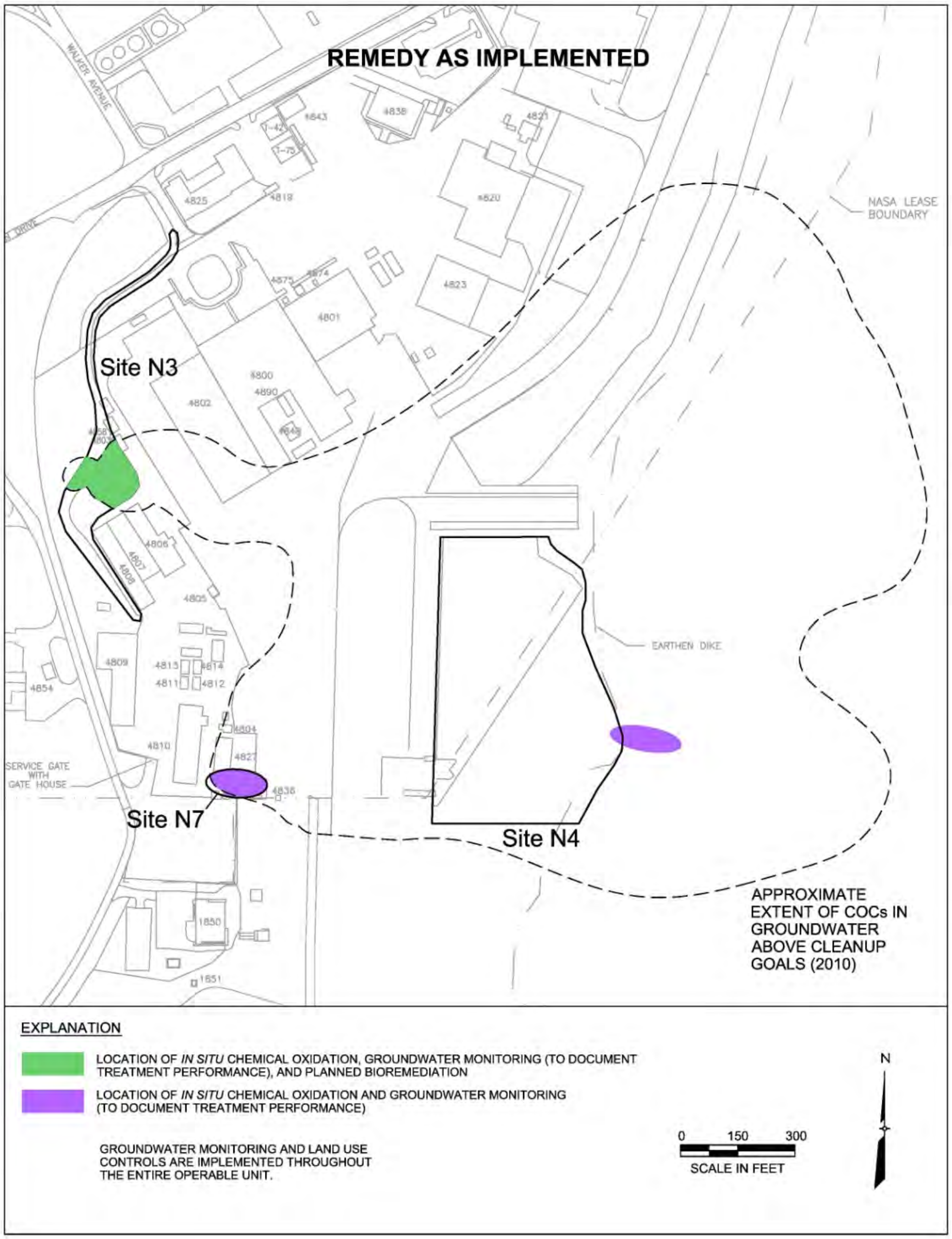

Figure ES-3

In addressing Question B, changes in toxicity data and risk assessment methodologies are identified as potentially having an adverse effect on the calculated VIP risk, and the protectiveness of the remedy for the VIP.

Under Question C, an area of groundwater contamination at Site 25 (Operable Unit 8), located upgradient of the OU6 commingled plume, is identified as an issue. Because the Site 25 groundwater contamination has not impacted OU6 groundwater, current protectiveness of the OU6 remedy has not been affected. The final remedy selected for Site 25 may affect the OU6 plume and in turn affect the future protectiveness of the OU6 remedy.

In addressing Questions A, B, and C, the following protectiveness statement has been developed:

> The remedy is expected to be protective of human health and the environment in the long term upon attainment of groundwater cleanup goals, which are expected to require more than 100 years to achieve, through a combination of *in situ* treatment (chemical oxidation and bioremediation) and natural attenuation. Exposure pathways that could result in unacceptable risks in the short term are being controlled through institutional controls that are preventing exposure to, and the ingestion of, contaminated groundwater. All current threats at the site have been addressed by the implementation of LUCs.
>
> Long-term protectiveness of the remedy will be verified by evaluating the future residential indoor air risk and, if applicable, modifying the LUC boundary to restrict residential development in areas with unacceptable indoor air risk. Long-term protectiveness will also be verified by installing and sampling additional groundwater monitoring wells to fully delineate the commingled plume.
>
> The remedy is protective in the short-term because unacceptable risks are being controlled through LUCs. Short-term protectiveness of the remedy will be verified by evaluating changes to the VIP protocol and assessing those changes as applicable to OU6 site conditions. The evaluation may result in collection and analysis of soil vapor samples from beneath building foundations to evaluate vapor intrusion risk for industrial users.

A content checklist and completed five-year review summary form (including a reiteration of issues, follow-up actions, and the protectiveness statement) are attached to the end of this Executive Summary.

Five-Year Review Summary Form

SITE IDENTIFICATION		
Site name: Edwards Air Force Base		
EPA ID: CA1570024504		
Region: IX	**State:** CA	**City/County:** Kern
SITE STATUS		
NPL status: Final		
Remediation status: Operating		
Multiple OUs?* Yes	**Construction completion date:** 6/27/2011 (per FFA schedule)	
Has site been put into reuse? No		
REVIEW STATUS		
Lead agency: United States Air Force/National Aeronautics and Space Administration		
Author name: Ai Duong		
Author title: Remedial Project Manager	**Author affiliation:** United States Air Force	
Review period: 11/2/2010 to 8/22/2011		
Date(s) of site inspection: 3/8/2011 and 3/9/2011		
Type of review: Post-SARA		
Review number: 1 (first)		
Triggering action: Signing of Record of Decision.		
Triggering action date: 9/28/2006		
Due date: 9/28/2011		

Notes:

CA = California
FFA = Federal Facility Agreement
OU = operable unit
SARA = Superfund Amendments and Reauthorization Act

Five-Year Review Summary Form, cont'd.

Issues:

Issue 1. An area of groundwater contamination at Site 25 is located upgradient of the Operable Unit 6 (OU6) commingled plume. Because the Site 25 groundwater contamination has not impacted the OU6 groundwater plume, current protectiveness of the OU6 remedy has not been affected. The final remedy selected for Site 25 may affect the OU6 plume and in turn the future protectiveness of the OU6 remedy.

Issue 2. The OU6 plume's downgradient edge is not fully delineated at Sites N1 and N4. If the plume is migrating significantly towards the groundwater subbasin, future protectiveness could be threatened as the subbasin contains drinking water supply wells.

Issue 3. Changes in toxicity criteria and vapor intrusion assessment/investigation methodology may indicate a greater vapor intrusion pathway (VIP) risk than initially estimated and affect remedy protectiveness.

Issue 4. Changes in toxicity criteria (e.g., naphthalene and ethylbenzene) may indicate a greater residential health risk than initially estimated and affect remedy protectiveness.

Issue 5. The Base's geographic information system (GIS) needs to continue to be operated and updated as the land use control (LUC) boundary is adjusted to ensure future OU6 remedy protectiveness for construction and ground-disturbing activities, OU6 well field maintenance, *in situ* chemical oxidation (ISCO), and groundwater monitoring are needed to ensure continued protectiveness.

Issue 6. In May of 2011, the United States Air Force discontinued the Environmental Restoration Program (ERP) information exchange webpage, which was used to obtain and exchange critical information among remedial project managers.

Recommendations and Follow-up Actions:

Issue 1. Use data generated by continued groundwater monitoring at Site 25 (Operable Unit 8) under a separate project to estimate the Site 25 plume extent, capture, and migration characteristics.

Issue 2. Install additional monitoring wells and perform groundwater modeling to delineate the leading edge of the OU6 plume and to monitor and predict cleanup progress. Additional ISCO treatment may be required at the leading edge. Recommended future step-out monitoring wells include locations south of existing monitoring wells N4-MW04, N4-MW05, N4-MW11, N4-MW12, N4-MW13, and N7-MW13, Other recommended monitoring wells include locations west of N1-MW08 and N1-MW10.

Issue 3. Methodologies for determining risk to indoor air from subsurface contaminants have been revised since the Record of Decision was signed. An evaluation of the updated VIP guidance methodologies as they relate to site conditions will be performed. The evaluation may result in a field investigation.

Issue 4. Because of the changes in toxicity criteria (e.g., naphthalene and ethylbenzene), recalculate the residential health risk and assess the need to take additional action to meet remedial action objectives.

Five-Year Review Summary Form, cont'd.

Recommendations and Follow-up Actions, cont'd.

Issue 5. Update LUC boundary in the Base's GIS as necessary. Continue adherence to review and approval procedures for construction and ground-disturbing activities. Perform well maintenance including well completion repairs and well labeling with identification tags. Continue ISCO in the areas of highest volatile organic compound (VOC) concentrations at Sites N3, N4, and N7, and groundwater monitoring for n-nitrosodimethylamine, metals (including total and hexavalent chromium), and VOCs. Conduct tracer testing with ISCO injections to ensure the plume is not significantly displaced by injections.

Issue 6. Re-establish an ERP information exchange website.

Protectiveness Statement(s):

The remedy is expected to be protective of human health and the environment in the long term upon attainment of groundwater cleanup goals, which are expected to require more than 100 years to achieve, through a combination of *in situ* treatment (chemical oxidation and bioremediation) and natural attenuation. Exposure pathways that could result in unacceptable risks in the short term are being controlled through institutional controls that are preventing exposure to, and the ingestion of, contaminated groundwater. All current threats at the site have been addressed by the implementation of LUCs.

Long-term protectiveness of the remedy will be verified by evaluating the future residential indoor air risk and, if applicable, modifying the LUC boundary to restrict residential development in areas with unacceptable indoor air risk. Long-term protectiveness will also be verified by installing and sampling additional groundwater monitoring wells to fully delineate the commingled plume.

The remedy is protective in the short-term because unacceptable risks are being controlled through LUCs. Short-term protectiveness of the remedy will be verified by evaluating changes to the VIP protocol and assessing those changes as applicable to OU6 site conditions. The evaluation may result in collection and analysis of soil vapor samples from beneath building foundations to evaluate vapor intrusion risk for industrial users.

Other Comments:

No additional comments are necessary.

Content Checklist for Five-Year Review Reports

General Report Format

- -- Signed concurrence memorandum (will be included in final report)
- -- Title page with signature and date (will be included in final report)
- √ Completed five-year review summary form
- √ List of documents reviewed
- √ Site maps
- √ List of tables and figures
- √ Interview report
- √ Site inspection checklist
- √ Photos documenting site conditions

Introduction

- √ The purpose of the five-year review
- √ Authority for conducting the five-year review
- √ Who conducted the five-year review and when
  - √ Organizations providing analyses in support of the review
  - √ Other review participants or support agencies
- √ Review number
- √ Trigger action and date
- √ Number, description, and status of all operable units at the site
- -- If review covers only part of a site, explain approach (*not applicable*)
  - -- Define which areas are covered in the five-year review
  - -- Summarize the status of other areas of the site that are not covered in the present five-year

Site Chronology

- √ List all important site events and relevant dates

Background

- √ General site description
- √ Former, current, and future land use(s) of the site and surrounding areas
- √ History of contamination
- √ Initial response
- √ Basis for taking remedial action

Content Checklist for Five-Year Review Reports

Remedial Actions

- √ Regulatory actions
- √ Remedial action objectives
- √ Remedy description
- √ Remedy implementation
- √ Systems operations/Operations & Maintenance (O&M) (series of injection events)
  - -- Systems operations/O&M requirements (*not applicable*)
  - √ Systems operations/O&M operational summary (injection summary)
  - √ Summary of costs of system operations/O&M effectiveness (injection costs)

Progress Since Last Five-Year Review (*not applicable*)

- -- Protectiveness statements from last review
- -- Status of recommendations and follow-up actions from last review
- -- Results of implemented actions, including whether they achieved the intended effect
- -- Status of any other prior issues

Five-Year Review Process

- √ Administrative components
  - √ Notification of potentially interested parties of initiation of review process
  - √ Identification of five-year review team members (as appropriate)
  - √ Outline of components and schedule of your five-year review
- √ Community involvement
  - √ Community notification
  - -- Other community involvement activities (*not applicable*)
- √ Document review
- √ Data review
- √ Site inspection
  - √ Inspection date
  - √ Inspection participants
  - √ Site inspection scope and procedures
  - √ Site inspection results and conclusions
  - √ Inspection checklist
- √ Interviews
  - √ Interview date(s) and location(s)
  - √ Interview participants (name, title, etc.)
  - √ Interview documentation
  - √ Interview summary

Content Checklist for Five-Year Review Reports

Technical Assessment

- √ Answer Question A: Is the remedy functioning as intended by the decision documents?
  - √ remedial action performance
  - √ system operations (injection)
  - √ cost of system operations
  - √ opportunities for optimization
  - √ early indicators of potential issues
  - √ implementation of institutional controls and other measures

- √ Answer Question B: Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives (RAOs) used at the time of the remedy selection still valid?
  - √ changes in standards, newly promulgated standards, TBCs
  - √ expected progress toward meeting RAOs
  - √ changes in exposure pathways
  - √ changes in land use
  - √ new contaminants and/or contaminant sources
  - √ remedy byproducts
  - √ changes in toxicity and other contaminant characteristics
  - √ risk recalculation/assessment

- √ Answer Question C: Has any other information come to light that could call into question the protectiveness of the remedy?
  - √ new or previously unidentified ecological risks
  - √ natural disaster impacts
  - √ any other information that could call into question the protectiveness of the remedy
- √ Technical Assessment Summary

Issues

- √ Issues identified during the technical assessment and other five-year review activities
- √ Determination of whether issues affect current or future protectiveness
- -- A discussion of unresolved issues raised by support agencies and the community (*not applicable*)

Recommendations and Follow-up Actions

- √ Required/suggested improvements to identified issues or to current site operations
- √ Note parties responsible for actions
- √ Note agency with oversight authority
- √ Schedule for completion of actions related to resolution of issues

Content Checklist for Five-Year Review Reports

Protectiveness Statements

- √ Protective statement(s) for each OU
- √ Comprehensive protectiveness statement covering all of the remedies at the site

Next Review

- √ Expected date of next review
- **--** If five-year reviews will no longer be done, provide a summary of that portion of the technical analysis presented in the report that provides the rationale for discontinuation of five-year reviews (*not applicable*)

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1.0 INTRODUCTION

The United States (U.S.) Air Force and the National Aeronautics and Space Administration (NASA) implemented a remedial action (RA) at Operable Unit 6 (OU6), Edwards Air Force Base (AFB), California, in May 2005 to remediate groundwater impacted by various chlorinated and aromatic hydrocarbons. Trichloroethene (TCE), a solvent used in aeronautical operations, is the principal chlorinated hydrocarbon encountered at OU6, while the aromatic hydrocarbons include benzene, toluene, ethylbenzene and xylenes (BTEX), which are typically found in petroleum products. In September 2006, the Air Force (the lead agency) and NASA, with the approval of the U.S. Environmental Protection Agency (USEPA), Region IX and concurrence of the California Department of Toxic Substances Control (DTSC) and the California Regional Water Quality Control Board (CRWQCB), Lahontan Region, signed a Record of Decision (ROD) (Earth Tech, Inc. [Earth Tech], 2006) and agreed to a final RA approach to remediate the impacted OU6 groundwater following the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process. A decision of No Action for OU6 soil was documented in the ROD (Earth Tech, 2006).

1.1 BASIS, PURPOSE, AND AUTHORITY

This is the first five-year review for OU6. Pursuant to CERCLA (42 USC § 9621[c]) and the National Contingency Plan (NCP), the triggering action for a five-year review is remedy initiation. This Five-Year Review Report was prepared to coincide with the five-year anniversary of the remedy initiation that occurred with the signing of the ROD. 40 Code of Federal Regulations §300.430(f)(4)(ii) states:

> *If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after the initiation of the selected remedial action.*

The purpose of the five-year review is to determine whether the remedy at a site is protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in

Five-Year Review Reports. In addition, Five-Year Review Reports identify issues found during the review, if any, and identify recommendations to address them.

This five-year review (the first for OU6 and for Edwards AFB) was conducted for the entire OU6 from November 2010 through August 2011 by Edwards AFB and NASA as documented within this report. The five-year review is required because the designated beneficial use of groundwater as drinking water has not been restored and contaminants remain at the site above levels that allow for unlimited use and unrestricted exposure. Support for the review process was provided by AECOM Technical Services, Inc. (AECOM) in accordance with Contract Number FA8903-08-D-8770, Task Order Number 0024, between the U.S. Air Force Center for Engineering and the Environment and AECOM. This report was prepared in accordance with the *Comprehensive Five-Year Review Guidance* (USEPA, 2001).

1.2 REMEDIAL MEASURES STATUS FOR OTHER AREAS

In response to Edwards AFB's listing on the National Priorities List (NPL), and to facilitate the investigation of wastes from past military and/or tenant agency use, and implement response actions, the Base was divided into 10 Operable Units (OUs) (Figure 1-1). The OU6 RA is intended to be the final action for the OU and is addressed independently of the other nine OUs at Edwards AFB. The OUs are defined by lease boundaries where applicable, geographical location, similarities in contaminant types and distribution, and/or hydrologic setting. OUs 1, 6, and 8 are located in the Main Base area; OU2 is located in the South Base area; OU3 consists of abandoned or no longer required water wells located throughout the Base; OUs 4 and 9 are located in the Air Force Research Laboratory (AFRL) area; OU5/10 is located in the North Base area (formerly OUs 5 and 10); and OU7 includes miscellaneous/individual sites located outside of the other OUs. OU6 is defined by the NASA Dryden Flight Research Center (DFRC) lease boundary. The following sections briefly describe OUs 1, 2, 3, 4/9, 5/10, 7, and 8, and Site 25, which is close to and upgradient from OU6.

1.2.1 OPERABLE UNIT 1 – MAIN BASE FLIGHTLINE

The Main Base Flightline OU1 covers the flightline from the NASA DFRC complex on the north to Main Base Runway 4/22 on the south. OU1 is primarily used for aircraft testing and maintenance by

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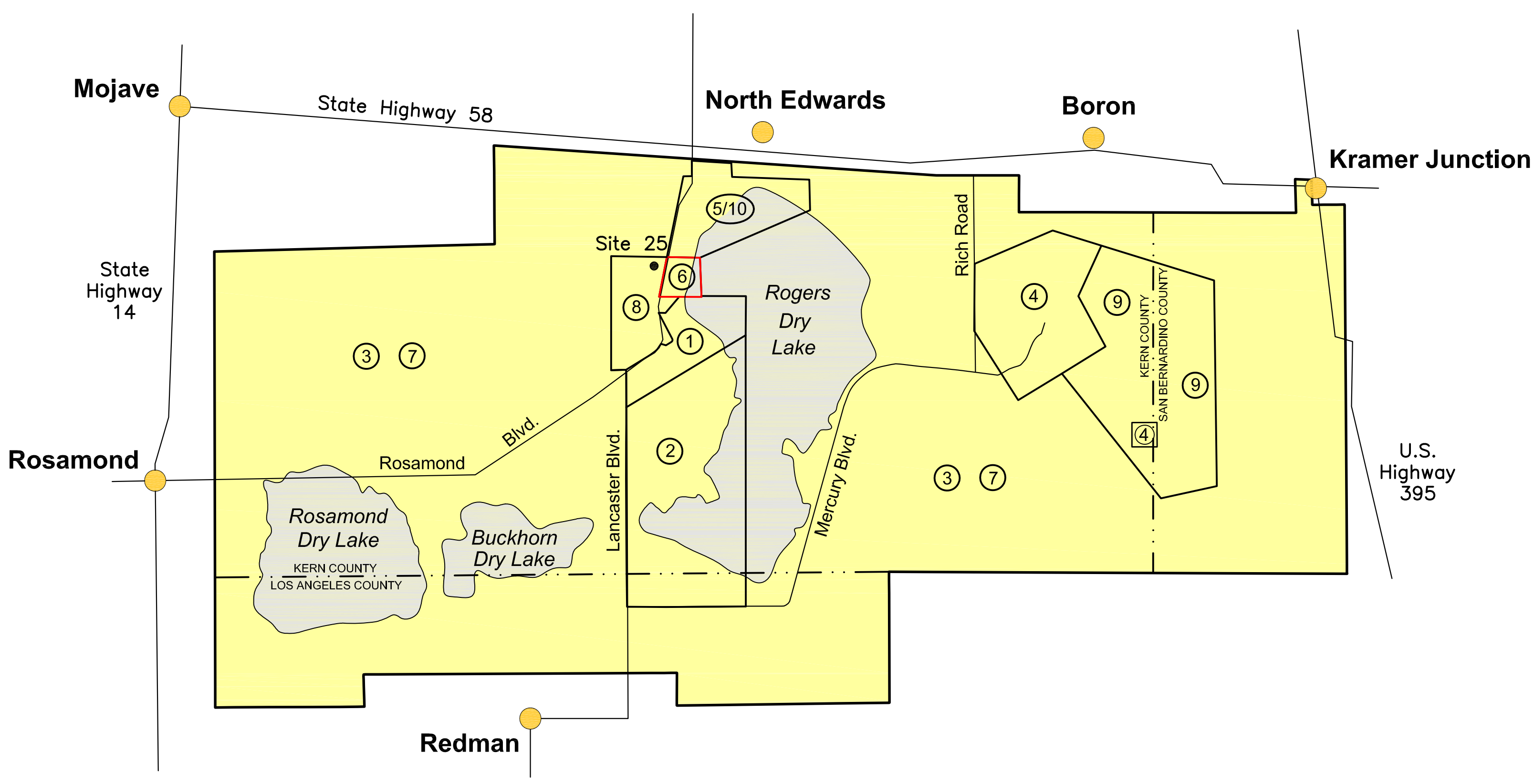

Operable Units

	(actual or *planned* date of ROD)
① **Main Base Flightline**	
-all sites	*2012*
② **South Base**	
-Sites 5, 14, 29, 69, 76, 78, 79, 86, 96, 417	2009
-Sites 81/102	*2013*
③ **Basewide Water Wells**	
-all sites	2003
④ **AFRL and** ⑨ **AFRL-East**	
-South AFRL (Sites 37, 120, 133, 321)	2007
-AFRL soil and debris sites	2008
-AFRL Arroyos (Sites 36, 162, and 461)	*2011*
-Northeast AFRL (Sites/AOCs 115, 116, 118, 177/325, 318, and 178)	*2013*
-Mars Blvd. (Sites 27, 125, 127, 167, 333)	*2013*
(5/10) **North Base**	
-all sites	*~2015*
⑥ **NASA Dryden**	
-Sites N2, N3, N7	2006
⑦ **Basewide Miscellaneous**	
-CWM Sites 442 and 426	2009
-non-CWM Site 3	*2011*
-non-CWM Sites 269, 280, 294, and 339	*2013*
⑧ **Northwest Main Base**	
-Sites 61, 226, 257, 299, 300, and 301	*2013*
-Site 25	*~2015*

NOTES:
PLANNED DATES IN ITALICS.

~ = APPROXIMATELY
AFRL = AIR FORCE RESEARCH LABORATORY
AOC = AREA OF CONCERN
BLVD. = BOULEVARD
CWM = CHEMICAL WARFARE MATERIEL
NASA = NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ROD = RECORD OF DECISION

0 5
Scale in Miles

REVISED DRAFT FINAL

Operable Unit Location Map

Date 08-2011	Operable Unit 6 First Five-Year Review Report Edwards AFB	Figure
Project No. 60133976		**1-1**

various aerospace contractors. Major contaminant sources include a removed jet fuel pipeline, former leaking underground storage tanks (USTs), engine test cells, and waste disposal areas.

A ROD is being prepared and will address all sites within the OU. The ROD is planned to be submitted in 2012 (Figure 1-1).

1.2.2 OPERABLE UNIT 2 – SOUTH BASE

The South Base OU2 area is located south of the Main Base and on the southwestern edge of Rogers Dry Lake. Military development, operations, and activities began as early as the 1940s in the area of the current OU2. Over the years, the Air Force has used South Base as a place to train troops, and test aircraft and related equipment. This has resulted in contamination from a variety of fuels and solvents, as well as solid wastes generated by these activities. OU2 consists of four distinct areas with three that require cleanup: the Old South Base Cantonment area, the landfill/evaporation ponds area, and the South Base sled track area.

Two RODs will address the sites within OU2. The first ROD was submitted in 2009 for Sites 5, 14, 29, 69, 76, 78, 86, 96, and 417 with a five-year review planned for 2014. The second ROD is planned to be submitted in 2013 for Sites 81/102 (Figure 1-1).

1.2.3 OPERABLE UNIT 3 – BASEWIDE WATER WELLS

The Basewide Water Wells OU3 includes all unused wells (i.e., former homestead water wells, Base supply wells, playa research wells, and test wells) located on Base property. There were more than 660 water wells identified and investigated at Edwards AFB. Remedial investigation activities were conducted at eight of the well locations, with the wells subsequently destroyed and sealed. A Basewide Water Wells Closure Program was implemented to manage the destruction, sealing, and closure of former homestead water wells and playa research wells located on Base. Between July 1996 and October 2003, 401 abandoned and unused water wells were sealed as part of this program.

Based on the results of the program, Basewide Water Wells OU3 was closed as a No Action ROD. The No Action ROD was submitted in 2003 (Figure 1-1).

1.2.4 OPERABLE UNITS 4 AND 9 – AIR FORCE RESEARCH LABORATORY (FORMERLY PHILLIPS LABORATORY)

The AFRL is located in the northeastern portion of Edwards AFB east of Rogers Dry Lake. The main activity at the AFRL was testing of rocket systems on Leuhman Ridge. During the tests, the rocket exhaust was cooled by several thousand gallons of water, which at some test locations was allowed to discharge into arroyos on the northern side of Leuhman Ridge. Other sites within OU4 include waste disposal (dry) wells associated with machine shops and missile assembly buildings; parts-cleaning operations; a solid propellant cutting facility; fuel transport and storage facilities; and a former beryllium-use area. Sites in OU9 also include facilities for testing liquid and solid rocket motors, and associated shop and fuel storage areas. Sites at the AFRL were originally assigned to either OU4 or OU9. Later, during preparation of the Remedial Investigation Summary Reports for OU4 and OU9, AFRL sites with groundwater contamination were assigned to one of four areas (the South AFRL, AFRL Arroyos, Northeast AFRL, and Mars Boulevard) to aid to the development of ROD documents.

Five RODs will address the sites within OUs 4 and 9 (Figure 1-1). The first ROD was submitted in 2007 for South AFRL Sites 37, 120, 133, and 321 with a five-year review planned for 2012. A second ROD was submitted in 2008 for the AFRL soil and debris site with a five-year review planned for 2013. The third ROD is planned to be submitted in 2011 for AFRL Arroyos Sites 36, 162, and 461. The fourth and fifth RODs are planned for submittal in 2013 for the Northeast AFRL Sites and Areas of Concern 115, 116, 118, 177/325, 318, and 178; and Mars Boulevard Sites 27, 125, 127, 167, and 333.

1.2.5 OPERABLE UNIT 5/10 – NORTH BASE

OU5/10 consists of the occupied portion of North Base, which includes the North Base complex and the former NASA Jet Propulsion Laboratory, and the unoccupied portion of North Base, which corresponds to the area located north of Rogers Dry Lake. The occupied and unoccupied portions of North Base were designated as OUs 5 and 10, respectively, until the OUs were combined in 2005 to form OU5/10. Operations involving the use of hazardous materials and generation of hazardous waste occurred at various locations within OU5/10. The operations included aircraft repair and cleaning, rocket testing, photographic laboratory operations, painting, and fluid replacement. Rocket testing activities included processing perchlorate for use in rocket motors.

A ROD is being prepared and will address all sites within the OU. The ROD is planned to be submitted in about 2015 (Figure 1-1).

1.2.6 Operable Unit 7 – Basewide Miscellaneous

The Basewide Miscellaneous OU7 includes all Environmental Restoration Program (ERP) sites and potential release locations not included in other OUs, including outlying regions in the western portion of Edwards AFB, the area east of Rogers Dry Lake (excluding the AFRL), and the area south of the South Base. A variety of facilities are contained within this operable unit including landfills, burn sites, USTs, rifle ranges, drum storage areas, and evaporation ponds. A number of abandoned facilities (East Camp, Mojave Corporation, etc.) are also included in OU7. A large portion of the area east of Rogers Dry Lake is occupied by the Precision Impact Range Area, where aircraft weapons and systems are tested.

Three RODs will address the sites within OU7 (Figure 1-1). The first ROD was submitted in 2009 for Chemical Warfare Materiel (CWM) Sites 442 and 426 with a five-year review planned for 2014. The second ROD is planned to be submitted in 2011 for non-CWM Site 3. The third ROD is planned to be submitted in 2013 for non-CWM Sites 269, 280, 294, and 339.

1.2.7 Operable Unit 8 - Northwest Main Base

The Northwest Main Base OU8 is located west of the NASA DFRC complex and northwest of the Main Base. Industrial facilities in OU8 include tank farms; a jet fuel pipeline; hazardous waste, paint and waste paint storage areas; photography laboratory; automotive hobby shop; and other miscellaneous facilities. Leaks, improper storage, and intentional spillage of materials are the primary sources of contamination at OU8.

Two RODs will address the sites within OU8 (Figure 1-1). The first ROD is planned to be submitted in 2013 for Sites 61, 226, 257, 299, 300, and 301. The second ROD is planned to be submitted in about 2015 for Site 25.

Site 25 The majority of OU8 operations are located in the southeast portion of the OU. However, Site 25 is located in the northeast corner of OU8 near the boundary with OU6 (Figure 1-1). OU8 Site 25 is the source for a 1.2-mile long TCE plume extending into the southwestern corner of OU6.

The OU8 Site 25 plume has the potential to commingle with the OU6 plume and an OU1 TCE plume if the OU8 Site 25 plume continues to migrate downgradient toward the groundwater subbasin. To evaluate remedial solutions, a *Draft Final Feasibility Study and Technical Impracticability Evaluation Report* (AECOM, 2011a) was prepared for OU8 Site 25. Remedial alternatives were developed in the *Feasibility Study and Technical Impracticability Evaluation Report* to prevent the plume from reaching the groundwater subbasin.

A groundwater extraction and treatment system (GETS) consisting of an extraction well array constructed just west of the NASA DFRC complex was in operation from November 2001 to June 2010 to limit Site 25 plume migration. The GETS is temporarily offline to evaluate the affect extraction has had on Site 25 plume migration and groundwater levels.

2.0 SITE CHRONOLOGY

Site use involving potentially hazardous substances began in 1946, and investigations and studies at OU6 began in 1988. The findings related to the historical studies identified 20 potentially contaminated areas. Of these 20 areas, 3 sites within the NASA DFRC boundary (Sites N2, N3, and N7) are considered to be the original source areas of the OU6 chlorinated and aromatic hydrocarbon commingled groundwater plume (Figure 2-1). An overview of these activities is presented in Table 2-1 with further details provided below.

NASA DFRC has leased a portion of the Edwards AFB flightline since 1946 to support Space Shuttle, flight testing, and aeronautical research operations. During that time, workers performed test, evaluation, and maintenance activities involving toxic and hazardous materials. These materials often spilled and soaked into the ground or were disposed of inappropriately. Current use and disposal of these materials are strictly regulated to prevent releases to the environment.

In 1981, a preliminary assessment was performed for Edwards AFB, and a brief preliminary assessment and site inspection study was conducted at NASA DFRC in 1988. From 1991 to 1993, a comprehensive Expanded Source Investigation/ Resource Conservation and Recovery Act (RCRA) Facility Assessment (ESI/RFA) was performed and covered the entire Base, including the NASA DFRC facility. The ESI/RFA involved the assessment and inspection of over 1,000 features from small hazardous waste storage facilities to large-multiple story aircraft hangar/maintenance facilities. Based on the results of the ESI/RFA, 20 sites and/or areas of concern were identified within OU6 as contaminated or potentially contaminated.

Following Edwards AFB's formal listing on the NPL on 30 August 1990, the U.S. Air Force entered into a Federal Facility Agreement (FFA) with the USEPA, California DTSC, and CRWQCB. The FFA establishes the process for involving the USEPA, the State, and the public in the Edwards AFB remedial response process. It provides a procedural framework for developing, implementing, and monitoring response actions at Edwards AFB in accordance with CERCLA; Superfund Amendments and Reauthorization Act (SARA) of 1986; the NCP; pertinent provisions of RCRA; and applicable or relevant and appropriate state laws.

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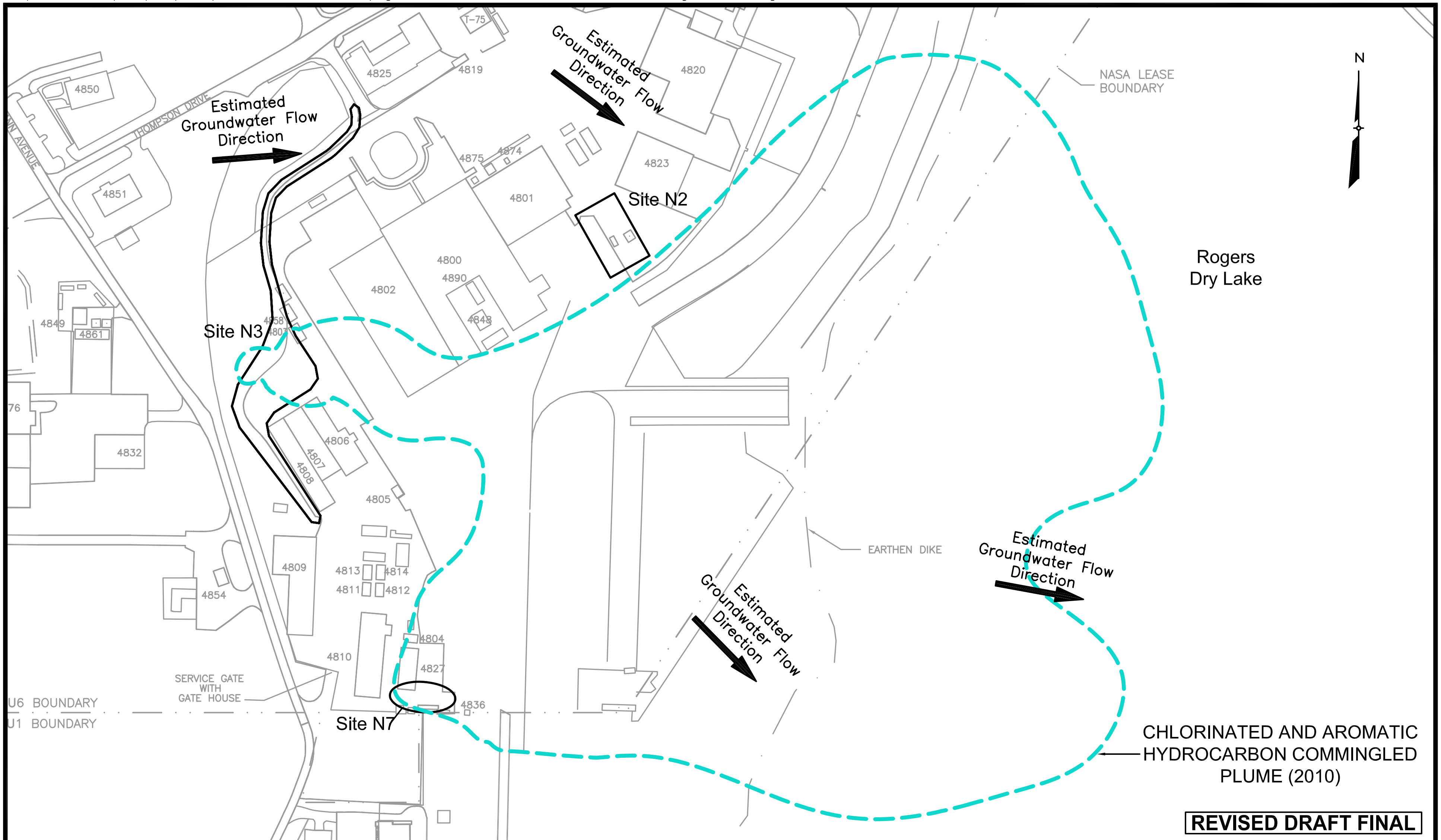
P:\60133976\WP\90\cad\Revised Draft Final\Figure 2-1 OU6 TCE Benzene 2010.dwg - 20 Aug 2011



EXPLANATION

OU6 = OPERABLE UNIT 6

TRICHLOROETHENE (TCE), A SOLVENT USED IN AERONAUTICAL OPERATIONS, IS THE PRINCIPAL CHLORINATED HYDROCARBON ENCOUNTERED IN OU6 GROUNDWATER. AROMATIC HYDROCARBONS INCLUDE BENZENE, TOLUENE, ETHYLBENZENE, AND XYLENES (BTEX), WHICH ARE TYPICALLY FOUND IN PETROLEUM PRODUCTS.

0 175 350

SCALE IN FEET

OU6 Commingled Plume - 2010

Date 08-2011	**Operable Unit 6 First Five-Year Review Report Edwards AFB**	Figure
Project No. 60133976		**2-1**

TABLE 2-1. CHRONOLOGY OF SITE EVENTS

Date(s)	Site/Area	Event	Reference
1946 - Present	OU6	Use, management, and disposal of hazardous substances/waste related to aircraft operations, testing, and maintenance.	Earth Tech, 2000b
1988 – 1998	OU6	Initial identification of contamination and remedial investigations.	Earth Tech, 2000b
8/1990	OU6	NPL listing.	Earth Tech, 2000b
10/1990	Edwards AFB	entered into a FFA with the USEPA, California DTSC, and CRWQCB	Earth Tech, 2000b
5/1992 – 2/1997	N3	GW extraction TS using a recovery trench.	RESNA, 1992
1995 – 2004	OU6	Groundwater monitoring program.	Earth Tech, 2004
5/1997 – 6/1997	N3	Dual extraction air sparging PS.	Rust 1997b
6/1997	N2	Dual extraction air sparging PS.	Rust 1997a
7/1997	N7	GW extraction PS.	Rust 1997c
10/1998 – 6/2001	N3	Dual extraction TS.	Earth Tech, 2001a
11/1998 – 6/1999	N2	SV extraction and air sparging TS.	Earth Tec, 2000a
10/1998 – 4/1999	N7	Dual extraction TS.	Earth Tech 2001b
8/2000	N7	Potassium permanganate ISCO TS.	Earth Tech, 2004
6/2002 – 5/2003	N3	Fenton-based reagent and persulfate ISCO TS.	Earth Tech, 2008
8/2004	OU6	Feasibility Study complete.	Earth Tech, 2004
4/2005	OU6	Proposed Plan presented.	Earth Tech, 2005
2/2008 – 5/2010	OU6	RA design.	Earth Tech, 2008 and AECOM, 2010
5/2005 – 10/2006	N3 and N7	RA Pre-ROD (Phase I) implementation.	Earth Tech, 2008
6/2005 – 7/2005	N3 and N7	Sodium permanganate ISCO TS.	Earth Tech, 2008
4/2005 - 12/2006	OU6	Proposed Plan public comment period and ROD signed.	Earth Tech, 2005 and 2006
10/2007 – 10/2008	N3 and N7	RA Post-ROD (Phase II) implementation through 2008.	Earth Tech, 2009
9/2008 – 10/2010	N3 and N7	RA Post-ROD (Phase II) implementation through October 2010.	AECOM, 2011b

Notes:

AFB = Air Force Base
CRWQCB = California Regional Water Quality Control Board
DTSC = Department of Toxic Substances Control
Earth Tech = Earth Tech, Inc.
FFA = Federal Facility Agreement
GW = groundwater
ISCO = *in situ* chemical oxidation
NPL = National Priorities List
OU = operable unit
PS = pilot study
RA = remedial action
ROD = Record of Decision
SV = soil vapor
TS = treatability study
USEPA = United States Environmental Protection Agency

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3.0 BACKGROUND

3.1 PHYSICAL CHARACTERISTICS

Edwards AFB is located in the Southern California counties of Kern, Los Angeles, and San Bernardino, approximately 2 miles east of the city of Rosamond (Figure 1-1). NASA DFRC is a tenant organization at Edwards AFB; the 838-acre leased facility is designated as Environmental Restoration Program OU6 and is located in the north-central portion of the Base on the main flightline, wholly within Kern County.

OU6 is located on the northwestern edge of Rogers Dry Lake, in generally flat, but gently sloping terrain. Surface elevations vary by approximately 30 feet (ft) between the high points on the western side of OU6 and the low points along the lakebed. Subsurface materials at OU6 consist of granitic bedrock overlain by a relatively thin layer of unconsolidated alluvial and lake bed deposits. The alluvial layer consists of sandy sediments that appear to have been derived from granitic bedrock outcrops. The bedrock at OU6 is generally competent, except for surface weathering and localized fracturing.

Due to the near surface occurrence of bedrock, the saturated zone at OU6 lies almost entirely within fractures in the granitic bedrock. Groundwater depth ranges from approximately 30 ft below grade along the western side of OU6 to approximately 5 ft below grade along the eastern side of OU6. Shallow groundwater elevations measured in October 2010 were used to construct potentiometric surface contour maps (generated using Surfer 8.01 by Golden Software Inc. of Golden Colorado) to show approximate flow directions (Figure 3-1). The contours indicate that shallow groundwater generally flows east toward Rogers Dry Lake throughout the site with some localized variations caused by pumping at Site 25, northeast of OU6. Pumping at Site 25 ceased in June 2010, however groundwater levels had not yet recovered by October 2010.

The population density of Edwards AFB is approximately 120 people per square mile. The nearest population center to OU6 is North Edwards, which is approximately 6 miles north with a population of less than 1,500 people. The nearest city is Lancaster, which is approximately 15 miles southwest with a population of approximately 160,000 people.

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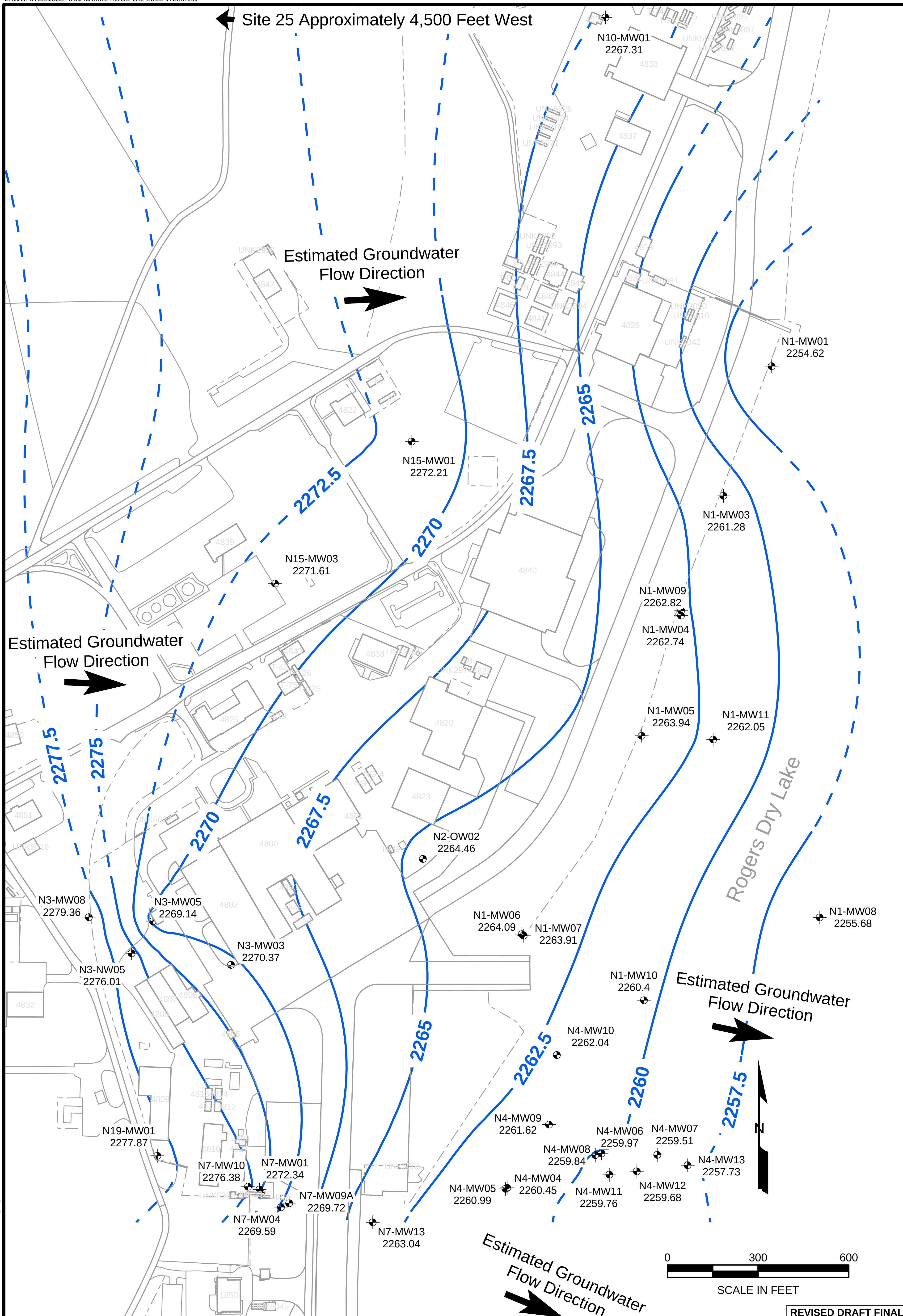

EXPLANATION

N7-MW10 2276.38 — MONITORING WELL WITH WELL NUMBER AND GROUNDWATER ELEVATION USED TO ESTIMATE CONTOURS

GROUNDWATER ELEVATION CONTOUR IN FEET ABOVE MEAN SEA LEVEL (DASHED WHERE EXTRAPOLATED)

GROUNDWATER ELEVATIONS ARE PRESENTED IN FEET ABOVE MEAN SEA LEVEL.

GROUNDWATER ELEVATION CONTOURS OCTOBER 2010

Date 08-2011 Project No. 60133976	**Operable Unit 6 First Five-Year Review Report Edwards AFB**	Figure **3-1**

OU6 is not an environmentally sensitive area and provides low quality ecological habitat due to proximity to industrial processes and related development, i.e., paved ground surface with relatively dense traffic patterns (Tetra Tech, 2003). No threatened or endangered plants, invertebrates, birds, reptiles, or mammals have been reported.

3.2 LAND AND RESOURCE USE

Land uses surrounding NASA DFRC are industrial in nature and support aeronautical flight testing. DFRC is NASA's primary flight research center. Current research facilities include: the Flight Loads Laboratory, the Walter C. Williams Research Aircraft Integration Facility, and the Western Aeronautical Test Range. Elements of NASA DFRC's mission include: perform flight research and technology integration to revolutionize aviation and pioneer aerospace technology, validate space exploration concepts, conduct airborne remote-sensing and science missions, and support operations of the Space Shuttle and the International Space Station – for NASA and the nation (NASA, 2009). Mission-critical activities involve the movement of aircraft on taxiways in the vicinity of contamination. RA activities, including the placement of sampling points and equipment outside of aircraft traffic areas, must be implemented to minimize impact to mission-critical activities. As shown on Figure 3-2, the majority of the contaminant plume underlies key aircraft ramps and taxiways.

The Base General Plan (GP) (Edwards AFB, 2009) and the NASA DFRC Master Plan (MP) (Development One, Inc. [Development One], 2009) specify that NASA DFRC will continue to be used for industrial purposes. No residential uses, including day care facilities or other sensitive uses that would result in higher exposure amounts beyond worker exposures, within any portion of OU6 are anticipated as the Air Force will continue to occupy the Base indefinitely. The area surrounding OU6 has been, and will continue to be, industrial use for military research and development. Because the surrounding area will continue as industrial use, ecological habitat will likely continue to be low quality.

The *Water Quality Control Plan for the Lahontan Region* (Basin Plan) designates the following beneficial uses for groundwater in the Antelope Valley hydrologic basin (including the North Muroc subbasin, which is the closest subbasin to OU6): municipal, agricultural, industrial, and freshwater

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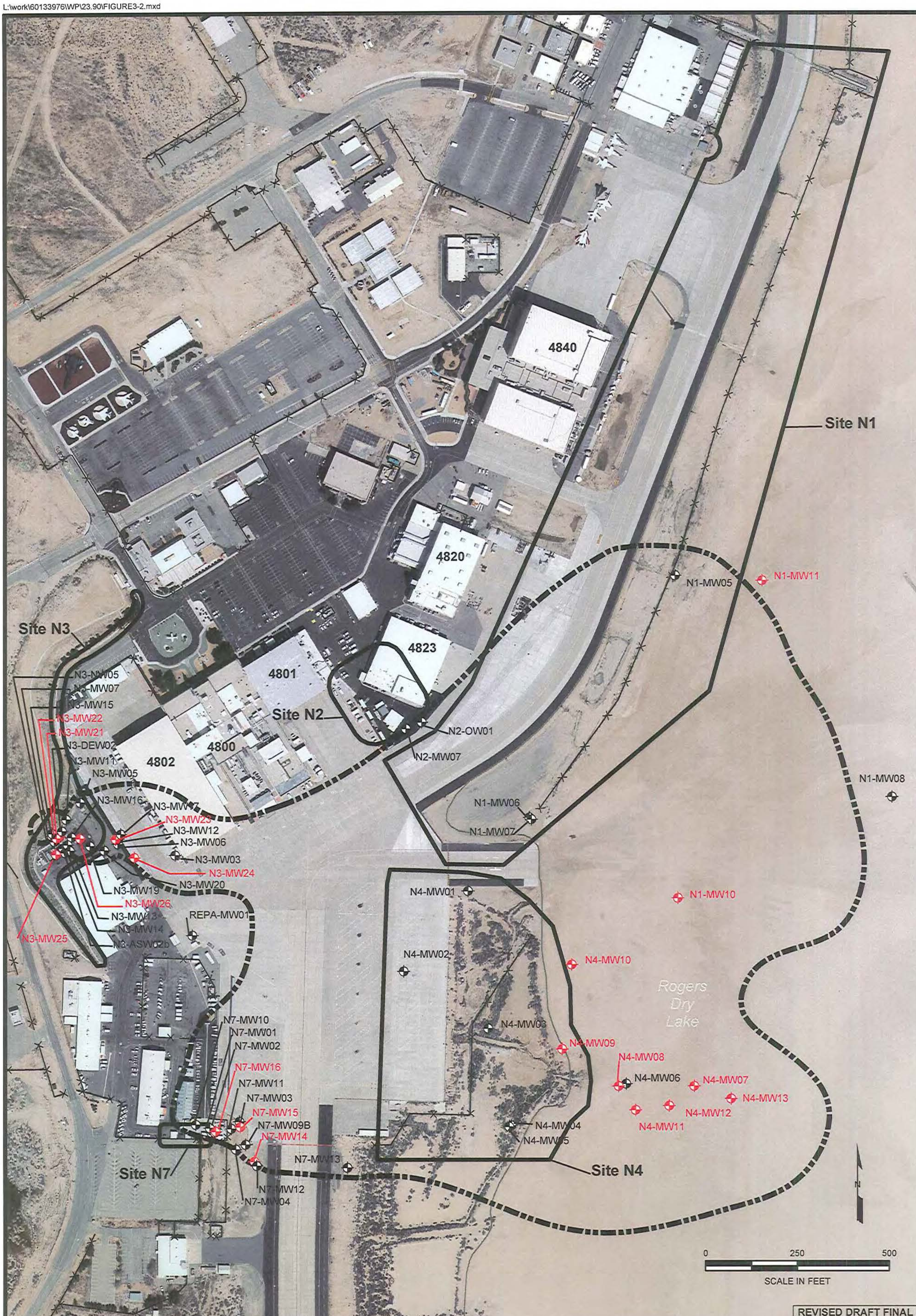
L:\work\60133976\WP\23.90\FIGURE3-2.mxd



EXPLANATION

N3-MW03 MONITORING WELL

N1-MW10 MONITORING/INJECTION WELL INSTALLED DURING THE REVIEW PERIOD

SITE BOUNDARY

BENZENE AND TRICHLOROETHENE COMMINGLED PLUME BASED ON 2010 CONTAMINANT CONCENTRATIONS

SECURITY FENCE

Site Aerial View

Date 08-2011		Figure
Project No. 60133976	Operable Unit 6 First Five-Year Review Report Edwards AFB	3-2

replenishment (CRWQCB, 1995). However, there are no current or planned future uses of groundwater at OU6.

Surface water bodies at OU6 consist of man-made stormwater retention ponds and the intermittent filling of Rogers Dry Lake during the winters. OU6 stormwater drains to the lakebed via surface runoff, engineered drainages, and storm drains.

3.3 HISTORY OF CONTAMINATION

Historical activities at OU6 involved drum and underground tank storage of solvents and fuels, and use of coating-related materials (paints, thinners, strippers, and plating materials) in aircraft operation and maintenance. Contaminants in soil are not present at levels representing a risk to human health and the environment. As documented in the ROD (Earth Tech, 2006), a decision of No Action was selected for the soils as contaminant concentrations in the soils were found to be within USEPA's acceptable risk range. No groundwater contaminant sources were identified in soil during investigation activities (Earth Tech, 2000b).

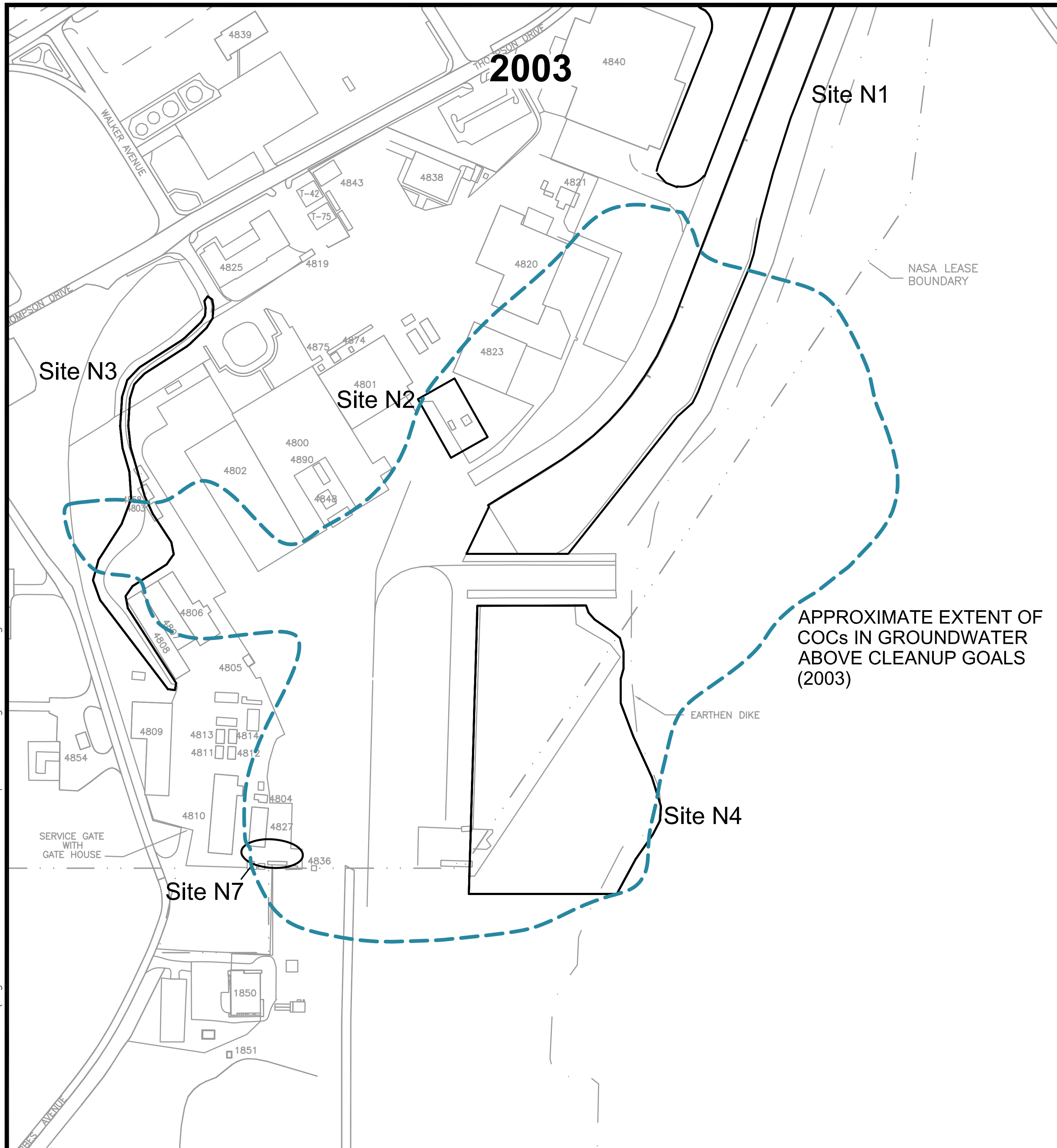
The historical chemical usage within OU6 resulted in a groundwater plume that encompasses multiple source areas. As documented in the ROD (Earth Tech, 2006), locations of former releases to the environment in OU6 have been designated as Sites N1, N2, N3, N4, and N7. The location and nature of these releases contributed to a single commingled groundwater plume that encompasses all of the source areas and extends from the Site N3 area in the west, east beneath Sites N1, N2, N4, and N7, and eventually to Rogers Dry Lake (Figure 3-2). The groundwater plume consists of chlorinated hydrocarbons (principally TCE, a solvent used in aeronautical operations) and aromatic hydrocarbons (including BTEX, typically found in petroleum products), which are present at levels representing a potential risk to human health and the environment. Groundwater contaminants of concern (COCs) and cleanup goals (Maximum Contaminant Levels [MCLs]) were identified in the ROD (Earth Tech, 2006) and include 17 volatile organic compounds (VOCs). These COCs and their respective historical concentration ranges present at OU6, and respective cleanup goals are presented in Table 3-1. Figure 3-3 shows the shape of the commingled plume in 2003 and in 2010. The 2003 delineation is shown because, data collected in 2003 were the basis for the remedies developed in the

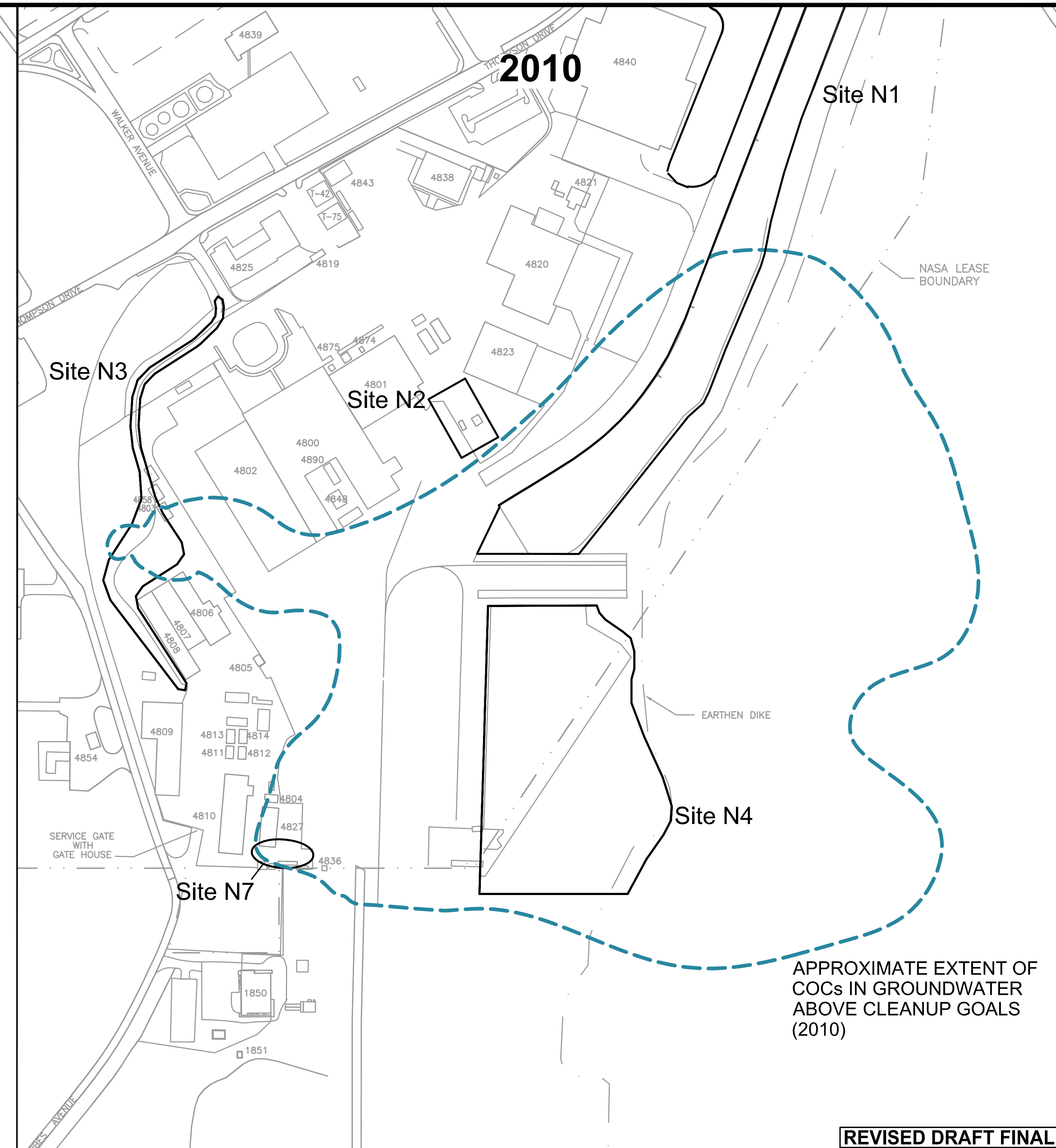
TABLE 3-1. CONTAMINANTS OF CONCERN

COC	Historical COC Concentration[a] Minimum	Date	Maximum	Date	2010 Maximum Concentration	Cleanup Goal[b]
benzene	0.12	3/2001	19,000	7/2002	7,000	1
carbon tetrachloride	0.17	9/2001	7,000	3/2002	4,000	0.5
chloroform	0.12	9/2001	3,200	6/2002	2,100	80
1,2-dibromoethane[c]	0.55	10/2009	220	3/2002	13	0.05
1,1-dichloroethane	0.1	3/2001	100	6/2003	ND	5
1,2-dichloroethane	0.16	6/2010	310	7/2002	130	0.5
cis-1,2-dichloroethene	0.15	9/2001	14,000	6/2010	14,000	6
trans-1,2-dichloroethene	0.14	1/2001	42	5/2005	17	10
1,2-dichloropropane	0.17	9/2001	55	6/2003	ND	5
ethylbenzene	0.17	3/2001	2,100	3/2002	1,500	300
methylene chloride	0.2	9/2000	350	11/2002	65	5
1,1,2,2-tetrachloroethane	1.7	4/2004	430	4/2004	42	1
toluene	0.13	9/2001	34,000	3/2002	5,400	150
1,1,2-trichloroethane	0.14	9/2000	54	9/2001	ND	5
trichloroethene	0.2	4/2004	45,000	3/2002	20,000	5
vinyl chloride	0.07	9/2003	200	6/2003	ND	0.5
total xylenes	0.24	3/2001	7,300[d]	6/2010	7,300	1,750

Notes:

All concentrations are presented in micrograms per liter.
Results do not include grab samples.
[a] Minimum and maximum concentrations detected during all sampling events.
[b] Cleanup goals are based upon Maximum Contaminant Levels (California Department of Public Health, 2008).
[c] 1,2-dibromoethane is also known as ethylene dibromide.
COC = contaminant of concern
ND = not detected





REVISED DRAFT FINAL

EXPLANATION

COC = CONTAMINANT OF CONCERN
OU6 = OPERABLE UNIT 6

17 COCs HISTORICALLY PRESENT AT OU6 ABOVE CLEANUP GOALS. COMMINGLED PLUME DELINEATION IS BASED ON ESTIMATED EXTENT OF PRIMARY COCs BENZENE AND TRICHLOROETHENE (TCE) AT CONCENTRATIONS ABOVE THEIR RESPECTIVE CLEANUP GOALS.

0 175 350
SCALE IN FEET

N

OU6 Plume Comparison

Date 08-2011	**Operable Unit 6**	Figure
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P:\60133976\WP\90\cad\Revised Draft Final\Figure 3-3 OU6 Plume Comparison.dwg — 23 Aug 2011

Feasibility Study (FS) (Earth Tech, 2004) and the final remedy selection in the ROD (Earth Tech, 2006). The 2010 delineation is presented because it is based on the most recent data available within this review period.

3.3.1 SITE N1 RELEASES

Site N1 is the Northern Retention Pond consisting of a series of topographic depressions that lie along the eastern edge of OU6 (Figure 3-2). The retention pond is unlined, except for the wedge-shaped strip located southeast of Building 4823, which is paved with asphalt and used to manage surface water runoff originating from the northern portion of OU6, preventing direct out flow onto Rogers Dry Lake (Rust Environment & Infrastructure [Rust], 1996b). During the site inspection (see Section 6.5), Mr. Phil Saxton (AECOM RA Operation and Maintenance Site Manager) noted that in recent years less water appears to flow to the Northern Retention Pond. Mr. Dan Morgan (NASA DFRC Environmental Manager) confirmed that the reduction in outflow to the Northern Retention Pond is a result of a 2006 drainage realignment and internal process modifications to eliminate freshwater discharges to the storm drains.

Prior to the remedial investigation, Site Nl was suspected to have been potentially contaminated by petroleum oil and lubricants (POL), solvents, aircraft fuels, and chromium as a result of:

- Discharges of POL and solvents from the Auxiliary Propulsion Unit test facility near Building 4801;
- Aircraft run-up area activities between Building 4823 and the Northern Retention Pond;
- Dust control practices that may have involved the application of waste POL;
- Releases of deluge water and aqueous film forming foam (fire suppressant) due to false alarms; and
- Cooling tower blowdown wastewater containing chromium that was discharged to the storm drainage system.

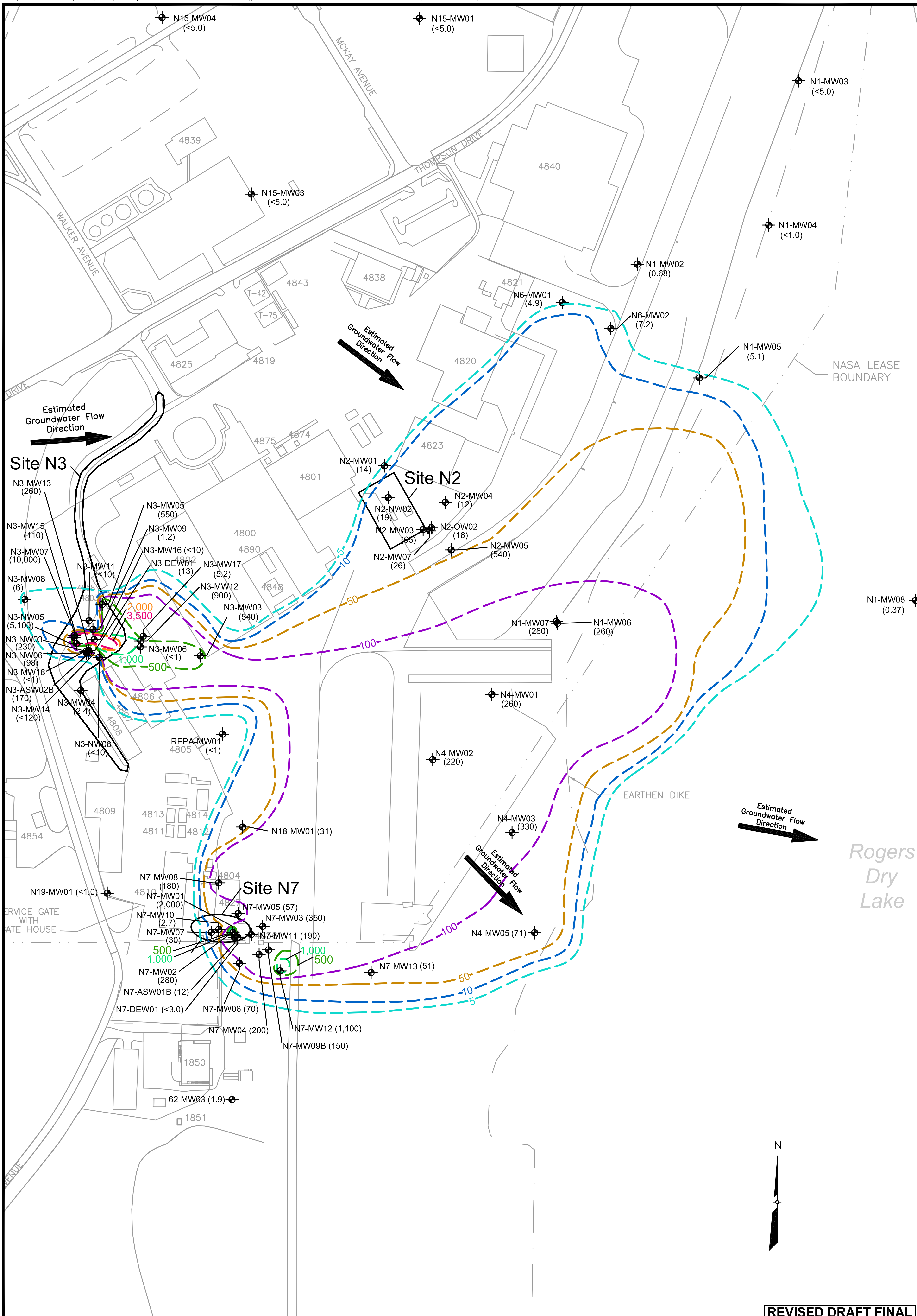
POL-related contaminants in the Site N1 area are not identified as COCs in the ROD (Earth Tech, 2006). Additionally, chromium is not considered a COC; however, the groundwater samples from the commingled chlorinated hydrocarbon plume are routinely analyzed for metals associated with the ongoing *in situ* chemical oxidation (ISCO) component of the RA.

COCs *cis*-1,2-dichloroethene (DCE) and TCE have been detected in samples collected from wells in the Site N1 area at concentrations above their respective cleanup goals (MCLs) of 6 and 5 micrograms per liter (μg/L) and contribute to the OU6 commingled chlorinated hydrocarbon plume. *Cis*-1,2-DCE concentrations in samples collected from shallow monitoring well N1-MW06 have ranged from 6.2 μg/L in 2008 to 28 μg/L in 2001 and in samples collected from deep monitoring well N1-MW07 have ranged from 9.1 μg/L (estimated value) in 2008 to 17 μg/L in 2003. These wells, with a sampling history starting in 2000, are within relatively close proximity to each other, and represent both shallow and deep groundwater, respectively. TCE concentrations in samples collected from shallow monitoring well N1-MW06 have ranged from 72 μg/L in 2006 to 340 μg/L in 2000 and in samples collected from deep monitoring well N1-MW07 have ranged from 130 μg/L (estimated value) in 2007 to 280 μg/L in 2003. TCE trend graphs for monitoring wells N1-MW06 and N1-MW07 are presented in Appendix A. The OU6 TCE plume as delineated in 2003 and in 2010 is shown on Figures 3-4 and 3-5, respectively. Recent groundwater monitoring results (2010 sampling results further discussed in Section 6.4) indicate the portion of the plume in the southern Site N1 area extends further downgradient than originally defined by 2003 groundwater data as presented in the FS and the ROD (Figure 3-3).

3.3.2 Site N2 Releases

Site N2 is located southeast of Building 4801 (Figure 3-2) and is the location of the Former Drainage Area for the former X-15 aircraft auxiliary propulsion unit (APU) test facility. The APUs, which ran high-speed turbines to provide emergency power to aircraft hydraulic systems, were fueled by hydrogen peroxide. During testing, excess hydrogen peroxide was released to the Former APU Drainage Area, which was an unlined depression approximately 6 ft deep by 100 ft wide by 150 ft long. In the early 1960s, the drainage area was filled in and the area was paved with asphalt. The Former APU Drainage Area may have received runoff from the aircraft run-up area formerly located on the concrete apron and ramp south and east of the former APU test facility (Rust, 1996a).

Site N2 also includes the Building 4801 Dilution Pits in the western half of the Former APU Drainage Area. The Dilution Pits, located northeast of the former APU test facility, consisted of three pits similar in construction to a three-chamber oil/water separator. The Dilution Pits measured 4 ft by 4 ft by 6 ft deep and were constructed of concrete with a metal grate cover. The pits were used to dilute hydrogen peroxide that drained from the former APU test facility. Potential wastes at both the Dilution Pits and the Former APU Drainage Area were hydrogen peroxide, solvents, jet fuel, and



EXPLANATION

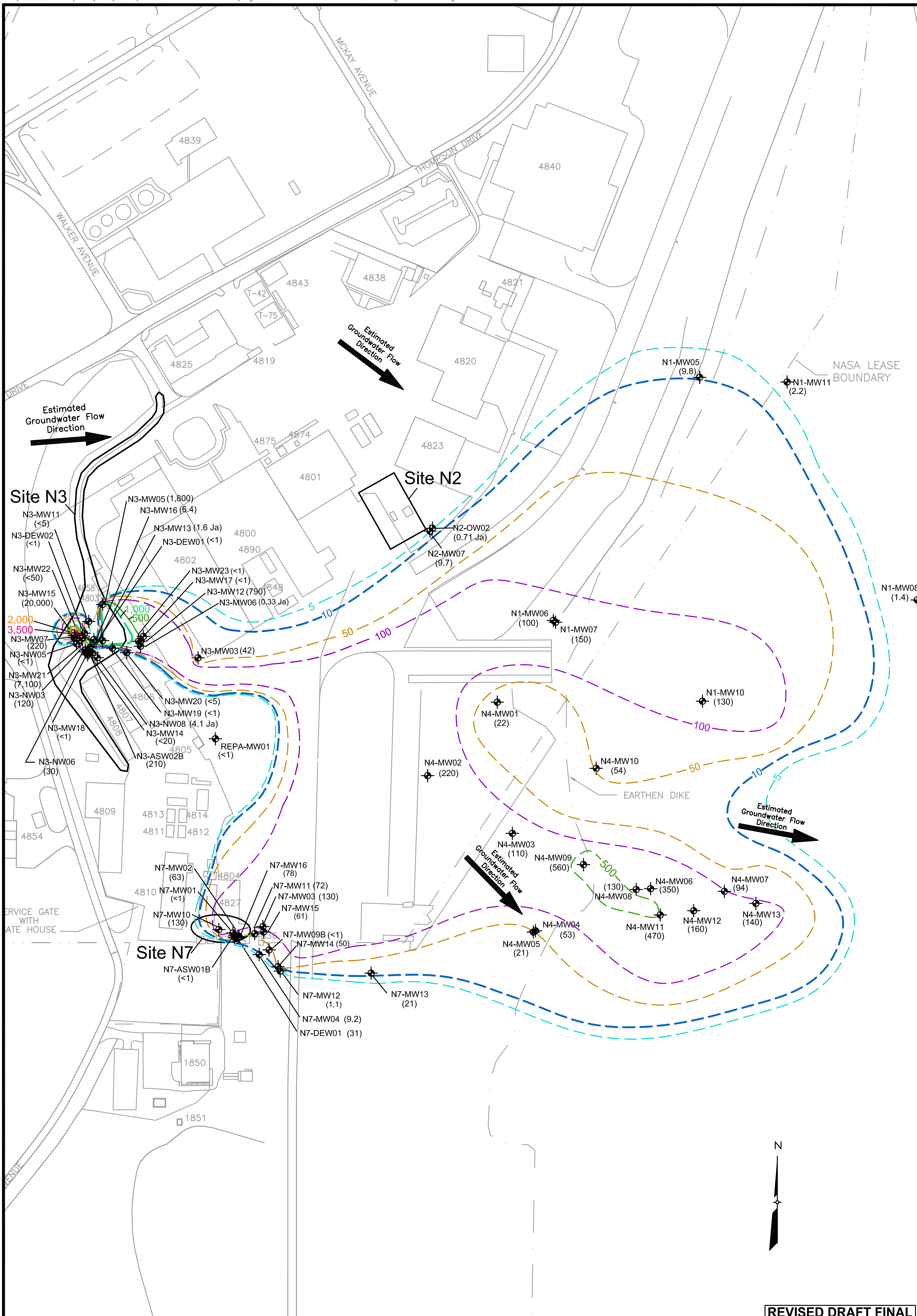
N3-NW03 (230) — MONITORING WELL WITH TRICHLOROETHENE (TCE) CONCENTRATION IN MICROGRAMS PER LITER

— 5 — INFERRED TCE CONCENTRATION CONTOUR (INTERVALS = 5, 10, 50, 100, 500, 1,000, 2,000, AND 3,500 MICROGRAMS PER LITER) BASED ON 2003 RESULTS

0 125 250
SCALE IN FEET

OU6 Plume
TCE Groundwater Concentration Contours
2003

Date 08-2011	**Operable Unit 6**	Figure
Project No. 60133976	**First Five-Year Review Report** **Edwards AFB**	**3-4**



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EXPLANATION

N3-MW03 (120) — MONITORING WELL WITH TRICHLOROETHENE (TCE) CONCENTRATION IN MICROGRAMS PER LITER

— 5 — INFERRED TCE CONCENTRATION CONTOUR (INTERVALS = 5, 10, 50, 100, 500, 1,000, 2,000, AND 3,500 MICROGRAMS PER LITER) BASED ON JUNE-JULY 2010 MONITORING RESULTS

0 125 250
SCALE IN FEET

OU6 Plume
TCE Groundwater Concentration Contours
2010

Date 08-2011	Operable Unit 6 First Five-Year Review Report Edwards AFB	Figure
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hydrazine from the former APU test facility and aircraft run-up area, and chromium associated with runoff from the cooling tower blowdown.

Historically, TCE concentrations attributable to on-site sources exceeded the 5-μg/L cleanup goal (MCL) in groundwater at Site N2. TCE concentrations in samples collected from shallow monitoring well N2-OW02 have ranged from 0.71 μg/L (estimated value) in 2008 to 16 μg/L in 2003 and samples collected from deep monitoring well N2-MW07 have ranged from 9.4 μg/L in 2008 to 51 μg/L in 2001. These wells, with a sampling history starting in 2000, are within relatively close proximity to each other, and represent both shallow and deep groundwater, respectively. TCE trend graphs for monitoring wells N2-OW02 and N2-MW07 are presented in Appendix A. The OU6 TCE plume as delineated in 2003 and in 2010 is shown on Figures 3-4 and 3-5, respectively.

3.3.3 SITE N3 RELEASES

Site N3, the Former Gas Station, is located in the southwest portion of the NASA DFRC complex (Figure 3-2). The site is comprised of the following:

- Building 4889 Former Gas Station
- Building 4886 Former Drum Dispensing Area
- Building 4889 Former Drum Dispensing Area
- Building 4889 Drainage Ditch

The Former Gas Station previously contained three USTs (all removed in 1991): a 5,000-gallon, fiberglass, leaded gasoline UST; a 6,000-gallon, fiberglass, unleaded gasoline UST; and a 1,000-gallon, steel, jet fuel number 4 (JP-4) (originally leaded gasoline) UST (Earth Tech, 2000b).

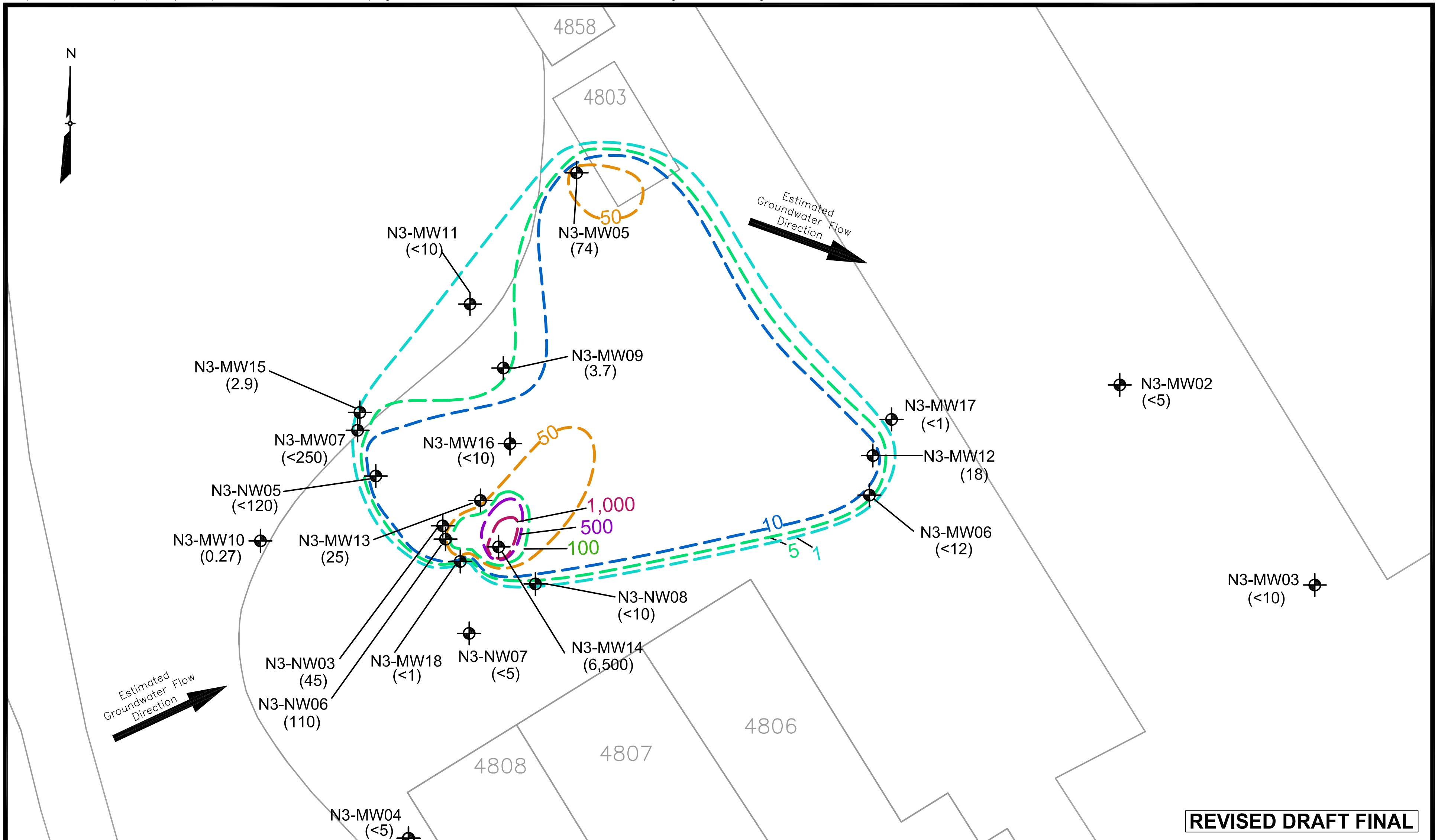
The two gasoline tanks failed integrity tests performed in September 1986 and the JP-4 tank passed. In 1988, investigations at the Former Gas Station identified BTEX, gasoline, and chlorinated solvents in groundwater surrounding the Former Gas Station.

The Drainage Ditch extends north and west of the Former Gas Station, the Former Drum Dispensing Area at Building 4803, and Former Buildings 4886 and 4889. The Drainage Ditch is an open concrete-lined feature, with an average depth of 2 ft and length of 900 ft. The outfall of the Drainage Ditch is the Southern Retention Pond (Site N4).

In 1992, Earth Tech reported the presence of three 55-gallon drums stored at the Former Drum Dispensing Area associated with Building 4803 and fifteen 55-gallon drums and associated drip pans stored at the Former Building 4886 Drum Dispensing Area. Hazardous materials stored at Site N3 included ethylene glycol, lubricating oil, degreasers, and solvents. The Drainage Ditch may have received these products due to leakage from the Former Drum Dispensing Area. During the site inspection (see Section 6.5), Mr. Dan Morgan (NASA DFRC Environmental Manager) noted that Buildings 4886 and 4889 (and associated drum dispensing areas) had been removed, and drums were no longer stored at Building 4803.

Historically, all 17 COCs listed in Table 3-1 have been detected in groundwater samples collected from Site N3 at concentrations exceeding their respective cleanup goals (MCLs). Additionally, all the historical maximum COC concentrations listed in Table 3-1 were detected in samples collected from Site N3 monitoring wells. While chlorinated hydrocarbons attributable to former on-site sources (drum storage and dispensing) contribute to the OU6 commingled plume (which includes former sources at Sites N1, N2, N4, and N7), aromatic hydrocarbons are specific to the Site N3 area and are attributable to former on-site sources (USTs). The aromatic and chlorinated hydrocarbons are commingled in the Site N3 area.

The principal aromatic hydrocarbons detected at Site N3 include benzene, ethylbenzene, toluene and total xylenes. Due to its presence at high concentrations over a wide area, benzene is used as an indicator for plume delineation and concentration trends in aromatic hydrocarbons at Site N3. Benzene concentrations in samples collected from shallow monitoring well N3-NW05 have ranged from 0.26 μg/L (estimated value) in 2007 to 99 μg/L in 2000 and in samples collected from deep monitoring well N3-MW07 have ranged from 1.1 μg/L in 2010 to 71 μg/L in 2000. These wells, with a sampling history starting in 2000, are within relatively close proximity to each other, and represent both shallow and deep groundwater, respectively. The highest historical benzene concentration (19,000 μg/L) at OU6 was detected in the sample collected from monitoring well N3-MW14 in 2002 (Table 3-1). The benzene concentration detected in the most recent sample collected from monitoring well N3-MW14 (in 2010) was 7,000 μg/L. Benzene trend graphs for monitoring wells N3-MW07, N3-MW14, and N3-NW05 are presented in Appendix A. The Site N3 benzene plume as delineated in 2003 and in 2010 is shown on Figures 3-6 and 3-7, respectively. The highest historical ethylbenzene



EXPLANATION

N3-NW03 (45) MONITORING WELL WITH BENZENE CONCENTRATION IN MICROGRAMS PER LITER

– – 1 – – INFERRED BENZENE CONCENTRATION CONTOUR (INTERVALS = 1, 5, 10, 50, 100, 500, AND 1,000 MICROGRAMS PER LITER) BASED ON 2003 RESULTS

0 25 50
SCALE IN FEET

Site N3
Benzene Groundwater Concentration Contours
2003

Date 08-2011	**Operable Unit 6** **First Five-Year Review Report** **Edwards AFB**	Figure **3-6**
Project No. 60133976		

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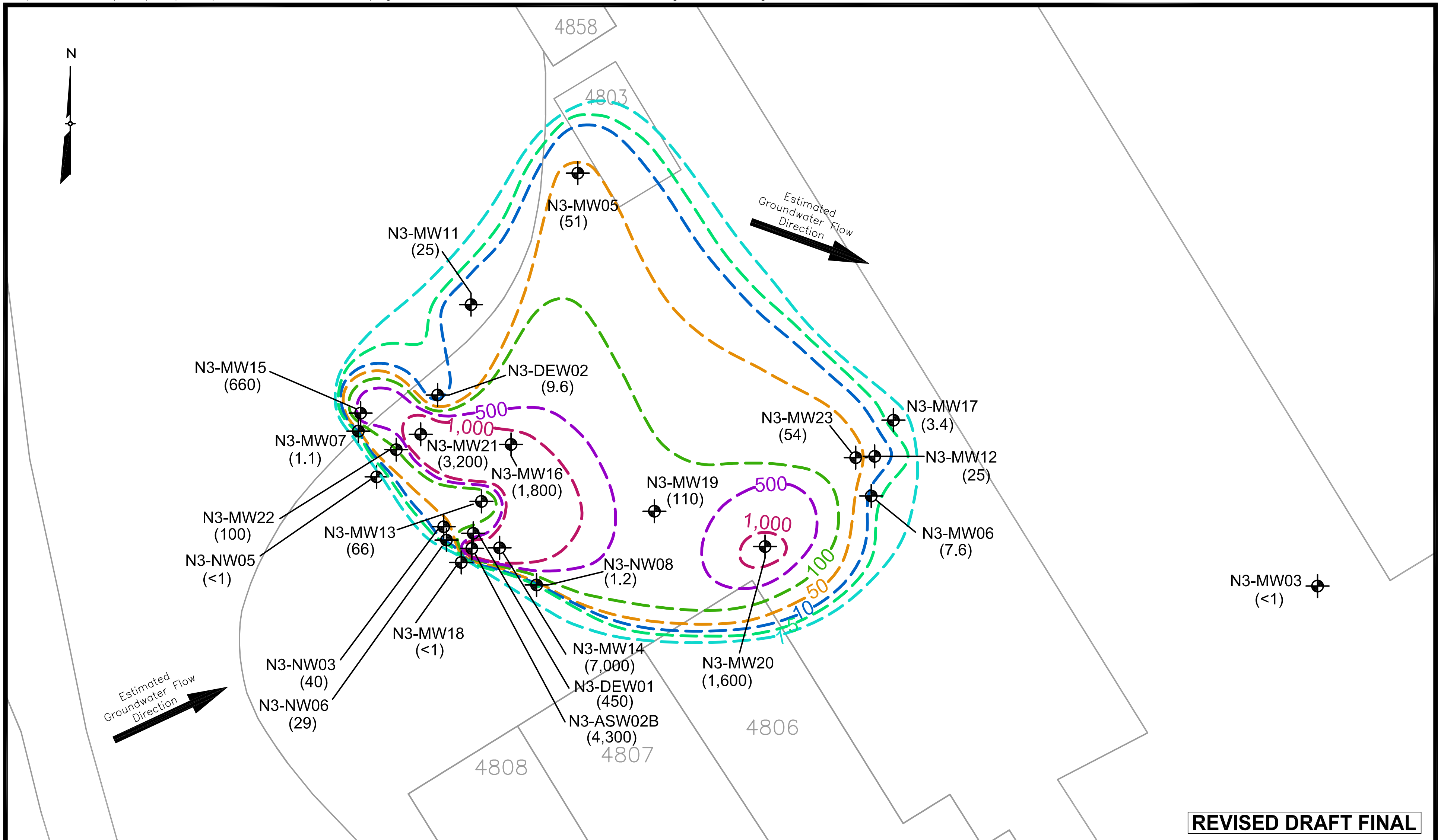

EXPLANATION

N3-MW03 (40) — MONITORING WELL WITH BENZENE CONCENTRATION IN MICROGRAMS PER LITER

-- 1 -- INFERRED BENZENE CONCENTRATION CONTOUR (INTERVALS = 1, 5, 10, 50, 100, 500, AND 1,000 MICROGRAMS PER LITER) BASED ON JUNE-JULY 2010 MONITORING RESULTS

0 25 50

SCALE IN FEET

Site N3
Benzene Groundwater
Concentration Contours
2010

Date 08-2011	Operable Unit 6 First Five-Year Review Report Edwards AFB	Figure
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concentration at OU6 (2,100 μg/L) was detected in the sample collected from monitoring well N3-MW13 in 2002 (Table 3-1). As with the historical high for benzene, the highest historical toluene concentration at OU6 (34,000 μg/L) was detected in the sample collected from monitoring well N3-MW14 in 2002 (Table 3-1). The highest historical total xylenes concentration at OU6 (7,300 μg/L) was detected in the sample collected from monitoring well N3-MW21 in 2010 (Table 3-1).

The principal chlorinated hydrocarbons detected at Site N3 include carbon tetrachloride (CT), 1,2-dichloroethane (DCA), *cis*-1,2,-DCE, and TCE. Due to its presence at high concentrations over a wide area, TCE is used as an indicator for plume delineation and concentration trends in chlorinated hydrocarbons at Site N3. TCE concentrations in samples collected from shallow monitoring well N3-NW05 have ranged from 180 μg/L in 2007 to 8,500 μg/L in 2002 and in samples collected from deep monitoring well N3-MW07 have ranged from 220 μg/L in 2010 to 13,000 μg/L in 2004. These wells, with a sampling history starting in 2000, are within relatively close proximity to each other, and represent both shallow and deep groundwater, respectively. The highest historical TCE concentration at OU6 (45,000 μg/L) was detected in the sample collected from monitoring well N3-MW15 in 2002 (Table 3-1). The TCE concentration detected in the most recent sample collected from monitoring well N3-MW15 (in 2010) was 20,000 μg/L. TCE trend graphs for monitoring wells N3-MW07, N3-MW15, and N3-NW05 are presented in Appendix A. The OU6 TCE plume as delineated in 2003 and in 2010 is shown on Figures 3-4 and 3-5, respectively. The highest historical CT concentration at OU6 (7,000 μg/L) was detected in the sample collected from monitoring well N3-MW15 in 2002 (Table 3-1). The highest historical 1,2-DCA concentration at OU6 (310 μg/L) was detected in the sample collected from monitoring well N3-ASW02B in 2002 (Table 3-1). The highest historical *cis*-1,2-DCE concentration at OU6 (14,000 μg/L) was detected in the sample collected from monitoring well N3-MW21 in 2010 (Table 3-1).

3.3.4 SITE N4 RELEASES

Site N4, the Southern Retention Pond, is unlined and used to manage surface water runoff originating from the southern portion of the NASA DFRC complex (Figure 3-2). The earthen dike delineating the eastern side of the pond no longer prevents surface water flow onto Rogers Dry Lake. During the site inspection (see Section 6.5), Mr. Phil Saxton (AECOM RA Operation and Maintenance Site Manager) noted that in recent years more water appears to flow to the Southern Retention Pond. This is in contrast to Mr. Saxton's observation of a decrease in flow to the Northern Retention Pond (Site N1) discussed in Section 3.3.1. Dan Morgan (NASA DFRC Environmental Manager) confirmed that the increase in outflow to the Southern Retention Pond is a result of a 2006 drainage realignment.

Site N4 includes the former Liquid Oxygen Wash Rack and a concrete ramp that slopes down from the taxiway to the edge of the retention pond. The wash rack was constructed in the 1950s to manage alcohol fuels and hydrogen peroxide from experimental aircraft that were discharged during jettison valve testing and tank purging operations. The wash rack was later used to steam clean aircraft and aerospace ground equipment until it was deactivated in 1991 (Earth Tech, 2000b). Site N4 was suspected to have been potentially contaminated by POL, solvents, aircraft fuels, chromium, alcohol, and hydrogen peroxide as a result of:

- Discharges and spills of POL and solvents in the southern portion of the NASA DFRC complex;
- Steam cleaning of aircraft and aerospace ground equipment;
- Dust control practices that may have involved the application of waste POL;
- Cooling tower blowdown wastewater containing chromium that was discharged to the storm drainage system; and
- Discharges of alcohol fuel and hydrogen peroxide oxidizer during jettison valve testing and tank purging operations.

CT, 1,2-DCA, *cis*-1,2-DCE, and TCE have been detected in samples collected from wells in the Site N4 area at concentrations exceeding their respective cleanup goals (MCLs) of 0.5, 0.5, 6, and 5 μg/L, and are therefore considered COCs. These COCs contribute to the eastern edge of OU6 commingled chlorinated hydrocarbon plume. Recent groundwater monitoring results (see Section 6.4) indicate the portion of the OU6 commingled plume in the southern portion of Site N1 and the northern portion of Site N4 area extends further downgradient than originally defined in the ROD (Earth Tech, 2006) (Figure 3-3).

Due to its presence at high concentrations over a wide area, TCE is used as an indicator for plume delineation and concentration trends in chlorinated hydrocarbons at Site N4. TCE concentrations in samples collected from shallow monitoring well N4-MW05 have ranged from 21 μg/L in 2008 to 76 μg/L in 2007. TCE was only detected in the sample collected from deep monitoring well N4-MW04 in 2010, and the concentration was 53 μg/L. These wells, with a sampling history starting in 2000, are within relatively close proximity to each other, and represent both shallow and deep groundwater, respectively. TCE concentrations in samples collected from monitoring well N4-MW06 (installed in 2004) have exhibited an increasing trend from 100 μg/L in 2005 to 350 μg/L in 2010. TCE trend graphs for monitoring wells N4-MW04, N4-MW05, and N4-MW06 are presented in Appendix A. The OU6 TCE plume as delineated in 2003 and in 2010 is shown on Figures 3-4 and 3-5, respectively. The presence of TCE at leading edge well N4-MW06 is discussed in Section 6.4. The highest historical CT concentration at Site N4 (450 μg/L) was detected in the sample collected from monitoring well N4-MW09 in 2010. The highest historical 1,2-DCA concentration at Site N4 (5.2 μg/L) was detected in the sample collected from monitoring well N4- MW09 in 2010. The highest historical *cis*-1,2-DCE concentration at Site N4 (22 μg/L) was detected in the sample collected from monitoring well N4-MW03 in 2004.

3.3.5 SITE N7 RELEASES

Site N7, Building 4827 Former Drum Storage Areas, is located south of Building 4827 along the southern boundary of the NASA DFRC complex (Figure 3-2). The storage areas were reportedly used for storage of drummed hazardous materials and wastes such as paints, paint thinners, and POL. During a 1992 site visit, drums containing antifreeze, motor oil, and paint primer were observed. The drum storage areas were reportedly used from before 1980 until 1993. A stormwater drainage channel that manages stormwater runoff from Forbes Avenue and the northern portion of the Main Base area, passes north to south through the site.

Historically, CT, *cis*-1,2,-DCE, and TCE concentrations, attributable to on-site sources, exceeded their respective cleanup goals (MCLs) of 0.5, 6, and 5 μg/L in groundwater at Site N7 and are identified as COCs (Table 3-1). Due to its presence at high concentrations over a wide area, TCE is used as an indicator for plume delineation and concentration trends in chlorinated hydrocarbons at Site N7. TCE concentrations in samples collected from shallow monitoring well N7-MW01 have ranged from 15 μg/L in 2006 to 2,000 μg/L in 2003 and in samples collected from deep monitoring well N7-MW02 have ranged from 57 μg/L to 2002 to 300 μg/L in 2003. These wells, with a sampling history starting in 2000, are within relatively close proximity to each other, and represent both shallow and deep groundwater, respectively. The highest historical TCE concentration at Site N7 (2,000 μg/L) was detected in the sample collected from monitoring well N7-MW01 in 2003. TCE trend graphs for monitoring wells N7-MW01 and N7-MW02 are presented in Appendix A. The OU6 TCE plume as delineated in 2003 and in 2010 is shown on Figures 3-4 and 3-5, respectively. The highest historical CT concentration at Site N7 (1.6 μg/L) was detected in the sample collected from monitoring well N7-MW06 in 2002. The highest historical *cis*-1,2,-DCE concentration at Site N7 (1,400 μg/L) was detected in the sample collected from monitoring well N7-MW16 in 2010.

3.3.6 HISTORICAL CONTAMINANT VOLUME ESTIMATES

Although 17 compounds were identified as COCs, two indicator contaminants, benzene and TCE have been used to estimate plume configuration. The earliest estimates of contaminant volume dissolved in groundwater were presented in the FS (Earth Tech, 2004) and were based on concentration contours derived from the 2003 groundwater monitoring events (Figures 3-4 and 3-6). According to the FS, the estimated volumes of benzene and TCE were approximately 0.25 and 49 gallons, respectively. As part of the five-year review process, the plume configurations and related mass/volume calculations were reviewed and slightly revised. The resulting recalculated 2003 totals of benzene and TCE are approximately 0.24 and 48 gallons, respectively. The calculations are presented in Appendix B.

3.4 INITIAL RESPONSE

Potential release locations were initially identified in 1988 and, following Edwards AFB's listing on the NPL on 30 August 1990, the U.S. Air Force entered into a FFA with the USEPA, California DTSC, and CRWQCB in October 1990. The FFA established the process for involving federal and state regulatory agencies and the public in the Edwards AFB remedial response process. It provided a procedural framework for developing, implementing, and monitoring response actions at Edwards AFB in accordance with CERCLA, SARA, the NCP, pertinent provisions of the RCRA, and applicable state laws (Earth Tech, 2000b). Remedial investigations were performed until 1998, and pilot and treatability studies were performed between 1992 and 2005. The FS (Earth Tech, 2004) was completed in August 2004 and made available for review. The Proposed Plan (Earth Tech, 2005) was presented to the public in April 2005. The RA began in May 2005, prior to the signing of the ROD in September 2006 (Earth Tech, 2006). Aircraft-related operations have not been interrupted throughout the CERCLA process and are expected to continue indefinitely.

3.5 SUMMARY OF BASIS FOR TAKING ACTION

Historical chemical usage within OU6 resulted in a groundwater plume that encompasses multiple source areas. Locations of former releases to the environment in OU6 have been designated as Sites N1, N2, N3, N4, and N7. The location and nature of these releases contributed to a single commingled VOC groundwater plume that encompasses all of the source areas and extends from the Site N3 area in the west, east beneath Sites N1, N2, N4, and N7, and eventually reaches Rogers Dry Lake (Figure 3-2).

Risk assessments (Earth Tech, 2003) performed prior to the signing of the ROD did not identify significant risks to human health or the environment under current land use scenarios and only groundwater was considered a medium of concern for future human exposure. However, MCLs are exceeded; exceeding MCLs in groundwater is also considered to represent risk for actual or potential drinking water. Groundwater at OU6 is not currently used for drinking water; thus, potential risks associated with ingestion of COCs in groundwater are reduced by the lack of complete exposure pathways for current land use scenarios. Although there are no current impacts to humans and resources that humans use, or impacts to the environment anticipated, an RA was warranted in order to prevent future human exposure to groundwater contaminant concentrations exceeding regulatory thresholds and to restore the groundwater to its designated beneficial use as drinking water.

COCs and cleanup goals (MCLs) were identified in the ROD (Earth Tech, 2006), and include 17 VOCs. These COCs and their respective historical concentration ranges present at OU6, and respective cleanup goals are presented in Table 3-1 and discussed on a site by site basis in Section 3.3 with figures providing the estimated commingled plume extent (Figures 3-2 and 3-3). The primary target compounds are benzene and TCE, trend graphs for which are presented in Appendix A. The estimated TCE plume extents in 2003 and 2010 are provided on Figures 3-4 and 3-5, respectively. The estimated benzene plume extents in 2003 and 2010 are provided on Figures 3-6 and 3-7, respectively. TCE and benzene concentration variations are further discussed in Section 6.4.

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4.0 REMEDIAL ACTION

4.1 REMEDY SELECTION

As the decision document associated with OU6, the ROD (Earth Tech, 2006) provided the remedy selection with the final version signed on 28 September 2006. The remedial action objectives (RAOs) as presented in the ROD include:

- Restoration of groundwater to its designated beneficial use as drinking water; and
- Prevention of exposure of human receptors to contaminated groundwater until groundwater contaminant concentrations are below MCLs.

The exposure pathways that need to be prevented and/or minimized are groundwater ingestion and dermal contact, and inhalation of groundwater vapors. Though the inhalation pathway includes direct inhalation of vapors from groundwater and indirect inhalation within buildings through the vapor inhalation pathway (VIP), the selected remedy was designed to be protective of direct inhalation only as the risk assessment showed no unacceptable VIP risk requiring action (this is further discussed in Section 7.2.4). The RAOs will be met through the implementation of four RA components:

- Land Use Controls (LUCs): Implement, monitor, maintain, enforce, and report LUCs on groundwater in accordance with the Base GP (Edwards AFB, 2009) and the NASA DFRC MP (Development One, 2009)
- *In Situ* Chemical Oxidation (ISCO): Treatment of high concentration portions of the chlorinated hydrocarbon (primarily TCE) plume via ISCO (Sites N3 and N7 areas)
- Bioremediation: Treatment of high concentration portions of the aromatic hydrocarbon plume (primarily benzene) via enhanced natural attenuation (bioremediation) (Site N3 area)
- Groundwater Monitoring: Demonstrate the effectiveness of natural attenuation in low concentration areas of the groundwater plume (Plume Containment) through periodic groundwater monitoring (Sites N1 and N4 areas), and document reduction in contaminant levels throughout the plume (Sites N1, N2, N3, N4, and N7 areas)

The areas in which the various RA components were targeted for implementation are shown on Figure 4-1.

4.1.1 LAND USE CONTROLS

The RA includes LUC implementation during remediation of contaminated groundwater to restrict residential development (including child development centers, kindergarten through 12th grade schools,

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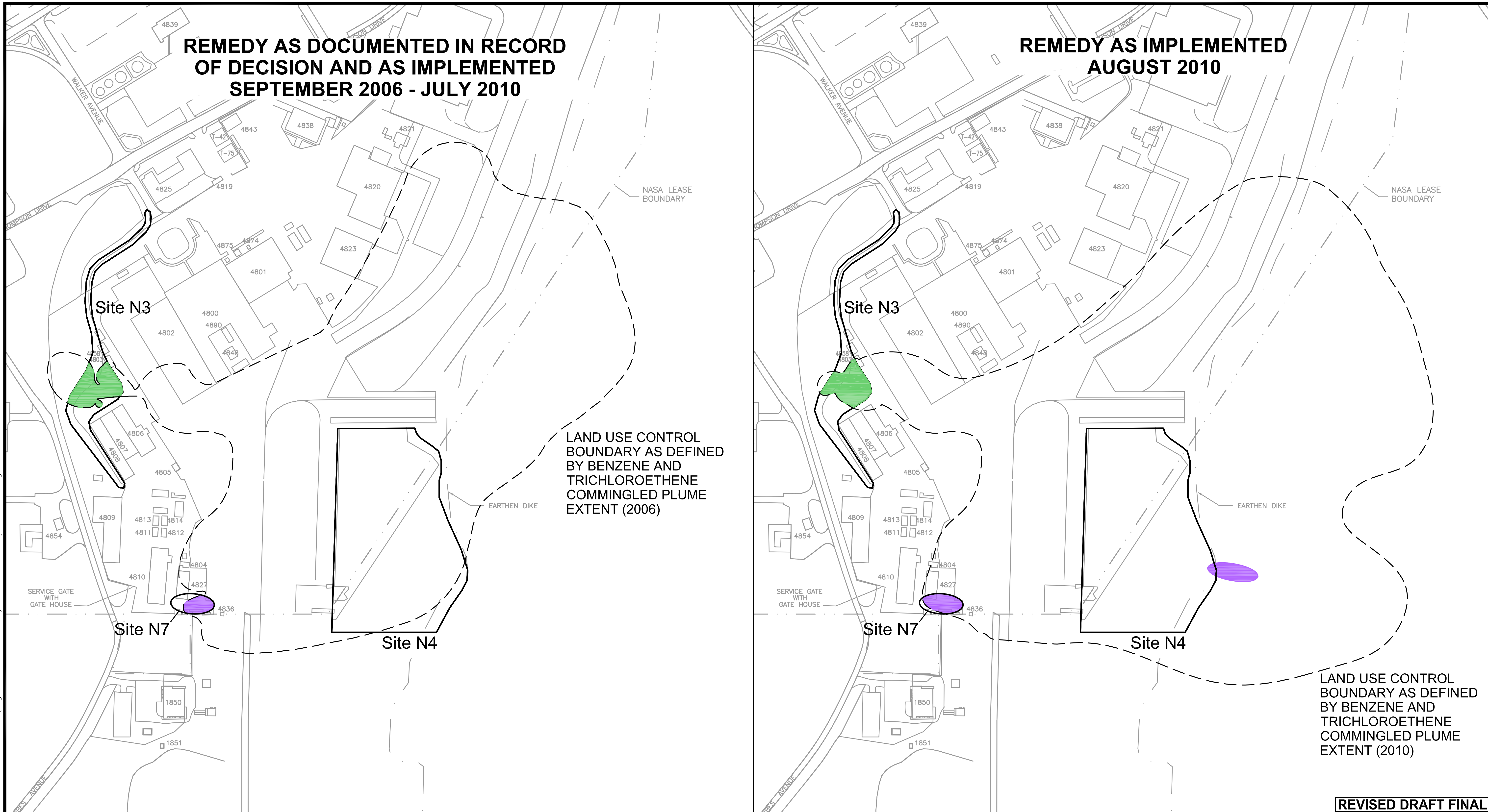

EXPLANATION

LOCATION OF *IN SITU* CHEMICAL OXIDATION, GROUNDWATER MONITORING (TO DOCUMENT TREATMENT PERFORMANCE), AND PLANNED BIOREMEDIATION

LOCATION OF *IN SITU* CHEMICAL OXIDATION AND GROUNDWATER MONITORING (TO DOCUMENT TREATMENT PERFORMANCE)

GROUNDWATER MONITORING AND LAND USE CONTROLS ARE IMPLEMENTED THROUGHOUT THE ENTIRE OPERABLE UNIT.

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Remedy Component Locations

Date 08-2011	Operable Unit 6 First Five-Year Review Report Edwards AFB	Figure
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P:\60133976\WP\90\cad\Revised Draft Final\Figure 4-1 Remedy Locations.dwg – 22 Aug 2011 play areas, and hospitals) where contamination is at levels that do not allow for unlimited use and unrestricted exposure, and to maintain worker safety. Once cleanup levels for groundwater are achieved and indicate that the site is available for unlimited use and unrestricted exposure, LUCs will no longer be maintained, monitored, reported, or enforced. LUCs involving restrictions on residential use were developed to prevent and/or minimize ingestion and dermal contact with groundwater, and direct inhalation of groundwater vapors. LUCs were not specified for the indirect inhalation of groundwater vapors through the VIP into buildings because the risk assessment showed no unacceptable VIP risk for the current industrial use and the residential scenario was not evaluated. The VIP is further discussed in Section 7.2.4.

The complete narrative of LUCs as specified in the ROD is attached as Appendix C.

Key LUC components are listed below:

- Annotating the residential development restrictions in the Base GP (Edwards AFB, 2009) and NASA DFRC (MP Development One, 2009).
- Prohibiting residential development in designated areas set forth in the GP and MP.
- Review and approval procedures for any construction and ground-disturbing activities within the OU6 LUC boundary (Figure 4-2), including construction and dig permits.
- Notifications to state and federal agencies prior to changes in land use or property transfers.
- LUC monitoring and reporting.

NASA DFRC is a secured facility within a military base. LUCs such as the security gate house and fencing shown on Figure 4-2 are intrinsic to the NASA DRFC operations.

Until OU6 is cleaned up to levels appropriate for unlimited use and unrestricted exposure, the Base GP (Edwards AFB, 2009) will reflect the restrictions on development and land use. Upon completion of RA, the Base GP will be updated to modify the site-specific use restrictions as appropriate. The Base GP provides links or references to geographic information system (GIS)-based maps and associated databases for all sites and groundwater contaminant plumes where LUCs are in effect. These GIS-based maps and associated databases and metadata are the primary management tool for implementing, documenting, and managing LUCs, and are webaccessible via Web Map to allow Base personnel to view them. Chemical data from soil and groundwater sampling locations are entered into the GIS as

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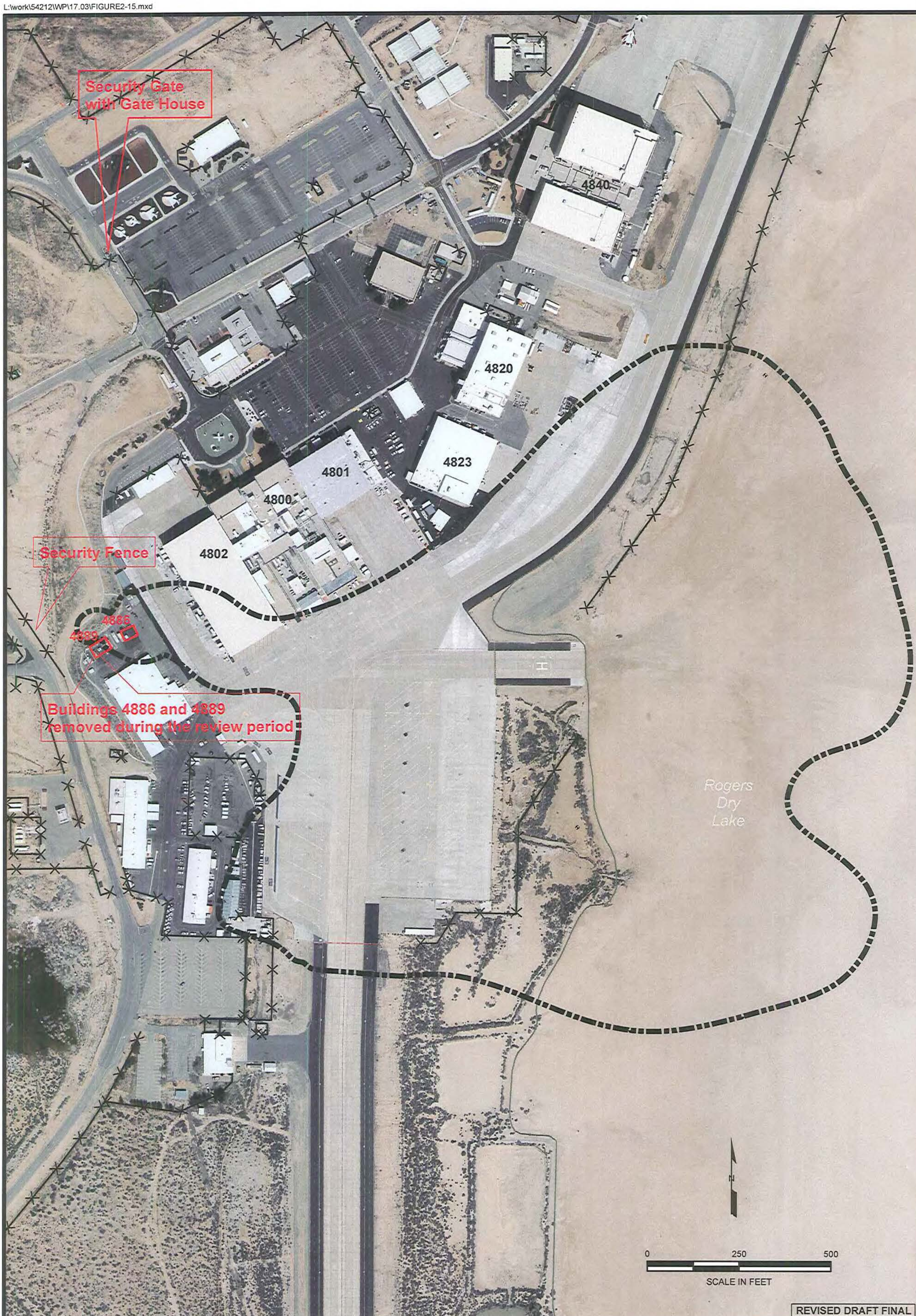
L:\work\54212\WP\17.03\FIGURE2-15.mxd



EXPLANATION

LAND USE CONTROL BOUNDARY BASED ON 2010 CONTAMINANT CONCENTRATIONS

SECURITY FENCE

Operable Unit 6
Land Use Control Boundary

Date 08-2011 Project No. 60133976	**Operable Unit 6** **First Five-Year Review Report** **Edwards AFB**	Figure **4-2**

they are submitted by contractors. Boundary layers indicating the extent of restricted areas are generated by the GIS. Specific information contained within the GIS includes:

- A statement that restrictions are required because of the presence of pollutants or contaminants;
- The current land use of the site;
- The geographic control boundaries; and
- The land use restrictions.

The footprints of areas impacted with COCs are periodically updated in the database from ERP documents. LUC boundaries are based on contamination boundaries, which are updated on a regular basis when new data are available. Restrictions required by the ROD for each layer are either entered into the GIS or referenced by hyperlink to the ROD. Included information describes the required restrictions (such as restrictions on excavation and groundwater use or engineering controls on residential structures), generally allowed uses where applicable, and any specifically required inspections or monitoring (Earth Tech, 2007).

4.1.2 *IN SITU* CHEMICAL OXIDATION

The RA includes ISCO of contaminants at the groundwater plume areas of highest contaminant concentration. ISCO involves the injection of oxidation reagents directly into the subsurface to destroy organic contaminants. Organic contaminants are transformed into constituents such as water and carbon dioxide. A total of 22 existing wells were originally identified for use as injection points for the chemical oxidation reagent (sodium permanganate) at Sites N3 and N7 (Figure 4-1). The injection time intervals, number of events, and RA duration were to be determined based upon field conditions, and the design has been modified as data were compiled. Design modifications are further discussed in Sections 4.2.3 and 4.3.2.3.

4.1.3 BIOREMEDIATION

Bioremediation is a process in which microbes break down hydrocarbons to produce carbon dioxide, water, and, in the case of chlorinated contaminants (e.g., TCE, 1,2-DCA, CT), inorganic salts. Because previous studies have shown that sodium permanganate solution used for ISCO is not effective at treating aromatic hydrocarbons (benzene) and some ethanes (1,2-DCA), portions of the plume impacted by these contaminants will be treated by bioremediation following the completion of the ISCO portion of the RA. Limited-scale bioremediation using a food-grade oxygen-release compound will be employed at some Site N3 wells to accelerate biodegradation of aromatic hydrocarbons.

4.1.4 GROUNDWATER MONITORING

The RA includes groundwater monitoring to track treatment performance in the high-concentration plume areas and to demonstrate the effectiveness of natural attenuation in the low-concentration plume areas. Wells within and outside the plume are monitored to establish that treatment is occurring and to ensure that plume behavior does not change in unexpected ways that might threaten the regional groundwater subbasin. Following ISCO and bioremediation portions of the RA, monitoring will continue to be employed to verify plume containment and document achievement of the cleanup standards and compliance with applicable or relevant and appropriate requirement (ARARs).

4.2 REMEDY IMPLEMENTATION

The RA has been implemented as presented in the Remedial Action Work Plan (RAWP) (Earth Tech, 2008) and RAWP Addendum (AECOM, 2010). Summaries of the activities are presented in Table 4-1 and in the following sections.

4.2.1 LAND USE CONTROLS

The U.S. Air Force and NASA DFRC are responsible for implementing LUCs. NASA DFRC is a secured facility within a military base. LUCs such as the security gate house and fencing shown on Figure 4-2 are intrinsic to the NASA DRFC operations and were in place when the ROD was signed. Due to the mobile nature of the ISCO treatment systems, lack of a permanent treatment compound, and potential impact to mission-critical activities such as aircraft movement, permanent treatment-related signage and fencing are not used. RA activities occur within the NASA DFRC secured area or the secured area maintained by Edwards AFB flightline management.

TABLE 4-1. SUMMARY OF REMEDIAL ACTION ACTIVITIES

	Event	Date	Task	Documentation
	LUCs	September 2006 - Present	Enforcement of LUCs and Annual LUC reporting (Calendar Years 2007 to 2010)	95 ABW/EM, 2008, 2009, 2010, and 2011
Phase I	Pre-ROD baseline monitoring	May 2005	Sampling of 39 wells	Appendix A of the *RAWP* (Earth Tech, 2008)
Phase I	Pre-ROD injection event	June - July 2005	Injection at 12 wells	
Phase I	Pre-ROD well installation	September 2005	Installation of 2 wells	
Phase I	Pre-ROD performance monitoring	August - October 2006	Sampling of 36 wells	
Phase II	Baseline monitoring	October - November 2007	Sampling of 38 wells	IRACR for Phase II Injection Event I of III (Earth Tech, 2009)
Phase II	Injection Event I	March 2008	Injection at 21 wells	
Phase II	Injection well installation	August and December 2008	Installation of 7 wells (4 wells [August] and 3 wells [December])	
Phase II	First performance monitoring	September - October 2008	Sampling of 46 wells	
Phase II	Injection well installation	September 2009	Installation of 3 wells	IRACR for Phase II Injection Event II of III (AECOM, 2011b)
Phase II	Monitoring well installation	May 2010	Installation of 6 wells	
Phase II	Second performance monitoring	June - July 2010	Sampling of 46 wells	
Phase II	Injection Event II	August 2010	Injection at 10 wells	

Notes:

All injections utilized sodium permanganate solution.

First performance monitoring event is documented in the *IRACR for Phase II, Injection Event I of III* and the *IRACR for Phase II, Injection Event II of III*.

95 ABW/EM = 95th Air Base Wing, Environmental Management Directorate
AECOM = AECOM Technical Services, Inc.
Earth Tech = Earth Tech, Inc.
IRACR = Interim Remedial Action Completion Report
LUC = land use control
RAWP = Remedial Action Work Plan
ROD = Record of Decision

Because the Base GP provides links to GIS-based maps and associated databases, the Base GP was annotated to include LUCs specified in the ROD by entering information into the GIS. In 2006, land use restrictions required by the ROD were entered into the GIS by referencing pertinent sections of the ROD via hyperlink. Additionally, the GIS was updated with the geographic control boundary established in the ROD and as shown on the left side of Figure 4-1. The LUC boundary is based on the contamination boundaries that are updated as new data are available. The current LUC boundary is based on 2010 data and is shown on the right side of Figure 4-1 and on Figure 4-2. The Base conducts annual LUC inspections and provides annual LUC reports (Calendar Years 2007 to 2010) to the USEPA, Region IX, California DTSC, and CRWQCB (95th Air Base Wing, Environmental Management Directorate [95 ABW/EM], 2008, 2009, 2010, and 2011).

The NASA DFRC MP was annotated in 2007 to include the following LUC RA-related language (95 ABW/EM, 2008):

> *In September 2006, the U.S. EPA, California Department of Toxic Substance Control, California Regional Water Quality Control Board, the Air Force, and NASA signed a legally binding Record of Decision (ROD) declaring that the soil at the Center has no human health or ecological risks, but that the groundwater is contaminated. The ROD commits NASA to a groundwater cleanup remedy relying primarily on ISCO. In addition, the ROD established land use controls for the entire Center that overlies the contaminated plume. (Refer to Figure 4.3-J for additional plume information.) The LUCs forbid residential, commercial, or school construction in the area. In addition, all excavation in the area is restricted and must be evaluated for potential worker or community hazards and appropriate controls/mitigation preformed. The required evaluation is initiated by the proponent of any excavation at the Center obtaining a Digging Permit from Facilities, which is then reviewed and approved by Code SH Environmental.*

4.2.2 REMEDIAL ACTION WELL INSTALLATION

During the review period, wells were installed in support of both the ISCO and groundwater monitoring components of the RA. Two wells (N3-MW21 and N7-MW14) were installed in September 2005 for use as injection/monitoring points. Four wells (N3-MW22, N3-MW23, N7-MW15, and N7-MW16) were installed in August 2008 and three wells (N3-MW24, N3-MW25, and N3-MW26) were installed in December 2008 as monitoring points, and as potential injection locations. Three wells (N4-MW07, N4-MW08, and N4-MW09) were installed in September 2009 for use as injection points. Six wells (N1-MW10, N1-MW11, N4-MW10, N4-MW11, N4-MW12, and N4-MW13) were installed in May 2010 for use as monitoring points. Well locations are presented on Figure 4-3.

RA activities must be coordinated to minimize impact to mission-critical activities. The majority of the commingled plume is inaccessible to ISCO and groundwater monitoring due to its location below aircraft taxiways and ramps. The LUC boundary indicated on Figure 4-2 coincides with the current commingled plume boundary as understood based on June-July 2010 monitoring results and presents the extent to which the commingled plume is overlain by mission-critical aircraft taxiways and ramps.

4.2.3 *In Situ* Chemical Oxidation

Three ISCO injection events have been performed under the RA and groundwater monitoring wells were used as injection points for the introduction of sodium permanganate solution into the groundwater. Injection completed prior to ROD signing included the first event (Phase I of the RA) at 12 wells between 21 June and 14 July 2005 as reported in Appendix A of the RAWP (Earth Tech, 2008). Two injection events were performed following the signing of the ROD as part of Phase II of the RA. An event was performed at 21 wells between 3 and 13 March 2008 as reported in the *Interim Remedial Action Completion Report* (*IRACR) for Phase II Injection Event I of III* (Earth Tech, 2009), and at 10 wells between 16 and 26 August 2010 as reported in the *IRACR for Phase II Injection Event II of III* (AECOM, 2011b).

The RAWP (Earth Tech, 2008) provided details regarding the injection events to be performed following the signing of the ROD as part of Phase II of the RA. Injection wells for Phase II Injection Event I (March 2008) were selected based upon historical laboratory analytical results for samples collected from wells located in areas of highest TCE concentrations at Sites N3 and N7. Injection well selection for subsequent events was based on the following criteria:

- injection wells utilized during the previous injection event where TCE concentrations above 5 μg/L are present in groundwater
- any wells where TCE concentrations above 300 μg/L are present in groundwater

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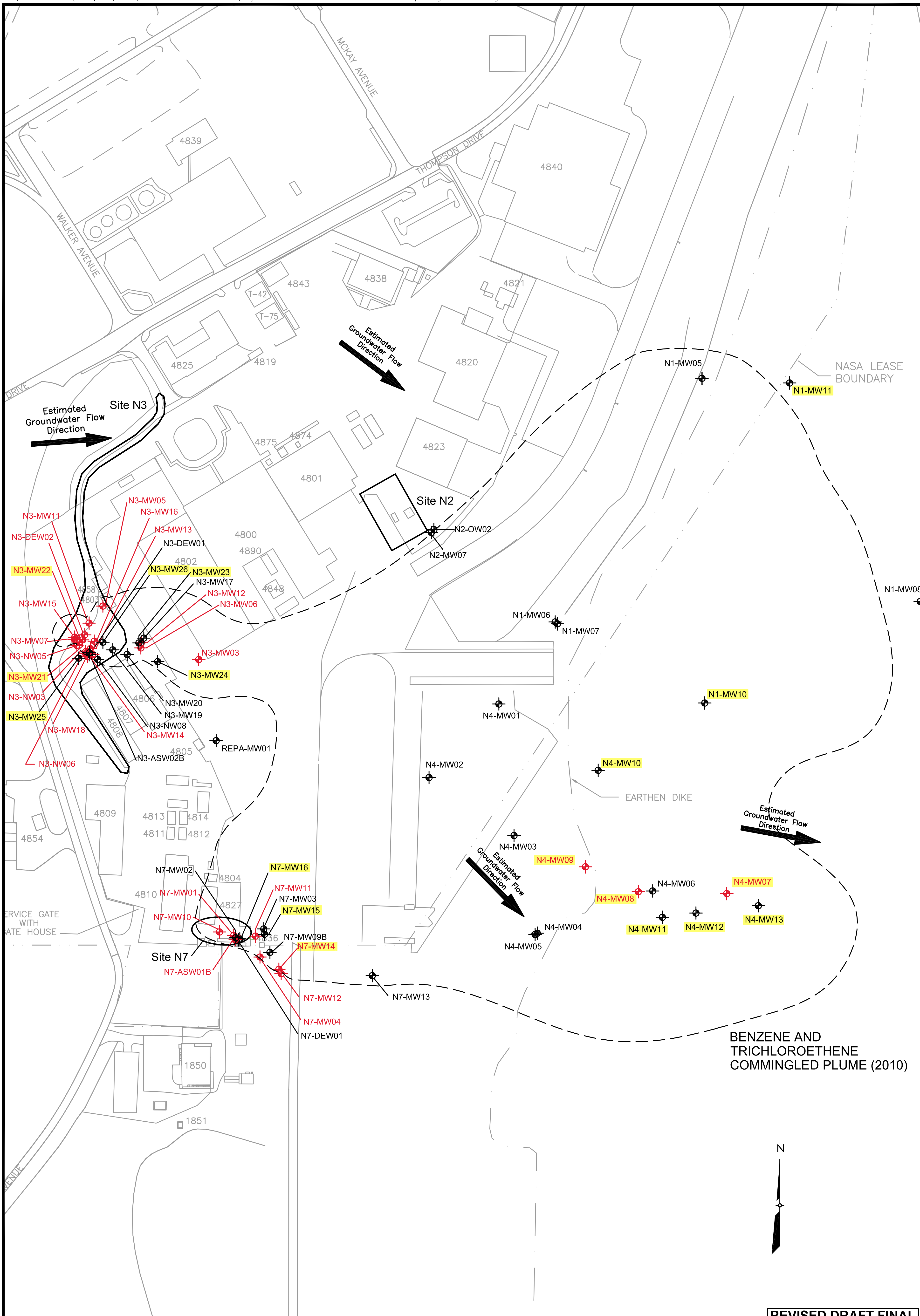

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EXPLANATION

N1-MW10 MONITORING WELL

N3-MW06 MONITORING WELL/INJECTION WELL USED AS INJECTION POINT IN 2005 AND/OR DURING SUBSEQUENT INJECTION EVENTS

NOTES:
HIGHLIGHTED WELLS WERE INSTALLED DURING THE REPORTING PERIOD.
INJECTION WELLS PER EVENT ARE DETAILED IN TABLE 4-2.

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OU6 Plume
Well Location Map

Date 08-2011	**Operable Unit 6** **First Five-Year Review Report** **Edwards AFB**	Figure
Project No. 60133976		**4-3**

The second criterion of targeting locations with TCE concentrations above 300 μg/L resulted in a modification to the ISCO implementation as envisioned in the ROD. As shown on Figure 4-1, the ISCO component of the RA selected in the ROD was to be implemented at Sites N3 and N7, which represented the highest concentration areas of the commingled chlorinated hydrocarbon plume. The RAWP further defined the high concentration areas as areas with TCE concentrations above 300 μg/L. At the time Phase II Injection Event I (March 2008) was implemented, TCE concentrations above 300 μg/L were limited to the Sites N3 and N7 areas. However, prior to Phase II Injection Event II (August 2010), TCE concentrations exceeding 300 μg/L were detected in the Site N4 area and therefore the ISCO component of the RA was implemented at Site N4 in addition to Sites N3 and N7 during the August 2010 injection event (Figure 4-1).

4.2.4 BIOREMEDIATION

Aerobic bioremediation will be implemented at OU6 to enhance the natural attenuation of aromatic hydrocarbons by deploying oxygen release compound filter socks following the completion of all ISCO injection events. ISCO can result in the transformation of organic compounds into daughter products that are more biodegradable than the parent compounds. However, native microbes may be negatively impacted by exposure to chemical reagents with contaminant biotransformation rates limited until aquifer conditions return to pre-ISCO treatment conditions (Earth Tech, 2008). For these reasons, bioremediation will be implemented only after no evidence of residual permanganate exists and post-treatment performance groundwater sample analytical results indicate TCE concentrations are below the cleanup level (5 µg/L). Bioremediation was not implemented during this review period and will be implemented following the completion of the ISCO portion of the RA, likely after the next five-year review period.

4.2.5 GROUNDWATER MONITORING

Groundwater sampling was performed to establish baseline concentrations and to allow for the comparison of contaminant concentrations in groundwater to previous results to evaluate ISCO performance in the high-concentration portions of the plume, and plume stability in the low concentration portions of the plume. Two events were performed prior to the signing of the ROD and three events were performed subsequent to ROD finalization. Pre-ROD baseline monitoring occurred from 10 to 26 May 2005 and a performance monitoring event was completed from 22 August to

3 October 2006. Post-ROD baseline monitoring occurred from 31 October to 21 November 2007, and two performance monitoring events were completed from 16 September to 7 October 2008 and from 22 June to 9 July 2010.

4.3 OPERATION AND MAINTENANCE

The remedial approach does not include traditional operation and maintenance tasks. Instead the RA primarily consists of implementing LUCs and a series of injection and monitoring events using mobile equipment. The relevant details of these activities, wells utilized, costs, effectiveness, and difficulties encountered are presented in the following subsections.

4.3.1 LAND USE CONTROLS

LUC operation and maintenance tasks were related to the Base's GIS. The LUC boundary was revised in the GIS as necessary based on the most recent, vetted, and available sampling results. The LUC boundary was most recently revised to coincide with the 5-µg/L TCE and 1-µg/L benzene isoconcentration contours based on the June-July 2010 monitoring results (Figure 4-2). TCE and benzene are used to define the LUC boundary because these two COCs are present at concentrations above their respective MCLs over the largest area. Review and approval procedures were followed for construction and ground-disturbing activities within the OU6 LUC boundary (95 ABW/EM, 2008, 2009, 2010, and 2011). Security fencing was maintained and patrolled by NASA DFRC as part of daily mission activities.

4.3.2 *IN SITU* CHEMICAL OXIDATION AND GROUNDWATER MONITORING

The ISCO and groundwater monitoring RA components were implemented concurrently during the review period.

4.3.2.1 Phase I Injection Event

During the pre-ROD or Phase I Injection Event (June-July 2005), 16,707 gallons of sodium permanganate solution were introduced into the aquifer by pressurized injections at Sites N3 and N7. Pressurized injections were performed utilizing a mobile treatment unit with the reagent (sodium permanganate) delivered to 12 well heads via reinforced polyethylene tubing. Flow rates ranged from 2 to 8 gallons per minute (gpm) with pressures ranging from 25 to 80 pounds per square inch (Earth

Tech, 2008). Solution concentrations ranged from approximately 2 to 4 percent. TCE concentrations in injections wells (those that accepted pressurized injection of sodium permanganate at flow rates of 6 to 8 gpm) were reduced by approximately 94 percent. A summary of wells used as injection points, and sampled to evaluate the performance of injection events and monitor the low-concentration areas of the commingled plume, is presented in Table 4-2. Well locations are shown on Figure 4-3.

4.3.2.2 Phase II Injection Event I

During the post-ROD or Phase II Injection Event I (March 2008) both gravity-fed and pressurized injection approaches were employed at Sites N3 and N7 due to a decline in pressurized acceptance rates at some previously employed wells. A total of 21 wells were injected with sodium permanganate solution: 14 wells by pressurized injection and 7 by gravity-fed injection. During pressurized injection activities, 12,574 gallons of sodium permanganate solution were injected among 14 wells at concentrations ranging between 2 and 3 percent (Earth Tech, 2009). Gravity-fed injection to the subsurface was conducted by placing a secondarily contained drum of sodium permanganate solution on an elevated platform, plumbing the drum to a well, and allowing gravity to introduce the reagent to the subsurface. Approximately 1,688 gallons of 4 percent sodium permanganate solution were injected among 7 wells.

Post-injection groundwater sampling results from the September-October 2008 monitoring event (conducted 6 months after Phase II Injection Event I) indicated TCE reductions in 22 monitoring wells (out of a total of 37 monitoring wells sampled), with complete TCE destruction likely at an additional 6 monitoring wells. However, sampling results from the June-July 2010 monitoring event (conducted 27 months after Phase II Injection Event I) indicated that TCE concentrations had rebounded to preinjection levels in approximately 5 wells. The increase in concentrations may be the result of untreated groundwater moving into the treatment zone within 6 to 27 months following Phase II Injection Event I.

4.3.2.3 Phase II Injection Event II

During the post-ROD or Phase II Injection Event II (August 2010) only gravity-fed injection was employed at Sites N3, N4, and N7. Sodium permanganate solution was introduced into the subsurface at 10 wells (Table 4-2) using gravity-fed injection techniques (AECOM, 2011b). A total of

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TABLE 4-2. INJECTION AND MONITORING LOCATIONS
(Page 1 of 2)

Well	Monitoring Event May 2005	Phase I Injection Event June-July 2005 (Pre-ROD)	Monitoring Event August–October 2006	Monitoring Event October–November 2007	Phase II Injection Event I March 2008 (Post-ROD)	Monitoring Event September-October 2008	Monitoring Event June-July 2010	Phase II Injection Event II August 2010 (Post-ROD)
N1-MW04	X		X					
N1-MW05	X		X	X		X		
N1-MW06	X		X	X		X		
N1-MW07	X		X	X		X		
N1-MW08	X		X	X		X	X	
N1-MW10							X	
N1-MW11							X	
N2-MW07	X		X	X		X		
N2-OW02	X		X	X		X		
N3-ASW02B				X			X	
N3-DEW01						X		
N3-DEW02	X		X	X	X	X	X	
N3-MW03	X	X	X	X	X	X	X	
N3-MW05					X	X	X	X
N3-MW06	X	X	X	X	X	X	X	
N3-MW07	X	X	X	X	X	X	X	X
N3-MW11	X	X	X	X	X	X	X	
N3-MW12				X		X	X	X
N3-MW13	X		X	X	X	X	X	
N3-MW14	X	X	X	X	X	X	X	
N3-MW15	X		X	X	X	X	X	X
N3-MW16	X	X	X	X	X	X	X	
N3-MW17	X		X	X		X		
N3-MW18	X	X	X	X	X	X	X	
N3-MW19	X		X	X		X		
N3-MW20	X		X	X		X		
N3-MW21				X	X	X	X	X
N3-MW22						X	X	
N3-MW23							X	
N3-NW03	X		X	X	X	X	X	
N3-NW05	X	X	X	X		X	X	
N3-NW06	X		X		X	X	X	
N3-NW08						X		
N4-MW03	X							
N4-MW04							X	
N4-MW05	X			X				
N4-MW06	X			X			X	
N4-MW07							X	X
N4-MW08							X	X
N4-MW09							X	X
N4-MW10							X	
N4-MW11							X	

TABLE 4-2. INJECTION AND MONITORING LOCATIONS
(Page 2 of 2)

Well	Monitoring Event May 2005	Phase I Injection Event June-July 2005 (Pre-ROD)	Monitoring Event August–October 2006	Monitoring Event October–November 2007	Phase II Injection Event I March 2008 (Post-ROD)	Monitoring Event September-October 2008	Monitoring Event June-July 2010	Phase II Injection Event II August 2010 (Post-ROD)
N4-MW12							X	
N4-MW13							X	
N7-ASW01B	X		X		X	X	X	
N7-DEW01	X		X	X		X	X	
N7-MW01	X	X	X	X	X	X	X	
N7-MW02	X			X		X	X	
N7-MW03	X		X	X		X	X	
N7-MW04	X	X	X	X	X	X	X	
N7-MW09B	X		X	X		X	X	
N7-MW10		X		X	X	X	X	X
N7-MW11	X	X	X	X	X	X	X	X
N7-MW12	X		X	X	X	X	X	
N7-MW13	X		X	X		X	X	
N7-MW14			X	X	X	X	X	
N7-MW15						X	X	
N7-MW16						X	X	
REPA-MW01	X		X	X		X	X	

Note:
ROD = Record of Decision

4,950 gallons of 4 percent solution were injected from 16 to 26 August 2010. Post injection sampling results were not available within this review period. A third injection event under Phase II was planned prior Injection Event I at Sites N3 and N7, and installation of additional injection wells and monitoring wells in the Sites N1 and N4 areas delayed implementation of Phase II Injection Event II and consequently delayed Phase II Injection Event III.

4.3.3 COSTS

Actual costs differed significantly from the original costs (Table 4-3) developed in 2003 in the FS and as documented in the ROD, primarily due to a difference in the scheduling of field tasks. The original estimated total cost was $1,194,000. The total operational cost for 5 years is $730,000, which is 39 percent lower than estimated. The cost estimates were based on the assumptions that injection would be started in the first year (fiscal year [FY] 2007), though injection was not implemented until the second year (FY 2008). Estimates assumed that only monitoring would be performed during the second and fourth years (FY 2008 and FY 2010); both injection and monitoring were performed during those years. The persistence of permanganate may also result in the alteration of injection event scheduling. Within the five-year review period, well maintenance consisted of removing plant roots from several lakebed monitoring wells, installing several dedicated low-flow pumps, and repairs to well monuments. These activities were conducted in the fourth and fifth years (FY 2010 and FY 2011) with approximately $26,000 in incurred cost. Cost differences generally resulted from revisions to the remedial approach and schedule, not failures or shortcomings of the remedy.

TABLE 4-3. SUMMARY OF REMEDIAL ACTION OPERATIONAL COSTS

Fiscal Year	Estimated Operational Costs[a]	Actual Operational Costs	Difference	Explanation of Difference Between Actual and Estimated Costs
2007	$434,000	$110,000	$324,000	Injection not implemented in FY 2007 (Year 1).
2008	$184,000	$219,000	-$35,000	Injection and monitoring performed.
2009	$188,000	$61,000	$127,000	Sampling effort was reduced with some funds reallocated to well installation (capital costs).
2010	$192,000	$249,000	-$57,000	Injection and monitoring performed.
2011	$196,000	$91,000	$105,000	Sampling effort was reduced with some funds reallocated to five-year review effort (performed in FY 2011 (Year 5) as opposed to FY 2012 (Year 6) as originally estimated).
Total	$1,194,000	$730,000	$464,000	

Notes:

The remedial action does not include traditional operation and maintenance tasks. Estimated and actual operational costs are associated with injection operations, monitoring, and site control activities.

Estimated and actual operational costs are rounded to the nearest $1,000.

[a] Estimated costs as presented in the Record of Decision (Earth Tech, 2006).

FY = fiscal year

5.0 PROGRESS SINCE LAST REVIEW

This is the first five-year review for OU6.

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6.0 FIVE-YEAR REVIEW PROCESS

6.1 ADMINISTRATIVE COMPONENTS

The remedial project managers (RPMs) were notified of the initiation of the five-year review process during the 18 November 2010 Restoration Advisory Board (RAB) meeting. The RPMs are representatives of the U.S. Air Force, USEPA, California DTSC, and CRWQCB that manage response actions at Edwards AFB in accordance with CERCLA. The U.S. Air Force is the lead agency. Members of the five-year review team include the U.S. Air Force, NASA DFRC, CRWQCB, and support contractors. Members of the U.S. Air Force involved in the review include Mr. Ai Duong (RPM) and Mr. Tom Merendini (OU6 project manager). Mr. Dan Morgan (NASA DFRC Environmental Manager) conducted the site inspection. Mr. Tim Post (CRWQCB RPM) participated in the site inspection. Mr. Albert Chang (TYBRIN Corporation [Air Force contractor]) conducted the inspection of the GIS. Ms. Jennifer Martin (MECx [NASA contractor]) performed data review of the dig permits. AECOM (NASA contractor) staff that participated in the site inspection, conducted interviews, and provided data review include Mr. Todd Battey, Ms. Kimberly Coleman, Mr. Phil Saxton, Mr. Mark Jackson, and Mr. Ray Kaminsky.

Development of the review schedule occurred from 3 to 30 November 2010 and a revision of that schedule occurred on 11 February 2011 determining 28 September 2011 as the five- year review report submittal date. The review includes the following components:

- Community involvement;
- Document review;
- Data review;
- Site inspection;
- Interviews; and
- Five-year review report development and review.

6.2 COMMUNITY INVOLVEMENT

The Community Relations Plan (JT3/CH2M HILL, 2008) for Edwards AFB provides a framework for making information fully and readily available to on- and off-base communities; establishing two-way communication between Edwards AFB and the public; responding to community concerns and needs that may arise during Base cleanup efforts; and fulfilling the Department of Defense and Air Force objective of "maximum disclosure with minimum delay." The RAB was established in January 1995 to promote community awareness. OU6 RA status updates have historically been provided to the RAB on a quarterly basis. However, as of March 2011, the RAB is held on a semiannual basis, and therefore the OU6 RA status updates will be provided semiannually.

The community was notified of the initiation of the five-year review process during the 18 November 2010 RAB meeting with an update provided during the February 2011 RAB meeting. An announcement was published in the May 2011 edition of the "Dryden X-Press" newsletter providing contact information available to address questions and/or comments. A summary of results is planned to be published in the October 2011 edition. The final version of the Five-Year Review Report will be placed in the public repositories located at the Colonel Vernon P. Saxon, Jr. Aerospace Museum in Boron, California; the Edwards AFB Library on Base; the Kern County Public Library in Rosamond, California; and the Los Angeles County Public Library in Lancaster, California.

6.3 DOCUMENT REVIEW

This five-year review included a review of relevant documents as presented in Table 6-1. ARARs, as listed in the ROD, were also reviewed (Appendix D).

6.4 DATA REVIEW

This section provides a review of dig permits as they relate to the LUC remedy component. Because the groundwater monitoring component of the RA was implemented in part to evaluate the performance of the ISCO RA component, a review of groundwater monitoring data is also presented.

6.4.1 LAND USE CONTROLS DATA REVIEW

As discussed in Section 4.1.1, the LUC remedy component includes approval procedures for all construction and ground-disturbing activities within the OU6 LUC boundary (Figure 4-2), including construction and dig permits. Dig permit data for excavations within this review period are tabulated in Table 6-2. Whether excavations are within the LUC boundary, the purpose/objectives for each of the excavations, and the excavation depths are provided.

TABLE 6-1. DOCUMENTS REVIEWED

Document	Reference	Purpose of Document	Use During the Five-Year Review
Feasibility Study	Earth Tech, 2004	Analysis of alternatives for the remedial approach	RA approach, plume configurations, and mass/volume calculations
Record of Decision	Earth Tech, 2006	Documentation of remedial decision	Goals of the remedy, site background, basis for action, cleanup levels, and ARARs
Remedial Action Work Plan	Earth Tech, 2008	RA design	Modifications to the RA for comparison to original assumptions
Remedial Action Work Plan Addendum	AECOM, 2010	RA design	Modifications to the RA for comparison to original assumptions
Basewide LUC Implementation Plan	Earth Tech, 2007	Basewide LUC implementation	LUC implementation
Annual LUC Report	95 ABW/EM, 2008	LUC status documentation	Status of LUCs for 2007 Calendar Year
Annual LUC Report	95 ABW/EM, 2009	LUC status documentation	Status of LUCs for 2008 Calendar Year
Annual LUC Report	95 ABW/EM, 2010	LUC status documentation	Status of LUCs for 2009 Calendar Year
Annual LUC Report	95 ABW/EM, 2011	LUC status documentation	Status of LUCs for 2010 Calendar Year
Interim Remedial Action Completion Report, Injection Event I of III	Earth Tech, 2009	RA design, construction, and functionality of the RA, and documentation of progress to completion.	History of the RA, plume status, and performance versus expectations information
Interim Remedial Action Completion Report, Injection Event II of III	AECOM, 2011b	RA design, construction, and functionality of the RA, and documentation of progress to completion.	History of the RA, plume status, and performance versus expectations information

Notes:

95 ABW/EM = 95th Air Base Wing, Environmental Management Directorate
AECOM = AECOM Technical Services, Inc.
ARAR = applicable or relevant and appropriate requirement
Earth Tech = Earth Tech, Inc.
LUC = land use control
RA = remedial action

TABLE 6-2. EXCAVATION ACTIVITIES

Date Required	Inside LUC boundary (Yes/No)	Location	Type of Project	Excavation Depth (feet)	PPE Required (Yes/No)
Mission-Related Excavations					
2/25/2008	No	New Substation	Trenching for Electric Substation	3	No
3/27/2008	No	Bldg. 4841	Excavate New Duct Bank	3	No
3/27/2008	No	Substation 3	Excavating for New Duct Bank and Substation.	3	No
5/1/2008	No	Bldg. 4838	Upgrade Electrical Distribution System Phase IV	3	No
5/21/2008	No	Bldg. 4839	Trench for Solar Panel Communication	1.7	No
6/18/2008	No	Bldg. 4838	Excavate Utility Trench for Electrical Duct Bank and Maintenance Hole	3	No
6/23/2008	No	Road leading to ATF	Demolish Existing Asphalt Pavement	0.7	No
6/23/2008	No	Thompson Drive	Excavate Utility Trench for Storm Drain Pipe	0.7	No
7/14/2008	No	Bldg. 4872 Substation 16	Drilling for Soils Investigation for new Substation	1.7	No
8/26/2008	No	Bldg. 4876, Lily Ave., Various aircraft ramp locations	Drilling for Soils Investigation for new Substation	3	No
10/9/2008	No	Bldg. 4825	Install cables to support gates	3	No
10/28/2008	No	Bldg. 4838 and Substation 26	Electrical System Distribution Upgrades Phase IV	3	No
1/5/2009	No	Various DFRC Locations	Fire Water Mains Project	3	No
1/5/2009	Yes	Lilly Ave., Bldg. 4876, Walker Ave. And various Aircraft Ramps	Repair DFRC Storm Drainage Facilities	3	No
1/5/2009	No	Bldg. 4838	Upgrade Electrical Distribution System Phase IV	3	No
1/28/2009	No	Bldg. 4826 and Lakebed Ramp Shoulders	Trenching for New Storm Drain Pipe	2	No
3/23/2009	No	Lilly Ave.	Repair DFRC Storm Drainage Facilities.	3	No
3/31/2009	No	Bldg. 4838	Relocation of conduits feeding Bldg. 4838 Substation 26	3	No
4/6/2009	No	Bldg. 4849	Demolish Bldg. 4849	1	No
4/22/2009	No	Bldg. 4841	Replacement of fire hydrant isolation valves	6	No
6/8/2009	Yes	Bldgs. 4820, 4823, 4801, 4802 aircraft ramps	Repair of Aircraft Ramps Various Locations	2	No
6/24/2009	No	Bldg. 4824	Repair Storm Drains	2	No

TABLE 6-2. EXCAVATION ACTIVITIES
(Page 2 of 3)

Date Required	Inside LUC boundary (Yes/No)	Location	Type of Project	Excavation Depth (feet)	PPE Required (Yes/No)
Mission-Related Excavations (continued)					
6/29/2009	No	Bldg. 4838	Construct McKay Avenue Extension	3	No
8/3/2009	No	Bldg. 4847	Install giant voice pole with fixtures	10	No
8/3/2009	Yes	Ramps Bldg. 4802	Demo and grind asphalt ramps - Westside Bldg. 4802	2	No
8/4/2009	No	Bldg. 4833 and Bldg. 4835	Drill ground source heat pump test well	800	No
8/11/2009	Yes	Substation 13	Repair Substation 13	0.5	No
8/24/2009	No	Bldg. 4825 Gate 1	Hand dig for buried conduit and excavate location of new swing arm barricade	2	No
8/31/2009	No	Bldgs. 4840 and 4821 vegetation next to Tow way	Repair DFRC Storm Drainage near Shuttle Area	0.5	No
9/2/2009	Yes	Life Support	Connect new Sewer Line	3	No
9/23/2009	No	Bldg. 4982	New foundation and underground conduits for new transformer pad	3	No
9/23/2009	No	Gate 5	Install new conduit and concrete at Gate 5 for new wheel	2	No
10/22/2009	No	Bldg. 4839	Underground replacement of elbows and new switch gear concrete pad	3	No
11/6/2009	No	Facilities Support Center	Drilling for geotechnical investigation of soils	25	No
12/14/2009	No	CITC	Pot holing for utilities	3	No
12/16/2009	No	Various DFRC Locations Bldg. 703	Geotechnical soil sample collection	5	No
12/21/2009	No	CITC	Utility Trenching	3	No
3/1/2010	No	Gate 51 along McKay Ave	Identify utility lines to support building badge readers	3	No
3/8/2010	No	Hydrant numbers 18, 25, 26	Modify fire lines to supporting hydrants	2	No
6/1/2010	No	Bldg. 4854	Demolish asphalt, fuel tanks, pipes, chain link fence and posts. Old fuel station	3	No
8/4/2010	No	LRO	Install underground conduit	2	No
9/7/2010	No	DAOF	Remove asphalt to install new concrete footings	2	No
9/7/2010	No	Bldg. 4824	Connect Bldg. 4824 to sanitary sewer	NA	No
9/14/2010	No	Water Tank NB-108	Expose water pipe that supplies water to tank NB-108	4	No

TABLE 6-2. EXCAVATION ACTIVITIES
(Page 3 of 3)

Date Required	Inside LUC boundary (Yes/No)	Location	Type of Project	Excavation Depth (feet)	PPE Required (Yes/No)
Remedy-Related Excavations					
8/2008	Yes	Sites N3 and N7	Installation of wells N3-MW22, N3-MW23, N7-MW15, and N7-MW16	100 to 103	Yes
12/2008	Yes	Site N3	Installation of wells N3-MW24, N3-MW25, and N3-MW26	100 to 103	Yes
9/2009	No	Site N4	Installation of wells N4-MW07, N4-MW08, and N4-MW09	100	Yes
5/2010	No	Sites N1 and N4	Installation of wells N1-MW10, N1-MW11, N4-MW10, N4-MW11, N4-MW12, and N4-MW13	27 to 30	Yes

Notes:

Well installations were components of the remedy.
Shaded rows indicate that activities were performed in 2009.

ATF = Aeronautical Tracking Facility
Ave. = avenue
Bldg. = building
CITC = Consolidated Information Technology Center
DAOF = Dryden Aircraft Operations Facility
LRO = Long-Range Optics
LUC = land use control
NA = not available
PPE = personal protective equipment

As discussed in Section 4.3.1, the LUC boundary is revised in the GIS as necessary based on the most recent, vetted, and available sampling results. The LUC boundary was most recently revised to coincide with the 5-µg/L TCE and 1-µg/L benzene isoconcentration contours based on the June-July 2010 monitoring results (Figure 4-2). TCE and benzene concentrations in groundwater are used to define the LUC boundary because, based on MCL exceedances, these two plumes exhibit the largest aerial extent. The LUC boundary as defined in the ROD (Figure 4-1) was implemented during all excavations performed within this review period (the activities are presented in Table 6-2). Based on June-July 2010 monitoring results, the LUC boundary was revised and expanded to the east, encroaching upon Rogers Dry Lake (Figure 4-1). All mission-related excavations within this review period occurred on the western portion of the facility where the plume footprints and LUC boundary have remained relatively constant. No mission-related excavations occurred in the eastern portion of the LUC boundary area where the expansion occurred. Because there are no utilities or buildings in the eastern portion of the plume, and since Rogers Dry Lake is considered part of the flightline, it is also unlikely that any future mission-related excavations will be performed in the LUC boundary expansion area. Remedy-related excavations did occur inside the LUC boundary expansion area; however, personal protective equipment (PPE) was employed during the efforts.

6.4.1.1 Calendar Year 2007

Dig permits for Calendar Year 2007 were not available for review. However, the 2007 annual LUC report (95 ABW/EM, 2008) documented the following excavations:

- Soil composition boreholes for a new building were drilled approximately 1,600 feet outside the LUC boundary. Due to the proximity to the LUC area, drill rig personnel were cautioned to shut down activities and notify Code Safety Health in the event groundwater or any unusual odors were encountered (no groundwater was encountered and there were no unusual odors).
- A shallow trench was excavated at Site N3. Workers were required to wear PPE and to stop work if groundwater was encountered (no groundwater was encountered).

The soil composition boreholes were drilled to obtain geotechnical data for new building construction. Site N3 is one of the areas in which the ISCO component of the remedy has been implemented (Figure 4-1). The trenching activities at Site N3 did not impact ISCO activities or damage monitoring/injection wells.

6.4.1.2 Calendar Year 2008

Both mission-related and remedy-related excavation activities were performed in 2008 (Table 6-2). None of the 12 mission-related excavations conducted in 2008 were advanced within the LUC boundary (as defined in the ROD), none exceeded a depth of 3 feet, and none encountered groundwater, which occurs at depths greater than 5 feet. The purpose of the July and August 2008 drilling activities was to generate geotechnical data for new construction and none of the mission-related excavation activities impacted the remedy. Remedy-related activities included the installation of wells N3-MW22, N3-MW23, N3-MW24, N3-MW25, N3-MW26, N7-MW15, and N7-MW16 as discussed in Section 4.2.2. Excavation activities performed in 2008 are further documented in the 2008 annual LUC report (95 ABW/EM, 2009).

6.4.1.3 Calendar Year 2009

Both mission-related and remedy-related excavation activities occurred in 2009 (Table 6-2). Of the 25 mission-related excavations conducted in 2009, 5 occurred within the LUC boundary (as defined in the ROD). The 5 mission-related excavations did not exceed 3 feet deep and groundwater was not encountered. Of the 20 mission-related excavations occurring outside of the LUC boundary, 5 excavations equaled or exceeded 5 feet deep and may have encountered groundwater. However, these activities were performed in the western portion of the facility where the plume is well delineated and the LUC boundary is well-defined. As these activities were performed outside the boundary, it is unlikely contaminated groundwater was encountered. Two flush-mount completion well boxes for RA injection/monitoring wells were replaced as part of the paving project associated with the 8 June 2009 aircraft ramp repair. Well integrity was not affected. None of the mission-related excavation activities impacted the remedy. Remedy-related activities included the installation of wells N4-MW07, N4-MW08, and N4-MW09 as discussed in Section 4.2.2. Excavation activities performed in 2009 are further documented in the 2009 annual LUC report (95 ABW/EM, 2010).

6.4.1.4 Calendar Year 2010

Both mission-related and remedy-related excavation activities were performed in 2010 Table 6-2. None of the 7 mission-related excavations conducted in 2010 occurred within the LUC boundary (as defined in the ROD). None of the excavations exceeded 4 feet deep and groundwater was not encountered. None of the mission-related excavation activities impacted the remedy. Remedy-related activities included the installation of wells N1-MW10, N1-MW11, N4-MW10, N4-MW11, N4-MW12, and N4-MW13 as discussed in Section 4.2.2. Excavation activities performed in 2010 are further documented in the 2010 annual LUC report (95 ABW/EM, 2011).

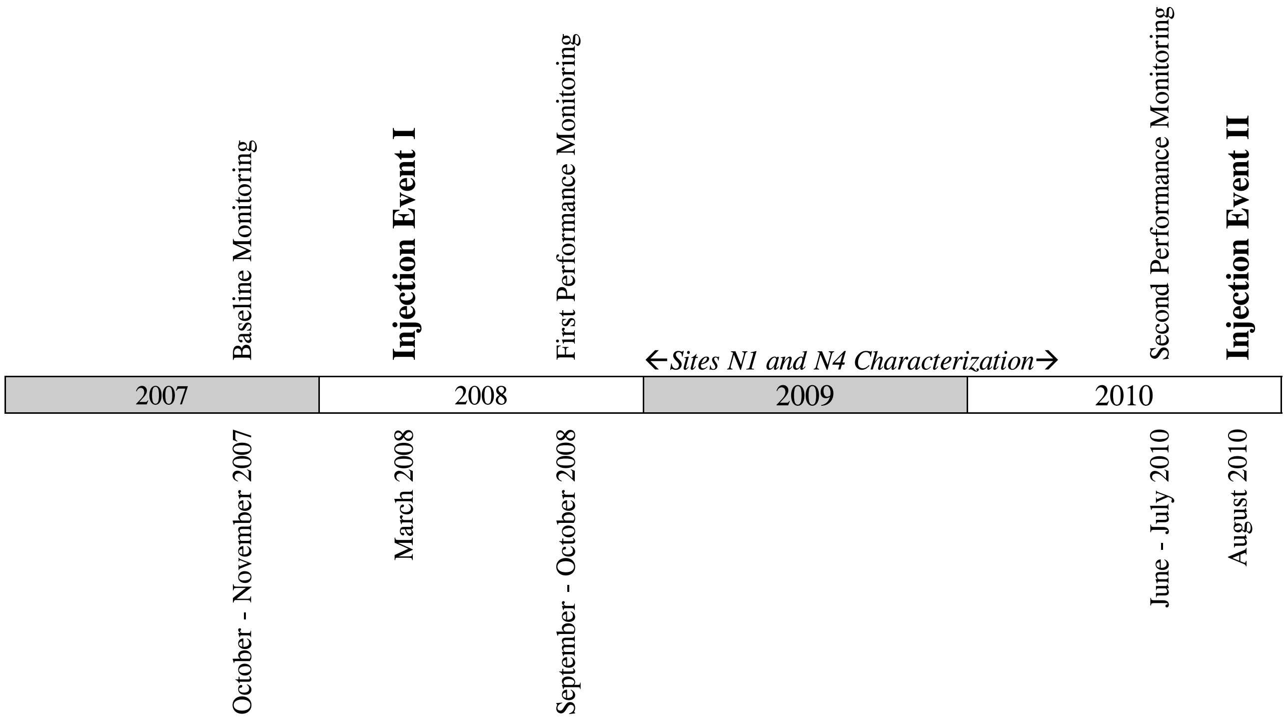
6.4.2 *IN SITU* CHEMICAL OXIDATION AND GROUNDWATER MONITORING DATA REVIEW

The groundwater monitoring component of the RA was implemented to evaluate the performance of the ISCO RA component in high concentration areas (defined as areas with TCE concentrations greater than 300 μg/L) and to evaluate the concentration trends in low concentration areas (defined as areas with TCE concentrations less than 300 μg/L). This section provides a review of groundwater monitoring data.

Laboratory analytical data were reviewed for groundwater samples collected from groundwater monitoring wells during monitoring events performed in October-November 2007, September-October 2008, and June-July 2010. A timeline for activities performed within the review period is presented on Figure 6-1. Prior to the signing of the ROD, one injection event (Phase I) was performed in June-July 2005, and influenced the 2007 monitoring event results. Additional injection events as part of Phase II of the RA were performed in March 2008 (Injection Event I) and August 2010 (Injection Event II). Performance monitoring associated with Injection Event I was performed in September-October 2008 and June-July 2010. Performance monitoring associated with Injection Event II was performed in March - April 2011; however, sampling results will not be available within this five-year review period.

An overview of the June-July 2010 analytical results, which are the most recent results available within this five-year review period, and TCE concentration comparisons between monitoring events are presented in the following subsections. Data collected in 2003 were the basis for the remedies developed in the FS (Earth Tech, 2004) and the final remedy selection in the ROD (Earth Tech, 2006) and, therefore, were included as the baseline for the data review comparisons.

FIGURE 6-1. TIMELINE OF MONITORING AND INJECTION



6.4.2.1 Review of 2010 COC Monitoring Results

The most recent monitoring results (June-July 2010) within the review period indicate that, of the 17 VOCs identified in the ROD as COCs for OU6 (Table 3-1), 13 were detected in the groundwater samples. All of the 13 COCs were detected at concentrations exceeding their respective cleanup goals (MCLs). The four COCs not detected in any of the June-July 2010 samples were 1,1-dichloroethane, 1,2-dichloropropane, 1,1,2-trichloroethane, and vinyl chloride. A comparison of the maximum organic analyte concentrations detected in groundwater during the June-July 2010 performance monitoring event to cleanup goals is presented in Table 6-3 and detailed results are presented in the IRACR (AECOM, 2011b).

TABLE 6-3. MAXIMUM ORGANIC ANALYTE CONCENTRATIONS DETECTED IN GROUNDWATER COMPARED TO CLEANUP GOALS – SECOND PERFORMANCE MONITORING EVENT – JUNE-JULY 2010

Parameter	Maximum Concentration[a] (µg/L)	Location of Maximum Concentration	Cleanup Goal (CG)[b] (µg/L)	No. of Samples Exceeding CG/Total No. of Samples
Volatile Organic Compounds				
benzene	7,000	N3-MW14	1	17/51
carbon tetrachloride	4,000	N3-MW22	0.5	19/51
chloroform	2,100	N3-MW22	80[c]	7/51
1,2-dibromoethane[c]	13	N3-MW16	0.05	2/51
1,2-dichloroethane	130	N3-ASW02B	0.5	18/51
cis-1,2-dichloroethene	14,000	N3-MW21	6	24/51
trans-1,2-dichloroethene	17	N7-MW16	10	1/51
ethylbenzene	1,500	N3-MW21	300	3/51
methylene chloride	65	N3-MW22	5	5/51
1,1,2,2-tetrachloroethane	42 Ja	N3-MW22	1	1/51
toluene	5,400	N3-MW21	150	3/51
trichloroethene	20,000	N3-MW15	5	33/51
xylenes, total	7,300	N3-MW21	1,750	*1/51*
m- & p-xylene	3,800	N3-MW21	1,750[d]	*1/51*
o-xylene	3,500	N3-MW21	1,750[d]	*1/51*

Notes:

Contaminants of concern 1,1-dichloroethane, 1,2-dichloropropane, 1,1,2-trichloroethane, and vinyl chloride were not detected.
[a] Maximum concentration does not include previous investigations.
[b] Cleanup goals established for Operable Unit 6 are based on the primary maximum contaminant level (MCL).
[c] 1,2-dibromoethane is also known as ethylene dibromide.
[d] MCL for total xylenes.
µg/L = micrograms per liter
Ja = detected above the detection limit but less than the reporting limit, considered quantitatively uncertain
No. = number

6.4.2.2 Event-Specific TCE Concentration Variations

TCE has been used as an indicator compound during the project to assess ISCO progress. TCE concentration comparisons between monitoring events are presented in the following subsections.

Monitoring Events 2003 and 2007 Comparison

The data collected during the 2003 monitoring event were the basis for the remedies developed in the FS (Earth Tech, 2004) and the final remedy selection in the ROD (Earth Tech, 2006), and the data collected during the 2007 monitoring event represent site conditions following the Phase I Injection Event (2005). Comparing the TCE data from the 2003 and 2007 monitoring events provides a means of evaluating the performance of the Phase I Injection Event (2005). Of the 29 wells sampled during both the 2003 and 2007 monitoring events, results from 23 wells showed reductions in TCE concentrations. Table 6-4 presents TCE concentration variations in samples collected from wells included in both monitoring events.

Monitoring Events 2007 and 2008 Comparison

The data collected during the 2007 monitoring event represent baseline site conditions for Phase II Injection Event I implementation (March 2008) and 2008 monitoring event (September-October 2008) data represent site conditions following the Phase II Injection Event I (March 2008). Comparing the TCE data from the 2007 and 2008 monitoring events provides a means of evaluating the performance of the Phase II Injection Event I. Of the 37 wells sampled during both the 2007 and 2008 monitoring events, results from 22 wells showed reductions in TCE concentrations (Table 6-5). Complete TCE destruction was likely at wells N3-DEW02, N3-MW06, N3-MW18, N7-MW01, N7-MW12, and N7-MW14 due to the presence of very high levels of permanganate ions in the 2008 samples. However, matrix interference related to chemical interference in these samples with very high levels of permanganate ions resulted in the rejection of TCE data during the data validation process.

Monitoring Events 2008 and 2010 Comparison

The data collected during the 2008 and 2010 monitoring events represent site conditions following the Phase II Injection Event I (March 2008). The 2008 and 2010 monitoring events followed the Phase II Injection Event I by 6 and 27 months, respectively. Comparing the TCE data from the 2008 and 2010

TABLE 6-4. TCE CONCENTRATION VARIATIONS – 2003 TO 2007

	TCE Concentration		Approximate Decrease 2003 to 2007	
Well	2003 Monitoring Event[(a)] (µg/L)	2007 Monitoring Event[(b)] (µg/L)	µg/L	Percent
N1-MW05	5.1	20	-14.9	-292.2
N1-MW06	260	100	160	61.5
N1-MW07	280	130	150	53.6
N1-MW08	0.37	1.9	-1.53	-413.5
N2-MW07	26	25	1	3.8
N2-OW02	16	1.6	14.4	90.0
N3-DEW02	7,700	1,200	6,500	84.4
N3-MW03	540	**100**	**440**	**81.5**
N3-MW06	1,900	**1,200**	**700**	**36.8**
N3-MW07	8,400	**2,200**	**6,200**	**73.8**
N3-MW11	14	**<1**	**14**	**100**
N3-MW12	960	730	230	24.0
N3-MW13	39	260	-221	-566.7
N3-MW15	4,600	20,000	-15,400	-334.8
N3-MW16	130	**17**	**113**	**86.9**
N3-MW17	600	430	170	28.3
N3-MW18	1.5	**<1**	**1.5**	**100**
N3-NW03	180	<40	180	100
N3-NW05	6,100	**180**	**5,920**	**97.0**
N4-MW05	71	76	-5	-7.0
N7-MW01	2,000	**1,900**	**100**	**5.0**
N7-MW02	280	180	100	35.7
N7-MW03	350	240	110	31.4
N7-MW04	200	**150**	**50**	**25.0**
N7-MW09B	150	27	123	82.0
N7-MW11	160	**3**	**157**	**98.1**
N7-MW12	1,100	380	720	65.5
N7-MW13	51	44	7	13.7
REPA-MW01	<1	<1	---	---

Notes:

Bold indicates that the well was used as an injection point during the Phase I Injection Event (2005).
Negative numbers indicate a concentration increase.
Only wells sampled during both events are included.
[(a)] Performed in March 2003.
[(b)] Performed in October-November 2007.
< = less than
µg/L = micrograms per liter
TCE = trichloroethene

TABLE 6-5. TCE CONCENTRATION VARIATIONS – 2007 TO 2008

Well	TCE Concentration 2007 Monitoring Event[(a)] (µg/L)	TCE Concentration 2008 Monitoring Event[(b)] (µg/L)	Approximate Decrease 2007 to 2008 µg/L	Approximate Decrease 2007 to 2008 Percent
N1-MW05	20	9.8	10.2	51
N1-MW06	100	100	0	0
N1-MW07	130	150	-20	-15.4
N1-MW08	1.9	1.8	0.1	5.3
N2-MW07	25	9.7	15.3	61.2
N2-OW02	1.6	0.71	0.89	55.6
N3-DEW02	1,200	**Rejected**	**---**	**---**
N3-MW03	**100**	**1.3**	**98.7**	**98.7**
N3-MW06	**1,200**	**Rejected**	**---**	**---**
N3-MW07	**2,200**	**<1**	**2,200**	**100**
N3-MW11	**<1**	**<10**	**---**	**---**
N3-MW12	730	630	100	13.5
N3-MW13	260	**67**	**193**	**74.2**
N3-MW14	**<250**	**<50**	**---**	**---**
N3-MW15	20,000	**<5**	**20,000**	**100**
N3-MW16	**17**	**<1**	**17**	**100**
N3-MW17	430	<1	430	100
N3-MW18	**<1**	**Rejected**	**---**	**---**
N3-MW19	<5	<1	---	---
N3-MW20	9.3	<5	4	100
N3-MW21	19,000	**<10**	**19,000**	**100**
N3-NW03	<40	**18**	**-18**	**-100**
N3-NW05	**180**	<5	**175**	**100**
N4-MW05	76	21	55	72.4
N4-MW06	270	280	-10	-3.7
N7-DEW01	560	<25	535	100
N7-MW01	**1,900**	**Rejected**	**---**	**---**
N7-MW02	180	<10	170	100
N7-MW03	240	100	140	58.3
N7-MW04	**150**	**<20**	**130**	**100**
N7-MW09B	27	<25	2	100
N7-MW10	**<1**	**1.5**	**-1.5**	**-100**
N7-MW11	**3**	**<1**	**3**	**100**
N7-MW12	380	**Rejected**	**---**	**---**
N7-MW13	44	42	2	4.5
N7-MW14	210	**Rejected**	**---**	**---**
REPA-MW01	<1	<1	---	---

Notes:

Bold indicates that the well was used as an injection point during Phase II Injection Event I (March 2008).
Negative numbers indicate a concentration increase.
Only wells sampled during both events are included.
(a) Performed in October-November 2007.
(b) Performed in September-October 2008.

< = less than
µg/L = micrograms per liter
Rejected = result rejected during validation, TCE concentration likely below the reporting limit.
TCE = trichloroethene

monitoring events provides a means of evaluating the long-term performance of the Phase II Injection Event I. Of the 34 wells sampled during both the 2008 and 2010 monitoring events, results from 5 of the wells showed reductions in TCE concentrations (Table 6-6) while 15 wells showed an increase in TCE concentrations. These increases in TCE concentrations may be the result of untreated groundwater moving into the treatment zone and further indicates that rebound occurred within 27 months following Phase II Injection Event I. The greatest increases in TCE concentrations were observed at wells N3-MW15 and N3-MW21 and therefore, these wells were among the wells selected for injection during Phase II Injection Event II (August 2010). Results from the 2008 and 2010 monitoring events showed continued increase in TCE concentrations at well N4-MW06 (Figure 6-2), which indicates possible plume instability in the vicinity of this well. Wells N4-MW07, N4-MW08, and N4-MW09 were selected for injection during Phase II Injection Event II to address increasing TCE concentrations near well N4-MW06. Post-injection sampling results for Phase II Injection Event II were not available within this five-year review period.

6.4.2.3 Overall TCE Concentration Variations (2003 to 2010)

The data collected during the 2003 monitoring event were the basis for the remedies developed in the FS (Earth Tech, 2004) and the final remedy selection in the ROD (Earth Tech, 2006), and the data collected during the 2010 monitoring event represent the most recent results available within this five-year review period. Comparing the TCE data from the 2003 and 2010 monitoring events provides a means of evaluating the overall performance of the remedy. Of the 23 wells sampled during both of the 2003 and 2010 monitoring events, 20 wells exhibited an overall decrease in TCE concentrations and 18 of those wells showed significant (greater than 50 percent) decreases (Table 6-7). TCE concentrations increased in samples collected from two wells during that timeframe, N3-MW15 and N1-MW08, and TCE was not detected in the samples from well REPA-MW01. The increase at well N1-MW08 is not statistically significant because of the relatively low TCE concentrations detected in both samples, less than 1.5 μg/L (which is below the 5-μg/L cleanup goal [MCL]). The increase in TCE concentrations detected in samples from well N3-MW15 (from 4,600 μg/L in 2003 to 20,000 μg/L in 2010) may be attributable to rebounding as this well was treated with a Fenton-based reagent in 2003 as part of an ISCO treatability study. The 2010 concentration is a significant decrease from the historical high TCE concentration (45,000 μg/L) at N3-MW15, detected in 2002.

TABLE 6-6. TCE CONCENTRATION VARIATIONS – 2008 TO 2010

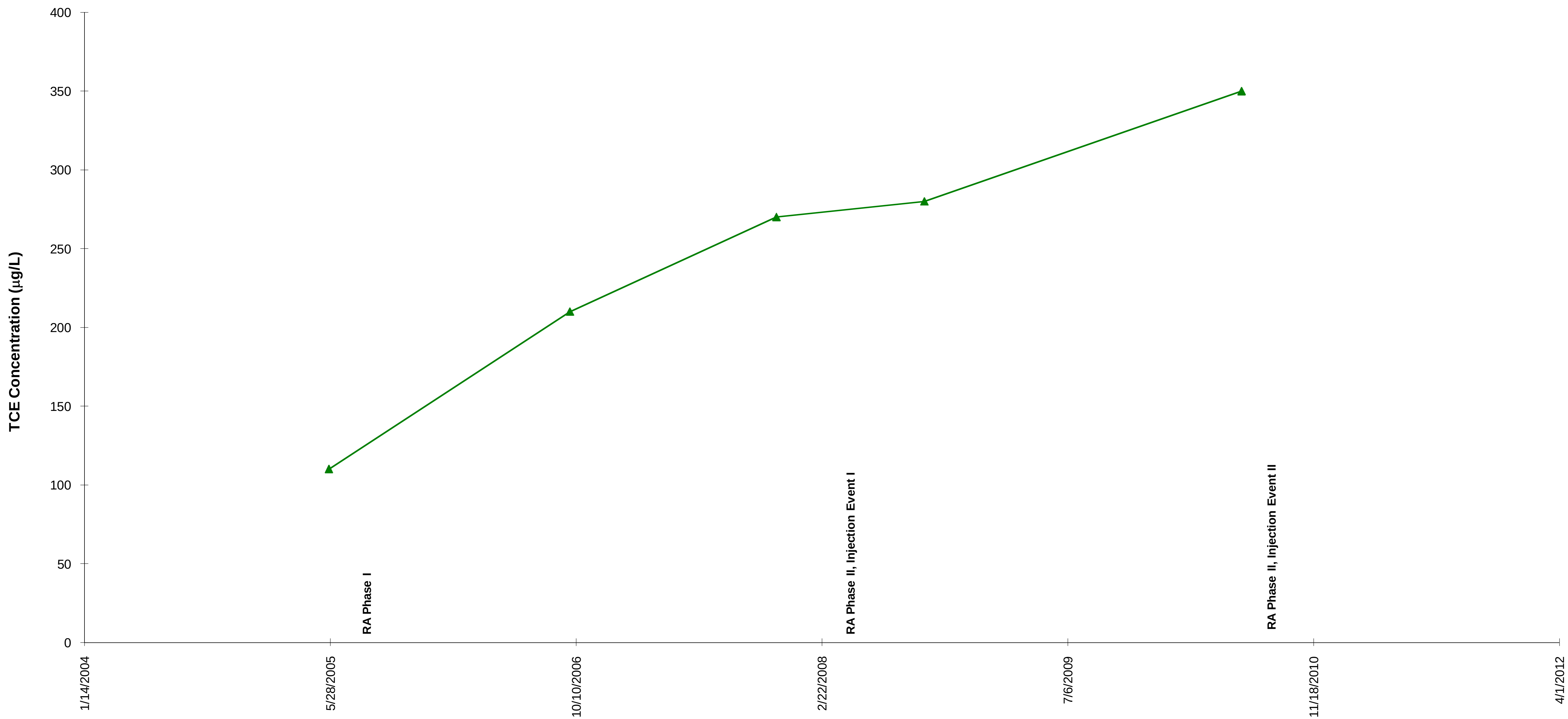
Well	TCE Concentration 2008 Monitoring Event[a] (µg/L)	TCE Concentration 2010 Monitoring Event[b] (µg/L)	Approximate Decrease 2008 to 2010 µg/L	Approximate Decrease 2008 to 2010 Percent
N1-MW08	1.8	1.4	0.4	22.2
N3-DEW02	**Rejected**	< 1	**---**	**---**
N3-MW03	**1.3**	42	**-40.7**	**-3,130.8**
N3-MW05	**2,000**	**1,800**	**200**	**10.0**
N3-MW06	**Rejected**	0.33	**---**	**---**
N3-MW07	**< 1**	**220**	**---**	**---**
N3-MW11	**< 10**	< 1	**---**	**---**
N3-MW12	630	**790**	**-160**	**-25.4**
N3-MW13	**67**	1.6	**65.4**	**97.6**
N3-MW14	**< 50**	< 20	**---**	**---**
N3-MW15	**< 5**	**20,000**	**-20,000**	**---**
N3-MW16	**< 1**	6.4	**-6.4**	**---**
N3-MW18	**Rejected**	< 1	**---**	**---**
N3-MW21	**< 10**	**7,100**	**-7100**	**---**
N3-MW22	< 5	< 50	---	---
N3-MW23	< 1	< 1	---	---
N3-NW03	**18**	120	**-102**	**-566.7**
N3-NW05	< 5	< 1	---	---
N3-NW06	**48**	30	**18**	**37.5**
N4-MW06	280	350	-70	-25.0
N7-DEW01	< 25	31	-31	---
N7-MW01	**Rejected**	< 10	**---**	**---**
N7-MW02	< 10	63	-63	---
N7-MW03	100	130	-30	-30.0
N7-MW04	**< 20**	9.1	**-9.1**	---
N7-MW09B	< 25	< 1	---	---
N7-MW10	**1.5**	**130**	**-128.5**	**-8,566.7**
N7-MW11	**< 1**	**72**	**-72**	**---**
N7-MW12	**Rejected**	1.1	---	---
N7-MW13	42	21	21	50.0
N7-MW14	**Rejected**	50	---	---
N7-MW15	< 1	61	-61	---
N7-MW16	< 1	78	-78	---
REPA-MW01	< 1	< 1	---	---

Notes:

Bold indicates that the well was used as an injection point during Phase II Injection Event I (March 2008).
Negative numbers indicate a concentration increase.
Only wells sampled during both events are included.
[a] Performed in September-October 2008.
[b] Performed in June-July 2010.

< = less than
µg/L = micrograms per liter
Rejected = result rejected during validation, TCE concentration likely below the reporting limit.
TCE = trichloroethene

Figure 6-2. TCE Concentration Trends in Downgradient Monitoring Well N4-MW06



***Notes*:**

Monitoring Well N4-MW06 installed 26 July 2004

RA - Remedial Action

RA Phase I Injection at nearby Site N7 (6/21/05 to 7/14/05)

RA Phase II, Injection Event I at nearby Site N7 (3/3/08 to 3/21/08)

RA Phase II, Injection Event II at Site N4 and nearby Site N7 (8/16/10 to 8/26/10)

TABLE 6-7. TCE CONCENTRATION VARIATIONS – 2003 TO 2010

	TCE Concentration		Approximate Decrease 2003 to 2010	
Well	2003 Monitoring Event[a] (µg/L)	2010 Monitoring Event[b] (µg/L)	µg/L	Percent
N1-MW08	0.37	1.4	-1.03	-278
N3-DEW02	7,700	**< 1**	**7,700**	**100**
N3-MW03	540	**42**	**498**	**92**
N3-MW06	1,900	**0.33**	**1,899.7**	**99.98**
N3-MW07	8,400	**220**	**8,180**	**97**
N3-MW11	14	**< 1**	**14**	**100**
N3-MW12	960	**790**	**170**	**18**
N3-MW13	39	**1.6**	**37.4**	**95.9**
N3-MW15	4,600	**20,000**	**-15,400**	**-335**
N3-MW16	130	**6.4**	**123.6**	**95.1**
N3-MW18	1.5	**< 1**	**1.5**	**100**
N3-NW03	180	**120**	**60**	**33**
N3-NW05	6,100	< 1	6,100	100
N3-NW06	80	**30**	50	63
N7-MW01	2,000	**< 10**	**1,990**	**100**
N7-MW02	280	63	217	78
N7-MW03	350	130	220	63
N7-MW04	200	**9.1**	**190.9**	**95.5**
N7-MW09B	150	< 1	150	100
N7-MW11	160	**72**	**88**	**55**
N7-MW12	1,100	**1.1**	**1,098.9**	**99.9**
N7-MW13	51	21	30	59
REPA-MW01	< 1	< 1	---	---

Notes:

Bold indicates that the well was used as an injection point.
Negative numbers indicate a concentration increase.
Only wells sampled during both events are included.
[a] Performed in March 2003.
[b] Performed in June-July 2010.
< = less than
µg/L = micrograms per liter
Rejected = result rejected during validation, TCE concentration likely below the reporting limit.
TCE = trichloroethene

The 2003 groundwater monitoring data for samples collected from wells N3-DEW02, N3-MW06, N3-MW07, N3-MW15, and N3-NW05 at Site N3, and wells N7-MW01 and N7-MW12 at Site N7 indicated that the wells were located in the areas of highest TCE concentrations at the respective sites. Trend graphs for TCE concentrations for these wells and N7-MW02, a deep well near N7-MW01, are presented in Appendix A. The percent decreases in TCE concentrations from the 2003 to 2010 timeframe were at or near 100 percent at these wells with the exception of N3-MW15 (Table 6-7). As described above, the TCE concentrations in samples collected from N3-MW15 have likely rebounded from reductions realized during a previous treatability study. The significant decreases in TCE at the highest concentration area wells indicate that the ISCO component of the RA is progressing successfully.

A review of Table 3-1 in Section 3.3 indicates a decreasing trend in concentrations of 15 of the 17 COCs, including TCE, and further indicates that the ISCO component of the RA is progressing successfully. Only *cis*-1,2-DCE and total xylenes were detected at historical maximum concentrations during the 2010 sampling event. Both *cis*-1,2-DCE and total xylenes were detected at their respective historical maximum concentrations of 14,000 and 7,300 µg/L in 2010 samples collected from well N3-MW21 and may be an indication of biodegradation processes. *Cis*-1,2-DCE is a breakdown product of the biodegradation of TCE, and therefore a decrease in TCE concentrations is accompanied by an increase in *cis*-1,2-DCE concentrations. A review of 2007 and 2010 data verifies this inverse relationship for TCE and *cis*-1,2-DCE concentrations detected in samples collected from well N3-MW21. During the 2007 sampling event, TCE and *cis*-1,2-DCE were detected at concentrations of 19,000 and 5,500 µg/L, respectively. During the 2010 sampling event, TCE and *cis*-1,2-DCE were detected at concentrations of 7,100 and 14,000 µg/L, respectively. Because, ISCO treatment of TCE does not result in the formation of *cis*-1,2-DCE, this trend is unlikely to be the result of the Phase II Injection Event I. The formation of *cis*-1,2-DCE may be the result of co-metabolic biodegradation of TCE along with benzene, toluene, and xylene (which are also present in groundwater samples collected from well N3-MW21).

6.4.2.4 Leading Edge TCE Concentration Variations

TCE concentrations at newly installed wells N1-MW10 (130 µg/L), N4-MW07 (94 µg/L), N4-MW11 (470 µg/L), N4-MW12 (160 µg/L), and N4-MW13 (140 µg/L) indicate that the commingled plume extends further downgradient than delineated earlier based on previous monitoring events. Well locations and associated 2003 and 2010 TCE concentrations are shown on Figures 3-4 and 3-5, respectively. Figure 6-3 presents the extent of the TCE plume delineated in 2003 (at the time of remedy development in the FS [Earth Tech, 2004]), in 2004 as presented in the ROD (Earth Tech, 2006), and in 2010. The area in blue indicates the change in estimated plume configuration along the east/southeastern leading edge as a result of TCE concentrations detected in newly installed wells N1-MW10, N4-MW07, N4-MW11, N4-MW12, and N4-MW13. Trend graphs for wells with an adequate number of data points are included on Figure 6-4, and indicate that the extent of leading edge plume instability appears to be limited to the southern portion of Site N1 and the northern portion of Site N4 as indicated by increasing TCE concentrations at monitoring well N4-MW06. TCE concentrations in samples collected from monitoring well N4-MW06 have consistently increased since its initial sampling in 2005. Additionally, analytical results from the 2010 monitoring event indicate that an area of relatively high TCE concentrations, ranging from 21 to 560 μg/L (Figure 3-5), exists in the Site N4 area. To address this high concentration area and apparent plume instability in the vicinity of monitoring well N4-MW06, Site N4 area injection wells (N4-MW07, N4-MW08, and N4-MW09) were included in the Phase II Injection Event II. Though performance monitoring results associated with the Phase II Injection Event II are not available within this review period, continued sodium permanganate solution injections at the Site N4 area will likely be required.

6.4.2.5 Chromium Concentration Variations

Sodium permanganate was selected as the ISCO reagent (Earth Tech, 2006). Permanganate has the potential to convert naturally occurring trivalent chromium to hexavalent chromium, a carcinogen. However, treatability studies performed at the site indicated that hexavalent chromium was transitional and would return to the trivalent form in groundwater once oxidation conditions degraded (within 5 years of introducing permanganate into OU6 groundwater). Total chromium and hexavalent chromium are, and will continue to be, included as analytes in the RA monitoring program. Trend graphs indicate the expected increase in total chromium concentrations immediately following injection events (AECOM, 2011b). Decreases in total chromium or hexavalent chromium concentrations in wells N7-MW10 and N7-MW11 were observed within 3 years following injection. Adequate sampling history at Site N7, dating back to the 2000 ISCO treatability study, allow for the construction of trend graphs for wells at that site. Chromium concentration trend graphs for Site N7 wells are included in

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EXPLANATION

(green)	ESTIMATED AREA OF TCE PLUME WHERE ABOVE 5 µg/L FOR 2003 AND 2010
(yellow)	ESTIMATED TCE PLUME EXTENT BASED ON MARCH AND JUNE 2003 DATA (5 µg/L) PER THE FEASIBILITY STUDY (EARTH TECH, 2004)
(blue)	ESTIMATED TCE PLUME EXTENT BASED ON JUNE-JULY 2010 DATA (5 µg/L) PER THE INTERIM REMEDIAL ACTION COMPLETION REPORT (AECOM, 2011)
— — —	ESTIMATED TCE PLUME EXTENT BASED ON APRIL-MAY 2004 DATA (5 µg/L) PER THE RECORD OF DECISION (EARTH TECH, 2006) AND LAND USE CONTROL BOUNDARY

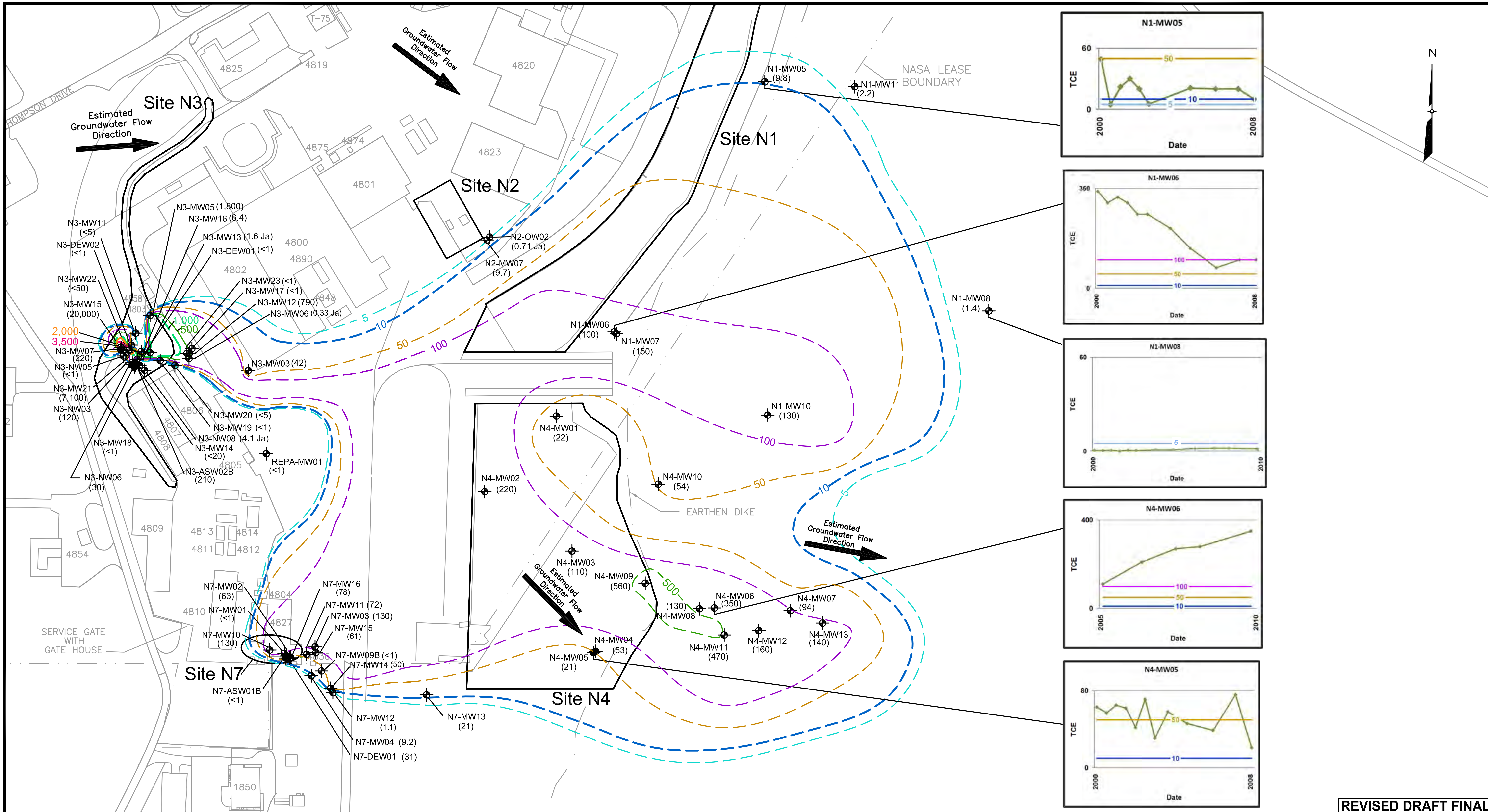
µg/L MICROGRAMS PER LITER
TCE TRICHLOROETHENE

Approximate Extent of TCE in Groundwater

Date 08-2011
Project No. 60133976

Operable Unit 6
First Five-Year Review Report
Edwards AFB

Figure **6-3**



EXPLANATION

N3-MW03 (120) — MONITORING WELL WITH TCE CONCENTRATION IN µg/L

— 5 — INFERRED TCE CONCENTRATION CONTOUR (INTERVALS = 5, 10, 50, 100, 500, 1,000, 2,000, AND 3,500 µg/L) BASED ON JUNE-JULY 2010 MONITORING RESULTS

NOTES:
TREND GRAPH Y AXIS REPRESENTS TCE CONCENTRATIONS IN µg/L.
TREND GRAPHS ARE PRESENTED ONLY FOR LEADING EDGE WELLS AND ONLY FOR WELLS THAT HAVE BEEN SAMPLED AT LEAST THREE TIMES.
TREND GRAPH DATA POINTS DO NOT INCLUDE GRAB SAMPLES OR REMEDIATION SYSTEM SAMPLES.

µg/L = MICROGRAMS PER LITER
TCE = TRICHLOROETHENE

0 125 250
SCALE IN FEET

OU6 Plume Leading Edge TCE Groundwater Concentration Trends

Date 08-2011 Project No. 60133976	**Operable Unit 6 First Five-Year Review Report Edwards AFB**	Figure **6-4**

P:\60133976\WP\90\cad\Revised Draft Final\Figure 6-4 OU6 TCE 2010-trend.dwg - 17 Aug 2011

Appendix A. Because the presence of permanganate interferes with its detection, a limited number of hexavalent chromium laboratory analytical data are available.

6.4.2.6 Benzene Concentration Variations

Benzene in groundwater will be addressed as a future RA component after completion of the ISCO operations. The highest benzene concentrations in groundwater in 2010 were detected in samples collected from wells N3-MW14, N3-MW16, and N3-MW21. Graphs of benzene concentrations in groundwater generated for N3-MW14 and N3-MW16 do not exhibit apparent trends (Appendix A). An adequate number of data points for well N3-MW21 are not available to provide a relevant trend graph. Additional trend graphs are included in the *IRACR for Phase II Injection Event II of III* (AECOM, 2011b). Clear trends were not identified with the exception of concentrations in samples collected from N3-MW06 (used as an injection well), which significantly decreased since injection began in 2005 (Appendix A). Since benzene is not amenable to ISCO using permanganate, this trend is likely due to dilution of the aquifer with reagent solution. Well locations and associated 2003 and 2010 benzene concentrations are shown on Figures 3-6 and 3-7, respectively. Figure 6-5 presents the extent of the Site N3 benzene plume delineated in 2003 (at the time of remedy development in the FS [Earth Tech, 2004]), in 2004 as presented in the ROD, and in 2010. The expansion of the estimated plume extent to the south is due to benzene concentrations detected in well N3-MW20, installed in July 2004. Biodegradation will likely be implemented in this area prior to the rest of the plume as TCE concentrations are below the MCL and, therefore, the well has not been included in the ISCO component of the RA.

6.4.2.7 N-nitrosodimethylamine (NDMA) Data

Hydrazine fuels are used for rocket propellants by the U.S. Air Force and NASA. Hydrazines are unstable in the natural environment and rapidly decompose when exposed to the atmosphere. NDMA is a decomposition product.

NDMA is present in groundwater at Site N3 (Figure 6-6) in the area of the benzene plume. Of the trend graphs presented in the IRACR (AECOM, 2011b), only wells N3-MW06 and N3-MW07 have an adequate number of data points since 2003 to provide relevant trend graphs (Appendix A). Although no trends are apparent, concentration decreases in injection well N3-MW06 have been observed

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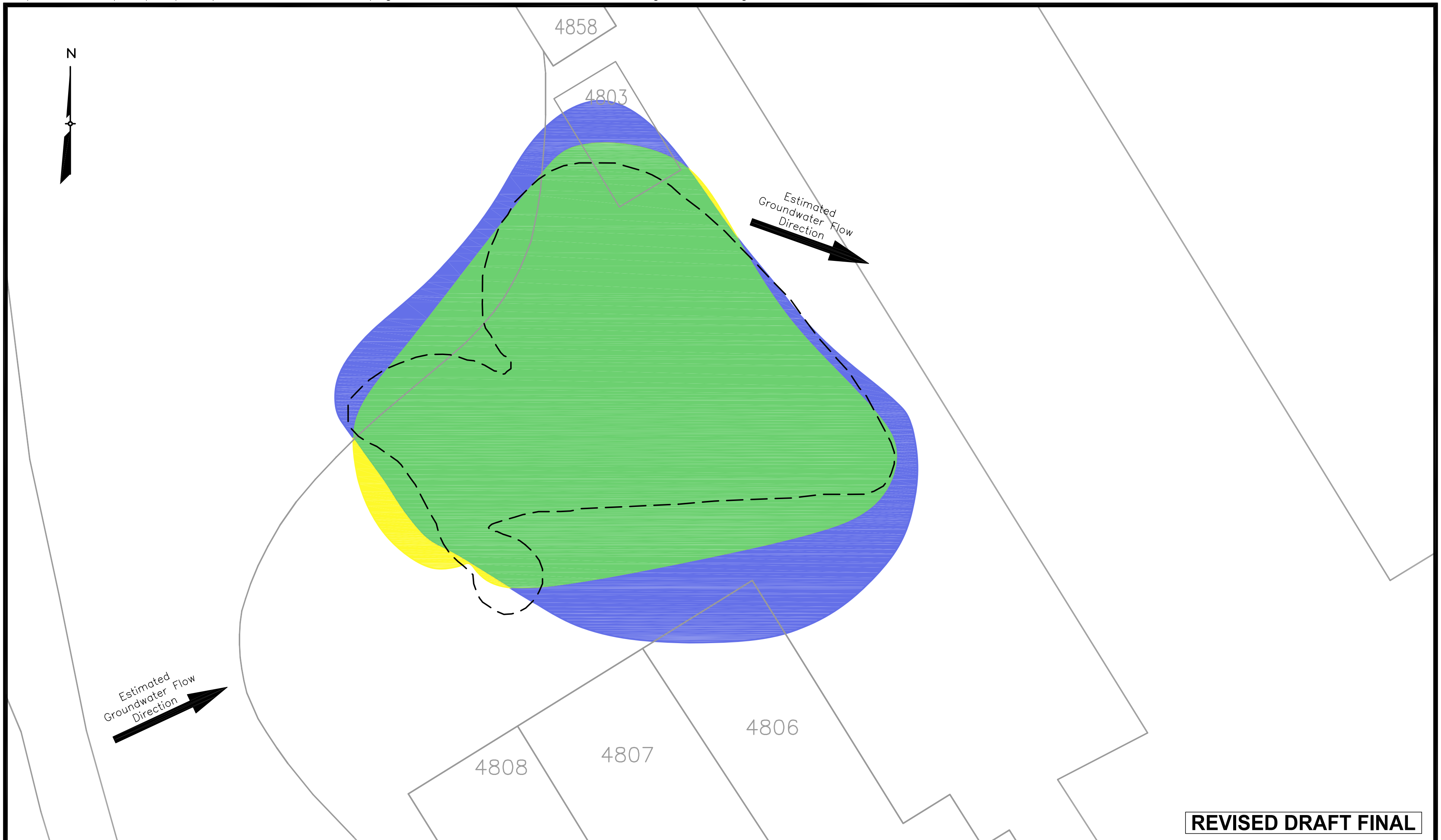
P:\60133976\WP\90\cad\Revised Draft Final\Figure 6-5 OU6 Benzene Extent.dwg — 17 Aug 2011



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EXPLANATION

ESTIMATED AREA OF BENZENE PLUME WHERE ABOVE 1 µg/L FOR 2003 AND 2010

ESTIMATED BENZENE PLUME EXTENT BASED ON MARCH AND JUNE 2003 DATA (1 µg/L) PER THE FEASIBILITY STUDY (EARTH TECH, 2004)

ESTIMATED BENZENE PLUME EXTENT BASED ON JUNE-JULY 2010 DATA (1 µg/L) PER THE INTERIM REMEDIAL ACTION COMPLETION REPORT (AECOM, 2011)

— — — ESTIMATED BENZENE PLUME EXTENT BASED ON APRIL-MAY 2004 DATA (1 µg/L) PER THE RECORD OF DECISION (EARTH TECH, 2006)

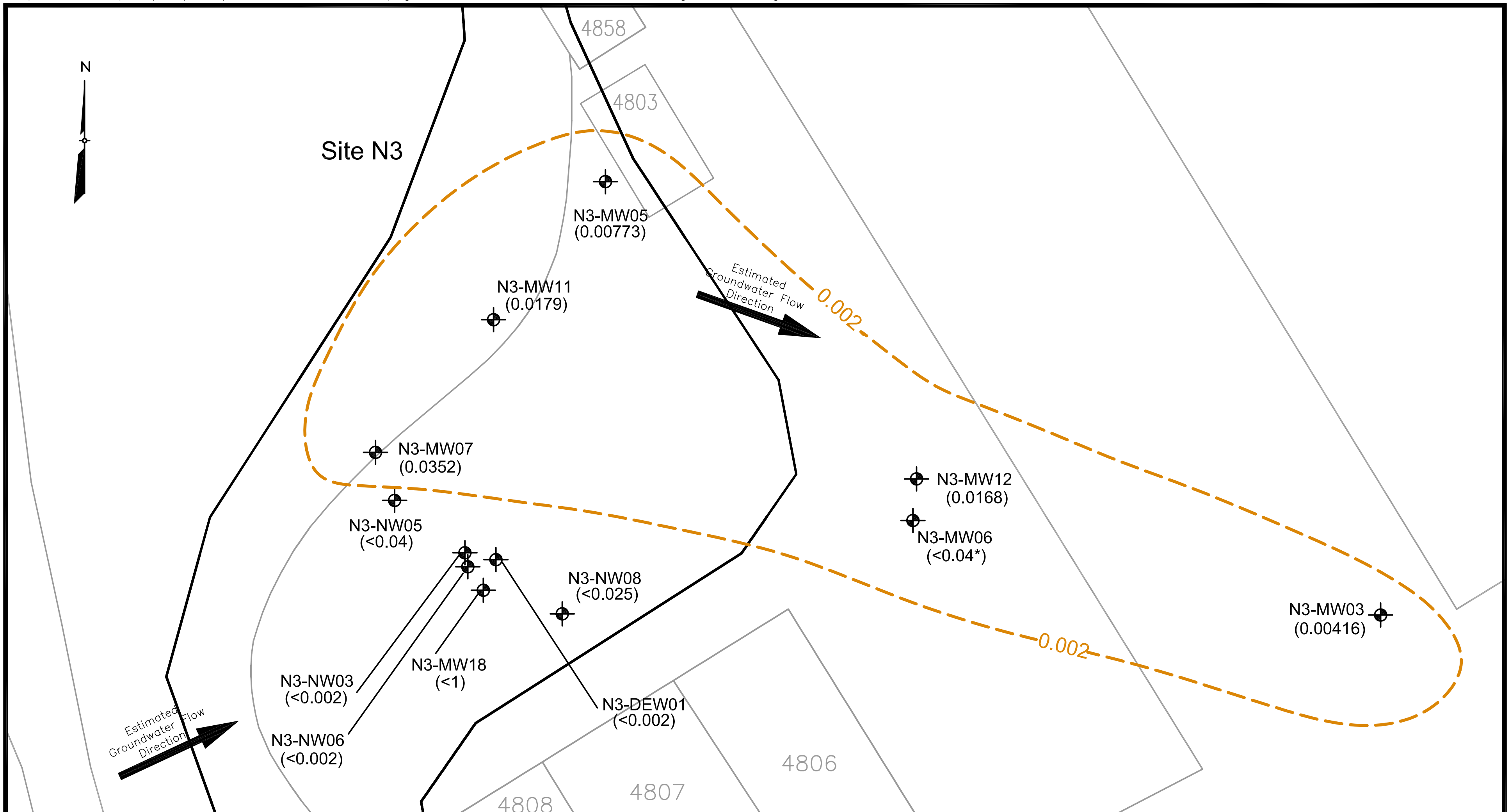
µg/L MICROGRAMS PER LITER

0 25 50
SCALE IN FEET

Site N3
Approximate Extent of Benzene in Groundwater

Date 08-2011	**Operable Unit 6**	Figure
Project No. 60133976	**First Five-Year Review Report** **Edwards AFB**	**6-5**

P:\60133976\WP\90\cad\Revised Draft Final\Figure 6-6 Site N3 NDMA Conc.dwg – 17 Aug 2011



EXPLANATION

N3-MW07 (0.0352) — MONITORING WELL WITH NDMA CONCENTRATION IN µg/L

0.002 — INFERRED EXTENT OF NDMA IN GROUNDWATER ABOVE THE REPORTING LIMIT OF 0.002 µg/L

µg/L — MICROGRAMS PER LITER
NDMA — N-NITROSODIMETHYLAMINE

*CONCENTRATION NOT USED IN CONTOURING; WELL HAS HISTORICALLY HAD NDMA DETECTED IN GROUNDWATER SAMPLES.

NOTE:
DUE TO THE HIGH LEVELS OF PERMANGANATE, THE SAMPLE-SPECIFIC ESTIMATED DETECTION LIMITS EXCEEDED THE 0.002 µg/L REPORTING LIMIT, RAISING THE REPORTING LIMIT FOR NON-DETECT RESULTS TO 0.040 µg/L IN SOME SAMPLES.

0 25 50
SCALE IN FEET

REVISED DRAFT FINAL

Site N3
Approximate Extent of NDMA in Groundwater

Date 08-2011
Project No. 60133976

Operable Unit 6
First Five-Year Review Report
Edwards AFB

Figure **6-6**

following injection events. Following the Phase I Injection Event, NDMA decreased from a pre-injection concentration of 0.14 to 0.07 μg/L in groundwater samples collected from well N3-MW06. NDMA was not detected above the reporting limit in groundwater samples collected from well N3-MW06 following the Phase II Injection Event I. Because NDMA is similar to benzene in that it is not amenable to ISCO treatment, reductions are likely the result of dilution by the reagent solution. NDMA was not identified as a COC in the ROD and a cleanup goal (MCL) has not been promulgated. In addition, it does not present an indoor air risk and LUCs at OU6 protect from exposure. However, NDMA will continue to be included in the monitoring program to evaluate treatment by bioremediation in the event that a cleanup goal (MCL) is promulgated or a toxicity value is formally issued.

6.4.3 RECOMMENDATIONS

Continued revision of the LUC boundary in the GIS as necessary based on the most recent, vetted, and available sampling results is recommended as is the continued adherence to review and approval procedures for construction and ground-disturbing activities. Continued ISCO in the areas of highest VOC concentrations at Sites N3, N4, and N7, and groundwater monitoring for NDMA, metals (including total and hexavalent chromium), and VOCs are recommended. Inclusion of a tracer in future ISCO injections is recommended to evaluate whether injections are displacing the plume. Installation of monitoring wells downgradient of Sites N1, N4, and N7 (locations to be presented in a future work plan), and groundwater modeling is recommended in Section 9.0 to delineate the plume's downgradient extent and to determine future compliance as it relates to the possible migration of the plume toward the groundwater subbasin (location indicated on Figure 6-3). Generation of graphic conceptual site models showing the horizontal and vertical extent of the plume is recommended.

6.5 SITE INSPECTION

As part of the five-year review, a site inspection, well field inspection, and GIS inspection were conducted. The site inspection was conducted on 8 March 2011 by Mr. Dan Morgan (NASA DFRC Environmental Manager), who was accompanied by Mr. Tim Post (CRWQCB, Lahontan Region RPM for Edwards AFB), and Mr. Todd Battey, Mr. Phil Saxton, and Ms. Kimberly Coleman (all with RA support contractor AECOM). The Site Inspection Report and associated Five-Year Review Site Inspection Checklist are presented in Appendix E. Inspection of the well field was completed on 9 March 2011 by Mr. Phil Saxton and Ms. Kimberly Coleman. The purpose of the inspection was to assess the conditions of the well heads within OU6, verify that the physical controls at OU6 are consistent with the LUCs, and to verify that current subsurface activities comply with the permitting procedures established under the RA.

During the site inspection at Sites N1 and N4, Mr. Phil Saxton noted that in recent years less water appears to flow to the Northern Retention Pond (Site N1), while more water appears to flow to the Southern Retention Pond (Site N4). Mr. Dan Morgan explained that the change in outflow to the retention ponds is a result of a 2006 drainage realignment and internal process modifications to eliminate freshwater discharges to the storm drains.

During the site inspection at Site N3, Mr. Dan Morgan noted that Buildings 4886 and 4889 (and associated drum dispensing areas) had been removed, and drums were no longer stored at Building 4803.

Issues regarding the well conditions included damaged well completions and the lack of proper identification tags at routinely sampled wells. The LUCs employed under the RA include prohibitions on the use or disturbance of groundwater until cleanup levels are achieved. No activities were observed that violate the institutional controls. Due to the mobile nature of the ISCO treatment systems, lack of a permanent treatment compound, and potential impact to mission-critical activities such as aircraft movement, permanent treatment-related signage and fencing are not used. LUCs such as the security gate house and perimeter fencing shown on Figure 4-2 are intrinsic to the NASA DRFC operations. Perimeter fencing and security measures appeared to be maintained and consistent with the ROD at the time of the site inspection.

Because the GIS is the primary management tool for implementing, documenting, and managing LUCs, the GIS was inspected by Mr. Albert Chang of TYBRIN Corporation (Air Force contractor) on 3 August 2011. The inspection was performed by accessing OU6 information by Web Map. The inspection verified that land use restrictions are included in the GIS via hyperlink to LUC ROD sections. Additionally, the GIS is up-to-date regarding the geographic control boundary (boundary based on June-July 2010 TCE and benzene results).

6.6 INTERVIEWS

During the 8 March 2011 site inspection (Appendix E), Mr. Dan Morgan of NASA DFRC, Mr. Tim Post of CRWQCB, and Mr. Phil Saxton (Operation and Maintenance Site Manager) of AECOM provided information regarding the status and performance of the RA. Mr. Dan Morgan and Mr. Phil Saxton participated in supplemental interviews in August 2011. Interviews with site workers (Mr. Mark Morgan, Ms. Lori Davey, and Mr. Pedro Arevalo) were conducted in May 2011. Mr. Joseph Healy (USEPA RPM), Mr. Kevin Depies (California DTSC RPM), Mr. John Steude (CRWQCB RPM), and Mr. Stephen Watts (Edwards AFB GIS manager) were interviewed in the July-August 2011 time period. Interview records and documentation forms are included in Appendix F.

None of the interviewees was aware of any LUC violations or of any community concerns related to the remedy. No concerns regarding the protectiveness of the remedy or accessibility of remedy information were voiced by Edwards AFB, NASA, and AECOM personnel interviewed. Common concerns among the RPMs were the lack of plume delineation in the Site N1 and Site N4 areas as discussed in Section 6.4.2.4, and the protectiveness of the remedy for the VIP (further discussed in Section 7.2). Regarding accessibility of remedy information, Mr. Depies noted that Edwards AFB is no longer maintaining the ERP information exchange webpage (BSX), which was used to obtain and exchange critical information. Mr. Depies recommended that the webpage be reinstated or a new webpage be established. The establishment of an information exchange webpage is identified as a program-wide issue in Section 8.0.

No public input was generated as a result of May 2011 “Dryden X-Press” newsletter announcement.

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7.0 TECHNICAL ASSESSMENT

Per guidance (USEPA, 2001), the technical assessment portion of the five-year review should provide the answers to three questions:

- Question A: Is the remedy functioning as intended by the decision documents? (Section 7.1)
- Question B: Are the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of the remedy still valid? (Section 7.2)
- Question C: Has any other information come to light that could call into question the protectiveness of the remedy? (Section 7.3)

The appropriate information is presented in the following subsections.

7.1 QUESTION A: IS THE REMEDY FUNCTIONING AS INTENDED BY THE DECISION DOCUMENTS?

This section addresses whether remedy components, as implemented, will maintain the effectiveness of the response action. As presented in Section 4.3.3, differences between estimated and actual implementation costs generally resulted from revisions to the remedial approach and schedule, not failures or shortcomings of the remedy. An opportunity for optimization includes groundwater modeling to predict plume configuration, and to aid in determining optimal injection and monitoring well locations and timing of injection events. Elevated TCE concentrations at Site N4 are possible early indicators of plume instability (a potential problem) as further discussed in Section 7.1.4.

7.1.1 LAND USE CONTROLS

LUCs have been successfully employed as expected at OU6 and within the review period. As discussed in Section 4.1.1, the LUC remedy component includes approval procedures for all construction and ground-disturbing activities within the OU6 LUC boundary (Figure 4-2), including construction and dig permits. The LUC boundary is revised in the GIS as necessary based on the most recent, vetted, and available sampling results. As confirmed during the inspection of the GIS (Section 6.5), the LUC boundary was most recently revised to coincide with the 5-µg/L TCE and 1-µg/L benzene isoconcentration contours based on the June-July 2010 monitoring results (Figure 4-2). TCE and benzene concentrations in groundwater are used to define the LUC boundary because, based on MCL exceedances, these two plumes exhibit the largest aerial extent. The LUC boundary as defined in the

ROD (Figure 4-1) was implemented during all excavations performed within this review period (the activities are presented in Table 6-2). Based on June-July 2010 monitoring results, the LUC boundary was revised and expanded to the east, encroaching upon Rogers Dry Lake (Figure 4-1). All mission-related excavations within this review period occurred in the western portion of the facility where the plume footprints and LUC boundary have remained relatively constant. No mission-related excavations occurred in the eastern portion of the LUC boundary area where the expansion occurred. Because there are no utilities or buildings in the eastern portion of the plume, and since Rogers Dry Lake is considered part of the flightline, it is also unlikely that any future mission-related excavations will be performed in the LUC boundary expansion area. Remedy-related excavations did occur inside the LUC boundary expansion area; however, PPE was employed during the efforts.

LUCs such as the security gate house and fencing shown on Figure 4-2 are intrinsic to the NASA DRFC operations, were in place when the ROD was signed, and appeared to be maintained and consistent with the ROD at the time of the site inspection (Section 6.5). Due to the mobile nature of the ISCO treatment systems, lack of a permanent treatment compound, and potential impact to mission-critical activities such as aircraft movement, permanent treatment-related signage and fencing are not used. RA activities occur within the NASA DFRC secured area or the secured area maintained by Edwards AFB flightline management.

7.1.2 *IN SITU* CHEMICAL OXIDATION

Injection activities were initiated in 2005, prior to the signing of the ROD, with the implementation of the pre-ROD or Phase I Injection Event. Formal remedial design documentation was completed in February 2008 (Earth Tech, 2008), the first injection event of post-ROD or Phase II was performed in March 2008, and the second injection event was in August 2010. A summary of post-ROD (Phase II) injection event characteristics is presented in Table 7-1. The number of wells utilized for injection decreased from 21 wells used during Injection Event I to 10 wells used during Injection Event II due to the persistence of permanganate (as evidenced by purple groundwater) in candidate wells. The solution concentration percentage was adjusted up to 4 percent for ease of mixing the sodium permanganate solution in the field as the product was purchased at 40 percent solution. The remedial design specified a minimum injection volume of 57 gallons per injection well. Approximately 70 percent of the injection wells in Phase II Injection Events I and II accepted at least 57 gallons of sodium permanganate solution. In general, if a well did not accept at least 57 gallons of sodium permanganate solution during Injection Event I it was not used for injection during Injection Event II. Exceptions include wells N3-MW07 and N7-MW10. Wells N3-MW07 and N7-MW10 performed poorly during Injection Event I; however, injection at these two wells was again attempted during Injection Event II, due to relatively high TCE concentrations. Prior to Injection Event II, TCE was detected in groundwater samples collected from wells N3-MW07 and N7-MW10 at concentrations of 220 and 130 μg/L, respectively (Table 6-6). These concentrations represent a 21,900 percent increase in well N3-MW07 and a 8,600 percent increase in well N7-MW10 following Injection Event I. Post-injection sampling results for Injection Event II are not available within this review period to evaluate the degree of TCE destruction within groundwater around these wells.

TABLE 7-1. SUMMARY OF INJECTION EVENT CHARACTERISTICS

Injection Event Characteristic	Remedial Design	Phase II Injection Event I (March 2008)	 Injection Event II (August 2010)
Number of Injection Wells	22	21	10
Sodium Permanganate Solution Concentration (percent)	1.8	2 to 4	4
Volume per Well (gallons)	57 (minimum)	15 out of 21 wells accepted 57 gallons or greater of sodium permanganate solution	7 out of 10 wells accepted 57 gallons or greater of sodium permanganate solution
Time Since Previous Event (months)	6 to 18	33	29

The RA implementation was also impacted by the identification of elevated contaminant concentrations in the area of Site N4. The project schedule was deferred to allow for the installation of additional injection wells in that area.

In order to determine if the ISCO component of the remedy is functioning as intended, TCE has been used as the indicator contaminant to estimate plume configuration and mass reduction over time. Complete plume delineation has not been performed in the southern portion of Site N1 and the northern portion of Site N4 (as discussed in Section 7.1.4), leading to uncertainty regarding plume extent estimates and resulting 2010 contaminant mass estimates for the entire OU6 plume. However, artificial plume boundaries have been established at Sites N3 and N7 to allow for consistent future contaminant mass estimates in the treatment areas (Figures B-1 through B-4 in Appendix B).

Treatment by ISCO has been performed in the source areas at Sites N3 and N7, and near the leading edge in the area of Site N4 (monitoring well N4-MW06 vicinity). The remedy was selected and documented in the ROD (Earth Tech, 2006) based upon 2003 data presented in the FS (Earth Tech, 2004), including the contaminant mass estimates for the entire OU6 plume; therefore, the data from those estimates were used as a baseline for determining cleanup progress (Appendix B). Based upon estimates calculated for the entire plume from 2003 and 2010 data, the mass of TCE has increased by approximately 6 percent (Table 7-2), due to the identification of a high concentration area at Site N4. Within that same timeframe, TCE mass has been reduced in the Site N3 and Site N7 treatment areas by 37 percent and 72 percent, respectively. Site N4 TCE mass reduction quantities are not available as ISCO implementation has occurred relatively recently in 2010 and post-injection monitoring results are not available within this review period.

TABLE 7-2. PLUME MASS AND VOLUME SUMMARY

Compound	2003 Volume (Gallons)	2010 Volume (Gallons)	2003 Mass (Pounds)	2010 Mass (Pounds)	Difference (Percent)
OU6 Plume					
trichloroethene	48.26[a]	51.31[b]	587.35	624.43	+6
Site N3 Treatment Area					
benzene	0.24[c]	2.51[d]	1.76	18.57	+954
trichloroethene	6.96[e]	4.38[f]	84.85	53.41	-37
Site N7 Treatment Area					
trichloroethene	3.06[g]	0.87[h]	37.17	10.49	-72

Notes:

[a] Based on concentration range and contour areas shown on Figure B-5 in Appendix B.
[b] Based on concentration range and contour areas shown on Figure B-6 in Appendix B.
[c] Based on concentration range and contour areas shown on Figure B-7 in Appendix B.
[d] Based on concentration range and contour areas shown on Figure B-8 in Appendix B.
[e] Based on concentration range and contour areas shown on Figure B-1 in Appendix B.
[f] Based on concentration range and contour areas shown on Figure B-2 in Appendix B.
[g] Based on concentration range and contour areas shown on Figure B-3 in Appendix B.
[h] Based on concentration range and contour areas shown on Figure B-4 in Appendix B.

As presented in Section 6.4.2.3, data collected during the 2003 monitoring event were the basis for the remedies developed in the FS (Earth Tech, 2004) and the final remedy selection in the ROD (Earth Tech, 2006), and the data collected during the 2010 monitoring event represent the most recent results available within this five-year review period. Comparing the TCE data from the 2003 and 2010 monitoring events provides a means for evaluating the overall performance of the remedy. Of the 23 wells sampled during both of the 2003 and 2010 monitoring events, 20 wells exhibited an overall decrease in TCE concentrations and 18 of those wells showed significant (greater than 50 percent) decreases (Table 6-7). TCE concentrations increased in samples collected from two wells during that timeframe, N3-MW15 and N1-MW08, and TCE was not detected in the samples from well REPA-MW01. The increase at well N1-MW08 is not statistically significant because of the relatively low TCE concentrations detected in both samples, less than 1.5 µg/L (which is below the 5-µg/L cleanup goal [MCL]). The increase in TCE concentrations detected in samples from well N3-MW15 (from 4,600 µg/L in 2003 to 20,000 µg/L in 2010) may be attributable to rebounding as this well was treated with a Fenton-based reagent in 2003 as part of an ISCO treatability study. The 2010 concentration is a significant decrease from the historical high TCE concentration (45,000 µg/L) at N3-MW15, detected in 2002.

The 2003 groundwater monitoring data for samples collected from wells N3-DEW02, N3-MW06, N3-MW07, N3-MW15, and N3-NW05 at Site N3, and wells N7-MW01 and N7-MW12 at Site N7 indicated that the wells were located in the areas of highest TCE concentrations at the respective sites. Trend graphs for TCE concentrations for these wells and N7-MW02, a deep well near N7-MW01, are presented in Appendix A. The percent decreases in TCE concentrations from the 2003 to 2010 timeframe were at or near 100 percent at these wells with the exception of N3-MW15 (Table 6-7). As described above, the TCE concentrations in samples collected from N3-MW15 have likely rebounded from reductions realized during a previous treatability study, but were 55 percent less than the pre-ISCO treatability study concentration. The significant decreases in TCE at the highest concentration area wells indicate that the ISCO component of the RA is progressing successfully.

A review of Table 3-1 in Section 3.3, indicates a decreasing trend in concentrations of 15 of the 17 COCs, including TCE, and further indicates that the ISCO component of the RA is progressing successfully.

7.1.3 BIOREMEDIATION

The delineated benzene mass increased by 954% since 2003 (Table 7-2). Because ISCO is not expected to address the presence of aromatic hydrocarbons (such as benzene), and because the bioremediation remedy component to address benzene has not yet been implemented, the increase in benzene mass is not an indication of remedy failure. The increase in mass is not a result of an ongoing source, but a result of further delineation of the benzene plume. The estimated benzene plume configuration was extended to the south due to benzene concentrations detected in well N3-MW20, installed in July 2004 (Section 6.4.2.6). Additionally, a review of Table 3-1 in Section 3.3 indicates a decreasing trend in benzene concentrations. The highest historical benzene concentration (19,000 μg/L) at OU6 was detected in the sample collected from monitoring well N3-MW14 in 2002. The maximum benzene concentration detected in the most recent groundwater sampling event (2010) was also in a sample collected from monitoring well N3-MW14 (7,000 μg/L).

The bioremediation component to address benzene and other aromatic hydrocarbons will be implemented after the completion of the ISCO component (Earth Tech, 2008) and outside the five-year review period presented in this report. Further delineation of the benzene plume may be warranted prior to or during bioremediation implementation, and to address the VIP.

7.1.4 GROUNDWATER MONITORING

As discussed in Section 6.4.2.4, since remedy implementation an area of relatively high TCE concentrations (ranging from 21 to 560 μg/L [Figure 3-5]) exists in the Site N4 area. Recent groundwater monitoring results indicate that the OU6 commingled plume is not delineated in the northern portion of Site N4 and the southern portion of Site N1, and that these areas of the commingled plume extend further downgradient than originally defined in the ROD. Trend graphs for leading edge wells with an adequate number of data points (Figure 6-4), indicate that leading edge plume instability is limited to the northern portion of Site N4 as shown by increasing TCE concentrations at monitoring well N4-MW06. TCE concentrations in samples collected from monitoring well N4-MW06 have consistently increased since its initial sampling in 2005. Per the ROD, if any unexpected behavior was observed during the groundwater monitoring, the five-year review would include a contingency plan to capture anomalous migration of contaminants. To address this possible plume expansion in the vicinity of monitoring well N4-MW06, the ISCO RA component was implemented at Site N4 in August 2010. Additional monitoring wells will be installed for plume delineation, which along with modeling of the plume leading edge, will provide greater accuracy in plume estimation. The estimates will provide the basis for more reliable contaminant mass/volume calculations that may yield a better understanding of RA progress.

7.2 QUESTION B: ARE THE EXPOSURE ASSUMPTIONS, TOXICITY DATA, CLEANUP LEVELS, AND RAOS USED AT THE TIME OF THE REMEDY STILL VALID?

The validity of assumptions on which the RA was selected, including potential changes in standards, exposure pathways, contaminants characteristics, and risk assessment methods are examined in the following subsections.

7.2.1 CHANGES IN STANDARDS

Cleanup standards were specified in the OU6 ROD for the compounds identified as COCs (Table 3-1). The cleanup standards adopted for these chemicals were the lower of either the federal or the California MCLs for drinking water, none of which have changed since the submittal of the ROD.

7.2.2 CHANGES IN EXPOSURE PATHWAYS

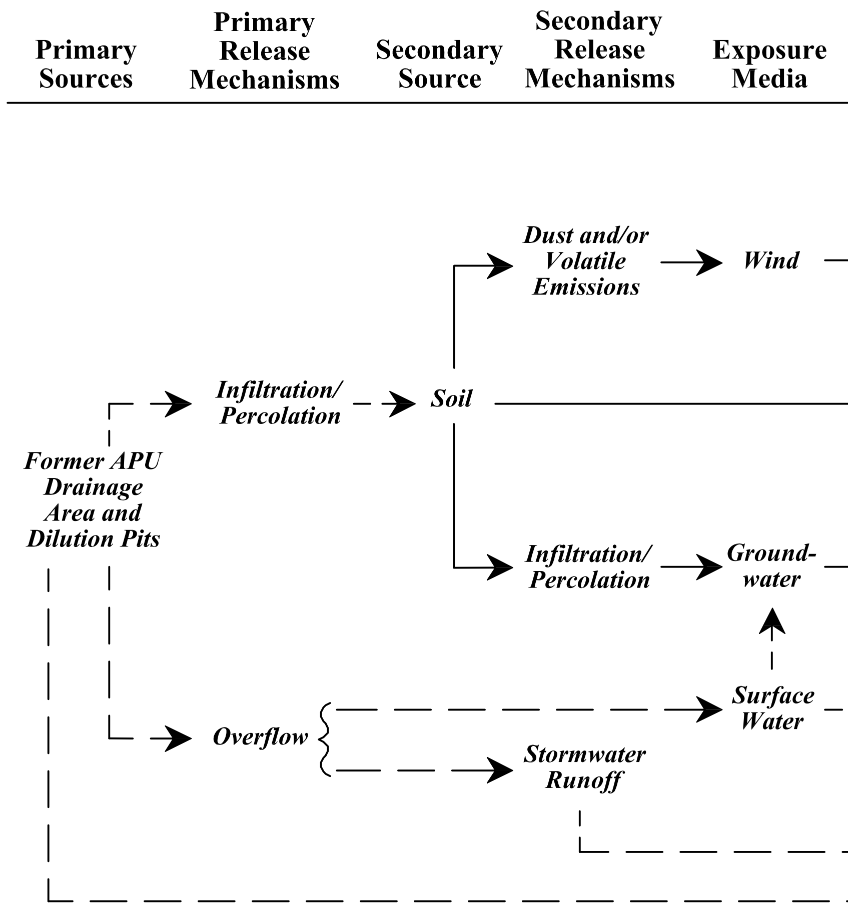
As part of the five-year review, observations were made of each site, and interviews were conducted with NASA personnel (Mr. Dan Morgan was interviewed during the site inspection and additional site staff/workers were interviewed in May 2011) to address the following issues:

- Whether human health or ecological routes of exposure or receptors have been identified or changed since the ROD was signed in a way that could affect the protectiveness of the remedy;
- Whether there are newly identified contaminants or contaminant sources, including unanticipated toxic byproducts of the remedy (not previously addressed by the decision documents);
- Whether physical site conditions or the understanding of these conditions have changed in a way that could affect the protectiveness of the remedy; and
- Whether land use has changed since the remedy selection or whether it is expected to change in the future.

The results of the information obtained to address these issues are that the physical setting of the sites covered in the ROD have changed little since the ROD was signed. The only significant change to the physical nature of these sites is the demolition and removal of structures at Site N3, Buildings 4886 and 4889, which formerly housed a boiler used for heating purposes and electric switching equipment, respectively (Figure 4-2). The removal of these buildings did not result in any significant changes to the exposure pathways previously identified for the site. Though not a ROD requirement, the current Base GP (Edwards AFB, 2009) continues to indicate that OU6 will be used for industrial purposes only and the NASA DFRC MP (Development One, 2009) indicates that office activity will be relocated outside of the flightline. Because, the majority of the plume is located beneath the flightline, relocation of office activities outside of the flightline also means that office activity will be relocated to areas outside the portions of OU6 where groundwater is impacted or anticipated to be impacted in the future.

The proposed relocation of office activity to areas outside the groundwater plume is expected to reduce the potential exposure to site-related chemicals, but is not a ROD requirement and will not significantly change exposure pathways for either human or ecological receptors. Although not strictly related to changes in site use, the positions of the constituents in the plumes have changed in the 5 years since the ROD was signed. These changes were discussed in Sections 3.3, 6.4.2.4, and 6.4.2.6. While concentrations of plume constituents have decreased in some areas, they have increased in others. Although some of these increases have resulted in higher groundwater concentrations near some buildings to levels that are higher than have been detected in the past, they have not resulted in higher concentrations than have been detected historically in OU6. The implication of these changes as they pertain to this five-year review is evaluated in more detail in Section 7.2.5, and the outcome of these changes is found to not result in an imminent risk to indoor workers.

Exposure pathways at Sites N2, N3, and N7 are depicted on Figures 7-1, 7-2, and 7-3, respectively. These figures have been updated from those presented in the ROD, and include footnotes for complete and potentially complete pathways to explain either why they are not being addressed as part of the RA because of risk management decisions or indicate the remedial actions that have been implemented in accordance with the ROD. As previously discussed in Sections 4.1 and 4.1.1 and as noted on Figures 7-1, 7-2, and 7-3, though the inhalation pathway includes direct inhalation of vapors from groundwater and indirect inhalation within buildings through the VIP, the selected remedy was designed to be protective of direct inhalation only as the risk assessment showed no unacceptable VIP risk requiring action (this is further discussed in Section 7.2.4). Groundwater impacts are being addressed by the selected remedy through treatment and LUCs, but No Further Action was selected for soil at Sites N2, N3, and N7 based on the results of the OU6 human health risk assessment (HHRA) (Earth Tech, 2003) and predictive ecological risk assessment (Tetra Tech, 2003). Exposures to COCs from soil as a



Exposure Media	Exposure Route	Human: Current Industrial	Human: Future Industrial	Human: Future Construction	Human: Future Res/Sens	Human: Risk Mgt. Decisions/RA	Ecological: Terrestrial	Ecological: Aquatic
Wind	Inhalation	Yes[1]	Yes[2]	Yes[2]	Yes[2]	a	No[3]	No[3]
Soil	Ingestion	Yes[1]	Yes[2]	Yes[2]	Yes[2]	a	No[3]	No[3]
Soil	Dermal Contact	Yes[1]	Yes[2]	Yes[2]	Yes[2]	a	No[3]	No[3]
Groundwater	Ingestion	No[3]	Yes[2]	Yes[2]	Yes[2]	b	No[3]	No[3]
Groundwater	Inhalation-Dir	No[3]	Yes[2]	Yes[2]	Yes[2]	b	No[3]	No[3]
Groundwater	Inhalation-VIP*	Yes[1]	Yes[2]	Yes[2]	Yes[2]	c	No[3]	No[3]
Groundwater	Dermal Contact	No[3]	Yes[2]	Yes[2]	Yes[2]	b	No[3]	No[3]
Surface Water	Ingestion	No[4]	No[4]	No[4]	No[4]		No[4]	No[4]
Surface Water	Inhalation	No[4]	No[4]	No[4]	No[4]		No[4]	No[4]
Surface Water	Dermal Contact	No[4]	No[4]	No[4]	No[4]		No[4]	No[4]
Stormwater Runoff	Ingestion	No[4]	No[4]	No[4]	No[4]		No[4]	No[4]
Stormwater Runoff	Inhalation	No[4]	No[4]	No[4]	No[4]		No[4]	No[4]
Stormwater Runoff	Dermal Contact	No[4]	No[4]	No[4]	No[4]		No[4]	No[4]

Notes:
* In 2006 when the Record of Decision was signed documenting the CERCLA response, the inhalation pathway of concern did not include VIP. However, due to changing toxicity criteria and risk assessment methodologies (see Sections 7.2.3 and 7.2.4), reassessment of the VIP to verify protectiveness is included as a recommendation (Section 9.0).

Current and Future, as used in this figure, are defined relative to the point at which the Record of Decision was signed.

[1] complete pathway
[2] potential pathway, currently incomplete
[3] incomplete pathway
[4] incomplete, not applicable because pathway no longer exists

APU = auxiliary propulsion unit
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
Dir = direct
Mgt. = management
PAH = polycyclic aromatic hydrocarbon
RA = remedial action
Res/Sens = residential/sensitive use
VIP = vapor instrusion pathway

Yellow highlights indicate pathway retained for a CERCLA response

Gray shading indicates pathways not retained either because pathway does not exist or risks are within acceptable limits

— — → Pathway no longer exists due to previous Air Force construction project

Risk Mgt. Decisions/RA:

a. Organic lead and PAH risk drivers for soil. Organic lead detections were suspect; eliminated as a risk driver. PAHs detected in shallow soil samples collected beneath asphalt; PAHs likely associated with asphalt; PAHs not part of original CERCLA release.

b. Addressed by RA: treatment, land use control.

c. Under review during the next five-year review period and retained under the inhalation remedial action objective.

REVISED DRAFT FINAL

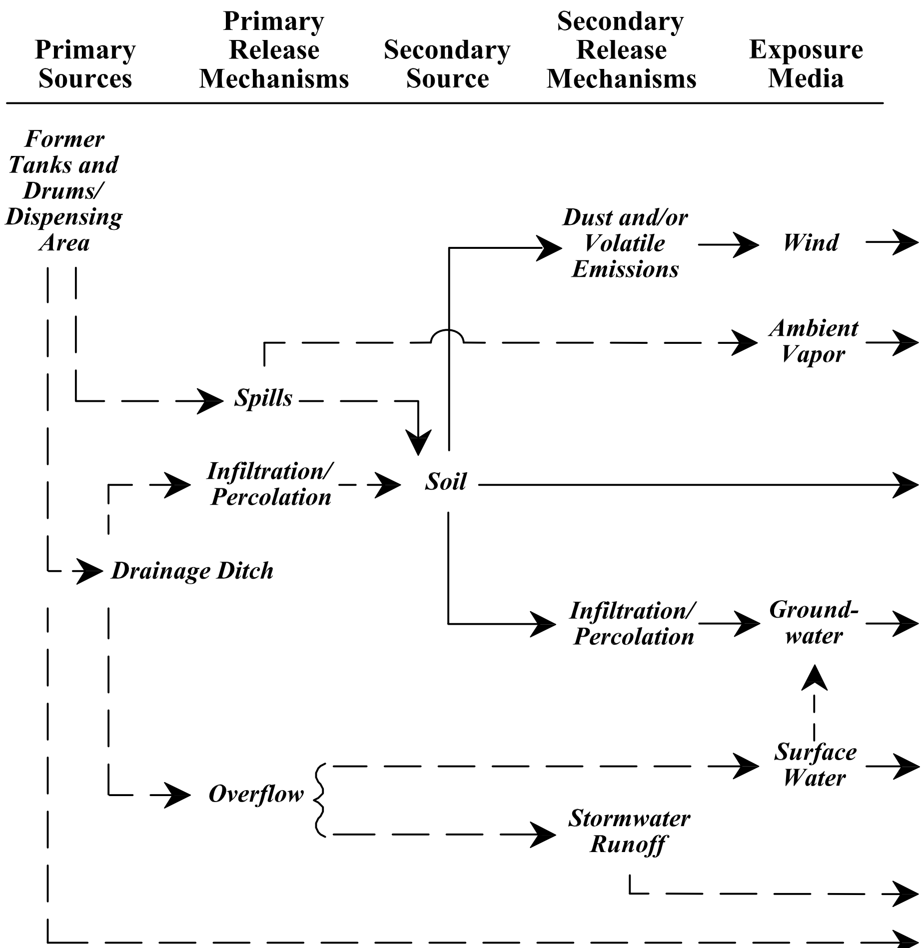
Site N2 Exposure Pathways Retained For A CERCLA Response

Date 08-2011

Project No. 60133976

Operable Unit 6
First Five-Year Review Report
Edwards AFB

Figure 7-1



Receptor

Exposure Media	Exposure Route	Human: Current Industrial	Human: Future Industrial	Human: Future Construction	Human: Future Res/Sens	Human: Risk Mgt. Decisions/RA	Ecological: Terrestrial	Ecological: Aquatic
Wind	Inhalation	Yes[1]	Yes[2]	Yes[2]	Yes[2]	a	No[3]	No[3]
Ambient Vapor	Inhalation	No[4]	No[4]	No[4]	No[4]		No[4]	No[4]
Soil	Ingestion	Yes[1]	Yes[2]	Yes[2]	Yes[2]	a	No[3]	No[3]
Soil	Dermal Contact	Yes[1]	Yes[2]	Yes[2]	Yes[2]	a	No[3]	No[3]
Groundwater	Ingestion	No[3]	Yes[2]	Yes[2]	Yes[2]	b	No[3]	No[3]
Groundwater	Inhalation-Dir	No[3]	Yes[2]	Yes[2]	Yes[2]	b	No[3]	No[3]
Groundwater	Inhalation-VIP*	Yes[1]	Yes[2]	Yes[2]	Yes[2]	c	No[3]	No[3]
Groundwater	Dermal Contact	No[3]	Yes[2]	Yes[2]	Yes[2]	b	No[3]	No[3]
Surface Water	Ingestion	No[4]	No[4]	No[4]	No[4]		No[4]	No[4]
Surface Water	Inhalation	No[4]	No[4]	No[4]	No[4]		No[4]	No[4]
Surface Water	Dermal Contact	No[4]	No[4]	No[4]	No[4]		No[4]	No[4]
Stormwater Runoff / Drainage Ditch	Ingestion	No[4]	No[4]	No[4]	No[4]		No[4]	No[4]
Stormwater Runoff / Drainage Ditch	Inhalation	No[4]	No[4]	No[4]	No[4]		No[4]	No[4]
Stormwater Runoff / Drainage Ditch	Dermal Contact	No[4]	No[4]	No[4]	No[4]		No[4]	No[4]

Notes:
* In 2006 when the Record of Decision was signed documenting the CERCLA response, the inhalation pathway of concern did not include VIP. However, due to changing toxicity criteria and risk assessment methodologies (see Sections 7.2.3 and 7.2.4), reassessment of the VIP to verify protectiveness is included as a recommendation (Section 9.0).
Current and Future, as used in this figure, are defined relative to the point at which the Record of Decision was signed.

[1] complete pathway
[2] potential pathway, currently incomplete
[3] incomplete pathway
[4] incomplete, not applicable because pathway no longer exists

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
Dir = direct
Mgt. = management
PAH = polycyclic aromatic hydrocarbon
RA = remedial action
Res/Sens = residential/sensitive use
VIP = vapor instrusion pathway

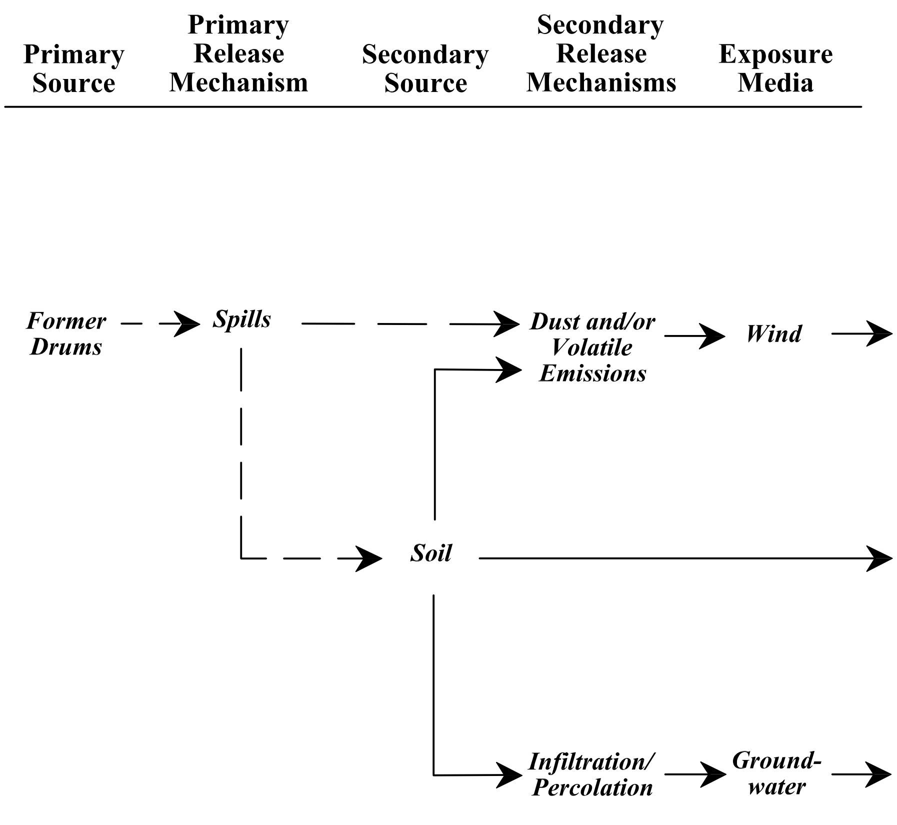
Yellow highlights indicate pathway retained for a CERCLA response
Gray shading indicates pathways not retained either because pathway does not exist or risks are within acceptable limits
— — → Pathway no longer exists due to a previous Air Force construction project

Risk Mgt. Decisions/RA:
a. Organic lead and PAH risk drivers for soil. Organic lead detections were suspect; eliminated as a risk driver. PAHs detected in shallow soil samples collected beneath asphalt; PAHs likely associated with asphalt; PAHs not part of original CERCLA release.
b. Addressed by RA: treatment, land use control.
c. Under review during the next five-year review period and retained under the inhalation remedial action objective.

REVISED DRAFT FINAL

Site N3 Exposure Pathways Retained For A CERCLA Response

Date 08-2011
Project No. 60133976
Operable Unit 6
First Five-Year Review Report
Edwards AFB
Figure 7-2



Receptor

Exposure Route	Human: Current Industrial	Human: Future Industrial	Human: Future Construction	Human: Future Res/Sens	Human: Risk Mgt. Decision/RA	Ecological: Terrestrial	Ecological: Aquatic
Inhalation	Yes[1]	Yes[2]	Yes[2]	Yes[2]	a	No[3]	No[3]
Ingestion	Yes[1]	Yes[2]	Yes[2]	Yes[2]	a	No[3]	No[3]
Dermal Contact	Yes[1]	Yes[2]	Yes[2]	Yes[2]	a	No[3]	No[3]
Ingestion	No[3]	Yes[2]	Yes[2]	Yes[2]	b	No[3]	No[3]
Inhalation-Dir	No[3]	Yes[2]	Yes[2]	Yes[2]	b	No[3]	No[3]
Inhalation-VIP*	Yes[1]	Yes[2]	Yes[2]	Yes[2]	c	No[3]	No[3]
Dermal Contact	No[3]	Yes[2]	Yes[2]	Yes[2]	b	No[3]	No[3]

Notes:

* In 2006 when the Record of Decision was signed documenting the CERCLA response, the inhalation pathway of concern did not include VIP. However, due to changing toxicity criteria and risk assessment methodologies (see Sections 7.2.3 and 7.2.4), reassessment of the VIP to verify protectiveness is included as a recommendation (Section 9.0).

Current and Future, as used in this figure, are defined relative to the point at which the Record of Decision was signed.

[1] complete pathway
[2] potential pathway, currently incomplete
[3] incomplete pathway

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
Dir = direct
Mgt. = management
PAH = polycyclic aromatic hydrocarbon
RA = remedial action
Res/Sens = residential/sensitive use
VIP = vapor instrusion pathway

Yellow highlights indicate pathway retained for a CERCLA response

Gray shading indicates pathways not retained either because pathway does not exist or risks are within acceptable limits

— — → Pathway no longer exists

Risk Mgt. Decision/RA:

a. PAHs risk driver for soil; PAHs detected in shallow soil samples collected beneath asphalt; PAHs likely associated with asphalt; PAHs not part of original CERCLA release.

b. Addressed by RA: treatment, land use control.

c. Under review during next five-year review period and retained under the inhalation remedial action objective.

REVISED DRAFT FINAL

Site N7
Exposure Pathways
Retained For A CERCLA Response

Date 08-2011 / Project No. 60133976	Operable Unit 6 / First Five-Year Review Report / Edwards AFB	Figure 7-3

secondary source via inhalation of windborne dust and volatile emissions, and ingestion and dermal contact were considered to be complete or potentially complete pathways for human receptors. However, the recommended remedy for soil at these sites was No Action because the risk assessment process used was conservative in nature, the calculated human health and environment risks fell within or less than the risk management range, and contaminants identified as risk drivers were likely not associated with Air Force/NASA DFRC use of the site. Organic lead was initially identified as a risk driver at Sites N2 and N3; however, the validity of organic lead results was suspect and organic lead was eliminated from further consideration as a risk driver. Polycyclic aromatic hydrocarbons (PAHs) were a risk driver for all three sites. PAHs were detected in shallow soil samples beneath asphalt pavement. PAHs are a common component of asphalt, and given the shallowness of the soil samples in which the PAHs were detected, it is likely that the PAHs were associated with the asphalt. Therefore, the PAHs did not appear to be a part of the original CERCLA release.

7.2.3 CHANGES IN TOXICITY AND OTHER CONTAMINANT CHARACTERISTICS

Guidance indicates that a review should be performed of toxicity criteria used for determining cleanup levels as part of the five-year review process. However, the OU6 cleanup levels are based on promulgated standards (MCLs).

Although, as noted in Section 7.2.1, none of the MCLs used as cleanup levels have changed since the ROD was signed, many of the MCLs predate the ROD, and thus the toxicity criteria used to derive the MCLs may have changed since the MCLs were established. To address this possibility, the toxicity criteria available when the OU6 HHRA (Earth Tech, 2003) was submitted were compared to the current criteria for the chemicals for which cleanup goals have been established. The results indicated that, except for chloroform and ethylbenzene, the criteria have either decreased or remained unchanged.

The oral cancer slope factor for chloroform decreased slightly from 6.1×10^{-3} reciprocal milligrams per kilogram-day [$(mg/kg\text{-}day)^{-1}$] to 3.1×10^{-2} $(mg/kg\text{-}day)^{-1}$. However, due to the changes in the procedure used to calculate risk-based drinking water levels, the concentration of chloroform corresponding to a cancer risk of 1×10^{-6} has actually increased slightly from 0.16 to 0.19 μg/L. Thus, the MCL for chloroform of 80 μg/L is currently as protective (at a cancer risk of 1 x 10^{-4}) as when the ROD was finalized.

The California MCL for ethylbenzene was established in 2003 and was based on its non-carcinogenic endpoints. Although the USEPA has not, DTSC has classified ethylbenzene as a human carcinogen (DTSC, 2007). The risk-based concentration based on a non-carcinogenic potential was 1,300 μg/L and the corresponding MCL was protective for these risks. However, the risk-based concentration based on its carcinogenic potential is 1.5 μg/L (USEPA, 2011). The current MCL for ethylbenzene is not protective of the potential cancer risk for ethylbenzene. There is no schedule to review and possibly revise the California MCL. Ethylbenzene is present above 1.5 μg/L and will be addressed as part of the bioremediation RA component. LUCs are in place preventing current and future human exposure.

The guidance for assessing toxicity changes (as part of the five-year review process) specifies that this review applies only to those criteria used for risk-based cleanup levels. Although the OU6 ROD does not propose such risk-based cleanup levels, a review was conducted on the possible impact of changes in the risk-based screening levels used to develop preliminary human health risks for soil and groundwater chemicals because these risks were used to select the chemicals for which cleanup levels were proposed in the ROD. USEPA Region IX Preliminary Remediation Goals (PRGs) from the year 2000 were used as the risk-based levels used in the OU6 HHRA. PRGs were replaced in November 2010 by Regional Screening Levels (RSLs) (USEPA, 2011). The results of this review are provided as Appendix G.

The results of this review show that the cancer risks and non-cancer hazards based on RSLs for groundwater under a residential scenario were less than or essentially the same as risk levels calculated for the ROD with two exceptions. The cancer risk associated with groundwater in the Site N2 area minimally increased from 2.72 x 10^{-3} to 3.00 x 10^{-3}. The cancer risk associated with groundwater in the Site N3 area increased from 6.28 x 10^{-1} to 1.18 x 10^{0}. This change is attributable to the classification of naphthalene as a carcinogen in 2005. The high potential risk now predicted for naphthalene and the absence of an MCL suggest that naphthalene in groundwater may pose a health risk under the hypothetical residential exposure scenario. However, it should be noted that this risk, like that for all the soil and groundwater risks presented for OU6, is based on the maximum groundwater concentrations detected at the time the HHRA was prepared in 2002. A better representation of this risk would require more recent and sufficient data to develop a 95 percent upper confidence limit of the mean to represent the reasonable maximum exposure concentration. Groundwater monitoring data collected within the last 2 to 3 years are available to support this assessment.

Although most of the hazards associated with soil decreased, some hazards and the risks associated with soil tended to increase using the RSLs under both the industrial and residential use scenarios. However, as summarized in the ROD, because of the sporadic nature of the detections and/or the presence of naturally occurring or asphalt-based compounds of the chemicals that drive the risks in soil, the risks are not likely associated with hazardous material releases on site. For this reason, site-related soil impacts were determined to pose no significant risks to human health or the environment, and No Action related to soil was deemed appropriate per the decision documented in the ROD (Earth Tech, 2006).

The above discussion focuses on the risks for soil and groundwater presented in the ROD. However, the ROD also presented the results of the potential risk from groundwater VOCs that might migrate through the vadose zone and into buildings routinely occupied by indoor workers. The results of these assessments indicated that the risks were all within or less than the cancer risk range of 10^{-4} to 10^{-6} and a Hazard Index (HI) of 1. For this reason, cleanup levels to protect this potential exposure pathway were not established. It should be noted that since concentrations of groundwater VOCs were present at the site in excess of their MCLs (i.e., the cleanup goals established for OU6 in the ROD) and those groundwater VOCs did not lead to unacceptable indoor air risks, it is reasonable to conclude that the MCLs were also protective of the groundwater-to-indoor air pathway (VIP). However, since the toxicity criteria by which some of the VOCs evaluated for the VIP assessment may have changed, it is possible that these chemical may pose an imminent risk to the health of indoor workers. This possibility is considered in the uncertainty assessment presented in Section 7.2.5.

7.2.4 CHANGES IN RISK ASSESSMENT METHODS

The OU6 HHRA (Earth Tech, 2003) evaluated both direct and indirect exposure scenarios to site-related soil and groundwater chemicals. In general, the direct exposure pathways were assessed using risk-based chemical screening levels. However, since screening levels were not available for the VIP from the subsurface into indoor air, one of the major indirect pathways, the HHRA used the Johnson and Ettinger (J&E) vapor intrusion model. Although the current version of this model is still used, other aspects of the assessment of the VIP have changed since the HHRA was completed and the ROD was signed. Since the work plan for the HHRA was completed in 2001, guidance for the assessment of the VIP has been developed by DTSC (DTSC, 2005) and the USEPA (USEPA, 2002). In addition, Edwards AFB is currently developing a VIP protocol specifically for Edwards AFB in conjunction with the DTSC and the USEPA. The major differences between the approach used in the HHRA and current guidance are summarized below and the potential impacts of these differences are discussed in Section 7.2.5.

During the OU6 HHRA, the VIP was assessed only at sites with VOCs in soil, soil vapor (SV), or groundwater, and for sites with buildings that were, or could be, occupied on a routine basis (in accordance with the HHRA Work Plan). As a result, the VIP was evaluated at only four of the six sites. In the two that were not evaluated (Sites N4 and N14), VOCs were present in soil, groundwater, or both. However, since no buildings were present at either site, the VIP was not evaluated. The current guidance assumes that future development will generally include occupied buildings, and thus an HHRA conducted using the current guidance might assess the VIP at all six sites. However, since OU6 has never been and is not anticipated to be used for residential purposes in the future, this change is not likely to have changed the assessment conducted for the HHRA.

In the four sites where the VIP was assessed during the HHRA, SV data were used for evaluation of three sites (Sites N2, N3, and N7). For the remaining site (Site N1), soil and groundwater data were used for the VIP evaluation. Current guidance emphasizes the use of SV data and considers the use of soil data as unacceptable. While the use of groundwater data is acceptable, under current guidance groundwater data should only be considered when SV data cannot be collected and only for initial screening purposes. Current guidance encourages the collection and use of SV from beneath the foundation of the buildings, rather than from the locations used at OU6, which were collected from soil vapor associated with the soil vapor extraction and monitoring system. The uncertainties associated with the use of soil vapor collected from this system as opposed to designated soil vapor monitoring wells as is currently recommended is discussed in Section 7.2.5. In general, since the total cancer risks and HIs for Sites N2, N3 and N7 were significantly below 1×10^{-4} and HI of 1, respectively, it is unlikely that repeating the VIP assessments at these sites using current methodology would alter the conclusions for this pathway.

While the VIP risks for Site N1 were closer to the upper end of the risk management levels of 1 x 10^{-4} cancer risk and an HI of 1, the fact that these results were obtained using soil and groundwater data makes it difficult to predict whether the conclusion would be different using current methodology

7.2.5 DISCUSSION OF UNCERTAINTIES ASSOCIATED WITH CHANGES IN RISK ASSESSMENT METHODS AND SITE CONDITIONS

One of the purposes of a five-year review is to determine if changes in site conditions or to the elements making up past assessments may have changed in such a way that the previous conclusions may no longer be valid. Therefore, the purpose of this section is to discuss uncertainties in the VIP risk results that may now be present as a result of changes in site conditions or in the procedures used to assess indoor air risks since the HHRA and the ROD were prepared. The elements to be considered are discussed in the following subsections.

7.2.5.1 Changes in VOC Concentrations

Groundwater concentrations were used in the HHRA to assess the potential risks for both the hypothetical drinking water pathway and the industrial VIP. As shown on Figures 7-1, 7-2, and 7-3, groundwater VOCs are the indirect source for the VIP via the subsurface vapor transport pathway. As discussed in Section 6.4, concentrations of the risk-driving VOCs in groundwater (TCE and benzene) have changed significantly in Sites N1, N2, N3 and N7 groundwater since the HHRA, which included the VIP assessment, was conducted in 2002 and 2003. In general, concentrations of groundwater VOCs have generally decreased. The few exceptions to this trend are found in monitoring wells downgradient of the initial sources where concentrations have either shown no consistent trend or have increased. It should be noted that where concentrations have increased (e.g., TCE in N3 MW05 and N1-MW08, and benzene in N3-MW05), they have not exceeded the maximum detected concentrations that were used for the assessment of groundwater risk at these sites (and VIP risk at Site N1) in the HHRA. These changes in VOC concentrations imply that the location of the plumes relative to buildings currently occupied on a routine basis may have also changed. These plumes are presented on Figures 3-5 and 3-7 showing the current extent of TCE and benzene at OU6. These chemicals were selected since they represent the primary constituents of the impacted groundwater and the primary risk drivers previously identified for the VIP. These figures represent the interpretation of the extent of groundwater impact as of 2010. Six buildings were identified above or near these plumes: Buildings 4803, 4805, 4806, 4807, 4810, and 4827. Of these, only three buildings were identified as being occupied on a routine basis: Buildings 4806, 4807, and 4810. Site personnel familiar with the activity patterns for OU6 verified that these buildings were occupied daily throughout the work week. Occupancy at a lower frequency would make it highly unlikely that exposure would lead to adverse health effects, especially considering the fact that these buildings are located only on the margins of the plumes.

To assess the potential risk, if any, posed by groundwater VOCs via the VIP, it is useful to put the concentrations into context with their potential impact on indoor air for the three routinely occupied buildings. To do this, the advanced groundwater version of the J&E model (Version 3.1) was used to calculate the groundwater concentration corresponding to a 1×10^{-6} cancer risk for both TCE and benzene for the industrial use scenario. This concentration was conservatively calculated using the values for the building, soil, and exposure parameters recommended by the DTSC for calculating California Human Health Screening Levels for soil vapor (DTSC, 2005). These values are considered conservative because they assume sandy soil and a small building (10 by 10 meters) to represent the much larger occupied buildings. The value for the depth to water (5 feet) is also considered conservative because it represents the lower extent of the range for OU6 (approximately 5.2 feet to 23.8 feet). The toxicity criteria (i.e., the inhalation unit risk [IUR]) were selected in accordance with the July 2006 U.S. Air Force memo for selecting Toxicity Criteria for Use in Risk Assessment and Establishing Risk-Based Cleanup Levels. Accordingly, the IUR recommend by the California Environmental Protection Agency for TCE (2×10^{-6} $(ug/m^3)^{-1}$) and by USEPA for benzene (7.8×10^{-6} $(\mu g/m^3)^{-1}$) were used. The resulting risk-based concentrations for TCE and benzene were 30.6 and 13.2 µg/L, respectively. Examination of the proximity of these three buildings to these concentrations on Figures 3-5 and 3-7 shows that a corner of Building 4806 appears to be located over levels of benzene in excess of the benzene screening level. Buildings 4807 and 4810 do not appear to be over portions of either the TCE or the benzene plumes with concentrations of those constituents that exceed the calculated risk-based groundwater screening level.

The juxtaposition of the three routinely occupied buildings to the risk-based groundwater screening levels indicates that groundwater VOCs do not present a threat to the health of indoor workers via the VIP. Even though a portion of Building 4806 overlies groundwater containing benzene concentrations over the benzene screening level, the overlap is only a small portion of the entire building. This, together with the health-protective nature of the screening level supports the conclusion that the potential VIP risks for the building are well within the level of risk considered acceptable (i.e., a cancer risk of 10^{-6} or less) and that no imminent health risks are likely.

It should be noted that the groundwater plumes contain VOCs other than TCE and benzene. However, the results in the HHRA showed that the contribution of these other VOCs to the total potential VIP risk is not likely to change the conclusion reached above (i.e., no imminent risk) because the risks from these other VOCs were determined to contribute much lower levels of risk (often an order of magnitude lower) than TCE and benzene.

7.2.5.2 Changes in How VOC Concentrations in Soil Gas are Measured

The VIP was assessed using soil gas results at Sites N2, N3, and N7, and using soil and groundwater results at Site N1. Soil gas samples were collected in 1998 and 1999 from sampling ports installed to monitor the progress of the groundwater treatment systems operating at Sites N2, N3, and N7. Groundwater sparging and soil vapor extraction systems were installed as part of a treatability study. Samples of soil gas from the influent side of the system were collected using evacuated Summa canisters while the extraction system was off. These samples were tested using USEPA Methods TO-14 and SW8260B. While these samples provided an accurate means of measuring the progress of the remediation, the procedures are not consistent with current guidance for the construction and sampling of soil gas monitoring wells. For example, many of the samples represent wells from several locations rather than from individual locations as required in the current guidance. In addition, some of the wells were completed below the saturated zone because some were used for air sparging following lowering of the water table. It is also likely that samples were collected at rates exceeding 200 milliliters per minute and that sampling was not preceded by leak testing as currently required. These and other possible differences with current procedures do not necessarily mean that the concentrations used for the VIP assessment are biased high or low. However, they introduce some degree of uncertainty into the assessment that cannot be evaluated at this time.

As noted above, the VIP assessment for Site N1 was conducted using soil and groundwater data because soil gas data were not available. Current guidance allows for the use of groundwater data under such circumstances. However, the uncertainty associated with the use of groundwater data is generally greater than that for the use of soil gas data. This uncertainty is due to the fact that the model used to simulate vapor transport from the subsurface (the J&E vapor intrusion model) assumes a simple steady state equilibrium relationship between the dissolved and the vapor phases that is governed entirely by the Henry's Law constant for each chemical. Although this relationship is reasonably accurate for a single chemical, the presence of multiple chemicals leads the model to over-predict the vapor concentration for individual chemicals in a mixture. Therefore, the uncertainty associated with the use of groundwater data generally leads to the over-prediction of VIP risks. This may be one of the reasons why the risks for Site N1 are higher than those at the sites for which soil vapor data were used.

7.2.5.3 Changes in How Indoor Air Risks are Modeled

The VIP and associated risks were assessed using the J&E model, as mentioned previously. The parameters that affect the modeling generally fall into three groups: changes in source concentrations (i.e., changes in soil vapor or groundwater concentrations), changes in modeling approach (i.e., how the model uses source, soil, and building parameters to estimate indoor air concentrations), and changes in exposure and toxicity criteria used to calculate potential risk. Changes in source concentrations have already been discussed. Changes in modeling approach and toxicity criteria are discussed below.

<u>**Changes in Modeling Approach**</u>

The VIP for site N1, N2, N3, and N7 were evaluated because VOCs were present and these sites had buildings that could have been routinely occupied. The J&E model was used in the HHRA for these evaluations. The version available at the time the HHRA was prepared was Version 1.2 from the USEPA. The basics of the model used in the HHRA and the model currently available (Version 3.1) have not changed appreciably. There have been some changes to the values for some of the model parameters. For example, some of the values for the soil properties (e.g., total and air-filled porosity), chemical properties for some chemicals (e.g., Henry's Law constants, soil-to-water partition, and diffusivity coefficients), and transport factors (the adoption of a conservative default value for the average vapor flow rate into a building) have changed since the HHRA was prepared. The impact of these changes would be chemical- and site-specific. However, the general impact is not likely to be large and thus relatively little uncertainty is expected to be associated with these changes.

Changes in Toxicity Criteria

The OU6 HHRA was developed during the period from 2002 to 2003. By agreement among the RPMs, the toxicity criteria available at the time the assessment was begun were the criteria used throughout the assessment. In general, the toxicity criteria were consistent with those used for the USEPA Region IX PRGs to be consistent with the fact that the PRGs were used to calculate the soil and groundwater risks. The only exceptions to this general rule were for benzene and 1,4-dichlorobenzene where the criteria developed by the Office of Environmental Health Hazard Assessment were used at the request of the DTSC. Between the time the HHRA was produced and now, several of the toxicity criteria used for the VIP assessments have changed. These differences and the potential impact they may have on the VIP risks presented in the HHRA and ROD are summarized in Table 7-3.

The results in Table 7-3 show that 30 chemicals were evaluated in the VIP assessments for Sites N1, N2, N3, and N7. The table shows that the toxicity values for many of the chemicals have changed. The values for eight of the chemicals have increased and for eight others have decreased. In addition to these changes, it should be noted that three chemicals (bromochloromethane, 1,1-dichloroethene, and chloromethane) that were considered carcinogens are now considered non-carcinogens and the same number (three) that were considered non-carcinogens are now considered carcinogens (1,1-dichloroethane, ethylbenzene, and naphthalene).

TABLE 7-3. CHANGES IN TOXICITY CRITERIA USED TO ASSESS THE VIP AT OU6

Analyte	Cancer/ Non-Cancer	Change in Risk	Factor	Comment
1,1,2,2-tetrachloroethane	C	no change		
1,1,2-trichloroethane	C	no change		
1,1-dichloroethane				no longer considered a non-carcinogen
1,1-dichloroethene				no longer considered a carcinogen
1,2,4-trimethylbenzene	NC	decrease	<2x	
1,2-dichlorobenzene	NC	no change		
1,2-dichloroethane	C	no change		
1,3,5-trimethylbenzene	NC	decrease	<2x	
1,4-dichlorobenzene	C	no change		
2-hexanone	NC	increase	2x	
acetone	NC	2x		
benzene	C	<2x		
bromochloromethane				no longer considered a carcinogen
bromodichloromethane	C	increase	<2x	
carbon disulfide	NC	increase	7x	
carbon tetrachloride	C	decrease	7x	
chlorobenzene	NC	decrease	2.5x	
chloroform	C	no change		
chloromethane				no longer considered a carcinogen
cis-1,2-dichloroethene				no criteria currently available for the inhalation route
ethylbenzene				no longer considered a non-carcinogen
methyl ethyl ketone	NC	increase	<2x	
methylene chloride	C	no change		
naphthalene				no longer considered a non-carcinogen
tetrachloroethene	C	increase	<2x	
toluene	NC	13x		
total xylenes	NC	increase	3x	
trans-1,2-dichloroethene	NC	increase	<2x	
trichloroethene	C	increase	<2x	
vinyl chloride	C	decrease	<2x	

Notes:
[1] based on comparison with June 2011 USEPA Region Regional Screening Levels
< = less than
C = carcinogen
NC = noncarcinogen
USEPA = United States Environmental Protection Agency
X = times

Even though a similar number of the toxicity values increased as decreased, the net effects of these changes are difficult to predict since that would depend on the concentrations of each VOC detected at each site. Therefore, the degree of uncertainty introduced into the VIP assessments is site-specific. The largest impacts are expected to be for the carcinogenic chemicals previously considered to be non-carcinogenic at the time of the assessments. To estimate the magnitude of these possible impacts, the calculated concentrations of the indoor air levels of naphthalene and ethylbenzene at Site N3 (where the highest soil vapor levels of these VOCs were detected) was examined. Using the estimated indoor air concentrations reported in the HHRA for these chemicals, and the current industrial air RSLs (USEPA, June 2011), their contribution to the total VIP cancer risk of 9×10^{-9} would have been only an additional 3×10^{-10}. These results suggest that the changes in the risk results at the other sites where these chemicals were detected at lower levels are not likely to have altered the general results of the VIP assessments presented in the HHRA and the ROD.

Changes in toxicity criteria can be expected to affect exposure routes other than the VIP. For example, naphthalene was detected in groundwater at several sites. The changes in its toxicity values for Site N3 were discussed in Section 7.2.3 and were determined to produce significant changes in the potential risk to the future hypothetical residential receptor. The magnitude of the uncertainty these changes might introduce into the assessments presented in the HHRA and ROD cannot be determined at this time. To evaluate the impact of these changes and determine if the cleanup goals established in the ROD are sufficiently protective, data representative of current conditions in site groundwater need to be reviewed, and if sufficient data for the chemicals in question (e.g., naphthalene and ethylbenzene) are available, an updated risk assessment may be conducted as part of the next five-year review.

7.2.6 EXPECTED PROGRESS TOWARD MEETING REMEDIAL ACTION OBJECTIVES

Although the ISCO component of the RA is progressing as expected, estimation of the timeframe to achieve RAOs will not be possible until full plume delineation in the areas of Site N1 and Site N4 is accomplished.

7.3 QUESTION C: HAS ANY OTHER INFORMATION COME TO LIGHT THAT COULD CALL INTO QUESTION THE PROTECTIVENESS OF THE REMEDY?

The following subsections present additional information that was considered during the five-year review when determining the protectiveness of the remedy.

7.3.1 SITE 25

TCE has been detected in groundwater samples collected from well 18-MW01, west of OU6, the likely source of which is the Site 25 plume in OU8. Although this well is located outside of the estimated capture zone of the Site 25 GETS and may be migrating, it does not appear that the Site 25 and OU6 solvent plumes have commingled. Because the Site 25 plume has not impacted OU6 groundwater, the current protectiveness of the OU6 remedy has not been affected. The uncaptured portion of the Site 25 plume is due south of the GETS extraction well array, and full plume containment has been maintained west of the array.

To evaluate final remedial solutions, a *Draft Final Feasibility Study and Technical Impracticability Evaluation Report* (AECOM, 2011a) was prepared for Site 25. Among the alternatives evaluated were groundwater containment at the lakebed boundary and containment at the groundwater subbasin. Alternatives with either of these components would allow the Site 25 plume to commingle with the OU6 groundwater plume affecting the OU6 RA performance in the next 50 years.

7.3.2 OTHER POTENTIAL IMPACTS TO PROTECTIVENESS

No complete pathways to potential human receptors were identified and no ecological targets were identified during previous risk assessments. No new pathways or receptors were identified during the five-year review and no weather-related events have affected the protectiveness of the remedy. No natural disasters have impacted protectiveness, and no new circumstances or information have been identified that affect the assumed protectiveness of the remedy. No unforeseen byproducts have resulted from the injection process.

7.4 SUMMARY OF TECHNICAL ASSESSMENT

Based upon the data review, the site inspection, and the interviews conducted, the remedy is functioning as intended under the assumptions presented in the ROD; progress has been made toward treatment of the areas of high VOC concentrations using ISCO. However, the area of low VOC concentrations is larger than originally assumed and may not be contained in the Site N4 area. There have been no changes in the physical conditions of the site that would affect the protectiveness of the remedy. Progress has been made toward meeting all ARARs cited in the ROD.

The MCLs used as cleanup levels were established prior to the submittal of the ROD and the toxicity criteria used to derive the MCLs may have changed since the MCLs were established. However, none of the MCLs used as cleanup levels have changed since the ROD was signed.

The standardized risk assessment methodology has changed since the HHRA was performed, encouraging the use of SV data collected from directly beneath the foundations of occupied buildings. No such data were used during the HHRA, possibly affecting the protectiveness of the remedy.

Two issues/factors have affected the previous understanding of the plume nature and extent, causing difficulties in the estimation of timeframes for the achievement of RAOs. Accurate predictions for the achievement of RAOs will not be possible until the expansion of the Site 25 plume upgradient of OU6 and the OU6 plume data gap identified in the areas of Sites N1 and N4 are addressed.

There is no other information that indicates that the protectiveness of the remedy is inadequate.

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8.0 ISSUES

During the technical assessment, issues were identified that warranted consideration to determine if they may impact current or future protectiveness. No unresolved issues were raised by the public. These issues are presented in Table 8-1.

TABLE 8-1. ISSUES

Issue	Affects Protectiveness (Yes/No) Current	Affects Protectiveness (Yes/No) Future
Site 25 upgradient groundwater contamination	No	Yes
Plume delineation data gap at the leading edge	No	Yes
Changes in vapor intrusion pathway risk assessments	No	Yes
Determine risk associated with naphthalene and ethylbenzene	No	Yes
Remedy operation and maintenance	Yes	Yes
Shutdown of ERP information exchange website	No	No

Note:
ERP = Environmental Restoration Program

8.1 SITE 25 GROUNDWATER CONTAMINATION

Because the Site 25 plume has not impacted the OU6 groundwater plume, current protectiveness of the OU6 remedy has not been affected. The final remedy selected for Site 25 may affect the OU6 plume.

8.2 LEADING EDGE DATA GAP

TCE has been detected in groundwater samples collected from well N4-MW13, the furthest downgradient well, which is located at the southeast leading edge of the plume (AECOM, 2011b). This indicates that the plume extends beyond the monitored area and a data gap exists. Because exposure pathways that could result in unacceptable risks in the short term are being controlled through institutional controls, current protectiveness has not been affected. The ISCO RA component was implemented at Site N4 during the Phase II, Injection Event II in August 2010. Continued ISCO treatment in the Site N4 area will likely be required to reduce TCE concentrations. If ISCO treatment is unsuccessful in reducing TCE concentrations at Site N4 and if the recommended Site N1 and Site N4 characterization indicates that the plume is migrating significantly towards the groundwater subbasin, future protectiveness could be threatened as the subbasin contains drinking water supply wells.

8.3 CHANGES IN VAPOR INTRUSION PATHWAY RISK ASSESSMENT

Since the signing of the ROD, DTSC and the USEPA have developed guidance documents for the assessment of human health risk associated with indoor air contamination via the VIP. As discussed in Section 7.2.4, these agencies' guidance recommends evaluation procedures that differ significantly from those used in the HHRA. For example, the current guidance recommends that the VIP assessment be based on VOC concentrations in soil vapor samples collected from beneath the foundation of the buildings to be investigated rather than collected out in the open (as was the case for Sites N2, N3, and N7) or the soil and groundwater data used for Site N1. However, as presented in the discussion of uncertainties, despite the fact that this approach differs from the current one, the results are not likely to be masking an imminent threat to the health of indoor workers via the VIP. Briefly, the reason is two-fold: 1) groundwater VOC concentrations (i.e., the source for the VIP) have decreased compared to the levels used in the VIP assessment, and 2) the VIP risks calculated were relatively low (i.e., between 9×10^{-8} and 6×10^{-11} for the sites that used soil vapor data, and 4×10^{-6} for the site that used groundwater data). Given these circumstances, it is unlikely that repeating the VIP assessments at these sites using current methodology would alter the conclusions by raising the risk results above the levels considered within the risk management range. Furthermore, for Site N1 (the site with the highest calculated VIP risks) no buildings exist that are routinely occupied at Site N1 and no new construction is planned per the NASA DFRC MP (Development One, 2009). Because Site N1 is immediately adjacent to the flightline and no construction would be undertaken in that area, remedy protectiveness would not be compromised. If the land use changes, future protectiveness could be threatened.

In a related issue raised during the 20 July 2011 RPM technical meeting, the toxicity criteria used for risk calculations were different for a number of the VOCs evaluated in the assessment, including naphthalene and ethylbenzene. This issue was discussed in the uncertainty section of this report (Section 7.2.5) and is briefly summarized in Section 8.4, below.

8.4 NAPHTHALENE AND ETHYLBENZENE RISK

Issues relating to naphthalene and ethylbenzene risk are discussed in the following subsections.

8.4.1 Naphthalene and Ethylbenzene Risk in Groundwater

In Section 7.2.3 (Changes in Toxicity and Other Contaminant Characteristics), it was noted that the assessment of potential risk of groundwater COCs to future hypothetical residential receptors presented in the HHRA and ROD was based on the toxicological information available at the time. Since then, various changes in toxicity criteria have been published. Among these changes was the re-assignment of naphthalene from a non-carcinogen to a carcinogen. The discussion in Section 7.2.3 noted the difference this change would make if the assessment were conducted today. As a result of the discussion this topic generated during the 20 July 2011 RPM technical meeting, it was agreed that the potential cancer risk presented by naphthalene and any other chemical that was evaluated as a non-carcinogen, but is currently considered a carcinogen (e.g., ethylbenzene), would be evaluated. The first step in this assessment is to determine if sufficient analytical data are available to characterize current concentrations of these chemicals in the groundwater at OU6. If they are, then a decision will be made as to whether an updated assessment of the potential risk to future hypothetical receptors should be conducted.

8.4.2 Naphthalene and Ethylbenzene VIP Risk

One of the issues raised during the 20 July 2011 technical RPM meeting was that when the VIP risks were assessed in the HHRA, the toxicity criteria used for risk calculations were different for a number of the VOCs included in the assessment. Although it is possible for these differences to both over-estimate and under-estimate the potential cancer risks were they to be evaluated today, it was agreed that the changes likely to have the greatest impact would be for those chemicals originally evaluated as non-carcinogens that would be evaluated as carcinogens today. The two VOCs that fall into this category are naphthalene and ethylbenzene.

To estimate the magnitude of these possible impacts, the calculated concentrations of the indoor air levels of naphthalene and ethylbenzene at Site N3 (where the highest soil vapor levels of these VOCs were detected) was examined. Using the estimated indoor air concentrations reported in the HHRA for these chemicals, and the current industrial air RSLs (USEPA, June 2011), their contribution to the total VIP cancer risk of 9×10^{-9} would have been only an additional 3×10^{-10}. These results suggest that the changes in their toxicity assessments at the other sites where they were detected at lower levels are not likely to have altered the general results of the VIP assessments presented in the HHRA and ROD.

8.5 REMEDY OPERATION AND MAINTENANCE

Continued revision of the LUC boundary in the GIS as necessary based on the most recent, vetted, and available sampling results is recommended as is the continued adherence to review and approval procedures for construction and ground-disturbing activities. Continued well maintenance is recommended, including well completion repairs and well labeling with identification tags. Continued ISCO in the areas of highest VOC concentrations at Sites N3, N4, and N7, and groundwater monitoring for NDMA, metals (including total and hexavalent chromium), and VOCs are recommended. Inclusion of a tracer in future ISCO injections is recommended to evaluate whether injections are displacing the plume.

8.6 SHUTDOWN OF ERP INFORMATION EXCHANGE WEBSITE

In May of 2011, the U.S. Air Force discontinued the ERP information exchange webpage (BSX), which was used to obtain and exchange critical information. Currently, the U.S. Air Force is considering several alternatives to replace the BSX. Regulatory agencies will be notified once selections of alternatives are finalized.

9.0 RECOMMENDATIONS AND FOLLOW-UP ACTIONS

The issues described in Section 8.0 of this report warrant follow-up actions as presented in Table 9-1. The U.S. Air Force and NASA will be responsible for any follow-up actions, with regulatory oversight by the USEPA, DTSC, and CRWQCB. Table 9-2 contains a summary of anticipated remedial action activities and related document submittals for the next 5 years. Anticipated remedial action activities summarized in Table 9-2 include recommended follow-up actions.

TABLE 9-1. RECOMMENDATIONS AND FOLLOW-UP ACTIONS

Issue	Recommendations and Follow-up Actions	Anticipated Completion	Affects Protectiveness (Yes/No) Current	Affects Protectiveness (Yes/No) Future
Site 25 upgradient groundwater contamination	Semiannual monitoring of the Site 25 plume will continue under a separate project. Data will be used to estimate the plume extent, capture, and migration characteristics.	Ongoing	No	Yes
Plume delineation data gap at the leading edge	Additional monitoring wells will be installed and modeling performed to completely delineate the leading edge of the plume and monitor and predict cleanup progress. Additional ISCO treatment may be required at the leading edge. Recommended future step-out monitoring wells include locations south of existing monitoring wells N4-MW04, N4-MW05, N4-MW11, N4-MW12, N4-MW13, and N7-MW13. Other recommended monitoring wells include locations west of N1-MW08 and N1-MW10.	2013	No	Yes
Changes in vapor intrusion pathway risk assessments	Methodologies for determining risk to indoor air from subsurface contaminants has been revised since the ROD was signed. An evaluation of the updated VIP guidance methodologies as they relate to site conditions will be performed. The evaluation may result in a field investigation.	2013	No	Yes
Determine risk associated with naphthalene and ethylbenzene	Because of changes in the toxicity criteria (e.g., naphthalene and ethylbenzene), recalculate the residential health risk and assess the need to take additional action to meet RAOs	2012	No	Yes
Remedy operation and maintenance	Update LUC boundary in the GIS as necessary. Continue adherence to review and approve procedures for construction and ground-disturbing activities. Perform well maintenance, including well completion repairs and well labeling with identification tags. Continue ISCO in the areas of highest VOC concentrations at Sites N3, N4, and N7 and groundwater monitoring for NDMA, metals (including total and hexavalent chromium), and VOCs are recommended. Conduct tracer testing with ISCO injections.	Ongoing	Yes	Yes
Shutdown of ERP information exchange website	Re-establish an ERP information exchange website.	2011	No	No

Notes:

e.g. = *exempli gratia,* for example
ERP = Environmental Restoration Program
GIS = geographic information system
ISCO = *in situ* chemical oxidation

LUC	=	land use control
NDMA	=	N-nitrosodimethylamine
RAO	=	remedial action objective
ROD	=	Record of Decision
VIP	=	vapor intrusion pathway
VOC	=	volatile organic compound

TABLE 9-2. SUMMARY OF ANTICIPATED REMEDIAL ACTION ACTIVITIES IN THE NEXT FIVE YEARS

	Event	Date	Task	Documentation	Projected Document Submittal Date
	LUCs	Ongoing	Enforcement of LUCs	Annual report	Annually in February
Ph	Third performance monitoring	March – April 2011	Sampling of 60 wells	Performance monitoring report	Second quarter Calendar Year 2013
	Fourth performance monitoring	March – April 2012	Sampling of 60 wells		
	Monitoring well installation	June 2012	TBD	RAWP Addendum and IRACR for Phase II Injection Event III of III	
	Fifth performance monitoring	September - October 2012	TBD	IRACR for Phase II Injection Event III of III	
	VIP evaluation	September 2011 – August 2012	TBD	VIP evaluation report	Third quarter Calendar Year 2012
	VIP field investigation		TBD	VIP work plan	
	Risk assessment for VIP and ethylbenzene and naphthalene		TBD	Risk assessment report	
	Groundwater modeling	September 2011 – August 2012	TBD	Groundwater modeling report	Third quarter Calendar Year 2012
	Third injection event	April 2013	TBD	IRACR for Phase II Injection Event III of III	
	Monitoring well installation	June 2013	TBD	RAWP and IRACR for Phase II Injection Event IV	Second quarter Calendar Year 2016
	Sixth performance monitoring	September - October 2013	TBD	IRACR for Phase II Injection Event III of III	
	Fourth injection event	April 2014	TBD		
	Seventh performance monitoring	September - October 2014	TBD		
	Eighth performance monitoring	September - October 2015	TBD		
	Ninth performance monitoring	September - October 2016	TBD	Performance monitoring report	Second quarter Calendar Year 2017

Notes:

LUC = land use control

IRACR	=	interim remedial action completion report
RAWP	=	Remedial Action Work Plan
TBD	=	to be determined
VIP	=	vapor intrusion pathway

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10.0 PROTECTIVENESS STATEMENT

The remedy is expected to be protective of human health and the environment in the long term upon attainment of groundwater cleanup goals, which are expected to require more than 100 years to achieve, through a combination of *in situ* treatment (chemical oxidation and bioremediation) and natural attenuation. Exposure pathways that could result in unacceptable risks in the short term are being controlled through institutional controls that are preventing exposure to, and the ingestion of, contaminated groundwater. All current threats at the site have been addressed by the implementation of LUCs.

Long-term protectiveness of the remedy will be verified by evaluating the future residential indoor air risk and, if applicable, modifying the LUC boundary to restrict residential development in areas with unacceptable indoor air risk. Long-term protectiveness will also be verified by installing and sampling additional groundwater monitoring wells to fully delineate the commingled plume.

The remedy is protective in the short-term because unacceptable risks are being controlled through LUCs. Short-term protectiveness of the remedy will be verified by evaluating changes to the VIP protocol and assessing those changes as applicable to OU6 site conditions. The evaluation may result in collection and analysis of soil vapor samples from beneath building foundations to evaluate vapor intrusion risk for industrial users.

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11.0 NEXT REVIEW

The next five-year review for OU6 is required by September 2016, five years from the finalization date of this review.

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12.0 REFERENCES

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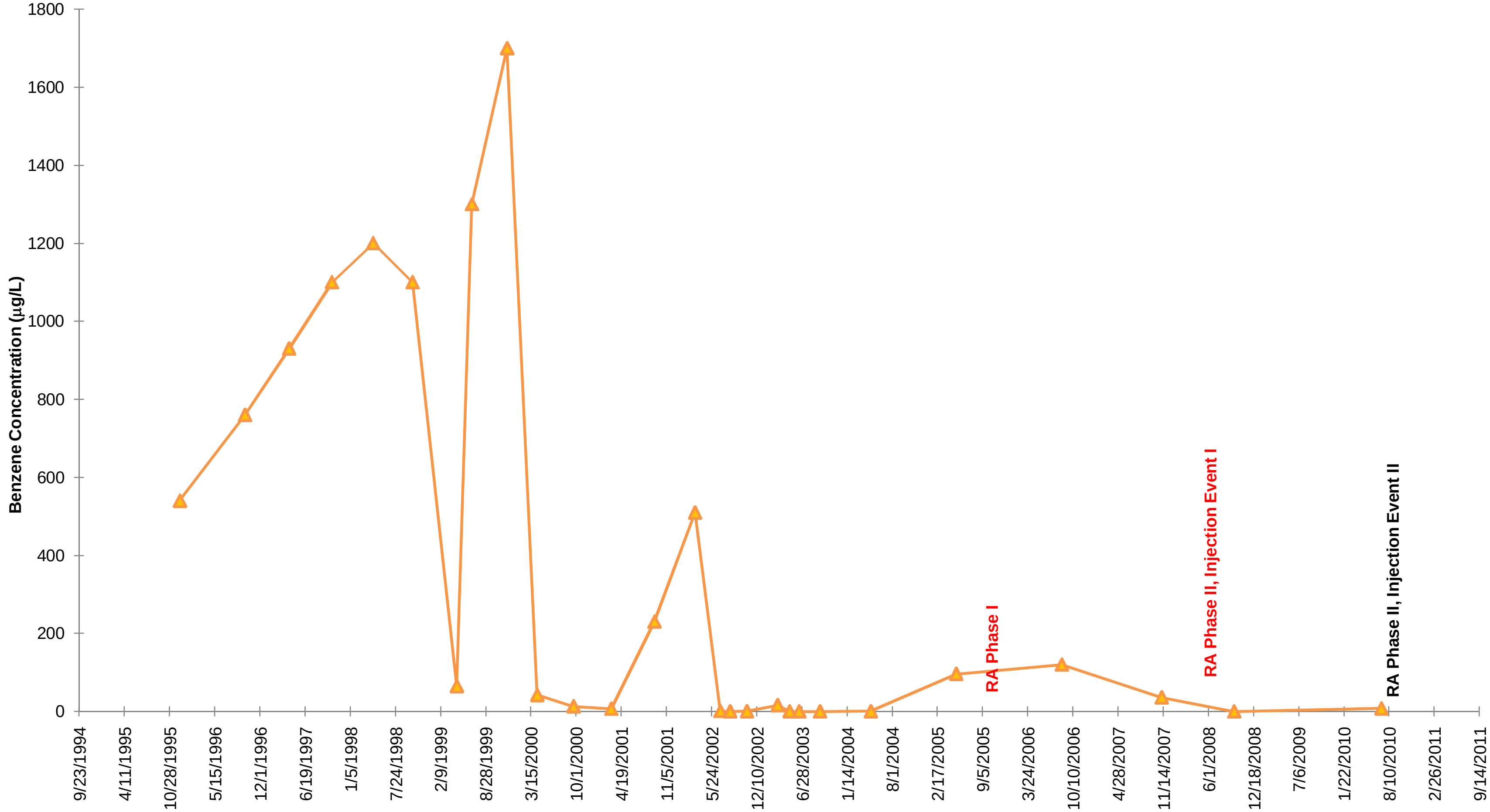
APPENDIX A

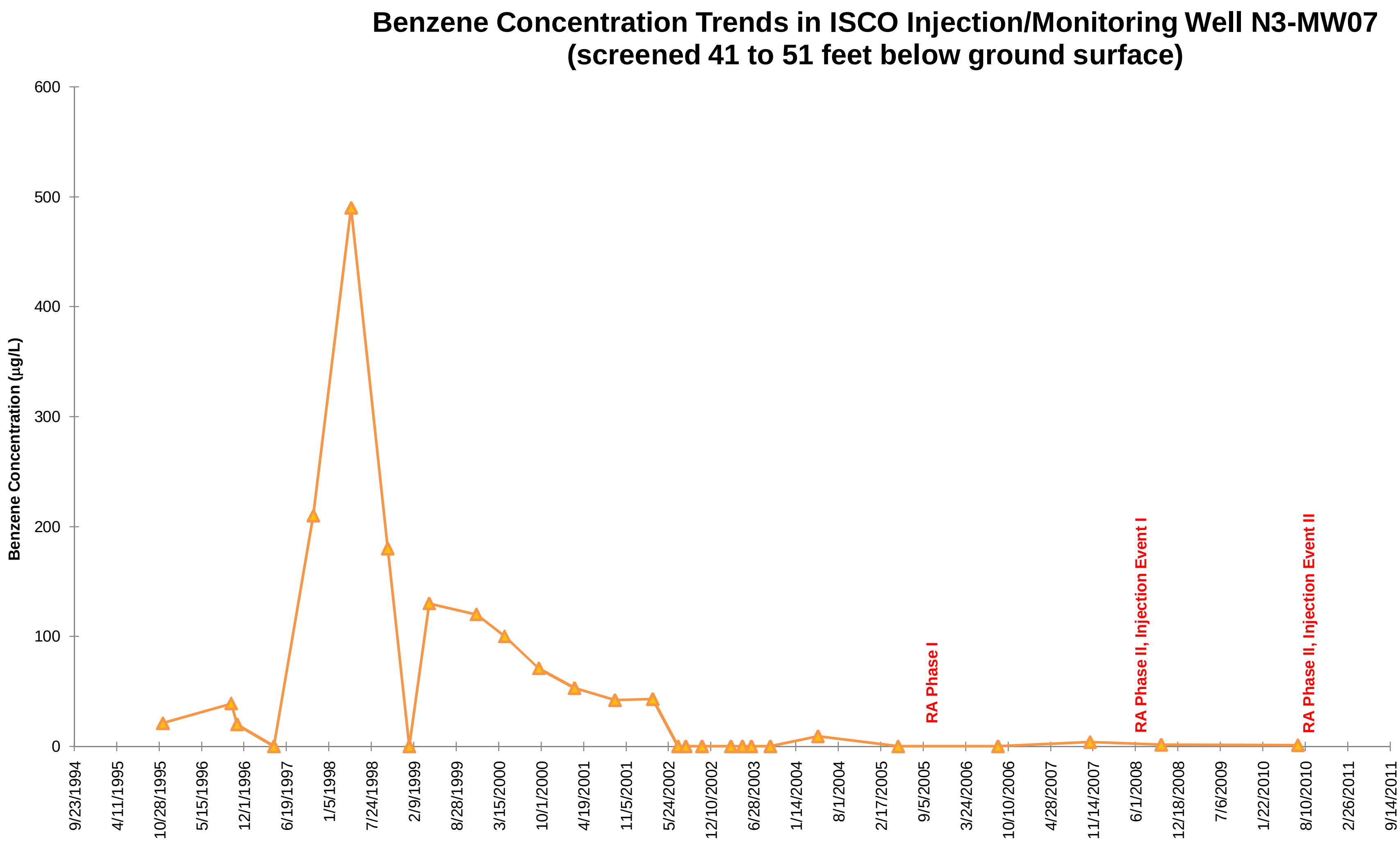
HISTORICAL CONCENTRATION TREND GRAPHS FOR CONTAMINANTS OF CONCERN

Benzene Concentration Trends in ISCO Injection/Monitoring Well N3-MW06
(screened 20 to 38 feet below ground surface)



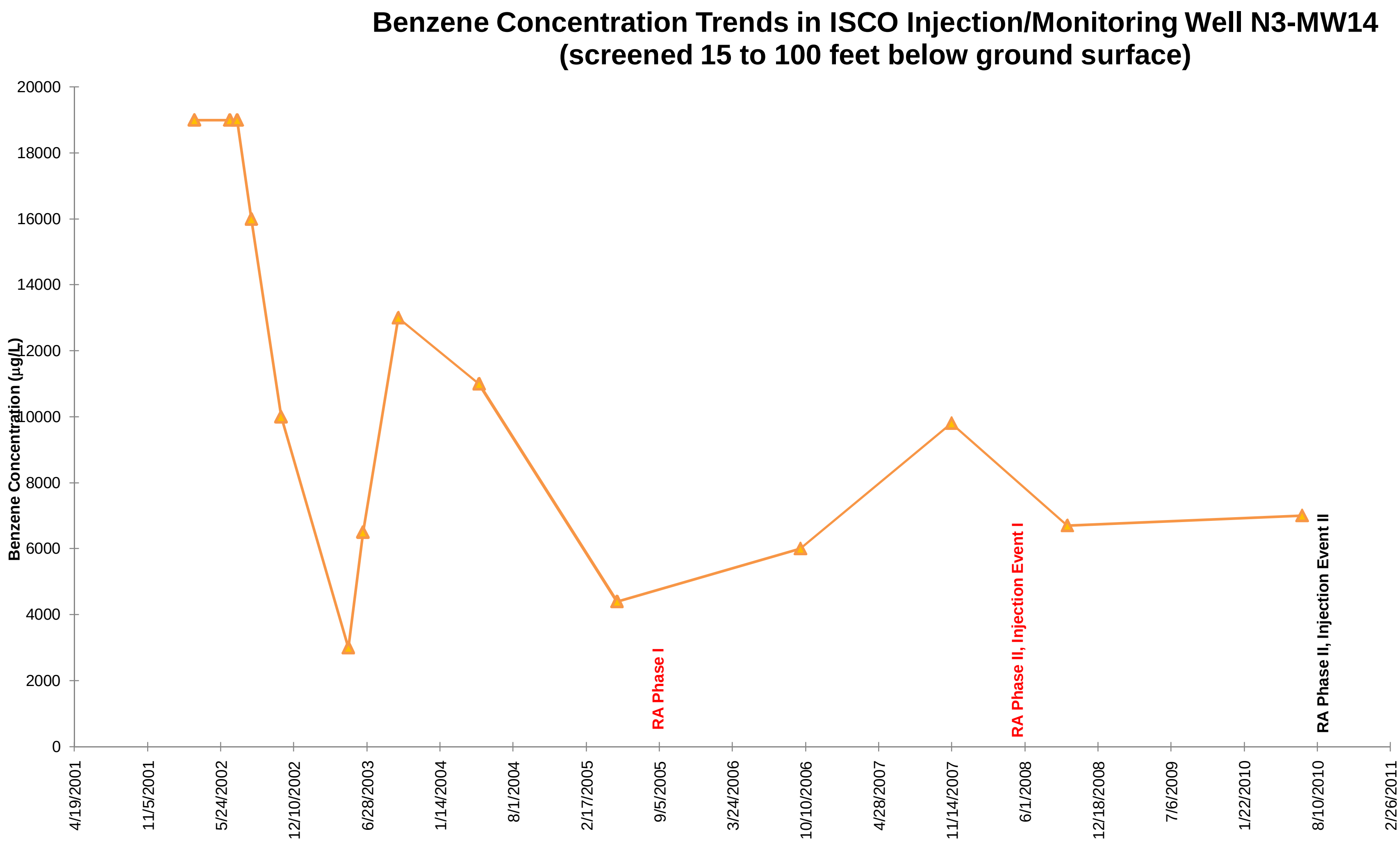
***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action

Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)



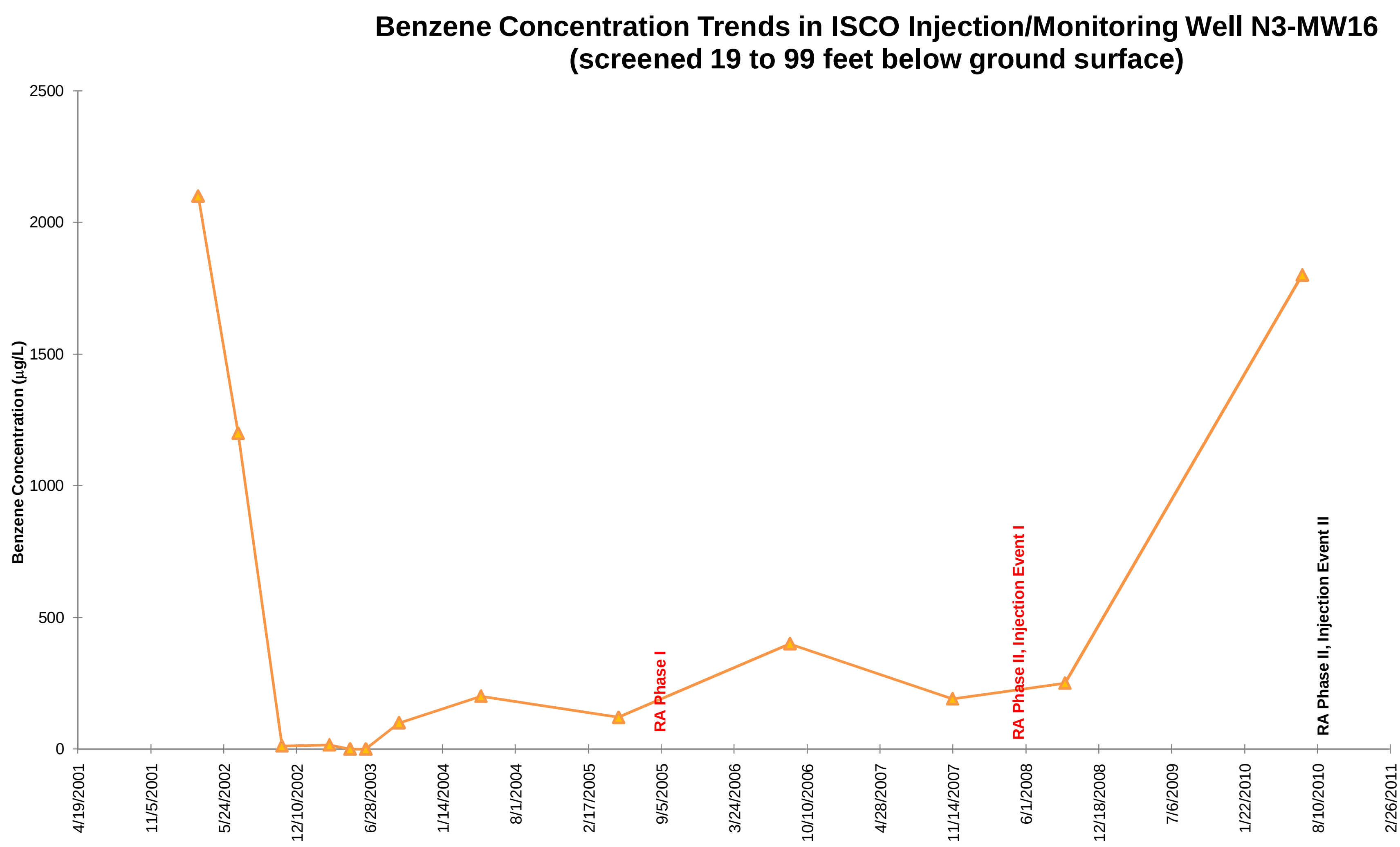
***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action

Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)



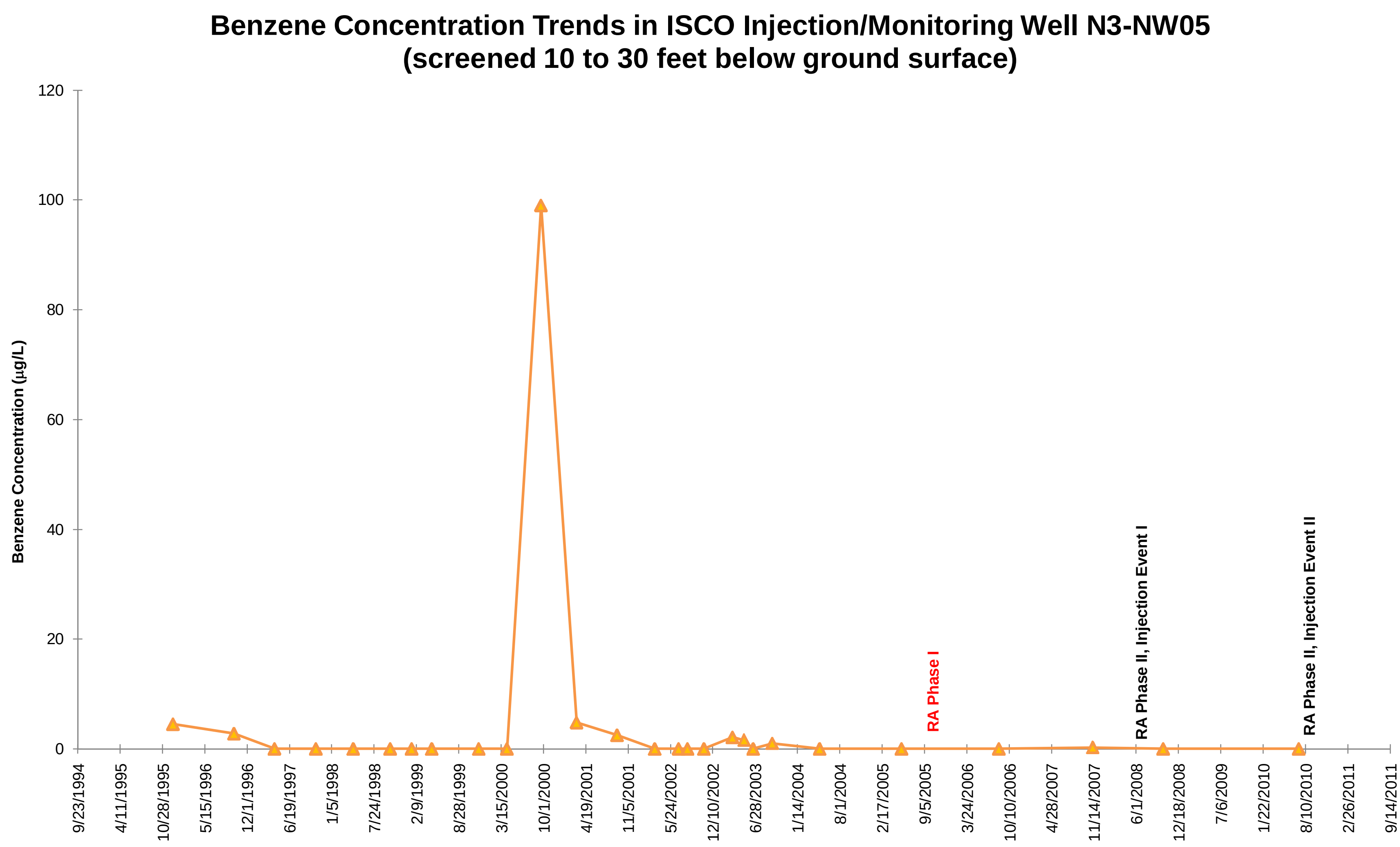
***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action

Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)



***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action

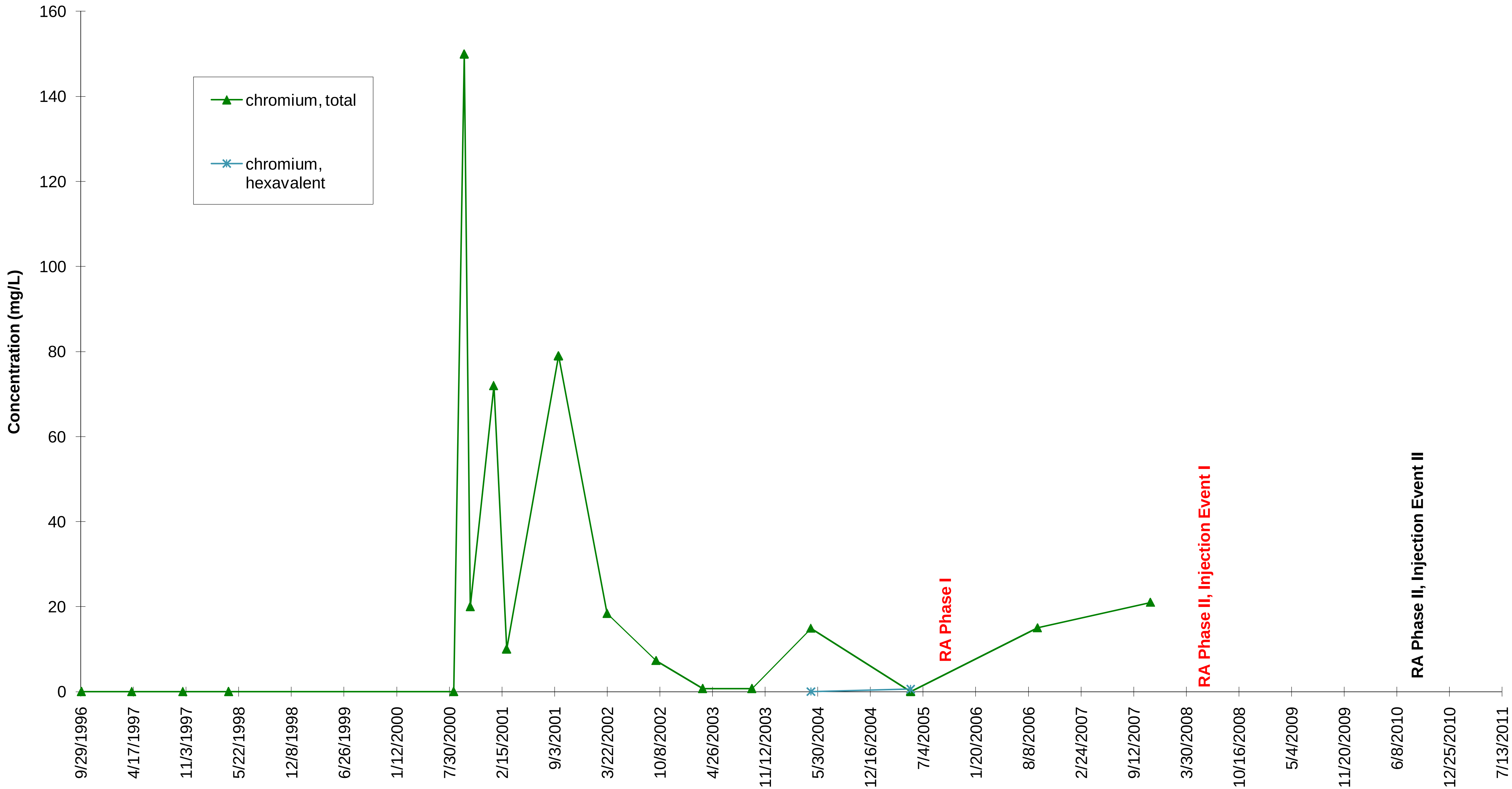
Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)



***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action

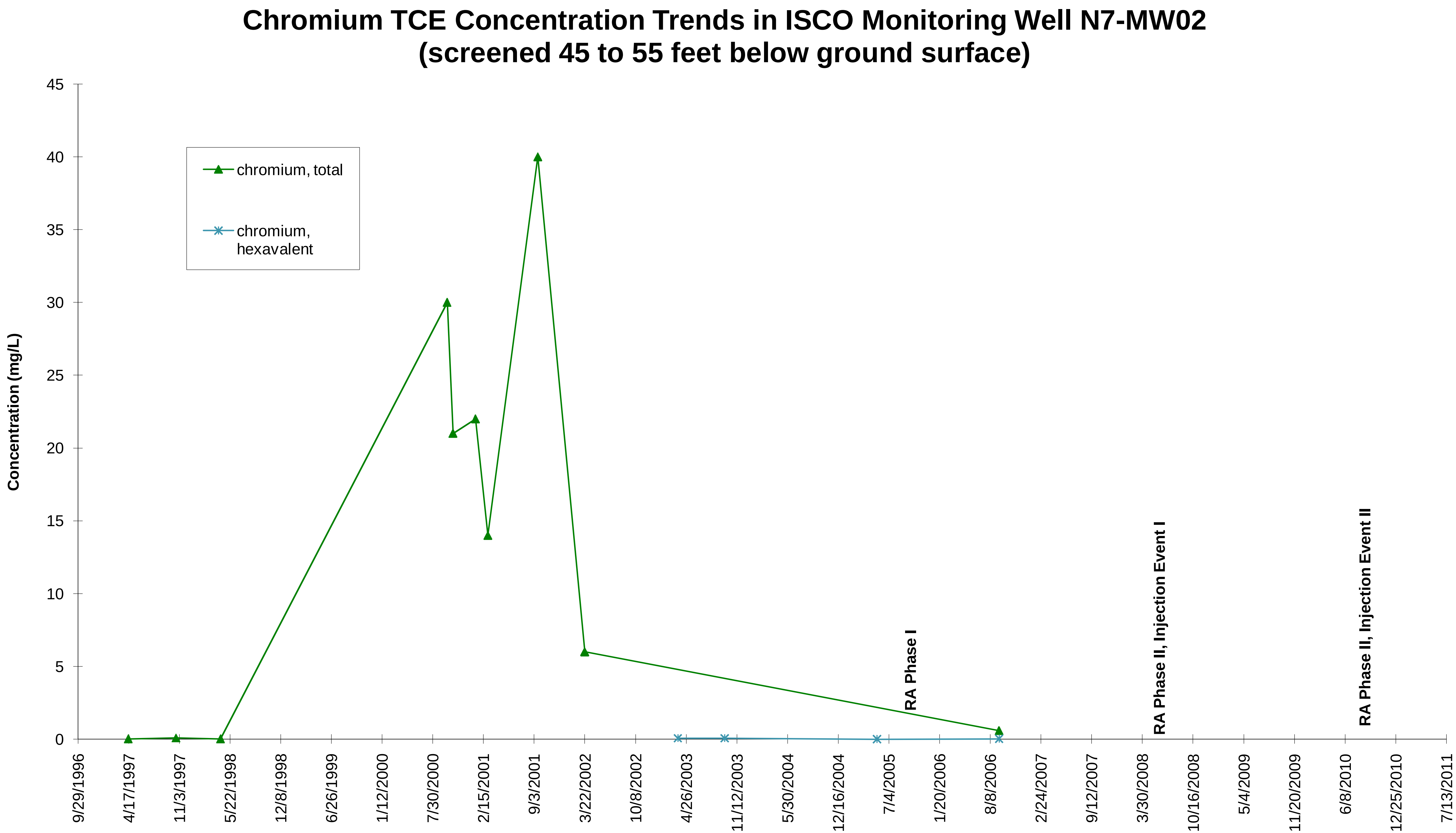
Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)

Chromium Concentration Trends in ISCO Injection/Monitoring Well N7-MW01 (screened 12 to 22 feet below ground surface)



***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action

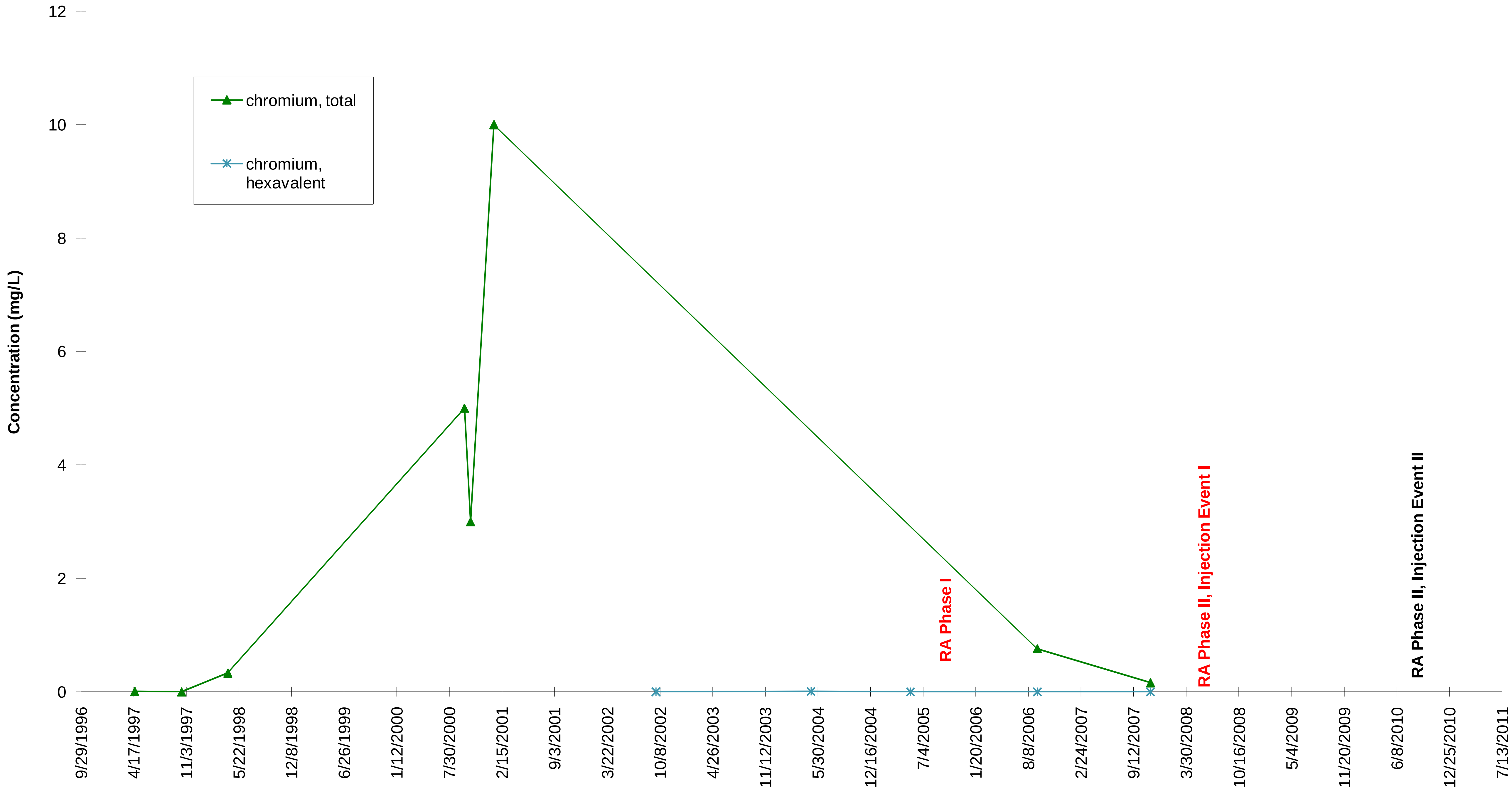
Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)



***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action

Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)

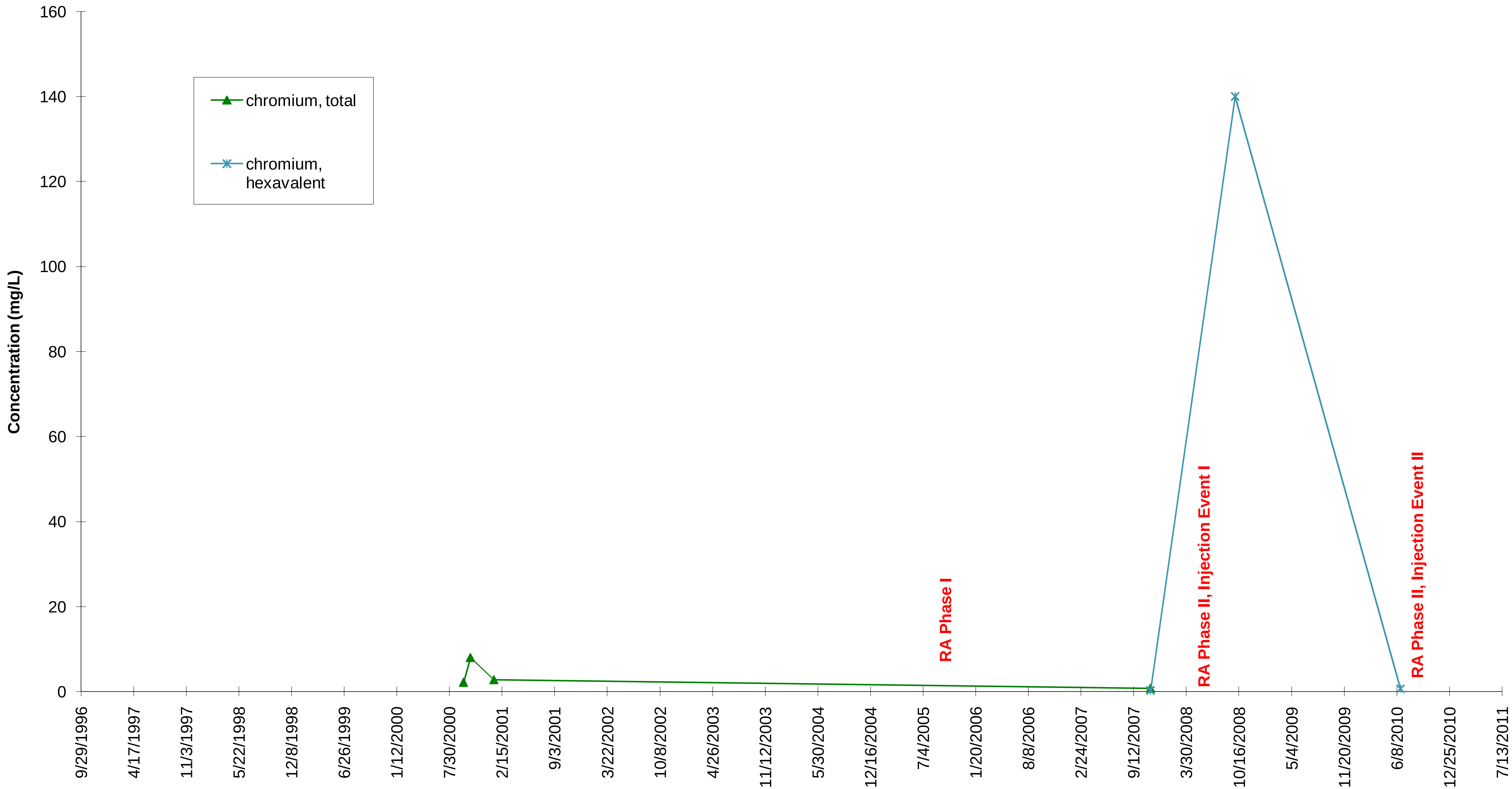
Chromium Concentration Trends in ISCO Injection/Monitoring Well N7-MW04
(screened 25 to 50 feet below ground surface)



***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action

Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)

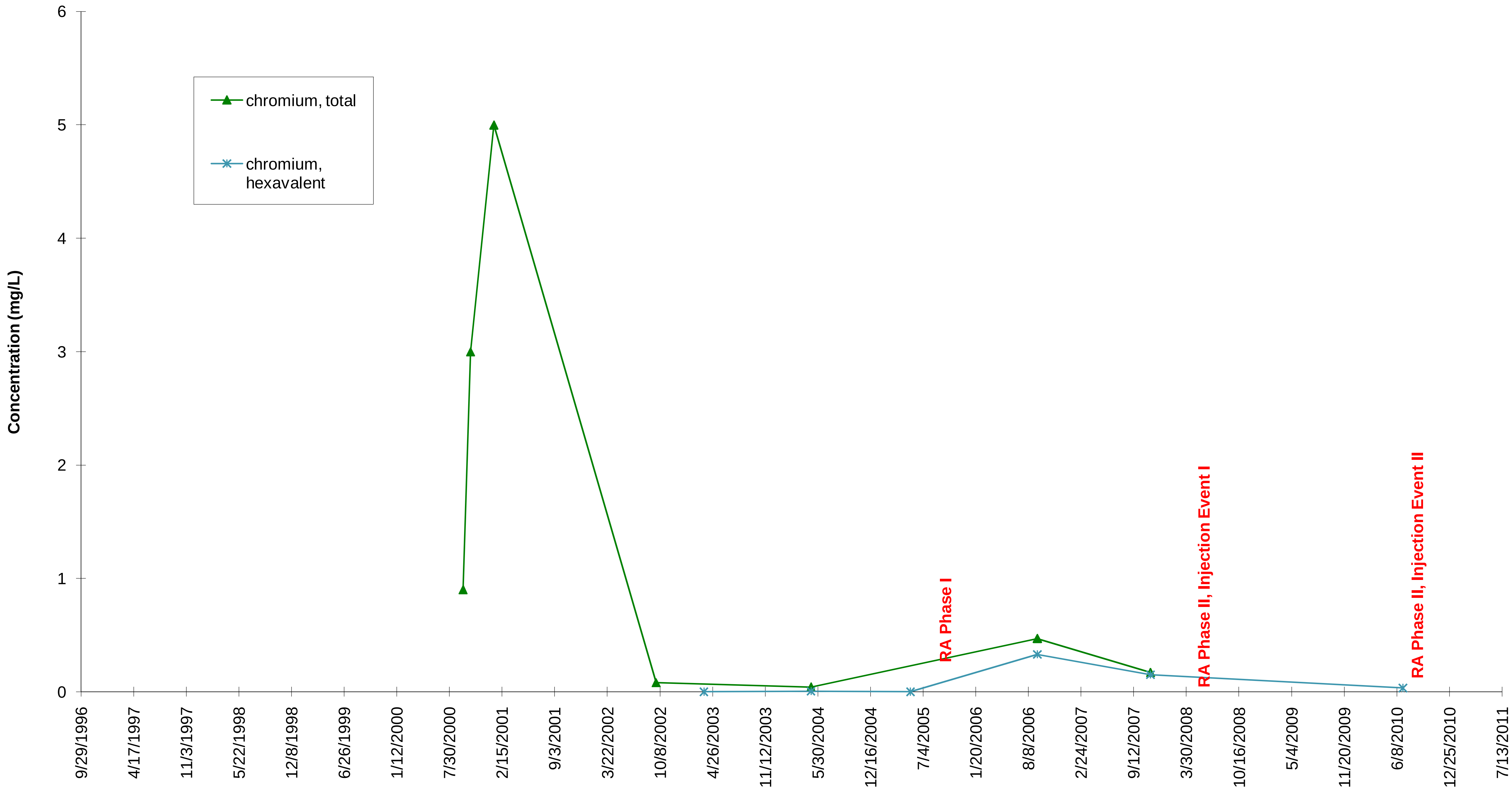
Chromium Concentration Trends in ISCO Injection/Monitoring Well N7-MW10
(screened 15 to 35 feet below ground surface)



***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action

Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)

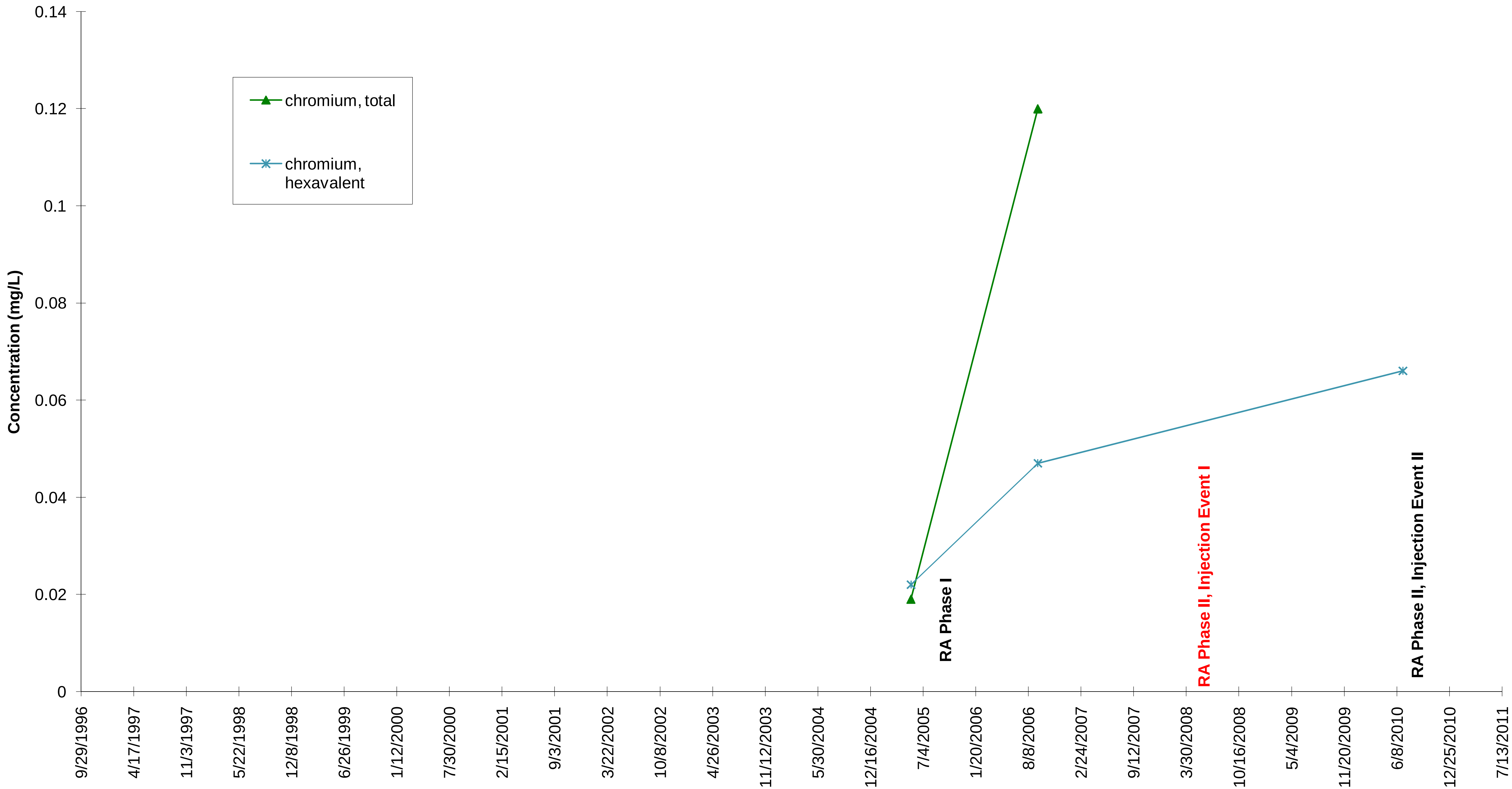
Chromium Concentration Trends in ISCO Injection/Monitoring Well N7-MW11
(screened 15 to 40 feet below ground surface)



***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action

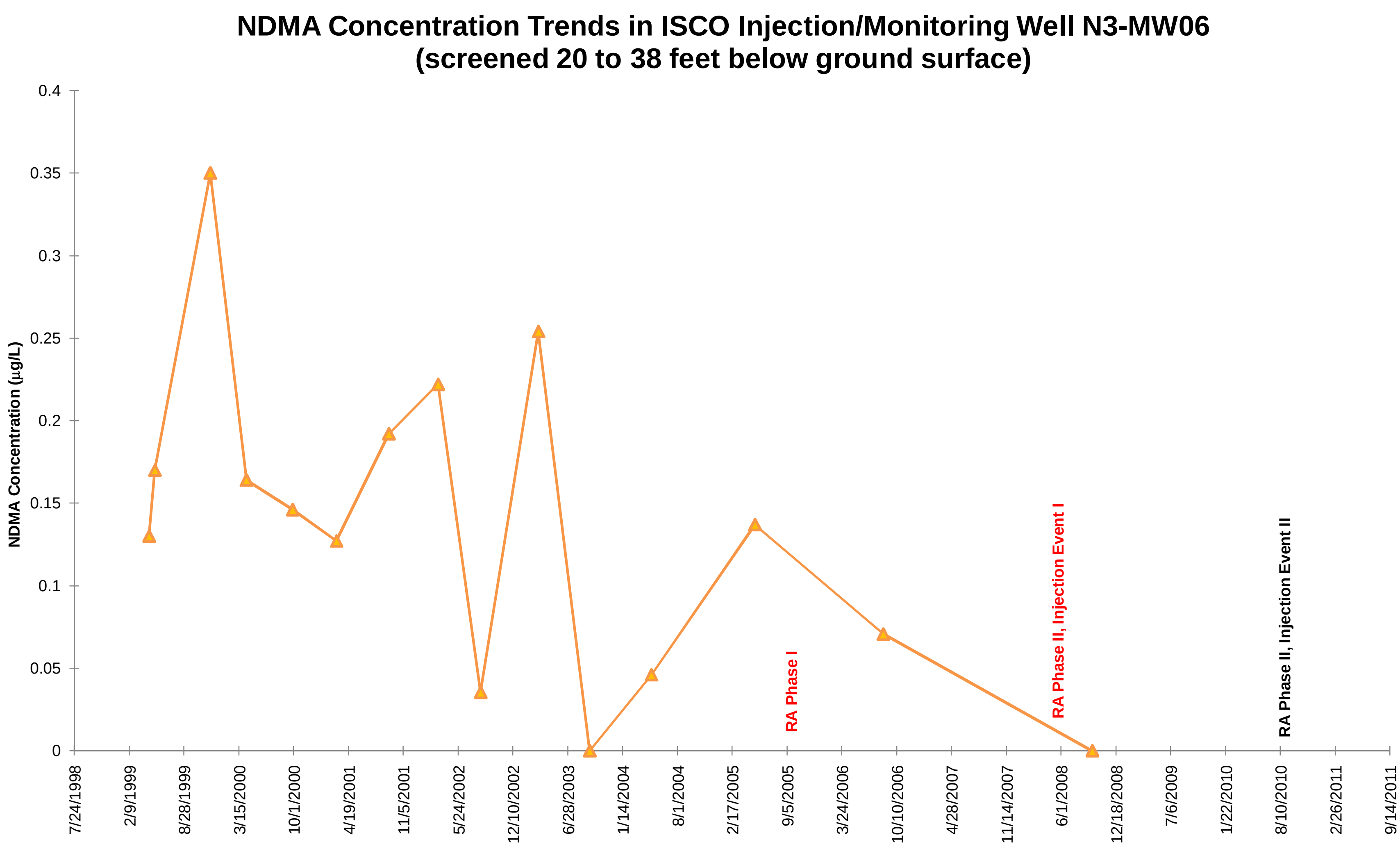
Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)

Chromium Concentration Trends in ISCO Injection/Monitoring Well N7-MW12 (screened 10 to 40 feet below ground surface)



***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action

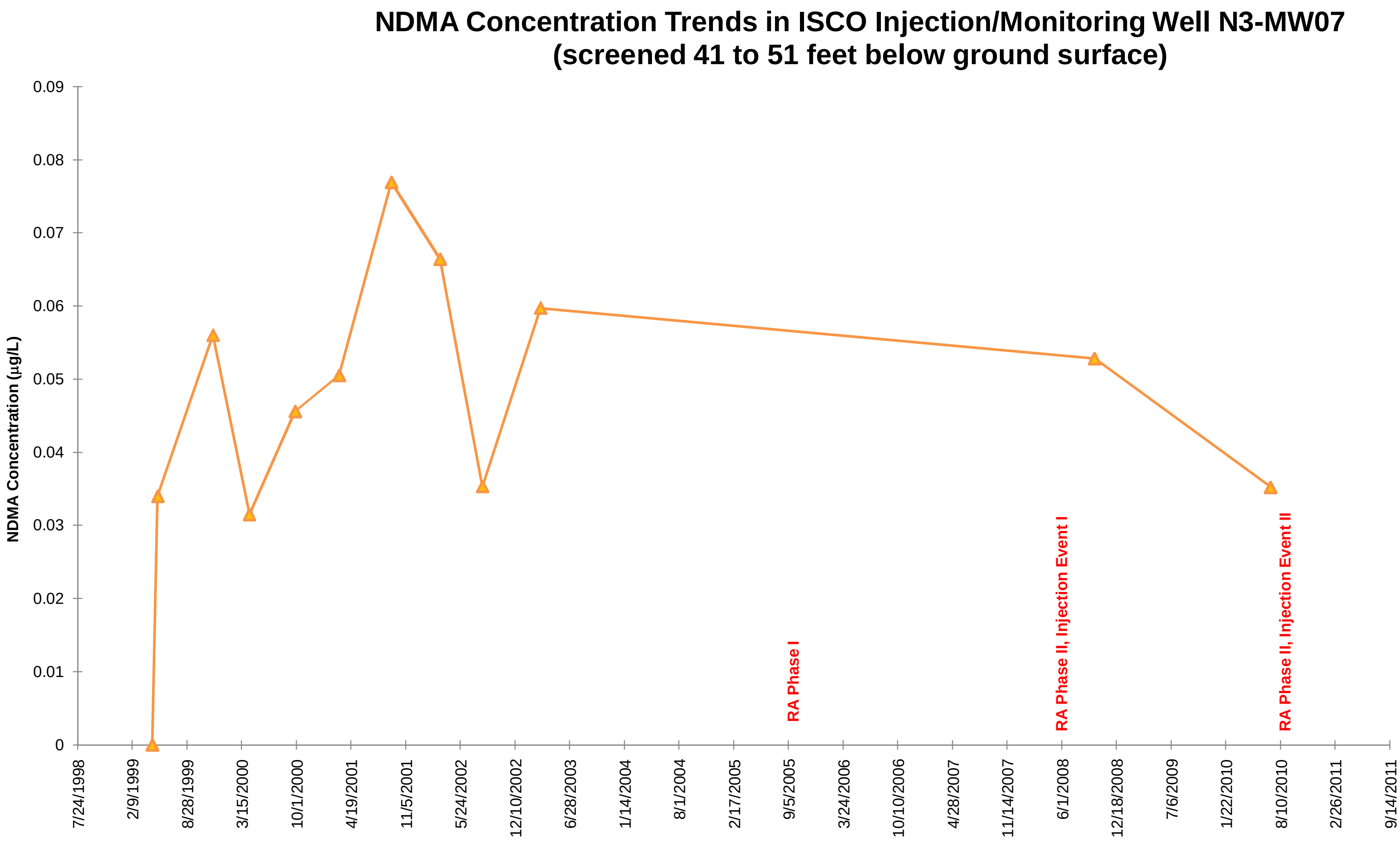
Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)



***Notes*:**

ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action

Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)



Notes:

ISCO - *In Situ* Chemical Oxidation

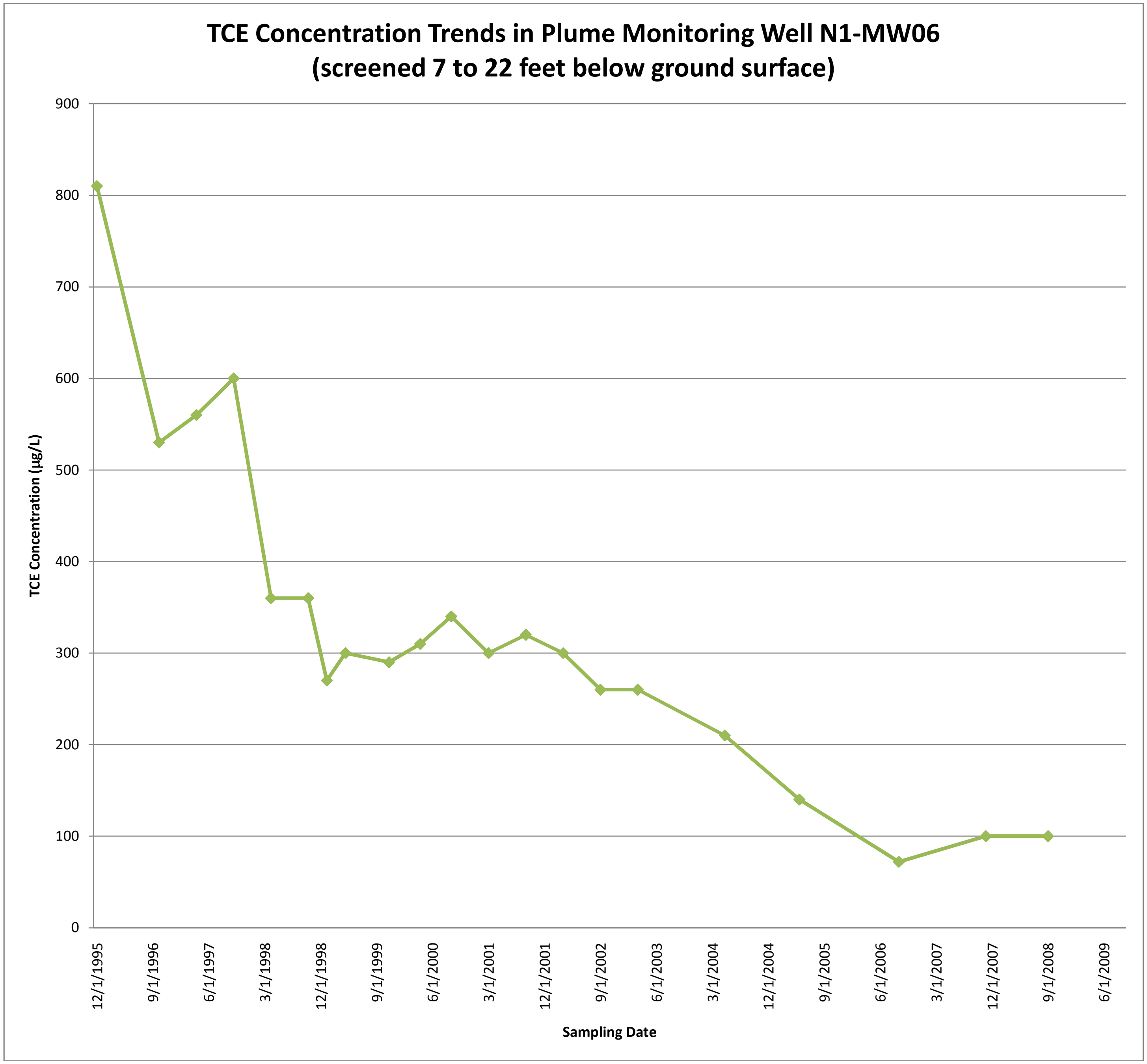
RA - Remedial Action

Red Font Color Indicates Subject Well Used For Injection During Indicated Event

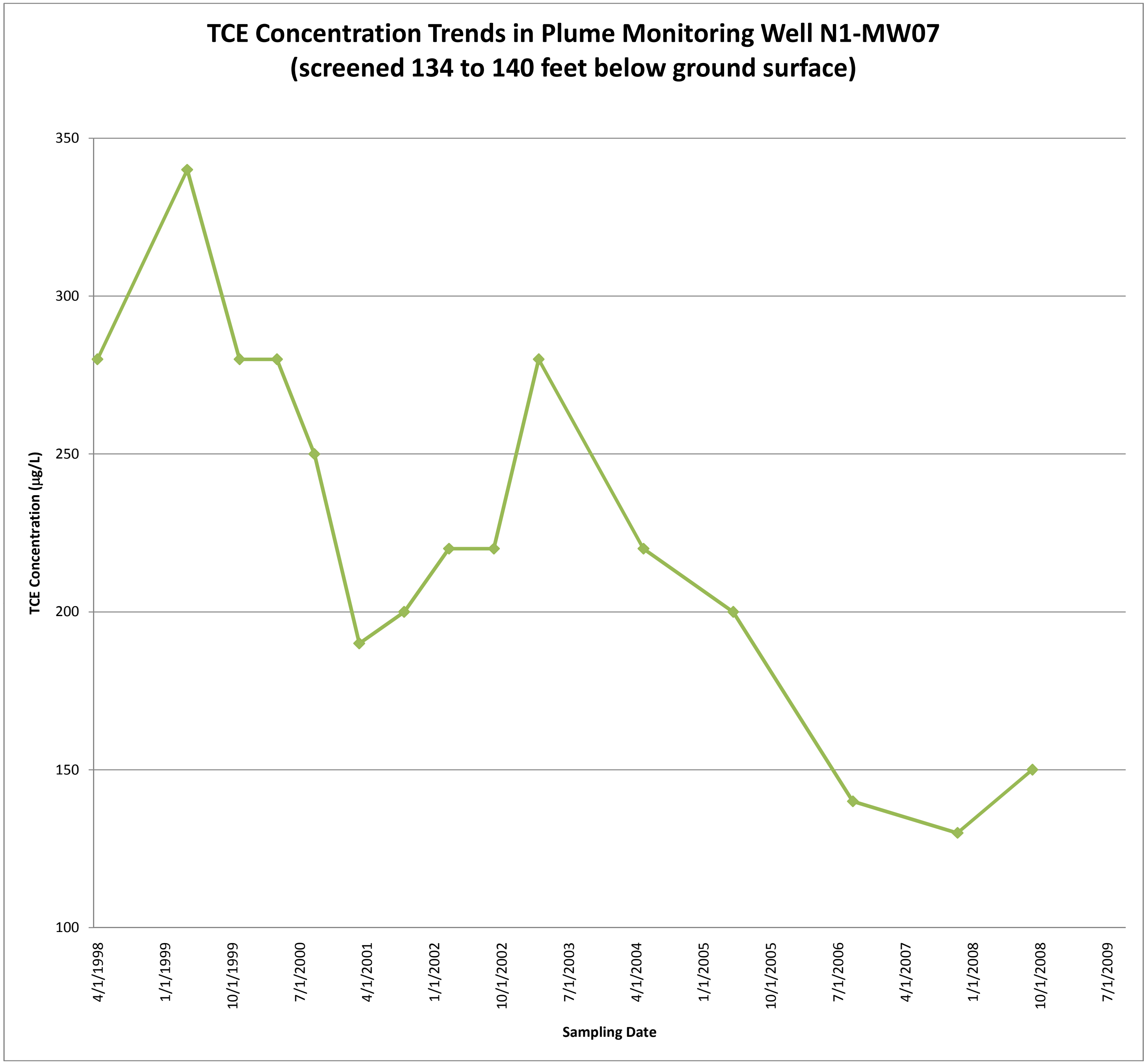
RA Phase I Injection (6/21/05 to 7/14/05)

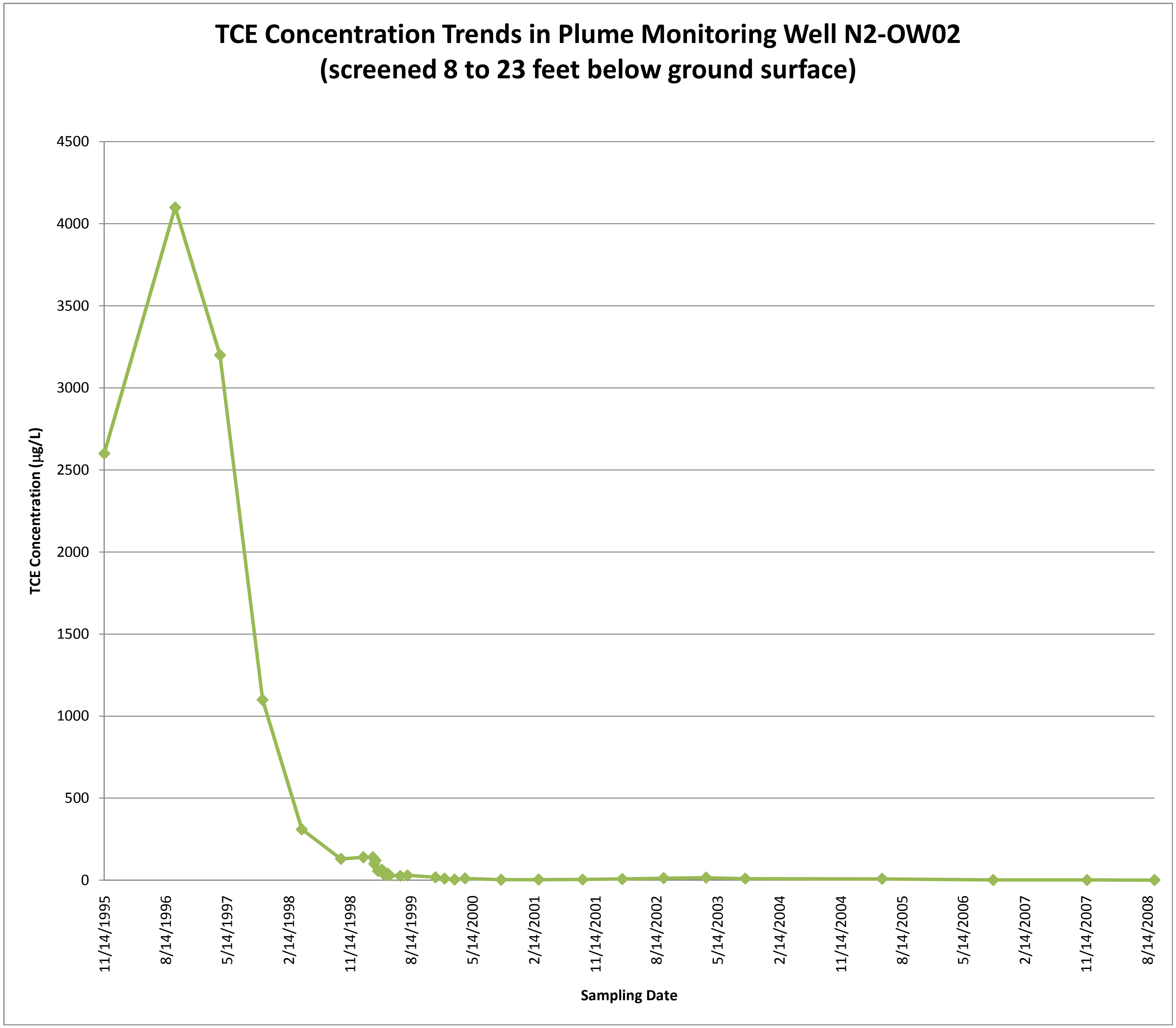
RA Phase II, Injection Event I (3/3/08 to 3/21/08)

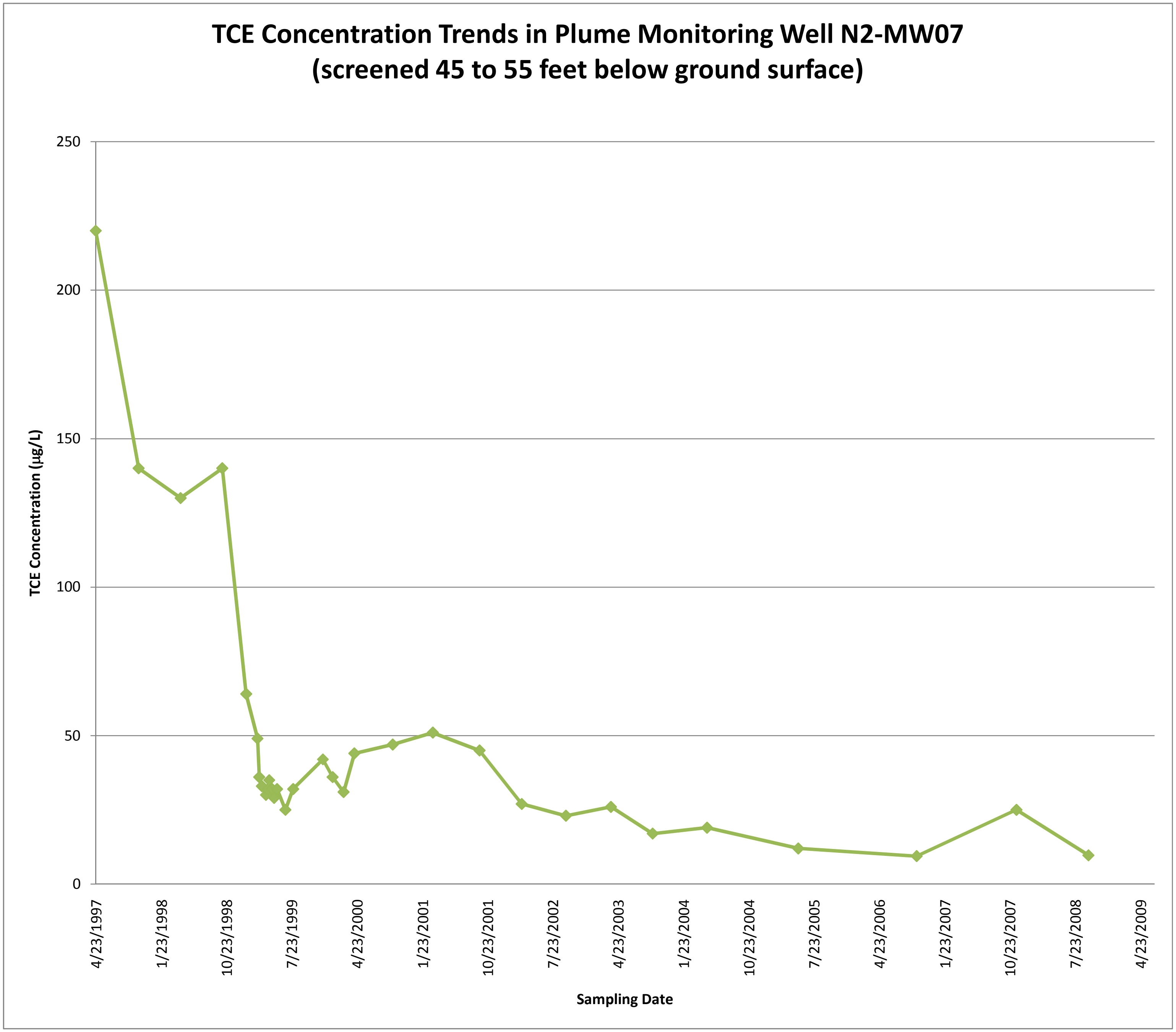
RA Phase II, Injection Event II (8/16/10 to 8/26/10)

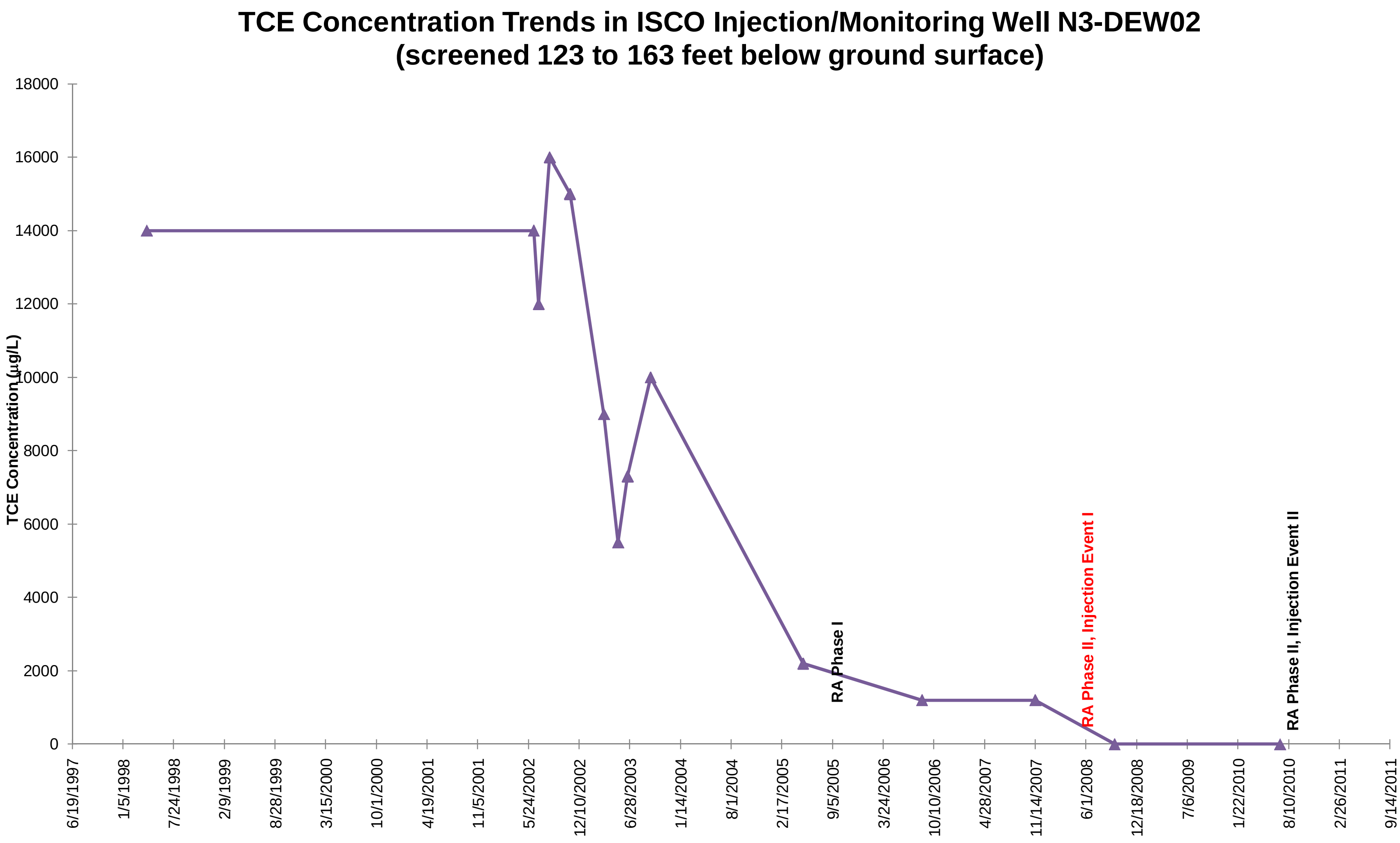


TCE Concentration Trends in Plume Monitoring Well N1-MW06
(screened 7 to 22 feet below ground surface)
TCE Concentration (µg/L)
900
800
700
600
500
400
300
200
100
0
12/1/1995
9/1/1996
6/1/1997
3/1/1998
12/1/1998
9/1/1999
6/1/2000
3/1/2001
12/1/2001
9/1/2002
6/1/2003
3/1/2004
12/1/2004
9/1/2005
6/1/2006
3/1/2007
12/1/2007
9/1/2008
6/1/2009
Sampling Date


TCE Concentration Trends in Plume Monitoring Well N1-MW07
(screened 134 to 140 feet below ground surface)
350
300
250
200
150
100
TCE Concentration (µg/L)
4/1/1998
1/1/1999
10/1/1999
7/1/2000
4/1/2001
1/1/2002
10/1/2002
7/1/2003
4/1/2004
1/1/2005
10/1/2005
7/1/2006
4/1/2007
1/1/2008
10/1/2008
7/1/2009
Sampling Date

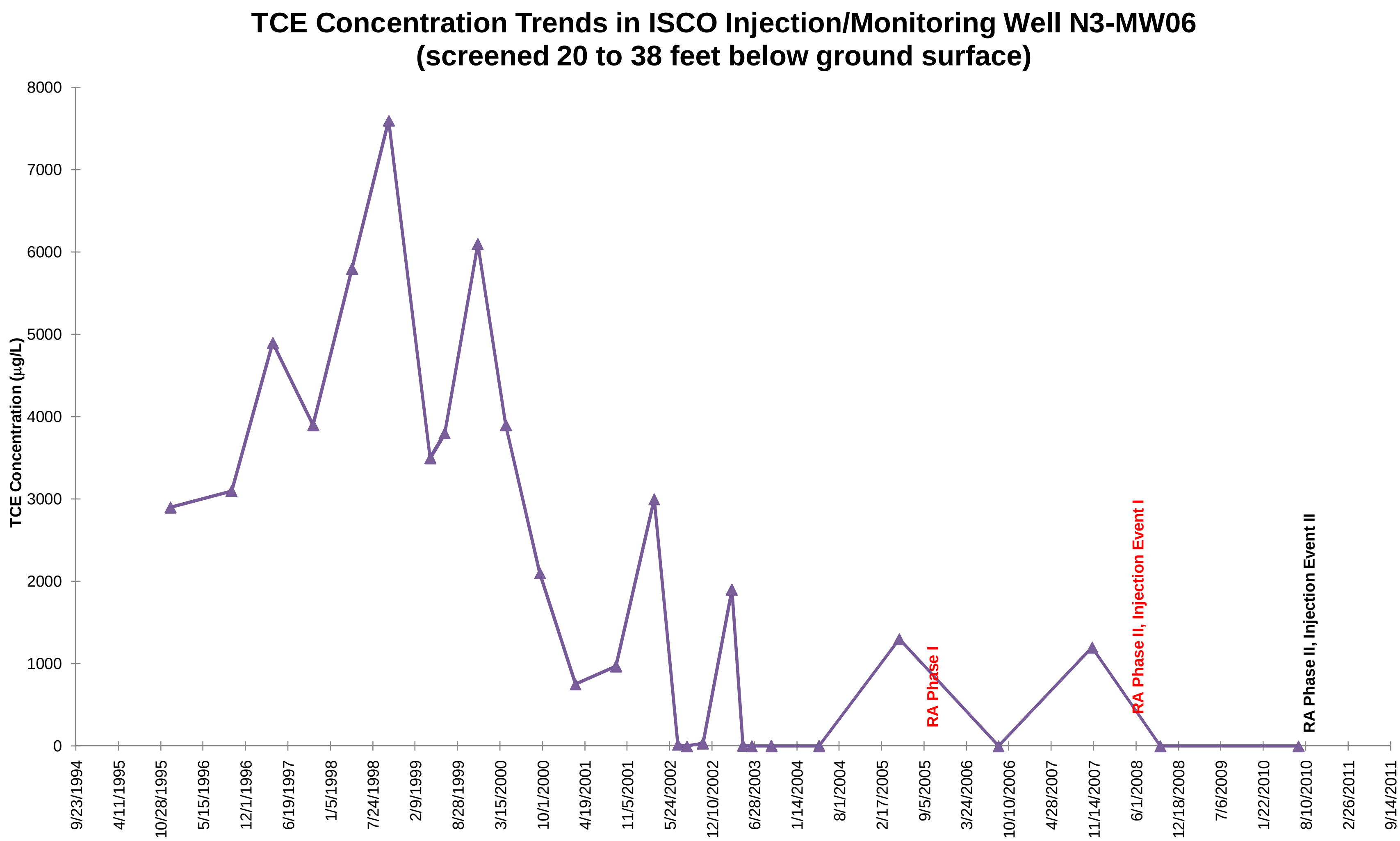

TCE Concentration Trends in Plume Monitoring Well N2-OW02
(screened 8 to 23 feet below ground surface)
TCE Concentration (µg/L)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
11/14/1995
8/14/1996
5/14/1997
2/14/1998
11/14/1998
8/14/1999
5/14/2000
2/14/2001
11/14/2001
8/14/2002
5/14/2003
2/14/2004
11/14/2004
8/14/2005
5/14/2006
2/14/2007
11/14/2007
8/14/2008
Sampling Date


TCE Concentration Trends in Plume Monitoring Well N2-MW07
(screened 45 to 55 feet below ground surface)
TCE Concentration (µg/L)
250
200
150
100
50
0
4/23/1997
1/23/1998
10/23/1998
7/23/1999
4/23/2000
1/23/2001
10/23/2001
7/23/2002
4/23/2003
1/23/2004
10/23/2004
7/23/2005
4/23/2006
1/23/2007
10/23/2007
7/23/2008
4/23/2009
Sampling Date



***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action
TCE - Trichloroethene

Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)



***Notes*:**

ISCO - *In Situ* Chemical Oxidation

RA - Remedial Action

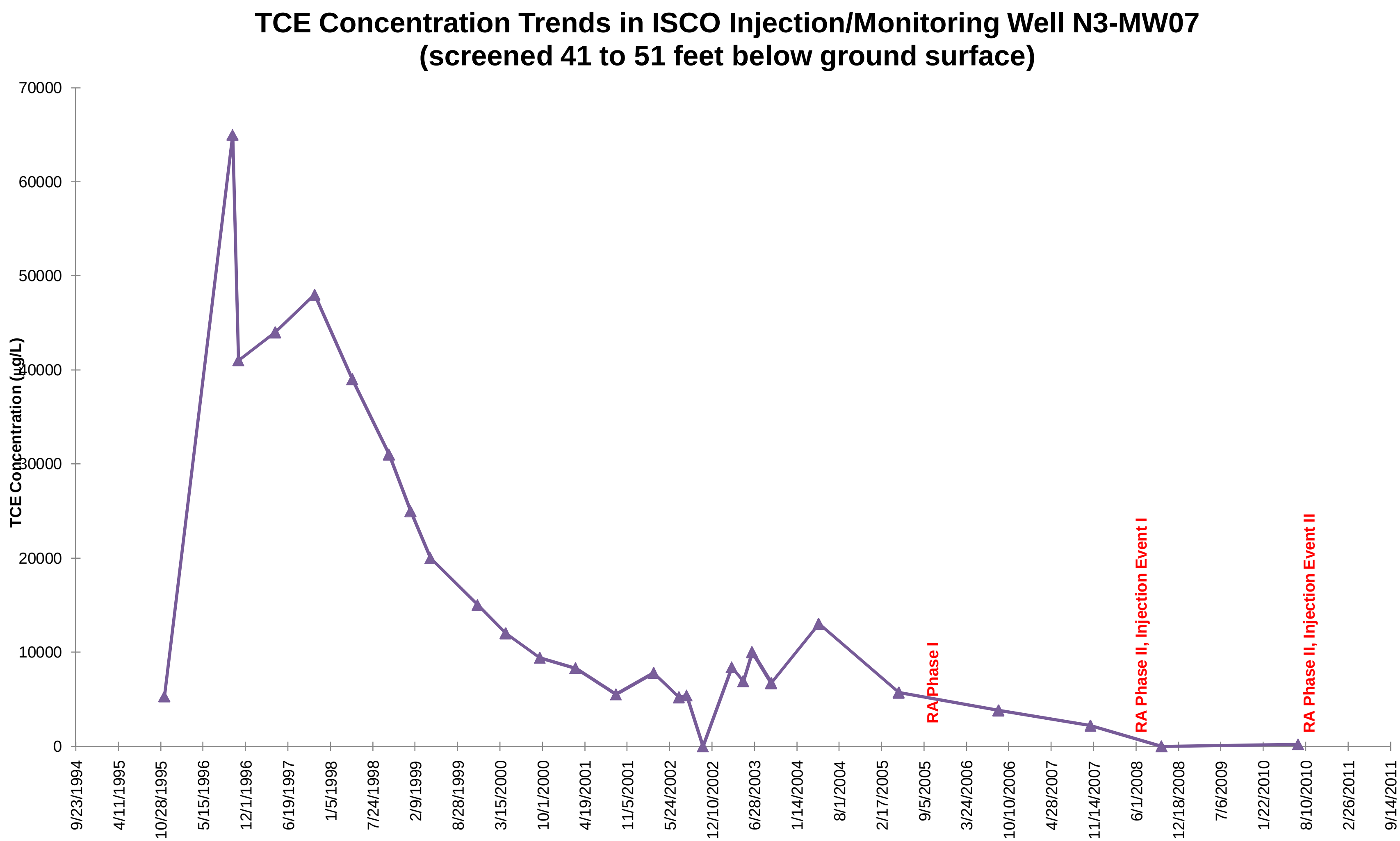
TCE - Trichloroethene

Red Font Color Indicates Subject Well Used For Injection During Indicated Event

RA Phase I Injection (6/21/05 to 7/14/05)

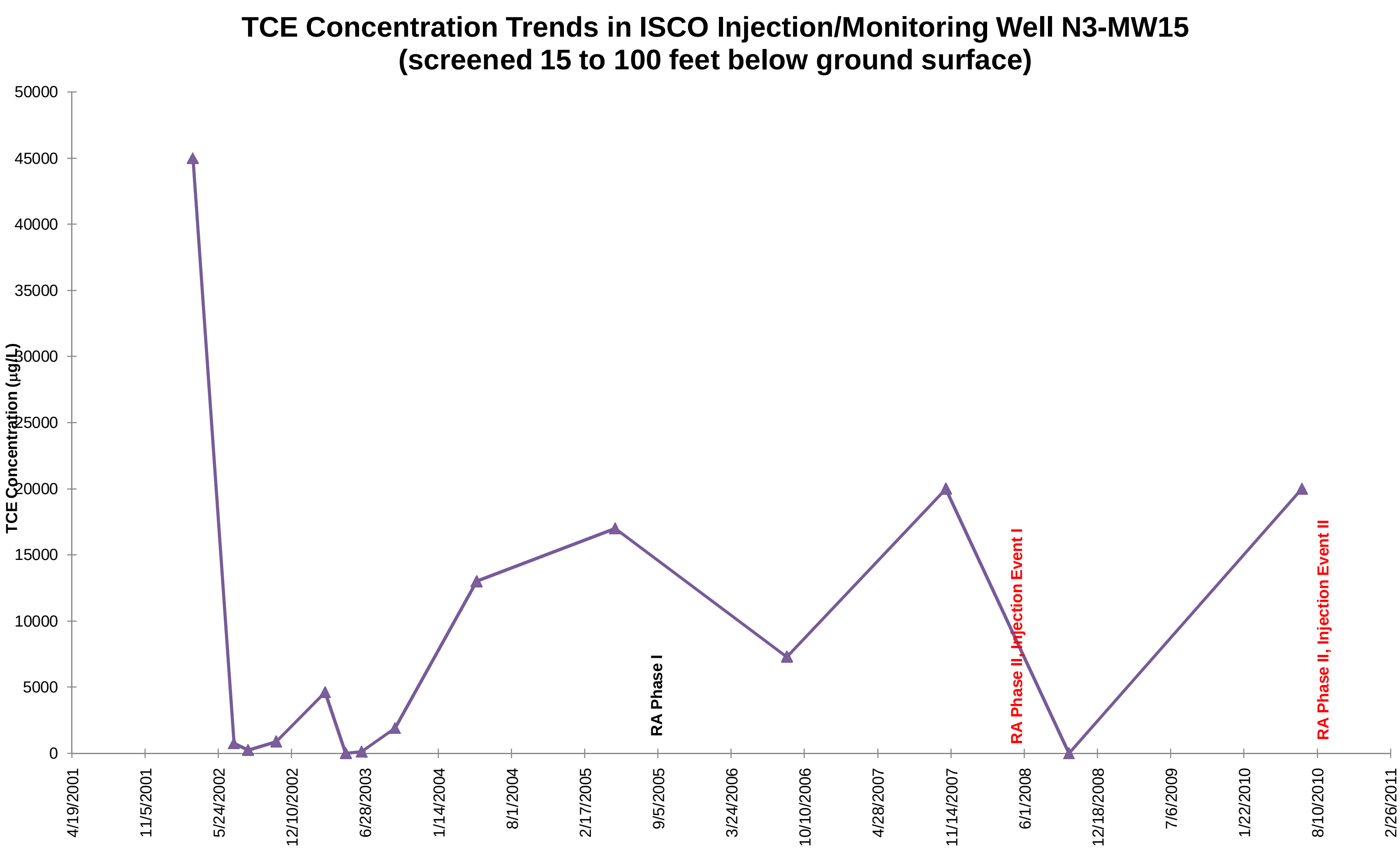
RA Phase II, Injection Event I (3/3/08 to 3/21/08)

RA Phase II, Injection Event II (8/16/10 to 8/26/10)



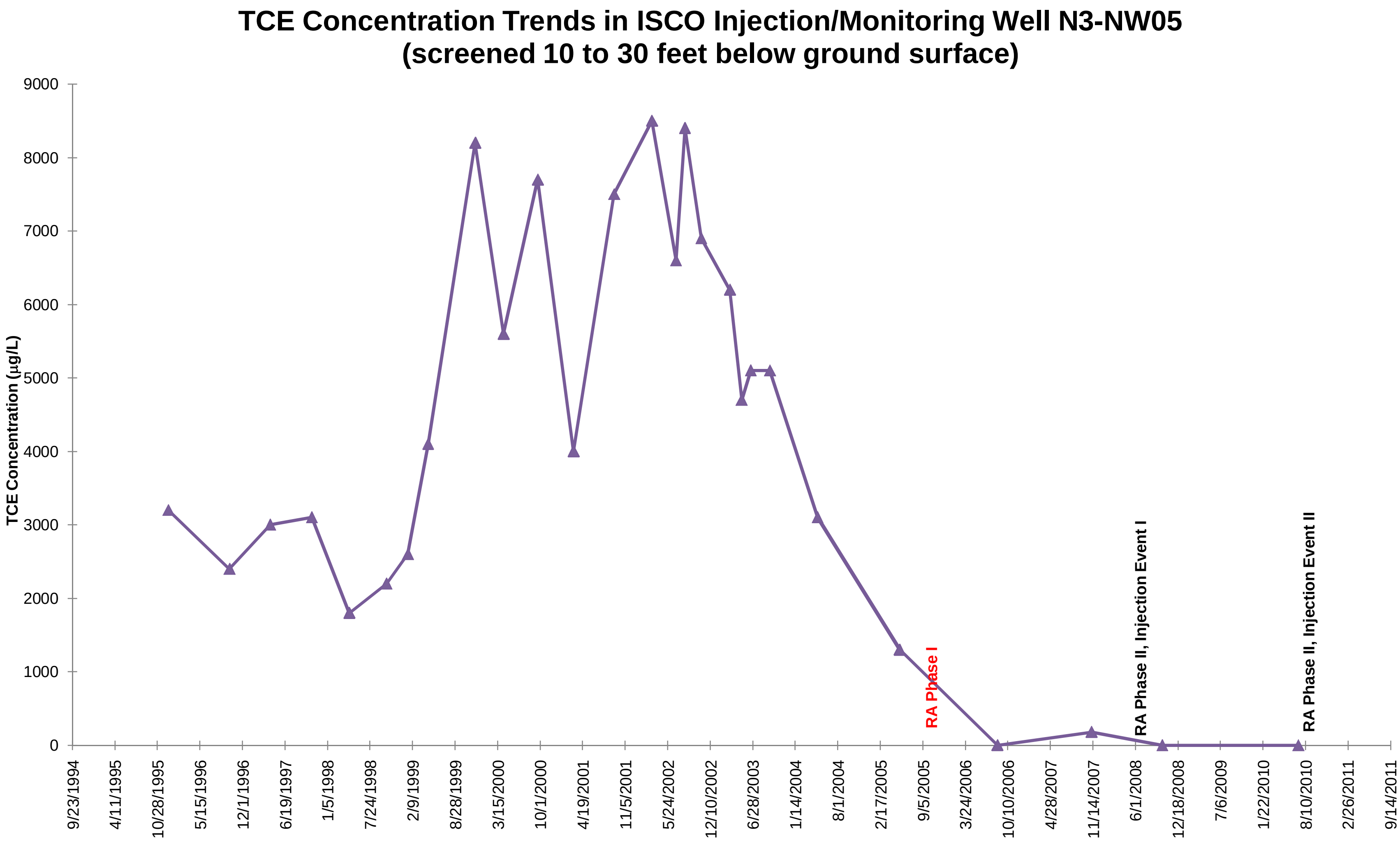
***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action
TCE - Trichloroethene

Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)



***Notes*:**
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action
TCE - Trichloroethene

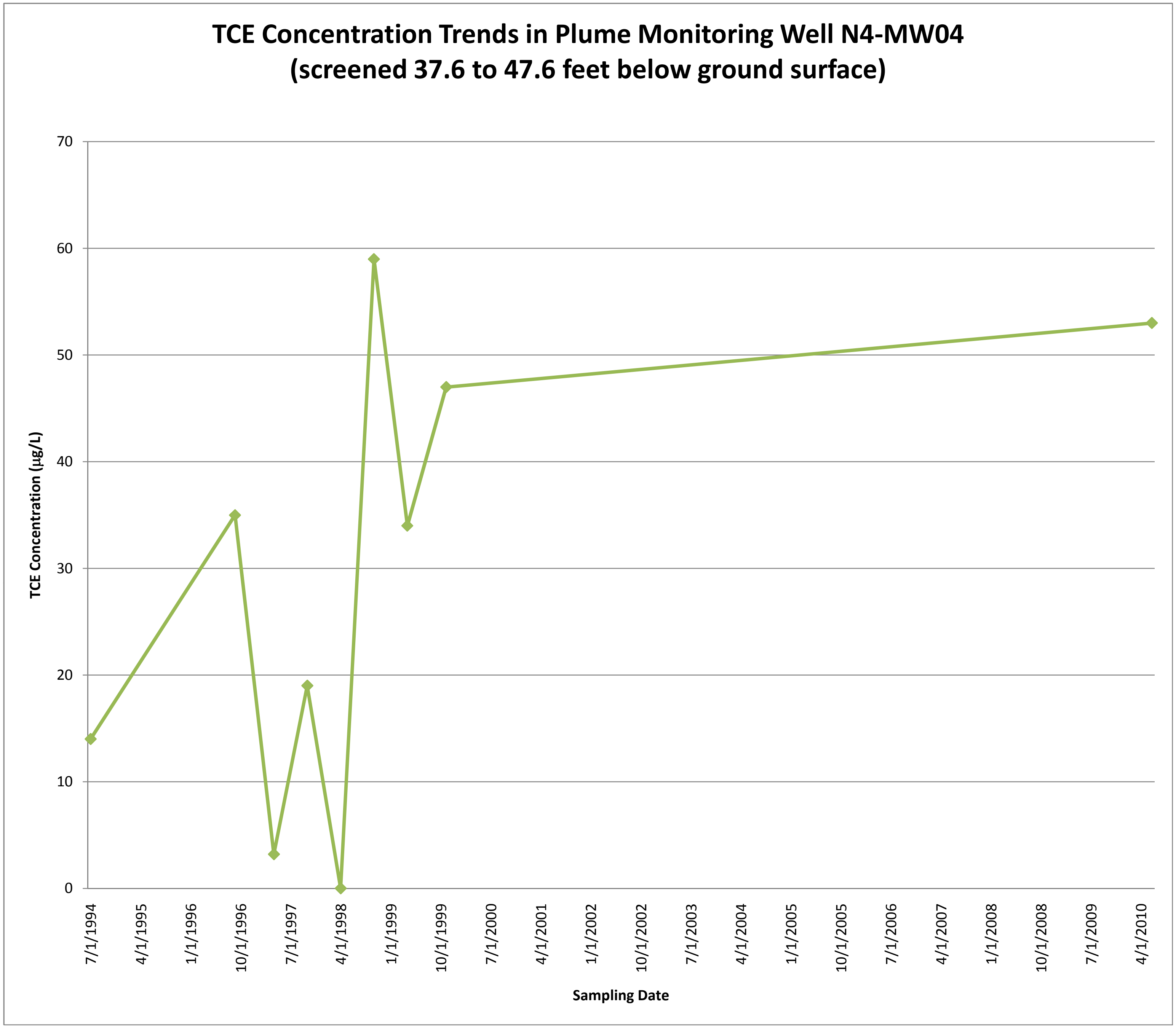
Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)

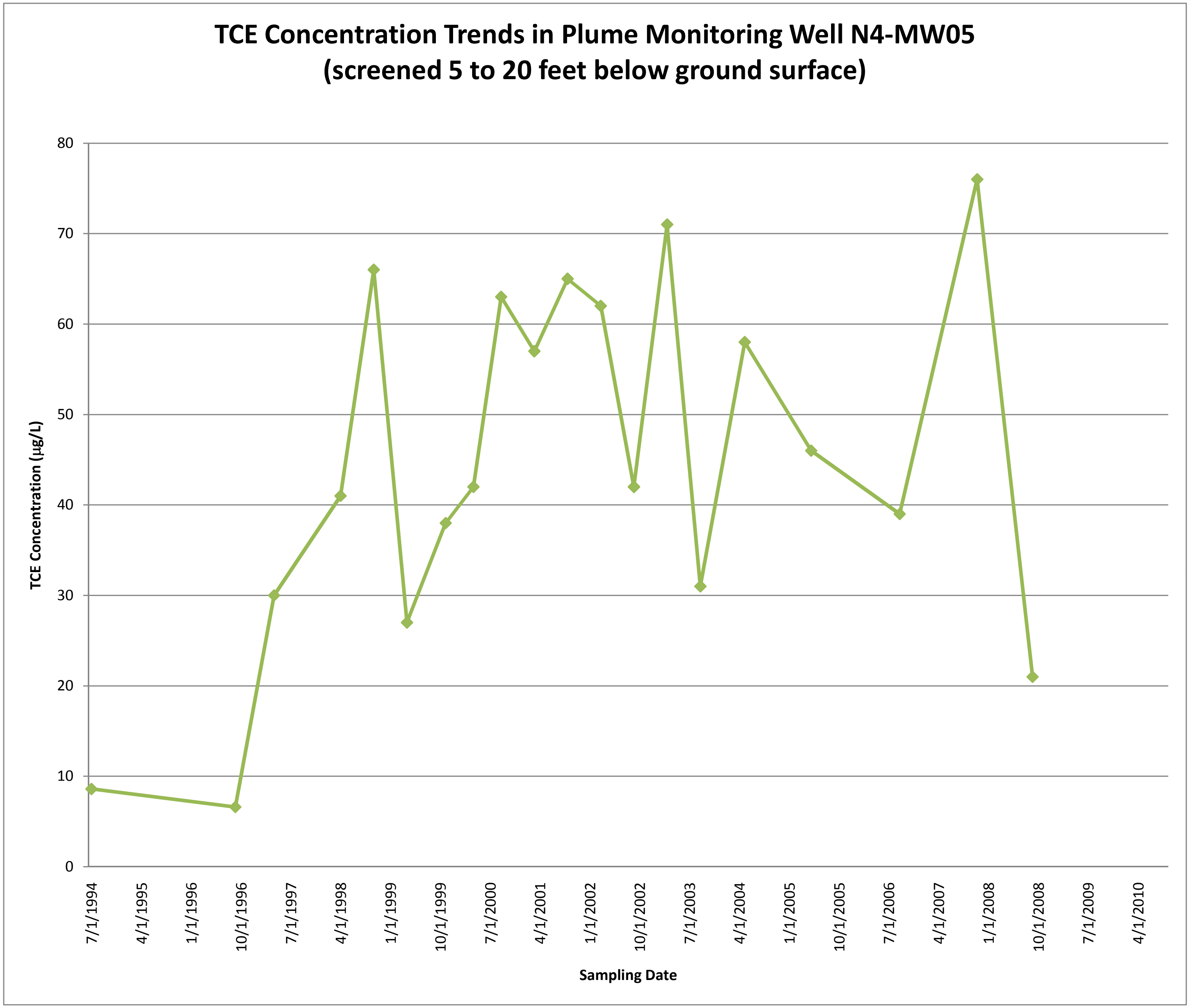


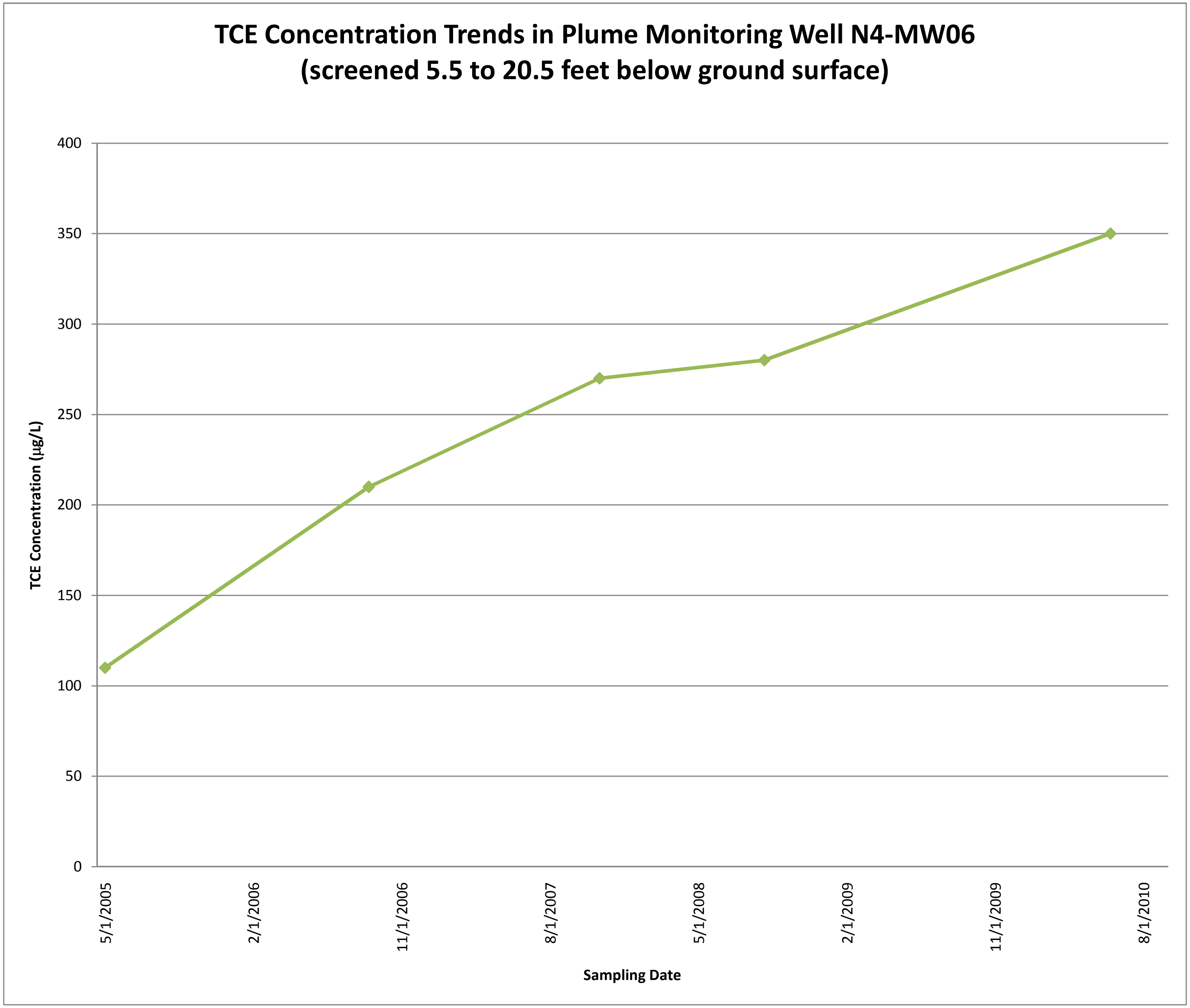
***Notes*:**

ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action
TCE - Trichloroethene

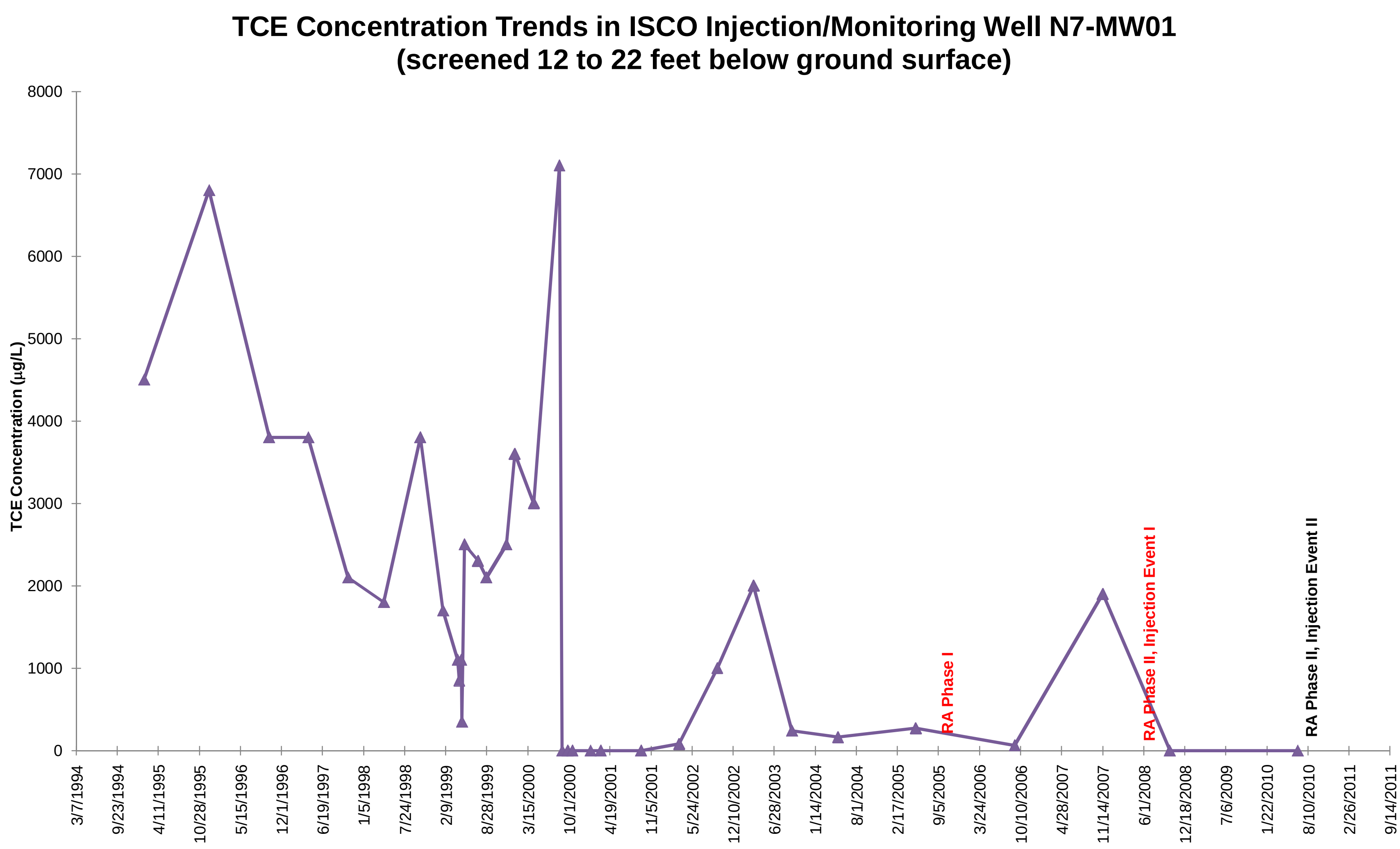
Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)


TCE Concentration Trends in Plume Monitoring Well N4-MW04
(screened 37.6 to 47.6 feet below ground surface)
TCE Concentration (µg/L)
70
60
50
40
30
20
10
0
7/1/1994
4/1/1995
1/1/1996
10/1/1996
7/1/1997
4/1/1998
1/1/1999
10/1/1999
7/1/2000
4/1/2001
1/1/2002
10/1/2002
7/1/2003
4/1/2004
1/1/2005
10/1/2005
7/1/2006
4/1/2007
1/1/2008
10/1/2008
7/1/2009
4/1/2010
Sampling Date


TCE Concentration Trends in Plume Monitoring Well N4-MW05
(screened 5 to 20 feet below ground surface)
TCE Concentration (µg/L)
0
10
20
30
40
50
60
70
80
7/1/1994
4/1/1995
1/1/1996
10/1/1996
7/1/1997
4/1/1998
1/1/1999
10/1/1999
7/1/2000
4/1/2001
1/1/2002
10/1/2002
7/1/2003
4/1/2004
1/1/2005
10/1/2005
7/1/2006
4/1/2007
1/1/2008
10/1/2008
7/1/2009
4/1/2010
Sampling Date

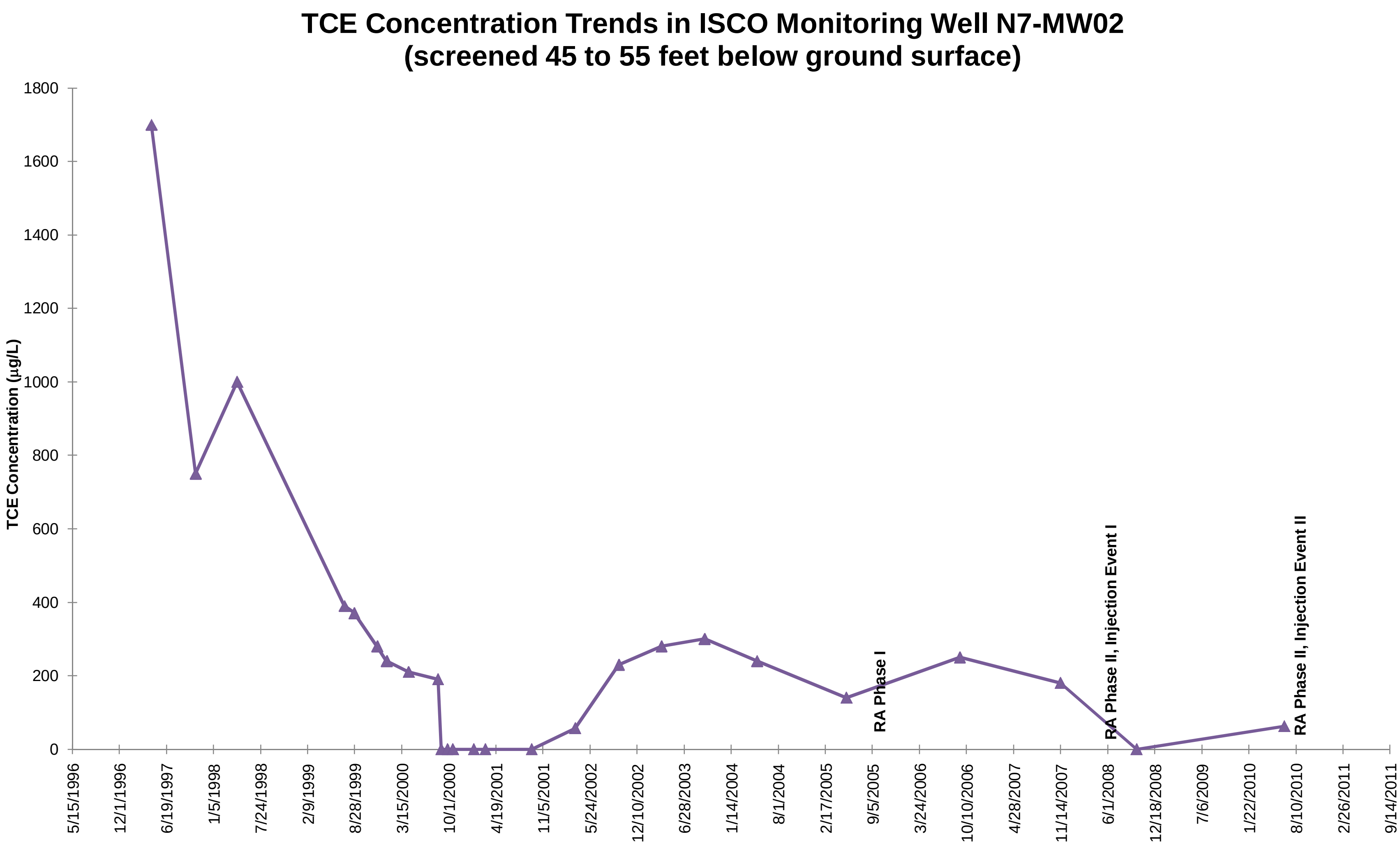


TCE Concentration Trends in Plume Monitoring Well N4-MW06
(screened 5.5 to 20.5 feet below ground surface)
TCE Concentration (µg/L)
400
350
300
250
200
150
100
50
0
5/1/2005
2/1/2006
11/1/2006
8/1/2007
5/1/2008
2/1/2009
11/1/2009
8/1/2010
Sampling Date



Notes:
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action
TCE - Trichloroethene

Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)



Notes:
ISCO - *In Situ* Chemical Oxidation
RA - Remedial Action
TCE - Trichloroethene

Red Font Color Indicates Subject Well Used For Injection During Indicated Event
RA Phase I Injection (6/21/05 to 7/14/05)
RA Phase II, Injection Event I (3/3/08 to 3/21/08)
RA Phase II, Injection Event II (8/16/10 to 8/26/10)

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APPENDIX B

CONTAMINANT VOLUME AND MASS CALCULATIONS

TABLE B-1. CALCULATION OF MASS AND VOLUME OF TCE DISSOLVED IN SITE N3 GROUNDWATER - 2003

TCE Concentration Range (µg/L)[a]	Average TCE Concentration (µg/L)	(lbs/ft^3)[b]	Surface Area of Concentration Contour (ft^2)[a]	Aquifer Thickness (ft)[c]	Aquifer Porosity (%)[d]	Water Volume (ft^3)[e]	Mass of TCE (lbs)[f]	Volume of TCE (gal)[g]	Approximate Percent of Total Mass
> 3,500	3,803[h]	4.21E-04	2,972	90	30	80,244	19.03	1.56	22.4
2,000 – 3,500	2,750	1.72E-04	1,009	90	30	27,243	4.69	0.38	5.5
1,000 - 2,000	1,500	9.36E-05	3,117	90	30	84,159	7.88	0.65	9.3
500 - 1,000	750	4.68E-05	21,276	90	30	574,452	26.88	2.21	31.7
100 – 500	300	1.87E-05	44,298	90	30	1,196,046	22.37	1.84	26.4
50 – 100	75	4.68E-06	18,459	90	30	498,393	2.33	0.19	2.7
10 – 50	30	1.87E-06	22,439	90	30	605,853	1.13	0.09	1.3
5 – 10	7.5	4.68E-07	42,917	90	30	1,158,759	0.54	0.04	0.6
Total			156,487			4,225,149	84.85	6.96	

Notes:

(a) TCE concentration range and contour areas are based on 2003 laboratory analytical data as presented in the *Feasibility Study* (Earth Tech, 2004) and on Figure B-1 of this report.

(b) Calculated as: $\mu g / L \times \frac{g}{10^6 \mu g} \times \frac{lb}{454 g} \times 28.32 \frac{L}{ft^3}$

(c) Assumed based on past sampling events.

(d) Assumed.

(e) Calculated as: Surface area of concentration contour (ft^2) x Aquifer thickness (ft) x Porosity (unitless).

(f) Calculated as: Average TCE concentration (lbs/ft^3) x Water volume (ft^3).

(g) Calculated as: $Mass\ of\ TCE\ (pounds) \times \frac{454g}{lb} \times (density\ of\ TCE)\ \frac{cm^3}{1.46g} \times \frac{L}{10^3 cm^3} \times \frac{gal}{3.785L}$

(h) Average of the four results within the contour interval

% = percent
> = greater than
µg = micrograms
µg/L = micrograms per liter
cm^3 = cubic centimeters
ft = feet
ft^2 = square feet
ft^3 = cubic feet
g = grams
gal = gallons
lb = pounds
L = liters
TCE = trichloroethene

TABLE B-2. CALCULATION OF MASS AND VOLUME OF TCE DISSOLVED IN SITE N3 GROUNDWATER - 2010

TCE Concentration Range (µg/L)[a]	Average TCE Concentration (µg/L)	Average TCE Concentration (lbs/ft³)[b]	Surface Area of Concentration Contour (ft²)[a]	Aquifer Thickness (ft)[c]	Aquifer Porosity (%)[d]	Water Volume (ft³)[e]	Mass of TCE (lbs)[f]	Volume of TCE (gal)[g]	Approximate Percent of Total Mass
> 3,500	15,050[h]	9.39E-04	510	90	30	13,770	12.93	1.06	24.2
2,000 – 3,500	2,750	1.72E-04	364	90	30	9,828	1.69	0.14	3.2
1,000 - 2,000	1,500	9.36E-05	6,849	90	30	184,923	17.31	1.42	32.4
500 - 1,000	750	4.68E-05	3,667	90	30	99,009	4.63	0.38	8.7
100 – 500	300	1.87E-05	28,080	90	30	758,160	14.18	1.16	26.5
50 – 100	75	4.68E-06	10,835	90	30	292,545	1.37	0.11	2.6
10 – 50	30	1.87E-06	23,004	90	30	621,108	1.16	0.10	2.2
5 – 10	7.5	4.68E-07	10,729	90	30	289,683	0.14	0.01	0.3
Total			84,038			2,269,026	53.41	4.38	

Notes:

(a) TCE concentration range and contour areas are based on 2010 laboratory analytical data as presented in the *Draft Interim Remedial Action Completion Report* (AECOM, 2011) and on Figure B-2 of this report.

(b) Calculated as: $\mu g / L \times \frac{g}{10^6 \mu g} \times \frac{lb}{454 g} \times 28.32 \frac{L}{ft^3}$

(c) Assumed based on past sampling events.

(d) Assumed.

(e) Calculated as: Surface area of concentration contour (ft^2) x Aquifer thickness (ft) x Porosity (unitless).

(f) Calculated as: Average TCE concentration (lbs/ft^3) x Water volume (ft^3)

(g) Calculated as: $\textit{Mass of TCE (pounds)} \times \frac{454g}{lb} \times \textit{(density of TCE)} \frac{cm^3}{1.46g} \times \frac{L}{10^3 cm^3} \times \frac{gal}{3.785L}$

(h) Average of the two concentrations detected within the contour interval

% = percent
> = greater than
µg = micrograms
µg/L = micrograms per liter
cm^3 = cubic centimeters
ft = feet
ft^2 = square feet
ft^3 = cubic feet
g = grams
gal = gallons
lb = pounds
L = liters
TCE = trichloroethene

TABLE B-3. CALCULATION OF MASS AND VOLUME OF TCE DISSOLVED IN SITE N7 GROUNDWATER - 2003

TCE Concentration Range (µg/L)[(a)]	Average TCE Concentration (µg/L)	Average TCE Concentration (lbs/ft³)[(b)]	Surface Area of Concentration Contour (ft²)[(a)]	Aquifer Thickness (ft)[(c)]	Aquifer Porosity (%)[(d)]	Water Volume (ft³)[(e)]	Mass of TCE (lbs)[(f)]	Volume of TCE (gal)[(g)]	Approximate Percent of Total Mass
> 1,000 west	1,500[(h)]	9.36E-05	246	90	30	6,642	0.62	0.05	1.7
> 1,000 east	1,050[(h)]	6.55E-05	1,021	90	30	27,567	1.81	0.15	4.9
500 – 1,000 west	750	4.68E-05	174	90	30	4,698	0.22	0.02	0.6
500 – 1,000 east	750	4.68E-05	2,465	90	30	66,555	3.11	0.26	8.4
100 – 500	300	1.87E-05	56,178	90	30	1,516,806	28.38	2.33	76.3
50 – 100	75	4.68E-06	15,432	90	30	416,664	1.95	0.16	5.2
10 – 50	30	1.87E-06	17,704	90	30	478,008	0.89	0.07	2.4
5 – 10	7.5	4.68E-07	14,930	90	30	403,110	0.19	0.02	0.5
Total			108,150			2,920,050	37.17	3.06	

Notes:

(a) TCE concentration range and contour areas are based on 2003 laboratory analytical data as presented in the *Feasibility Study* (Earth Tech, 2004) and on Figure B-3 of this report.

(b) Calculated as: $\mu g/L \times \frac{g}{10^6 \mu g} \times \frac{lb}{454 g} \times 28.32 \frac{L}{ft^3}$

(c) Assumed based on past sampling events.

(d) Assumed.

(e) Calculated as: Surface area of concentration contour (ft^2) x Aquifer thickness (ft) x Porosity (unitless).

(f) Calculated as: Average TCE concentration (lbs/ft^3) x Water volume (ft^3)

(g) Calculated as: $Mass\ of\ TCE\ (pounds) \times \frac{454g}{lb} \times (density\ of\ TCE)\ \frac{cm^3}{1.46g} \times \frac{L}{10^3 cm^3} \times \frac{gal}{3.785L}$

(h) Average of contour value and the single data point within that contour

% = percent
> = greater than
µg = micrograms
µg/L = micrograms per liter
cm^3 = cubic centimeters
ft = feet
ft^2 = square feet
ft^3 = cubic feet
g = grams
gal = gallons
lbs = pounds
L = liters
TCE = trichloroethene

TABLE B-4. CALCULATION OF MASS AND VOLUME OF TCE DISSOLVED IN SITE N7 GROUNDWATER - 2010

TCE Concentration Range (µg/L)[a]	Average TCE Concentration (µg/L)	Average TCE Concentration (lbs/ft^3)[a]	Surface Area of Concentration Contour (ft^2)[a]	Aquifer Thickness (ft)[c]	Aquifer Porosity (%)[d]	Water Volume (ft^3)[e]	Mass of TCE (lbs)[f]	Volume of TCE (gal)[g]	Approximate Percent of Total Mass
> 100	130[h]	8.10E-06	37,959	90	30	1,024,893	8.30	0.68	79.2
50 – 100	75	4.68E-06	12,403	90	30	334,881	1.57	0.13	14.9
10 – 50	30	1.87E-06	10,947	90	30	295,569	0.55	0.05	5.3
5 – 10	7.5	4.68E-07	5,150	90	30	139,050	0.07	0.01	0.6
Total			66,459			1,794,393	10.49	0.87	

Notes:

(a) TCE concentration range and contour areas are based on 2010 laboratory analytical data as presented in the *Draft Interim Remedial Action Completion Report* (AECOM, 2011) and on Figure B-4 of this report.

(b) Calculated as: $\mu g / L \times \frac{g}{10^6 \mu g} \times \frac{lb}{454 g} \times 28.32 \frac{L}{ft^3}$

(c) Assumed based on past sampling events.

(d) Assumed.

(e) Calculated as: Surface area of concentration contour (ft^2) x Aquifer thickness (ft) x Porosity (unitless).

(f) Calculated as: Average TCE concentration (lbs/ft^3) x Water volume (ft^3)

(g) Calculated as: $\textit{Mass of TCE (pounds)} \times \frac{454g}{lb} \times \textit{(density of TCE)} \frac{cm^3}{1.46g} \times \frac{L}{10^3 cm^3} \times \frac{gal}{3.785L}$

(h) Average of detections within contour

% = percent
> = greater than
µg = micrograms
µg/L = micrograms per liter
cm^3 = cubic centimeters
ft = feet
ft^2 = square feet
ft^3 = cubic feet
g = grams
gal = gallons
lb = pounds
L = liters
TCE = trichloroethene

TABLE B-5. CALCULATION OF MASS AND VOLUME OF TCE DISSOLVED IN OU6 GROUNDWATER - 2003

TCE Concentration Range (µg/L)[a]	Average TCE Concentration (µg/L)	Average TCE Concentration (lbs/ft³)[b]	Surface Area of Concentration Contour (ft²)[a]	Aquifer Thickness (ft)[c]	Aquifer Porosity (%)[d]	Water Volume (ft³)[e]	Mass of TCE (lbs)[f]	Volume of TCE (gal)[g]	Approximate Percent of Total Mass
> 3,500	3,803[h]	2.37E-04	2,972	90	30	80,244	19.04	1.56	3.2
2,000 – 3,500	2,750	1.72E-04	1,009	90	30	27,243	4.67	0.38	0.8
1,000 - 2,000[i]	1,500	9.36E-05	3,117	90	30	84,159	7.87	0.65	1.3
> 1,000[j]	1,500[k]	9.36E-05	246	90	30	6,642	0.62	0.05	0.1
> 1,000[l]	1,050[k]	6.55E-05	1,021	90	30	27,567	1.81	0.15	0.3
500-1000n3[i]	750	4.68E-05	21,276	90	30	574,452	26.88	2.21	4.6
500-1000[j]	750	4.68E-05	174	90	30	4,698	0.22	0.02	0.0
500-1000[l]	750	4.68E-05	2,465	90	30	66,555	3.11	0.26	0.5
100 – 500	300	1.87E-05	844,431	90	30	22,799,637	426.66	35.05	72.6
50 – 100	75	4.68E-06	534,707	90	30	14,437,089	67.54	5.55	11.5
10 – 50	30	1.87E-06	510,587	90	30	13,785,849	25.80	2.12	4.4
5 – 10	7.5	4.68E-07	247,533	90	30	6,683,391	3.13	0.26	0.5
Total			2,169,538			58,577,526	587.35	48.26	

Notes:

(a) TCE concentration range and contour areas are based on 2003 laboratory analytical data as presented in the *Feasibility Study* (Earth Tech, 2004) and on Figure B-5 of this report.

(b) Calculated as: $\mu g / L \times \frac{g}{10^6 \mu g} \times \frac{lb}{454 g} \times 28.32 \frac{L}{ft^3}$

(c) Assumed based on past sampling events.

(d) Assumed.

(e) Calculated as: Surface area of concentration contour (ft^2) x Aquifer thickness (ft) x Porosity (unitless).

(f) Calculated as: Average TCE concentration (lbs/ft^3) x Water volume (ft^3)

(g) Calculated as: $\textit{Mass of TCE (pounds)} \times \frac{454g}{lb} \times \textit{(density of TCE)}\ \frac{cm^3}{1.46g} \times \frac{L}{10^3 cm^3} \times \frac{gal}{3.785L}$

(h) Average of the two concentrations detected within the contour interval

(i) Contour interval at Site N3

(j) Contour interval at the Site N7 western plume

(k) Average of contour value and the single data point within that contour

(l) Contour interval at the Site N7 eastern plume

% = percent
> = greater than
µg = micrograms
µg/L = micrograms per liter
cm³ = cubic centimeters
ft = feet
ft² = square feet
ft³ = cubic feet
g = grams
gal = gallons
lb = pounds
L = liters
TCE = trichloroethene

TABLE B-6. CALCULATION OF MASS AND VOLUME OF TCE DISSOLVED IN OU6 GROUNDWATER - 2010

TCE Concentration Range (µg/L)[(a)]	Average TCE Concentration (µg/L)	Average TCE Concentration (lbs/ft³)[(b)]	Surface Area of Concentration Contour (ft²)[(a)]	Aquifer Thickness (ft)[(c)]	Aquifer Porosity (%)[(d)]	Water Volume (ft³)[(e)]	Mass of TCE (lbs)[(f)]	Volume of TCE (gal)[(g)]	Approximate Percent of Total Mass
> 3,500	15,050[(h)]	9.39E-04	510	90	30	13,770	12.93	1.06	2.1
2,000 – 3,500	2,750	1.72E-04	364	90	30	9,828	1.69	0.14	0.3
1,000 – 2,000	1,500	9.36E-05	6,849	90	30	184,923	17.30	1.42	2.8
500 – 1,000	750	3.31E-05	3,667	90	30	99,009	3.27	0.27	0.5
> 500[(i)]	530[(j)]	4.68E-05	17,147	90	30	462,969	21.66	1.78	3.5
100 – 500	300	1.87E-05	887,732	90	30	23,968,764	448.54	36.85	71.8
50 – 100	75	4.68E-06	643,283	90	30	17,368,641	81.26	6.68	13.0
10 – 50	30	1.87E-06	692,881	90	30	18,707,787	35.01	2.88	5.6
5 – 10	7.5	4.68E-07	219,417	90	30	5,924,259	2.77	0.23	0.4
Total			2,471,850			66,739,950	624.43	51.31	

Notes:

(a) TCE concentration range and contour areas are based on 2010 laboratory analytical data as presented in the *Draft Interim Remedial Action Completion Report* (AECOM, 2011) and on Figure B-6 of this report.

(b) Calculated as: $\mu g / L \times \frac{g}{10^6 \mu g} \times \frac{lb}{454 g} \times 28.32 \frac{L}{ft^3}$

(c) Assumed based on past sampling events.

(d) Assumed.

(e) Calculated as: Surface area of concentration contour (ft^2) x Aquifer thickness (ft) x Porosity (unitless).

(f) Calculated as: Average TCE concentration (lbs/ft^3) x Water volume (ft^3)

(g) Calculated as: $Mass\ of\ TCE\ (pounds) \times \frac{454g}{lb} \times (density\ of\ TCE)\ \frac{cm^3}{1.46g} \times \frac{L}{10^3 cm^3} \times \frac{gal}{3.785L}$

(h) Average of the two concentrations detected within the contour interval

(i) Closed contour in the Site N4 area

(j) Average of contour value and the single data point within that contour

% = percent
> = greater than
µg = micrograms
µg/L = micrograms per liter
cm^3 = cubic centimeters
ft = feet
ft^2 = square feet
ft^3 = cubic feet
g = grams
gal = gallons
lb = pounds
L = liters
TCE = trichloroethene

TABLE B-7. CALCULATION OF MASS AND VOLUME OF BENZENE DISSOLVED IN OU6 GROUNDWATER - 2003

Benzene Concentration Range (µg/L)[(a)]	Average Benzene Concentration (µg/L)	Average Benzene Concentration (lbs/ft³)[(b)]	Surface Area of Concentration Contour (ft²)[(a)]	Aquifer Thickness (ft)[(c)]	Aquifer Porosity (%)[(d)]	Water Volume (ft³)[(e)]	Mass of Benzene (lbs)[(f)]	Volume of Benzene (gal)[(g)]	Approximate Percent of Total Mass
> 1,000	3,600[(h)]	2.25E-04	107	90	30	2,889	0.65	0.09	36.9
500 – 1,000	750	4.68E-05	121	90	30	3,267	0.15	0.02	8.7
100 – 500	300	1.87E-05	236	90	30	6,372	0.12	0.02	6.8
50 – 100	75	4.68E-06	1,321	90	30	35,667	0.17	0.02	9.5
10 – 50	30	1.87E-06	12,539	90	30	338,553	0.63	0.09	35.9
5 –10	7.5	4.68E-07	1,972	90	30	53,244	0.02	0.00	1.4
1 – 5	3	1.87E-07	3,186	90	30	86,022	0.02	0.00	0.9
Total			19,482			526,014	1.76	0.24	

Notes:

(a) Benzene concentration range and contour areas are based on 2003 laboratory analytical data as presented in the *Feasibility Study* (Earth Tech, 2004)and on Figure B-7 of this report.

(b) Calculated as: $\mu g / L \times \frac{g}{10^6 \mu g} \times \frac{lb}{454 g} \times 28.32 \frac{L}{ft^3}$

(c) Assumed based on past sampling events.

(d) Assumed.

(e) Calculated as: Surface area of concentration contour (ft²) x Aquifer thickness (ft) x Porosity (unitless).

(f) Calculated as: Average Benzene concentration (lbs/ft³) x Water volume (ft³)

(g) Calculated as: $\text{Mass of Benzene (pounds)} \times \frac{454 g}{lb} \times \text{(density of Benzene)} \frac{cm^3}{0.88 g} \times \frac{L}{10^3 cm^3} \times \frac{gal}{3.785 L}$

(h) Average of contour value and the single data point within that contour

% = percent
> = greater than
µg = micrograms
µg/L = micrograms per liter
cm³ = cubic centimeters
ft = feet
ft² = square feet
ft³ = cubic feet
g = grams
gal = gallons
lb = pounds
L = liters

TABLE B-8. CALCULATION OF MASS AND VOLUME OF BENZENE DISSOLVED IN OU6 GROUNDWATER - 2010

Benzene Concentration Range (µg/L)[a]	Average Benzene Concentration (µg/L)	Average Benzene Concentration (lbs/ft^3)[b]	Surface Area of Concentration Contour (ft^2)[a]	Aquifer Thickness (ft)[c]	Aquifer Porosity (%)[d]	Water Volume (ft^3)[e]	Mass of Benzene (lbs)[f]	Volume of Benzene (gal)[g]	Approximate Percent of Total Mass
> 1,000 west	4,075[h]	2.54E-04	1,716	90	30	46,332	11.78	1.60	63.4
> 1,000 east	1,300[i]	8.11E-05	154	90	30	4,158	0.34	0.05	1.8
500 – 1,000 west	750	4.68E-05	1,321	90	30	35,667	1.67	0.23	9.0
500 – 1,000 east	750	4.68E-05	959	90	30	25,893	1.21	0.16	6.5
100 – 500	300	1.87E-05	5,026	90	30	135,702	2.54	0.34	13.7
50 – 100	75	4.68E-06	6,029	90	30	162,783	0.76	0.10	4.1
10 - 50	30	1.87E-06	4,582	90	30	123,714	0.23	0.03	1.2
5 – 10	7.5	4.68E-07	2,031	90	30	54,837	0.03	0.00	0.1
1 – 5	3	1.87E-07	2,589	90	30	69,903	0.01	0.00	0.0
Total			24,407			658,989	18.57	2.51	

Notes:

(a) Benzene concentration range and contour areas are based on 2010 laboratory analytical data as presented in the *Draft Interim Remedial Action Completion Report* (AECOM, 2011) and on Figure B-8 of this report.

(b) Calculated as: $\mu g/L \times \frac{g}{10^6 \mu g} \times \frac{lb}{454 g} \times 28.32 \frac{L}{ft^3}$

(c) Assumed based on past sampling events.

(d) Assumed.

(e) Calculated as: Surface area of concentration contour (ft^2) x Aquifer thickness (ft) x Porosity (unitless).

(f) Calculated as: Average Benzene concentration (lbs/ft^3) x Water volume (ft^3)

(g) Calculated as: $\text{Mass of Benzene (pounds)} \times \frac{454g}{lb} \times \text{(density of Benzene)} \frac{cm^3}{0.88g} \times \frac{L}{10^3 cm^3} \times \frac{gal}{3.785L}$

(h) Average of the four concentrations within the contour

(i) Average of contour value and the single data point within that contour

% = percent
> = greater than
µg = micrograms
µg/L = micrograms per liter
cm^3 = cubic centimeters
ft = feet
ft^2 = square feet
ft^3 = cubic feet
g = grams
gal = gallons
lb = pounds
L = liters

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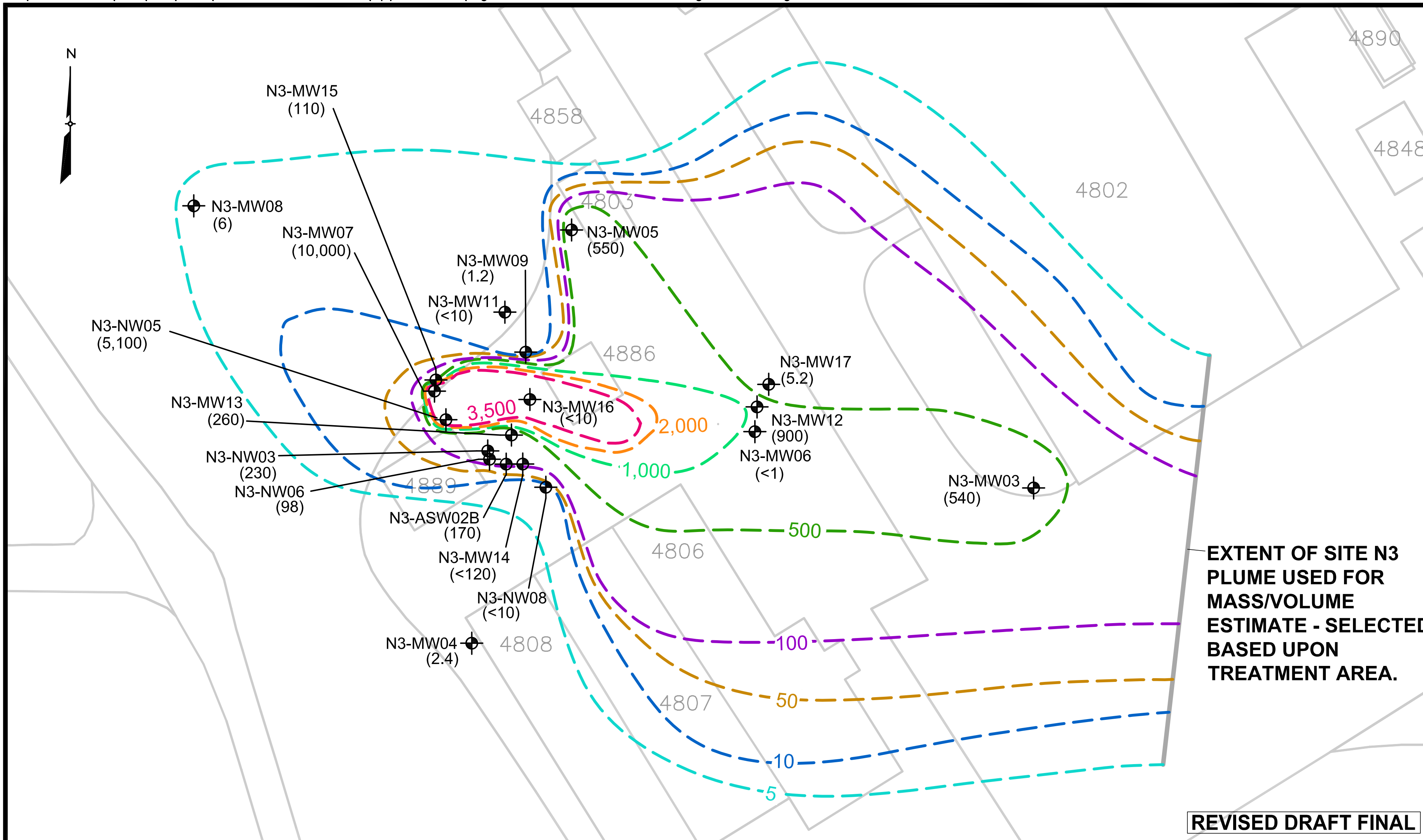


EXPLANATION

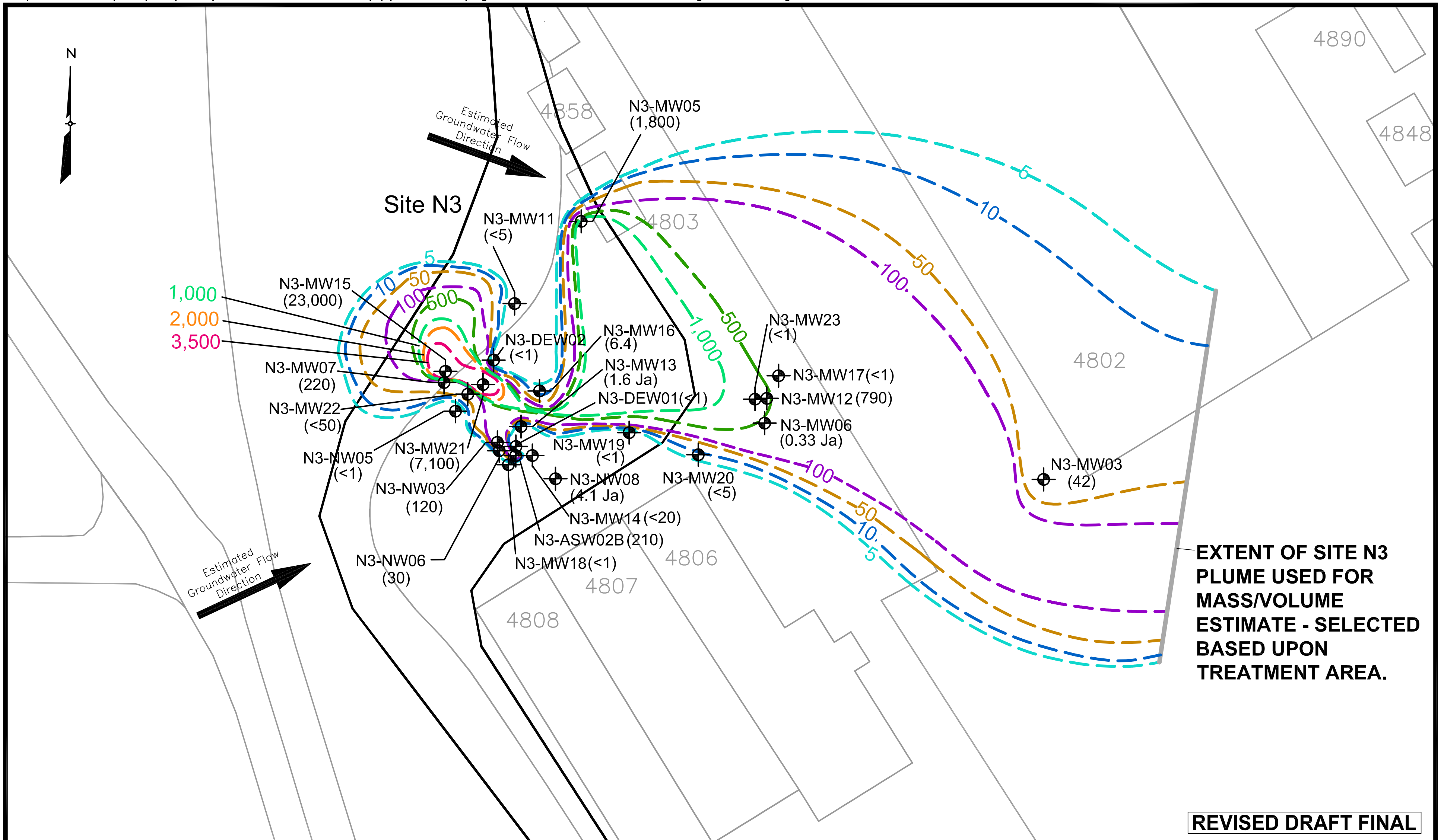
N3-NW03 (230) — MONITORING WELL WITH TRICHLOROETHENE (TCE) CONCENTRATION IN MICROGRAMS PER LITER

- - 5 - - INFERRED TCE CONCENTRATION CONTOUR (INTERVALS = 5, 10, 50, 100, 500, 1,000, 2,000, AND 3,500 MICROGRAMS PER LITER) BASED ON 2003 RESULTS

0 40 80
SCALE IN FEET

Site N3
TCE Groundwater Concentration Contours
2003

Date 08-2011	**Operable Unit 6**	Figure
Project No. 60133976	**First Five-Year Review Report** **Edwards AFB**	**B-1**



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EXPLANATION

N3-NW03 (120) MONITORING WELL WITH TRICHLOROETHENE (TCE) CONCENTRATION IN MICROGRAMS PER LITER

– 5 – INFERRED TCE CONCENTRATION CONTOUR (INTERVALS = 5, 10, 50, 100, 500, 1,000, 2,000, AND 3,500 MICROGRAMS PER LITER) BASED ON JUNE-JULY 2010 MONITORING RESULTS

0 40 80
SCALE IN FEET

Site N3
TCE Groundwater Concentration Contours
2010

Date 08-2011	**Operable Unit 6**	Figure
Project No. 60133976	**First Five-Year Review Report** **Edwards AFB**	**B-2**

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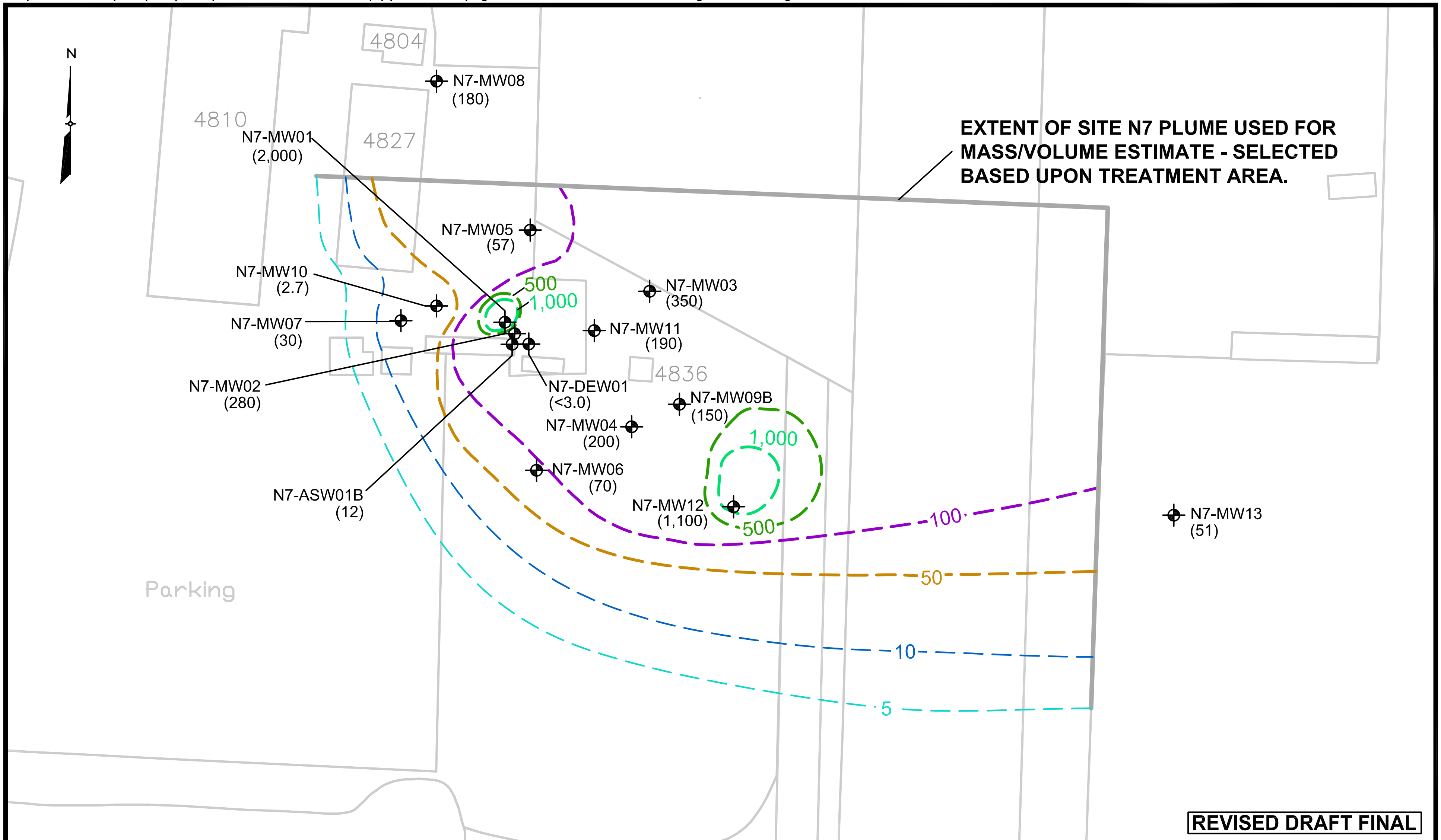

EXPLANATION

N7-MW02 (280) — MONITORING WELL WITH TRICHLOROETHENE (TCE) CONCENTRATION IN MICROGRAMS PER LITER

— 5 — INFERRED TCE CONCENTRATION CONTOUR (INTERVALS = 5, 10, 50, 100, 500, AND 1,000 MICROGRAMS PER LITER) BASED ON 2003 RESULTS

0 40 80
SCALE IN FEET

Site N7
TCE Groundwater Concentration Contours
2003

Date 08-2011	Operable Unit 6	Figure
Project No. 60133976	First Five-Year Review Report Edwards AFB	B-3

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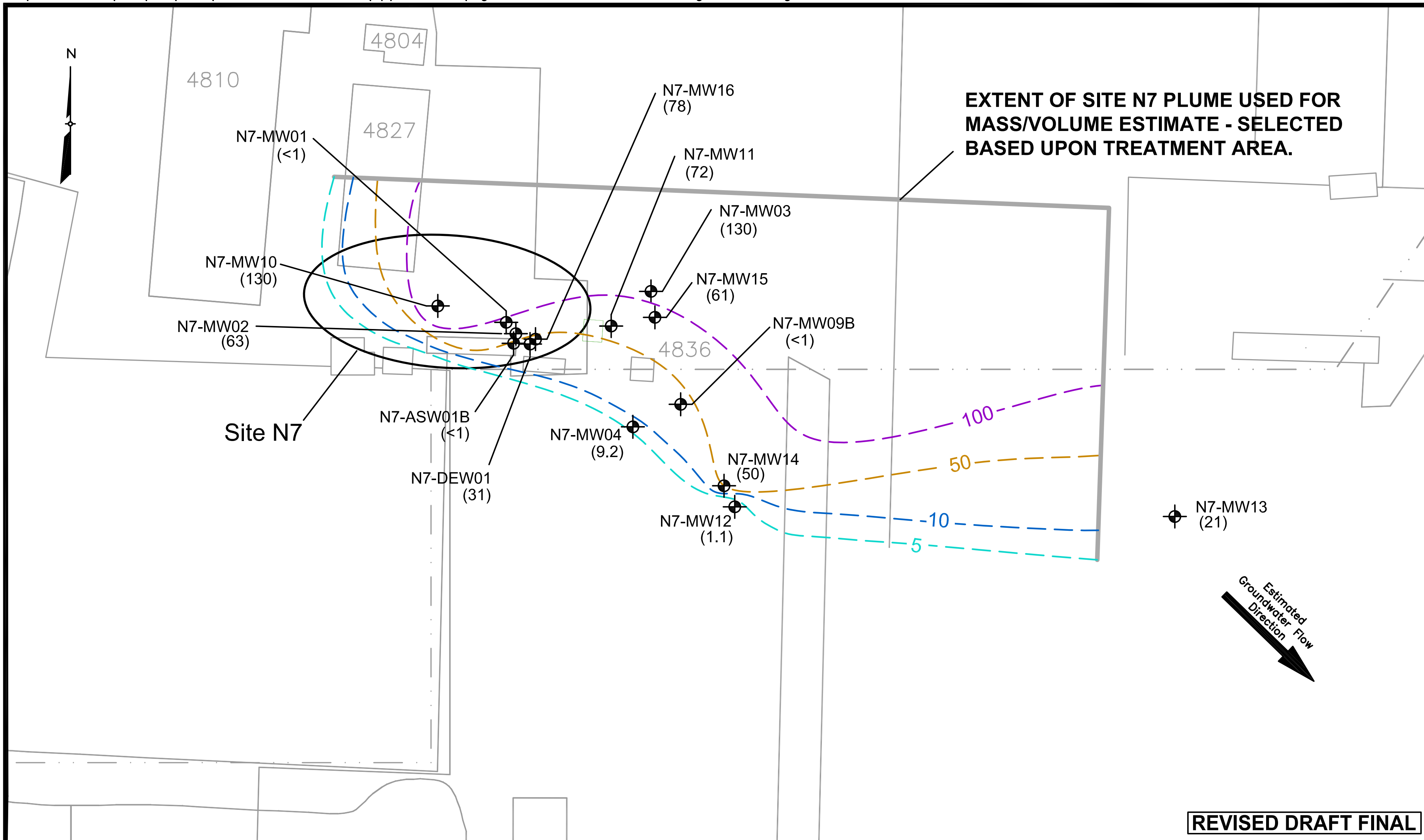

EXPLANATION

N7-MW02 (63) — MONITORING WELL WITH TRICHLOROETHENE (TCE) CONCENTRATION IN MICROGRAMS PER LITER

— 5 — — INFERRED TCE CONCENTRATION CONTOUR (INTERVALS = 5, 10, 50, AND100 MICROGRAMS PER LITER) BASED ON JUNE-JULY 2010 MONITORING RESULTS

0 40 80
SCALE IN FEET

Site N7
TCE Groundwater Concentration Contours
2010

Date 08-2011	**Operable Unit 6**	Figure
Project No. 60133976	**First Five-Year Review Report** **Edwards AFB**	**B-4**

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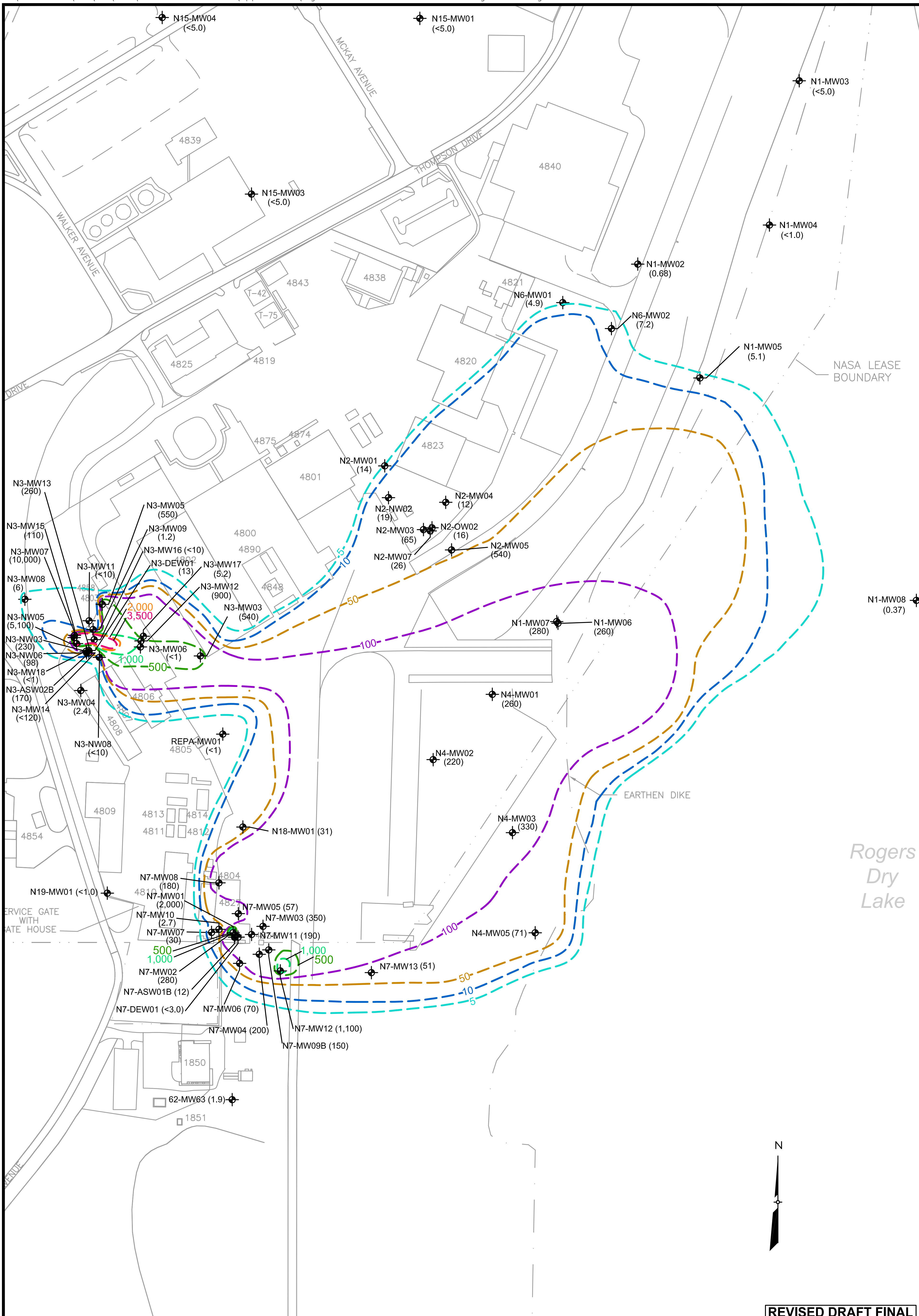


EXPLANATION

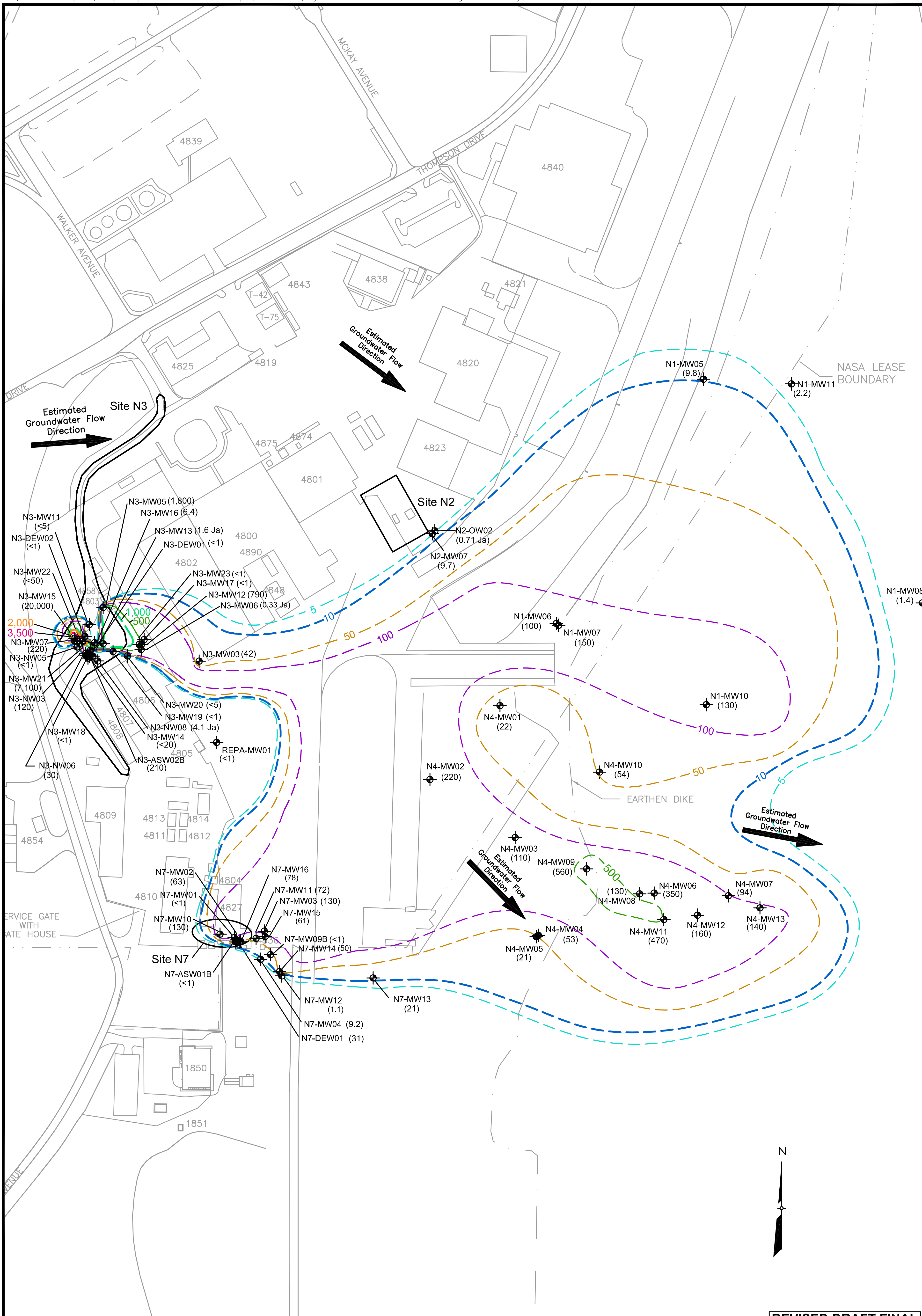
N3-NW03 (230) — MONITORING WELL WITH TRICHLOROETHENE (TCE) CONCENTRATION IN MICROGRAMS PER LITER

5 — INFERRED TCE CONCENTRATION CONTOUR (INTERVALS = 5, 10, 50, 100, 500, 1,000, 2,000, AND 3,500 MICROGRAMS PER LITER) BASED ON 2003 RESULTS

0 125 250
SCALE IN FEET

OU6 Plume
TCE Groundwater Concentration Contours
2003

Date 08-2011	**Operable Unit 6**	Figure
Project No. 60133976	**First Five-Year Review Report** **Edwards AFB**	**B-5**



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EXPLANATION

N3-MW03 (120) — MONITORING WELL WITH TRICHLOROETHENE (TCE) CONCENTRATION IN MICROGRAMS PER LITER

— 5 — INFERRED TCE CONCENTRATION CONTOUR (INTERVALS = 5, 10, 50, 100, 500, 1,000, 2,000, AND 3,500 MICROGRAMS PER LITER) BASED ON JUNE-JULY 2010 MONITORING RESULTS

0 125 250
SCALE IN FEET

OU6 Plume
TCE Groundwater Concentration Contours
2010

Date 08-2011	**Operable Unit 6** **First Five-Year Review Report** **Edwards AFB**	Figure
Project No. 60133976		**B-6**

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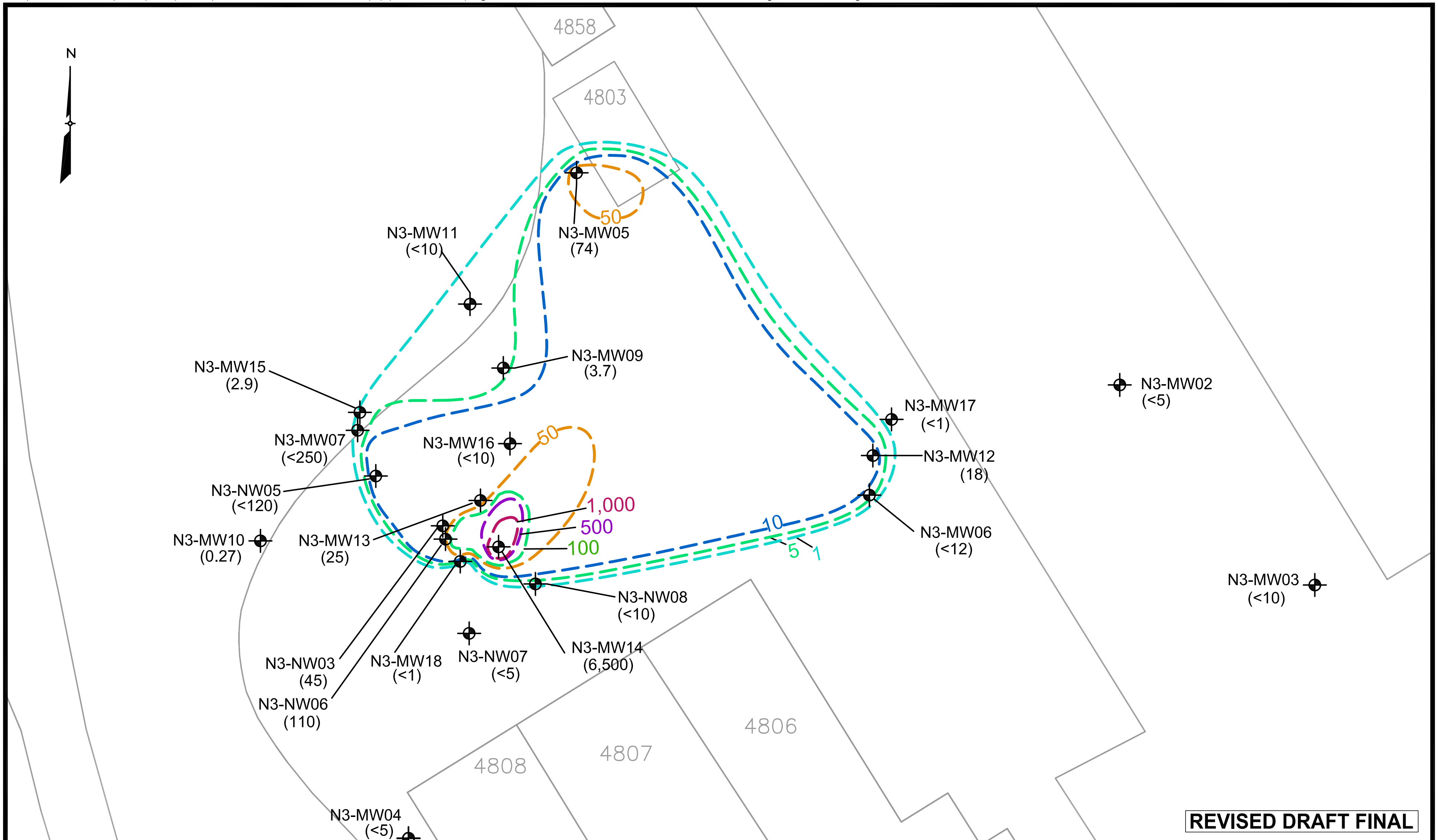


REVISED DRAFT FINAL

EXPLANATION

N3-NW03 (45) — MONITORING WELL WITH BENZENE CONCENTRATION IN MICROGRAMS PER LITER

— 1 — INFERRED BENZENE CONCENTRATION CONTOUR (INTERVALS = 1, 5, 10, 50, 100, 500, AND 1,000 MICROGRAMS PER LITER) BASED ON 2003 RESULTS

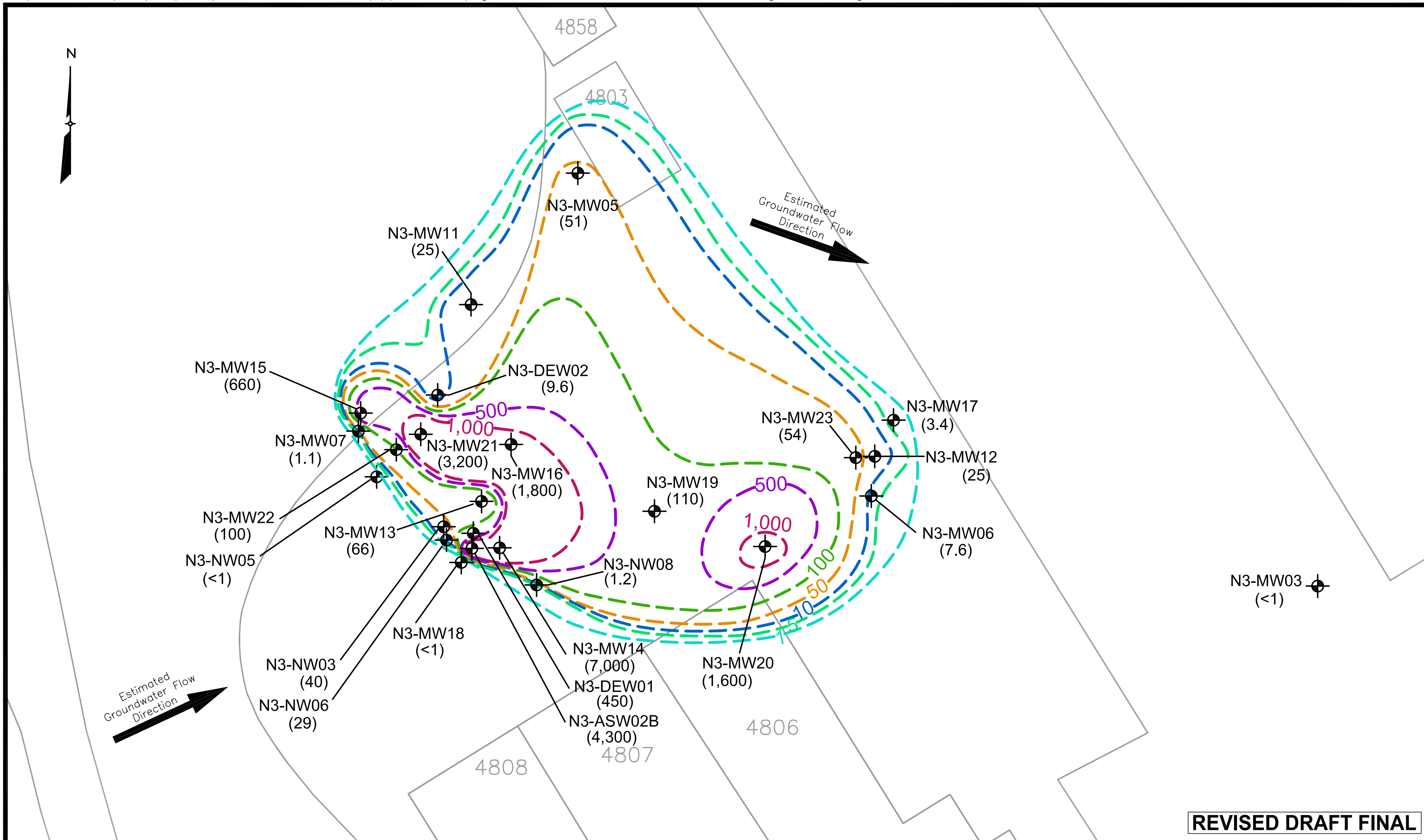
0 25 50

SCALE IN FEET

Site N3
Benzene Groundwater Concentration Contours
2003

Date 08-2011	**Operable Unit 6** **First Five-Year Review Report** **Edwards AFB**	Figure
Project No. 60133976		**B-7**

P:\60133976\WP\90\cad\Revised Draft Final\Appendix B\Figure B-8 Site N3 Benzene 2010.dwg - 16 Aug 2011



EXPLANATION

N3-MW03 (40) MONITORING WELL WITH BENZENE CONCENTRATION IN MICROGRAMS PER LITER

1 INFERRED BENZENE CONCENTRATION CONTOUR (INTERVALS = 1, 5, 10, 50, 100, 500, AND 1,000 MICROGRAMS PER LITER) BASED ON JUNE-JULY 2010 MONITORING RESULTS

0 25 50
SCALE IN FEET

Site N3
Benzene Groundwater Concentration Contours
2010

Date 08-2011	Project No. 60133976	**Operable Unit 6 First Five-Year Review Report Edwards AFB**	Figure **B-8**

APPENDIX C

LAND USE CONTROL EXCERPT FROM ROD

2.12 SELECTED REMEDY

2.12.1 SUMMARY OF THE RATIONALE FOR THE SELECTED REMEDY

The selected remedy for soil is No Action.

Alternative 4, the selected remedy for the groundwater, utilizes chemical oxidation treatment at the areas of highest contaminant concentrations, enhanced natural attenuation of aromatic hydrocarbons, hydrologic control (the natural aquifer characteristics that resulted in the steady-state condition of the plume), LUCs to maintain incomplete exposure pathways, and groundwater monitoring to address and monitor treatment performance.

The selected remedy is the most cost-effective and implementable remedial alternative for groundwater at OU6 that includes treatment and does not impact mission-critical activities. It will achieve compliance with ARARs and applies treatment as the primary component to degrade VOCs in groundwater for a significantly lower cost than Alternative 3.

2.12.2 DESCRIPTION OF THE SELECTED REMEDY

The selected remedy for soil is No Action.

The selected remedy for groundwater will include multiple components, some based on other alternatives. These components are LUCs, groundwater monitoring, *in situ* chemical oxidation, and 5-year reviews.

2.12.2.1 LUCs

The Air Force is committed to implement, monitor, maintain, and enforce remedies that protect human health and the environment in accordance with CERCLA and the NCP. DFRC is a tenant of Edwards AFB. The use of OU6 is restricted to research, development, and aerospace testing purposes. The 95th Air Base Wing, Environmental Restoration Branch (95 ABW/CEVR) works closely with NASA DFRC on all environmental issues and acts as a conduit to the USEPA and the State and will be involved in LUC implementation.

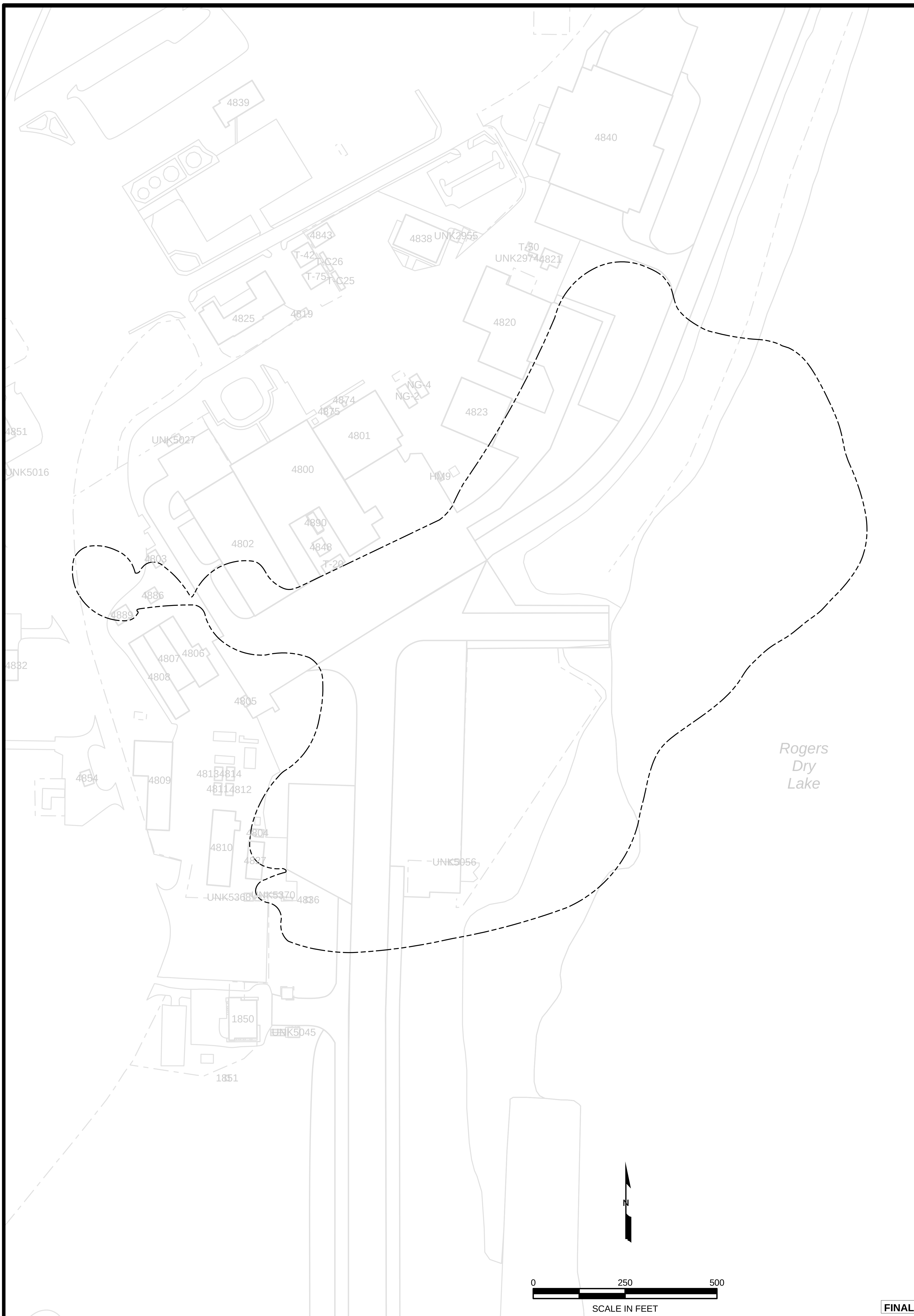
Implementation

The selected remedy requires LUCs to be in place during remediation of contaminated groundwater within the OU6 plume area where contaminant levels do not allow for unlimited use and unrestricted exposure. Figure 2-15 depicts the boundary of groundwater contamination requiring LUCs. The Air Force's commitment to include more specific LUC maps in the GP and NASA DFRC MP is discussed below.

LUC measures to be used at OU6 are in accordance with specific provisions of 22 California Code of Regulations (CCR) Section 67391.1 that were determined by the Air Force to currently be relevant and appropriate requirements. Subsections (a), (b), and (e)(2) of 22 CCR Section 67391.1 provide that if a remedy at property owned by the federal government will result in levels of hazardous substances remaining on property at levels not suitable for unlimited use and unrestricted exposure, and it is not feasible to record a land use covenant (as is the case with the OU6 sites subject to LUCs), then the ROD is to clearly define and include limitations on land use and other IC mechanisms to ensure that future land use will be compatible with the levels of hazardous substances remaining on the property. These limitations and mechanisms are more specifically set forth in this section of the ROD, to include annotating the residential development restrictions in the GP and MP, and continuing to follow the review and approval procedures for any construction and ground-disturbing activities within the OU6 LUC boundary.

The following LUCs apply to groundwater industrial controls for OU6. The objectives are to restrict residential development (including child development centers, kindergarten through 12th grade [K-12] schools, play areas, and hospitals) where contamination is at levels that do not allow for unlimited use and unrestricted exposure and to maintain worker safety. These goals will be achieved through the following:

- Annotating the residential development restrictions in the GP and MP
- Prohibiting residential development in designated areas set forth in the GP and MP
- Continuing administrative measures (described in the following paragraph)



EXPLANATION

-·-·-·-·- LAND USE CONTROL BOUNDARY

Operable Unit 6
Land Use Control Boundary

Date 09-2006 Project No. 54212	**Operable Unit 6** **Record of Decision** **Edwards AFB**	Figure **2-15**

These LUCs are accomplished by a prohibition on residential development in designated areas set forth in the GP and MP, and administrative measures. The administrative measures are the NASA DFRC Work Request procedures, the NASA DFRC Facilities Engineering Digging Permit procedures, and the Environmental Impact Assessment Process (EIAP). The EIAP, Work Request, and Facilities Engineering Digging Permit procedures restrict development during the interim period before remedial actions are implemented. A Facilities Engineering Digging Permit is required for any project that involves any mechanical soil excavation, such as digging trenches for underground lines or excavating soil for building foundations. The permit lists the DFRC Safety, Health, and Environmental Office and other support offices that review the excavation plans for approval. If constraints involving soil disturbance or worker safety exist at the excavation area, the permit describes the appropriate procedures that will prevent unknowing exposure to groundwater contamination and measures the workers must implement before the start of excavation.

The Air Force and/or NASA DFRC will implement the following measures at all sites with LUCs.

- Include in the GP and MP any specific restrictions required at each site, a statement that restrictions are required because of the presence of pollutants or contaminants, the current land users and uses of the site, the geographic control boundaries, and the objectives of the land use restrictions. Unless a site is cleaned up to levels appropriate for unlimited use and unrestricted exposure, the GP and MP will reflect the prohibitions on residential development (including child development centers, K-12 schools, play areas, and hospitals). Upon completion of a remedial action at a site, the GP and MP will be updated to modify the site-specific use restrictions as appropriate. The section describing the specific restrictions will also refer the reader to the Base Environmental Office or NASA DFRC Safety, Health, and Environmental Office, if more information is needed. The GP and MP will each contain a map depicting the geographic boundaries of all OU6 sites where LUCs are in effect.
- While LUCs are in place, maintain administrative control of the integrity of current and future remedial or monitoring systems and maintain existing administrative controls (presented in the subsequent section). LUCs will remain in place as long as groundwater contamination concentrations remain above levels allowing for unlimited use and unrestricted exposure. Neither the Air Force nor NASA DFRC will modify or terminate LUCs, implement actions, or modify land use without USEPA and California DTSC approval. The Air Force shall seek prior concurrence before any anticipated action (by the Air Force or NASA DFRC) that may disrupt the effectiveness of the LUCs or any action that may alter or negate the need for LUCs.
- Whenever the Air Force transfers real property that is subject to ICs and resource use restrictions to another federal agency, the transfer documents shall require that the federal transferee include the ICs, and applicable resource use restrictions in its resource use plan or equivalent resource use mechanism. The Air Force shall advise the recipient federal agency of all obligations contained in the ROD, including the obligation that a State Land Use Covenant

will be executed and recorded pursuant to 22 CCR Section 67391.1 in the event the federal agency transfers the property to a non-federal entity.

- Whenever the Air Force proposes to transfer real property subject to resource use restrictions and ICs to a non-federal entity, it will provide information to that entity in the draft deed and transfer documents regarding necessary resource use restrictions and ICs, including the obligation that a State Land Use Covenant will be executed and recorded pursuant to 22 CCR Section 67391.1. The signed deed will include ICs and resource restrictions equivalent to those contained in the State Land Use Covenant and this ROD.
- The Air Force will provide notice to USEPA and the State at least 6 months prior to any transfer or sale of OU6 so that USEPA and the State can be involved in discussions to ensure that appropriate provisions are included in the transfer terms or conveyance documents to maintain effective ICs. If it is not possible for the facility to notify USEPA and the State at least 6 months prior to any transfer or sale, then the facility will notify USEPA and the State as soon as possible but no later than 60 days prior to the transfer or sale of any property subject to ICs. In addition to the land transfer notice and discussion provisions above, the Air Force further agrees to provide USEPA and the State with similar notice, within the same time frames, as federal-to-federal transfer of property. The Air Force shall provide a copy of the executed deed or transfer assembly to USEPA and the State.
- NASA DFRC will notify the Air Force and the Air Force will notify the USEPA and the State at least 30 days in advance of any proposed land use changes that are inconsistent with LUC objectives or the selected remedy and any changes to the GP or MP that would affect the LUCs.
- NASA DFRC will notify the Air Force and the Air Force will notify the USEPA and the State as soon as practicable, but no longer than 10 days after discovery of any activity that is inconsistent with LUC objectives or use restrictions, or any action that may interfere with the effectiveness of LUCs, as well as provide the USEPA and the State within 10 days of notification of the breach with a tentative plan (including a timeline of proposed actions and delivery dates) regarding how the Air Force and NASA DFRC will address the breach or with a description of how the breach has been addressed.
- Address as soon as practicable any activity that is inconsistent with LUC objectives or use restrictions or any other action that may interfere with the effectiveness of LUCs, but in no case will the process be initiated later than 30 days after the Air Force and NASA DFRC becomes aware of the breach.
- NASA DFRC shall conduct periodic monitoring and take prompt action to restore, repair, or correct any LUC deficiencies or failures identified. A different monitoring schedule may be agreed upon according to the schedule provisions of the FFA, if all parties agree and if the change reasonably reflects the risk presented by the site.

It is understood that the Air Force is responsible for remedy implementation and ensuring integrity of the remedy. NASA DFRC, with oversight by the Air Force, is responsible for implementing (to the degree controls are not already in place), monitoring, maintaining, and enforcing the identified controls. If NASA DFRC and the Air Force determine that it cannot meet specific LUC requirements, it is understood that the remedy may be reconsidered and that additional measures may be required to ensure the protection of human health and the environment.

In addition, to assure the USEPA and the State and the public that the Air Force will fully comply with and be accountable for the performance measures identified herein, NASA DFRC will supply information to the Air Force for, and the Air Force will timely submit to USEPA and California DTSC, an annual monitoring report on the status of LUCs and/or other remedial actions, including the operation and maintenance and monitoring thereof, and how any LUC deficiencies or inconsistent uses have been addressed. The report also will be filed in the information repositories. The report would not be subject to approval and/or revision by USEPA and the State. The annual monitoring reports will be used in preparation of the 5-year reviews to evaluate the effectiveness of the remedy and will verify that state and local agencies were notified of the use restrictions and controls affecting the property and that the use of the property has conformed to such restrictions and controls.

Availability of the Edwards AFB General Plan, NASA DFRC Master Plan, and Existing Administrative Procedures

The first step in restricting specific types of development at a site is to revise the GP and MP to place constraints ensuring that these sites are never used for residential development (including child development centers, K-12 schools, play areas, and hospitals). The GP resides in the office of the Base community planner, and the MP is available at the NASA DFRC Facilities Planning Office. Accordingly, the GP and MP will be revised to include residential development prohibitions and any specific restrictions required at each site, a statement that restrictions are required because of the presence of pollutants or contaminants, the current land users and uses of the site, the geographic control boundaries, and the objectives of the land use restrictions.

All proposed construction requires approval of the appropriate NASA DFRC office to ensure compliance with the GP and MP.

Form DFRC 8-0053, Facilities Work Request, must be submitted and approved before the start of any building project at NASA DFRC. Approval of the Work Request involves the comparison of the building site with the constraints in the MP. The Work Request serves as the document for communicating any construction constraints to the appropriate offices. Any constraints at the site result in the disapproval of the form unless the requester makes appropriate modifications to the building plans. The DFRC Facilities Engineering and Asset Management Office (CODE F) is responsible for the final approval of proposed building projects through the Configuration Control Board review process.

NASA DFRC will also use form DFRC 8-0808, Facilities Engineering Digging Permit, to enforce the groundwater LUCs, as previously discussed. The requester submits the Facilities Engineering Digging Permit to the Facilities Office, CODE F, for any project that involves any mechanical soil excavation, and it is circulated to appropriate offices for review of needed safety procedures. The DFRC Facilities Engineering and Asset Management Office (CODE F) is responsible for the final approval of excavation projects through the permit review process.

Both the Work Request and Facilities Engineering Digging Permit are subject to an EIAP review conducted pursuant to the National Environmental Policy Act, as promulgated for NASA in 14 Code of Federal Regulations (CFR) Part 1216 Subpart 1216.3. The EIAP analysis is initiated when a proponent of a proposed action fills out a form DFRC 8-0039, Request for Environmental Impact Analysis. A proponent of an action is required to submit the Work Request and/or Facilities Engineering Digging Permit with the form DFRC 8-0039 to the Safety, Health, and Environmental Office so that the appropriate environmental analysis of the proposed action and alternatives to the proposed action is accomplished prior to any construction activities. The NASA DFRC environmental staff (air, water, cultural and natural resources, restoration, and others) and the community planner review DFRC forms 8-0039 that involve facilities construction. Major new construction may result in a determination that a formal publicized Environmental Assessment is necessary. The EIAP process works to ensure proposed construction sites are reviewed in accordance with the MP. The process also ensures that all environmental factors, as well as the Base's ROD LUCs, are considered in siting construction projects.

Cleanup Levels

Based on the current industrial land use and the reasonably foreseeable future long-term land use that is projected to be industrial, potential risks associated with COCs in groundwater are mitigated by the lack of complete exposure pathways. However, should the groundwater at OU6 ever be used for beneficial purposes, ingestion of the water from this aquifer would pose a potential risk to human health because

APPENDIX D

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Item No.	Requirement	Citation	Federal, State or Local Requirement	Description	ARAR Determination	Comments	Applicable Sites	Change Since ROD Finalized?	Change to Protectiveness
Chemical-specific ARARs									
1	Primary Drinking Water Standards (Non-zero MCLGs and MCLs)	Safe Drinking Water Act, 40 CFR Part 141, Sections 141.11, 141.50-.51, 141.61-.62 40 CFR Part 300, Sections 300.430(e)(2)(i)(C)	Federal	MCLGs are goals under the SDWA which are set at levels at which no adverse health effects will occur and allow an adequate margin of safety. MCLs are promulgated and enforceable maximum concentrations of drinking water priority pollutants that are set as closely as feasible to MCLGs, considering best technology, treatment techniques, and other factors. The NCP states that primary drinking water standards are legally applicable only to drinking water at the tap, but are relevant and appropriate as cleanup standards for groundwater and surface water that have been determined to be current or future drinking water sources. Under CERCLA 121(d)(2)(A), remedial actions shall attain MCLGs where relevant and appropriate. The NCP provides that where an MCLG has been set at a level of zero, the MCL for that contaminant shall be attained.	Relevant and appropriate	This regulation addresses drinking water-based cleanup goals for groundwater plumes at OU6. The AF and State agree, in this particular case, that use of MCLs as cleanup standards, in conjunction with Institutional Controls, is protective of human health at OU6. Only State MCLs that are more stringent than Federal MCLs are ARARs. For the constituents at OU6, there are no State MCLs that are more stringent than Federal MCLs.	N2, N3, and N7	Yes	An MCL of 6 μg/L was established for perchlorate. However, perchlorate is not a COC for OU6 as perchlorate detections are sporadic. The change in this ARAR does not result in a change in the protectiveness of the selected remedy.
		22 CCR, Div. 4, Ch. 15, Articles 4, 4.5, and 5.5, Sections 64431 et seq., 64444	State	Establishes standards for public water supply systems, including primary MCLs. State MCLs must be at least as stringent as Federal MCLs. State MCLs are incorporated into State and Regional Water Quality Board Water Quality Control Plans as water quality objectives for protection of current and potential drinking water supply sources. MCLs are some of the applicable upper-end objectives for ambient ground and surface water where the water is a source of drinking water, as defined in the Water Quality Control Plans.					
2	Policies and Procedures for Investigation and Cleanup and Abatement	SWRCB Resolution No. 92-49 Water Code Sections 13140, 13240, 13304, 13307	State	State Board Resolution No. 92-49 establishes policies and procedures for the oversight of investigation and cleanup and abatement activities resulting from discharges of waste which affect or threaten water quality. It requires cleanup of all waste discharged and restoration of affected water to background conditions (i.e., the water quality that existed before the discharge). Requires actions for cleanup and abatement to conform to Resolution No. 68-16, water quality control plans and policies, and applicable provisions of California Code of Regulations, Title 23, Division 3, Chapter 15 (Discharges of Hazardous Waste to Land) as feasible.	Relevant and appropriate	Section III.G of Resolution 92-49 is relevant and appropriate. The AF has performed a TEFA for groundwater at OU6 to satisfy requirements for corrective action under SWRCB Resolution 92-49. The AF and the State agree that the cleanup standards for groundwater, in this particular case, are MCLs.	N2, N3, and N7	No	NA
3	Water Quality Control Plan, South Lahontan Basin (Basin Plan)	23 CCR Div. 4, Ch. 1, Article 6, Section 3950 Water Code Sections 13140 and 13240	State	The Porter-Cologne Water Quality Control Act established authority of the SWRCB and RWQCB to regulate discharges into Waters of the State. The Basin Plan establishes beneficial uses and the water quality criteria based upon such uses (water quality objectives). The Basin Plan serves to protect the beneficial uses and water quality of the surface and groundwater in the South Lahontan Basin.	Relevant and appropriate	The water quality objectives for chemical constituents in groundwater are relevant and appropriate.	N2, N3, and N7	No	NA

Item No.	Requirement	Citation	Federal, State or Local Requirement	Description	ARAR Determination	Comments	Applicable Sites	Change Since ROD Finalized?	Change to Protectiveness
Location-specific ARARs									
4	California Endangered Species Act	CDFG Code Section 2050-2055 14 CCR Div. 1, Subdivision 3, Ch. 6 Section 783.1	State	Establishes species, subspecies, and varieties of native California plants or animals as endangered, threatened, or rare. Prohibits the taking, importation, or sale of any species, or any part thereof, of an endangered species or a threatened species. Contains provisions concerning CDFG coordination with State and Federal agencies and with project applicants. Recommends avoidance of adverse impacts on species of special concern and their habitat.	Relevant and appropriate	Potentially an ARAR where the State law has a listing that is more stringent than the Federal Endangered Species Act and Migratory Bird Treaty Act. As stated in AF Instruction 32-7064, dated 17 September 2004, State protected species will be protected when practicable and the appropriate State authority will be contacted if conflicts arise. State may provide procedures for minimization of impacts and harm to species.	All	No	NA
5	Fish and Wildlife Protection and Conservation	CDFG Code Section 1600-1607 (except 1606) 14 CCR, Div. 1.5, Ch. 4, Subchapter 4, Sections 916, 916.2, Subchapter 5, Sections 936, 936.2, and Subchapter 6, Sections 956, 956.2	State	Declares the protection and conservation of fish and wildlife to be an important public interest. Section 1602 prohibits substantial diversion or obstruction of the natural flow of, or substantial change or use of any material from the bed, channel, or bank of, any river, stream, or lake, or deposition or disposal of debris, waste, or other material containing crumbled, flaked, or ground pavement where it may pass into any river, stream, or lake without prior notification and approval from CDFG. This section is a general statement of policy that does not impose a substantive requirement. Rather it imposes a reporting requirement when stream diversion, dredging, or waste disposal affecting fish and wildlife is to take place.	Relevant and appropriate	Remedial action must be protective and conserve fish and wildlife resources. As stated in AF Instruction 32-7064, dated 17 September 2004, State protected species will be protected when practicable and the appropriate State authority will be contacted if conflicts arise. State may provide procedures for minimization of impacts and harm to species.	All	No	NA
6	Wildlife Species/Habitats	CDFG Code Sections 2000, 2014, 3005, 3511, 3513, and 12000 et seq. 14 CCR, Div. 1, Subchapter 2, Section 250, Section 507; Subchapter 3, Section 650	State	Prohibits the taking of birds and mammals. This code section imposes a substantive, promulgated environmental protection requirement covering destruction of wildlife caused by unlawful discharges of pollutants to waters of the State in violation of Division 7 (Section 13000 et seq.) of the Water Code.	Relevant and appropriate	As stated in AF Instruction 32-7064, dated 17 September 2004, State protected species will be protected when practicable and the appropriate State authority will be contacted if conflicts arise. State may provide procedures for minimization of impacts and harm to species.	All	No	NA

Item No.	Requirement	Citation	Federal, State or Local Requirement	Description	ARAR Determination	Comments	Applicable Sites	Change Since ROD Finalized?	Change to Protectiveness
Location-specific ARARs (continued)									
7	Mammals and Reptiles Provisions	CDFG Code Sections 4700 and 5050 14 CCR, Div. 1, Subdivision 3, Ch. 3, Section 670	State	Prohibits the possession of mammals and reptiles that are identified as "fully protected."	Relevant and appropriate	Potentially applicable where the State law has a listing that is more stringent than the Federal and State Endangered Species Act or Migratory Bird Treaty Act. As stated in Air Force Instruction 32-7064, dated 17 September 2004, State protected species will be protected when practicable and the appropriate State authority will be contacted if conflicts arise. State may provide procedures for minimization of impacts and harm to species.	All	No	NA
8	Rare Native Plants	CDFG Code Sections 1900 et seq. and 2080 14 CCR, Div. 1, Subdivision 3, Ch. 6, Section 783	State	Contain provisions concerning native plant protection including: criteria for determining endangered plant species; designation of endangered plants; and other prohibitions.	Relevant and appropriate	As stated in AF Instruction 32-7064, dated 17 September 2004, State protected species will be protected when practicable and the appropriate State authority will be contacted if conflicts arise. State may provide procedures for minimization of impacts and harm to species.	All	No	NA
Action-specific ARARs									
9	Standards Applicable to Generators of Hazardous Waste	40 CFR Part 262 22 CCR, Div. 4.5, Ch. 12, Articles 1-4, Sections 66262.10-.47	Federal State	These regulations apply to generators of hazardous waste. Edwards AFB is a large quantity generator of hazardous waste (EPA ID CA1570024504) and already subject to these requirements. Establishes standards for generators of RCRA and [1]California hazardous wastes, including those for hazardous waste determination, accumulation, identification numbers, manifesting, pre-transport, and record keeping, and reporting requirements.	Applicable if soil cuttings, purge water, or spent carbon are hazardous waste.	Applicable to waste generated (soil cuttings, purge water from groundwater sampling, and spent carbon from onsite treatment of purge water) as part of OU6 groundwater remedies if these wastes are hazardous. Substantive requirements are potentially ARARs if excavated soils or treatment residuals exceed RCRA or [1]California hazardous waste thresholds. Hazardous remediation waste may be stored onsite in Corrective Action Temporary Units. These Corrective Action Temporary Units are not subject to the less than 90-day accumulation time requirement. Temporary units may operate for 1 year with an opportunity for a 1-year extension.	Soil cuttings, purge water, and spent carbon generated from groundwater monitoring of Sites N2, N3, and N7 plumes	No	NA

Item No.	Requirement	Citation	Federal, State or Local Requirement	Description	ARAR Determination	Comments	Applicable Sites	Change Since ROD Finalized?	Change to Protectiveness
Action-specific ARARs (continued)									
10	Underground Injection Control Program	40 CFR Parts 144, 146, 147, Sections 144.13(c), 144.82-.83, 144.89; Sections 146.5 and 146.10; Section 147.251	Federal	Protects groundwater from contamination by subsurface emplacement of fluids. According to Section 144.13(c), wells used to reinject contaminated groundwater that has been treated into the same formation from which it was drawn are not prohibited if such injection is approved by EPA, or a State, pursuant to provisions for cleanup of releases under CERCLA, 42 U.S.C. 9601–9657, or pursuant to requirements and provisions under RCRA, 42 U.S.C. 6901 through 6987. Wells for injection of treatment chemicals or treated groundwater into shallow wells are designated Class V wells according to Section 146.5. Section 144.82 prohibits the movement of fluid containing any contaminant into an underground source of drinking water if it would cause a violation of primary drinking water standards under 40 CFR Part 141, or other health-based standards, or may otherwise adversely affect the health of persons. Injection well closure must prohibit emplaced fluid movement. States and EPA Regions can establish more stringent requirements if needed to protect underground sources of drinking water. Section 144.83 specifies inventory requirements for the operation of the injection well. Section 144.89 contains well closure requirements. Section 146.10 contains well plugging and abandonment requirements. Section 147.251 states that EPA administers the UIC program in California for Class V wells.	Applicable	Substantive portions are applicable to the injection of sodium permanganate or other oxidizing chemicals in the Sites N2, N3, and N7 plumes. Reinjection of treated groundwater qualifies for the exemption in Section 144.13(c) for groundwater treatment systems.	N2, N3, and N7	No	NA
11	Statement of Policy with Respect to Maintaining High Quality of Waters in California (Non-degradation Policy)	SWRCB Resolution Number 68-16 (23 CCR Section 2900)	State	Resolution No. 68-16 (anti-degradation policy) has been incorporated into all Regional Board Basin Plans, including the Lahontan Water Board's Basin Plan. This resolution requires that the quality of waters of the State that is better than needed to protect all beneficial uses be maintained unless certain findings are made. Discharges to high quality waters must be treated using best practicable treatment or control necessary to prevent pollution or nuisance and to maintain the highest quality water. This resolution also requires cleanup to background quality or lowest concentrations technically and economically feasible to achieve. Beneficial uses, at minimum, must be protected.	Applicable	State Water Resources Control Board Resolution 68-16 is an ARAR for the injection or reinjection of sodium permanganate, any treatment chemicals, or any reagent into groundwater to treat contaminants.	N2, N3, and N7	No	NA
12	Sources of Drinking Water Policy	SWRCB Resolution No. 88-63; Porter-Cologne Water Quality Act (CWC Sections 13000, 13140, 13240) H&S Code Section 25356.1.5 (a)	State	Resolution 88-63 has been incorporated into all Regional Board Basin Plans, including the Lahontan Water Board's Basin Plan. This resolution designates all ground and surface waters of the State as drinking water except where the TDS is greater than 3,000 ppm, the well yield is less than 200 gpd from a single well, the water is a geothermal resource or in a waste water conveyance facility, or the water cannot reasonably be treated for domestic use using either best management practices or best economically achievable treatment practices.	Applicable	The AF agrees with the designation of the current and potential use of the groundwater for this OU as drinking/domestic use.	N2, N3, and N7 groundwater remedial action	No	NA

Item No.	Requirement	Citation	Federal, State or Local Requirement	Description	ARAR Determination	Comments	Applicable Sites	Change Since ROD Finalized?	Change to Protectiveness
Action-specific ARARs (continued)									
13	Definition of and Criteria for Identifying Hazardous Wastes	40 CFR 261.3 22 CCR, Div. 4.5, Ch. 11, Article 1, Sections 66261.2-.3; Articles 3, Sections 66262.24 -.33; Article 5, Sections 66261.100-.101	Federal State	Defines wastes that are subject to regulation as a RCRA or [1]California hazardous waste. Excavated contaminated soil, extracted groundwater, and spent treatment residuals (e.g., granular activated carbon) must be classified using AF knowledge of the timing and nature of the release as well as waste toxicity characteristic testing. If, after good faith effort, the AF determines that the contaminated soil or groundwater contains a listed RCRA or [1]California hazardous waste or fails the Federal or State toxicity characteristic tests, then the excavated soil or extracted groundwater is considered hazardous based on EPA's "contained-in" policy and must be managed as hazardous remediation waste. Contaminated soils or groundwater that are treated *in situ* are not subject to the identification or classification requirements.	Applicable	The definitions of hazardous waste in Article 1 and toxicity characteristic criteria (i.e., TTLC and STLC levels) in Section 66261.24 are applicable for the characterization of soil cuttings from well installation, as well as purge water and spent carbon from groundwater monitoring and onsite water treatment. The soil cuttings are not expected to be hazardous. Treated purge water that is discharged to the Base sanitary wastewater treatment facility will no longer be hazardous waste and will be subject to discharge limits based on the facility's discharge permit limits. Spent carbon will be tested prior to off-site disposal or regeneration.	Onsite purge water treatment at Sites N2, N3, and N7	No	NA
14	Hazardous Waste Land Disposal Restrictions	40 CFR Part 268 22 CCR, Div. 4.5, Ch. 18, Section 66268	Federal State	Identifies hazardous wastes that are restricted from land disposal without prior treatment to UTS. Hazardous remediation wastes that are managed off-site are subject to the LDR UTS specified in Section 66268 for wastewater (liquid) and non-wastewater (solid). Hazardous soils must be treated to 90% reduction in concentration capped at 10 times the UTS for principal hazardous constituents (90% capped at 10 x UTS). On-site treatment or disposal of hazardous remediation wastes are not strictly subject to the LDR treatment standards, but are subject to similar treatment standards specified in the Corrective Action Management Unit Amendment Rule codified in 40 CFR 264.550-.555 and 22 CCR 66264.550-.553.	Applicable	LDR applicable to off-site disposal of soil cuttings, treated groundwater, and spent carbon if these remediation wastes are RCRA or [1]California hazardous waste, as determined through toxicity characteristic testing using TCLP and TTLC/STLC.	Offsite disposal of hazardous remediation wastes from Sites N2, N3, and N7	No	NA
15	Land Use Controls	22 CCR, Div. 4.5, Ch. 39, Section 67391.1 Civil Code Section 1471, a & b	State	Requires that if a remedy will result in hazardous substances remaining on a property at levels not suitable for unrestricted use, the limitations or controls are clearly set forth and defined in the response action decision document, and that the decision document include an implementation and enforcement plan. In the event of a property transfer, requires the state to enter into restrictive land use covenants with land-owners and their successors under such circumstances, with exceptions for federal-to-federal property transfers.	Relevant and appropriate	Institutional controls, limiting exposure to contaminated groundwater, are required at OU6 until hazardous substance concentrations in groundwater are suitable for unrestricted use. Although it is not contemplated that property at OU6 will be transferred, in the event that such property is transferred, the AF and the State have agreed to follow the procedure laid out in Section 2.12.2.1 LUC of this ROD.	All portions of OU6 groundwater plumes with original sources at N2, N3, and N7 requiring institutional controls	No	NA

Notes:

[1]California hazardous waste (as used in this table) is the same as non-RCRA hazardous waste as defined in Section 66261.101 of CCR Title 22.

μg/L	=	micrograms per liter
AF	=	Air Force
AFB	=	Air Force Base
ARARs	=	Applicable or Relevant and Appropriate Requirements
Basin Plan	=	Water Quality Control Plan for Lahontan Region
CA	=	California
CCR	=	California Code of Regulations
CDFG	=	California Department of Fish and Game
CERCLA	=	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	=	Code of Federal Regulations
Ch.	=	Chapter
COC	=	contaminant of concern
CWC	=	California Water Code
Div.	=	Division
e.g.	=	*exempli gratia* (for example)
EPA	=	Environmental Protection Agency
et seq.	=	*et sequentes* (and the following)
gpd	=	gallons per day
H&S	=	health and safety
ID	=	identification
i.e.	=	*id est*, that is
LDR	=	land disposal restriction
MCL	=	Maximum Contaminant Level
MCLG	=	Maximum Contaminant Level Goal
NA	=	not applicable
NCP	=	National Contingency Plan
No.	=	number
OU	=	Operable Unit
OU6	=	Operable Unit 6
ppm	=	parts per million
RCRA	=	Resource Conservation and Recovery Act
ROD	=	Record of Decision document
RWQCB	=	Regional Water Quality Control Board
SDWA	=	Safe Drinking Water Act
STLC	=	soluble threshold limit concentration
SWRCB	=	State Water Resources Control Board
TCLP	=	toxic characteristic leaching procedure
TDS	=	total dissolved solid
TEFA	=	Technical and Economic Feasibility Analysis
TTLC	=	total threshold limit concentration
UIC	=	Underground Injection Control
U.S.C.	=	United States Code
UTS	=	universal treatment standard

APPENDIX E

SITE INSPECTION REPORT

Five-Year Review Site Inspection Checklist

Information may be completed by hand and attached to the Five-Year Review report as supporting documentation of site status. "N/A" refers to "not applicable."

I. SITE INFORMATION	
Site name: Operable Unit 6, NASA DFRC	**Date of inspection:** 8 and 9 March 2011
Location and Region: Edwards AFB, EPA Region IX	**EPA ID:** CA1570024504
Agency, office, or company leading the five-year review: 95ABW CEV and NASA DFRC SH&E	**Weather/temperature:** sunny/63˚F

Remedy Includes:

- Landfill cover/containment
- √ Access controls
- √ Institutional controls
- Groundwater pump and treatment
- Surface water collection and treatment
- Monitored natural attenuation
- Groundwater containment
- Vertical barrier walls
- √ Other: *in situ* chemical oxidation treatment using permanganate of high-concentration portions of chlorinated hydrocarbon plume, enhanced natural attenuation treatment of high-concentration portions of aromatic hydrocarbon plume, groundwater monitoring to demonstrate and document natural attenuation of low-concentration areas of groundwater plume.

Attachments: √ Inspection team roster attached √ Cost Summary attached √ Site photos attached

II. INTERVIEWS (Check all that apply)

1. **O&M site manager** Phil Saxton (Name) Field Supervisor (Title) 8 March 2011 (Date)
   Interviewed √ at site at office by phone Phone no. 661-810-0476
   Problems, suggestions; some well completions require repair (i.e., cracks in concrete of flush-mount well completions, some bolt holes in well covers need to be rethreaded). Brass Well ID tags should be affixed to monitoring wells.

2. **O&M staff** ______________________ (Name) ______________________ (Title) ____________ (Date)
   Interviewed at site at office by phone Phone no. ______________
   Problems, suggestions; Report attached ____
   ____

3. **Local regulatory authorities and response agencies** (i.e., State and Tribal offices, emergency response office, police department, office of public health or environmental health, zoning office, recorder of deeds, or other city and county offices, etc.) Fill in all that apply.

Agency CRWQCB, Lahontan Region
Contact Tim Post | Remedial Project Manager | 8 March 2011 | (760) 241-4942
(Name | Title | Date | Phone no.)
Problems; suggestions; Mr. Post participated in the site inspection. During the site inspection, Mr. Post noted that the Water Board considers any plume expansion a continual release to the waters of California. This was noted in regards to the expansion of the TCE plume in the Site N1 and Site N4 areas.

Agency USEPA Region IX
Contact Joseph Healy | Remedial Project Manager | 29 July 2011 | (415) 972-3269
(Name | Title | Date | Phone no.)
Problems; suggestions; Report attached.

Agency California DTSC
Contact Kevin Depies | Remedial Project Manager | 29 July 2011 | (916) 255-6547
(Name | Title | Date | Phone no.)
Problems; suggestions; Report attached.

Agency CRWQCB, Lahontan Region
Contact John Steude | Remedial Project Manager | 12 August 2011 | (530) 542-5571
(Name | Title | Date | Phone no.)
Problems; suggestions; Report attached.

4. **Other interviews** (optional) Report attached.

Additional interviews with onsite NASA Dryden staff, the Edwards AFB GIS manager, and the RA operation and maintenance manager are documented in Appendix F.

III. ON-SITE DOCUMENTS & RECORDS VERIFIED (Check all that apply)

1. **O&M Documents**

O&M manual	Readily available	Up to date	√N/A
As-built drawings	Readily available	Up to date	√N/A
Maintenance logs	Readily available	Up to date	√N/A

Remarks The remedial action utilizes mobile injection equipment and not the standard aboveground treatment system. A work plan and work plan addendum are readily available and up to date at the NASA SH&E office and at the remedial action contractor's field office.

2. **Site-Specific Health and Safety Plan** √Readily available √Up to date N/A

Contingency plan/emergency response plan	√Readily available	√Up to date	N/A

Remarks Copies of the site-specific health and safety plan are readily available and up to date at the NASA SH&E office and at the remedial action contractor's field office.

3. **O&M and OSHA Training Records** √Readily available √ Up to date N/A

Remarks OSHA training records are readily available and up to date at the remedial action contractor's field office.

4. **Permits and Service Agreements**

Air discharge permit	Readily available	Up to date	√N/A
Effluent discharge	Readily available	Up to date	√N/A
Waste disposal, POTW	Readily available	Up to date	√N/A
Other permits______________________	Readily available	Up to date	√N/A

Remarks NASA DFRC issues dig permits. Dig permits are available at the NASA DFRC SH&E office. Ms. Jennifer Martin (NASA DFRC contractor) inspected/reviewed dig permits issued during this five-year review period 8 to 22 August 2011.

5. **Gas Generation Records** Readily available Up to date √N/A

Remarks____

6. **Settlement Monument Records** Readily available Up to date √N/A

Remarks____

7. **Groundwater Monitoring Records** √Readily available √Up to date N/A

Remarks Groundwater monitoring records are included in the interim remedial action completion reports, copies of which are available and up to date at the NASA SH&E office and at the remedial action contractor's field office.

8. **Leachate Extraction Records** Readily available Up to date √N/A

Remarks____

9. **Discharge Compliance Records**

Air	Readily available	Up to date	√N/A
Water (effluent)	Readily available	Up to date	√N/A

Remarks____

10. **Daily Access/Security Logs** Readily available Up to date N/A

Remarks Site is within NASA DFRC secured area. Full badging is required. Logs are kept at the NASA Security office and not available for review.

IV. O&M COSTS

1. **O&M Organization**
State in-house   Contractor for State
PRP in-house   Contractor for PRP
Federal Facility in-house   √Contractor for Federal Facility

2. **O&M Cost Records**
Readily available   Up to date
√Funding mechanism/agreement in place
Original O&M cost estimate $1,994,000   √Breakdown attached

Total annual cost by year for review period if available

From (Date)	To (Date)	Total cost	
September 2006	September 2007	$110,000	√Breakdown attached
September 2007	September 2008	$219,000	√Breakdown attached
September 2008	September 2009	$61,000	√Breakdown attached
September 2009	September 2010	$249,000	√Breakdown attached
September 2010	September 2011	$91,000	√Breakdown attached

3. **Unanticipated or Unusually High O&M Costs During Review Period**
Describe costs and reasons: Actual costs differed significantly from the original costs developed in 2003 in the FS and as documented in the ROD, primarily due to a difference in the scheduling of field tasks. The total operational cost for 5 years is $730,000, which is 39 percent lower than estimated. The cost estimates were based on the assumptions that injection would be started in the first year (fiscal year [FY] 2007), though injection was not implemented until the second year (FY 2008). Estimates assumed that only monitoring would be performed during the second and fourth years (FY 2008 and FY 2010); both injection and monitoring were performed during those years. The persistence of permanganate may also result in the alteration of injection event scheduling. Within the five-year review period, well maintenance consisted of removing plant roots from several lakebed monitoring wells, installing several dedicated low-flow pumps, and repairs to well monuments. These activities were conducted in the fourth and fifth years (FY 2010 and FY 2011) with approximately $26,000 in incurred cost. Cost differences generally resulted from revisions to the remedial approach and schedule, not failures or shortcomings of the remedy.

V. ACCESS AND INSTITUTIONAL CONTROLS   √Applicable   N/A

A. Fencing

1. **Fencing damaged**   Location shown on site map   √Gates secured   N/A
Remarks No damage observed

B. Other Access Restrictions

1. **Signs and other security measures**   Location shown on site map   N/A
Remarks Motion detectors along fence line on lakebed side.

C. Institutional Controls (ICs)	
1.	**Implementation and enforcement** Site conditions imply ICs not properly implemented — Yes √No N/A Site conditions imply ICs not being fully enforced — Yes √ No N/A Type of monitoring (*e.g.*, self-reporting, drive by) site is secured and patrolled daily by NASA DFRC security. Frequency daily Responsible party/agency 95 ABW/CEVR Contact: Ai Duong (Name) — Remedial Project Manager (Title) — 24 February 2011 (Date) — 661-277-1474 (Phone no.) Reporting is up-to-date — √Yes No N/A Reports are verified by the lead agency — Yes No √N/A Specific requirements in deed or decision documents have been met — √Yes No N/A Violations have been reported — Yes No √N/A Other problems or suggestions: Clarification: Information presented above was obtained by review of Annual LUC Reports prepared by 95 ABW/CEVR and submitted to Mr. Joe Healy (USEPA Region IX, Lead Regulatory Agency). It is unknown if the reports are "verified" after submittal. The GIS was inspected by Mr. Albert Chang of TYBRIN Corporation (Air Force contractor) on 3 August 2011. The inspection was performed by accessing OU6 information by Web Map. The inspection verified that land use restrictions are included in the GIS via hyperlink to LUC ROD sections. Additionally, the GIS is up-to-date regarding the geographic control boundary (boundary based on June-July 2010 TCE and benzene results).
2.	**Adequacy** √ICs are adequate ICs are inadequate N/A Remarks____
D. General	
1.	**Vandalism/trespassing** Location shown on site map √No vandalism evident Remarks____
2.	**Land use changes on site** N/A Remarks During the site inspection at Site N3, Mr. Dan Morgan noted that Buildings 4886 and 4889 (and associated drum dispensing areas) had been removed, and drums were no longer stored at Building 4803. During the site inspection at Sites N1 and N4, Mr. Phil Saxton noted that in recent years less water appears to flow to the Northern Retention Pond (Site N1), while more water appears to flow to the Southern Retention Pond (Site N4). Mr. Dan Morgan explained that the change in outflow to the retention ponds is a result of a 2006 drainage realignment and internal process modifications to eliminate freshwater discharges to the storm drains.
3.	**Land use changes off site** √N/A Remarks____

VI. GENERAL SITE CONDITIONS				
A. Roads	√Applicable	N/A		
1.	**Roads damaged** Remarks______	Location shown on site map	√Roads adequate	N/A

B. Other Site Conditions
Remarks ______ ______ ______ ______ ______ ______

VII. LANDFILL COVERS Applicable √ N/A			
A. Landfill Surface			
1.	**Settlement** (Low spots) Areal extent______ Depth______ Remarks______ ______	Location shown on site map	Settlement not evident
2.	**Cracks** Lengths______ Widths______ Depths______ Remarks______ ______	Location shown on site map	Cracking not evident
3.	**Erosion** Areal extent______ Depth______ Remarks______ ______	Location shown on site map	Erosion not evident
4.	**Holes** Areal extent______ Depth______ Remarks______ ______	Location shown on site map	Holes not evident
5.	**Vegetative Cover** Grass Cover properly established No signs of stress Trees/Shrubs (indicate size and locations on a diagram) Remarks______ ______		
6.	**Alternative Cover (armored rock, concrete, etc.)** N/A Remarks______ ______		

7.	**Bulges**	Location shown on site map	Bulges not evident
	Areal extent______________ Height____________		
	Remarks____		
8.	**Wet Areas/Water Damage**	Wet areas/water damage not evident	
	Wet areas	Location shown on site map	Areal extent______________
	Ponding	Location shown on site map	Areal extent______________
	Seeps	Location shown on site map	Areal extent______________
	Soft subgrade	Location shown on site map	Areal extent______________
	Remarks____		
9.	**Slope Instability** Slides	Location shown on site map	No evidence of slope instability
	Areal extent______________		
	Remarks____		
B. Benches	Applicable	N/A	
	(Horizontally constructed mounds of earth placed across a steep landfill side slope to interrupt the slope in order to slow down the velocity of surface runoff and intercept and convey the runoff to a lined channel.)		
1.	**Flows Bypass Bench**	Location shown on site map	N/A or okay
	Remarks____		
2.	**Bench Breached**	Location shown on site map	N/A or okay
	Remarks____		
3.	**Bench Overtopped**	Location shown on site map	N/A or okay
	Remarks____		
C. Letdown Channels	Applicable	N/A	
	(Channel lined with erosion control mats, riprap, grout bags, or gabions that descend down the steep side slope of the cover and will allow the runoff water collected by the benches to move off of the landfill cover without creating erosion gullies.)		
1.	**Settlement**	Location shown on site map	No evidence of settlement
	Areal extent______________ Depth____________		
	Remarks____		
2.	**Material Degradation**	Location shown on site map	No evidence of degradation
	Material type_______________ Areal extent_____________		
	Remarks____		
3.	**Erosion**	Location shown on site map	No evidence of erosion
	Areal extent______________ Depth____________		
	Remarks____		

4. **Undercutting** Location shown on site map No evidence of undercutting
Areal extent______________ Depth____________
Remarks____
____

5. **Obstructions** Type_____________________ No obstructions
Location shown on site map Areal extent______________
Size____________
Remarks____
____

6. **Excessive Vegetative Growth** Type____________________
No evidence of excessive growth
Vegetation in channels does not obstruct flow
Location shown on site map Areal extent______________
Remarks____
____

D. Cover Penetrations Applicable N/A

1. **Gas Vents** Active Passive
Properly secured/locked Functioning Routinely sampled Good condition
Evidence of leakage at penetration Needs Maintenance
N/A
Remarks____
____

2. **Gas Monitoring Probes**
Properly secured/locked Functioning Routinely sampled Good condition
Evidence of leakage at penetration Needs Maintenance N/A
Remarks____
____

3. **Monitoring Wells** (within surface area of landfill)
Properly secured/locked Functioning Routinely sampled Good condition
Evidence of leakage at penetration Needs Maintenance N/A
Remarks____
____

4. **Leachate Extraction Wells**
Properly secured/locked Functioning Routinely sampled Good condition
Evidence of leakage at penetration Needs Maintenance N/A
Remarks____
____

5. **Settlement Monuments** Located Routinely surveyed N/A
Remarks____
____

E. Gas Collection and Treatment Applicable N/A
1. **Gas Treatment Facilities** Flaring Thermal destruction Collection for reuse Good condition Needs Maintenance Remarks____
2. **Gas Collection Wells, Manifolds and Piping** Good condition Needs Maintenance Remarks____
3. **Gas Monitoring Facilities** (*e.g.*, gas monitoring of adjacent homes or buildings) Good condition Needs Maintenance N/A Remarks____
F. Cover Drainage Layer Applicable N/A
1. **Outlet Pipes Inspected** Functioning N/A Remarks____
2. **Outlet Rock Inspected** Functioning N/A Remarks____
G. Detention/Sedimentation Ponds Applicable N/A
1. **Siltation** Areal extent______________ Depth____________ N/A Siltation not evident Remarks____
2. **Erosion** Areal extent______________ Depth____________ Erosion not evident Remarks____
3. **Outlet Works** Functioning N/A Remarks____
4. **Dam** Functioning N/A Remarks____

H. Retaining Walls Applicable N/A

1. **Deformations** Location shown on site map Deformation not evident
Horizontal displacement____________ Vertical displacement_______________
Rotational displacement____________
Remarks____
____

2. **Degradation** Location shown on site map Degradation not evident
Remarks____
____

I. Perimeter Ditches/Off-Site Discharge Applicable N/A

1. **Siltation** Location shown on site map Siltation not evident
Areal extent______________ Depth____________
Remarks____
____

2. **Vegetative Growth** Location shown on site map N/A
Vegetation does not impede flow
Areal extent______________ Type____________
Remarks____
____

3. **Erosion** Location shown on site map Erosion not evident
Areal extent______________ Depth____________
Remarks____
____

4. **Discharge Structure** Functioning N/A
Remarks____
____

VIII. VERTICAL BARRIER WALLS Applicable √N/A

1. **Settlement** Location shown on site map Settlement not evident
Areal extent______________ Depth____________
Remarks____
____

2. **Performance Monitoring** Type of monitoring__________________________
Performance not monitored
Frequency________________________________ Evidence of breaching
Head differential__________________________
Remarks____
____

IX. GROUNDWATER/SURFACE WATER REMEDIES Applicable √N/A
A. Groundwater Extraction Wells, Pumps, and Pipelines Applicable N/A
1. **Pumps, Wellhead Plumbing, and Electrical** Good condition All required wells properly operating Needs Maintenance N/A Remarks____ ____ ____
2. **Extraction System Pipelines, Valves, Valve Boxes, and Other Appurtenances** Good condition Needs Maintenance Remarks____ ____
3. **Spare Parts and Equipment** Readily available Good condition Requires upgrade Needs to be provided Remarks____ ____
B. Surface Water Collection Structures, Pumps, and Pipelines Applicable N/A
1. **Collection Structures, Pumps, and Electrical** Good condition Needs Maintenance Remarks____ ____
2. **Surface Water Collection System Pipelines, Valves, Valve Boxes, and Other Appurtenances** Good condition Needs Maintenance Remarks____ ____
3. **Spare Parts and Equipment** Readily available Good condition Requires upgrade Needs to be provided Remarks____ ____

C. Treatment System Applicable N/A
1. **Treatment Train** (Check components that apply) Metals removal Oil/water separation Bioremediation Air stripping Carbon adsorbers Filters____ Additive (*e.g.*, chelation agent, flocculent)____ Others____ Good condition Needs Maintenance Sampling ports properly marked and functional Sampling/maintenance log displayed and up to date Equipment properly identified Quantity of groundwater treated annually_________________________ Quantity of surface water treated annually_________________________ Remarks____
2. **Electrical Enclosures and Panels** (properly rated and functional) N/A Good condition Needs Maintenance Remarks____
3. **Tanks, Vaults, Storage Vessels** N/A Good condition Proper secondary containment Needs Maintenance Remarks____
4. **Discharge Structure and Appurtenances** N/A Good condition Needs Maintenance Remarks____
5. **Treatment Building(s)** N/A Good condition (esp. roof and doorways) Needs repair Chemicals and equipment properly stored Remarks____
6. **Monitoring Wells** (pump and treatment remedy) Properly secured/locked Functioning Routinely sampled Good condition All required wells located Needs Maintenance N/A Remarks____
D. Monitoring Data
1. Monitoring Data √Is routinely submitted on time √ Is of acceptable quality
2. Monitoring data suggests: Groundwater plume is effectively contained √Contaminant concentrations are declining

D. Monitored Natural Attenuation

1. **Monitoring Wells** (natural attenuation remedy)
√Properly secured/locked √Functioning √Routinely sampled √Good condition
√All required wells located √Needs Maintenance N/A
Remarks Some well completions require repair (i.e., cracks in concrete of flush-mount well completions, some bolt holes in well covers need to be rethreaded). Brass Well ID tags should be affixed to all routinely sampled monitoring wells.

X. OTHER REMEDIES

If there are remedies applied at the site which are not covered above, attach an inspection sheet describing the physical nature and condition of any facility associated with the remedy. An example would be soil vapor extraction.

XI. OVERALL OBSERVATIONS

A. Implementation of the Remedy

Describe issues and observations relating to whether the remedy is effective and functioning as designed. Begin with a brief statement of what the remedy is to accomplish (i.e., to contain contaminant plume, minimize infiltration and gas emission, etc.).
Remedy addressed chlorinated and aromatic hydrocarbon contamination in groundwater. Remedy includes land use controls (LUCs) to prevent current and future human exposure. Physical controls are consistent with the LUCs, and current subsurface activities comply with the permitting procedures established under the remedial action. The remedy includes *in situ* chemical oxidation (ISCO) treatment of hot spot chlorinated hydrocarbon (primarily trichloroethene [TCE]) areas using sodium permanganate as the reagent. TCE mass removal has been demonstrated at Sites N3 and N7. However, based upon estimates calculated for the entire plume from 2003 and 2010 data, the mass of TCE has increased by approximately 6 percent, due to the identification of a high concentration area at Site N4 and the benzene mass has increased by 954 percent. The increase in mass is not a result of an ongoing source, but a result of further delineation of the benzene plume. Remedy includes bioremediation of hot spot aromatic hydrocarbon (primarily benzene) area by deploying oxygen release compound filter socks in wells. To be implemented following ISCO treatment. Remedy includes monitoring low concentration plume areas to document and demonstrate natural attenuation and continual reduction in the overall size of the plume. Groundwater sampling of newly installed wells along the plume's leading edge indicate that the plume is larger than predicted.

B. Adequacy of O&M

Describe issues and observations related to the implementation and scope of O&M procedures. In particular, discuss their relationship to the current and long-term protectiveness of the remedy.
The remedy is functioning as intended under the assumptions presented in the Record of Decision (ROD); progress has been made toward treatment of the areas of high volatile organic compound (VOC) concentrations using ISCO. However, the area of low VOC concentrations is larger than originally assumed and may not be contained in the southern portion of Site N1 and in the Site N4 vicinity. There have been no changes in the physical conditions of the site that would affect the protectiveness of the remedy. Progress has been made toward meeting all ARARs cited in the ROD.

C.	**Early Indicators of Potential Remedy Problems**
	Describe issues and observations such as unexpected changes in the cost or scope of O&M or a high frequency of unscheduled repairs that suggest that the protectiveness of the remedy may be compromised in the future. Elevated TCE concentrations at Sites N1 and N4 are possible early indicators of plume expansion.
D.	**Opportunities for Optimization**
	Describe possible opportunities for optimization in monitoring tasks or the operation of the remedy. An opportunity for optimization includes groundwater modeling to predict plume configuration and aid in determining optimal injection and monitoring well locations and timing of injection events.

Inspection Team Roster

Site Inspection conducted 8 and 9 March 2011

Team Member	Title	Organization
Dan Morgan	Environmental Manager	NASA DFRC SH&E
Tim Post	Remedial Project Manager	California RWQCB, Lahontan Region
Todd Battey	Deputy Program Manager	AECOM (Remedial Action Contractor)
Kimberly Coleman	Project Manager	AECOM (Remedial Action Contractor)
Phil Saxton	O&M Site Manager	AECOM (Remedial Action Contractor)

GIS Inspection conducted 3 August 2011

Team Member	Title	Organization
Albert Chang	OU6 Technical Support	TYBRIN Corporation (Air Force Contractor)

Dig Permit Inspection/Review conducted 8 to 22 August 2011

Team Member	Title	Organization
Jennifer Martin	Senior Environmental Protection Specialist	MECx (NASA Contractor)

Cost Summary

Fiscal Year	Estimated Operational Costs[a]	Actual Operational Costs	Difference	Explanation of Difference Between Actual and Estimated Costs
2007	$434,000	$110,000	$324,000	Injection not implemented in FY 2007 (Year 1).
2008	$184,000	$219,000	-$35,000	Injection and monitoring performed.
2009	$188,000	$61,000	$127,000	Sampling effort was reduced with some funds reallocated to well installation (capital costs).
2010	$192,000	$249,000	-$57,000	Injection and monitoring performed.
2011	$196,000	$91,000	$105,000	Sampling effort was reduced with some funds reallocated to five-year review effort (performed in FY 2011 (Year 5) as opposed to FY 2012 (Year 6) as originally estimated).
Total	$1,194,000	$730,000	$464,000	

Notes:

The remedial action does not include traditional operation and maintenance tasks. Estimated and actual operational costs are associated with injection operations, monitoring, and site control activities.

Estimated and actual operational costs are rounded to the nearest $1,000.

[a] Estimated costs as presented in the Record of Decision (Earth Tech, 2006).

FY = fiscal year

Photos Documenting Site Conditions

Security fencing and signage for the NASA DFRC complex. Due to the mobile nature of the ISCO treatment systems, lack of a permanent treatment compound, and potential impact to mission-critical activities such as aircraft movement, permanent treatment-related signage and fencing are not used. RA activities occur within the NASA DFRC secured area or the secured area maintained by Edwards AFB flightline management.

Site N3 area. Building 4889 was removed during the review period. The yellow bollards in the foreground indicate the former building footprint.

Example flush-mount completion monitoring well with brass ID tag. Many of the monitoring/injection wells at Sites N2, N3, and N7 are installed flush mount in aircraft ramps and taxiways.

APPENDIX F

INTERVIEW REPORT

INTERVIEW DOCUMENTATION FORM

The following is a list of individual interviewed for this five-year review. See the attached contact record(s) for a detailed summary of the interviews.

Name	Title/Position	Organization	Date
Mark Morgan	Code F (Facilities)	Tybrin Corporation	12 May 2011
Lori Davey	Code CF	NASA DFRC	12 May 2011
Pedro Arevalo	Code F (Facilities)	TYBRIN Corporation	12 May 2011
Kevin Depies	Remedial Project Manager	California DTSC	29 July 2011
Joesph Healy	Remedial Project Manager	USEPA Region IX	29 July 2011
Dan Morgan	Environmental Manager	NASA DFRC	4 August 2011
Stephen Watts	GIS Manager	95 ABW/CEV	4 August 2011
John Steude	Remedial Project Manager	CRWQCB, Lahontan Region	12 August 2011
Phil Saxton	RA Operation and Maintenance Site Manager	AECOM	12 August 2011

INTERVIEW RECORD

Site Name: Operable Unit 6, NASA DFRC	**EPA ID No.:** CA1570024504	
Subject: Five-Year Review	**Time:** 1330	**Date:** 12 May 2011
Type: √ Telephone Visit Other **Location of Visit:** not applicable	Incoming √ Outgoing	

Contact Made By:

Name: Kimberly Coleman	**Title:** Operable Unit Manager	**Organization:** AECOM (Air Force Contractor)

Individual Contacted:

Name: Mark Morgan	**Title:** Facilities (Code F)	**Organization:** Tybrin Corporation
Telephone No: 661-276-3916 **E-Mail Address:** mark.e.morgan@nasa.gov	**Street Address:** DFRC **City, State, Zip:** Edwards AFB, CA 93523-0273	

Summary Of Conversation

Mr. Mark Morgan supports the Facilities (Code F) organization at NASA DFRC. Mr. Morgan stated that he is aware of the remedial action being implemented at NASA DFRC, but did not have an opinion or impression of the project. He is not aware of any events, incidents, or activities at the site such as vandalism or trespassing. He noted that NASA DFRC is a fenced and fully secured facility within an air force base. As part of Code F, Mr. Morgan oversees the digging permit process, which is triggered when more than 6 inches of surface material is disturbed during construction projects. As part of the digging permit process, the proposed digging location is compared to the groundwater plume location and locations of monitoring wells and required PPE is specified.

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INTERVIEW RECORD

Site Name: Operable Unit 6, NASA DFRC	**EPA ID No.:** CA1570024504	
Subject: Five-Year Review	**Time:** 1345	**Date:** 12 May 2011
Type: √ Telephone Visit Other **Location of Visit:** not applicable	Incoming √ Outgoing	

Contact Made By:

Name: Kimberly Coleman	**Title:** Operable Unit Manager	**Organization:** AECOM (Air Force Contractor)

Individual Contacted:

Name: Lori Davey	**Title:** Code CF	**Organization:** NASA Dryden
Telephone No: 661-276-2772 **E-Mail Address:** lori.c.davey@nasa.gov	**Street Address:** DFRC **City, State, Zip:** Edwards AFB, CA 93523-0273	

Summary Of Conversation

Ms. Davey supports the Code CF organization at NASA DFRC and is a financial accountant familiar with the remedial action. She participates in annual audits to assess NASA's liabilities and compares policies and procedures with environmental laws. Ms. Davey had no questions or concerns regarding the project.

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INTERVIEW RECORD

Site Name: Operable Unit 6, NASA DFRC	**EPA ID No.:** CA1570024504	
Subject: Five-Year Review	**Time:** 1600	**Date:** 12 May 2011
Type: √ Telephone Visit Other **Location of Visit:** not applicable	Incoming √ Outgoing	

Contact Made By:

Name: Kimberly Coleman	**Title:** Operable Unit Manager	**Organization:** AECOM (Air Force Contractor)

Individual Contacted:

Name: Pedro Arevalo	**Title:** Facilities (Code F)	**Organization:** Tybrin Corporation
Telephone No: 661-276-6028 **E-Mail Address:** pedro.j.arevalo@nasa.gov	**Street Address:** DFRC **City, State, Zip:** Edwards AFB, CA 93523-0273	

Summary Of Conversation

Mr. Pedro Arevalo supports the Facilities (Code F) organization at NASA DFRC. Mr. Arevalo stated that he had no questions or concerns regarding the project. He is not aware of any security incidents regarding vandalism or trespassing. As part of Code F, Mr. Arevalo oversees the digging permit process, which is triggered when more than 6 inches of surface material is disturbed during construction projects. Mr. Arevalo noted that as part of the digging permit process, the NASA DFRC Environmental Manager, Mr. Dan Morgan compares the proposed digging location to the plume location. Mr. Arevalo noted that for safety reasons, NASA does not allow digging within 7 days of a shuttle landing.

Page 1 of 1

INTERVIEW RECORD

Site Name: Operable Unit 6, NASA DFRC	**EPA ID No.:** CA1570024504	
Subject: Five-Year Review	**Time:** 1134	**Date:** 29 July 2011
Type: √ Telephone Visit √ Other(email response) **Location of Visit:** not applicable	√ Incoming Outgoing	

Contact Made By:

Name: Kimberly Coleman	**Title:** Operable Unit Manager	**Organization:** AECOM (Air Force Contractor)

Individual Contacted:

Name: Kevin Depies	**Title:** Remedial Project Manager	**Organization:** California Department of Toxic Substances Control

Telephone No: 916-255-6547 **E-Mail Address:** kdepies@dtsc.ca.gov	**Street Address:** 8800 Cal Center Drive **City, State, Zip:** Sacramento, CA 95826-3200

Summary Of Conversation

Mr. Depies provided the following information by phone at 1134 on 29 July 2011:
Years associated with project: 2 years

Mr. Depies provided the following information by email (dated 29 July 2011):

1. Do you have access to information on the remedies in place at OU6; and do you access that information (e.g., at the Edwards AFB Website, Information Repository, Administrative Record File, or at Restoration Advisory Board [RAB] meetings)?

Response: *Yes. The Air Force has generally made access to information fairly easy, but I am very concerned with the Air Force shutting down the Edwards environmental program webpage (BX) which we use to obtain and exchange critical information. Not having this webpage complicates our work and results in needless wasted time. The webpage has been down for at least a few months now and should be either reinstated or a new webpage established as soon as possible.*

2. Are you aware of any changes in site conditions that you feel may impact the protectiveness of the remedies implemented at OU6?

Response: *Yes, I recently became aware that the downgradient extent of the plume is still undefined and extends further downgradient than originally projected by the Air Force. I think defining the plume extent should be a high priority.*

3. To the best of your knowledge, have there been any violations of the land use controls at OU6; with the exception of previously approved activities (e.g., those approved under the ABW/CEVR process); that required a response from your office? If so, please provide details of the events and results of the responses.

Summary Of Conversation (cont'd)

Response: *I'm not aware of any LUC violations and the draft Five-Year Review notes that there were none. We are relying on the Air Force and NASA to enforce the LUCs and report violations to the regulatory agencies.*

4. Are you aware of any community concerns regarding the protectiveness of the remedies at ERP OU6? If so, please provide details.

Response: *We routinely solicit community input in RAB and other Edwards public meetings and am not aware of any concerns on the OU 6 remedy protectiveness.*

5. Do you have any comments, suggestions, or recommendation regarding management of the remedies in place at

OU6? If so, please provide details.

Response: *Yes, as I mentioned before, we need to define the OU 6 groundwater plume as soon as possible and adjust the remedy to ensure cleanup of the entire plume.*

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INTERVIEW RECORD

Site Name: Operable Unit 6, NASA DFRC	**EPA ID No.:** CA1570024504	
Subject: Five-Year Review	**Time:** 1532	**Date:** 29 July 2011
Type: Telephone Visit √ Other(email response) **Location of Visit:** not applicable	√ Incoming Outgoing	

Contact Made By:

Name: Kimberly Coleman	**Title:** Operable Unit Manager	**Organization:** AECOM (Air Force Contractor)

Individual Contacted:

Name: Joseph Healy	**Title:** Remedial Project Manager	**Organization:** USEPA Region IX
Telephone No: 415-972-3269 **E-Mail Address:** healyjoseph@epa.gov	**Street Address:** Mail Stop (SFD-8-1), 75 Hawthorne St reet **City, State, Zip:** San Francisco CA 94105	

Summary Of Conversation

Mr. Healy provided the following information by email at 1030 on 3 August 2011:
Years associated with project: *Almost five years. I began in October 2006.*

Mr. Healy provided the following information by email at 1532 on 29 July 2011:

1. Do you have access to information on the remedies in place at OU6; and do you access that information (e.g., at the Edwards AFB Website, Information Repository, Administrative Record File, or at Restoration Advisory Board [RAB] meetings)?

Response: *For land use controls, I have been shown some examples of the GIS-based database recording of LUC compliance boundaries and requirements that is maintained at Edwards AFB. I assume I could arrange a spot check for the OU6 buildings upon request during one of my many visits to Edwards; however, I have not yet done so. My understanding is that that information is not publically available on a web site and that I do not have access via a controlled government website. I believe such an option might come up under some new discussions as the Air Force considers some changes to their GIS-based system.*

2. Are you aware of any changes in site conditions that you feel may impact the protectiveness of the remedies implemented at OU6?

Response: *Yes. I am aware that the Air Force intends to refine their conceptual site model based on new characterization data and evaluations concerning the extent of the groundwater contamination hot spots and leading edges of the plume. The exact locations of higher concentrations of groundwater contaminants may affect the indoor air exposure pathway for workers within occupied buildings. However, I understand that the Air Force will re-evaluate the current status of buildings in relation to new characterization data, new toxicity data, and newer risk evaluation methodologies that have become available since the 2006 ROD was signed. Although I would be surprised if the newer data and methodologies resulted in the need to change or modify the remedy, I feel this should be verified and more exact LUC compliance boundaries should be presented if appropriate. I*

Summary Of Conversation (cont'd)

believe the Air Force is looking into these matters right now, using existing data to begin planning the re-evaluation.

3. To the best of your knowledge, have there been any violations of the land use controls at OU6; with the exception of previously approved activities (e.g., those approved under the ABW/CEVR process); that required a response from your office? If so, please provide details of the events and results of the responses.

Response: *I am fairly certain there have been no violations.*

4. Are you aware of any community concerns regarding the protectiveness of the remedies at ERP OU6? If so, please provide details.

Response: *I am not aware of any community concerns about the OU 6 remedy.*

5. Do you have any comments, suggestions, or recommendation regarding management of the remedies in place at OU6? If so, please provide details.

Response*: I have requested that the Air Force improve their interim reporting process by making it comparable to other Operable Units at Edwards AFB, which issue annual reports on LUC management and periodic progress reports from groundwater monitoring. Because the groundwater plume might change in size or concentration over time or in response to the chemical treatment (injections), I would like to see some interim depictions of the contamination contours in groundwater relative to the building footprints and relative to the current depictions of the LUC compliance boundaries maintained in the Edwards AFB GIS system. I think this would be easily supported with periodic progress reports that show the progress of groundwater treatment. I believe the Air Force is planning to provide a schedule for such reports as part of their update of the Remedial Action Work Plan.*

I strongly encourage the Air Force to consider improvements to their future Five Year Reviews for this operable unit and the other operable units scheduled over the next several years. A key improvement would be the submission of a draft and a draft final Five Year Review Report to the regulators for comment. Although this is not required by the Edwards AFB Federal Facilities Agreement, it is successfully practiced at many other federal facilities for five year reviews.

INTERVIEW RECORD

Site Name: Operable Unit 6, NASA DFRC	**EPA ID No.:** CA1570024504	
Subject: Five-Year Review	**Time:** 1511	**Date:** 4 August 2011
Type: Telephone Visit √ Other(email response) **Location of Visit:** not applicable	√ Incoming Outgoing	

Contact Made By:

Name: Kimberly Coleman	**Title:** Operable Unit Manager	**Organization:** AECOM (Air Force Contractor)

Individual Contacted:

Name: Dan Morgan	**Title:** SH&E Environmental Manager	**Organization:** NASA DFRC
Telephone No: 661-276-3976 **E-Mail Address:** dan.morgan@nasa.gov	**Street Address:** NASA DFRC, MS 4850 **City, State, Zip:** Edwards, CA 93523	

Summary Of Conversation

Mr. Morgan has been associated with the project for over 5 years.

Mr. Morgan provided the following information by email at 1511 on 4 August 2011:

1. Do you have access to information on the remedies in place at OU6; and do you access that information (e.g., at the Edwards AFB Website, Information Repository, Administrative Record File, or at Restoration Advisory Board [RAB] meetings)?

Response: *Yes, as NASA Remedial Project Manager, I have full access to remedy information.*

2. Are you aware of any changes in site conditions that you feel may impact the protectiveness of the remedies implemented at OU6?

Response: *Although there is always the chance that site conditions may change, the only change we now know of – the discovery that the extreme easterly (lakebed) edge of the plume is undefined, most likely has not negatively impacted protectiveness. There are no buildings over the newly discovered plume area and the Center has no personnel that work over the lakebed. It is possible that the leading edge was never adequately defined and it seems to me, based on the low concentrations our new wells found, that we will likely find that the actual boundary is nearby. At any rate, if we find that there is movement, the movement is away from the Center so personnel are not being affected. In addition, the low concentrations indicate that there is no significant loss of COCs and that any movement is quite slow, decreasing the probability of the plume reaching the deeper aquifer. Further investigation will define these issues but at this point there is no indication that protectiveness has been reduced. I have no reason to suspect that protectiveness has changed during the 5-year review period.*

3. To the best of your knowledge, have there been any violations of the land use controls at OU6; with the exception of previously approved activities (e.g., those approved under the ABW/CEVR process); that required a response from your office? If so, please provide details of the events and results of the responses.

Summary Of Conversation (cont'd)

Response: *I know of no violations – digging permits are obtained for all excavations at the Center and they are all reviewed by the environmental office. Any digging over the plume that would approach the water table would be coordinated through our Industrial Hygienist for development of a Health and Safety Plan related to potential community/worker inhalation hazards or contact with contaminated groundwater. To date, all digging over the controlled area has been minor and has not triggered the need for a H&S Plan.*

4. Are you aware of any community concerns regarding the protectiveness of the remedies at ERP OU6? If so, please provide details.

Response: *No, although I occasionally get questions about the ongoing remedial action, I have never encountered any concerns.*

5. Do you have any comments, suggestions, or recommendation regarding management of the remedies in place at OU6? If so, please provide details.

Response: *No.*

INTERVIEW RECORD

Site Name: Operable Unit 6, NASA DFRC	**EPA ID No.:** CA1570024504	
Subject: Five-Year Review	**Time:** 1530	**Date:** 4 August 2011
Type: √ Telephone Visit Other(email response) **Location of Visit:** not applicable	Incoming √ Outgoing	

Contact Made By:

Name: Kimberly Coleman	**Title:** Operable Unit Manager	**Organization:** AECOM (Air Force Contractor)

Individual Contacted:

Name: Stephen Watts	**Title:** GIS Manager	**Organization:** 95 ABW/CEV
Telephone No: 661-277-1443 **E-Mail Address:** stephen.watts@edwards.af.mil	**Street Address:** 5 E. Popson Avenue, Bldg 2650A **City, State, Zip:** Edwards AFB, CA 93524-8060	

Summary Of Conversation

Dr. Watts provided the following information by phone at 1530 on 4 August 2011:

Dr. Watts' responses are paraphrased.

Years associated with project: *10 years.*

1. Do you have access to information on the remedies in place at OU6; and do you access that information (e.g., at the Edwards AFB Website, Information Repository, Administrative Record File, or at Restoration Advisory Board [RAB] meetings)?

Response: *Yes, though I am not the OU6 program manager. I have access to information through the administrative record. I make use of the information periodically.*

2. Are you aware of any changes in site conditions that you feel may impact the protectiveness of the remedies implemented at OU6?

Response: *I am not aware of any changes in site conditions that may impact the protectiveness of the remedies implemented at OU6. I am aware of the location of Site 25 contamination in relation to the OU6 plume.*

3. To the best of your knowledge, have there been any violations of the land use controls at OU6; with the exception of previously approved activities (e.g., those approved under the ABW/CEVR process); that required a response from your office? If so, please provide details of the events and results of the responses.

Response: *No, but I wouldn't know as dig permits (within the NASA lease boundary) are managed by NASA.*

4. Are you aware of any community concerns regarding the protectiveness of the remedies at ERP OU6? If so, please provide details.

Summary Of Conversation (cont'd)

Response: *No, I participate in the RAB meetings and know that the RAB members have been briefed (on OU6 activities) and I am not aware of any concerns.*

5. Do you have any comments, suggestions, or recommendation regarding management of the remedies in place at OU6? If so, please provide details.

Response*: No.*

INTERVIEW RECORD

Site Name: Operable Unit 6, NASA DFRC	**EPA ID No.:** CA1570024504	
Subject: Five-Year Review	**Time:** 1210	**Date:** 12 August 2011
Type: Telephone Visit √ Other(email response) **Location of Visit:** not applicable	√ Incoming Outgoing	

Contact Made By:

Name: Kimberly Coleman	**Title:** Operable Unit Manager	**Organization:** AECOM (Air Force Contractor)

Individual Contacted:

Name: John Steude	**Title:** Remedial Project Manager	**Organization:** CRWQCB, Lahontan Region
Telephone No: 530-542-5571 **E-Mail Address:** jsteude@waterboards.ca.gov	**Street Address:** 2501 Lake Tahoe Blvd. **City, State, Zip:** South Lake Tahoe, CA 96150	

Summary Of Conversation

Mr. Steude provided the following information by email at 1210 on 12 August 2011:

Years associated with project: *I have been associated with the project approximately one year.*

1. Do you have access to information on the remedies in place at OU6; and do you access that information (e.g., at the Edwards AFB Website, Information Repository, Administrative Record File, or at Restoration Advisory Board [RAB] meetings)?

Response: *I have access to information and primarily rely on documents in Lahontan Water Board files.*

2. Are you aware of any changes in site conditions that you feel may impact the protectiveness of the remedies implemented at OU6?

Response: *I am not aware of any confirmed changes in site conditions that I feel may impact the protectiveness of the remedies implemented at OU 6. There have been some unexpected increases in contaminant concentrations in monitoring wells. However, more data are needed to determine if the increases are anomalous or early signs of a trend. This issue is being appropriately addressed in the CERCLA process.*

3. To the best of your knowledge, have there been any violations of the land use controls at OU6; with the exception of previously approved activities (e.g., those approved under the ABW/CEVR process); that required a response from your office? If so, please provide details of the events and results of the responses.

Response: *I am not aware of any violations of land use controls.*

4. Are you aware of any community concerns regarding the protectiveness of the remedies at ERP OU6? If so, please provide details.

Summary Of Conversation (cont'd)

Response: *I am not aware of any community concerns regarding the protectiveness of the remedies at OU 6.*

5. Do you have any comments, suggestions, or recommendation regarding management of the remedies in place at OU6? If so, please provide details.

Response: *I provided regulatory comments on the OU 6 Five-Year Review. I do not currently have any additional comments, suggestions, or recommendations regarding management of remedies in place at OU 6.*

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INTERVIEW RECORD

Site Name: Operable Unit 6, NASA DFRC	**EPA ID No.:** CA1570024504	
Subject: Five-Year Review	**Time:** 1626	**Date:** 12 August 2011
Type: Telephone Visit √ Other(email response) **Location of Visit:** not applicable	√ Incoming Outgoing	

Contact Made By:

Name: Kimberly Coleman	**Title:** Operable Unit Manager	**Organization:** AECOM (Air Force Contractor)

Individual Contacted:

Name: Phil Saxton	**Title:** RA Operation and Maintenance Site Manager	**Organization:** AECOM
Telephone No: 661-810-0476 **E-Mail Address:** phil.saxton@aecom.com	**Street Address:** 100 Contractor Road **City, State, Zip:** Edwards, CA 93523	

Summary Of Conversation

Mr. Saxton has been associated with the project for 14 years.

Mr. Saxton provided the following information by email at 1626 on 12 August 2011:

1. Do you have access to information on the remedies in place at OU6; and do you access that information (e.g., at the Edwards AFB Website, Information Repository, Administrative Record File, or at Restoration Advisory Board [RAB] meetings)?

Response: *Yes I have access to information on the on-going and proposed remediation remedies for OU6. Documents are reviewed at Edwards AFB.*

2. Are you aware of any changes in site conditions that you feel may impact the protectiveness of the remedies implemented at OU6?

Response: *No.*

3. To the best of your knowledge, have there been any violations of the land use controls at OU6; with the exception of previously approved activities (e.g., those approved under the ABW/CEVR process); that required a response from your office? If so, please provide details of the events and results of the responses.

Response: *There have been none to the best of my knowledge.*

4. Are you aware of any community concerns regarding the protectiveness of the remedies at ERP OU6? If so, please provide details.

Response: *Not aware of any community concerns. I am frequently asked by NASA employees about what contaminants are in the groundwater and how remedies being implemented work. But generally all seem quite*

Summary Of Conversation (cont'd)

happy with the efforts being taken to protect their health & safety.

5. Do you have any comments, suggestions, or recommendation regarding management of the remedies in place at OU6? If so, please provide details.

Response*: None.*

APPENDIX G

CURRENT AND HISTORICAL SOIL AND GROUNDWATER RISKS AND HAZARDS

TABLE G-1. CURRENT AND HISTORICAL SOIL AND GROUNDWATER RISKS AND HAZARDS
OPERABLE UNIT 6

		Residential				Industrial			
Site	Exposure Medium	Cancer Risk 2000 PRGs[a]	Cancer Risk 2011 RSLs[b]	Hazard Index 2000 PRGs[c]	Hazard Index 2011 RSLs[d]	Cancer Risk 2000 PRGs[a]	Cancer Risk 2011 RSLs[b]	Hazard Index 2000 PRGs[c]	Hazard Index 2011 RSLs[d]
N1	Soil	9.10E-05	2.10E-04	4.49	2.9	1.80E-05	3.50E-05	1.00	0.23
	Groundwater	1.13E-02	1.17E-02	56.8	32.1	---	---	---	---
N2	Soil	1.16E-04	4.40E-04	857	855	2.29E-05	2.35E-05	60.0	84.8
	Groundwater	2.73E-03	3.00E-03	87.4	78.0	---	---	---	---
N3	Soil	1.38E-04	5.27E-04	874	873	2.76E-05	3.78E-05	61.4	85.9
	Groundwater	6.28E-01	1.18	23,537	774	---	---	---	---
N4	Soil	1.48E-05	4.85E-05	3.03	2.75	3.15E-06	4.30E-06	0.89	0.23
	Groundwater	1.03E-02	1.01E-02	26.5	18.0	---	---	---	---
N7	Soil	2.05E-04	8.00E-04	0.76	0.67	4.16E-05	5.71E-05	0.06	0.07
	Groundwater	1.21-2	1.21E-02	96.9	95.7	---	---	---	---
N14	Soil	5.63E-09	4.55E-09	0.15	0.15	2.44E-09	1.28E-09	0.006	0.001
	Groundwater	---	---	---	---	---	---	---	---

Notes:

[a] Total cancer risk based on 2000 PRGs (USEPA, 2000)
[b] Total cancer risk based on 2011 RSLs (USEPA, 2011)
[c] Hazard index based on 2000 PRGs (USEPA, 2000)
[d] Hazard index based on 2011 RSLs (USEPA, 2011)
PRG = preliminary remediation goal
RSL = regional screening level
USEPA = United States Environmental Protection Agency

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