CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LAHONTAN REGION

MEETING OF JULY 14, 2010
VICTORVILLE, CALIFORNIA

ITEM: 6

SUBJECT: **RESOLUTION AUTHORIZING THE EXECUTIVE OFFICER TO SIGN THE RECORD OF DECISION FOR OPERABLE UNIT 4, ARROYOS AREA, EDWARDS AIR FORCE BASE, KERN COUNTY**

CHRONOLOGY: This is a new item. On August 30, 2007, the Water Board considered a separate remedial action at Edwards Air Force Base that included a containment zone as part of the action.

ISSUE: Should the Water Board concur with the remedial action proposed by the Air Force that includes a groundwater Containment Zone, and authorize the Executive Officer to sign the Record of Decision? The Board is asked to evaluate whether the proposed action complies with State requirements based on information presented with this item.

DISCUSSION: Edwards Air Force Base (EAFB) has submitted a Draft Final Record of Decision (ROD) for a proposed remedial action at Operable Unit 4, the Arroyos Area. The proposed remedy includes a Containment Zone of 12.3 square miles for solvent contaminants in groundwater. This Containment Zone encompasses the predicted future maximum extent of the solvent plume. A Containment Zone is appropriate because of the technical impracticability of cleaning up groundwater.

Groundwater at the Arroyos Area contains a large mass of dissolved phase chlorinated solvents, primarily trichloroethylene (TCE) and perchloroethylene (PCE). The high concentrations of dissolved phase chlorinated solvents (>7,000 µg/L) detected indicate the likelihood of pure solvents, which are heavier than water. These pure (separate phase) solvents will continue to act as a contaminant source for hundreds or possibly thousands of years.

Contaminated groundwater is encountered in fractured granitic bedrock. It is currently infeasible to remediate the groundwater through known remedial technologies. This conclusion is based on pilot studies and attempts to install treatment systems in the fractured bedrock; and because of the great depths required to intercept the contaminants.

Under the proposal, the contaminant plume will continue to expand until steady-state conditions are reached while natural attenuation processes (primarily dilution and dispersion) reduce concentrations to non-detectable at the leading edge of the plume. The Air Force proposes to contain the groundwater plume within the proposed Containment Zone which is slightly larger than the predicted maximum extent of the contaminant plume, when the contaminants reach the alluvial aquifer several thousand feet downgradient from the source areas. The Air Force has requested a Technical Impracticability

Waiver from USEPA which would remove the requirement to attain cleanup levels within the Containment Zone. As part of the proposed remedy, management measures including land use controls and groundwater monitoring must be implemented to prevent human exposure to polluted groundwater and vapors, and to track plume movement over time. These measures will minimize the health risks to satisfy regulatory requirements.

The Air Force will monitor the plume and compare the results with modeled predictions. If the results show that contaminants at any concentration above the background (non-detectable for solvents) are predicted to move beyond the Containment Zone boundary, the Air Force will take the following steps; 1) conduct a Technical and Economic Feasibility Analysis (TEFA) as required by Resolution 92-49 (which includes a groundwater degradation analysis to satisfy Resolution 68-16), evaluating whether it is appropriate for contaminants to migrate beyond the boundary at concentrations greater than background but not to exceed water quality objectives and; 2) implement any measures necessary (including active remediation) to contain contaminants within the Containment Zone boundary at the concentrations determined by the TEFA.

The Air Force does not accept that California State requirements such as the Basin Plan's Water Quality Objectives for secondary drinking water standards, or State Board Resolutions 68-16 and 92-49 are requirements for this remedial action from a legal perspective. However, the Air Force has complied with these requirements from a technical perspective in the proposed action.

The ROD includes "agree-to-disagree" language that preserves each party's legal rights and allows the State to take further action if, in the future, the State finds that the remedy does not comply with California State requirements. Water Board staff has evaluated the proposed remedial action and finds that it complies with the State's groundwater cleanup requirements. It is currently not feasible to cleanup the solvent containments at this site. The proposed remedy provides the most feasible, cost effective method to manage contaminants in groundwater at the site and is appropriate in this case.

The unique aspect of this remedy is that it would result in a long-term (hundreds of years) Containment Zone over a very large area. This will be the second Containment Zone established in Region 6. The Water Board should note that EAFB anticipates, in the future, proposing possibly an additional Containment Zone of a similar size and duration in the Northeast Air Force Research Laboratory area.

RECOMMENDATION: Adoption of Resolution as proposed.

Enclosures:

1. Proposed Resolution
2. Staff Report

ENCLOSURE 1

06-0003

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LAHONTAN REGION

RESOLUTION NO. R6V-2010-(PROPOSED)

AUTHORIZING THE EXECUTIVE OFFICER TO SIGN
THE RECORD OF DECISION
FOR OPERABLE UNIT 4, ARROYOS AREA,
EDWARDS AIR FORCE BASE

Kern County

WHEREAS, the California Regional Water Quality Control Board, Lahontan Region, (Water Board) finds:

1. In May 2010, the United States Air Force submitted a Draft Record of Decision (ROD) for Operable Unit (OU) 4, Air Force Research Laboratory, Arroyos Area at Edwards Air Force Base. The major components of the selected remedy are: a technical impracticability waiver for achieving groundwater cleanup levels within a containment zone, natural attenuation; land use controls; contaminant monitoring, and continued groundwater monitoring and calibration of a computer groundwater model to evaluate contaminant transport.

2. The Air Force and Water Board "agree-to-disagree" over whether certain State requirements are Applicable or Relevant and Appropriate Requirements for purposes of the remedial action.

3. The remedy however, complies with State law, plans, and policies and is protective of water quality.

THEREFORE BE IT RESOLVED:

That the Lahontan Water Board authorizes the Executive Officer to:

1. Concur with proposed actions as documented in the OU 4 Arroyos Area Draft ROD; and

2. Sign the Final ROD when it is submitted provided there are no significant changes to the intent of the ROD from that described in the July 2010 Water Board Staff Report.

I Harold J. Singer, Executive Officer, do herby certify that the foregoing is a full, true, and correct copy of a Resolution adopted by the California Regional Water Control Board, Lahontan Region, on July 14, 2010.

HAROLD J. SINGER
EXECUTIVE OFFICER

ENCLOSURE 2

06-0005

STAFF REPORT

RECORD OF DECISION

OPERABLE UNIT 4/9

AIR FORCE RESEARCH LABORATORY – ARROYOS AREA

at

EDWARDS AIR FORCE BASE

July 2010

California Regional Water Quality Control Board, Lahontan Region
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STAFF REPORT

Record of Decision

Operable Unit 4/9

Air Force Research Laboratory – Arroyos Area

Edwards Air Force Base

July 14, 2010

1. Executive Summary

This report provides supporting information for a staff recommendation that the Water Board concur with the cleanup remedy proposed for Edwards Air Force Base (EAFB), Operable Units (OU) 4/9, Air Force Research Laboratory (AFRL) – Arroyos Area,. A Draft Record of Decision (RoD), dated March 2010 has been prepared documenting the selected remedies to address contaminants in surface soil, vadose zone, and groundwater to protect human health, welfare, and the environment.

The selected remedy proposed by the Air Force in the Arroyos RoD is to establish a Containment Zone, approximately 12.3 square miles areally and 500 feet below ground surface, large enough to encompass the predicted maximum extent of the solvent plume. A Containment Zone is recommended because of the technical impracticability, from an engineering perspective, of cleaning up groundwater to water quality objectives established in the *Water Quality Control Plan for the Lahontan Region* (Basin Plan).

The site contains an extensive mass of dissolved phase chlorinated solvents, primarily perchloroethene and trichloroethene, dichloroethene, with lesser amounts of perchlorate, nitrosodimethylamine, and nitrate. High concentrations of dissolved phase solvents indicate the likely presence of separate phase dense non-aqueous liquids (DNAPL). These DNAPLs will continue to act as contaminant source for hundreds, or possibly thousands, of years. An alluvial aquifer is present at the site approximately 12,500 feet down gradient of the source areas. Groundwater at the site is encountered in fractured granitic bedrock.

Currently, it is technically infeasible to remediate groundwater through pump and treat or in situ treatment (e.g., oxidant, nutrient, or bacteria injection) methods because the very low effective permeability of the fractures. Interconnection of fractures is also very low and become even less so with depth.

The contaminant plumes will continue to expand through natural advection and dispersion until steady-state conditions are reached and natural attenuation processes (dilution and dispersion) reduce concentrations to non-detectable at the leading edge of the plumes. The proposed Containment Zone is slightly larger than the predicted maximum extent of the contaminant plume after 1,000 years. A Technical Impracticability Waiver granted by U.S. Environmental Protection Agency, Region IX, would remove the requirement to attain cleanup levels within the Containment

Zone. Land use controls (LUC) and monitoring will also be implemented to prevent human exposure to polluted groundwater or vapors and track plume movement over time.

The Air Force proposes the primary maximum contaminant levels (MCLs) as the risk-based levels for cleanup at the Containment Zone boundary. The Air Force is proposing these risk-based concentrations because it does not agree that California's groundwater cleanup requirements such as the Basin Plan's Water Quality Objectives (WQOs) for Secondary MCLs or State Board Resolutions 68-16 and 92-49 are Applicable or Relevant and Appropriate Requirements (ARARs).

The Air Force will however ensure that cleanup standards (water quality objectives or WQOs) will not be exceeded outside of the Containment Zone boundary. The Air Force will prepare a Technical and Economic Feasibility Analysis (Degradation Analysis) if the plume is expected to migrate beyond the Containment Zone at concentrations greater than background but less than WQOs established at the Containment Zone boundary.

Water Board staff have evaluated the proposed remedy and finds that the substantive California state groundwater cleanup requirements are met. The RoD includes "agree-to-disagree" language that preserves the State's ability to take further action if, in the future, the remedy does not comply with these requirements. Furthermore, Water Board staff finds the proposed remedy meets the requirements for a Containment Zone and provides the most feasible, cost effective method to restore groundwater quality at the site.

The unique aspect of this remedy is that it would result in a long-term Containment Zone over a very large area. One Containment Zone has previously been established in Region 6 (the South AFRL TI Waiver/CZ that was adopted in 2007) Note that EAFB plans to propose an additional Containment Zone of a similar size and duration in the Northeast Area/Mars Boulevard area of AFRL.

2. EAFB Cleanup Approach Under CERCLA

EAFB is located in the Southern California toward the western portion of the Mojave Desert. The Base covers portions of Kern, Los Angeles, and San Bernardino counties (See **Figure 1**).

Pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA), EAFB was listed on US EPA's National Priorities List (NPL) on August 30, 1990 because of the presence of soil and groundwater contamination. EAFB then entered into a Federal Facilities Agreement (FFA) with U.S. Environmental Protection Agency (USEPA)-Region IX, California Department of Toxic Substances Control (DTSC) and the Lahontan Water Board in September 1990. The FFA provides a process for involving federal and state regulators and the public in developing and implementing cleanup decisions. It also provides a process, if necessary, for formal and informal dispute resolution.

The Air Force has divided EAFB's environmental restoration sites into Operable Units (OUs). These OUs are defined by geographic location, similar contaminants, and hydrogeology to facilitate the administration of the restoration program. The sites in each OU are taken through

the CERCLA process of: Remedial Investigation, Feasibility Study, Proposed Plan, Record of Decision, and Remedial Design/Remedial Action. The Air Force has split the AFRL sites into four areas, each with a planned RoD.

The soil and groundwater sites located at the Air Force Research Laboratory, formerly known as the Rocket Propulsion Laboratory or Phillips Laboratory, are included in OU 4/9. These sites contain a wide array of contaminants in soil and groundwater including: chlorinated hydrocarbons, rocket fuel residuals, and petroleum products.

This item, Arroyos Area RoD, is for polluted groundwater in commingled plumes from sites located on the northwest flank of Leuhman Ridge where the rocket test stands and support facilities are located. This RoD also addresses seepage of contaminated near Test Stand 1A and the possible intrusion of solvent vapors into existing buildings.

3. Arroyos Area Groundwater Contaminants

The AFRL, which began rocket research and testing in the 1950s, is located on Leuhman Ridge east of Rogers Dry Lake wholly within Kern County. Groundwater flows generally northwest from the top of the ridge, where the source areas are located, towards Rogers Dry Lake. There is about a 1,000-foot elevation difference from the top of Leuhman Ridge to Rogers Dry Lake, located about five miles to the west.

The AFRL contains facilities for research, development, testing, and evaluation of rocket propulsion systems. These facilities include rocket test stands, associate support facilities, waste sumps and disposal pits for waste rocket fuels and solvents related to testing activities. As a result of direct discharges to land and seepage from pits and sumps, the Arroyos Area exhibits an array of contaminants in groundwater, including: perchloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE), benzene, perchlorate and other rocket fuel residuals (N-nitrosodimethylamine and nitrate).

Table 2 is a list of chemicals of concern in groundwater at the Arroyos Area. This table describes the maximum concentrations of these chemicals that have been detected at the site and relevant federal or state water quality objectives (i.e., maximum contaminant levels (MCLs) for drinking water). The remedy proposes that the USEPA waive the requirement to attain groundwater cleanup to these levels within the Containment Zone – called a Technical Impracticability Waiver. The values shown in bold or italics on this table will apply as cleanup levels at the Containment Zone boundary.

4. Arroyos Contaminant Source Areas

The groundwater plumes in the Arroyos Area emanate from two source areas: Site 162 (Test Areas 1-14, 1-21, 1-40) and Site 461 (Test Stands 1A and 1D, Test Areas 120, 125). Groundwater plumes from these two source areas have merged into solvent plume with an areal extent of 3,000 acres of which 1,720 acres exceed TCE's primary MCL of 5.0 micrograms

per liter (µg/L). The plumes have migrated about 7,000 feet from the source areas (see **Figure 2**). The estimated current volume of impacted water is 5,168 acre-feet.

The highest currently detected concentrations of dissolved phase contaminants are summarized in the following table. These data are from wells near the source area.

Table 1

Contaminant	Current (2008) Concentrations
PCE	6,200 µg/L
TCE	7,000 µg/L
DCE	48,000 µg/L

µg/L = micrograms per liter or approximately parts per billion
PCE = perchloroethene, TCE = trichloroethene, DCE = dichloroethene

Separate phase dense non-aqueous phase liquids (DNAPL) have not been directly observed at the site. There is a very low likelihood of directly observing DNAPL in groundwater from highly fractured bedrock (due to the similar appearance of water and solvents). However, separate phase solvents trapped in the bedrock fractures are suspected from several lines of evidence. Depending on site conditions, dissolved phase chlorinated solvent concentrations as low as 1% of the pure phase solubility may indicate the presence of DNAPL[1]. The solubility of PCE in water is about 200,000 µg/L (1% = 2,000 µg/L) and for TCE is about 1,280,000 µg/L (1% = 12,800 µg/L). Thus, the observed concentrations of PCE and TCE provide an indirect indication that DNAPL is present at the site. Anecdotal evidence of solvents being discharged directly to land would also lead to the conclusion that DNAPL is present in the bedrock fractures. These suspected DNAPLs will continue to be a long-term source for continued dissolution of chlorinated solvents into groundwater.

5. Arroyos Area Site Hydrogeology and Existing Groundwater Water Quality

Leuhman Ridge is formed from quartz monzonite (a type of granite) intrusion that consists of competent and weathered fractured bedrock overlain by a relatively thin discontinuous veneer of unconsolidated alluvial deposits. The alluvium increases in thickness down slope away from the crest of the ridge towards Rogers Dry Lake.

Groundwater occurs under unconfined conditions in both the weathered and fractured bedrock. Depth to the static water table ranges from 15 to 266 feet below ground surface. Groundwater flow beneath the Arroyos Area is to the northwest towards Rogers Dry Lake. The static water level is found in the competent granitic bedrock until the bedrock surface drops away sharply,

[1] *Evaluation of the Likelihood of DNAPL Presence at NPL Sites*, EPA 540R-93-073, September 1993, Page 26.

due to faulting, and the groundwater flows into an alluvial aquifer connected to the North Muroc Sub-basin of the Antelope Valley Basin (DWR #6-44).

Aquifer yields in the fractured bedrock are generally low with an average sustained yield of 0.3 gallons per minute (gpm). About half of the monitoring wells on site do not produce the minimum sustained yield of 0.14 gpm, or 200 gallons per day, to be considered a drinking water source under State Board Resolution 88-63. This is not surprising however given the typical short screens and small diameter of a monitoring well. Down gradient of the source areas, groundwater-pumping rates of 35 gpm can be sustained in the shallow alluvial aquifer.

Groundwater quality in the fractured bedrock is generally poor. Total dissolved solids concentrations in wells installed on site range from 436 milligrams/liter (mg/L) to 8,100 mg/L with most values between 1,000 and 2,500 mg/L, which is above the recommended secondary drinking water standard of 500 mg/L. Additionally, naturally occurring groundwater within fractured bedrock exceeds drinking water standards for: arsenic, chloride, iron, manganese, nickel, selenium, sulfate, and thallium.

No groundwater production wells are present (or anticipated) in the Arroyos Area area. Two currently inactive EAFB well fields (Mary's and Lower) are located southwest of the Arroyos Area towards Rogers Dry Lake. These well fields are not predicted to be affected by the contaminant plumes. The Air Force has used the Lower Well field, in conjunction with imported water from the State Water Project, to supply domestic and industrial water to the AFRL. Water quality in the alluvial aquifer generally meets drinking water standards. However, arsenic concentrations in the Lower Well field approach the new, lowered arsenic drinking water standard of 10 μg/L.

6. Arroyos Area Site Investigation, Cleanup Actions and Pilot Tests

Remedial Investigations were performed from 1993 through 2005 and included soil gas sampling, soil borehole logging, soil sampling, monitoring well installation, groundwater sampling and analyses, packer testing, pump testing, core sampling, fracture analyses, three-dimension seismic reflection surveying, and borehole video logging. Groundwater monitoring has been performed at the Arroyos Area since 1998.

Interim removal actions have eliminated waste storage and disposal area sources on the ground surface that could have further contributed to the groundwater pollution (e.g., tanks, sumps, waste pits). Current waste disposal practices from ongoing rocket testing do not allow for direct discharge of waste to land for disposal (e.g., the use of PCE and TCE was discontinued in the early 1980s, as was the practice of releasing deluge water to the arroyos).

A pilot study to create an engineered fractured bedrock zone and thus increase the aquifer yield was conducted at Site 37 (South AFRL Area) in 2004. The results of that pilot study indicate that aquifer yield was not increased. Further large scale fracturing is infeasible due to limits (for safety and potential infrastructure damage) on the amount of explosives that can be used on site to create fractured zones at depth.

An In-Situ Bioremediation Treatability Study, using the hydrogen release compound Cl-Out® was conducted at Site 162 in 2007. The results of the study indicated that, although the technology was effective in small, localized areas, large scale effectiveness was unlikely due to the inability to distribute the injected solutions effectively into the bedrock fractures.

Other in-situ technologies have been, or are being, evaluated and tested at EAFB. **Table 3** shows a summary of in-situ technologies that have been evaluated at EAFB that may be applicable to the Arroyos Area. However, none of the technologies evaluated will be effective in the deep fractured granitic bedrock at the Arroyos Area because they are limited to shallow alluvial aquifer situations or have limited effectiveness in fractured bedrock. Introduction of oxidants or bacteria into the subsurface requires an even distribution of solution to the contaminants which, at the Arroyos Area, is very difficult to achieve within the fractured bedrock. A literature survey of other technologies indicates that none are likely to be effective in fractured bedrock. The Air Force remains committed to conducting field tests of remedial technologies as they are identified in the future. This is further described in the selected alternative (proposed remedy) discussed in Section 9.

Computer groundwater models can be effective tools to evaluate the current and predicted movement of groundwater and contaminants. Their effectiveness in providing scientific certainty is limited by the site-specific field data available to provide accurate input parameters to the model. Granular porous media groundwater models are the most common and are generally used to represent alluvial aquifer situations. Although groundwater models for fractured bedrock are available, effectively modeling a fractured bedrock system requires an enormous amount of data, simplifying assumptions, or both, to develop a detailed description of the aquifer properties controlling flow.

The Air Force used a granular porous media model MODFLOW® to evaluate groundwater flow, and MT3D® model for contaminant fate and transport, to assess the long-term movement of contaminants. In using these models, the Air Force decided to use the simplifying assumption that on the scale of the modeled area, the fractured bedrock mimics the characteristics of granular porous media. Obtaining the necessary data to produce a detailed fractured groundwater flow and contaminant transport model was determined to be impractical for the scale of both contaminant distribution (approximately 3 square miles) and modeled area (approximately 167 square miles). The rationale for using a granular porous media groundwater model at the Arroyos Area site includes:

- The movement of groundwater and contaminants is fracture controlled on a localized scale; however, on a regional scale, groundwater flow emulates granular porous media.
- Pump test results demonstrate a radial (cone-shaped) drawdown response to groundwater removal indicating hydrogeologic behavior similar to granular porous media.
- Groundwater elevations mimic surface topography and change little over time with no evidence of obvious asymmetry suggesting fracture-controlled flow direction(s).

- Contaminant distributions radiating outward down gradient from the source areas also do not indicate strong fracture control (preferred pathways) of contaminant transport.

To simulate (model) the likely persistence of DNAPLs, sources of TCE and/or PCE were assumed for a 1,000-year time frame providing continuous dissolution of solvents into groundwater. The computer model predicts the solvent plumes would migrate, reach maximum steady-state conditions in about 300 years, and persist for as long as DNAPLs persists in the fractures. The computer modeling performed provides an adequate assessment of contaminant plume movement over the Arroyos Area but is inadequate to predict specific interconnected fractures that are preferentially transporting contaminants.

The groundwater modeling for the Arroyos Area will be updated every five years using additional site-specific data and groundwater monitoring information collected during the Remedial Design/Remedial Action phase (post-RoD remedy implementation). Further refinement of the models will improve the accuracy and precision of the predicted contaminant plume movement and will be used to locate future groundwater monitoring wells (both lateral well placement and vertical well screen depth).

7. Remedial Action Objectives

Remedial Action Objectives (RAOs) for groundwater at the Arroyos Area were developed based upon the requirements of CERCLA, results of the Human Health Risk Assessment, results of the Programmatic Ecological Risk Assessment, identified ARARs, the site's characteristics, and an evaluation of the site's potential for groundwater restoration. The exposure pathways identified in the Risk Assessment (that need to be prevented or minimized) are: ingestion of or dermal contact with contaminated groundwater and inhalation of chlorinated solvent vapors from the contaminated groundwater.

The identified RAOs for the Arroyos Area are:

- Prevent human health exposure (ingestion and dermal contact) to groundwater impacted by the contaminants of concern (CoCs) listed in Table 2. Prevent migration outside of the Arroyos Area Containment Zone Boundary of groundwater impacted by the CoCs listed in Table 2.
- Prevent human inhalation of vapor-phase CoCs (identified by an asterisk in Table 2) emanating from the subsurface into indoor air at concentrations exceeding a cancer risk level of $1x10^{-6}$ or a non-cancer Hazard Index of 1.0.
- Below Test Stand 1A in Site 461, prevent exposure to human or environmental receptors to surface seep water containing VOCs (identified in Table 2) at concentrations above their respective MCLs.

8. Description of Remedial Alternatives

To accomplish the identified RAOs, the Air Force identified and evaluated numerous remedial alternatives in the *AFRL Arroyos Focused Feasibility Study* for their ability to satisfy the "nine CERCLA criteria." These criteria are:

1. Overall protectiveness;
2. Compliance with state and federal requirements;
3. Long-term effectiveness and permanence;
4. Reduction of toxicity, mobility, or volume;
5. Short-term effectiveness;
6. Implementability;
7. Cost;
8. Regulatory agency acceptance; and
9. Community acceptance.

The five retained remedial alternatives (identified as viable, addressed the nine criteria, and could achieve the RAOs) subsequently evaluated include the following common elements:

- Technical Impracticability Waiver for Chemical-Specific ARARs
- Containment Zone Designation
- Land Use Controls
- Further Investigation (ongoing until 2025)
- Long-Term Groundwater Monitoring
- Continued Treatment of Seep Water below Test Stand 1-A

The retained alternatives are:

- ***Alternative 1 – No Action***. Consideration of a No Action Alternative is required as a baseline against which to compare the other remedial alternatives considered. Alternative 1 does not meet the identified ARARs and is not protective of human health and the environment. There is no cost to implement this Alternative
- ***Alternative 1B – Technical Impracticability Waiver with Limited Action***. Alternative 1B (the Air Force's Preferred Alternative) relies on natural attenuation processes (primarily dispersion and dilution) coupled with low hydraulic flow velocities to contain the spread of contaminants inside the Containment Zone. This Alternative includes a reliance on low groundwater flow velocity in the fractured bedrock to limit contaminant migration to within the proposed Containment Zone. Continued migration of contaminants within the containment zone would be allowed; however, this Alternative requires additional actions be taken to prevent contaminants from migrating past the Containment Zone boundary. This Alternative also requires the installation of sentinel wells to track the leading edge of the plumes so that actions can be taken 10 – 30 years before the contaminants reach the Containment Zone Boundary.

Water Board staff focused their review of the proposed remedy's compliance with state ARARs in evaluating this Alternative. As noted previously, the Air Force and Water Board disagree whether the more stringent state groundwater cleanup requirements are ARARs. The total cost for this Alternative is estimated to be $202,300,000.

- ***Alternative 2B – Technical Impracticability Waiver with Plume Containment in the Alluvial Aquifer***. Plume containment will be accomplished by a pump and treat system as an active containment technology to be implemented if the contaminants reach the alluvial formation inside the Containment Zone Boundary. Alternative 2B includes the components of Alternative 1B plus the addition of plume containment by groundwater extraction and treatment once the leading edge of plume reaches the alluvial aquifer. The total cost for this Alternative is estimated to be $454,260,000.
- ***Alternative 3B - Technical Impracticability Waiver with Hot Spot Containment (Source Control)***. Source control would be accomplished using a "biobarrier." Alternative 3B includes the construction of a continuous 13,500-foot long biobarrier (composed of 2,700 injection wells), perpendicular to the direction of flow, to contain and treat the zones of solvent and perchlorate contamination greater than 1,000 µg/L. The total cost for this Alternative is estimated to be $6,298,840,000.
- ***Alternative 5 - Technical Impracticability Waiver with Hot Spot Containment and Plume Containment in the Alluvial Aquifer***. This Alternative combines the elements of Alternatives 2B and 3B combining the hot spot control with the future installation of the groundwater extraction and treatment system. The total cost for this Alternative is estimated to be $6,550,810,000.
- ***Alternative 6 - Technical Impracticability Waiver with Source Area Treatment and Plume Containment in the Alluvial Aquifer***. This Alternative assumes 10 years of aggressive source area treatment using in-situ chemical oxidation at Site 162-Test Area 1-14 and Site 461-Test Stands 1-A and 1-D to achieve DNAPL removal. Plume containment component is the same as Alternative 2B. To further characterize the site and aid in locating the contamination in the source areas, 111 monitoring wells will be installed throughout the three source areas. The total cost for this Alternative is estimated to be $855,990,000.

Alternatives 1 and 1B are easily implementable. Alternative 2B is a straightforward pump and treat process in the alluvial aquifer. The likelihood of success with Alternatives 3B, 5, and 6 is questionable considering the difficulty of distributing in-situ chemical oxidation and bioenhancement materials into the fractured bedrock. Costs escalate significantly from Alternative 2B through 6. No Community response to the Proposed Plan would seem to indicate that Alternative 1B is acceptable to the public. Alternative 1B was selected over the other alternatives due to cost and need for the absence of technologies of groundwater extraction and treatment or oxidant/biological treatment injections in fractured bedrock.

The USEPA, Region IX agrees that the site qualifies for a Technical Impracticability Waiver allowed under CERCLA to comply with the ARARs within the Containment Zone boundary. This is primarily due to technical infeasibility in fully intercepting contaminated groundwater or introducing solutions for treatment of contaminants into fractured bedrock.

The proposed remedy must under federal law, at a minimum, protect human health and the environment and comply with the identified ARARs (the "Threshold Criteria"). CERCLA does not create new cleanup standards, but does require site cleanups to conform to existing federal and state cleanup standards. These cleanup standards, called ARARs, must be identified during the CERCLA process and are listed in the RoD.

State cleanup standards become ARARs when they are: promulgated, legally enforceable, of statewide applicability and, are more stringent than federal standards. Water Board staff have consistently identified State Board Resolutions 68-16, 88-63, and 92-49 (see Section 9) as ARARs; however, since they are not "risk based" the Air Force does not agree that these Resolutions are ARARs.

The Dispute Resolution process in the FFA may be used to resolve disagreement over what particular state standards are ARARs. Alternatively, both parties may disagree over what standards are ARARs, but find technical agreement on the proposed remedy. In this case, the parties may "agree-to-disagree" over specific ARARs, but avoid dispute resolution and move foreword with remedy implementation. The RoD includes language that preserves the State's ability to take further action if, in the future, the remedy does not comply with the requirements of the State Board resolutions.

9. Selected Remedial Alternative

To achieve the listed RAOs, the Air Force proposes a Containment Zone area of about 12.3 square miles covering the maximum predicted extent of the solvent contaminant migration (See **Figure 2**). The Air Force would not, due to technical impracticability from an engineering perspective, be required to attain the groundwater cleanup levels within the Containment Zone. The Air Force would ensure that groundwater cleanup levels (MCL values shown in **Table 2**) are attained at the Containment Zone boundary, through active measures if necessary. The proposed Containment Zone area does include a portion of the alluvial Antelope Valley aquifer (See **Figure 2a**).

The major components of the Preferred Remedy (Alternative 1B) are:

- Contain impacted groundwater within the Containment zone by natural processes (dilution and dispersion) with the objective of preventing contaminants from entering the alluvial aquifer to the west of the Arroyos Area.
- Implement, maintain, and enforce Land Use Controls within the Containment Zone to prevent human exposure with polluted groundwater.

- Install additional monitoring wells near the down gradient extent of the plume, and in the source areas at various vertical intervals to assess water bearing zones (fracture sets) that are contaminant migration pathways.
- Demonstrate containment of contaminants above the MCLs by Long-Term Monitoring. Use the monitoring data to update and refine the groundwater model, which currently projects no contaminant migration beyond the Containment Zone boundary for at least 1,000 years. Install additional monitoring wells which will include: sentinel wells located near the down gradient plume extent, source areas wells in the zones of contaminant highest concentrations, mid-plume wells exhibiting intermediate contaminant concentrations, and wells at various vertical intervals to assess water bearing zones (fractures) that are contaminant migration pathways. The remedy assumes that approximately 36 monitoring wells will be sampled annually and 121 wells every 5 years.
- Institute active cleanup measures as necessary to prevent CoCs from migrating outside the Containment Zone at levels above MCL values listed in **Table 2**. (At this time pump and treat is the most likely method of containment should it be necessary.)
- If or when impacted groundwater is projected to reach the Containment Zone boundary within 10 years, the Air Force will conduct a groundwater Degradation Analysis to evaluate whether groundwater degradation beyond the Containment Zone boundary should be accepted and a Technical and Economic Feasibility Analysis to determine what contaminant levels would be appropriate.
- Continue to review technologies as part of the CERCLA 5-Year Review process. If a promising technology is identified to treat the same types of chemicals at similar concentrations and in a similar hydrogeologic setting, conduct a field test, at a cost not to exceed $250,000, to be executed by the following 5-year review. The Air Force proposes these studies to satisfy the State Board Resolution 92-49 Containment Zone requirements for providing compensatory mitigation.
- Over a 30-period, the present value cost of the remedy is $24,760,000 – with a recurring cost for as long as contaminants are present at concentrations that exceed the MCL values shown on **Table 2**. The total project cost is estimated at $202,300,000.
- Groundwater monitoring data will be used to track contaminants, provide input to verify the groundwater model, and verify plume containment in compliance with requirements contained in the RoD. The Federal process requires that each RoD be reviewed every 5 years until remedial objectives are attained. The RoD review evaluates performance of the selected remedy.
- During the Remedial Design/Remedial Action (post-RoD) phase, the Air Force may conduct additional studies as necessary to establish hydraulic properties in the area where the fractured bedrock aquifer abuts the alluvial aquifer. This may include, but is not limited to; installing additional monitoring wells, subsurface geophysics, and aquifer pump tests.

The major vapor migration components of the remedy are:

- Implement engineering controls to reduce the vapor intrusion pathway risk in buildings to acceptable levels.
- Implement, maintain, and enforce Land Use Controls within the Containment Zone to prevent human exposure with soil vapors that pose an unacceptable risk.
- Monitor and map the groundwater plume migration with respect to vapor contaminant concentrations that may pose an unacceptable risk.
- Initiate a sampling program to assess whether the vapor intrusion pathway is complete and periodically monitor indoor air in buildings that currently overlying the plume to determine if engineering controls are required to reduce the indoor air risk to acceptable levels.

10. Compliance with Water Board Requirements

The following California state laws, policies and regulations apply to groundwater cleanup:

- State Water Board Resolution 68-16 (*Statement of Policy with Respect to Maintaining High Quality of Waters in California*)
- State Water Board Resolution 88-63 (*Sources of Drinking Water Policy*)
- State Water Board Resolution 92-49 (*Policies and Procedures for Investigation and Cleanup and Abatement of Discharges Under Water Code Section 13304*)
- California Water Code (*Porter-Cologne Water Quality Control Act*)
- Basin Plan *(Water Quality Control Plan for the Lahontan Region*)

The Air Force's position is only State Board Resolution 88-63 and the MCLs, which are the water quality objectives identified in the Basin Plan, are ARARs. The Basin Plan does designate groundwater at the Arroyos Area for a Municipal Use. State Board Resolution 88-63 states that groundwaters with excessive salinity, contaminants that cannot be reasonably treated, or exhibit a low sustained yield should not be classified as a source of drinking water. One or more of these exceptions may apply to the Arroyos Area. For the foreseeable future groundwater within the fractured bedrock is not likely to be used for drinking water. Furthermore, the proposed remedy precludes extracting groundwater from within the Containment Zone to prevent human exposure to pollutants.

The Air Force does not consider secondary maximum contaminant levels (sMCLs), State Board Resolutions 68-16 or 92-49 to be ARARs. The RoD includes language indicating the State and Air Force "agree-to-disagree" whether these items are ARARs.

Water Board staff have reviewed the proposed remedy (Alternative 1B) for compliance with state groundwater cleanup requirements to determine if it meets technical compliance. This analysis is summarized in the following bullets and **Table 4**.

- To satisfy whether, and to what level, groundwater should be degraded at levels less than the cleanup standards down gradient of the Containment Zone, if contaminants are predicted to migrate beyond the Containment Zone boundary within 10 years, the Air Force will conduct a Degradation Analysis and Technical and Economic Feasibility Analysis.
- To satisfy whether a Containment Zone, under State Board Resolution 92-49 is appropriate, the Air Force has demonstrated that it is unreasonable (technically infeasible) to cleanup groundwater to the water quality objectives established in the Basin Plan within a reasonable timeframe.
- The Containment Zone Policy requires compensatory mitigation. To satisfy this requirement, the Air Force proposes to conduct field-scale pilot tests with costs not to exceed $250,000 per test. These field tests would further evaluate promising technologies for remediating chlorinated solvents in fractured bedrock environments where DNAPL may be present. If, after 30 years, no promising technologies are identified, the Air Force will select another suitable field test or remedial action for the inflation-adjusted equivalent of $250,000.
- The Containment Zone policy also requires a Management Plan to assess, cleanup, manage, monitor and mitigate remaining significant human health, water quality and environmental impacts. The Air Force has proposed a management plan and will further refine it during the Remedial Design. A long term monitoring strategy will be used to track the movement of contaminants within the Containment Zone.
- A Containment Zone must be established for a specific geographical area and depth. The RoD proposed to set the maximum depth of the Containment Zone at 500 feet below ground surface – deeper than the maximum observed contaminant depth. The ability to actually contain contaminants at a certain depth is very limited however and no active control of contaminants at a particular depth is proposed. Field observations indicate that bedrock fractures are less prevalent, show a decrease in size, and are less transmissive with depth.
- A Containment Zone must be limited in lateral and vertical extent; protective of human health, safety, and the environment; and not result in violation of water quality objectives outside of the Containment Zone. The proposed Containment Zone is within the fractured bedrock beneath the Arroyos Area and includes a small portion of the alluvial aquifer adjacent to the bedrock to allow for contaminant containment using conventional pump and treat methods if needed in the future. Land use restrictions protect against human health exposure to contaminants. The RoD requires that MCLs not be exceeded outside the Containment Zone and the Air Force agrees to complete a Degradation Analysis and Technical and Economic Feasibility Analysis for contaminants that may escape the Containment Zone at concentrations less than MCLs or for other contaminants that have risk-based levels. The Air Force disagrees whether this analysis is necessary for other contaminants (e.g., sMCLs).

- The Containment Zone policy requires a 45-day public notice before the Water Board considers a Containment Zone. Technically, the federal government is proposing a remedy that is consistent with establishing a Containment Zone through the RoD and the Water Board will only consider whether to concur with the proposed action. However, a 45-day public notice of the Water Board's consideration of this action was provided as described in **Table 4**.
- The State and Regional Water Boards must maintain a master list of Containment Zones that are established. Water Board staff will provide the State Board with a determination that a Containment Zone is established once the RoD is signed and may elect to post an announcement on the Water Board's public Internet site.

11. Conclusions

Water Board staff has reviewed the RoD and other available data and information for the Arroyos Area, EAFB OU 4/9, and believes the proposed remedy (Alternative 1B) is the most appropriate way to address the groundwater contamination and comply with ARARs and policies administered by the Water Board. Further, Water Board staff believes the proposed remedy satisfies the requirements for a Containment Zone that are established in State Board Resolution 92-49.

12. Recommendation

The Air Force has prepared the final RoD with an acceptable cleanup proposal. The Water Board is party to the FFA for the EAFB and is now asked to sign the RoD indicating it concurs with the actions proposed in the RoD. Staff recommends the Board adopt the enclosed resolution authorizing the Executive Officer to sign the RoD.

TABLE 2. Chemicals of Concern in Arroyos Groundwater

Analyte	Maximum Detected Concentration[a]	Location of Maximum Concentration	2008 Concentration of Location with Maximum Concentration	Federal ARARs/TBCs MCLGs[b]	Federal ARARs/TBCs Primary[b] MCLs	State of California ARARs/TBCs Primary[c] MCLs	State of California ARARs/TBCs NLs[d]
benzene	39 J	461-MW05	39 J	0	5	**1**	-
carbon tetrachloride	9.9 J Q	461-MW03	<20	0	5	**0.5**	-
1,2-dichloroethane	16 J	162-MW03	7.1 J	0	5	**0.5**	-
cis-1,2-dichloroethene (cis-1,2-DCE)*†	55,000	461-MW05	48,000	70	70	**6**	-
trans-1,2-dichloroethene (trans-1,2-DCE)	550	461-MW05	550	100	100	**10**	-
tetrachloroethene (PCE)* †	15,000	36-MW04	6,000	0	**5**	**5**	-
trichloroethene (TCE)*†	7,000	461-MW02	7,000	0	**5**	**5**	-
vinyl chloride	110	461-MW05	<200	0	2	**0.5**	-
N-nitrosodimethylamine (NDMA)	7.12	36-MW01	-	-	-	-	***0.01***
nitrate	33.4[e]	36-MW01	24	10[e]	**10**[e]	10[e]/45[f]	-
perchlorate	500	36-MW01	310	-	-	**6**	-

Notes:

This table shows the chemicals of concern (CoCs) in the groundwater at the AFRL Arroyos. Values in bold indicate ARARs to be waived within the AFRL Arroyos CZ. Values in italics indicate risk-based cleanup goals adopted for chemicals without MCLs. These chemicals will also be contained.

Concentrations of organic compounds and perchlorate are in micrograms per liter (µg/L). Nitrate concentrations are in milligrams per liter (mg/L).

* COCs posing a risk via the VIP.

† COCs posing a risk via the seep water (sample results included in Appendix A.1-4).

[a] Includes monitoring data through November 2008.

[b] Source: USEPA (2006).

[c] Source: CDPH (2009).

[d] Source: CDPH (2007).

[e] Nitrate reported as nitrogen.

[f] Nitrate reported as nitrate.

- non promulgated
ARAR applicable or relevant and appropriate requirement
CDPH California Department of Public Health
COC contaminant of concern
LTM long-term monitoring
MCL maximum contaminant level
MCLG maximum contaminant level goal
NL notification level
TBC to-be-considered criterion. NLs are TBCs.
TI technical impracticability
USEPA United States Environmental Protection Agency
VIP vapor intrusion pathway

Laboratory–Assigned Data Qualifiers:

J Result is detected below the reporting limit or is an estimated concentration.
Q The reporting limit is elevated due to elevated levels of other analytes.

06-0021

TABLE 3. Summary of Some In-Situ Technologies Tested at EAFB

OU	Site	Technology	Result	Applicability to Arroyos Area
1	19	Bio-enhanced In-well Stripping	Rebound occurred at lower concentrations.	Limited to shallow alluvial aquifer material.
1	19	Bioremediation - Whey Powder	TCE reduction to Cis-1,2-DCE.	Effectiveness in deep bedrock unlikely due to inability to apply in fractures.
2	5	Aerobic Bioremediation - PHOSter®	Free product petroleum thickness reduced. Dissolved phase petroleum hydrocarbon and TCE concentrations reduced.	Effectiveness in bedrock unlikely due to inability to apply in fractures. No petroleum hydrocarbons present for electron donor source.
4/9	37	Explosive fracturing of bedrock via a series of closely-spaced boreholes creating a high porosity zone/cutoff wall.	No increase in fracture hydraulic conductivity observed.	Effectiveness at AFRL unlikely due to constraints on volume of explosives allowed (to protect site infrastructure).
4/9	162	Hydrogen Release Compound Cl-Out®. PCE and TCE reduced to DCE.	May be effective in small, localized areas.	Large-scale effectiveness in fractured bedrock unlikely due to the inability to effectively distribute the injected solutions into the fractures.
5/10	207(N3)	Chemical Oxidation – Fenton's Reagent and Persulfate	Decrease in TCE – still above MCL.	Effectiveness in deep bedrock unlikely due to inability to apply in fractures.
5/10	211(N7)	Chemical Oxidation – Potassium Permanganate	VOCs reduced to less than detection with rebound occurring.	Effectiveness in deep bedrock unlikely due to inability to apply in fractures.
5/10	282	Nano-Scale Zero-Valent Iron	Effective reduction of VOCs with limited radius of influence	Effectiveness in deep bedrock unlikely due to inability to apply in fractures.
5/10	285	Perchlorate Soil Flushing	Effective in vadose zone.	No perchlorate present.
8	25	Hydraulic Fracturing	New fractures relatively shallow. Minimal improvement in hydraulic conductivity.	Effectiveness in deep bedrock unlikely.
8	25	In-Situ Chemical Oxidation. Introduction of permanganate solutions via infiltration trenches to degrade solvents.	Field scale pilot test started in Spring 2010. Report of results expected in late 2011.	If successful technology would be applicable due to the hydrogeologic similarities of the site.

TABLE 4. COMPARISON of PROPOSED REMEDY (ALTERNATIVE 1B) with CA STATE GROUNDWATER CLEANUP REQUIREMENTS

Citation	Major Requirement	Analysis
Resolution 92-49, Section III.G	Groundwater cleanup to levels that attain background or the best water quality that is reasonable, considering Resolution 68-16 and title 23, chapter 15, section 2550.4 Technical and Economic Feasibility Analysis , or TEFA, to establish an appropriate level that does not exceed water quality objectives.	Within the CZ, it is not required to cleanup groundwater. The USEPA waives the groundwater cleanup levels down to the either the MCL or risk-based levels. Cleanup levels established in Table 2 cannot be exceeded at the CZ boundary. The Air Force will complete a Degradation Analysis and Technical and Economic Feasibility Analysis if contaminants, at any level, are expected to migrate beyond the CA boundary within 10 years. Based on the computer groundwater model, the maximum predicted extent of the VOC plume would not reach the boundary down to the current detection limit of 0.5 ug/L for at least 300 years.
Resolution 92-49, Section III.H,2.b	Vessels that caused degradation must be removed, repaired, or closed. Other sources (such as DNAPL) must be removed, isolated or managed.	Pollution sources are eliminated. The CZ provides a management tool to evaluate plume migration. DNAPL within fractures would continue to act as a source of groundwater pollution for decades, or centuries.
Resolution 92-49, Section III.H,2.d	Propose a management plan to assess, cleanup, abate, manage, monitor and mitigate remaining human health, water quality, and environmental impacts.	There are no environmental impacts from the proposed remedy. The groundwater plume will be monitored to ensure it does not migrate past the CZ boundary. Every 5 years, the computer groundwater model will be revised to predict future plume movement. The monitoring plan will be finalized during the RD/RA process. Land use controls will be implemented to restrict groundwater pumping and prevent exposure to soil vapors.
Resolution 92-49, Section III.H,2.e	Provide reasonable mitigation measures to lessen or avoid significant environmental impacts.	The proposed remedy includes a $250,000 pilot study to evaluate any technology that has likelihood of success in the fractured bedrock environment to be completed by the next 5-Year Review. This is a recurring commitment. If no technology is identified in 30 years, the Air Force will propose alternative mitigation in an equivalent inflation-adjusted amount.
Resolution 92-49, Section III.H,2.f	Include a detailed proposed monitoring program.	The Air Force submitted a conceptual groundwater monitoring plan as part of the FS, Volume II. This plan will be refined during the RD/RA phase and is subject to the FFA Dispute Resolution process as a Primary Document.
Resolution 92-49, Section III.H,2.g	Include a detailed plan to evaluate data and evaluate response actions to ensure contaminants do not migrate beyond the CZ boundary.	The Air Force has taken actions to eliminate pollutant sources. The preferred alternative proposes to monitor VOC plume migration and take active measures (such as pump and treat) to ensure contaminants above cleanup levels do not migrate outside of the CZ.
Resolution 92-49, Section III.H.3	The CZ shall be limited in vertical and lateral extent and no larger than necessary based on individual facts.	It is reasonable to consider a CZ in highly fractured bedrock with high concentrations of VOCs that indicate DNAPL will act as an ongoing source. The vertical extent of the CZ is 500 feet, the maximum estimated depth of fractures that transmit water. The lateral extent of the CZ is 12.3 square miles and includes a small portion of the Antelope Valley alluvial groundwater basin to allow for the eventual capture of contaminants using conventional pump and treat technologies if necessary in the future.
Resolution 92-49, Section	A CZ shall not be designated in a critical recharge	While the fractured bedrock in the Arroyos Area (slopes of Leuhman Ridge) provides limited groundwater recharge to the Antelope Valley groundwater basin, it is not significant as most

Citation	Major Requirement	Analysis
III.H.3.d	area.	recharge to this basin occurs at the slopes of the San Gabriel and Tehachapi mountain ranges.
Resolution 92-49, Section III.H.8	Public notice shall be given to interested persons and agencies at least 45 days prior to adoption.	The Air Force has provided for extensive public review of the proposed remedy during the Proposed Plan phase, which included a public meeting. Notice of the Water Board's July 2010 public meeting to consider this item was published at least 45-days prior to the meeting in the Antelope Valley Press and Mojave Desert News newspapers. The agenda announcement, staff report and proposed resolution were mailed to interested persons prior to the meeting. CERCLA documents upon which the remedy is based were available for public review in the Water Board's Victorville office at least 45-days prior to the July 2010 meeting.
Resolution 92-49, Section III.H.9	Invite Technical Advisory Committee to review proposed CA, at least 45-days prior to adoption.	The US EPA and CA DTSC are parties to the FFA and participated in developing the CZ. The CA DFG, CA DHS, and KCDEHS have no objection to the plan.
Resolution 92-49, Section III.H.10	Both the State and Regional Water Boards will maintain a list of CZs that are designated.	Following adoption, Water Board staff will transmit this CZ to the State Water Board and may include a list of CZs on the Regional Water Board web page.
Resolution 68-16	Maintain high water quality unless change is demonstrated to be consistent with maximum benefit of the people, will not unreasonably affect beneficial uses, and not result in water quality less than policies. For any change, apply best practicable treatment of control of the discharge.	Compliance with this resolution is not applicable within the CZ. As previously stated, the Air Force will complete a Degradation Analysis and Technical and Economic Feasibility Analysis if contaminants, at any level, are expected to migrate beyond the CA boundary within 10 years.
California Water Code	Cleanup must conform to the Basin Plan and CA State Plans and Policies	Exceptions to this requirement are discussed herein.
Water Quality Control Plan for the Lahontan Region (Basin Plan)	Water quality objectives must be attained to protect designated beneficial uses of groundwater within the Antelope Valley groundwater basin.	Compliance with these objectives is not required within the CZ. The Air Force and Water Board disagree whether the sMCLs are applicable as cleanup levels within the CZ; however, it is anticipated that sMCLs, as a result of the discharge, will be attained before MCLs, which will persist for a very long time. As previously noted, the Air Force and Water Board disagree whether sMCLs apply at the boundary of the CZ. This issue remains open and must be resolved before waste constituents, at any concentration, migrate beyond the CZ boundary.

Notes:
RD/RA = Remedial Design/Remedial Action
CA DFG = California Department of Fish and Game
CA DHS = California Department of Health Services, Drinking Water Branch
CERCLA = Comprehensive Environmental Response Compensation & Liability Act
CZ = Containment Zone
FFA = Federal Facilities Agreement
FS = Feasibility Study
DNAPL = dense non-aqueous phase liquid
RoD = Record of Decision
VOCs = Volatile Organic Compounds
CA DTSC = CA Department of Toxic Substances Control
USEPA = U.S. Environmental Protection Agency
sMCLs = Secondary Maximum Contaminant Levels
MCLs = Maximum Contaminant Levels
KCDEHS = Kern County Department of Environmental Health Services

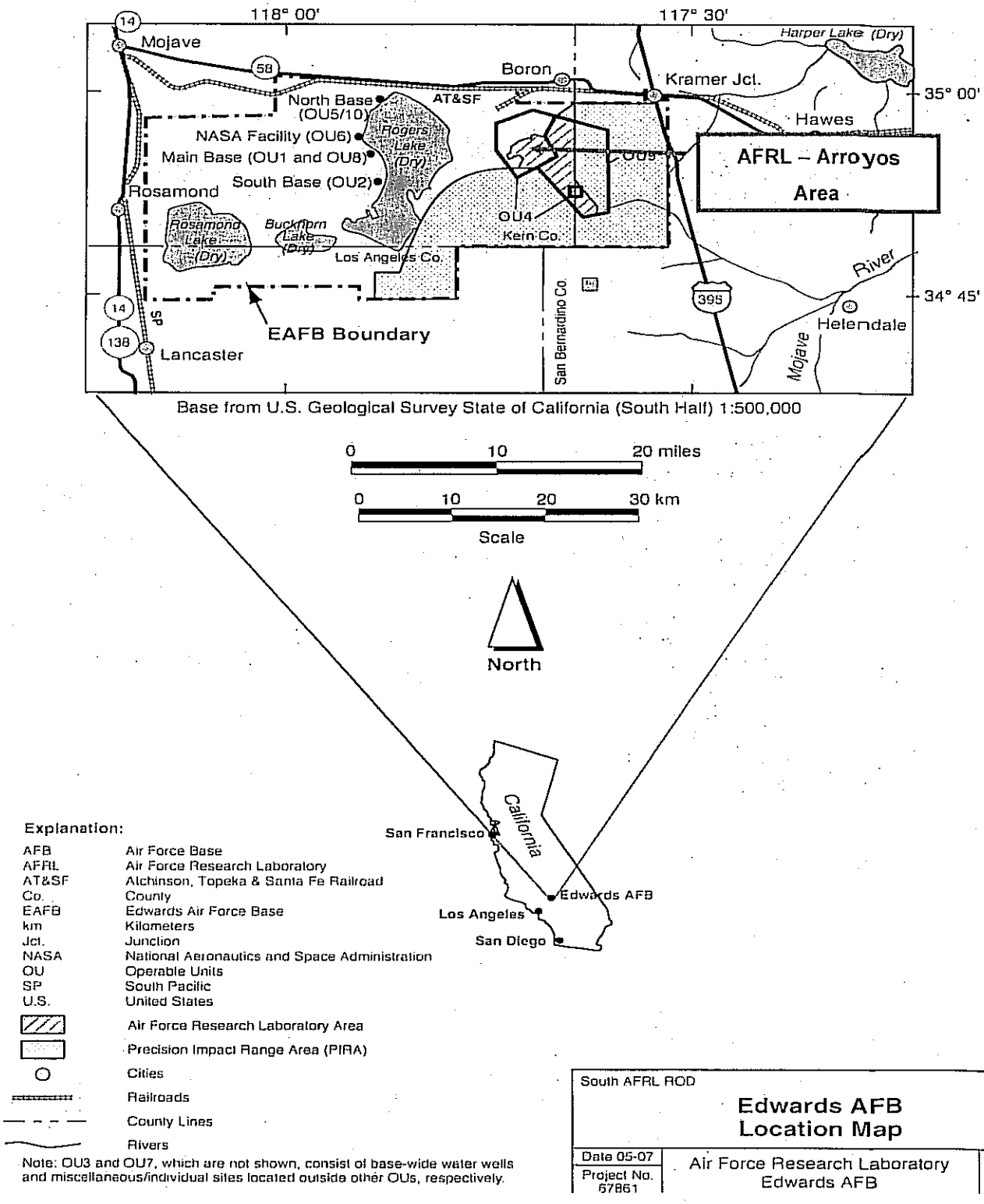

Figure 1. Edwards Air Force Base Location Map

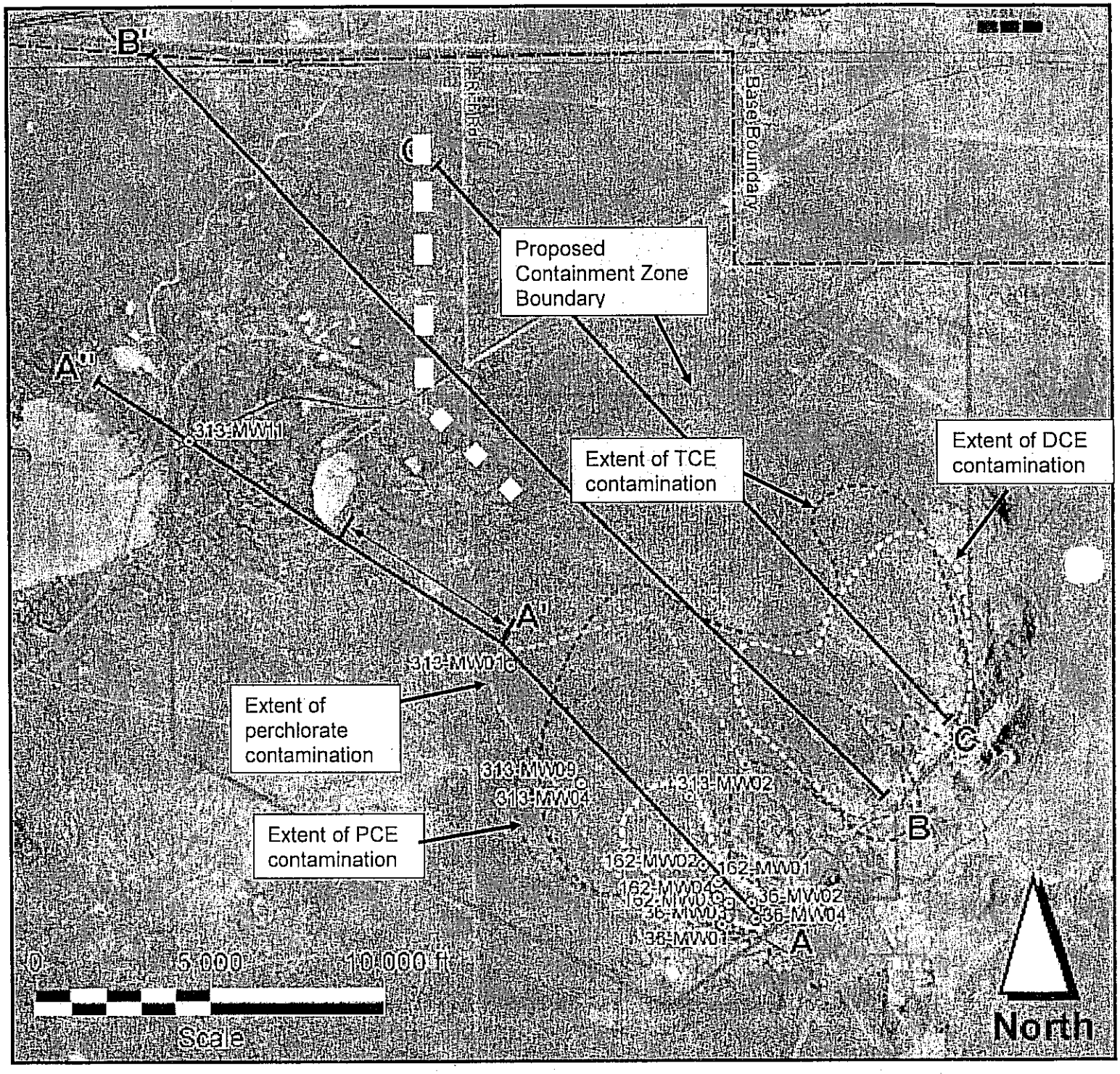

Figure 2. Arroyos Area Current Plume Extents & Major Sources Location Map

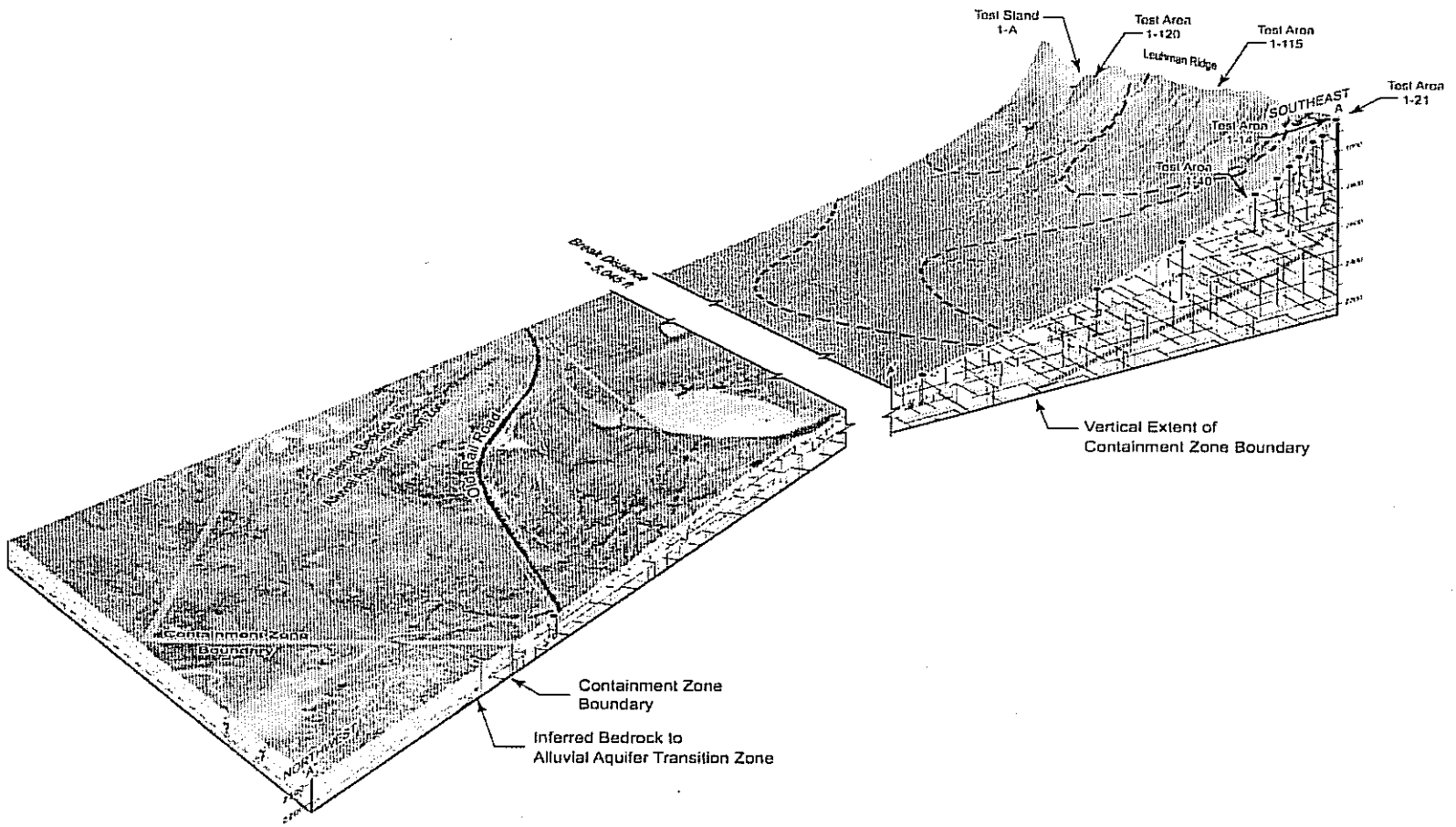

Figure 2a. Arroyos Area 3-D Cross Section (Looking toward the southeast along Section Line A-A'-A")