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Corrective Measures Evaluation Report for Tijeras Arroyo Groundwater

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Abstract

This Corrective Measures Evaluation report was prepared as directed by a Compliance Order on Consent issued by the New Mexico Environment Department to document the process of selecting the preferred remedial alternative for Tijeras Arroyo Groundwater. Supporting information includes background concerning the site conditions and potential receptors and an overview of work performed during the Corrective Measures Evaluation. The evaluation of remedial alternatives included identifying and describing four remedial alternatives, an overview of the evaluation criteria and approach, comparing remedial alternatives to the criteria, and selecting the preferred remedial alternative. As a result of the Corrective Measures Evaluation, monitored natural attenuation of the contaminants of concern (trichloroethene and nitrate) is the preferred remedial alternative for implementation as the corrective measure for Tijeras Arroyo Groundwater. Design criteria to meet cleanup goals and objectives and the corrective measures implementation schedule for the preferred remedial alternative are also presented.

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Acronyms

AOR	area of responsibility
ARG	ancestral Rio Grande
bgs	below ground surface
CME	Corrective Measures Evaluation
COA	City of Albuquerque
COC	contaminant of concern
COOC	Compliance Order on Consent
CMI	Corrective Measures Implementation
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ES&H	environment, safety, and health
ft	feet
FY	fiscal year
ISB	in situ bioremediation
KAFB	Kirtland Air Force Base
mg/L	milligrams per liter
MCL	maximum contaminant level
MNA	monitored natural attenuation
NMED	New Mexico Environment Department
RCRA	Resource Conservation and Recovery Act
sMMO	soluble methane monooxygenase
SNL/NM	Sandia National Laboratories/New Mexico
SWMU	Solid Waste Management Unit
TAG	Tijeras Arroyo Groundwater
TCE	trichloroethene
T&FR	technical and functional requirement
µg/L	micrograms per liter

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1.0 INTRODUCTION

Sandia National Laboratories, New Mexico (SNL/NM) is a government-owned, contractor-operated, multi-program laboratory overseen by the U.S. Department of Energy (DOE), National Nuclear Security Administration through the Sandia Site Office in Albuquerque, New Mexico. Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, operates SNL/NM under Contract DE-AC04-94AL85000. Activities conducted at the facility include:

- Research and development of advanced nuclear reactors,
- Simulation sources,
- Reactor safety,
- Energy-related programs, and
- Nuclear weapons systems.

The Tijeras Arroyo Groundwater (TAG) study area encompasses approximately 40 square miles (mi^2) located on the northwest portion of Kirtland Air Force Base (KAFB) (Figure 1-1). The name of the area is derived from Tijeras Arroyo, which is the most significant surface-water drainage feature within this area. There are three principal parties potentially responsible for groundwater contamination within the TAG study area: SNL/NM, KAFB, and the City of Albuquerque (COA). This Corrective Measures Evaluation (CME) report addresses groundwater contamination in the SNL/NM area of responsibility (AOR) within the TAG study area, as defined in Section 2.2.

Groundwater investigations conducted during the last 10 years by the SNL/NM Environmental Restoration Project have identified trichloroethene (TCE) and nitrate as the contaminants of concern (COCs) in the TAG SNL/NM AOR. The New Mexico Environment Department (NMED) issued a Compliance Order on Consent (COOC) (NMED 2004) to the DOE in which TAG was identified as an area of groundwater contamination requiring a CME. The COOC directed that a CME Work Plan be developed to identify and outline a process to evaluate remedial alternatives. The CME Work Plan was formally approved by the NMED in November 2004. Results of activities performed under the TAG CME Work Plan are documented in this CME Report.

The purpose of this CME Report is to select a preferred remedial alternative for the SNL/NM AOR based on the results of information gathered during the CME process. The CME was conducted to ascertain which remedial alternative would most effectively meet the project goals and objectives for cleanup within the regulatory framework. The performance and compliance goals and objectives were developed in the TAG CME Work Plan (SNL/NM 2004).

This document is organized in accordance with the COOC (NMED 2004) and the TAG CME Work Plan (SNL/NM 2004). Table 1-1 shows a crosswalk between the sections specified by the guidance of the COOC (as well as the CME Work Plan) and the sections of this document. Section 2.0 summarizes background information. Section 3.0 describes the remedial alternatives evaluation while Section 4.0 presents remedial alternative design criteria to meet the cleanup goals and objectives. Section 5.0 presents an outline for the Corrective Measures Implementation (CMI) Plan and presents the schedule for the CMI.

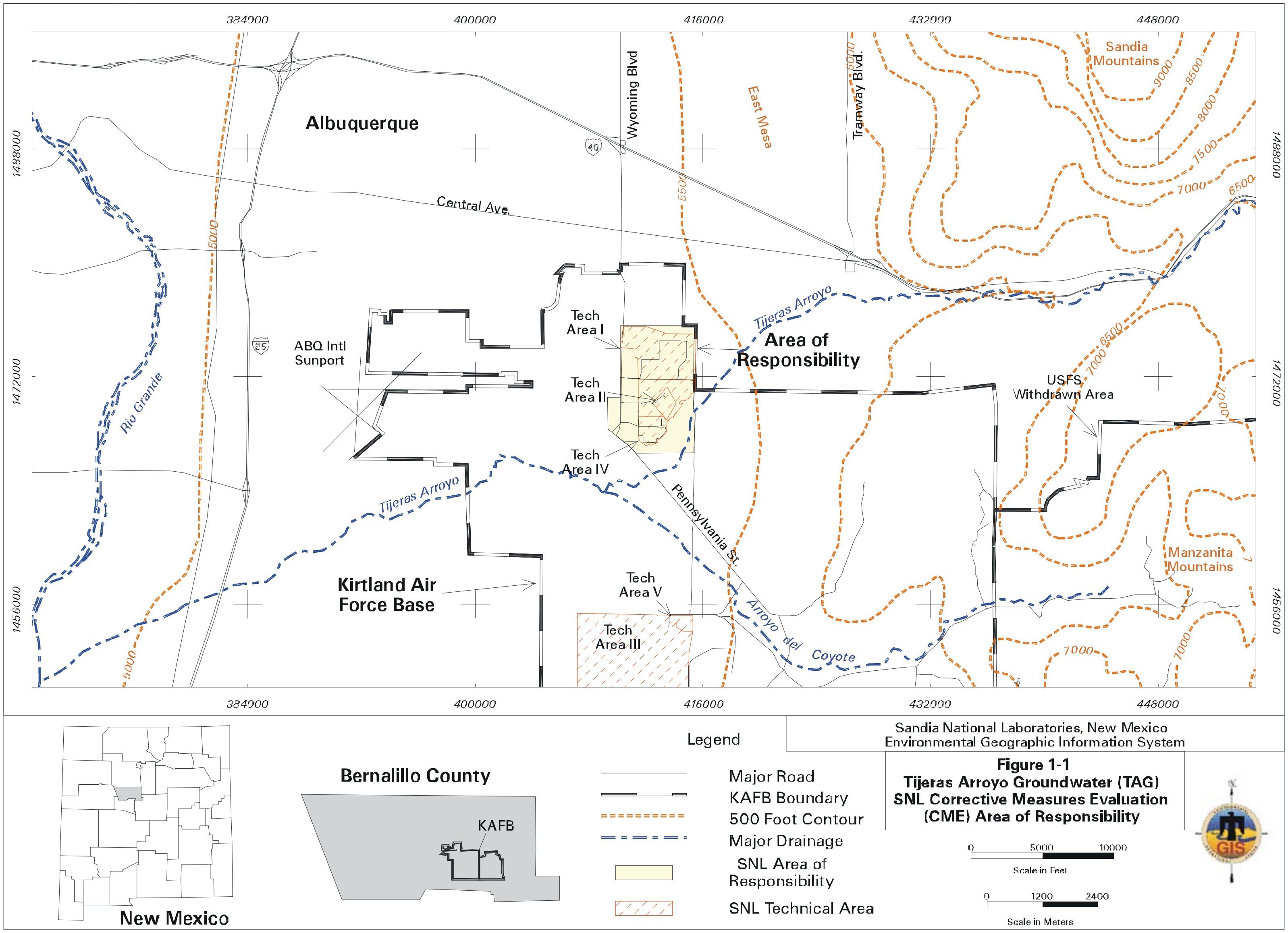

Figure 1-1. Tijeras Arroyo Groundwater SNL/NM area of responsibility.

Table 1-1. CME Report crosswalk table.

CME Report Requirements (as stated in the CME Work Plan and the COOC)	TAG CME Report (Section)
Introduction	1.0 Introduction
Background Information	2.0 Background Information
Site Conditions	2.1 Tijeras Arroyo Groundwater
Potential Receptors	2.2 SNL/NM Area of Responsibility for Tijeras Arroyo Groundwater
Regulatory Criteria	3.3 Evaluation Criteria
Identification of Remedial Alternatives	3.2 Identification and Description of Remedial Alternatives
Evaluation of Remedial Alternatives	3.0 Evaluation of Remedial Alternatives
Selection of a Preferred Remedial Alternative	3.4 Selection of a Preferred Remedial Alternative
Design Criteria to Meet Cleanup Objectives	4.0 Remedial Alternative Design Criteria to Meet Cleanup Goals and Objectives
Schedule	5.0 Corrective Measures Implementation Plan

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2.0 BACKGROUND INFORMATION

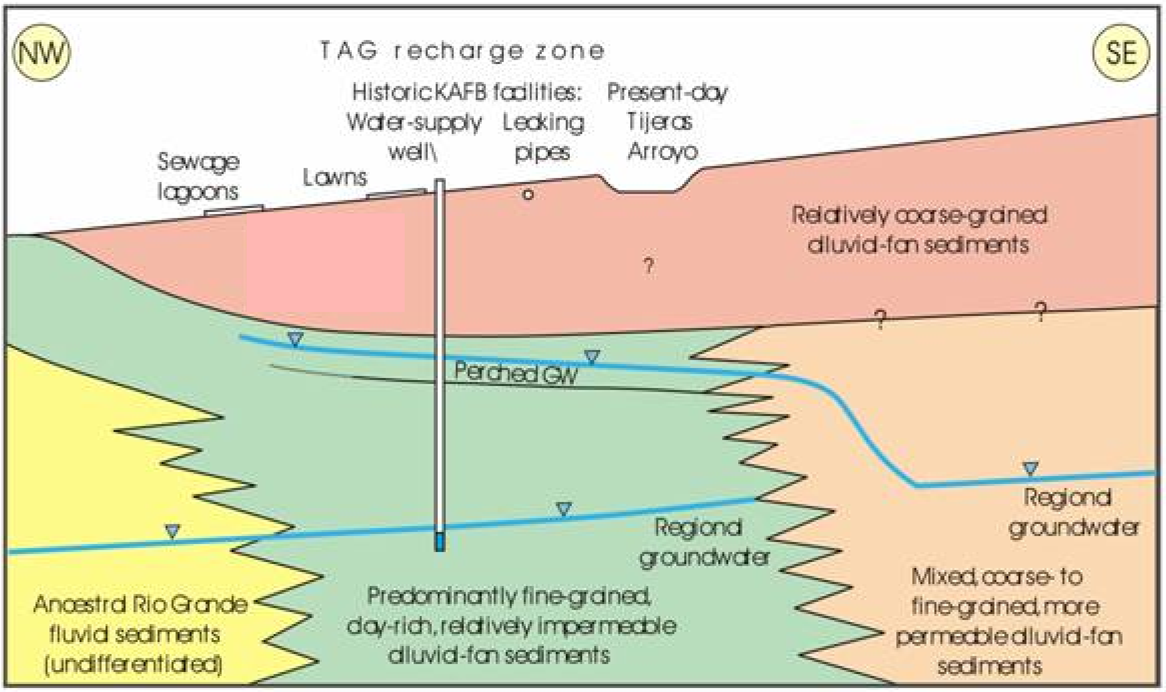
This section provides background information concerning the TAG study area (Section 2.1), the SNL/NM AOR within the TAG study area (Section 2.2), and COCs in the SNL/NM AOR (Section 2.3). Descriptions of site conditions and the project background, including delineation of SNL/NM responsibilities for contaminants in TAG, are included in the CME Work Plan (SNL/NM 2004).

This CME was completed as required by the COOC (NMED 2004) and under the direction of the CME Work Plan (SNL/NM 2004). Additional characterization activities at Tijeras Arroyo were performed simultaneously with the CME, in accordance with the *Tijeras Arroyo Groundwater Investigation Work Plan* (SNL/NM 2003), which is separate from the CME Work Plan. The TAG CME Work Plan and the TAG Investigation Work Plan both contain schedules that define dates for the delivery of plans and reports related to TAG. A Final TAG Investigation Report and the TAG CME Report were both scheduled for completion by September 30, 2005.

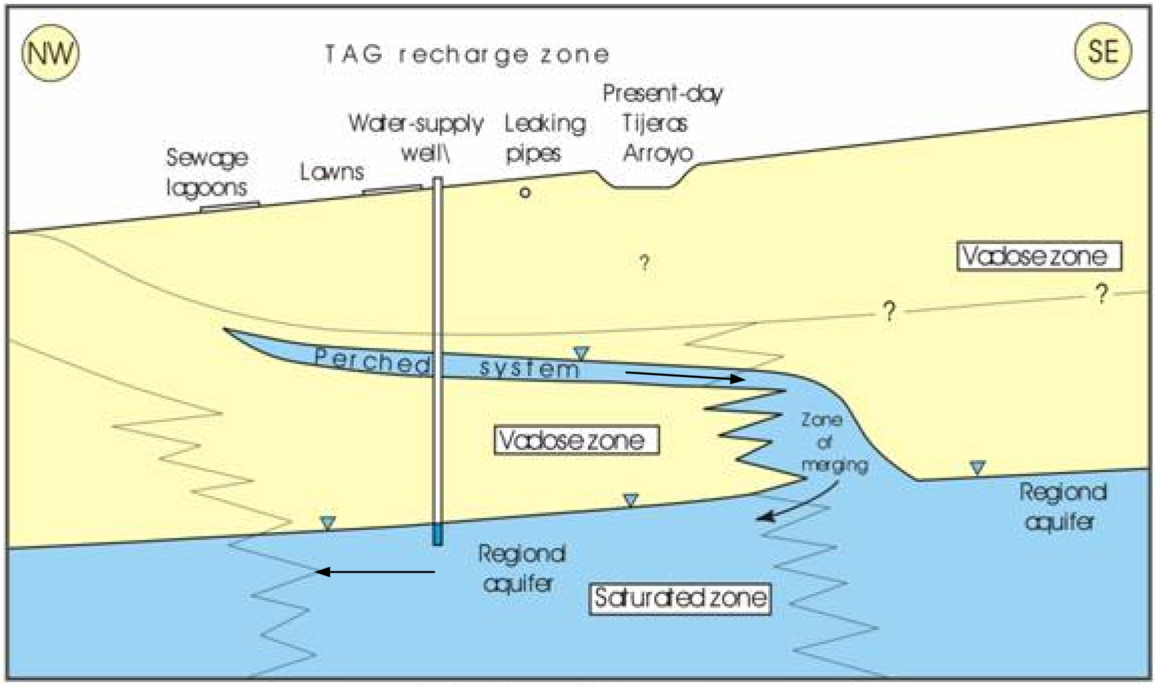
Although these schedules coincide, the COOC (NMED 2004) states that the CME process cannot proceed until characterization is sufficient. To meet the COOC schedule, SNL/NM proceeded with the CME assuming that the existing groundwater data were sufficient to commence the CME process. Throughout the CME process, the analytical data collected under the provisions of the TAG Investigation Work Plan were used to verify and supplement historical data. The groundwater analytical data collected under the provisions of the TAG Investigation Work Plan (SNL/NM 2003) are in agreement with historical concentrations (see Section 2.3 and Attachment A for details).

2.1 Tijeras Arroyo Groundwater

The TAG conceptual model is summarized in the CME Work Plan and illustrated in Figure 2-1. Two groundwater systems in the Upper Santa Fe Group have been identified in the TAG study area: (1) a perched groundwater system, and (2) the regional aquifer. In the northern portion of the TAG study area, the depth to potentiometric surface of the perched groundwater system ranges from approximately 220 to 330 ft below ground surface (bgs), whereas the depth to potentiometric surface of the regional aquifer is approximately 440 to 570 ft bgs. The perched groundwater system may merge with the regional aquifer in the southeastern portion of the perched groundwater system, although this connection has not been conclusively demonstrated. The upper-most saturated interval of the perched groundwater system is between 10 and 30 ft thick. Water in the perched system moves to the southeast and recharges the underlying regional aquifer southeast of Tijeras Arroyo. Groundwater in the regional aquifer migrates towards production wells.



A. Stratigraphic relationships.



B. TAG conceptual model.

DVH, Nov. 2002

Figure 2-1. TAG conceptual model (see SNL/NM 2004 for details).

2.2 SNL/NM Area of Responsibility for Tijeras Arroyo Groundwater

The scope of the SNL/NM CME includes only part of the TAG study area. Characterization of the TAG study area was undertaken by three potentially responsible parties: (1) SNL/NM, (2) the COA, and (3) KAFB. As a result, it was necessary for each party to clearly define their contribution to overall TAG remediation. The CME Work Plan (SNL/NM 2004) identified the specific area within the overall TAG study area for which SNL/NM has remediation responsibility. In order to clearly distinguish it from the overall TAG study area, the area that the CME addresses is referred to as the SNL/NM AOR.

The SNL/NM AOR encompasses an approximately two square miles area in the north-central part of KAFB. Figure 2-2 illustrates the location of 13 potential release sites within the SNL/NM AOR, as well as COA and KAFB potential release sites that are considered to be outside of the SNL/NM AOR. All of these potential release sites were included in the scope of the TAG study area investigations (SNL/NM 2002). For the SNL/NM AOR, only the 13 SNL/NM potential release sites were considered. These release sites are described in the CME Work Plan (SNL/NM 2004).

Based on a screening of potential release sites presented in the TAG Continuing Investigation Report (SNL/NM 2002), the potential SNL/NM AOR sources designated as a high concern level include:

- Solid Waste Management Unit (SWMU) 46 (Old Acid Waste Line Outfall)—TCE and nitrate,

- SWMU 227 (Bunker 904 Outfall)—TCE,

- SWMU 165 (Building 901 Septic System)—TCE and nitrate, and

- SWMU 187 (TA-I Sanitary Sewer System)—nitrate.

Historically, TCE and/or nitrate have been detected at sporadic locations in the SNL/NM monitoring well network (Figure 2-2). Data collected as part of the TAG Investigation indicate that TCE and/or nitrate at concentrations above their respective maximum contaminant levels (MCLs) have been detected in groundwater samples from five SNL/NM AOR monitoring wells, including TA2-W-26 (TCE), TA2-W-19 (TCE and nitrate), TJA-7 (nitrate), TA2-SW1-320 (nitrate), and TJA-2 (nitrate). TCE and nitrate contamination detected in samples from two other SNL/NM wells, WYO-4 (TCE) and TJA-4 (nitrate), are attributed to contaminant releases from KAFB, and therefore, were not included in the scope of this CME. Contamination detected in TA2-W-26 was considered as part of the SNL/NM AOR during the CME; however, it is noteworthy that this well is located cross-gradient of a potential TCE source operated by the COA (Eubank landfill), and cross-gradient or up-gradient of the potential TCE sources mentioned in the SNL/NM AOR.

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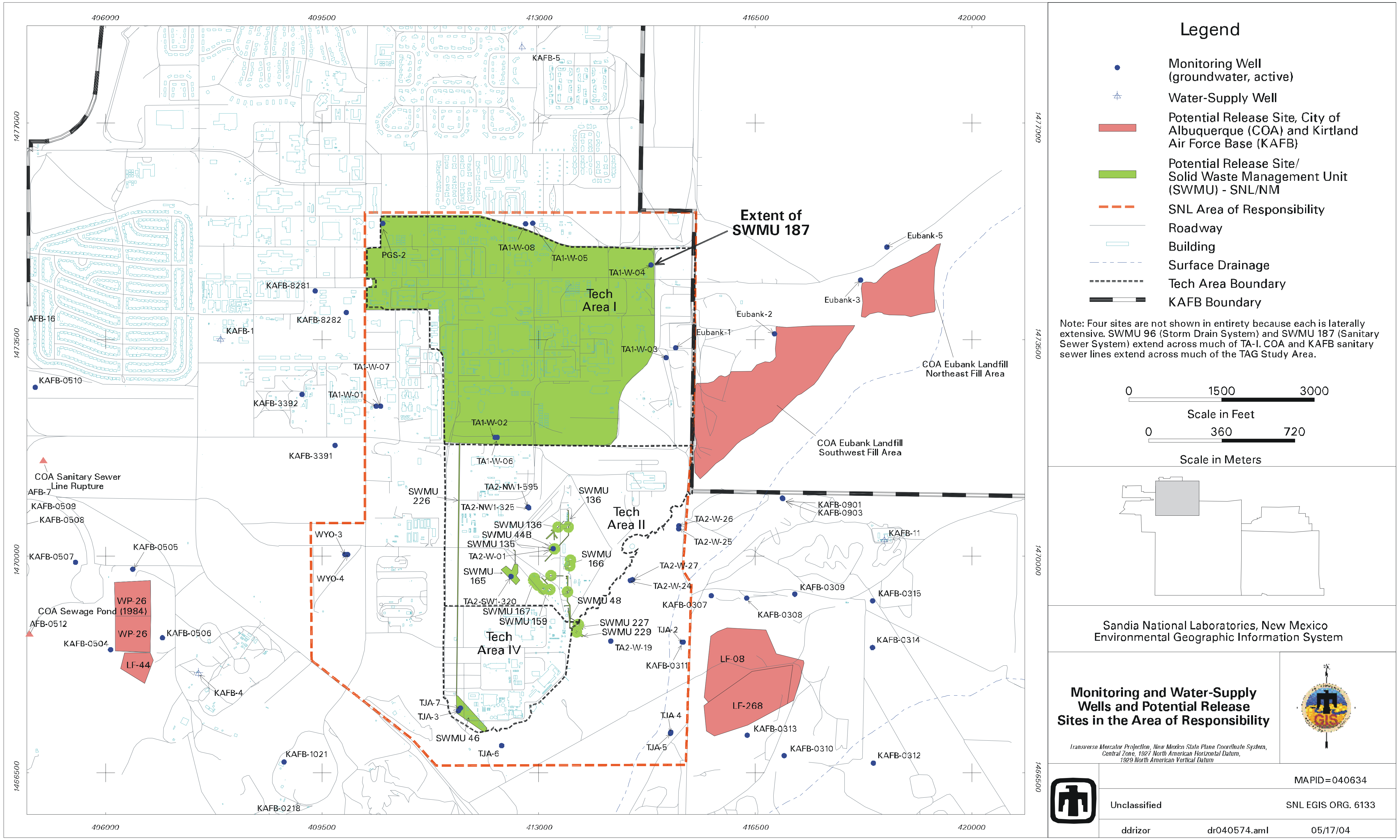

Figure 2-2. Monitoring and water supply wells and potential release sites in the area of responsibility.

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2.3 Contaminants of Concern

TCE and nitrate are the COCs for the TAG SNL/NM AOR. These contaminants have been identified based on historical groundwater monitoring results. The Environmental Protection Agency (EPA) and State of New Mexico drinking water standards (MCLs) for TCE and nitrate are 5 µg/L and 10 mg/L (as nitrogen), respectively. The SNL/NM AOR maximum historical concentrations and the maximum concentrations from a more recent sampling event are shown in Table 2-1.

Table 2-1. COCs in the TAG SNL/NM area of responsibility.

Contaminant	Maximum Historical Concentrations	Maximum Concentration from October 2004 Sampling	Federal/ New Mexico Drinking Water Standard (MCL)
VOLATILE ORGANIC COMPOUND (Perched System)			
Trichloroethene (TCE)	9.6 µg/L[a]	4.7 µg/L[b]	5 µg/L[d]
INORGANIC CHEMICAL (Perched System)			
Nitrate (as nitrogen)	44 mg/L[a]	27.1 mg/L[c]	10 mg/L[e]

µg/L = micrograms per liter
mg/L = milligrams per liter

a. Maximum concentrations detected in samples from any SNL/NM AOR well reported as of October 2004.
b. This was the maximum concentration detected in samples from any SNL/NM AOR well during the October 2004 sampling round and was detected in a sample from well TA2-W-19.
c. This was the maximum concentration detected in samples from any SNL/NM AOR well during the October 2004 sampling round and was detected in a sample from well TJA-7.
d. 40 CFR 141.61, “Maximum Contaminant Levels for Organic Contaminants”
e. 40 CFR 141.62, “Maximum Contaminant Levels for Inorganic Contaminants”

The CME addresses COCs found in the SNL/NM AOR. Attachment A contains time series COC concentration plots from five SNL/NM AOR wells from which concentrations of COCs have been detected above the MCL since 1999. These wells are:

- TA2-W-26 (TCE),
- TA2-W-19 (TCE and nitrate),
- TJA-7 (nitrate),
- TA2-SW1-320 (nitrate), and
- TJA-2 (nitrate).

No samples collected from SNL/NM AOR wells completed in the regional aquifer exceeded the MCL for either TCE or nitrate; therefore, no COCs have been identified for the regional aquifer. The CME focused exclusively on TCE and nitrate contamination in the perched groundwater system.

Maximum historical concentrations were used for the CME; however, it is noteworthy that more recent concentrations of these COCs have been substantially lower than historical maximum concentrations, as shown in Table 2-1 and Attachment A. The most current analytical data show that concentrations of both COCs are not increasing. Future groundwater monitoring data will be necessary to identify any declining trend because of the relatively slow rate of natural attenuation processes and the need for a longer sampling period using consistent methods. The historical data indicate that the extent of TCE and nitrate-contaminated groundwater is stable, or not expanding, because concentration trends are not increasing in perched system monitoring wells, and there are no continuing sources of contamination (SNL/NM 2004).

2.4 Potential Receptors

Production wells completed in the regional aquifer of the Albuquerque Basin are the only exposure pathways for COCs (TCE and nitrate) from the SNL/NM AOR to reach human receptors. These production wells are owned and operated by the COA, KAFB, and the Veterans Administration. Currently, there are no production wells in the perched system that access COC-contaminated groundwater from the SNL/NM AOR for domestic or industrial uses. The perched system does not discharge to any springs, and the depth to groundwater ranges from approximately 220 to 330 ft bgs. Therefore, COCs are inaccessible to human and ecological receptors. Although the COCs are currently inaccessible, the perched groundwater system probably merges with the regional aquifer southeast of the SNL/NM AOR. Evaluating the potential for transport of contaminants to production wells in the regional aquifer is summarized in Section 3.1.2 and presented in detail as Attachment C.

3.0 EVALUATION OF REMEDIAL ALTERNATIVES

This section presents detailed information gathered during the CME to evaluate the remedial alternatives. This work was directed by the CME Work Plan (SNL/NM 2004), which is summarized in Section 3.1. The remedial alternatives evaluated in this CME Report are identified and described in Section 3.2; an overview of the evaluation criteria and approach is provided in Section 3.3; and Section 3.4 identifies the preferred remedial alternative.

3.1 Overview of the Corrective Measures Evaluation

An initial list of 13 TCE and 7 nitrate treatment technologies was identified in the CME Work Plan (SNL/NM 2004). These technologies were screened based on applicability of each technology to the site. Following this technology screening, four technologies remained. These four technologies (Section 3.2) were identified as the four remedial alternatives to be considered for evaluation during the CME process, as shown in Figure 3-1.

The CME Work Plan identified four potential data-gathering activities that may be performed during the CME, as follows:

1. Paper study,
2. Numerical modeling,
3. Laboratory studies, and
4. Field-scale studies.

In accordance with the CME Work Plan (SNL/NM 2004), only activities that were determined to be necessary were performed. The utility of each data-gathering activity was determined in the Remedial Alternatives Data Gaps Review, which is summarized in Section 3.1.1 and included as Attachment B. Reports were prepared to document the results of each of the data-gathering activities. A summary of each report is presented in Sections 3.1.1 through 3.1.4. The reports are included in this CME Report as Attachments B through E. Figure 3-2 and Table 3-1 illustrate the CME process and list the reports, respectively.

The purpose of these reports was to:

- Report results and interpretation of results to the project leader, technical peer review panel, and technical support personnel;
- Document decisions made during the CME process and the results of the data-gathering stages; and
- Provide supporting information for the CME Report.

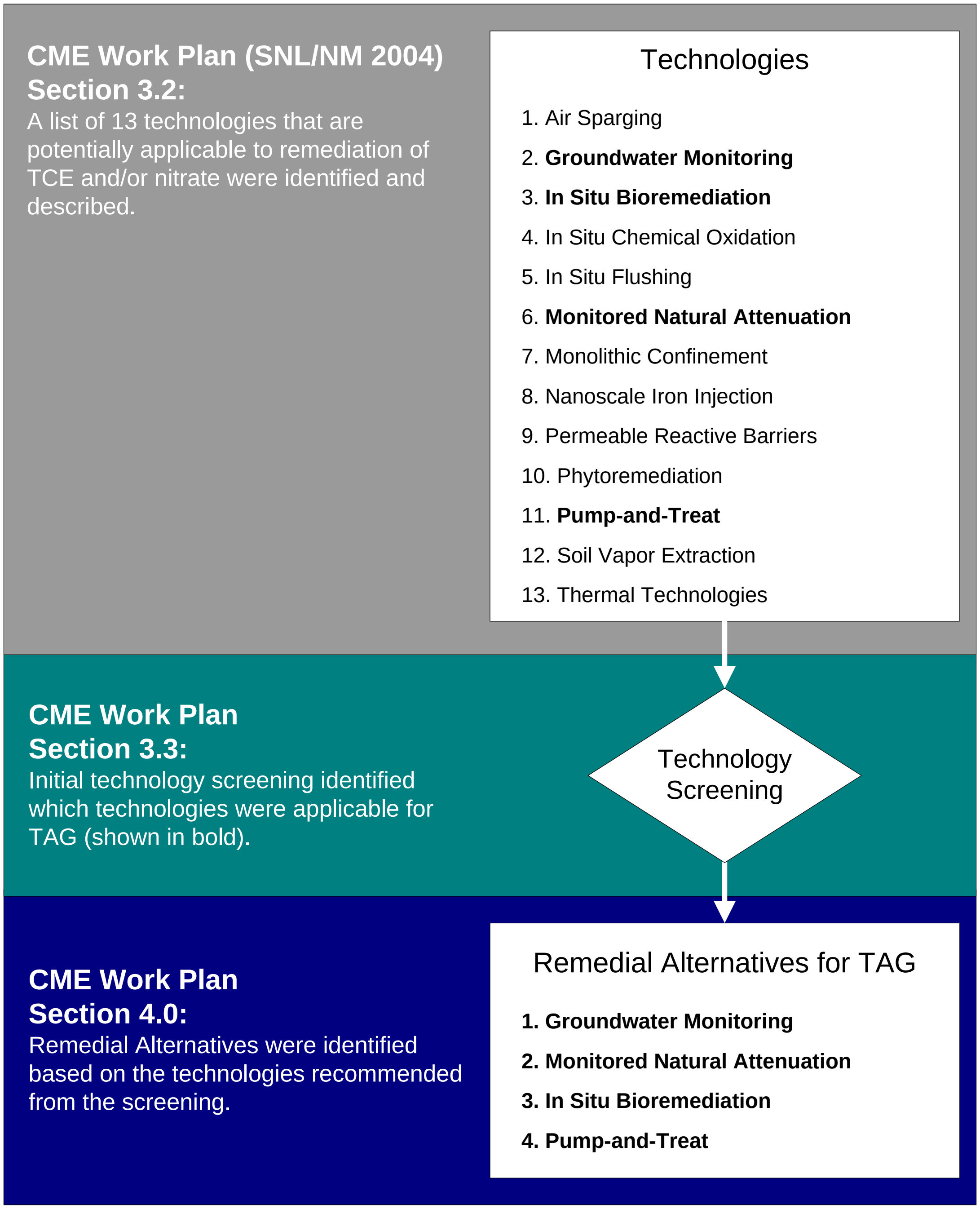


Figure 3-1. Illustration of the process of identifying remedial alternatives from the CME Work Plan (SNL/NM 2004).

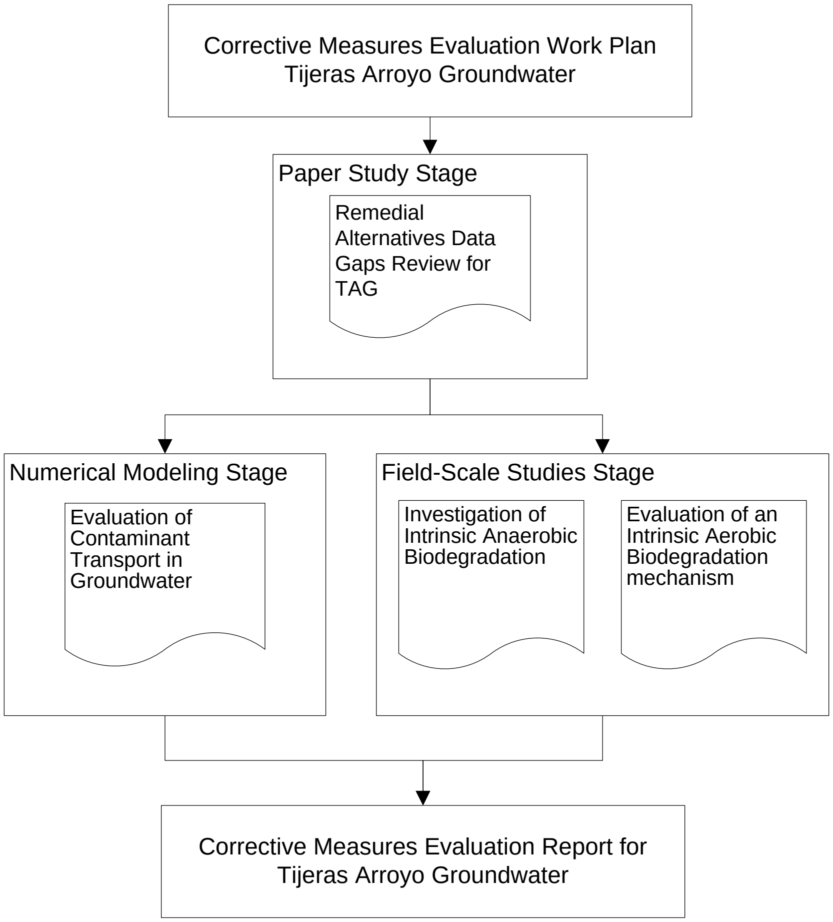


Figure 3-2. Illustration of the staged process of data gathering activities and production of informal reports.

Table 3-1. Documents produced in support of the CME.

CME Stage	Section in CME Report	Document Title	Attachment
Paper Study	Section 3.1.1	Remedial Alternatives Data Gaps Review	Attachment B
Numerical Modeling	Section 3.1.2	Evaluation of Contaminant Transport in Groundwater	Attachment C
Field-scale Studies	Section 3.1.3	Investigation of Intrinsic Anaerobic Biodegradation	Attachment D
Field-scale Studies	Section 3.1.4	Evaluation of an Intrinsic Aerobic Biodegradation Mechanism	Attachment E

3.1.1 Remedial Alternatives Data Gaps Review

The Remedial Alternatives Data Gaps Review documents the results of the paper study. The Remedial Alternatives Data Gaps Review presents conceptual designs for each remedial alternative. These conceptual designs include an overview of the remedial alternative, a description of the technical and functional requirements (T&FRs), and a list of the expected costs. The complete report is included as Attachment B.

A preliminary remedial alternative evaluation was performed based on information gathered during the paper study stage, which was the first stage of the CME process. This preliminary remedial alternative evaluation was intended to be updated upon completion of subsequent CME stages. The final remedial alternative evaluation is presented in Section 3.4. Completion of this Remedial Alternatives Data Gaps Review resulted in the following two conclusions:

1. Of the initial list of four remedial alternatives stated in the CME Work Plan (SNL/NM 2004), two remedial alternatives (groundwater monitoring and monitored natural attenuation [MNA]) were recommended for continued evaluation during the remainder of the CME (Figure 3-3).

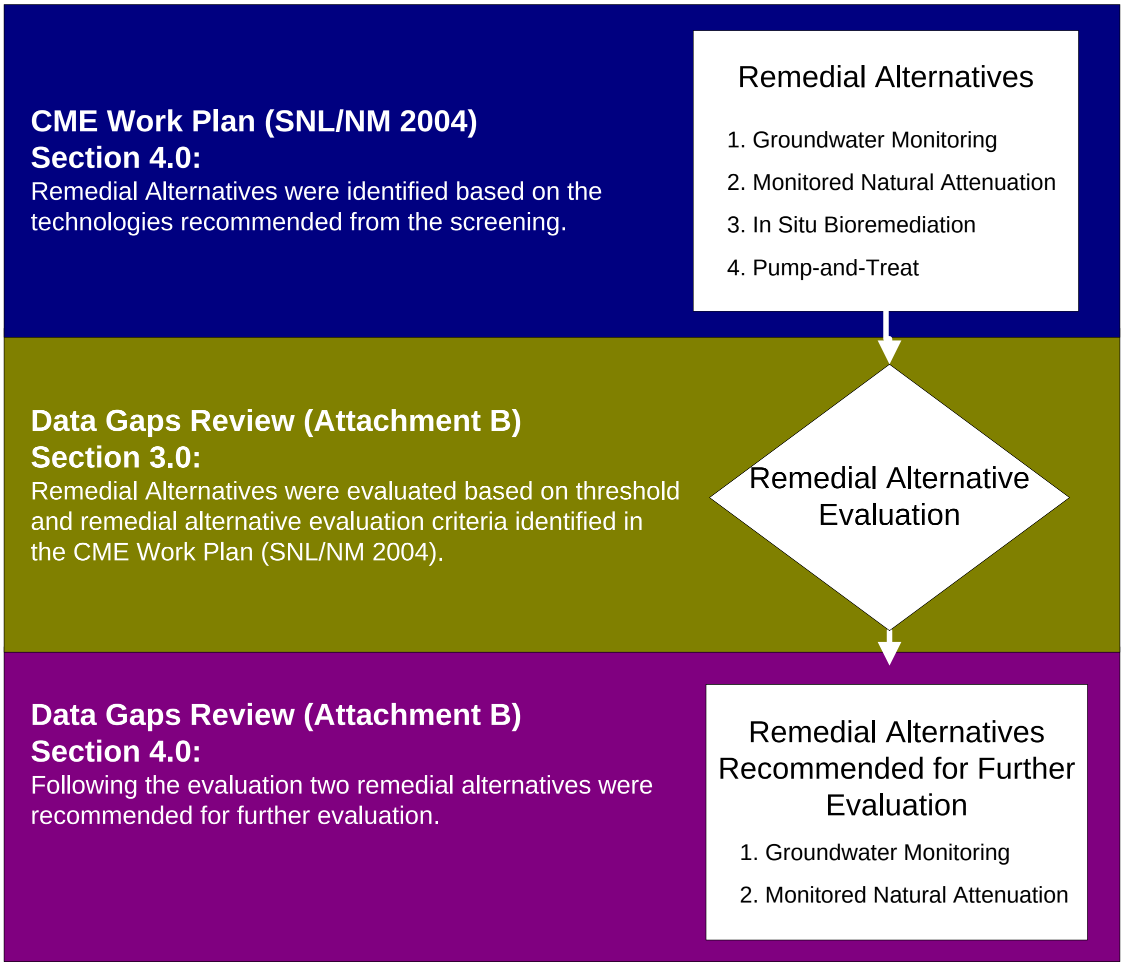
2. Data-gathering activities for the two remaining alternatives were recommended for two of the CME stages (numerical modeling and field-scale studies). Several of the data gathering activities discussed as possibilities in the CME Work Plan were determined to be unnecessary because they would provide data to evaluate alternatives that were not recommended for further evaluation (as shown in Figure 3-3).

Based on the information gathered, assessed, and summarized in the Remedial Alternatives Data Gaps Review, recommendations were made regarding the need to conduct activities to evaluate the two remaining remedial alternatives during the final three CME stages, as follows:

- Numerical modeling to determine the fate and transport of contaminants in the perched groundwater system of the SNL/NM AOR,
- Field-scale studies:
    - Investigation of anaerobic mechanisms of biodegradation during natural attenuation, and
    - Investigation of aerobic TCE biodegradation mechanisms during natural attenuation, as planned in the CME Work Plan (SNL/NM 2004).

The following activities were described in the CME Work Plan as potential activities but were not recommended because the remedial alternatives they support were eliminated in the Data Gaps Review:

- Laboratory studies to determine if microbes can be induced to degrade TCE,
- Field-scale studies:
    - An amendment injection field demonstration to evaluate in situ bioremediation (ISB) and estimate design parameters, and
    - Aquifer tests to determine pumping rates in a new extraction well for pump-and-treat implementation.



CME Work Plan (SNL/NM 2004)
Section 4.0:
Remedial Alternatives were identified based on the technologies recommended from the screening.

Data Gaps Review (Attachment B)
Section 3.0:
Remedial Alternatives were evaluated based on threshold and remedial alternative evaluation criteria identified in the CME Work Plan (SNL/NM 2004).

Data Gaps Review (Attachment B)
Section 4.0:
Following the evaluation two remedial alternatives were recommended for further evaluation.

Figure 3-3. Illustration of remedial alternative evaluations performed during the paper study.

3.1.2 Evaluation of Contaminant Transport in Groundwater

A numerical modeling study was performed to evaluate potential for a change in contaminant concentrations during transport to production wells located within the regional aquifer. The complete Evaluation of Contaminant Transport report is included as Attachment C.

This evaluation utilized a cross-sectional analysis to assess downgradient transport and dilution of nitrate and TCE, which were simulated as conservative solutes. The effects of dispersion, degradation, and sorption were intentionally neglected. Recognizing that the cross-sectional numerical flow and transport models would not be a rigorous representation of the system, several conservative assumptions were made so that the effects of dilution would be intentionally underestimated. The analysis consisted of the following three parts: (1) an estimate of discharge from the perched groundwater system, (2) simulation of transport through the alluvial fan lithofacies, and (3) simulation of transport through the ancestral Rio Grande (ARG) deposits. Contaminant concentrations were estimated for potential human receptors via production wells completed in the ARG lithofacies. The conclusions are as follows:

- The historical maximum nitrate concentration in the perched groundwater system (44 mg/L) will be reduced to 0.24 mg/L (as nitrogen) before reaching production wells completed in the ARG.
- The historical maximum TCE concentration in the perched groundwater system (9.6 µg/L) will be reduced to <0.03 µg/L before reaching production wells in the ARG.

The estimated travel times from the current locations of nitrate and TCE in the perched groundwater system to the ARG lithofacies where production wells are completed are at least 130 years for nitrate and at least 140 years for TCE. These travel times represent the arrival of the maximum predicted concentration at the production wells; however, as predicted, these maximum concentrations will not exceed MCLs. The estimated travel times are slightly different because the contaminants are currently in two different locations in the perched groundwater system. These travel times represent minimum or conservative estimates because solute retardation, travel time through the zone of merging, and travel time through the ARG were intentionally neglected.

3.1.3 Investigation of Intrinsic Anaerobic Biodegradation

An investigation of anaerobic contaminant biodegradation was performed as part of the CME to evaluate MNA. The complete Investigation of Intrinsic Anaerobic Biodegradation report is included as Attachment D. This evaluation was performed using the volatile organic compound contaminant biodegradation screening assessment described in the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (EPA 1998) and a biodegradation evaluation for nitrate.

The evaluation used sample data collected during six quarterly sampling rounds, beginning with the fourth quarter of Fiscal Year (FY) 2003 and ending with the first quarter of FY 2005. For each parameter, the significance of the data relative to assessing biodegradation and general observations was evaluated. The results indicated that biodegradation of TCE via the process of anaerobic reductive dechlorination is not occurring. In addition, biodegradation of nitrate via denitrification is not occurring.

3.1.4 Evaluation of an Intrinsic Aerobic Biodegradation Mechanism

As part of the CME, a field-scale study was performed to investigate the natural attenuation mechanism of aerobic biodegradation via cometabolic oxidation. The complete Evaluation of Intrinsic Aerobic Degradation report is included as Attachment E. This field study coupled enzyme activity probes (evidence of cometabolic enzyme activity) with DNA analysis (evidence of cometabolic gene presence) to evaluate cometabolic activity, or the potential for such activity in TAG.

Enzyme activity probes provide direct evidence that the mechanism for aerobic cometabolic oxidation of chlorinated ethenes is present and active in a given sample. Organisms that oxidize substrates (i.e., toluene or methane) also oxidize TCE. Thus, cometabolism of TCE will occur if the appropriate enzymes are both present and active. Probes that serve as alternate substrates for TCE cometabolizing enzymes have been developed for several of the toluene oxygenases and for the soluble methane monooxygenase (sMMO). These non-fluorescent probes are transformed by oxygenase enzymes into strongly fluorescent products, providing a clear, quantifiable signal only when the enzyme of interest is actively functioning. In addition to the enzyme probes, a series of control and inhibition studies were performed to verify the detected oxygenase activity.

The results of the analysis determined the presence and activity of at least one toluene oxygenase or sMMO enzyme in all but one (WYO-4) of the 12 wells sampled based on the application of enzyme activity probes. Fifty percent of the wells showed activity with the sMMO enzyme probe, while 92% (11 out of 12) showed a response with the toluene probes. Any positive response, even with only one probe, provides direct evidence of enzyme activity in the groundwater sample. Control studies confirmed the findings of the enzyme probe data, specifically that the probes accurately and efficiently targeted specific oxidative pathways. Inhibition studies confirmed that the activity measured was a result of the enzyme targeted and other oxygenase enzymes.

The detection of both sMMO and toluene oxygenase enzyme activity, as determined by enzyme activity probes in TAG samples, identifies cometabolism as a mechanism of natural attenuation. Active enzymes were found throughout the tested area, including samples taken from both inside and outside the TCE contamination area, in the perched groundwater system, and at all regional aquifer wells. These data provide conclusive evidence of active enzyme systems capable of TCE degradation and, more importantly, represent an active mechanism for the natural attenuation of TCE.

3.2 Identification and Description of Remedial Alternatives

Four remedial alternatives were identified in the CME Work Plan (SNL/NM 2004). These remedial alternatives included: (1) groundwater monitoring, (2) MNA, (3) ISB, and (4) pump-and-treat. Following a remedial alternative evaluation performed as part of the paper study (see Section 3.1.1 and Attachment B), two of the four remedial alternatives, Groundwater Monitoring and MNA, were recommended for further evaluation. ISB and pump-and-treat were determined to be significantly less effective than the other remedial alternatives and were therefore eliminated (Attachment B, Section 3.2). Analysis of contaminant transport (Section 3.1.2) and determination of the presence of an aerobic biodegradation mechanism for TCE (Section 3.1.4) demonstrated that natural attenuation mechanisms are present for both COCs. Evidence of these natural attenuation mechanisms no longer allows for an accurate comparison of groundwater monitoring and MNA as separate remedial alternatives. Evidence of these mechanisms precludes the need to evaluate groundwater monitoring, which is a remedial alternative that does not consider natural attenuation. Therefore, groundwater monitoring is no longer being considered. The remaining remedial alternative, MNA, is described in this section.

Implementation of MNA requires careful consideration of site conditions, including identifying natural attenuation mechanisms and potential receptors. MNA is not a default or presumptive remedial alternative but rather is an acceptable remedial alternative to be evaluated with other alternatives (EPA 1999). The EPA has provided policy and guidance on the use of MNA as a remedy in *Use of MNA at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (EPA 1999). The DOE used principles set forth in EPA's directive as a foundation for a decision-making framework for evaluating the effectiveness of MNA. This framework is set forth in the *Decision-Making Framework Guide for the Evaluation and Selection of Monitored Natural Attenuation Remedies at Department of Energy Sites* (DOE 1999). This decision-making framework was used when considering the MNA remedial alternative during the CME. Figure 3-4 is an illustration of DOE's tiered approach to evaluating MNA.

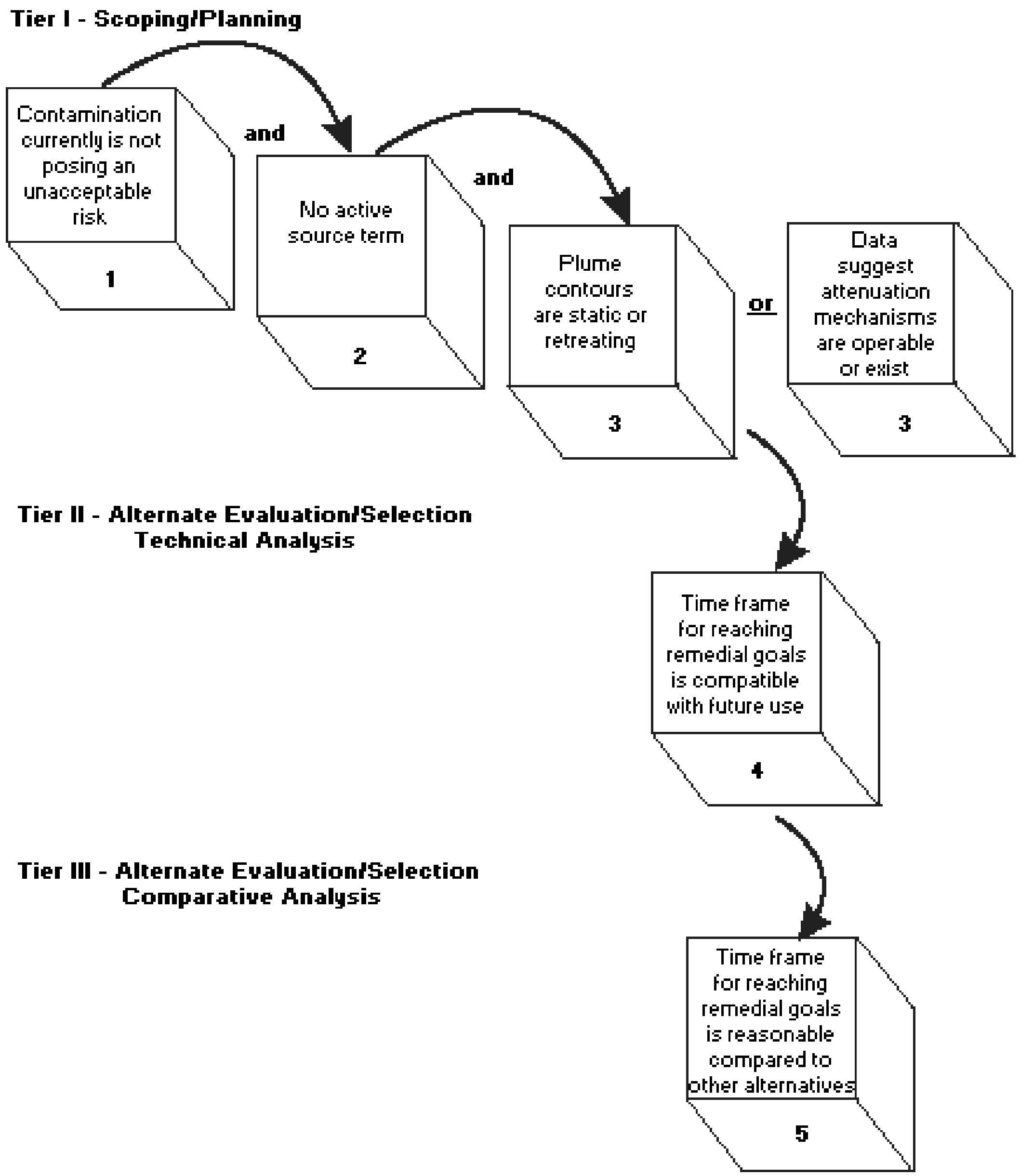


Figure 3-4. Decision framework for evaluating MNA (from DOE 1999).

MNA has been found to be an appropriate and applicable remedial alternative for the TAG SNL/NM AOR. Determinations made concerning each of the tiers of the decision-making framework are as follows:

1. **Tier I. Item 1. Contamination currently is not posing an unacceptable risk—**The contaminated groundwater in the perched system is currently inaccessible to potential receptors, because depth to potentiometric surface of the perched system ranges from approximately 220 to 330 ft bgs (SNL/NM 2004). In addition, the evaluation of contaminant transport in groundwater (Section 3.1.2 and Attachment C) demonstrated that contaminants do not pose an unacceptable risk to potential receptors via regional aquifer production wells in the future.

2. **Tier I. Item 2. There is no active source term—**An active source term is defined as a source inventory of contaminant that is being released to groundwater where the rate of contaminant release is greater than attenuation rates such that the inventory of mobile contaminants is increasing over time (DOE 1999). The approved CME Work Plan (SNL/NM 2004) identified four potential COC release sites of high concern. As summarized in the CME Work Plan, soil and soil vapor sampling and analyses have demonstrated that there are no continuing sources of COCs to groundwater in the vadose zone. Releases of wastewater to the groundwater have ceased, and all potential release sites are described in detail in the *Tijeras Arroyo Groundwater Continuing Investigation Report* (SNL/NM 2002).

3. **Tier I. Item 3. Plume contours are static or are retreating or data suggests that attenuation mechanisms are operable or exist—**COC concentration data (presented in Attachment A) show that COC concentrations are not increasing in groundwater within the SNL/NM AOR. In addition, natural attenuation mechanisms have been demonstrated. Natural attenuation processes or mechanisms may include biodegradation, dispersion, dilution, sorption, volatilization, stabilization, transformation, or destruction of contaminants (EPA 1999). The approach used during the CME process to evaluate MNA was to focus on investigating two of these natural attenuation mechanisms, dilution and biodegradation. Although other natural attenuation mechanisms may be operable, further reducing contaminant concentrations, they were not evaluated. Evaluation of dilution during transport (Section 3.1.2 and Attachment C) has demonstrated that this mechanism will reduce COC concentrations to well below their respective MCLs before reaching production wells. Evaluation of biodegradation mechanisms (Section 3.1.4 and Attachment E) has demonstrated that a mechanism for aerobic biodegradation of TCE exists.

4. **Tier II. Item 4. Timeframe for reaching remedial goals is compatible with future use—**There is no current use of TAG; however, in the future, perched system groundwater may migrate into the regional aquifer and then west and north off of KAFB where it could be extracted from the aquifer for potable water. The transport evaluation (Section 3.1.2 and Attachment C) demonstrates that contaminants derived from the SNL/NM AOR will never exceed the MCL at production wells completed in the ARG facies; hence, the remedial timeframe is compatible with future uses.

5. **Tier III. Item 5. Timeframe for reaching remedial goals is reasonable compared to other alternatives—**Consideration of the remedial timeframe is part of the criteria used to evaluate remedial alternatives (Section 3.3). A preliminary evaluation of remedial alternatives was performed using these criteria (see Section 3.1.1 and Attachment B). Natural attenuation processes are slower than the more active remediation strategies considered during the CME; however, considering the physical site constraints to implementing these other remedies, the longer timeframe for MNA is reasonable (see Attachment B for a discussion and comparison of these remedial alternatives).

Given these criteria and site-specific information, MNA is an appropriate remedial alternative for the SNL/NM AOR. The T&FRs that apply to the MNA remedial alternative are presented in Table 3-2. Assumptions of these T&FRs include the capability to monitor for the appropriate remedial timeframe, which will require maintaining the necessary equipment, utilities, personnel availability, and a sufficient monitoring well network. Cost elements to be considered for implementing MNA are outlined in Table 3-3 and include capital equipment and operations and maintenance cost items, as defined in Section 3.3.2.

Table 3-2. Technical and functional requirements for MNA.

Parameter	Requirement
Duration of monitoring	Groundwater monitoring will continue until it is demonstrated that contaminants are below MCLs for a period of time that will be determined during preparation of the CMI Plan.
Frequency of monitoring	Annual.
Analytes	All COCs (nitrate and TCE), water levels, and other parameters.
Analyses	The monitoring data will be analyzed and interpreted. This data will be used to monitor attenuation mechanisms and track COC concentration changes.
Reporting	Annual reporting for an initial performance operations period, followed by less frequent reporting during a long-term operations period. Reports will include analysis of concentration trends and comparison to predicted trends of attenuation, which will be included in the CMI Plan.
Replacement monitoring wells	The monitoring well network will be maintained throughout the remedial timeframe. Replacement of wells may be necessary due to regional water-level decline or other factors.
Equipment	All equipment necessary for monitoring, including pumps, sample bottles, power (generator or utilities), shipping supplies, purge water tanks, personal protection equipment, and any other necessary equipment shall be maintained for the duration of the monitoring program.
Equipment storage	Storage for field sampling equipment.
Waste storage	Storage of purge water until authorized to dispose.
Institutional controls	Institutional controls consist of engineering and administrative controls to protect current and future users from health risks associated with exposure to contaminated groundwater. Engineering controls consist of methods to restrict access to contaminated water, including locking devices on wellheads. Administrative controls include postings on wellheads identifying potential hazards and placing written notification of this corrective measure in the facility land-use master plan.
Operations	Operations consist of groundwater monitoring and maintenance associated with institutional controls.
Facilities	No additional facilities are required.

Table 3-3. Cost elements for the MNA remedial alternative.

Capital	Operations and Maintenance
• Costs associated with designing a long-term groundwater monitoring program • Indirect costs (legal and permitting fees)	• Costs of maintaining an adequate monitoring well network for the duration of the remedy. • Sampling and analyses costs. • Costs for data analyses and interpretation. • Reporting costs for the duration of the remedy. • Indirect operational costs, including institutional controls, contingency allowances, and administrative costs.

3.3 Evaluation Criteria

As presented in Section 3.2, MNA is an applicable remedial alternative for the SNL/NM AOR based on EPA guidance (EPA 1999) and DOE's decision-making framework guide (DOE 1999). This section is a presentation of how the MNA remedial alternative compares to the threshold and remedial alternative evaluation criteria described in the CME Work Plan (SNL/NM 2004) and specified in the COOC (Section VII.C.3, CME Criteria [NMED 2004]).

3.3.1 Threshold Criteria

As stated in the COOC (NMED 2004), in order to be selected, a remedy must meet the following threshold criteria:

- **Protective of human health and the environment.** Any proposed remedy must be protective of human health and the environment. As stated in the Resource Conservation and Recovery Act (RCRA) Corrective Action Plan (EPA 1994), "Remedies may include those measures that are needed to be protective, but are not directly related to media cleanup, source control, or management of wastes." Components of remedies considered for the TAG SNL/NM AOR include evaluating protection of human health and the environment for air emissions, potential formation of hazardous degradation products, hazards associated with operations and maintenance of the remedy, and remediation within an appropriate timeframe.

- **Attain media cleanup standard or alternative, approved risk-based cleanup goals.** Any proposed remedy must attain groundwater cleanup standards or goals. As stated in the RCRA Corrective Action Plan (EPA 1994)**,** "Remedies will be required to attain media cleanup standards set by the implementing agency, which may be derived from existing state or federal regulations (e.g., groundwater standards) or other standards. The media cleanup standards for a remedy will often play a large role in determining the extent of, and technical approaches to, the remedy." The cleanup goals and objectives for the SNL/NM AOR are described in Section 4.0. If a remedy cannot meet any one of these goals or objectives, it should no longer be considered.

- **Control the source or sources of releases so as to reduce or eliminate, to the extent practicable, further releases of contaminants that may pose a threat to human health and the environment.** Any proposed remedy must control the original source of the contamination in order to prevent any further releases. As stated in the RCRA Corrective Action Plan (EPA 1994), "Unless source control measures are taken, efforts to clean up releases may be ineffective or, at best, will essentially involve a perpetual cleanup." According to Section 1.4.3 of the CME Work Plan (SNL/NM 2004), source control is not a required component of the SNL/NM AOR because there is no ongoing source of contamination to the groundwater. Therefore, corrective measures and any technologies designed for source zone control or remediation are not needed.

- **Comply with standards for management of wastes.** Any proposed remedy must comply with all applicable state or federal regulations. As stated in the RCRA Corrective Action Plan (EPA 1994)**,** "Waste management activities will be conducted in compliance with all applicable state or federal regulations (e.g., closure requirements, land disposal restrictions)." In addition, waste is to be managed according to the requirements of SNL/NM's *Environment, Safety, and Health (ES&H) Manual*, "Chapter 19 - Waste Management" (SNL/NM 2005) that describes the main institutional requirements relevant to waste management on SNL/NM-controlled premises. Wastes resulting from sampling, including purge water and equipment, are the only wastes that will result from the MNA remedial alternative.

3.3.2 Remedial Alternative Evaluation Criteria

The remedial alternative evaluation criteria were used in an evaluation presented in the Data Gaps Review (Section 3.1.1 and Attachment B) that resulted in two recommended remedies for further evaluation (groundwater monitoring and MNA). However, as stated in Section 3.2, the groundwater monitoring alternative is no longer considered; therefore, the remedial alternative evaluation criteria are summarized in this section and a summary of how effectively the MNA remedial alternative meets these criteria is included in Section 3.4. The remedial alternative evaluation criteria are as follows:

- **Long-term reliability and effectiveness.** In general, this criterion evaluates the reliability of the remedy for meeting cleanup standards and reducing risk. As stated in the COOC, "Each remedy shall be evaluated for long-term reliability and effectiveness. This factor includes consideration of the magnitude of the risks that will remain after implementation of the remedy; the extent of long-term monitoring or other management that will be required after implementation of the remedy; the uncertainties associated with leaving contaminants in place; and the potential for failure of the remedy. A remedy that reduces risks with little long-term management, and that has proven effective under similar conditions, shall be preferred" (NMED 2004). This criterion includes defining the institutional controls to be established for each remedy.

- **Reduction of toxicity, mobility, or volume.** This criterion is intended to evaluate the effectiveness of the remedy for reducing TCE and nitrate concentrations in TAG. As stated in the COOC, "Each remedy shall be evaluated for its reduction in the toxicity, mobility, and volume of contaminants. A remedy that more completely and permanently reduces the toxicity, mobility, and volume of contaminants shall be preferred" (NMED 2004).

- **Short-term effectiveness.** In general, short-term effectiveness applies to the ability of the remedy to reduce risks during the remediation process. These risks include exposure to contaminants during remedy implementation and risks and hazards introduced by remedy implementation. As stated in the COOC, "Each remedy shall be evaluated for its short-term effectiveness. This factor includes consideration of the short-term reduction in existing risks that the remedy would achieve; the time needed to achieve that reduction; and the short-term risks that might be posed to the community, workers, and the environment during implementation of the remedy. A remedy that quickly reduces short-term risks, without creating significant additional risks, shall be preferred" (NMED 2004).

- **Feasibility.** As stated in the COOC, "Each remedy shall be evaluated for its feasibility, or the difficulty of implementing the remedy. This factor includes consideration of installation and construction difficulties; operation and maintenance difficulties; difficulties with cleanup technology; permitting and approvals; and the availability of necessary equipment, services, expertise, and storage and disposal capacity. A remedy that can be implemented quickly and easily and poses fewer and lesser difficulties shall be preferred" (NMED 2004).

- **Cost.** As stated in the COOC, "Each remedy shall be evaluated for its cost. This factor includes a consideration of both capital costs and operation and maintenance costs. A remedy that is less costly, but does not sacrifice protection of health and the environment, shall be preferred" (NMED 2004).

    - **Capital costs** shall include, without limitation, construction and installation costs; equipment costs; land development costs; and indirect costs, including engineering costs, legal fees, permitting fees, startup and shakedown costs, and contingency allowances.

    - **Operation and maintenance costs** shall include, without limitation, operating labor and materials costs; maintenance labor and materials costs; replacement costs; utilities; monitoring and reporting costs; administrative costs; indirect costs; and contingency allowances" (NMED 2004).

3.4 Selection of a Preferred Remedial Alternative

As stated in Section 3.2, the MNA remedial alternative is an applicable remedial alternative for both nitrate and TCE in the SNL/NM AOR. The CME process of data gathering activities and ongoing evaluations has demonstrated that none of the other three remedial alternatives identified in the CME Work Plan (groundwater monitoring, ISB, and pump-and-treat) are as effective or applicable; therefore, MNA is the preferred remedial alternative.

Given all of the information gathered during the CME, the MNA remedial alternative must meet the threshold criteria (Section 3.3.1). Table 3-4 summarizes how the MNA remedial alternative meets each of the threshold criteria. Over the course of the CME, the MNA remedial alternative has been shown to meet the remedial alternative criteria more effectively than the other remedial alternatives. Table 3-5 is a summary of how the MNA remedial alternative meets the evaluation criteria.

Table 3-4. Summary of MNA applicability considering threshold criteria.

Threshold Criterion	MNA Applicability
Protective of human health and the environment.	The MNA remedial alternative will involve continued monitoring and institutional controls that will be protective of human health and the environment. Transport analysis demonstrated that there is no unacceptable risk to receptors.
Attain media cleanup standard or alternative, approved risk-based cleanup goals.	Natural attenuation mechanisms will reduce contaminant concentrations to below MCLs.
Control the source or sources of releases so as to reduce or eliminate, to the extent practicable, further releases of contaminants that may pose a threat to human health and the environment.	There are no ongoing sources of contamination.
Comply with standards for management of wastes.	The only waste streams that will be generated are purge water from sampling, which is currently and will continue to be disposed of in compliance with standards and regulations.

Table 3-5. Summary of MNA effectiveness considering remedial alternative criteria.

Remedial Alternative Criterion	MNA Applicability
Long-term reliability and effectiveness	Natural attenuation mechanisms are operable. An intrinsic aerobic TCE biodegradation mechanism has been found in TAG and transport analysis has demonstrated that nitrate and TCE will be reduced to below MCLs before reaching production wells.
Reduction of toxicity, mobility, or volume	Natural attenuation mechanisms will reduce COC concentrations to below MCLs, thus reducing toxicity.
Short-term effectiveness	MNA relies on natural attenuation mechanisms to meet clean-up goals. These processes are operable; however, they are slower than more active alternatives.
Feasibility	MNA is significantly more feasible than other remedial alternatives. Overcoming the physical constraints of the site is a significant obstacle to other more active alternatives, while the infrastructure (monitoring network and equipment) is already in place for MNA.
Capital costs	Wells and equipment already exist.
Operations and maintenance costs	The only operations and maintenance will be monitoring and well maintenance, which will need to occur throughout the remedial timeframe.

4.0 REMEDIAL ALTERNATIVE DESIGN CRITERIA TO MEET CLEANUP GOALS AND OBJECTIVES

The remedial alternative strategy for MNA (presented in Section 3.2) identifies T&FRs and itemized cost elements. This strategy was developed during the CME process and will be expanded and further developed in the CMI Plan.

MNA was selected as the preferred remedial alternative for the SNL/NM AOR. Cleanup goals and objectives are criteria used to evaluate performance and can be divided into two types (performance and compliance) based on when the goal or objective is to be achieved. Goals are established as the milestones to meet upon completion of remediation. Objectives are tasks to be completed in order to meet the goals.

Performance goals and objectives are defined to support remedy performance evaluation during implementation and before final closure of the site. Compliance goals and objectives are defined to support decision making at the end of the remedy and to provide the framework for determining whether the remedy has restored groundwater to beneficial use within the restoration timeframe. Because the type of data collected may be quite different, it is important to distinguish between performance and compliance goals and objectives. The performance and compliance goals and objectives were developed in the TAG CME Work Plan (SNL/NM 2004) and are also stated below.

4.1 Performance Goals and Objectives

Performance goals and objectives are criteria and actions used to evaluate remedy performance during the operations phase to support evaluation of system performance data relative to end-state objectives. Performance monitoring data analysis leads to periodic decisions that the remedy is performing as expected and that the remedy will ultimately achieve the final remediation goal. The performance goals and objectives include:

Performance Goals:

- Establish and operate a remedy intended to reduce COC concentrations,
- Monitor distribution and changes in COC concentrations, and
- Collect sufficient data to support a decision to move into the compliance phase.

Performance Objectives:

- Collect groundwater samples for performance parameters (in addition to COCs) from TAG wells,
- Compile and analyze groundwater monitoring data to evaluate trends in COC concentrations,
- Compare trends to the COC cleanup standards, and
- Recommend continued operation of the remediation system or strategy and proceed to compliance evaluation.

4.2 Compliance Goals and Objectives

Compliance goals and objectives are criteria and actions used to evaluate remediation system or strategy effectiveness both during and at completion of the corrective measure. Compliance requirements may be imposed during remediation system or strategy operations (e.g., air emissions or waste management). In addition, compliance requirements exist for final closure of the site. These compliance goals and objectives serve to show that (1) the remedy is being implemented in a fashion that is consistent with the COOC (NMED 2004) during implementation, and (2) the remedy has accomplished the remediation goals at the end of the corrective measure. Groundwater cleanup levels are defined in Section VI.K.1.a of the COOC as the more restrictive of EPA MCLs or Water Quality Control Commission standards. The cleanup levels for COCs are defined by the MCLs, as these are the more restrictive of the two standards. The remedial timeframe will be defined in the CMI Plan. The compliance goals and objectives include:

Compliance Goals:

- Operate all remediation systems or strategies in compliance with applicable requirements,
- Reduce COC concentrations throughout the plume to below MCLs, and
- Implement institutional controls to protect human health and the environment during the remediation timeframe.

Compliance Objectives:

- Monitor all remediation systems or strategies for compliance with applicable requirements,
- Collect groundwater samples at TAG wells for COCs,
- Compare COC concentrations to cleanup standards, and
- Recommend site closure or continuation of long-term operations.

5.0 CORRECTIVE MEASURES IMPLEMENTATION PLAN

As stated in the Section VII.D.2 of the COOC (NMED 2004), the CMI Plan will outline the "design, construction, operation, maintenance, and performance monitoring for the selected remedy, and a schedule for implementation."

5.1 Corrective Measures Implementation Plan Outline

The following is a draft outline of the key components of the CMI Plan and includes the required CMI Plan elements listed in the COOC. Some of the elements stated in the COOC (i.e., results of pilot tests, construction work plan, and engineering design drawings and specifications) are not included in this outline because they are not applicable to the MNA remedial alternative. The outline is as follows:

I. Introduction

II. Background Information

III. Description of Selected Final Remedy

   a. Remediation System Objectives

   b. Cleanup Goals

IV. Remedy Implementation

   a. Implementation Team Qualifications

   b. Operation and Maintenance Plan

   c. Waste Management Plan

V. Remedy Performance Monitoring

   a. Sampling

   b. Contingency

VI. Schedule

   a. Implementation Schedule

   b. Reporting Schedule

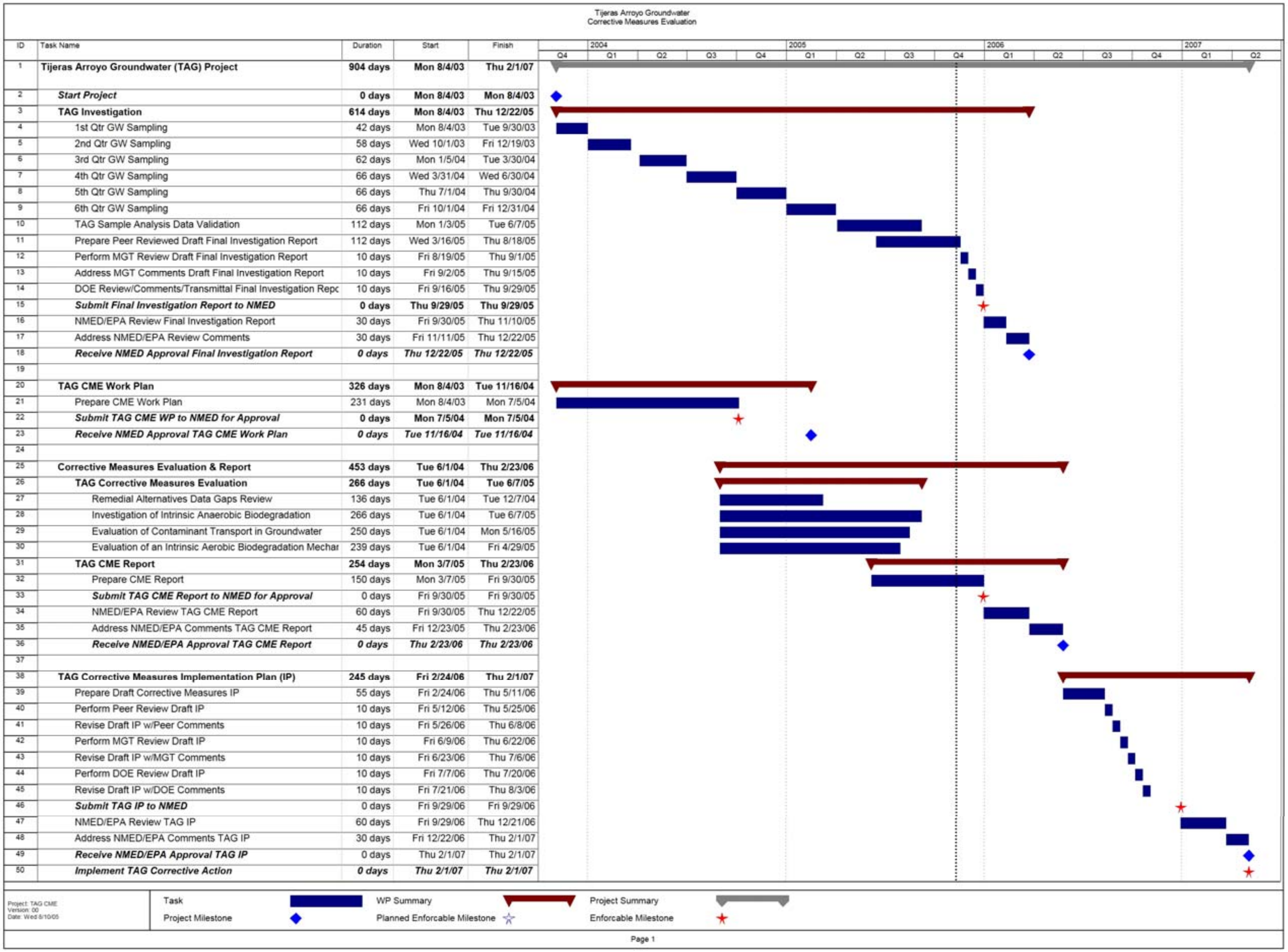
VII. Appendices

5.2 Corrective Measures Implementation Schedule

The basis for the CMI schedule (Figure 5-1) is the logical development of project tasks and activities that will support the implementation of corrective measures under the COOC. This schedule includes corrective measure tasks and milestones. Specific documents that have been, or will be, produced as part of the CME process are summarized in Table 5-1. This CME Report and the CMI Plan require NMED review and approval. These documents are identified deliverables and have clearly defined agency review and comment resolution periods. SNL/NM will proceed at risk with the corrective measures implementation, as outlined in the schedule.

Table 5-1. Summary of TAG documents and delivery dates.

Document	Status
TAG CME Work Plan	Completed and submitted to NMED in July 2004, the NMED approved the CME Work Plan in October 2004 pending a few modifications, these modifications were made in November 2004, and the final document was submitted to NMED in December 2004.
TAG Remedial Alternatives Data Gaps Review	Completed December 2004
TAG Investigation of an Intrinsic Aerobic Biodegradation Mechanism	Completed April 2005
TAG Evaluation of Intrinsic Anaerobic Biodegradation	Completed June 2005
TAG Evaluation of Contaminant Transport in Groundwater	Completed May 2005
TAG CME Report	Planned early submittal to NMED in August 2005.
TAG Corrective Measures Implementation Plan	Currently on schedule to meet September 30, 2006 NMED submittal date.



Tijeras Arroyo Groundwater
Corrective Measures Evaluation

ID	Task Name	Duration	Start	Finish
1	**Tijeras Arroyo Groundwater (TAG) Project**	**904 days**	**Mon 8/4/03**	**Thu 2/1/07**
2	***Start Project***	**0 days**	**Mon 8/4/03**	**Mon 8/4/03**
3	**TAG Investigation**	**614 days**	**Mon 8/4/03**	**Thu 12/22/05**
4	1st Qtr GW Sampling	42 days	Mon 8/4/03	Tue 9/30/03
5	2nd Qtr GW Sampling	58 days	Wed 10/1/03	Fri 12/19/03
6	3rd Qtr GW Sampling	62 days	Mon 1/5/04	Tue 3/30/04
7	4th Qtr GW Sampling	66 days	Wed 3/31/04	Wed 6/30/04
8	5th Qtr GW Sampling	66 days	Thu 7/1/04	Thu 9/30/04
9	6th Qtr GW Sampling	66 days	Fri 10/1/04	Fri 12/31/04
10	TAG Sample Analysis Data Validation	112 days	Mon 1/3/05	Tue 6/7/05
11	Prepare Peer Reviewed Draft Final Investigation Report	112 days	Wed 3/16/05	Thu 8/18/05
12	Perform MGT Review Draft Final Investigation Report	10 days	Fri 8/19/05	Thu 9/1/05
13	Address MGT Comments Draft Final Investigation Report	10 days	Fri 9/2/05	Thu 9/15/05
14	DOE Review/Comments/Transmittal Final Investigation Repc	10 days	Fri 9/16/05	Thu 9/29/05
15	***Submit Final Investigation Report to NMED***	**0 days**	**Thu 9/29/05**	**Thu 9/29/05**
16	NMED/EPA Review Final Investigation Report	30 days	Fri 9/30/05	Thu 11/10/05
17	Address NMED/EPA Review Comments	30 days	Fri 11/11/05	Thu 12/22/05
18	***Receive NMED Approval Final Investigation Report***	***0 days***	***Thu 12/22/05***	***Thu 12/22/05***
19				
20	**TAG CME Work Plan**	**326 days**	**Mon 8/4/03**	**Tue 11/16/04**
21	Prepare CME Work Plan	231 days	Mon 8/4/03	Mon 7/5/04
22	***Submit TAG CME WP to NMED for Approval***	**0 days**	**Mon 7/5/04**	**Mon 7/5/04**
23	***Receive NMED Approval TAG CME Work Plan***	***0 days***	***Tue 11/16/04***	***Tue 11/16/04***
24				
25	**Corrective Measures Evaluation & Report**	**453 days**	**Tue 6/1/04**	**Thu 2/23/06**
26	**TAG Corrective Measures Evaluation**	**266 days**	**Tue 6/1/04**	**Tue 6/7/05**
27	Remedial Alternatives Data Gaps Review	136 days	Tue 6/1/04	Tue 12/7/04
28	Investigation of Intrinsic Anaerobic Biodegradation	266 days	Tue 6/1/04	Tue 6/7/05
29	Evaluation of Contaminant Transport in Groundwater	250 days	Tue 6/1/04	Mon 5/16/05
30	Evaluation of an Intrinsic Aerobic Biodegradation Mechar	239 days	Tue 6/1/04	Fri 4/29/05
31	**TAG CME Report**	**254 days**	**Mon 3/7/05**	**Thu 2/23/06**
32	Prepare CME Report	150 days	Mon 3/7/05	Fri 9/30/05
33	***Submit TAG CME Report to NMED for Approval***	0 days	Fri 9/30/05	Fri 9/30/05
34	NMED/EPA Review TAG CME Report	60 days	Fri 9/30/05	Thu 12/22/05
35	Address NMED/EPA Comments TAG CME Report	45 days	Fri 12/23/05	Thu 2/23/06
36	***Receive NMED/EPA Approval TAG CME Report***	***0 days***	***Thu 2/23/06***	***Thu 2/23/06***
37				
38	**TAG Corrective Measures Implementation Plan (IP)**	**245 days**	**Fri 2/24/06**	**Thu 2/1/07**
39	Prepare Draft Corrective Measures IP	55 days	Fri 2/24/06	Thu 5/11/06
40	Perform Peer Review Draft IP	10 days	Fri 5/12/06	Thu 5/25/06
41	Revise Draft IP w/Peer Comments	10 days	Fri 5/26/06	Thu 6/8/06
42	Perform MGT Review Draft IP	10 days	Fri 6/9/06	Thu 6/22/06
43	Revise Draft IP w/MGT Comments	10 days	Fri 6/23/06	Thu 7/6/06
44	Perform DOE Review Draft IP	10 days	Fri 7/7/06	Thu 7/20/06
45	Revise Draft IP w/DOE Comments	10 days	Fri 7/21/06	Thu 8/3/06
46	***Submit TAG IP to NMED***	0 days	Fri 9/29/06	Fri 9/29/06
47	NMED/EPA Review TAG IP	60 days	Fri 9/29/06	Thu 12/21/06
48	Address NMED/EPA Comments TAG IP	30 days	Fri 12/22/06	Thu 2/1/07
49	***Receive NMED/EPA Approval TAG IP***	0 days	Thu 2/1/07	Thu 2/1/07
50	***Implement TAG Corrective Action***	***0 days***	***Thu 2/1/07***	***Thu 2/1/07***

Project: TAG CME
Version: 00
Date: Wed 8/10/05

Task	▬	WP Summary	▬	Project Summary	▬
Project Milestone	◆	Planned Enforcable Milestone	☆	Enforcable Milestone	★

Page 1

Figure 5-1. Corrective measures implementation schedule.

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6.0 REFERENCES

1. DOE, 1999, *Decision-Making Framework Guide for the Evaluation and Selection of Monitored Natural Attenuation Remedies at Department of Energy Sites*, Department of Energy, Office of Environmental Restoration, May 1999.

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9. SNL/NM, 2005, *Environment, Safety, and Health (ES&H) Manual*, CPR400.1.1, MN471001, Issue EZ, revision date May 31, 2005, Sandia National Laboratories, Albuquerque, New Mexico.

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Attachment A
Contaminant Distribution in Groundwater

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1.0 CONTAMINANT DISTRIBUTION IN GROUNDWATER

During the course of the corrective measures evaluation (CME) groundwater monitoring has continued as governed by the *Tijeras Arroyo Groundwater Investigation Work Plan* (SNL/NM 2003). The results of this investigation will be reported in the Final TAG Investigation Report, which is scheduled for completion by September 30, 2005. This attachment presents historical (SNL/NM 2004b) and more recent (SNL/NM 2004a, SNL/NM 2005) concentrations of the contaminants of concern (COCs), observed in samples from selected wells in the Sandia National Laboratories/ New Mexico (SNL/NM) Area of Responsibility (AOR).

Data are presented for wells where contaminants of concern (COCs) have been observed on at least one occasion since 1999 above the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) for drinking water, which is 5 µg/L for trichloroethene (TCE) and 10 mg/L (as nitrogen) for nitrate. The groundwater monitoring well network is shown on Figure A-1. Figures A-2 and A-3 are plots of concentration vs. time for TCE and nitrate respectively. Non-detect results are not shown in these plots. The groundwater analytical data collected under the provisions of the TAG Investigation Work Plan (SNL/NM 2003) are in agreement with historical concentrations. Observations from the data are:

- Concentrations of TCE have sporadically been greater than the MCL in samples from well TA2-W-19, and TCE was routinely detected above the MCL in samples from well TA2-W-26. More recent detections of TCE in both wells sampled using high flow sampling techniques have been below the MCL.

- Nitrate is widely distributed across the site at concentrations below the MCL and has routinely been detected, at concentrations above the MCL in samples from wells TJA-7 and TA2-SW-320. Nitrate has routinely been detected at concentrations near the MCL in samples from wells TA2-W-19 and TJA-2.

Concentration trends of TCE and nitrate in the SNL/NM AOR monitoring well network have shown that concentrations are not increasing and appear to be stable. Variation in observed concentrations over time is due to the change in sampling methods and other factors. Concentrations of both TCE and nitrate are not significantly increasing and are not expected to significantly increase as wastewater disposals to the environment have ceased. Future groundwater monitoring data will be necessary to discern a declining trend because of the relatively slow rate of natural attenuation processes and the need for a longer sampling period using consistent methods. The historical data indicate that the extent of TCE and nitrate contaminated groundwater is stable or not expanding, because concentration trends are not increasing as observed in samples form the SNL/NM TAG perched system monitoring wells and there are no continuing sources of contamination (SNL/NM 2004b.

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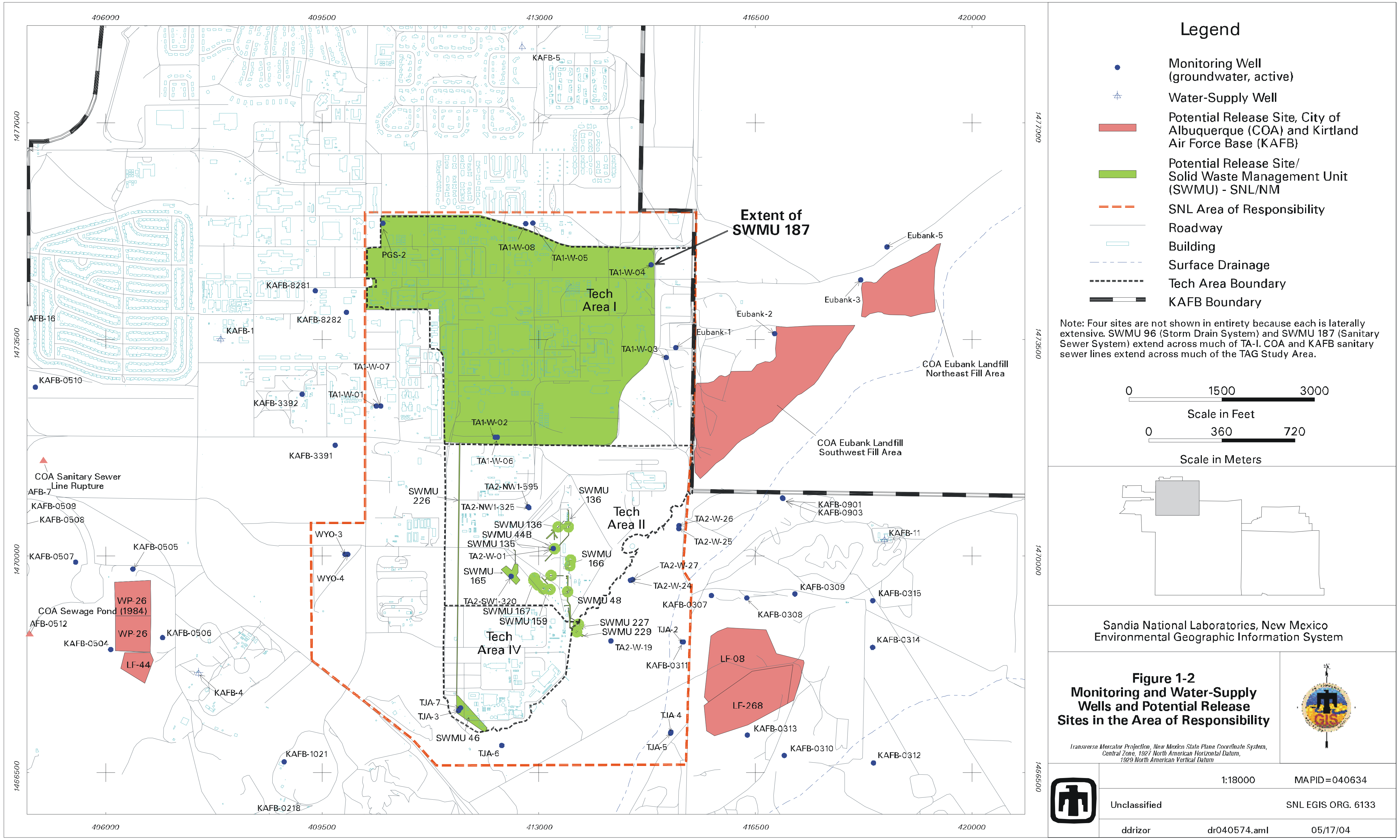

Figure A-1. Monitoring and Water Supply Wells and Potential Release Sites in the Area of Responsibility.

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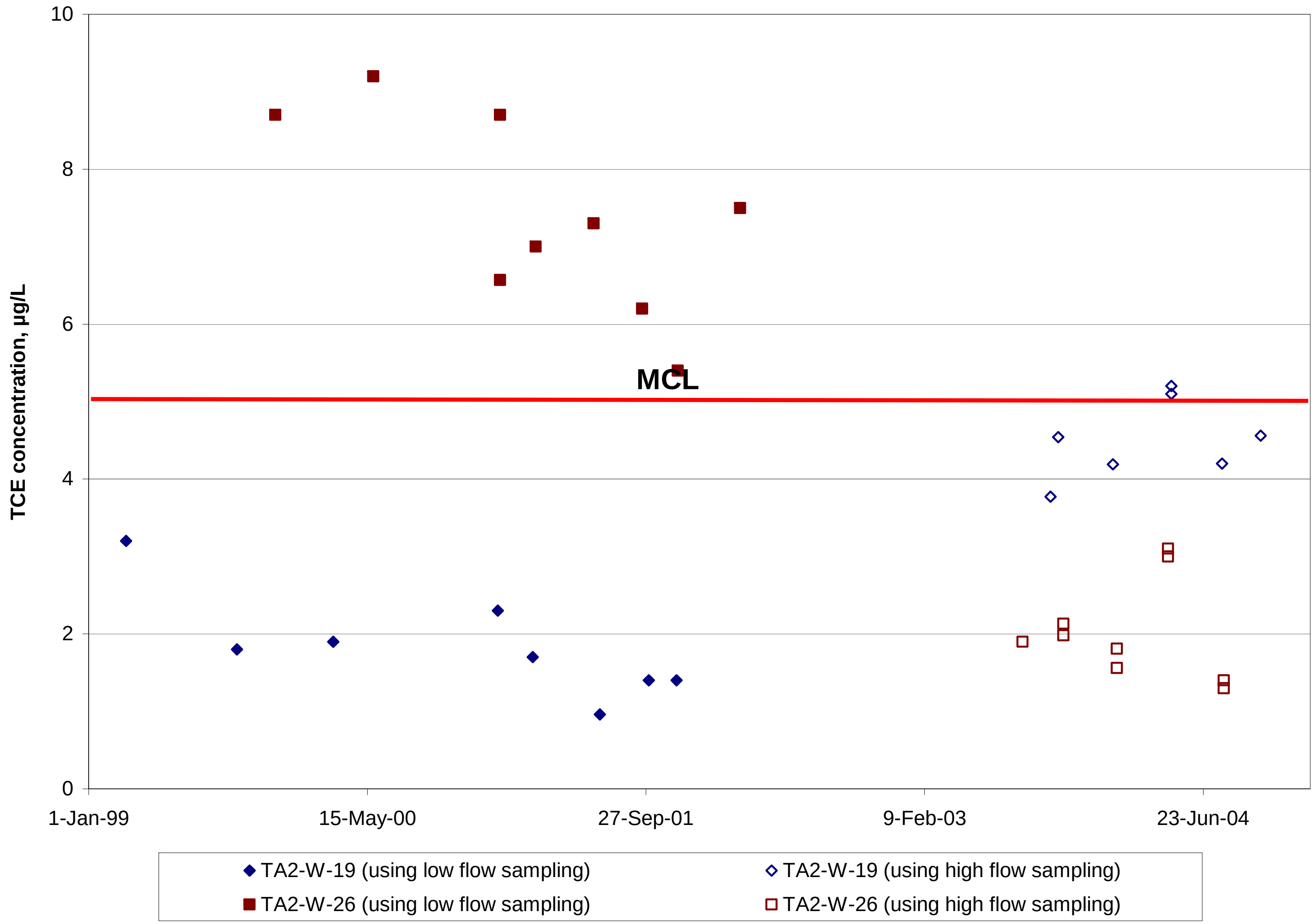

Figure A-2. TCE concentrations over time.

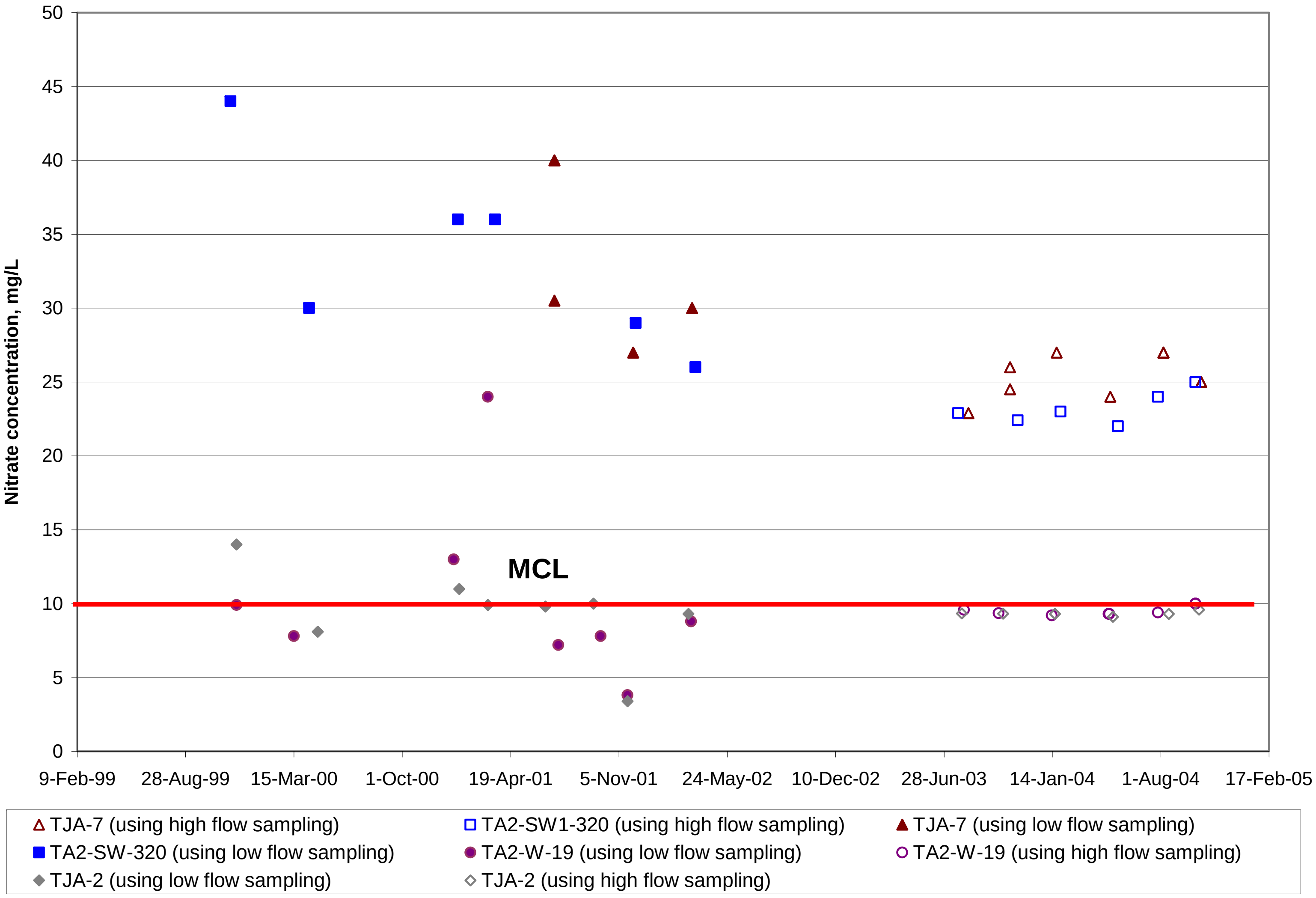

Figure A-3. Nitrate concentrations over time.

2.0 REFERENCES

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Attachment B
Remedial Alternatives Data Gaps Review

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Remedial Alternatives Data Gaps Review for Tijeras Arroyo Groundwater at Sandia National Laboratories/New Mexico

December 2004

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Sandia National Laboratories

ABSTRACT

The objective of this report is to continue the assessment of alternative technologies to support the Corrective Measures Evaluation (CME) process for remediation of Tijeras Arroyo Groundwater (TAG). This Remedial Alternative Data Gap Review is an informal report that documents decisions made as a result of the assessment and recommends activities to address the data gaps and provide sufficient information to complete the CME Report. Four remedial alternatives were identified in the TAG CME Work Plan. This report presents conceptual designs for the remedial alternatives which are used to perform an assessment based on the threshold and remedial alternative evaluation criteria from the Compliance Order on Consent. The four remedial alternatives, including a summary of decisions regarding each, are:

1. **Groundwater monitoring –** Groundwater monitoring will continue to be evaluated.
2. **Monitored natural attenuation (MNA) –** MNA will continue to be evaluated through numerical modeling and field scale studies.
3. **In situ bioremediation (ISB) –** No further data gathering activities are recommended for ISB because it has been demonstrated to be significantly less effective compared to other remedial alternatives.
4. **Pump and treat** - No further data gathering activities are recommended for pump and treat because it has been demonstrated to be significantly less effective compared to other remedial alternatives.

It is recommended that evaluation of data gaps for two remedial alternatives, groundwater monitoring and MNA, be performed. Characterization activities for the TAG study area are recommended field scale studies for both groundwater monitoring and MNA. However, these activities are not directed by nor conducted as part of this CME process but the data generated can be used as appropriate. For MNA, numerical modeling is recommended to investigate the fate and transport of contaminants in the perched groundwater system. Other field scale studies recommended for MNA include investigating anaerobic mechanisms of TCE and nitrate biodegradation and performing enzyme probe analyses to provide direct evidence of an aerobic cometabolic TCE degradation mechanism.

CONTENTS

FIGURES

TABLES

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ACRONYMS AND ABBREVIATIONS

AOR	Area of Responsibility
ARD	anaerobic reductive dechlorination
ARG	ancestral Rio Grande
bgs	below ground surface
CME	Corrective Measures Evaluation
COA	City of Albuquerque
COC	contaminant of concern
COOC	Compliance Order on Consent
DCE	dichloroethene
DOE	United States Department of Energy
EPA	United States Environmental Protection Agency
ft	feet or foot
ft/ft	feet per foot
ft/min	feet per minute
GAC	granular activated carbon
in.	inch or inches
ISB	in-situ bioremediation
KAFB	Kirtland Air Force Base
MCL	maximum contaminant level
MMO	methane monooxygenase
MNA	monitored natural attenuation
NMED	New Mexico Environmental Department
RCRA	Resource Conservation and Recovery Act
sMMO	soluble methane monooxygenase

SNL/NM	Sandia National Laboratories/ New Mexico
TAG	Tijeras Arroyo Groundwater
TBD	to be determined
TCE	trichloroethene
T&FRs	technical and functional requirements
VA	Veterans Administration

1.0 INTRODUCTION

The *Corrective Measures Evaluation Work Plan Tijeras Arroyo Groundwater* (SNL/NM 2004a), referred to in this data gap review as the Tijeras Arroyo Groundwater (TAG) Corrective Measures Evaluation (CME) Work Plan, was prepared as specified in the Compliance Order on Consent (COOC) issued by the New Mexico Environment Department (NMED) (NMED 2004). The TAG CME Work Plan outlines a process to evaluate remedial alternatives to identify a corrective measure for the Sandia National Laboratories/New Mexico (SNL/NM) Area of Responsibility (AOR). Four remedial alternatives were identified:

1. Groundwater monitoring,
2. Monitored natural attenuation (MNA),
3. In situ bioremediation (ISB), and
4. Pump and treat (ex situ treatment technology to be determined).

The objective of implementing these remedial alternatives is to meet the cleanup goals, objectives, and requirements stated in the TAG CME Work Plan, which include the following compliance goals:

- Operating all remediation systems or strategies in compliance with applicable requirements,
- Reducing contaminant of concern (COC) concentrations in groundwater to below maximum contaminant levels (MCLs), and
- Implementing institutional controls to protect human health and the environment during the remediation timeframe.

Reducing COC concentrations in groundwater to below MCLs is the main challenge for selecting the most effective and cost efficient remedial alternative; therefore, throughout this data gap review a remedial alternative that is potentially successful is one that will reduce COC concentrations to below MCLs.

Section 5.0 of the TAG CME Work Plan, “Remedial Alternative Evaluation Plan,” provides guidance on activities to be used for evaluating the four remedial alternatives (SNL/NM 2004a). The Remedial Alternative Evaluation Plan identifies data gathering activities to be carried out in four stages, as follows:

1. Paper study,
2. Numerical modeling,
3. Laboratory studies, and
4. Field scale studies.

1.1 CME Interim Documentation

As the four stages of data gathering activities are carried out, individual informal reports will be created to document the results of each stage in the evaluation process. These reports will be prepared by the CME implementation team to be reviewed by the project leader, technical peer review panel, and technical support personnel (project organizational structure is discussed in Section 7.2 of the TAG CME Work Plan (SNL/NM 2004a). The informal reports will be produced for project team internal review and discussion to define and document activities necessary to complete the TAG CME Report. The informal reports will not be officially published with Sandia document numbers and will be superseded by the data analysis and remedy selection presented in the CME report when it is published. The purpose of the informal reports includes:

- Reporting results and interpretation of results to the project leader, technical peer review panel and technical support personnel,
- Documenting decisions made during the data collection and analysis process for each of the four evaluation stages, and
- Providing supporting information that will eventually be included in the CME Report to be submitted to the NMED.

Figure 1-1 illustrates the four stage process of data gathering activities and the reports associated with each stage.

1.2 Organization

The TAG CME Work Plan presented objectives for the paper study stage to focus on the continuing assessment of available data and information on the alternative remedies being considered. The primary objectives for this assessment include presentation of conceptual designs, completion of a data gap review, and providing recommendations for additional activities needed to fill these data gaps to support completion of the CME Report. This report addresses the objectives of the paper study stage. The outcome of the process is a group of recommended data gathering activities. This data gap review is organized into the following sections:

- **Section 1. Introduction**. This section includes a presentation of the remedial alternatives being considered, a description of the objectives of this report, and a summary of the current conceptual model, as presented in the TAG CME Work Plan. Also, included in this section is a presentation of additional site data compiled during this data gap review.
- **Section 2. Remedial Alternative Conceptual Designs.** This section presents conceptual designs for the four remedial alternatives, consisting of considerations for evaluation, implementation information, process diagrams with associated technical and functional requirements (T&FRs) and assumptions, and cost descriptions.
- **Section 3. Remedial Alternative Evaluation**. This section presents the evaluation methods and results for each of the four remedial alternatives. The outcome of the evaluation is a list of remedial alternatives that will be considered for future data gathering activities.
- **Section 4. Recommendations for Further Studies**. Data gaps regarding individual remedial alternatives and application to TAG have been identified. This section identifies numerical modeling and field scale studies that will provide the necessary information to choose a preferred remedy.

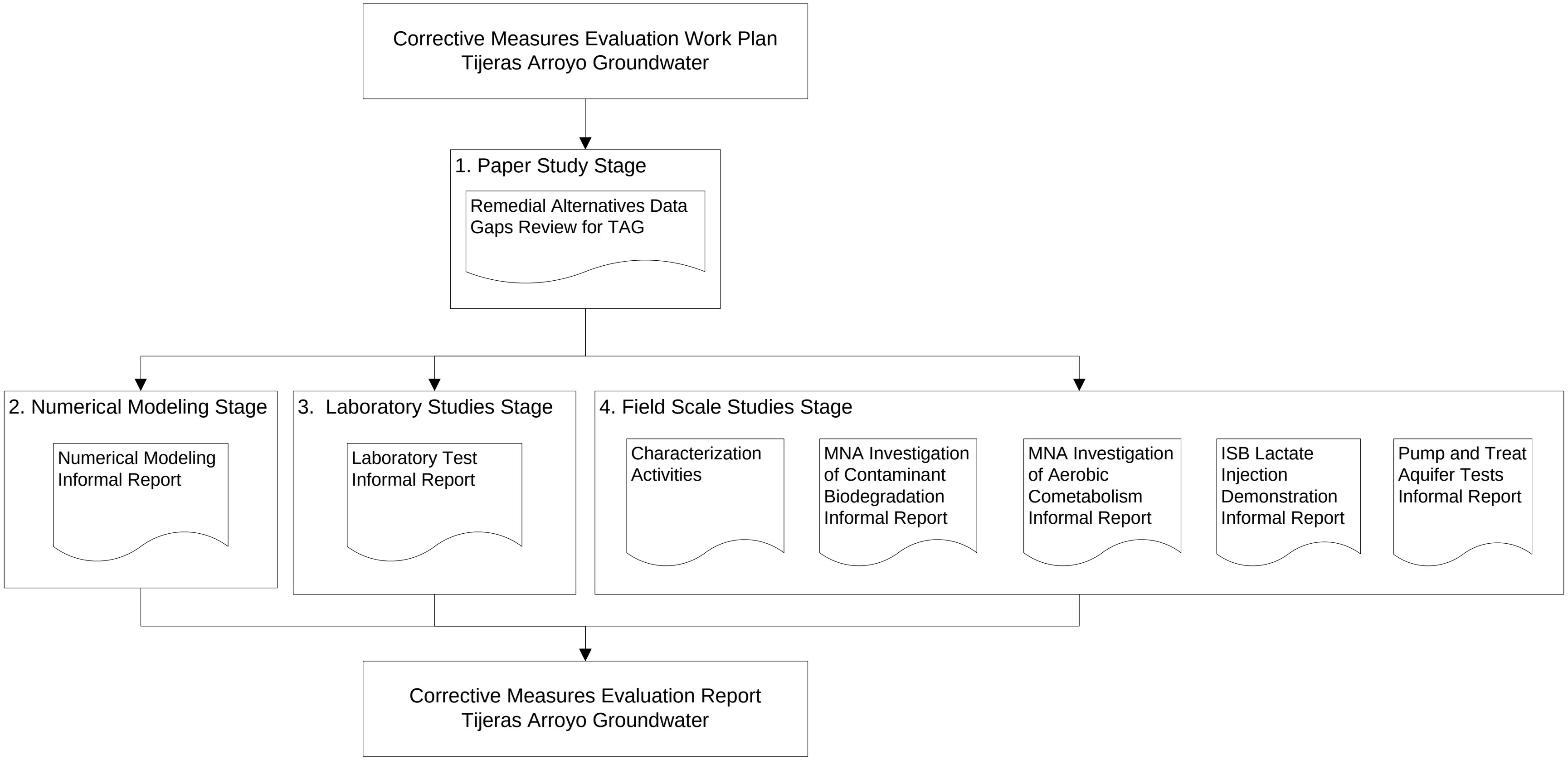

Figure 1-1. Illustration of the staged process of data gathering with potential activities and subsequent reports.

1.3 Current Conceptual Model Summary

Characterization of the TAG study area has been undertaken by three separate potentially responsible parties: SNL/NM, the City of Albuquerque (COA), and Kirtland Air Force Base (KAFB). As a result, it is necessary for each party to clearly define their contribution to overall TAG remediation. The TAG CME Work Plan identifies the specific area within the overall TAG study area for which SNL/NM has remediation responsibility. In order to clearly distinguish it from the overall TAG study area, the area that the TAG CME Work Plan and this report address will be referred to as the SNL/NM AOR. The SNL/NM AOR encompasses an approximately 2-square mile area in the north central part of KAFB (Figure 1-2).

Evaluation of remedial alternatives for contaminants of concern (COCs) in groundwater at SNL/NM AOR requires a current conceptual model of contaminant transport that will provide the basis for a technically defensible evaluation. The following summary includes information summarized from the TAG CME Work Plan (SNL/NM 2004a).

1.3.1 Hydrology

The TAG study area is situated within the Albuquerque Basin, which is bounded on both the eastern and western margins by north-south trending faults related to the Rio Grande rift. The study area overlies the eastern margin of the Albuquerque Basin where the faults mostly trend parallel to the Sandia-Manzanita-Manzano mountain front. For the TAG SNL/NM AOR, the stratigraphic unit of greatest interest is the Upper Santa Fe Group, which is composed mostly of two interfingering lithofacies: an alluvial-fan lithofacies and a fluvial lithofacies.
Both lithofacies are less than five million years old and are composed of unconsolidated to poorly-cemented gravel, sand, silt, and clay (Stone et al. 2000). The alluvial-fan lithofacies consists of poorly sorted piedmont-slope deposits derived from the Sandia, Manzanita, and Manzano Mountains east of the study area. Fine-grained units within the alluvial-fan lithofacies produce low-permeability zones that are capable of perching groundwater. The fluvial lithofacies is derived from the ancestral Rio Grande (ARG) to the north and is typically well sorted and medium- to coarse-grained.

Two aquifers in the Upper Santa Fe Group have been identified in the TAG study area: a perched system and the regional aquifer. In the northern portion of the study area, the upper surface of the perched system is present at depths ranging from approximately 220 to 330 ft below ground surface (bgs), whereas the upper surface of the regional aquifer is present at approximately 440 to 570 ft bgs. The regional aquifer is used as a potable water source by KAFB, COA, and the Veterans Administration (VA).

The perched system is presently understood to cover approximately 3.5 square miles. Monitoring wells bound the perched system on the western and southern margins. The northern margin of the perched system has not been fully defined and may extend across the KAFB boundary north of the Wyoming Gate and east to the Eubank Landfill. A southeastern margin is not discernible because the perched system merges with the regional aquifer. The direction of groundwater flow in the perched system is inferred to be principally to the southeast, with a horizontal gradient of approximately 0.007 ft/ft. The vertical gradient is approximately 0.95 ft/ft over most of the perched system, and continuous vertical flow is suggested by the merging of the two groundwater systems to the southeast.

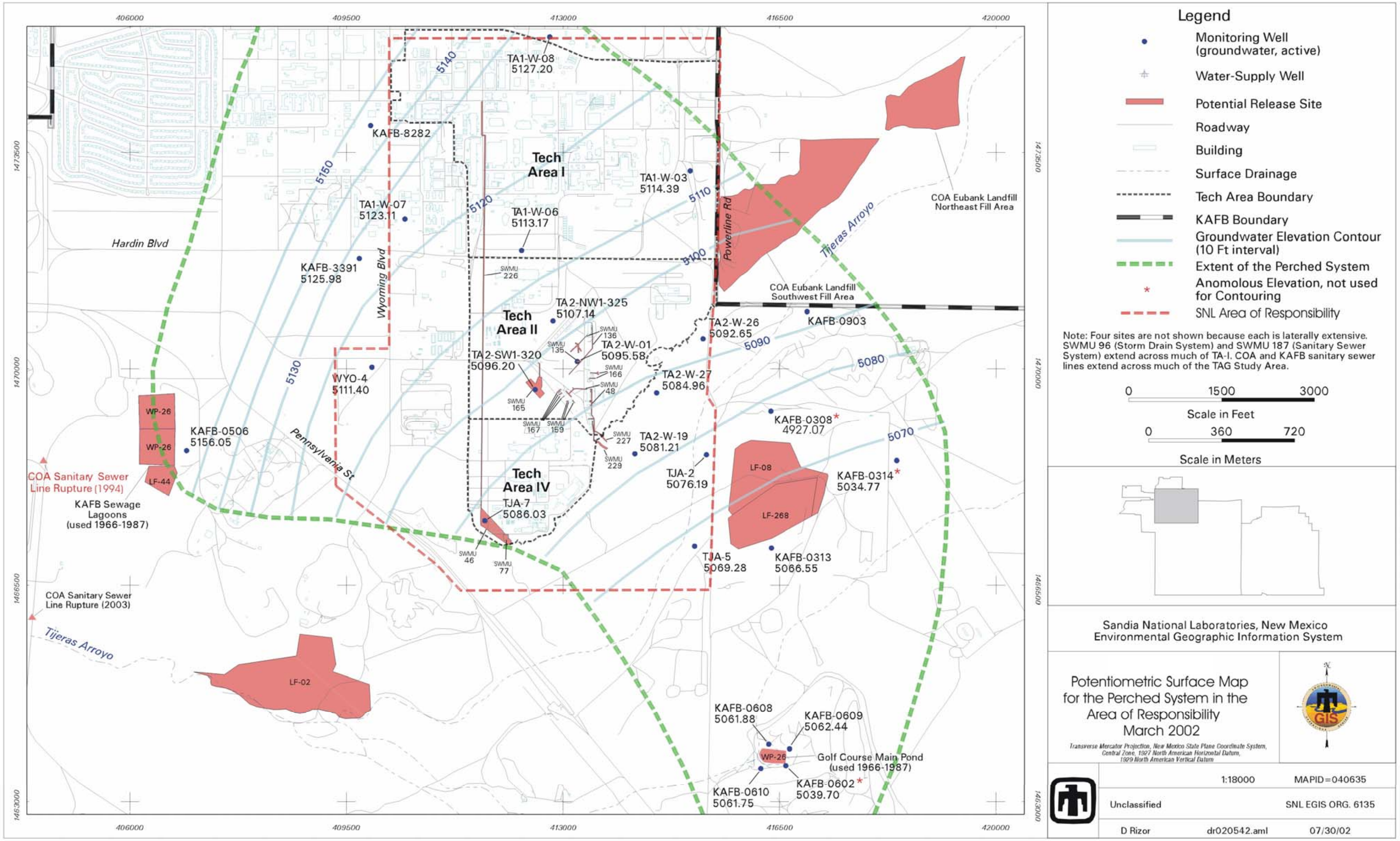

Figure 1-2. Potentiometric Surface Map for the Perched System in the Area of Responsibility, March 2002.

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Historically, water levels in the perched system have fluctuated across the study area (SNL/NM 2002). In the vicinity of the sewage lagoons and other areas northwest of Tijeras Arroyo, water levels have been declining since 1987, apparently in response to the lagoons being removed from service. Conversely, water levels have increased southeast of Tijeras Arroyo.

The direction of groundwater flow in the regional aquifer is to the northwest toward the KAFB, COA, and VA water-supply wells. The horizontal gradient of the regional aquifer across the central portion of the study area is approximately 0.009 ft/ft with steeper gradients evident near the mountain front. Vertical flow gradients within the TAG study area have not been measured but are inferred to be downward, consistent with TA-III/V groundwater studies.

Historically, water levels in the regional aquifer have fluctuated across the study area (SNL/NM 2002). A line of demarcation between increasing water levels and declining water levels is evident along the eastern extent of the ARG-fluvial lithofacies, which coincidentally trends along Wyoming Boulevard. Declining water levels approaching 1.5 ft/year are apparently associated with the KAFB, COA, and VA water-supply wells. Increases in groundwater elevations of up to 1.8 ft/year in the southeast portion of the study area probably reflect recharge of the regional aquifer from the perched system, Tijeras Arroyo, the golf course, and the mountain front.

The conceptual model shows that the thickness of the vadose zone is reduced in the central portion of the TAG study area where the perched system is present. Discontinuous, yet overlapping multiple lenses of unsaturated alluvial-fan sediments serve as a perching horizon beneath the perched system in that area. The perched system is present at approximately 220 to 330 ft bgs, and the regional aquifer system is present at approximately 440 to 570 ft bgs. Groundwater in the perched system most likely merges with the regional aquifer southeast of Tijeras Arroyo where the alluvial-fan sediments are slightly more permeable.

Tijeras Arroyo is the most significant surface-water drainage feature on KAFB and trends southwest across KAFB, eventually draining into the Rio Grande, approximately 6 miles west of KAFB. Surface water flows in the arroyo several times per year as a result of storm events. The annual precipitation for the area, as measured at the Albuquerque International Sunport, is 8.2 in. (SNL/NM 2001a). During most rainfall events, rainfall quickly infiltrates into the soil in the study area. However, virtually all of the moisture subsequently undergoes evapotranspiration. Estimates of evapotranspiration for the KAFB area range from 95 to 99% of the annual rainfall (SNL/NM 1998).

1.3.2. Contaminant Releases

A variety of potentially contaminated sites were evaluated within the TAG SNL/NM AOR. Three potential trichloroethene (TCE) sources and three potential nitrate sources were identified within the SNL/NM AOR, including potential TCE and nitrate sources at SWMU 46 (Old Acid Waste Line Outfall) and SWMU 165 (Building 901 Septic System), a potential TCE source at SWMU 227 (Bunker 904 Outfall), and a potential nitrate source at SWMU 187 (TA-I Sanitary Sewer System) (SNL/NM 2004a).

1.3.3. Contaminant Transport through the Vadose Zone

There is evidence of vapor-phase contaminants in the vadose zone; however, no free-phase TCE products and no water-saturated core samples have been detected in any of the soil samples collected from the boreholes. The original source of the TCE was from the aqueous phase (i.e., wastewater), and from the current vapor phase contaminants partitioned from the aqueous phase. All anthropogenic sources of recharge (i.e., wastewater) have been removed from service and no longer contribute water to the vadose zone.

Based on soil vapor and groundwater data collected in the vicinity of SWMU 227 (as stated in the TAG CME Work Plan) a residual TCE vapor plume does exist beneath SWMU 227. The primary mechanism for transporting these contaminants to the aquifer would be through partitioning back into the aqueous phase of additional recharge that might move through the system. During operations at SWMU 227, a recharge mechanism did exist (i.e. the wastewater disposal) to transport TCE from the vapor phase to the groundwater, which may have caused the groundwater contamination that is currently observed at TA2-W-19. However, since wastewater disposals have ceased, no recharge mechanism currently exists, and it is unlikely that additional TCE mass will be transported to the aquifer. The latest observations in vapor well 227-VW-01 and in perched system monitoring well TA2-W-19 are consistent with this hypothesis.

Nitrate was present in sewage wastewater disposed to septic systems and sanitary sewer lines in the area. The nitrate was transported to the perched system water table by high volumes of wastewater disposed at the sites. Because nitrate is extremely soluble and cannot exist as a separate phase (i.e., vapor or non-aqueous phase liquid [NAPL]), and because no water-saturated core samples have been encountered in any of the soil samples collected from boreholes, a secondary source of anthropogenic nitrate contamination does not exist in the vadose zone.

1.3.4. Contaminant Distribution and Transport through the Perched System

Overall, the distribution of TCE is discontinuous across the perched system and does not indicate a single release site. Based upon the historic use of chlorinated solvents across SNL/NM and KAFB, the known extent of TCE in groundwater is probably associated with multiple releases of aqueous-phase solvents and subsequent transport through the vadose zone.

The maximum historical concentration of TCE in the perched system was 9.6 μg/L, detected in TA2-W-26, and concentrations in only three SNL/NM wells have exceeded the maximum contaminant level (MCL) of 5.0 μg/L for TCE (TA2-W-19, TA2-W-26, and WYO-4). In the March/April 2002 groundwater sampling round, two of these three monitoring wells contained water with TCE concentrations that exceeded 5 μg/L; water from well TA2-W-26 had a concentration of 7.5 μg/L, while the duplicate samples at WYO-4 had TCE concentrations of 4.9 and 5.3 μg/L (refer to Figure 1-2 for well locations). In the three quarterly sampling events from July 2003 through February 2004, only water from WYO-4 had TCE concentrations exceeding 5 μg/L, ranging from 6.06 to 7.05 μg/L.

Well WYO-4 is an SNL/NM monitoring well that is located on KAFB property (Figure 1-2). Given that none of the SNL/NM potential release sites are near well WYO-4 and that groundwater flow in the perched system is to the southeast, the TCE concentrations present in water from WYO-4 are considered to represent contamination from an upgradient KAFB source.

Therefore, the TCE contamination present at this well is not considered to be within the scope of this CME.

The maximum historical concentration of nitrate in the perched system within the TAG SNL/NM AOR was 44 mg/L in water from wells TA2-W-19 and TA2-SW1-320, and a total of 9 SNL/NM wells have exceeded the MCL for nitrate during at least one sampling event. In March and April of 2002, two of the perched-system monitoring wells had nitrate concentrations that exceeded the MCL of 10 mg/L, with the highest concentration being 30 mg/L in well TJA-7. In the three quarterly sampling events from July 2003 through February 2004, four of the perched-system wells had nitrate concentrations that exceeded 10 mg/L, with the highest concentration being 29.8 mg/L in well TJA-7. Overall, concentrations of nitrate in the perched system exceeding MCLs are scattered across the SNL/NM AOR.

According to KAFB-IRP terminology, the nitrate contamination in the perched system forms what is referred to as Plume 3 (MWH Americas, Inc., 2003). Plume 3, which is centered on monitoring well TA2-SW1-320, is located under the southwest portion of TA-II and may extend southward to TJA-7. Monitoring wells in the perched system that have nitrate concentrations below the MCL surround these wells. The plume is 0.3 miles long and 0.2 miles wide (MWH Americas, Inc., 2003) and is thought to emanate from SWMU 165, the Building 901 Septic System.

1.3.5 Contaminant Distribution and Transport through the Regional Aquifer

Overall, the regional aquifer monitoring wells have generally yielded no samples with detectable TCE concentrations except for a historic peak in TCE of 3.2 µg/L in well PGS-2. At no time has an SNL/NM regional aquifer well exceeded the MCL for TCE. During March/April 2002, twelve SNL/NM regional-aquifer monitoring wells were sampled for TCE; none of the samples had detectable concentrations of TCE except for TJA-3 with 0.639 µg/L (an estimated value). The groundwater sample from merging-zone well TJA-4 did not contain TCE. In the three quarterly sampling events from July 2003 through February 2004, ten SNL/NM regional aquifer monitoring wells were sampled for TCE; none of the samples had detectable concentrations of TCE.

The maximum historical concentration of nitrate within the SNL/NM AOR for wells completed in the regional aquifer system was 49 mg/L in merging zone well TJA-4. However, this is the only SNL/NM AOR regional aquifer monitoring well that has ever had nitrate concentrations that exceed the MCL. During the March/April 2002 sampling round, TJA-4 had a nitrate concentration of 28 mg/L. In the three quarterly sampling events from July 2003 through February 2004, nitrate concentrations in TJA-4 ranged from 22.8 to 27.0 mg/L. The nitrate contamination in the regional aquifer southeast of TA-II forms what is referred to as Plume 4 (MWH Americas, Inc., 2003). Plume 4 is most likely responsible for the nitrate concentrations in TJA-4, a well completed in the zone of merging. The plume is 1.9 miles long and 1 mile wide and is associated with the active KAFB Landfill (MWH Americas, Inc., 2003).

1.3.6 Contaminants of Concern

Both TCE and nitrate are considered COCs for the perched system. Because no AOR regional aquifer wells have exceeded MCLs for either TCE or nitrate, no COCs are defined for the regional aquifer (SNL/NM 2004a). Therefore, the CME Work Plan and the CME process focus exclusively on TCE and nitrate contamination in the perched system.

Perched system wells with TCE concentrations that exceed MCLs, based on the results of the March/April 2002 sampling round, include WYO-4 and TA2-W-26 (Figure 1-2). Because the TCE contamination in well WYO-4 is attributed to KAFB releases, this well is not considered within the scope of the TAG CME Work Plan. Well TA2-W-19 has shown detections of TCE above the MCL; however, these detections have been sporadic over time with four detections at or above the MCL of 5 μg/L out of a total of 46 TCE concentration results reported since 1995. Based on data stated in the TAG CME Work Plan, a residual TCE vapor plume beneath SWMU 227 is not a continuing source to groundwater because recharge has ceased. Therefore, remedial alternatives for the SWMU 227 area will not be evaluated during the CME process. Therefore, only TCE contamination in the vicinity of TA2-W-26 will be addressed during the CME process. The TCE concentration at TA2-W-26 was 7.5 μg/L in March/April 2002.

Perched system wells with nitrate concentrations that exceed MCLs, based on the results of the March/April 2002 sampling round, include TJA-7 and TA2-SW1-320. Nitrate contamination in the vicinity of these two wells is within the scope of the CME and will be addressed during the CME process. Nitrate concentrations at these two wells were 30 mg/L (TJA-7) and 26 mg/L (TA2-SW1-320) in March/April 2002.

This report refers to three wells to illustrate the locations and distribution of COCs within the SNL/NM AOR. These three wells are:

- TA2-W-26 (TCE),
- TJA-7 (nitrate), and
- TA2-SW1-320 (nitrate).

1.3.7 Information Compiled for the Data Gaps Review

Table 1-1 is a compilation of properties for the perched groundwater system of the SNL/NM AOR. Most of these properties are discussed in more detail in the CME Work Plan (SNL/NM 2004a). However, the specific capacity of a hypothetical extraction well completed in the perched groundwater system had not been presented in the CME Work Plan and is presented here as part of the paper study.

Table 1-1. Summary of perched system properties for SNL/NM AOR.

Property	Minimum	Maximum
Horizontal hydraulic conductivity (K)(ft/min)	3.69×10^{-5} (SNL/NM 2004b)	2.12×10^{-3} (SNL/NM 2004b)
Vertical hydraulic conductivity (K)	1/100 of Horizontal K	1/10 of Horizontal K
Hydraulic gradient (ft/ft)	0.007 (SNL/NM 2003)	
Effective porosity	25% (SNL/NM 2004a)	
Groundwater velocity (ft/yr)	4 (SNL/NM 2004a)	10 (SNL/NM 2004a)
Estimated Specific capacity of potential wells (gpm/ft of drawdown)	0.1	3.5

Understanding the rate at which water can be extracted from or injected into a potential well is useful when evaluating remedial alternatives involving pumping or injection. A rough estimate of the specific capacities in each of three monitoring wells (TJA-7, TA2-W-26, and TA2-SW1-320) was calculated from purge monitoring data during recent sampling events. These estimations are not intended to be used in a remedial alternative design; rather, they have been used to demonstrate the relative feasibility of implementing remedial alternatives involving pumping or extraction. Relative drawdown was calculated as the difference between an initial water level reading prior to pumping and the corresponding water level after a stable pumping rate is achieved. Specific capacity was calculated for the last three measurements prior to sampling. The resulting specific capacities ranged from 0.1 (TJA-7) to 3.5 gpm/ft of drawdown (TA2-W-26).

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2.0 REMEDIAL ALTERNATIVE CONCEPTUAL DESIGNS

The purpose of this section is to provide details about each remedial alterative, including considerations for evaluation and implementation at SNL/NM AOR, and to present conceptual designs of the four remedial alternatives. Considerations for evaluation and implementation information are compiled from a review of the current literature, professional experience, and from calculations performed during the paper study stage (Appendices A, B, and C). Conceptual designs for each remedial alternative include an overview of the remedial alternative, a description of the T&FRs, and a list of the expected cost elements for each remedial alternative. The conceptual designs provide information for performing a remedial alternative evaluation and will be updated as laboratory, numerical modeling, and field studies provide more information. The expected duration of each remedial alternative is addressed as it relates to other remedial alternatives.

2.1 Groundwater Monitoring

Implementation of a groundwater monitoring remedial alternative consists of monitoring COCs. This section includes considerations for evaluation, implementation at SNL/NM AOR, T&FRs, and cost for groundwater monitoring of TCE and nitrate.

2.1.1 Considerations for Evaluation of Groundwater Monitoring

Advantages of groundwater monitoring, relative to more active remediation technologies, include a small secondary waste stream and no construction of treatment facilities. The existing monitoring well network would need to be maintained and consideration must be given to the need of replacing monitoring wells due to possible changes in the depth to water in the perched system.

2.1.2 Implementation of Groundwater Monitoring at SNL/NM AOR

The conceptual design for implementing a groundwater monitoring technology includes a description of the monitoring well network and a preliminary design of the monitoring strategy. It is assumed that implementation of groundwater monitoring as a long-term corrective action would include two operational phases: performance operations and long-term operations (Table 2-1). Performance operations include annual sampling and reporting during a period when performance is monitored and a long-term strategy is devised. Long-term operations include annual monitoring of these wells with an annual data review and a reporting requirement every 5 years. Remedy implementation would continue until compliance objectives are met. Figure 2-1 illustrates the process of implementing groundwater monitoring for TCE and nitrate. This figure illustrates the necessary inputs and waste streams that will be part of the implementation.

Table 2-1. Groundwater monitoring operational phases.

Operational Phase	Monitoring Frequency	Reporting Frequency	Timeframe
Performance Operations	Annual	Annual	TBD
Long-term Operations	Annual	5 Years	TBD

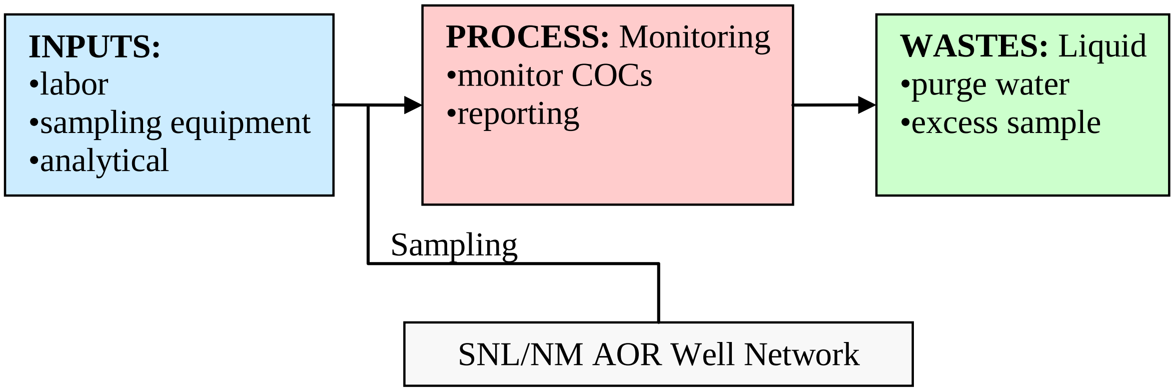


Figure 2-1. Process diagram for groundwater monitoring.

2.1.3 Technical and Functional Requirements

Implementation of this approach requires the ability to monitor the contaminants (TCE and nitrate) in groundwater. This requires that the existing monitoring well network be maintained. Monitoring would need to occur until it can be demonstrated that COCs are below MCLs. This would require no detections of COCs in monitoring wells for a period of time to be determined in the implementation work plan. Table 2-2 details the T&FRs.

Assumptions include:

- It can be determined during the CME that there is no risk to potential receptors.
- Groundwater monitoring as performed under the current program would be continued. This would include maintaining equipment, wells, utilities, and personnel resources.
- A sufficient monitoring well network exists.

2.1.4 Cost

Cost elements to be considered for implementing groundwater monitoring include capital equipment and operations and maintenance costs, as outlined in Table 2-3.

Table 2-2. T&FRs for groundwater monitoring.

Parameter	Requirement
Duration of groundwater monitoring	A remedy duration was not determined as part of the paper study. Monitoring would be conducted throughout the duration of the remedy.
Frequency of groundwater monitoring	Annual
Analytes and field parameters	TCE, nitrate, and water levels
Reporting	Annual reporting during performance operations; may be annual or every 5 years for long-term operations.
Equipment	All equipment necessary for monitoring, including pumps, sample bottles, power (generator or utilities), shipping supplies, purge water tanks, personal protection equipment, and any other necessary equipment.
Equipment storage	Storage for field sampling and waste containing equipment.
Waste storage	Storage of purge water until authorized to dispose.
Institutional controls	Institutional controls would consist of engineering and administrative controls to protect current and future users from health risks associated with contaminated groundwater. Engineering controls would include methods to restrict access to contaminated water, including locking devices on wellheads. Administrative controls would include postings on wellheads identifying potential hazards and placement of written notification of this corrective measure in the facility land-use master plan.

Table 2-3. Itemized cost elements for groundwater monitoring.

Capital	Operations and Maintenance
• Costs associated with designing a long-term groundwater monitoring program • Indirect costs (legal and permitting fees)	• Costs of maintaining an adequate monitoring well network for the duration of the remedy • Sampling and analyses costs for the duration of the remedy • Reporting costs for the duration of the remedy • Indirect operational costs including institutional controls, contingency allowances, and administrative costs

2.2 MNA

MNA is the reliance on natural attenuation processes to achieve site-specific remedial objectives within a reasonable timeframe (DOE 1999). This section includes considerations for evaluation, implementation at SNL/NM AOR, natural attenuation mechanisms, T&FRs, and cost for application of MNA for TCE and nitrate.

2.2.1 Considerations for Evaluation of MNA

Guidance for determining favorable conditions for MNA is stated in:

- *Use of MNA at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (EPA 1999), and
- *Decision-Making Framework Guide for Evaluation and Selection of Monitored Natural Attenuation Remedial Alternatives at Department of Energy Sites* (DOE 1999).

Source control technologies are to be used to control an active source term, which has been defined as a source inventory of contaminant that is being released to the groundwater where the rate of contaminant release is greater than attenuation rates such that the inventory of mobile contaminants is increasing over time (DOE 1999). As stated in the TAG CME Work Plan, two potential TCE and three potential nitrate sources have been identified within the SNL/NM AOR. However, none of these sources are actively contributing COCs to the perched system at concentrations above MCLs. Based on data stated in the TAG CME Work Plan, the mass of TCE that the vapor phase is contributing to the aquifer is minimal and the TCE vapor plume is immobile. Nitrate present in sewage wastewater has been transported to the perched system by high volumes of wastewater disposed at the sites and a secondary source of nitrate contamination in the vadose zone does not exist (SNL/NM 2004a). Therefore, source control technologies are not a necessary component of a remedial alternative for TCE or nitrate at SNL/NM AOR.

Figure 2-2 is a decision framework for implementing MNA (DOE 1999). The first tier of decision-making includes two options: (1) the contamination currently does not pose an unacceptable risk, there is no active source term, and plume contours are static or retreating or (2) data suggest attenuation mechanisms are operable or exist. Given these criteria and site-specific information, MNA can be a viable remedial alternative for SNL/NM AOR and a remedy involving MNA will be compared to the second and third tier criteria as the CME progresses. The applicability of MNA to reduce COC concentrations to below MCLs in a reasonable timeframe is evaluated as part of the paper study stage and the ongoing remedial alternative evaluation process.

2.2.2 Implementation of MNA at SNL/NM AOR

Implementation of MNA as a stand-alone remedial alternative would occur in two phases: 1) the performance operations phase and 2) the long-term operations phase (Table 2-4). The timeframe of these phases would be determined based on the capability to demonstrate that MNA will reduce COC concentrations to below MCLs. Prior to MNA implementation, characterization activities would be performed to determine whether intrinsic contaminant attenuation is taking place in the subsurface and to determine an appropriate monitoring strategy. Numerical groundwater models could be used to predict contaminant transport and the effects of dilution and dispersion of the contaminants. Indications of limited active biodegradation of TCE at TA2-W-26 include aerobic conditions and concentrations of cis-DCE slightly above the detection limit of 0.5 μg/L.

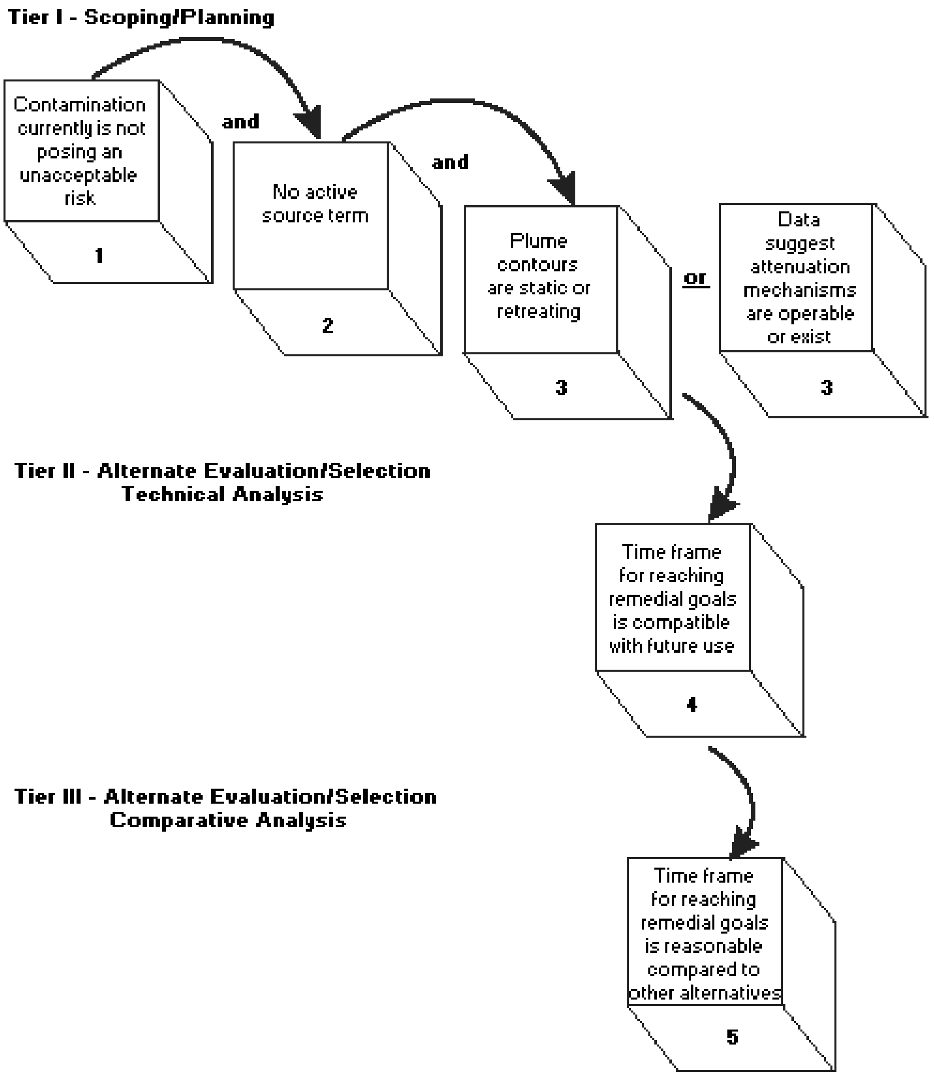


Figure 2-2. Decision framework for evaluating MNA (from DOE 1999).

Table 2-4. MNA operational phases.

Operational Phase	Monitoring Frequency	Reporting Frequency	Timeframe
Performance Operations	Annual	Annual	TBD
Long-Term Operations	Annual	5 Years	TBD

Monitoring is a key component of any MNA remedial alternative. Monitoring would begin during performance operations with the purpose of confirming natural attenuation processes and would continue through long-term operations to track the progress of MNA. The monitoring strategy would include clearly defined sampling frequency utilizing the current monitoring well network. A preliminary monitoring frequency is summarized in Table 2-4. Changes in the perched system water levels would be considered when determining the useful life of the existing monitoring well network. Analytes would include COCs and possibly other parameters to assess MNA performance.

Implementation of this remedial alternative would consist of characterization and monitoring of natural attenuation mechanisms and monitoring attenuation of contaminants in the subsurface without active remediation. Figure 2-3 illustrates the process of implementing MNA for TCE and nitrate. This figure illustrates the necessary inputs and waste streams that will be part of the implementation.

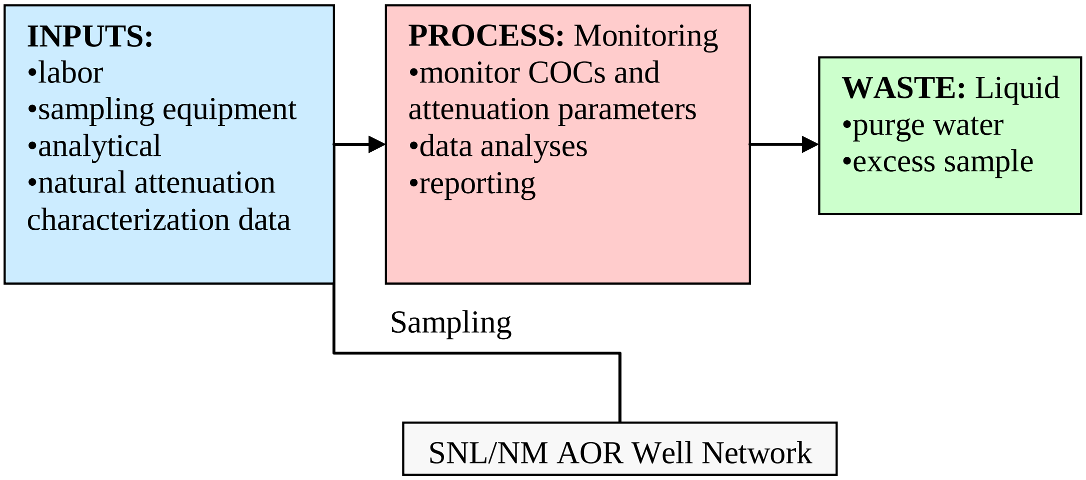


Figure 2-3. Process diagram for MNA.

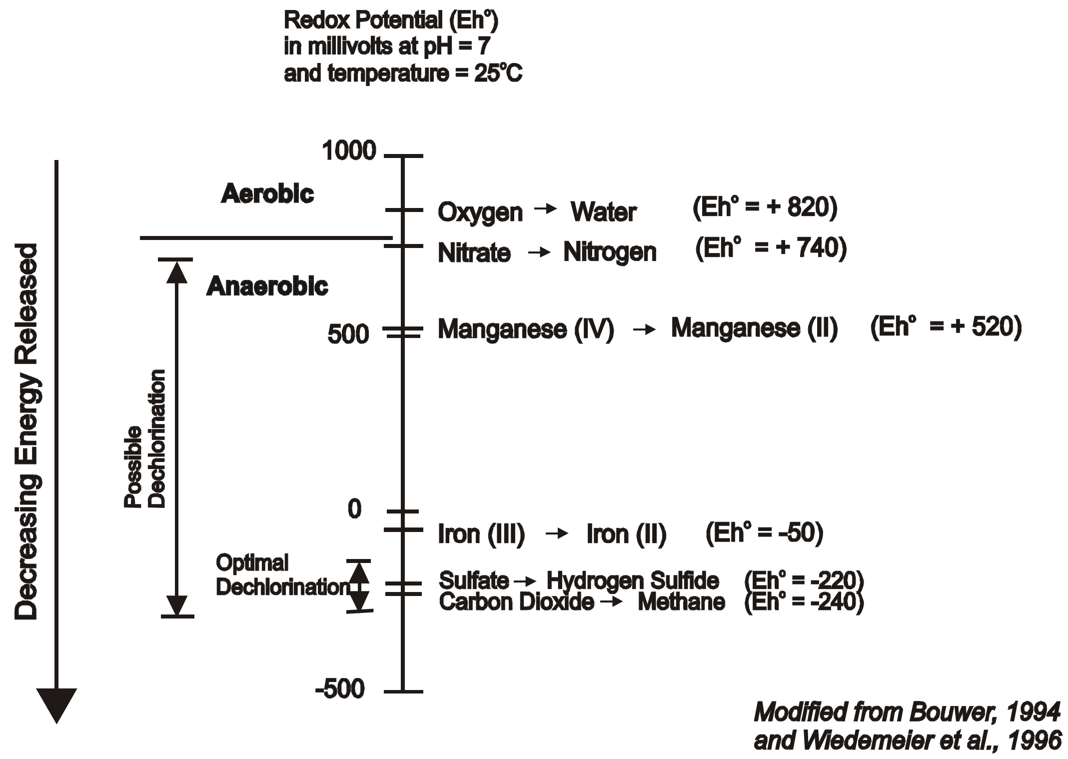
2.2.3 Natural Attenuation Mechanisms

Natural attenuation mechanisms may include degradation, volatilization, sorption, dilution, and dispersion. Dilution and dispersion are attenuation mechanism for nitrate, although under certain conditions degradation of nitrate may also occur. TCE is susceptible to attenuation through the mechanisms of sorption, dilution, dispersion, volatilization, and degradation through natural biological processes (biodegradation). Biodegradation mechanisms may include aerobic and anaerobic processes, including aerobic cometabolism and anaerobic reductive dechlorination (ARD).

Cometabolism is defined as the transformation of an organic compound by a microorganism that is unable to use the substrate as a source of energy or as one of its constituent elements (Alexander 1967). Cometabolism, as the name implies, occurs in conjunction with the metabolism of another substrate which the microorganisms use for carbon and/or energy. Thus, aerobic cometabolism requires the presence of the primary substrate and the cometabolic substrate. The primary substrate is required because the same enzyme that transforms the primary substrate also fortuitously transforms the cometabolic substrate. If the primary substrate is absent, the enzyme required for cometabolic transformation would not be induced and the cometabolic transformation would not occur.

TCE, cis-1,2-dichloroethene (cis-DCE), trans-1,2-dichloroethene (trans-DCE), and vinyl chloride have all been shown to be susceptible to cometabolic oxidation under aerobic conditions (e.g., Wilson and Wilson 1985; Semprini et. al. 1990). In addition, cis-DCE, trans-DCE, 1,1-dichloroethene, and vinyl chloride have been shown to be susceptible to direct oxidation under both aerobic (Vogel, Criddle, and McCarty 1987; Bradley and Chapelle 2000; Klier et al. 1999; Coleman et al. 2002) and anoxic conditions (Bradley and Chapelle 1998). Tetrachloroethene has been shown to be resistant to both direct and cometabolic oxidation (McCarty 1996). Several primary substrates induce aerobic cometabolism of chlorinated ethenes. Among them are methane, propane, butane, phenol, toluene, and ammonia. The enzyme methane monooxygenase (MMO), present in methanotrophs, is known to cometabolize TCE. One form of MMO, soluble MMO (sMMO), has been shown to catalyze rapid oxidation of chlorinated ethenes on the order of minutes to hours (e.g., Oldenhuis et. al. 1989; Aziz et. al. 1999).

Anaerobic biodegradation processes may include denitrification and ARD. Both processes are mechanisms through which indigenous microorganisms facilitate the degradation of contaminants to innocuous products. In zero-oxygen environments, microorganisms carry out respiration through reactions utilizing chemicals other than oxygen as terminal electron acceptors. Electron acceptors typically include nitrate, oxidized metals, sulfate, and carbon dioxide (Figure 2-4). Under strictly anaerobic conditions, TCE has been shown to be subject to microbial degradation under conditions where these compounds serve as a growth-linked electron acceptor. Denitrification is the process by which nitrate is utilized as a growth-linked electron acceptor.



Modified from Bouwer, 1994 and Wiedemeier et al., 1996

Figure 2-4. Energy available from typical microbial mediated redox reactions, and their relationship to reductive dechlorination.

2.2.4 Technical and Functional Requirements

Implementation of this approach must allow monitoring of contaminant attenuation mechanisms in the subsurface and the contaminant plume. This entails monitoring TCE, nitrate, and parameters to monitor attenuation mechanisms (i.e., redox parameters or dissolved gases). This monitoring would continue for the duration of the remedy. As mechanisms of natural attenuation are identified and numerical modeling is performed to predict contaminant transport, the number of wells to be monitored would be determined and predictions would be made to determine the duration of monitoring. Table 2-5 details the T&FRs.

Table 2-5. T&FRs for MNA.

Parameter	Requirement
Duration of monitoring	A remedy duration was not determined as part of the paper study. Monitoring would be conducted throughout the duration of the remedy.
Frequency of monitoring	Annual
Analytes and field parameters	COCs (TCE and nitrate), water levels, and other parameters necessary to monitor attenuation mechanisms (i.e., redox conditions and/or enzyme probes).
Analyses	The groundwater monitoring data would be analyzed and interpreted. This data would be used to monitor attenuation mechanisms and track COC concentration changes.
Reporting	Annual reporting for the first 5 years, followed by reporting every 5 years until the end of long-term operations. Reports would include analysis of concentration trends and comparison to predicted trends of attenuation.
Equipment	All equipment necessary for monitoring, including pumps, sample bottles, power (generator or utilities), shipping supplies, purge water tanks, personal protection equipment, and any other necessary equipment.
Equipment storage	Storage for field sampling and waste containing equipment.
Waste storage	Storage of purge water until authorized to dispose.
Institutional controls	Institutional controls would consist of engineering and administrative controls to protect current and future users from health risks associated with contaminated groundwater. Engineering controls would consist of methods to restrict access to contaminated water, including locking devices on wellheads. Administrative controls would include postings on wellheads identifying potential hazards and placing written notification of this corrective measure in the facility land-use master plan.

Assumptions include:

- The CME demonstrates that there is no unacceptable risk to potential receptors,
- Natural attenuation mechanisms for both TCE and nitrate are identified,
- Necessary equipment, utilities, and personnel are available, and
- A sufficient monitoring well network exists.

2.2.5 Cost

Cost elements of implementing MNA for TCE and nitrate would include capital equipment and operations and maintenance costs as listed in Table 2-6.

Table 2-6. Itemized cost elements for MNA.

Capital	Operations and Maintenance
• Costs associated with designing a long-term groundwater monitoring program • Costs of characterizing natural attenuation • Indirect costs (legal and permitting fees)	• Costs of maintaining an adequate monitoring well network for the duration of the remedy • Sampling and analyses costs • Reporting costs for the duration of the remedy • Costs for data analyses and interpretation • Indirect operational costs, including institutional controls, contingency allowances, and administrative costs

2.3 ISB

ISB is implemented by adding degradable organic carbon and/or nutrients to the aquifer. Indigenous microorganisms then increase in population and utilize available electron acceptors as they degrade organic carbon. The free energy yielded by redox reactions varies substantially depending upon the electron acceptor, as shown in Figure 2-4. During respiration, microorganisms preferentially utilize the electron acceptors yielding the greatest free energy. Figure 2-4 shows that the order of preference for the most common inorganic electron acceptors is oxygen, nitrate, manganese (IV), iron (III), sulfate, and carbon dioxide. Therefore, the dominant microbial community in a groundwater system is largely dependent upon the distribution of electron acceptors. Where oxygen is plentiful, aerobic bacteria will predominate; where oxygen is depleted but nitrate is plentiful, nitrate-reducing bacteria will predominate; and so on. Once highly reducing conditions are created (i.e., methanogenic), ARD becomes energetically favorable and complete dechlorination of chloroethenes to ethene is facilitated if dechlorinating microorganisms are present in sufficient number.

2.3.1 Considerations for Evaluation of ISB

ISB technology would be implemented by injecting an aqueous phase electron donor into several injection wells placed within the areas of highest contamination. A significant challenge to successful implementation of ISB for the SNL/NM AOR is distributing the electron donor to contaminated zones within the perched system. The following factors were considered when evaluating the feasibility of electron donor distribution:

- As stated in Section 1.3.6, TCE and nitrate concentrations higher than their respective MCLs have been observed in many locations across the two-square mile AOR. At three of these locations TCE and nitrate concentrations have recently been observed greater than the MCL; therefore, a minimum of three injection wells will be needed to distribute electron donor to these high concentration contaminated zones.

- Distribution of electron donor in the perched groundwater will be achieved by injecting electron donor solutions into injection wells. The extent over which electron donor will be distributed from a single injection well is limited by the volume of solution injected. The volume of solution injected will be very large considering the distribution of the contaminants in groundwater. The ability to inject these large volumes is limited by the number of injection points (wells) and the rate at which these injection wells will accept the injection. The estimated specific capacities (Section 1.3.7) suggest that the achievable injection rate may be limiting, thus requiring the construction of more than three injection wells.

- Unlike TCE, nitrate does not sorb to aquifer materials. When injecting electron donor solutions into high nitrate concentration zones, displacement of the nitrate contaminated groundwater may increase mobility of the contaminant. Injections would partially displace nitrate-contaminated water, and the contact between the amendments and the contaminated water would be limited to mixing during injections.

2.3.2 Implementation of ISB Technology at SNL/NM AOR

ISB implementation would target the high concentration locations. Figure 2-5 illustrates the process of implementing ISB for TCE and nitrate. The figure illustrates the necessary inputs and waste streams that will be part of the implementation. As demonstrated, implementation of ISB would require more inputs than the MNA or groundwater monitoring remedial alternatives. In addition ISB implementation would require constructing at least three injection wells.

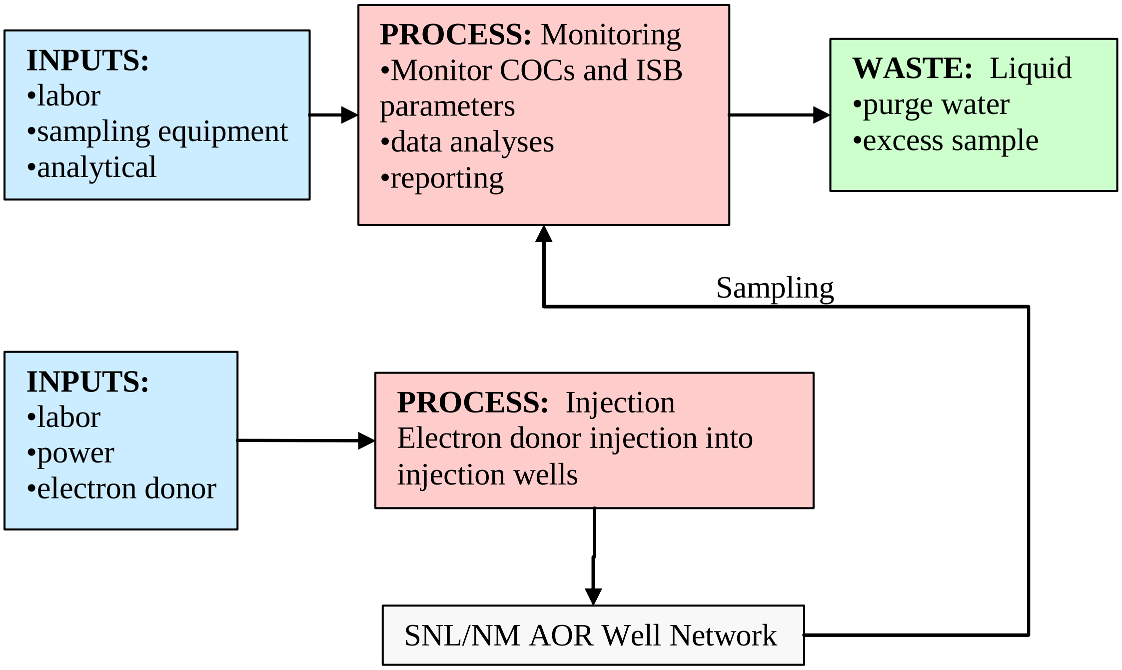


Figure 2-5. Process diagram for ISB.

2.3.3 Technical and Functional Requirements

Implementation of ISB would require injecting amendments to induce biological activity, which would change aquifer conditions from aerobic to anaerobic and induce anaerobic processes of biodegradation. The targeted aquifer zone will include groundwater containing TCE at concentrations greater than 5 µg/L and nitrate concentrations greater than 10 mg/L. The electron donor addition system must emplace enough electron donor to cause denitrification and ARD. This system would be composed of electron donor injection wells and would include electron donor injection facilities. Table 2-7 lists the T&FRs for this remedial alternative. Assumptions include:

- Necessary equipment, utilities, and personnel are available.
- A dechlorinating and/or denitrifying microbial community can be induced by addition of electron donor.
- A sufficient number of injection wells will be constructed in order to distribute the electron donor.

Table 2-7. T&FRs for ISB.

Parameter	Requirement
Remedy duration	Duration of ISB operations would be determined prior to implementation. It is estimated that ISB would require an implementation period followed by confirmatory monitoring.
Injection operations duration	One or two injections of electron donor should produce conditions conducive to ARD and denitrification. Therefore, injection operations may only last for a short time, provided that distribution of electron donor is achieved.
Injection wells	At least three injection wells will be necessary.
Injection facilities/ injection equipment	The injection facility would be capable of mixing sodium lactate into potable water. The facility can be temporary. Injection equipment will include a water supply (tanks or pumping), mixing equipment, and other necessary plumbing and equipment.
Duration of monitoring	Monitoring of groundwater would increase in frequency during and for a short period of time after the injection(s). It is estimated that monitoring would continue at a reduced frequency for several years after the beginning of remedy implementation.
Frequency of monitoring	ISB monitoring would include sampling and analyses necessary to monitor the effect of electron donor injections. A period of groundwater monitoring following ISB injections would be required to confirm that TCE and nitrate concentrations are below MCLs.
Analytes and field parameters	COCs (TCE and nitrate), water levels, and parameters necessary to monitor ISB operations (i.e., chemical oxygen demand to monitor electron donor distribution and utilization).
Analyses	The groundwater monitoring data would be analyzed and interpreted. Data would be used to track the performance of ISB and monitor contaminant reduction.
Reporting	Annual reporting for first 5 years, followed by annual data summaries with formal reports submitted every 5 years until the end of long-term operations. Reports would include analysis of concentration trends.
Sampling equipment	All equipment necessary for monitoring, including pumps, sample bottles, power (generator or utilities), shipping supplies, purge water tanks, personal protection equipment, and any other necessary equipment.
Equipment storage	Storage for field sampling and waste containing equipment
Waste storage	Storage of purge water until authorized to dispose.
Institutional controls	Institutional controls would consist of engineering and administrative controls to protect current and future users from health risks associated with contaminated groundwater. Engineering controls would consist of methods to restrict access to contaminated water, including locking devices on wellheads. Administrative controls would include postings on wellheads identifying potential hazards and placing written notification of this corrective measure in the facility land-use master plan.

2.3.4 Cost

Cost elements for implementing ISB would include capital and operations and maintenance costs, as listed in Table 2-8.

Table 2-8. Itemized cost elements for the ISB.

Capital	Operations and Maintenance
• Engineering costs to design ISB implementation	• Includes labor, material, and equipment costs to inject and cost of purchasing electron donor
• Construction of injection wells.	• Sampling and analyses costs (sampling and analyses may be more extensive to monitor redox conditions)
• Construction of injection facilities and injection equipment.	• Reporting costs for the duration of the remedy (the remedy may require less time and fewer reports)
• Indirect costs (legal and permitting fees)	• Costs for data analyses and interpretation
	• Indirect operational costs including institutional controls, contingency allowances, and administrative costs

2.4 Pump and Treat

Pump and treat is a broad term used to describe the pumping of contaminated groundwater to the surface where it can be treated. The general goal of pump and treat implementation at SNL/NM AOR would be to restore the aquifer by removing the mass of COCs from groundwater. The system would consist of extraction wells, ex-situ treatment systems for TCE and nitrate, and a disposal method for the treated water for each location where COC concentrations are above MCLs. Disposal of treated water could occur onsite through injection to the aquifer or by some other method.

2.4.1 Considerations for Evaluation of Pump and Treat

Pump and treat is one of the most widely used groundwater technologies, as it is implemented at about three-quarters of the Superfund sites with contaminated groundwater and at most sites where cleanup is conducted under the Resource Conservation and Recovery Act (RCRA) and state laws (EPA 1996). It is a well-developed technology that is applicable for TCE and nitrate. Pump and treat is appropriate for both contaminant reduction and containment of a plume.

A review of Environmental Protection Agency (EPA) literature on pump and treat reveals that this technology can have several significant disadvantages. The general goal of pump and treat is to remove contaminant mass from groundwater to restore the aquifer to beneficial use. Favorable conditions for accomplishing cleanup using pump and treat include the presence of contaminants that do not sorb and a homogeneous permeable aquifer. Neither condition is present at SNL/NM AOR, since TCE is a contaminant that tends to sorb and the aquifer is characterized by low permeability and heterogeneity.

Slow contaminant transport and interphase transfer has caused many pump and treat systems to continue to operate for decades. Sorption of TCE to aquifer materials retards the movement of these contaminants toward extraction wells, resulting in the need to flush multiple pore volumes of water through the contaminated aquifer zone to remove the contaminant mass (EPA 1997). An evaluation of 32 selected pump and treat systems showed that these systems require on average $4.9 million in capital costs and $730,000 in annual operating costs. Despite this, only two of the sites surveyed have been cleaned up (EPA 2001).

2.4.2 Considerations for Implementing Pump and Treat at SNL/NM AOR

Site-specific characteristics must be considered to evaluate implementation of pump and treat at SNL/NM AOR. Additional site characterization may need to take place to identify appropriate locations for installation of new wells and impacts of pumping to hydrogeology of the perched system and the regional aquifer underlying the TAG study area. Testing may be conducted to estimate or verify predicted capture zones, compare observed contaminant distribution to capture zones, and obtain well yield information to estimate treatment volumes.

Approximate order-of-magnitude scoping calculations, using site-specific information, have been performed to develop pump and treat conceptual designs. Two approaches to pump and treat described in EPA guidance (EPA 1997) were initially considered applicable for SNL/NM AOR. These two approaches were:

- Removing a sufficient number of pore volumes from within the contaminated aquifer volume to restore the aquifer, and
- Capturing the contaminant plume as it is transported across a downgradient transect or plane.

The first approach involves removing groundwater from the contaminated zone and essentially flushing that zone with uncontaminated groundwater from outside to remove dissolved contaminants and contaminants that are sorbed to aquifer materials or located within pore water that is not readily accessible. Extraction well(s) may be placed strategically to both contain the plume and remove contaminants. At a minimum three extraction wells, corresponding to the three locations of high concentrations discussed in Section 1.3.6, would be required to remove the contaminated groundwater from the SNL/NM AOR. Treatment systems would be designed to remove TCE and nitrate. Aquifer restoration is accomplished by removing multiple pore volumes of water. It has been suggested that it may be necessary to pump between 10 and 100 pore volumes to remove contaminants from an aquifer (EPA 1997). Scoping calculations of achievable extraction rates using the specific capacity range presented in Table 1-1, suggest that maximum achievable extraction rates may range from 0.4 to 200 gpm. This wide range of extraction rates is dependent on site constraints such as perched groundwater system thickness.

The second approach involves capturing the contaminant plume by creating a sufficient downgradient capture zone. The capture zone width was estimated according to the method summarized in EPA guidance (EPA 2002) and assuming a capture zone thickness of 30 ft (Appendix A). Calculations revealed that, given the range of perched system properties, a well pumped at its maximum capacity would create a sufficiently wide capture zone. However, as a result of the relatively slow groundwater velocity (4-10 ft/year) (SNL/NM 2004a), remediation using this method would require an unreasonably long time compared to other remedial alternatives.

2.4.3 Scoping Treatment Options

Several treatment options were considered for removal or degradation of TCE and/or nitrate contamination. These options include:

- Sorption of TCE to granular activated carbon (GAC),
- Volatilization of TCE using an air stripper,
- Treatment of both TCE and nitrate in an ex-situ bioreactor, and
- Removal of nitrate using ion exchange.

Two of the options listed above were found to not be practical for implementation. The options that were not considered practical are:

- **Removal of TCE using an air stripper**. Both air stripping and treatment with GAC are only applicable to TCE. These treatment options do not degrade the TCE, but rather transfer the contaminant to another media or phase. The major disadvantage of treatment using air stripping is that cost and commitment of resources would be significantly more than using GAC. Because air stripping requires a large reactor size that has a blower constantly running, it is more appropriate for higher concentrations than those present at SNL/NM AOR. Because it is more practical to use GAC to achieve removal of TCE, air stripping will no longer be considered.

- **Treatment of both TCE and nitrate in an ex-situ bioreactor**. There are several designs for treatment of both TCE and nitrate in an ex-situ biological reactor. The major advantage of this option is treatment by degrading both TCE and nitrate to innocuous products. However, this type of treatment has several major disadvantages that make it impractical for use at SNL/NM AOR. First, the presence of competing electron acceptors (oxygen, nitrate, and sulfate) and the relatively slow rate of dechlorination combine to require a long hydraulic retention time making the required reactor size very large. Second, it is difficult to maintain an active dechlorinating microbial community given the low chlorinated ethene concentrations. The ability to maintain this community is unknown and would be experimental. Third, waste streams (i.e., treated water and settled sludge) would contain biomass and would require disposing. Finally, the system requires the continued cost of extensive monitoring and constantly adding electron donor.

The other treatment options would be evaluated during pump and treat design. A conceptual design for each option is presented in Appendix B, including a list of advantages and disadvantages of each. Treatment options considered for the CME are sorption of TCE to GAC and removal of nitrate using ion exchange. The two treatment options would be applied to the pump and treat remedial alternative in the following manner:

- **Pump and treat for TCE using GAC and nitrate using ion-exchange.** Treatment of contaminated water would involve removal of TCE using GAC and removal of nitrate using ion exchange.

Application of this remedial alternative at SNL/NM AOR would involve extraction of contaminated groundwater and treating the water to remove TCE or nitrate. The water would be extracted sufficiently long to remove contaminants in the aquifer to below MCLs. Figure 2-6 illustrates the process of implementing pump and treat for TCE using GAC, and nitrate using ion-exchange. This figure illustrates the necessary inputs and waste streams that will be part of the implementation. As demonstrated, implementation of this remedial alternative would require more inputs than the MNA or groundwater monitoring remedial alternatives and would produce additional waste streams.

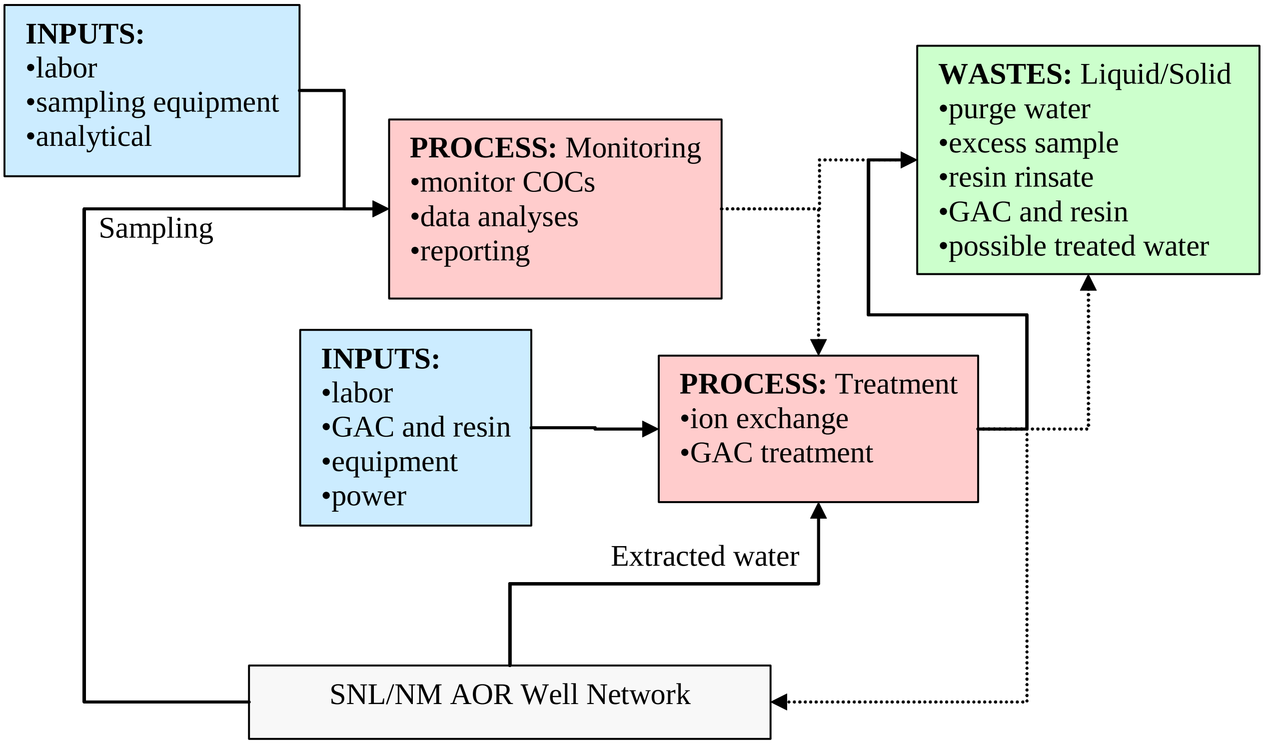


Figure 2-6. Process diagram for implementation of pump and treat.

2.4.4 Technical and Functional Requirements

Implementation of this remedial alternative would require pumping contaminated groundwater to the surface, treating the water for COCs to concentrations below MCLs, and disposing the water. The system would be composed of extraction wells, a treatment facility, and, depending on the disposal option chosen, may also require an injection well. Table 2-10 illustrates the T&FRs for this remedial alternative.

Assumptions include:

- Necessary equipment, utilities, and personnel are available.
- The treatment facility would be able to remove TCE and nitrate to below MCLs.

Table 2-10. T&FRs for pump and treat using GAC and ion-exchange.

Parameter	Requirement
Extraction wells	Extraction wells would be constructed that penetrate and are screened across the contaminated zone of the perched system.
Treatment facilities	The treatment facilities would be composed of a prefabricated building equipped with electric power.
Treatment equipment	GAC and ion exchange would be used to remove TCE and nitrate. Replacement of GAC and regeneration of resins will also be necessary.
Extraction rate	Extraction rate ranging from 0.38 to 52.5 gpm per well.
Pump and treat duration	Pumping operations would continue until contaminants are removed from the groundwater. Experience suggests that this will require removing several pore volumes from the entire contaminated zone. Treatment would need to occur as long as groundwater is being extracted.
Duration of monitoring	Groundwater monitoring would continue throughout pumping operations and for a period of 5 years following or until concentrations are below MCLs.
Frequency of monitoring	Regular monitoring of treatment facility influent, effluent, and intermediate sampling ports would be required. Groundwater monitoring would also be required during pump and treat operations and following pump and treat operations until COCs are below MCLs.
Analytes and field parameters	COCs (TCE and nitrate) and water levels
Analyses	The groundwater monitoring data would be analyzed and interpreted. Data would be used to track the performance of pump and treat and monitor contaminant reduction.
Reporting	Annual reporting for first 5 years, followed by reporting every 5 years until the end of long-term operations. Reports would include analysis of concentration trends and comparison to predicted trends of attenuation.

Table 2-10. (continued).

Parameter	Requirement
Sampling equipment	All equipment necessary for monitoring, including Bennett pumps, sample bottles, power (generator or utilities), shipping supplies, purge water tanks, personal protection equipment, and any other necessary equipment.
Equipment storage	Storage for field sampling and waste containing equipment
Waste storage	Storage for spent GAC containing sorbed TCE.
Institutional controls	Institutional controls would consist of engineering and administrative controls to protect current and future users from health risks associated with contaminated groundwater. Engineering controls would consist of methods to restrict access to contaminated water, including locking devices on wellheads. Administrative controls would include postings on wellheads identifying potential hazards and placing written notification of this corrective measure in the facility land-use master plan.

2.4.5 Cost

Cost elements of implementing pump and treat for TCE and nitrate would include capital and operations and maintenance costs, as listed in Table 2-11.

Table 2-11. Itemized cost elements for pump and treat.

Capital	Operations and Maintenance
Engineering costs to design pump and treat implementation	Costs associated with operations and maintenance of the treatment facilities. These would include replacement of GAC, regeneration of resin, labor, power, and other equipment costs.
Construction of extraction wells. May also include construction of an injection well(s).	Sampling and analyses costs. In addition to monitoring groundwater sampling and analyses would also include monitoring influent, effluent and other water samples from the treatment facility.
Construction of treatment facility and installation of treatment equipment (GAC drums and ion exchange unit).	Costs for data analyses and interpretation
Indirect costs (legal and permitting fees)	Reporting costs for the duration of the remedy (the remedy may require less time and fewer reports)
	Indirect operational costs including institutional controls, contingency allowances, and administrative costs

3.0 REMEDIAL ALTERNATIVE EVALUATION

The remedial alternative conceptual designs provided in this report summarize implementation strategies for remedial alternatives to support completion of a remedial alternative evaluation. The remedial alternative evaluation is intended to identify remedial alternatives that should be investigated through field, laboratory, or numerical modeling studies. Each remedial alternative is evaluated using the threshold and remedial alternative criteria, as stated in the TAG CME Work Plan (SNL/NM 2004a). The outcome of this evaluation is a list of remedial alternatives that pass the evaluation and recommendations of additional studies to fill data gaps identified for those remedial alternatives.

3.1 Threshold Criteria Evaluation

As specified in the COOC (NMED 2004), each remedial alternative must be evaluated based on the threshold criteria. Descriptions of the threshold criteria are stated in the TAG CME Work Plan (SNL/NM 2004a). The following threshold criteria were evaluated:

- Protect human health and the environment,
- Attain media cleanup standard or alternative, approved risk-based cleanup goals, and
- Comply with standards for management of wastes.

As discussed in the TAG CME Work Plan (SNL/NM 2004a), source control technologies are not a necessary component of a remedial alternative for TCE or nitrate at SNL/NM AOR; therefore, the source control threshold criterion was not evaluated. Remedial alternative conceptual design information was used to determine if the remedial alternative meets the threshold criterion. This evaluation was a YES/NO evaluation. The results of this evaluation are presented in Table 3-1. As demonstrated, all of the remedial alternatives received a YES rating for each of the three categories.

Table 3-1. Threshold criteria evaluation.

Remedial Alternatives	Protective of Human Health and Environment	Attain Media Cleanup Standards	Waste Management Standards Compliance
Groundwater Monitoring	YES	YES	YES
MNA	YES	YES	YES
ISB	YES	YES	YES
Pump and Treat	YES	YES	YES

YES = the remedial alternative meets the threshold criterion
NO = the remedial alternative does not meet the threshold criterion

Note: The threshold criterion, *Source Control*, is not included.

3.2 Remedial Alternative Evaluation

Because all remedial alternatives passed the threshold criteria evaluation, they were evaluated based on the remedial alternative evaluation criteria. The remedial alternative evaluation criteria are described in the TAG CME Work Plan (SNL/NM 2004a). As specified in the COOC (NMED 2004), the remedial alternative evaluation must be balanced and includes the following:

- Long-term reliability and effectiveness,
- Reduction of toxicity, mobility, or volume,
- Short-term effectiveness,
- Feasibility,
- Capital cost, and
- Operations and maintenance cost.

The remedial alternative conceptual design information was used to perform a comparative analysis for each remedial alternative using the remedial alternative threshold criteria. The comparative analysis was performed using the following ratings:

"Not effective" = Does not effectively meet the remedial alternative criterion within a timeframe comparable to other remedial alternatives,

"+" = Effectively meets the remedial alternative criterion, and

"+ +" = More effectively meets the remedial alternative criterion.

The total number of pluses represents how effectively the remedial alternative meets the criterion. A "Not effective" rating receives no score. Therefore, with six categories, the possible scores range from 0 – 12. This approach balances the critieria in order to evaluate each remedial alternative in a simple, comparative manner. Information supporting comparative analysis of the remedial alternatives is presented in Table 3-2, and the results of the analyses are presented in Table 3-3. The supporting information states a rationale for the comparative analysis rating assigned to each remedial alternative for each criterion. This includes comparison of remedial alternatives and identifying data gaps. Data gaps are identified where additional information is needed to accurately rate the criterion and this information can be collected in a cost- and time-efficient manner.

The comparative analyses shown in Table 3-3 demonstrate that the ISB and pump and treat remedial alternatives are considerably less effective than the other remedial alternatives. For both ISB and pump and treat, three facilities (i.e. injection wells, extraction wells, treatment facilities) would need to be constructed in order to implement the remedy at the three separate locations with COC concentrations above MCLs within the SNL/NM AOR. Although ISB will degrade contaminants in situ, there is a risk that nitrate may be displaced by electron donor injections resulting in increased mobility and volume of nitrate-contaminated water.

Table 3-2. Information supporting comparative analysis of the remedial alternatives.

Remedial Alternatives	**Long-Term Reliability and Effectiveness**	**Reduction of Toxicity, Mobility, or Volume**	**Short-Term Effectiveness**	**Feasibility**	**Cost**	
					Capital	**Operations and Maintenance**
Groundwater monitoring	Data gap. The CME process must demonstrate that there is no risk to receptors without natural attenuation. If it is demonstrated that there is no long-term risk in leaving contaminants in place, then the remedy is effective because the process of monitoring groundwater is reliable and is effective at tracking contaminants.	Would not consider toxicity reduction.	There is no immediate reduction in contaminant concentration. Short-term risk is less than pump and treat since contaminants are not brought to the surface.	Ready to implement immediately.	Costs less to implement than more active remedies	The timeframe of continued monitoring may be longer than more active remedial alternatives. There is a possible need to replace monitoring wells.
MNA	Data gap. If numerical modeling and/or field studies demonstrate that natural attenuation mechanisms are operable, then this remedial alternative will be effective.	Data gap. Need to identify natural attenuation mechanisms.	There is no immediate reduction in contaminant concentration. Short-term risk is less than pump and treat since contaminants are not brought to the surface.	Ready to implement immediately.	Costs less to implement than more active remedies	The timeframe of continued monitoring may be longer than more active remedial alternatives. There is a possible need to replace monitoring wells.
ISB	Successful implementation of ISB will degrade contaminants and remove long-term risk of exposure; however, there is also a risk that nitrate may be displaced by electron donor injections.	Reduces toxicity in situ, by degrading COCs; however, some nitrate may potentially be displaced resulting in temporary increased mobility and volume.	Reduces contaminant concentrations with minimal short-term risk from bringing contaminants to the surface.	Technically less feasible than MNA or groundwater monitoring due to the physical constraints of the aquifer and the distribution of contaminants.	Requires construction of new injection wells and injection equipment in several locations within the SNL/NM AOR.	Requires purchase of large amounts of electron donor and intensive operations.
Pump and treat	Pump and treat with the goal of restoring the groundwater to beneficial use would not be effective at this site based on experience at other sites and site specific constraints. Requires disposal of significant volumes of waste streams for the duration of operations.	Contaminants are transferred to a different media instead of destroyed in groundwater.	There may be an immediate reduction in concentration, but contaminants are brought to the surface increasing risk of exposure.	Technically less feasible than MNA or groundwater monitoring due to the physical constraints of the aquifer and the distribution of contaminants.	Requires well drilling and construction of infrastructure in several locations within the SNL/NM AOR.	Operation duration could be very long requiring considerable cost in maintaining a treatment system and pumping wells. Changes in water levels may also affect the remedial alternative.

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Table 3-3. Comparative analysis of remedial alternatives for SNL/NM AOR.

Remedial Alternatives	Long-Term Reliability and Effectiveness	Reduction of Toxicity, Mobility, or Volume	Short-Term Effectiveness	Feasibility	Cost: Capital	Cost: Operations and Maintenance	Totals
Groundwater monitoring	++	Not effective	+	++	++	+	8
MNA	++	+	+	++	++	+	9
ISB	++	+	++	Not effective	Not effective	Not effective	5
Pump and treat	Not effective	+	+	+	Not effective	Not effective	3

For pump and treat, the contamination will be transferred to a different media (i.e. resin used in ion exchange) instead of being destroyed in situ. This results in the additional cost of disposing of the spent GAC containing TCE and concentrated nitrate brine waste in the spent resin. Pump and treat may be an effective means of removing mass from the extracted water; however, observations from application of pump and treat at other sites indicates that it has not been an efficient means of restoring contaminated aquifers. Also, operations for pump and treat will involve a long operational timeframe with considerable maintenance costs.

As discussed in the TAG CME Work Plan (SNL/NM 2004a), if a remedial alternative is determined to be significantly less effective than the other remedial alternatives, then it will no longer be considered. It is recommended that the two remedial alternatives, ISB and pump and treat, no longer be evaluated as part of the CME.

The evaluation demonstrated that groundwater monitoring and MNA are comparable in effectiveness and cost. Small changes in rankings will not significantly change the overall score of the remedial alternatives. These two remaining remedial alternatives are still considered suitable for implementation at SNL/NM AOR but have different strengths and weaknesses, and will continue to be evaluated.

3.3 Summary of the Remedial Alternative Evaluation

Based on the information presented in this report, the list of remedial alternatives has been revised from the initial list of four, as stated in the TAG CME Work Plan (SNL/NM 2004a), to two remedial alternatives, groundwater monitoring and MNA. These alternatives that will be evaluated by conducting further studies are described in Section 4.

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4.0 RECOMMENDATIONS FOR FURTHER STUDIES

Data gaps regarding individual remedial alternatives and their application at SNL/NM AOR have been identified. Numerical modeling, field, and laboratory, studies have been identified to provide this information. A decision was made regarding the utility of performing each of these studies considering the results of the evaluation presented in Section 3 of this report. Table 4-1 presents specific activities and a recommendation of which activities should be performed. These activities correspond to stages of data gathering activities identified in the TAG CME Work Plan (SNL/NM 2004a). Based on the information and evaluation of remedial alternative data gaps presented in this report, it is recommended that numerical modeling be conducted for MNA and field scale studies be conducted for groundwater monitoring and MNA. It is also recommended that the following studies not be conducted:

- Laboratory and field scale studies for ISB, and
- Field scale studies for pump and treat.

4.1 Recommended Activities

It is recommended that evaluation of data gaps for two remedial alternatives, groundwater monitoring and MNA, be performed. Characterization activities for the greater TAG study area are recommended field scale studies for both groundwater monitoring and MNA; however, these activities are not directed by nor conducted as part of this CME process; however, the data generated can be used as appropriate. For MNA, numerical modeling is recommended to investigate the fate and transport of contaminants in the perched groundwater system. Other field scale studies recommended for MNA include investigating anaerobic mechanisms of TCE and nitrate biodegradation and performing enzyme probe analyses to provide direct evidence of an aerobic cometabolic TCE degradation mechanism.

4.1.1 Numerical Modeling

Past numerical modeling has been performed to determine the fate and transport of contaminants to downgradient receptors for the greater TAG study area (SNL/NM 2004a). However, additional information may be needed to adequately determine the fate and transport for the SNL/NM AOR because past modeling only included the regional system and did not include transport through the perched system. In order for contaminants within the SNL/NM AOR to reach downgradient receptors, they would have to travel through the perched system, to the merging zone, and then into the regional system. Obviously, any attenuation processes and travel time for these contaminants would be in addition to those predicted for particles released in the regional system during previous simulations. The merging zone between the perched and regional systems is thought to be southeast of TA-II and TA-IV. Given that predicted travel times from the regional system in this area are in excess of 90 years, and that particles must travel through some portion of the perched system in order to reach the regional system, it is unlikely that contaminants in the perched system will reach downgradient receptors (SNL/NM 2004a). However, a simplified numerical modeling approach will be implemented to estimate the potential for contaminant dilution during transport through the perched system, merging zone, and regional aquifer.

4.1.2 Field Scale Studies

The TAG Investigation Work Plan (SNL/NM 2003) has identified several characterization activities for the greater TAG study area. These activities include additional groundwater monitoring and soil vapor sampling at various locations throughout the greater TAG study area. These characterization activities are recommended field scale studies for both groundwater monitoring and MNA; however, these activities are not directed by nor conducted as part of this CME process, but the data generated can be used as appropriate.

These ongoing characterization activities for the greater TAG study area may be augmented as appropriate to investigate mechanisms for contaminant degradation to establish whether natural attenuation of COCs will occur. This may include investigating anaerobic mechanisms of TCE and nitrate biodegradation and performing enzyme probe analyses to provide direct evidence of an aerobic cometabolic TCE degradation mechanism.

4.2 Activities No Longer Recommended

Several laboratory and field scale activities were initially identified to fill anticipated data gaps regarding the ISB and pump and treat remedial alternatives. These included laboratory microcosm studies and field scale injection tests for ISB, and aquifer tests for pump and treat. A brief description of these activities is included in Table 4-1. It has been determined that the ISB and pump and treat remedial alternatives are significantly less effective than MNA or groundwater monitoring, and will no longer be considered as remedial alternatives. Therefore, these laboratory and field studies are no longer necessary.

Table 4-1. Recommended numerical modeling, field, and laboratory studies.

Stage (Remedial Alternative)	**Activity/Purpose**	**Perform?**
Numerical Modeling (MNA)	Fate and transport of contaminants in the perched groundwater system.	**Yes.** Numerical modeling goals and objectives will be determined by January 14, 2005, followed by the start of modeling activities.
Laboratory Study (ISB)	Laboratory microcosm studies to determine if dechlorinating microbes can be induced with electron donor in the perched system to degrade TCE to ethene.	**No.** The ISB remedial alternative is no longer being considered.
Field Scale Study (Groundwater Monitoring and MNA)	Characterization activities for the TAG study area including additional groundwater monitoring and soil vapor sampling.	**Yes.** Although these activities are not directed by nor conducted as a part of this CME process, the data generated will be used to support this CME as appropriate.
Field Scale Study (MNA)	Groundwater monitoring to investigate anaerobic mechanisms of TCE and nitrate biodegradation (potential additions to ongoing TAG study area characterization).	**Yes.** Goals and objectives will be determined by January 12, 2005, followed by the start of groundwater monitoring activities.
Field Scale Study (MNA)	Groundwater sampling and analyses to perform enzyme probe analyses to provide direct evidence of an aerobic cometabolic TCE degradation mechanism (potential additions to ongoing TAG study area characterization)	**Yes.** Goals and objectives will be determined by December 22, 2004, followed by the start of groundwater monitoring activities.
Field Scale Study (ISB)	Lactate injection demonstration to provide evidence that TCE degradation can be induced by injecting electron donor, and provide estimates for injection rate, injection frequency, and other design estimates for full scale implementation.	**No.** The ISB remedial alternative is no longer being considered.
Field Scale Study (Pump and Treat)	Aquifer tests to determine pumping rates in a new extraction well for a pump and treat system and provide more information on aquifer properties.	**No.** The pump and treat remedial alternative is no longer being considered.

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APPENDIX A

Capture Zone Analyses

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Equation 1 describes the method used to calculate the capture zone width (W). This method is adopted from Elements for Effective Management of Operating Pump and Treat Systems (EPA 2002).

$$W = \frac{Q}{C \times B \times K \times i} \qquad (1)$$

where:

Q = extraction rate (gpm)

C = volume conversion factor (7.481 gal/ft^3)

B = saturated thickness (ft)

K = hydraulic conductivity (ft/min)

i = hydraulic gradient (ft/ft).

This calculation assumed the following:

1. The horizontal hydraulic conductivity (K) ranges from 3.69×10^{-5} to 2.12×10^{-3} ft/min (SNL/NM 2004b).
2. The thickness (B) of the saturated zone is 10 to 30 ft (SNL/NM 2004a). The wells are screened over a 20 ft interval (SNL/NM 2003), 5 ft of drawdown was assumed for the minimum contaminant thickness of 10 ft and 15 ft of drawdown was assumed for the maximum contaminant thickness of 30 ft.
3. Effective porosity is assumed to be 25% (Table 1-2 of this report).
4. The horizontal hydraulic gradient (i) is 0.007 ft/ft (SNL/NM 2003).
5. The aquifer is homogenous and isotropic.
6. This analysis takes into account properties observed in three wells (TA2-W-26, TJA-7, and TA2-SW1-320).
7. The well is pumped continuously.
8. Effects of multiple extraction wells on each other are neglected.
9. There is no recharge.

As is shown in Table A-1, the estimated capture zone widths are large compared to the extent of contamination in the perched system. It can be concluded from these calculations that capturing the contaminant plume as it is transported across a downgradient location will not be a significant challenge if a sufficient number of wells are drilled. A more pertinent question may be: Is capturing the contaminant plume in this way an effective means of remediation? There is no contaminant source, and it may take many years for the plume to move past this downgradient capture zone as groundwater velocities range from 4-10 ft/year. Therefore, it is concluded that this approach to pump and treat remediation is not an effective approach when the goal of pump and treat is remediation of the aquifer.

Table A-1. Capture zone width calculation.

	Capture Zone Width (W), miles	
	Max. Specific Capacity and $K = 3.69 \times 10^{-5}$ ft/min	Min. Specific Capacity and $K = 2.12 \times 10^{-3}$ ft/min
B = 10 ft.	~172	~0.06
B = 30 ft.	~172	~0.06

APPENDIX B

TREATMENT AND DISPOSAL OPTIONS FOR PUMP AND TREAT

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This appendix provides details on ex-situ treatment and treated water disposal options that are being considered for implementation of pump and treat. These technologies or a combination of these technologies may be applied if a remedial alternative involving pump and treat is chosen as the preferred remedial alternative for SNL/NM AOR. The following sections provide details on two treatment options including granular activated carbon (GAC) and ion exchange.

B-1. Granular Activated Carbon Treatment for TCE

This treatment option uses sorption to GAC to treat contaminated groundwater. The technology effectiveness is well characterized for treatment of TCE. GAC treatment is not effective at removing nitrate. A treatment design is given here to provide estimates on the operating requirements. However, if the technology were implemented, the system would be designed based on more accurate data than the wide range of results presented here.

Design

The treatment unit will consist of a series of three 55-gallon drums of GAC (Figure B-1). The series of drums may be connected such that the down hole pumps will provide sufficient head for flow through the system. This design will require the following:

- A portable storage unit to house the treatment units. The storage unit will need to be equipped with a door, ventilation, electricity, and plumbing to the COA sewer system or on-site disposal system (i.e., injection well).
- Three 55-gal drums of GAC.
- A framework to support a tiered series of drums.
- Piping, fittings, and plumbing equipment. This should include a flow meter on the effluent line and sampling ports on all influent lines (coming from the wells), prior to each GAC drum, and on the effluent line.

Scoping calculations have been performed to estimate treatment unit size, design, and operation needs. Assumptions used in these calculations include:

- Constant influent of TCE concentrations is assumed. The concentrations are the maximum observed concentrations divided by the number of pore volumes that will be flushed.
- Literature values for isotherm constants were used (LLNL, 2000).
- The GAC density was assumed considering literature values (Droste 1997) and manufacturer's specifications.

The GAC would be regenerated every 7 to 86 days. Competing adsorbates may also limit the useful life of the GAC. Therefore, a large safety factor (5) has been applied to the calculations to account for these effects and provide a scoping estimation of operating parameters for evaluation of the alternative (not intended for remedial alternative design).

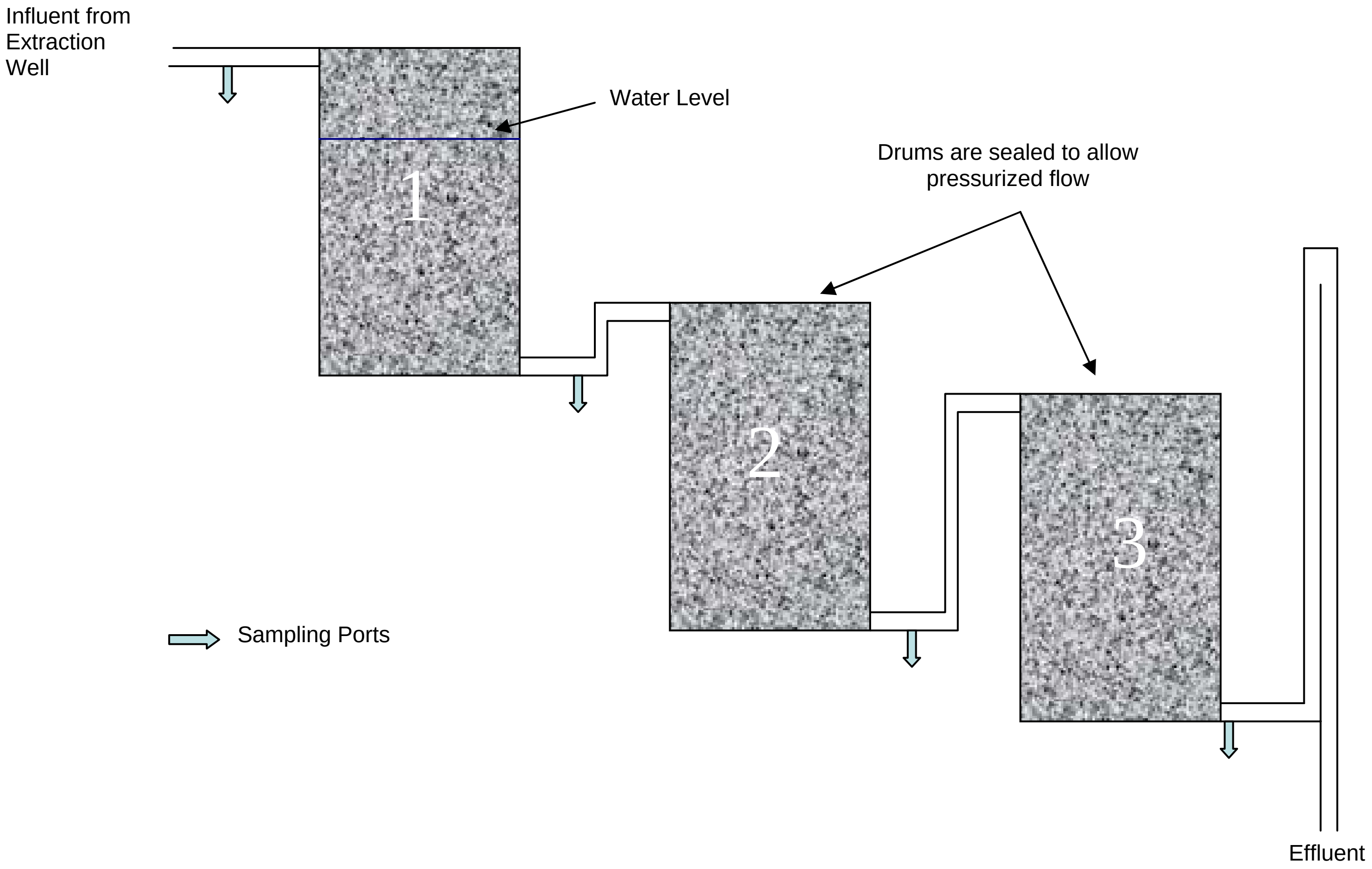

Figure B-1. Schematic of GAC treatment unit.

Operation will include regular monitoring of the influent, two sampling ports between the barrels, and effluent, and when necessary disposal and replacement of GAC. If TCE is detected in the sampling port between the second and third GAC container, then the system will be recharged with fresh GAC. This will likely be done by removing the GAC in the first container (the container attached to the influent line), and rotating the second container to the first place, the third container to the second place, and placing the fresh GAC in the third place (Figure C-1).

Advantages and Disadvantages Compared to Other Treatment Options

Advantages of implementing this treatment design include:

- Requires little maintenance,
- The risk of failure is small, considering the well-characterized effectiveness of activated carbon at removing TCE, and
- The activated carbon is capable of removing low concentrations of TCE.

Disadvantages include:

- Will not remove nitrate,
- A solid waste is produced, and
- The effect of competing sorbates on useful life of the GAC is unknown and will need to be characterized during remedial alternative implementation.

B-2. Ion Exchange Unit for Nitrate Removal

A treatment design is given here to provide estimates on the operating requirements for a nitrate removal system using ion exchange. However, if the technology were implemented, the system would be designed based on more accurate data than the wide range of results presented here.

Design

The technology uses anion exchange resins to remove nitrates. The resins are periodically recharged using a salt solution. The system used to calculate the results presented is a 1-ft^3 system. If flow into the system is high, the system volume will likely be increased in order to reduce the regeneration frequency; however, the total volume of brine will be the same in either case.

Qualities of the groundwater at SNL/NM AOR that may affect implementation of this technology include the presence of sulfate and hardness. Sulfate in the groundwater will compete with nitrate on the anion exchange resin. An average sulfate concentration of 40 mg/L was used in scoping calculations for which the results are presented in Table C-2. A safety factor of three was applied and there is significant uncertainty associated with these estimates. However, the estimated operating parameters provide a scoping estimation of ion exchange operating needs. Each regeneration will require flushing the resins with several pore volumes of salt solution. Hardness in the groundwater may interfere with the nitrate removal. Hardness in the groundwater at SNL/NM AOR is generally greater than 100 mg/L as calcium carbonate, and it may be necessary to remove this hardness. The average regeneration rate is approximately 0.3 to 3.1 hours between each regeneration.

Advantages and Disadvantages Compared to Other Treatment Options

Advantages of implementing this treatment design include:

- Low risk of failure and expected to remove nitrates up to 80%.

Disadvantages include:

- Hardness is present in the groundwater at levels greater than 100 mg/L as $CaCO_3$, which will likely interfere with effective operation of an ion exchange unit and may require a separate hardness removal step,
- Produces a concentrated nitrate brine waste stream, and
- Regeneration is frequent and may require significant maintenance.

Attachment C
Evaluation of Contaminant Transport in Groundwater

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Evaluation of Contaminant Transport, Tijeras Arroyo Groundwater, Sandia National Laboratories/New Mexico

May 2005

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Sandia National Laboratories

EXECUTIVE SUMMARY

The *Corrective Measures Evaluation Work Plan Tijeras Arroyo Groundwater* outlines a staged process for evaluating remedial alternatives for Tijeras Arroyo groundwater at Sandia National Laboratories/New Mexico (SNL/NM). The numerical modeling study described herein was performed as part of the Corrective Measures Evaluation to determine the effects of dilution on contaminants of concern in Tijeras Arroyo groundwater as they are transported downgradient.

A cross-sectional analysis was used to assess downgradient transport and dilution of a conservative solute. The analysis included the following three parts: (1) an estimate of discharge from the perched groundwater system, (2) an alluvial fan model section, and (3) an ancestral Rio Grande (ARG) model section. Solute concentrations were estimated for potential human receptors at pumping centers near Albuquerque, New Mexico, which are completed in the ARG lithofacies.

The flow models were used to simulate the effects of dilution on a solute that originates in the perched groundwater system and is transported with groundwater to production wells located in the ARG lithofacies. Recognizing that the cross-sectional numerical flow and transport models would not be a rigorous representation of the system, several conservative assumptions were made so that the effects of dilution would be intentionally underestimated.

The maximum concentration of a conservative solute at these production wells was simulated relative to the concentration of solute in groundwater leaving the perched system. When compared to observed concentrations in the perched groundwater system, these results led to the following conclusions:

- The historical maximum nitrate concentration in the SNL/NM area of responsibility is 44 mg/L (as nitrogen). The maximum concentration will be reduced to 0.24 mg/L (as nitrogen) before reaching production wells completed in the ARG. For comparison, the federal drinking water standard for nitrate is 10 mg/L (as nitrogen).

- The historical maximum trichloroethene concentration in the SNL/NM area of responsibility is 9.6 µg/L. The maximum concentration will be reduced to less than 0.03 µg/L before reaching production wells in the ARG. For comparison, the federal drinking water standard for TCE is 5 µg/L.

These estimates represent conservative estimates of concentration that intentionally neglect the effects of dispersion, degradation, and sorption on contaminant concentrations.

The travel time from the current locations of nitrate and TCE in the perched groundwater system to the ARG lithofacies where production wells are completed is at least 140 years for nitrate and at least 130 years for TCE. The estimated travel times are slightly different because the contaminants are currently in two different locations in the perched groundwater system. These travel times represent minimum or conservative estimates, because retardation, travel time through the zone of merging, and travel time through the ARG are intentionally neglected.

CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

AOR	area of responsibility
ARG	ancestral Rio Grande
bgs	below ground surface
CME	Corrective Measures Evaluation
COA	City of Albuquerque
COC	contaminant of concern
ft	foot or feet
ft/day	feet per day
ft/yr	feet per year
ft^3/day	cubic feet per day
ft/yr	feet per year
GMS	Department of Defense Groundwater Modeling System
KAFB	Kirtland Air Force Base
MCL	maximum contaminant level
mg/L	milligrams per liter
μg/L	microgram per liter
NMED	New Mexico Environmental Department
SNL/NM	Sandia National Laboratories/ New Mexico
SWMU	solid waste management unit
TA	technical area
TAG	Tijeras Arroyo groundwater
TCE	trichloroethene
USGS	United States Geological Survey
VA	Veterans Administration

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1.0 INTRODUCTION

This report presents the approach and results of a numerical modeling study performed to evaluate dilution of contaminants of concern (COCs) during transport from the Tijeras Arroyo Groundwater (TAG) area of responsibility (AOR) at Sandia National Laboratories/New Mexico (SNL/NM) to production wells completed in the regional aquifer, which are potential exposure points for human receptors.

The *Corrective Measures Evaluation Work Plan Tijeras Arroyo Groundwater* (SNL/NM 2004a), which was prepared as directed by the Compliance Order on Consent issued by the New Mexico Environment Department (NMED) (NMED 2004), outlines a staged process for evaluating remedial alternatives. This numerical modeling study has been performed as part of the Corrective Measures Evaluation (CME) process.

Characterization of the TAG Study Area has been undertaken by three potentially responsible parties: SNL/NM, the City of Albuquerque (COA), and Kirtland Air Force Base (KAFB). As a result, it is necessary for each party to clearly define their contribution to overall TAG remediation. The CME Work Plan (SNL/NM 2004a) identifies the specific area within the overall TAG study area for which SNL/NM has remediation responsibility. In order to clearly distinguish it from the overall TAG area, the area that the CME and this numerical modeling study addresses is referred to as the SNL/NM AOR. The SNL/NM AOR encompasses an approximately 2-square mile area in the north-central part of KAFB.

The “Remedial Alternatives Data Gaps Review for Tijeras Arroyo Groundwater” (SNL/NM 2005b) was prepared as part of the paper study stage of the CME. During the paper study stage, data gaps in the CME were identified. These data gaps include evaluating the potential for contaminants in the TAG SNL/NM AOR to reach production wells, and evaluating the effects of natural attenuation mechanisms on contaminant concentrations. Identification of these and other data gaps resulted in the revised CME process illustrated in Figure 1-1.

The evaluation of contaminant transport and dilution described in this document is the numerical modeling step of the CME process. This report presents a conceptual model upon which the modeling approach is based (Section 2.0), the methods and assumptions of the numerical modeling evaluation (Section 3.0), results and interpretations (Section 4.0), and conclusions (Section 5.0).

1.1 Purpose and Scope

This report describes a numerical modeling study performed to evaluate reduction in concentrations along the groundwater flow path between the current location of contaminants in the perched system and potential downgradient receptors at production wells completed in the regional aquifer. Steady-state, cross-sectional numerical flow models were developed. These numerical models were used to address dilution, which is one of the abiotic processes that contribute to reduction of contaminant concentrations as the contaminants are transported through the aquifer. Additional processes that may further reduce contaminant concentrations (i.e., dispersion, sorption, and biodegradation) were not simulated and thus, the simulated concentrations presented here are greater than concentrations that might actually be observed.

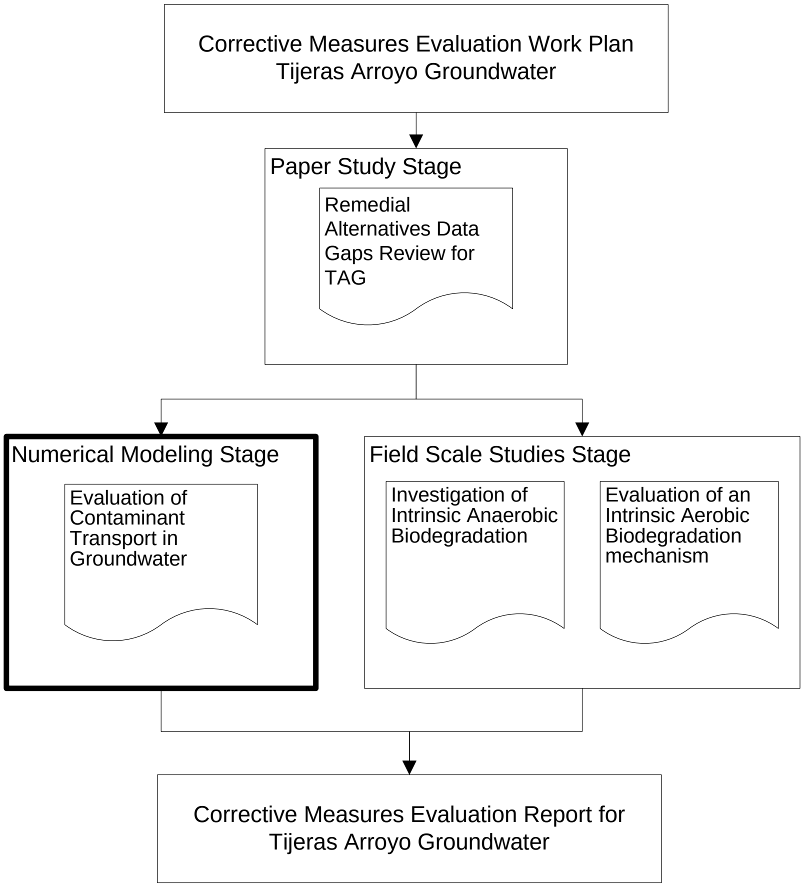

Figure 1-1. Illustration of the staged process of data gathering activities and production of subsequent reports.

2.0 CONCEPTUAL MODEL

The numerical modeling approach described in Section 3 is based on the conceptual model summarized here. This conceptual model includes a discussion of the hydrogeology of the perched system (Section 2.1), hydrogeology of the regional aquifer (Section 2.2), and contaminant sources and transport within the SNL/NM AOR (Section 2.3). The primary sources of the information presented in this section include the TAG CME Work Plan (SNL/NM 2004a) and the *Current Conceptual Model of Groundwater Flow and Contaminant Transport at Sandia National Laboratories/ New Mexico Technical Area V (*SNL/NM 2004b). The Technical Area V Conceptual Model is referenced here because the document summarizes the regional hydrogeologic context of the Albuquerque Basin.

Two aquifers in the Upper Santa Fe Group have been identified in the TAG study area: a perched system and the regional aquifer. In the northern portion of the TAG area, the depth to potentiometric surface of the perched system ranges from approximately 220 to 330 ft below ground surface (bgs), whereas the depth to potentiometric surface of the regional aquifer is approximately 440 to 570 ft bgs. The regional aquifer is used as a potable water source by KAFB, COA, and the Veterans Administration (VA).

Water moves to the southeast within the perched system and probably migrates from the perched system into the underlying regional aquifer southeast of Tijeras Arroyo. For this evaluation it is assumed that groundwater moves from the perched system into the regional aquifer, however, this has not been definitively proven. Groundwater in the regional aquifer migrates to the west and northwest in the alluvial fan lithofacies toward the highly permeable ancestral Rio Grande (ARG) lithofacies. After reaching the ARG lithofacies of the regional aquifer, groundwater flows northward toward pumping centers.

It is expected that trichloroethene (TCE) and nitrate present in the perched system will follow these groundwater flow paths. These contaminants will be diluted during transport to production wells in the ARG lithofacies. Dilution will occur first when perched groundwater recharges the regional aquifer in the alluvial fan lithofacies, and second as groundwater in the lower permeability alluvial fan lithofacies enters the higher permeability ARG lithofacies.

2.1 Perched Groundwater System

The perched groundwater system is present beneath the TAG study area, as shown in Figure 2-1. Discontinuous, yet overlapping multiple lenses of alluvial-fan clay and silt serve as a perching layer. Vertical groundwater flow is considered to be minimal because of these lenticular clay units. Table 2-1 summarizes hydrogeologic characteristics of the perched system.

Based on present information, the perched system extends over at least 3.5 square miles. Monitoring wells bound the perched system on the western and southern margins. The northern margin of the perched system has not been fully defined and may extend across the KAFB boundary north of the Wyoming Gate and east to the Eubank Landfill. A southeastern margin is not discernible because the perched system merges with the regional aquifer (i.e., the potentiometric surface of the perched system and the regional aquifer coincide). The direction of groundwater flow in the perched system is inferred to be principally to the southeast, with a horizontal gradient of approximately 0.008 ft/ft (SNL/NM 2002).

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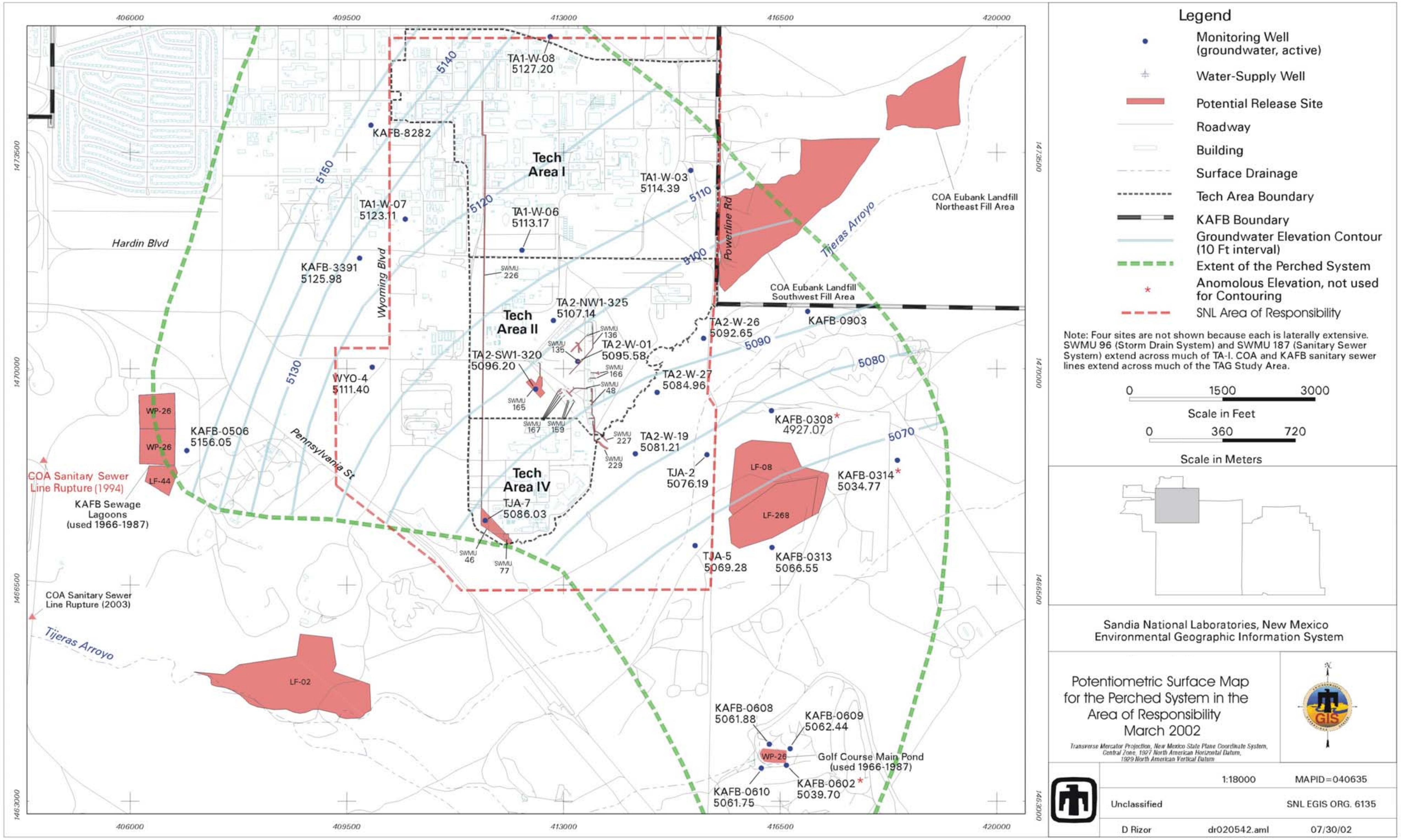

Note: Four sites are not shown because each is laterally extensive. SWMU 96 (Storm Drain System) and SWMU 187 (Sanitary Sewer System) extend across much of TA-I. COA and KAFB sanitary sewer lines extend across much of the TAG Study Area.

Figure 2-1. Potentiometric surface map for the perched system in the SNL/NM Area of Responsibility, March 2002 (SNL/NM 2004a).

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Table 2-1. Summary of perched system properties.

Property	Value or Range
Horizontal hydraulic conductivity (SNL/NM 2004c)	0.05 – 3.1 ft/day
Hydraulic gradient (SNL/NM 2002)	0.008 ft/ft
Assumed effective porosity (SNL/NM 2004a)	25%
Saturated thickness (SNL/NM 2004a)	10 – 30 ft
Groundwater flow direction (SNL/NM 2004a)	primarily to the southeast

Previous conceptual and numerical modeling supported an interpretation that the perched groundwater system is a result of past and ongoing water-management on a system primed for saturation by natural sources (Balleau Groundwater, Inc. 2002). Significant sources of past and present recharge to the perched groundwater system may include Tijeras Arroyo, Arroyo del Coyote, sewage lagoons, a golf course pond, SNL/NM waste disposal sites, leaking sewer lines, and irrigation of the Tijeras Arroyo Golf Course, parade grounds, and lawns.

Historically, water levels in the perched system have fluctuated across the TAG study area (SNL/NM 2002). Water levels have been declining since 1987 in the vicinity of the sewage lagoons and other areas northwest of Tijeras Arroyo, apparently in response to the lagoons being removed from service. Conversely, water levels have increased southeast of Tijeras Arroyo.

Tijeras Arroyo is the most significant surface-water drainage feature on KAFB and trends southwest across KAFB, eventually draining into the Rio Grande approximately six miles west of KAFB. Surface water flows in the arroyo several times per year as a result of storm events. The annual precipitation for the area, as measured at the Albuquerque International Sunport, is 8.2 in. (SNL/NM 2001a). During most rainfall events, rainfall quickly infiltrates into the soil; however, virtually all of the moisture subsequently undergoes evapotranspiration. Estimates of evapotranspiration for the KAFB area range from 95 to 99% of the annual rainfall (SNL/NM 1998).

2.2 Regional Aquifer

The geologic and hydrologic conditions of the regional aquifer in the Albuquerque Basin control groundwater flow and contaminant migration to potential human receptors at production wells. This section briefly describes the hydrogeologic setting (as defined by large-scale geologic features) (Section 2.2.1), the hydrostratigraphic framework of the Albuquerque Basin and the basin-fill sedimentary units of the Santa Fe Group (Section 2.2.2), recharge (Section 2.2.3), discharge (Section 2.2.4), and groundwater flow (Section 2.2.5). A summary of parameters pertinent to the numerical modeling effort is shown in Table 2-2.

Table 2-2. Summary of regional aquifer properties.

Property	Value
Horizontal hydraulic conductivity (SNL/NM 2002)	0.001 – 44.7 ft/day (alluvial fan lithofacies) and 10 – 150 ft/day (ARG lithofacies)
Hydraulic gradient (SNL/NM 2002)	approximately 0.009 ft/ft
Assumed effective porosity (SNL/NM 2004a)	25%
Saturated thickness (SNL/NM 2004a)	in excess of 1,000 ft
Groundwater flow direction (SNL/NM 2004a)	primarily to the northwest

2.2.1 Large-Scale Geologic Features

The Rio Grande Rift is a relatively continuous regional structural feature that extends north from Mexico, across New Mexico, and into southern Colorado. Formation of this feature began 25 million years ago in northern Mexico when tectonic forces began to pull apart the brittle upper crust of the North American Plate and continued toward the north.

The Rio Grande Rift is marked by a series of sediment-filled structural basins and adjoining uplifted mountain ranges. One of these basins, the Albuquerque Basin (also known as the Middle Rio Grande Basin), covers about 3,060 square miles in central New Mexico and extends from the Cochiti Reservoir on the north to San Acacia, New Mexico on the south. The Albuquerque Basin includes the COA and parts of Santa Fe, Sandoval, Bernalillo, Valencia, Socorro, Torrance, and Cibola Counties.

The major fault systems that bound the Albuquerque Basin have dominated the development of geologic and hydrologic features within the basin. These fault systems consist of sets of subparallel, high-angle, large-displacement normal faults that separate the subsided basin from adjoining uplifted mountain blocks. Fault blocks on the inside of the rift zone typically have dropped down relative to uplifted fault blocks on the eastern and western edges of the rift.

Rift zone faulting has controlled sedimentary deposition within the Albuquerque Basin throughout its history. Continued movement along faults has modified local drainage systems and formed topographically high areas that provided a ready source of newly-eroded sediments. Fault offsets brought Santa Fe Group sediments into contact with upfaulted Paleozoic rocks along the basin margins. Because active faulting was occurring at the same time as sedimentary deposition, faults also have offset stratigraphic units within the Santa Fe Group. In addition, fault zones have served as conduits for vertical groundwater flow and as regional hydrologic boundaries of the Santa Fe Group aquifer.

The uplifted mountains to the east of the Albuquerque Basin act as groundwater flow boundaries and provide a source of streamflow and alluvial sediments to the basin from mountain drainages. Streamflow originating from these drainages furnishes a source of surface-water recharge to alluvial fan sedimentary deposits along the basin margins. Chemical interactions between water and rocks in these drainages affect the chemistry of water recharged to the Santa Fe Group aquifer.

2.2.2 Hydrostratigraphic Framework

The Albuquerque Basin is filled with sedimentary deposits of the Santa Fe Group. Basin-fill deposits of the Santa Fe Group within the Albuquerque Basin are composed of distinct lithofacies, defined by depositional mode and characterized largely by texture. The ARG lithofacies consists of well-sorted, coarse-grained, fluvial sands and gravels that were transported from distant sources to the north during the development of the through-flowing drainage of the Rio Grande. ARG sediments typically are highly permeable. The alluvial-fan lithofacies consists of poorly sorted piedmont-slope deposits derived from the Sandia, Manzanita, and Manzano Mountains east of the TAG study area. These sediments typically are much less permeable than the coarser sediments of the ARG.

2.2.3 Regional Recharge

Recharge to the Santa Fe Group aquifer occurs from infiltration of streamflow from the Rio Grande and arroyos, from infiltration of precipitation, and from underflow originating from mountain-front recharge. On the federal property that includes SNL/NM, Tijeras Arroyo and other ephemeral drainages provide limited recharge, as does mountain-front recharge, where it connects across the fault complexes. Infiltration of precipitation through the vadose zone is estimated to provide a negligible contribution to groundwater within the Albuquerque Basin, as 95 to 99% or more is estimated to be lost to evapotranspiration.

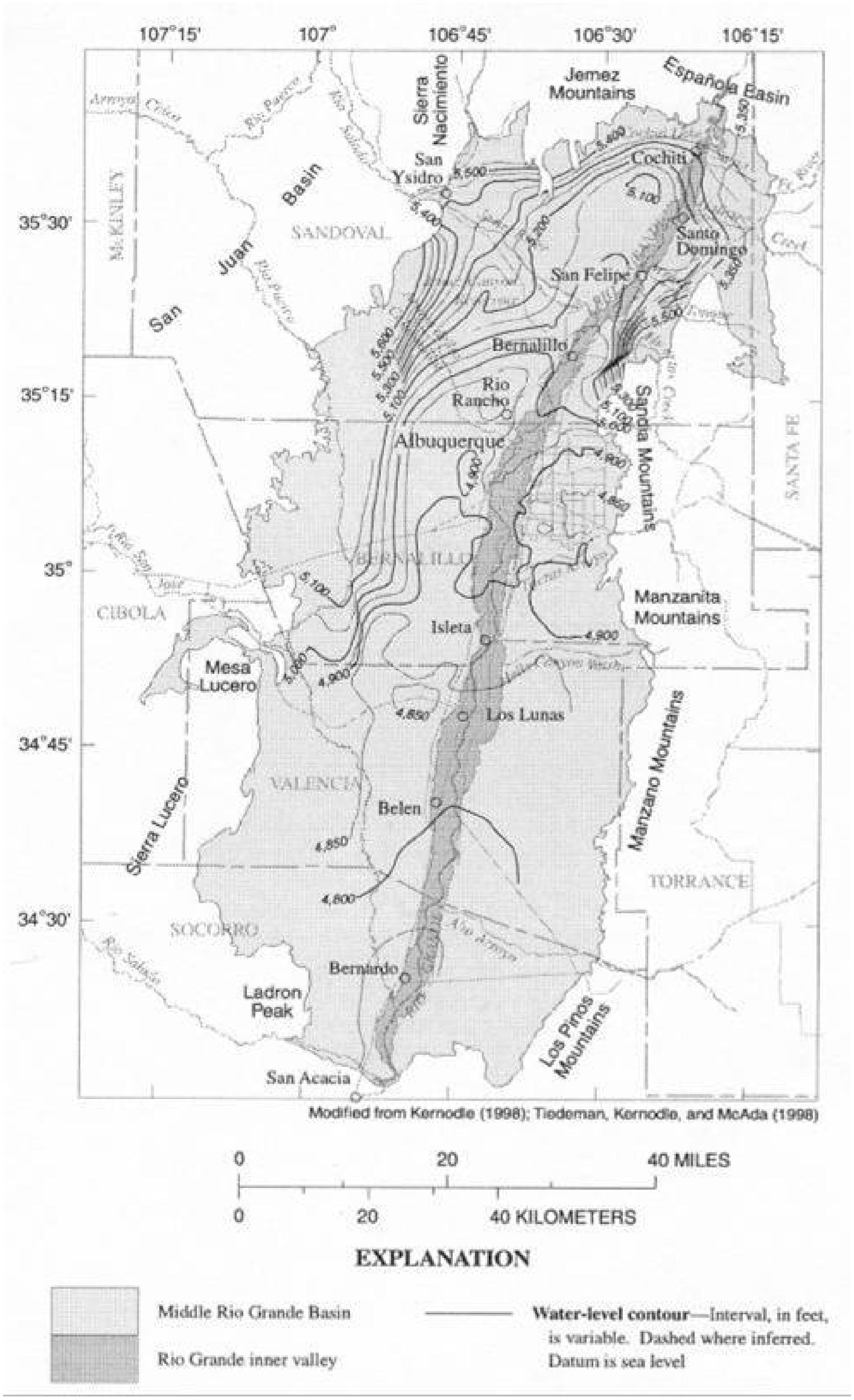
2.2.4 Regional Discharge

Regional discharge occurs as groundwater moves out of the Albuquerque Basin into downgradient basins in the Rio Grande Rift as underflow or through discharge to the Rio Grande. Discharge also occurs from pumping at the COA municipal production well fields. The discharge is greater than the recharge and effectively dewaters the aquifer on the federal property.

2.2.5 Regional Groundwater Flow

Prior to development of water resources in the Albuquerque area, groundwater in the Albuquerque Basin flowed generally from the north to the south, with a westward component of flow from recharge areas along mountain-front boundaries to the east. As the Santa Fe Group aquifer has been developed as a source for municipal and industrial water supplies, groundwater flow directions have been altered toward pumping centers (Figure 2-2).

Historically, water levels in the regional aquifer have fluctuated across the TAG study area (SNL/NM 2002). A line of demarcation between increasing water levels and declining water levels is evident along the eastern extent of the ARG lithofacies, which coincidentally trends along Wyoming Boulevard. Declining water levels approaching 1.5 ft/year are apparently associated with the COA, KAFB, and VA water-supply wells. Increases in groundwater elevations of up to 1.8 ft/year in the southeast portion of the TAG study area probably reflect recharge of the regional aquifer from the perched system, Tijeras Arroyo, the golf course, and the mountain front.



Modified from Kernodle (1998); Tiedeman, Kernodle, and McAda (1998)

From Bartolino and Cole 2002

Figure 2-2. Configuration of the regional groundwater surface in the Albuquerque Basin, 1994-1995.

The direction of groundwater flow in the regional aquifer is to the northwest toward the KAFB, COA, and VA water-supply wells. The horizontal hydraulic gradient in the regional aquifer across the central portion of the TAG study area is approximately 0.009 ft/ft with steeper gradients evident near the mountain front. Potentiometric surface elevation contours are shown on Figure 2-3 for the regional scale of the federal property and Figure 2-4 at the more local scale of the Tijeras Arroyo area.

On SNL/NM and KAFB property, the predominant groundwater flow was westward prior to water resources development (Bexfield and Anderholm 2000). Recent potentiometric surface elevation contour maps and numerical modeling studies show the significant hydrologic influence of the pumping centers just north of the federal boundaries. The Ridgecrest supply wells, in particular, are completed less than 1 mile north of the federal boundary and are screened in the north-south trending fluvial deposits (ARG). The capture zones of these wells extend south onto federal property (SNL/NM 2001b; Plate 3-2). The U.S. Air Force owns and operates a less influential network of supply wells within the federal boundaries. Together, these pumping centers contribute to the present post-development north-northwest groundwater flow direction in the ARG lithofacies.

2.2.6 Hydrostratigraphic Units

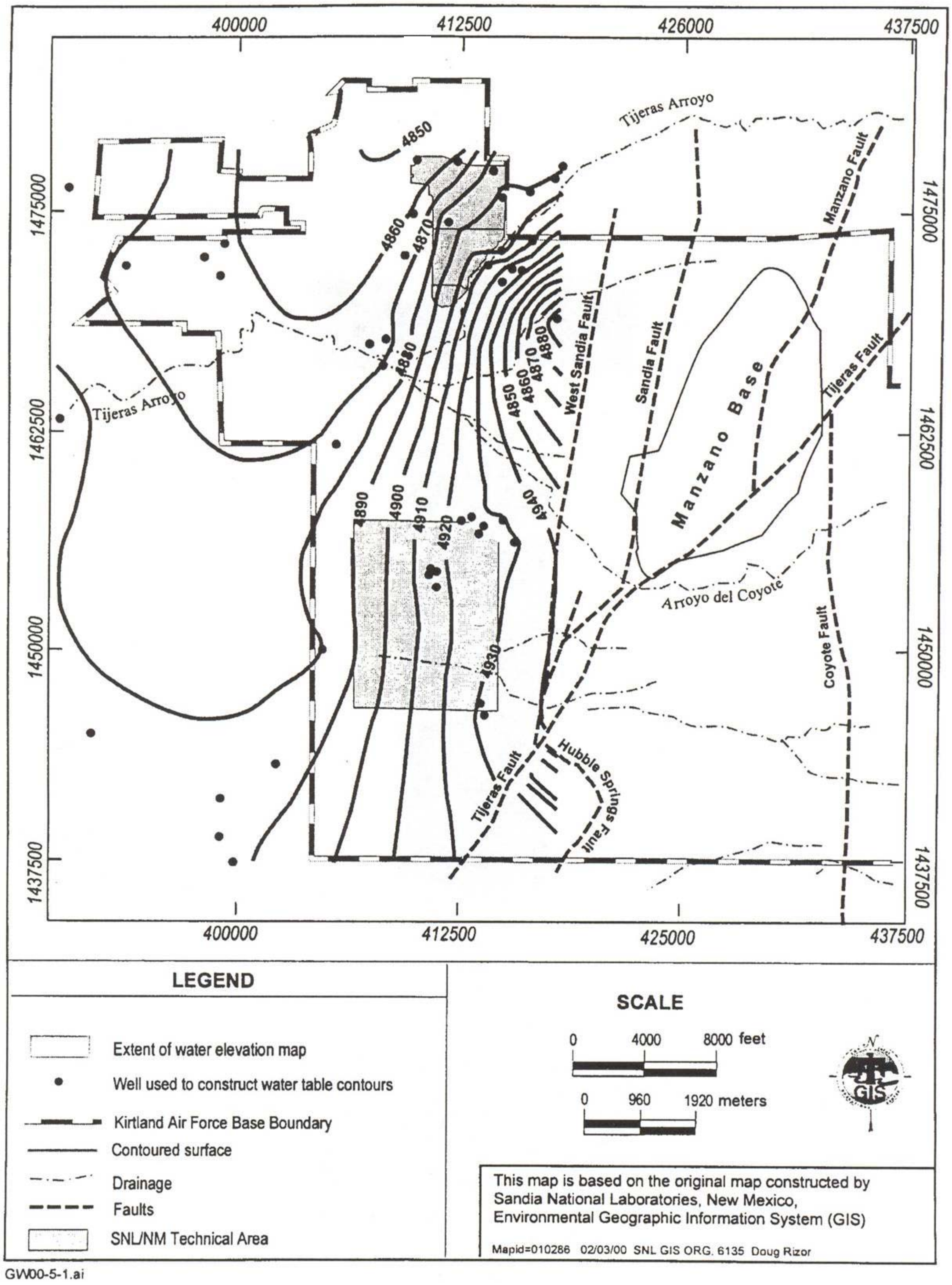
The aquifer in the alluvial fan lithofacies consists of fine-grained, layered, clay-rich sediments of the alluvial fan lithofacies of the Santa Fe Group. These sediments interfinger with the highly permeable sediments of the ARG to the west. The horizontal hydraulic conductivity of the alluvial fan lithofacies ranges from about 0.001 to 44.7 ft/day (SNL/NM 2002). The horizontal hydraulic conductivity of the ARG is as high as 150 ft/day. The vertical hydraulic conductivity of both lithofacies is considered to be much lower because of the layered characteristics of the sediments. The effective porosity (a measure of the interconnected pore spaces in the alluvial fan lithofacies) is approximated from measurements of total porosity and moisture content to be 25%.

2.2.7 Groundwater Flow in Alluvial Fan Lithofacies

Groundwater in the alluvial fan lithofacies is derived principally from mountain-front recharge to the east. Groundwater in the regional aquifer flows generally to the northwest in the TAG study area through the low-permeability alluvial fan lithofacies. Potentiometric contours indicate that groundwater flowpaths intercept the high-permeability ARG lithofacies and turn to the north in response to pumping at the large municipal well fields north of KAFB.

2.3 Distribution of Groundwater Contaminants

Contaminants of concern within the SNL/NM AOR include nitrate and TCE located within the perched system. The distribution of TCE is discontinuous across the perched system and does not indicate a single release site. Based upon the historic use of chlorinated solvents across SNL/NM and KAFB, the known extent of TCE in groundwater is probably associated with multiple releases of aqueous-phase solvents and subsequent transport through the vadose zone.



This map is based on the original map constructed by Sandia National Laboratories, New Mexico, Environmental Geographic Information System (GIS)

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From SNL/NM 2000

Figure 2-3. Subregional potentiometric surface elevation contour map for basin fill deposits, 2000.

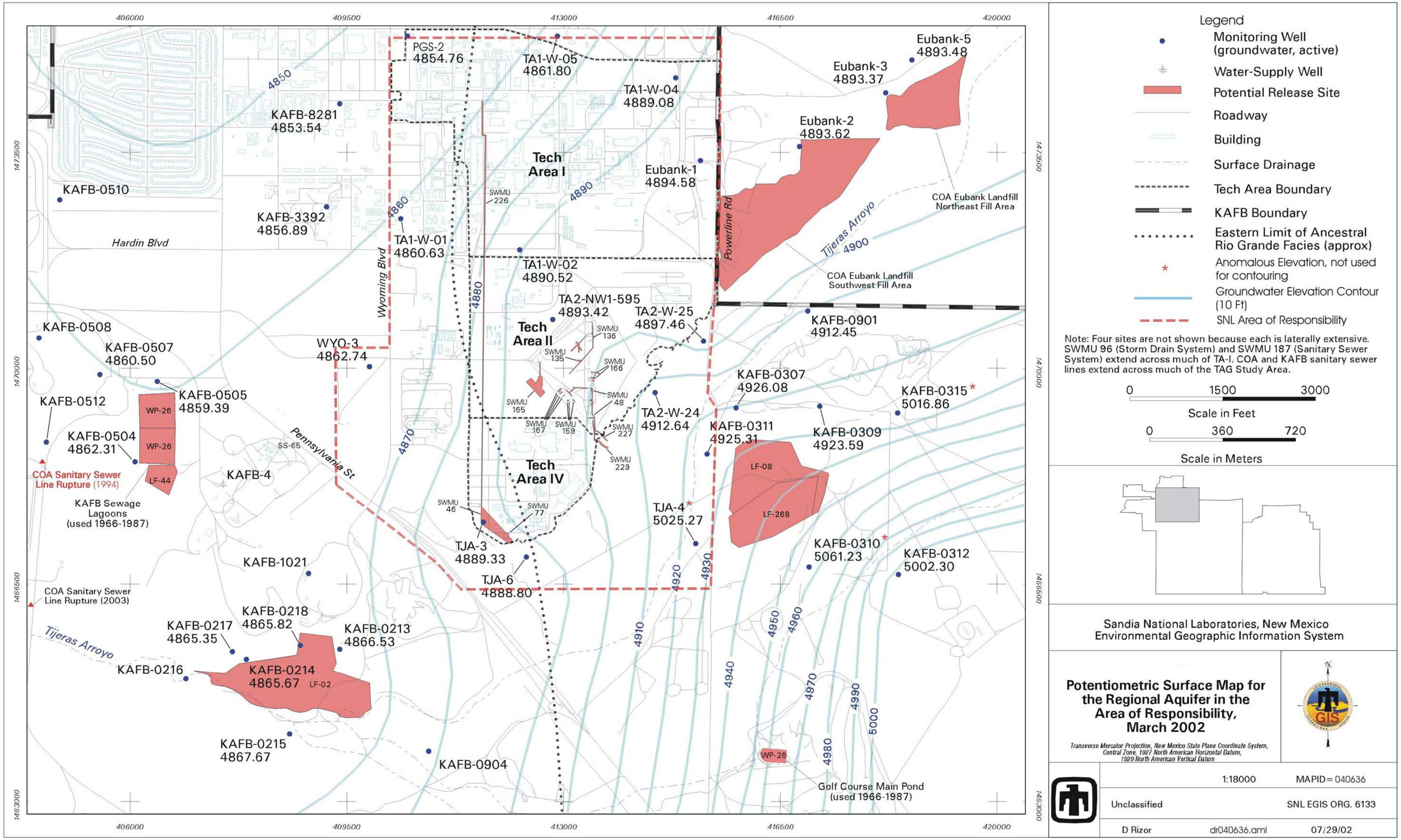

Figure 2-4. Potentiometric surface map for the regional aquifer in the TAG study area, March 2002.

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TCE concentrations in samples from three SNL/NM perched system wells (TA2-W-19, TA2-W-26, and WYO-4) have exceeded the maximum contaminant level (MCL) of 5.0 µg/L for TCE. The maximum historical concentration of TCE in the perched system was 9.6 µg/L, detected in March 1998 in a sample from well TA2-W-26. TCE detected in samples from well WYO-4 are not considered to be within the scope of the CME. Well WYO-4 is an SNL/NM monitoring well that is located on KAFB property. Given that none of the SNL/NM potential release sites are near well WYO-4 and that groundwater flow in the perched system is to the southeast, the TCE concentrations present in WYO-4 are considered to represent contamination from an upgradient KAFB source. Therefore, concentrations observed in samples from this well are not considered in this transport evaluation. More recently, (October 2004) the maximum detected TCE concentration in samples from SNL/NM AOR wells (not including WYO-4) was 4.65 µg/L in a sample from TA2-W-19 (SNL/NM 2005a).

According to KAFB Installation Restoration Program terminology, nitrate contamination in the perched system forms what is referred to as “Plume 3” (MWH Americas, Inc., 2003). Plume 3, which is centered on monitoring well TA2-SW1-320, is located under the southwest portion of TA-II and may extend southward to TJA-7. Monitoring wells in the perched system that have nitrate concentrations below the MCL surround these wells. The plume is 0.3 miles long and 0.2 miles wide (MWH Americas, Inc., 2003) and is thought to emanate from Solid Waste Management Unit (SWMU)-165, the Building 901 Septic System. The maximum historical concentration of nitrate in the perched system within the SNL/NM AOR was 44 mg/L in water from wells TA2-W-19 (in January 1996) and TA2-SW1-320 (in November 2001). More recently, (October 2004) the maximum detected nitrate concentration in a SNL/NM perched zone well was 27.1 mg/L (as nitrogen) in a sample from well TJA-7 (SNL/NM 2005a).

At no time has an SNL/NM regional aquifer or merging zone well exceeded the MCL for TCE, and generally, TCE has not been detected in regional aquifer monitoring wells (with the exception of a historic peak of 3.2 µg/L in well PGS-2 and an estimated value of 0.6 µg/L in TJA-3).

The maximum historical concentration of nitrate within the SNL/NM AOR for wells completed in the regional aquifer system was 49 mg/L in merging zone well TJA-4. However, this is the only SNL/NM regional aquifer monitoring well that has ever had nitrate concentrations that exceed the MCL (10 mg/L). The nitrate contamination in the regional aquifer southeast of TA-II forms what is referred to as “Plume 4” (MWH Americas, Inc., 2003). Plume 4 is most likely responsible for the nitrate concentrations in TJA-4, a well completed in the zone of merging. The plume is 1.9 miles long and 1 mile wide and is associated with the active KAFB Landfill (MWH Americas, Inc., 2003).

2.3.1 Implications of Contaminant Distribution to Numerical Modeling

Nitrate and TCE are the COCs considered in the numerical modeling study. These contaminants are likely distributed in various locations within the SNL/NM AOR perched zone. The locations of concern for the current study are defined by the monitoring wells in which historical concentrations have exceeded MCLs. These monitoring wells are TA2-W-26 (TCE), TJA-7 (nitrate), and TA2-SW1-320 (nitrate). The historical maximum observed concentrations were considered when interpreting the results of the modeling study, even though the most recently observed concentrations in samples from these wells are substantially lower.

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3.0 MODELING APPROACH

A numerical modeling study was performed to evaluate reduction in contaminant concentrations during transport from the perched system to potential downgradient receptors at pumping centers in the ARG lithofacies, including the Ridgecrest well field (COA municipal water production) and other potential pumping wells associated with KAFB and the VA.

The flow path from the perched system to potential pumping wells was estimated based on potentiometric data and hydrogeologic properties, as described in Section 2.0. A numerical modeling approach was devised for estimating the effects of dilution during transport on a conservative solute. This approach involved simulating three regions, including: (1) an estimate of flow out of the perched system, (2) transport through an alluvial fan model section, and (3) transport through an ARG model section. These simulated regions are shown in Figures 3-1 and 3-2, and the following is a short description of each:

1. <u>Perched Groundwater System Estimate of Flow</u>. This region included the perched groundwater system between the current location of contaminants and the zone of merging of the perched system and regional aquifer. This section was simulated as flow into the alluvial fan model section, which was estimated from observed aquifer parameters.

2. <u>Alluvial Fan Model Section.</u> This region included northwestern groundwater flow in alluvial fan lithofacies. A 1.4-mile long cross-sectional model was devised for this section in which the estimate of flow from the perched system comprises a portion (2.2%) of the total flow through the alluvial fan model section.

3. <u>ARG Model Section.</u> Groundwater flows northward through this region toward COA pumping centers. This region was simulated using a 10-mile long cross-sectional approach in which flow from the alluvial fan section formed a portion (11.5%) of the total flow through the ARG section.

The following are the general methods, assumptions, and limitations of the numerical modeling approach:

- The cross-sectional models developed for the alluvial fan and ARG model sections used the Department of Defense Groundwater Modeling System (GMS), employing the MODFLOW groundwater model (Harbaugh et al. 2000) and the MT3DMS transport model (Zheng and Wang 1999) with GMS pre- and post-processors (BYU 2003).

- The numerical modeling approach intentionally did not account for the processes of dispersion, sorption, or degradation. Therefore, the approach is conservative and concentrations are intentionally overestimated because these processes will decrease concentrations further (where active on a particular contaminant).

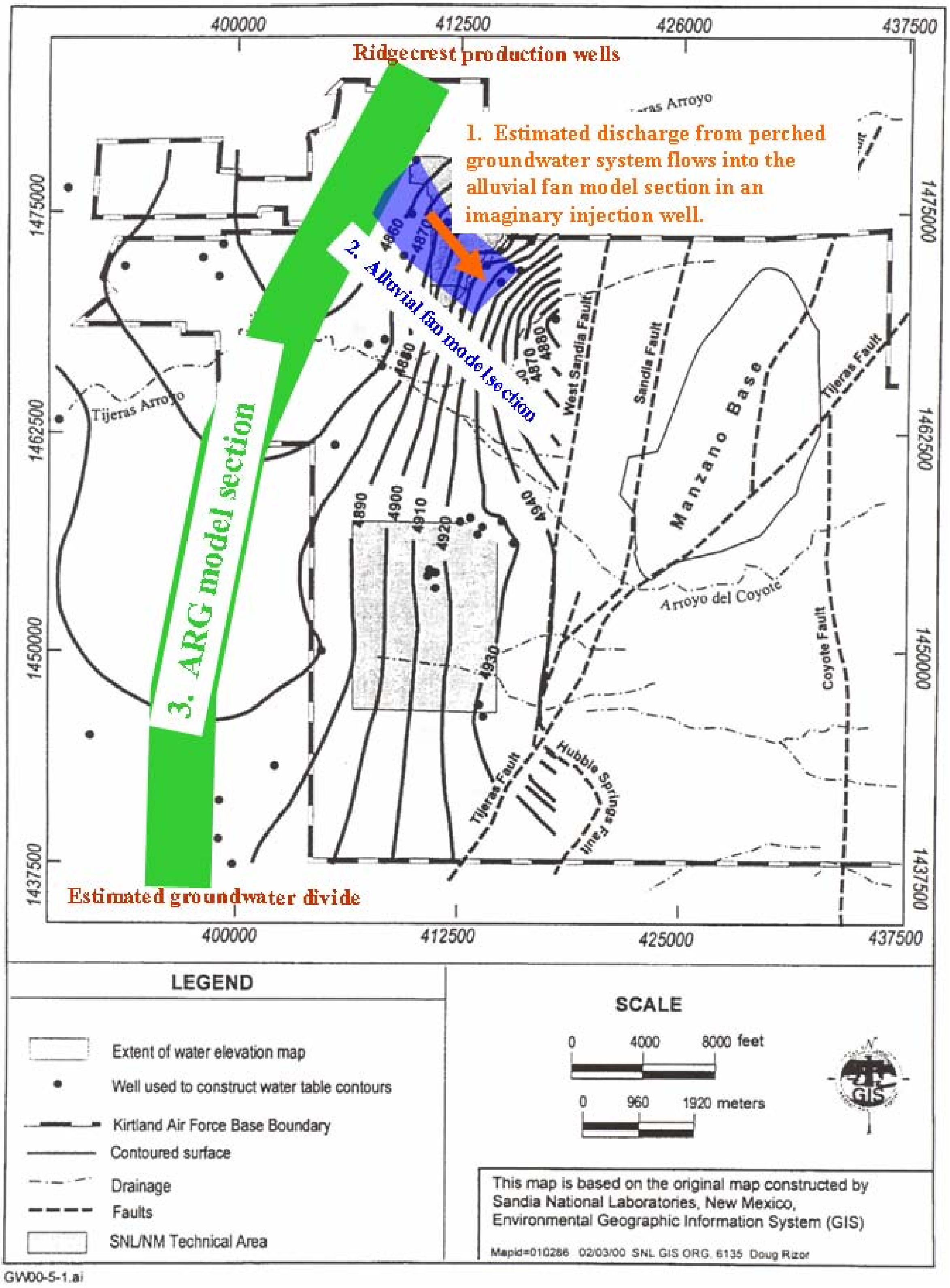

Figure 3-1. Regional potentiometric surface map and location of simulated regions.

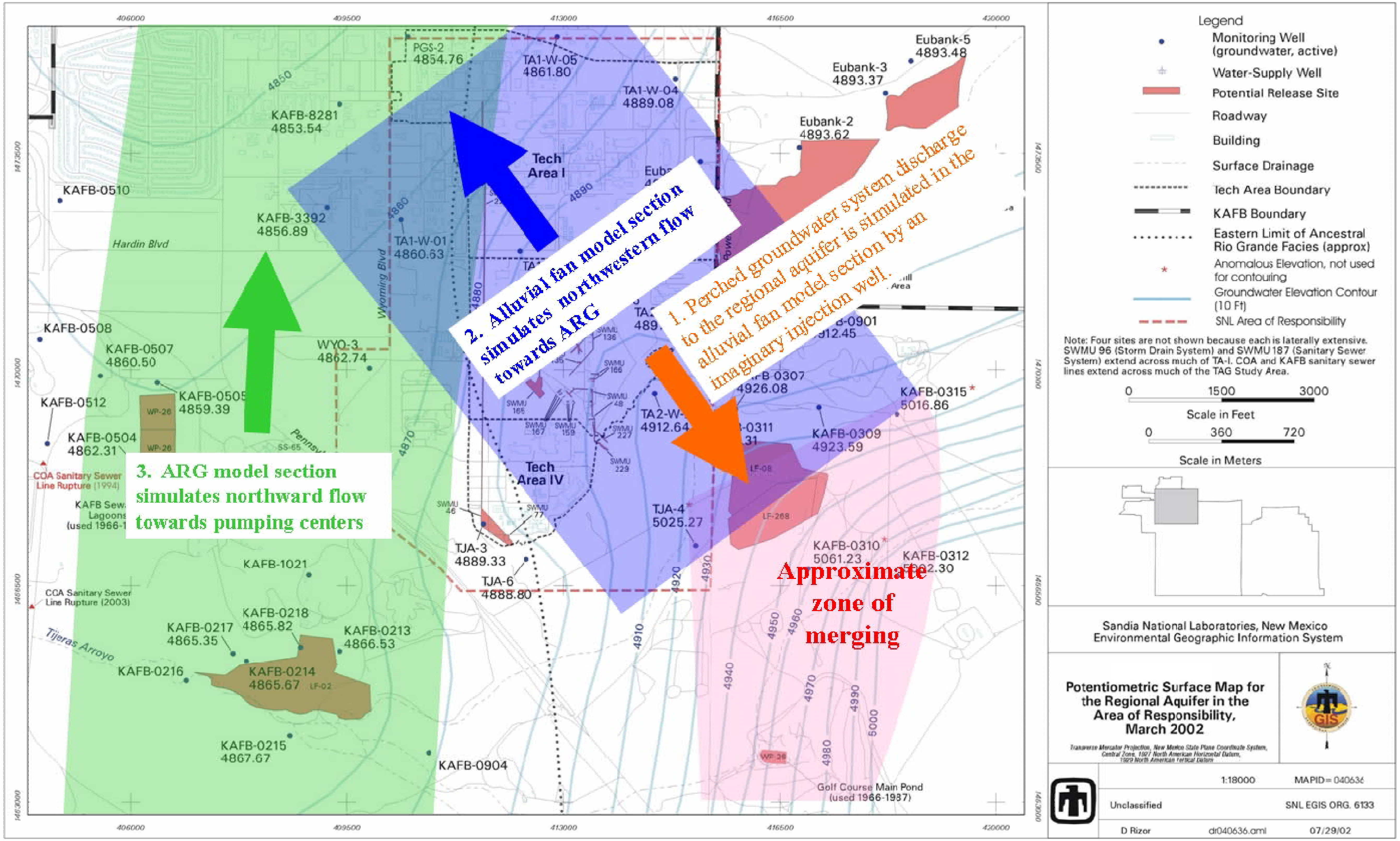

Figure 3-2. Local potentiometric surface map and location of simulated regions.

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- The numerical modeling approach simulated groundwater flow in the upper portion of the regional aquifer. This aquifer is estimated to have a saturated thickness in excess of 1,000 ft (SNL/NM 2004a). The approach assumed transport through single-layer numerical models that are 100 and 600 ft deep. This approach is conservative because it neglects additional dilution that might occur as groundwater from shallow and deep aquifer zones is mixed at production wells.
- As the solute moved from one hydrogeologic simulation to the next (i.e., from the alluvial fan model section into the ARG model section), the solute was simulated to be instantaneously mixed with pristine water throughout the model cells. This mixing is more likely to occur along the flow path or during withdrawal at pumping centers. As a consequence, the numerical modeling is useful for evaluating the relative reduction in concentration as it pertains to pumping wells completed in the ARG lithofacies, but should not be used for interpreting concentration changes at more localized scales.
- No flow was assumed to move across the transverse boundaries of the cross-sectional models because the sections were considered to be parallel to the flow path derived from the potentiometric surface.
- The width (cross-gradient dimension) of the cross sections was simulated to be 6,000 ft. This width is the width over which flow is estimated from the perched system (Section 3.1) and is used for each of the model sections (Sections 3.2 and 3.3).
- The simulated porosity of the material (25%) was constant throughout the numerical modeling sections. This value is a reasonable and accepted value for porous media (SNL/NM 2004a).
- Solute concentrations were simulated relative to an initial concentration of 1 unit (or 100%). The concentration in the simulated flow from the perched system was 1 unit concentration for the duration of the simulation. The numerical models were run until steady state concentrations were achieved at the downgradient boundary of the ARG model section simulating the Ridgecrest well field.
- The expected maximum concentration of contaminants at potential and existing production wells in the ARG lithofacies was estimated in Section 4.0. These estimates were based on applying the relative simulated concentration of solute in the ARG model section to observed historical maximum concentrations in the SNL/NM AOR. The concentrations are conservative estimates of the contribution of nitrate and TCE that may be transported from the SNL/NM AOR to production wells.

Table 3-1 provides summary information and input parameters for each of the three modeled regions. Sections 3.1 through 3.3 provide detailed information and input parameters about the simulation.

Table 3-1. Summary information and input parameters.

	Perched System Estimate of Flow (Section 3.1)	**Alluvial Fan Model Section (Section 3.2)**	**ARG Model Section (Section 3.3)**
Flow model length	N/A[a]	1.4 miles	10.0 miles
Cell width	6,000 ft	6,000 ft	6,000 ft
Vertical saturated Thickness	20 ft	100 ft	600 ft
Number of cells	N/A[a]	15	88
Upgradient boundary type	N/A[a]	constant head	no flow, simulating groundwater flow divide
Downgradient boundary type	Is an approximation of the zone of merging as shown on Figure 3-2	constant head	constant head
Hydraulic conductivity	1.6 ft/day	14.1 ft/day	150 ft/day
Effective porosity	N/A[a]	25%	25%
Potential receptor locations	None	None	Ridgecrest municipal pumping wells, KAFB supply wells, and VA supply wells

a. The perched system flow was estimated using the approach outlined in Section 3.1, which did not involve the use of a MODFLOW numerical model.

3.1 Estimate of Flow from the Perched Groundwater System

As stated in Section 2.0, the SNL/NM AOR includes perched system groundwater contaminated with TCE and nitrate. Groundwater in the perched system is known to merge with the regional aquifer within the zone of merging depicted on Figure 3-3. This section summarizes an estimate of discharge from the perched groundwater system through the zone of merging and into the alluvial fan lithofacies of the regional aquifer (Section 3.1.1) and an estimate of transport time of contaminants to the zone of merging (Section 3.1.2).

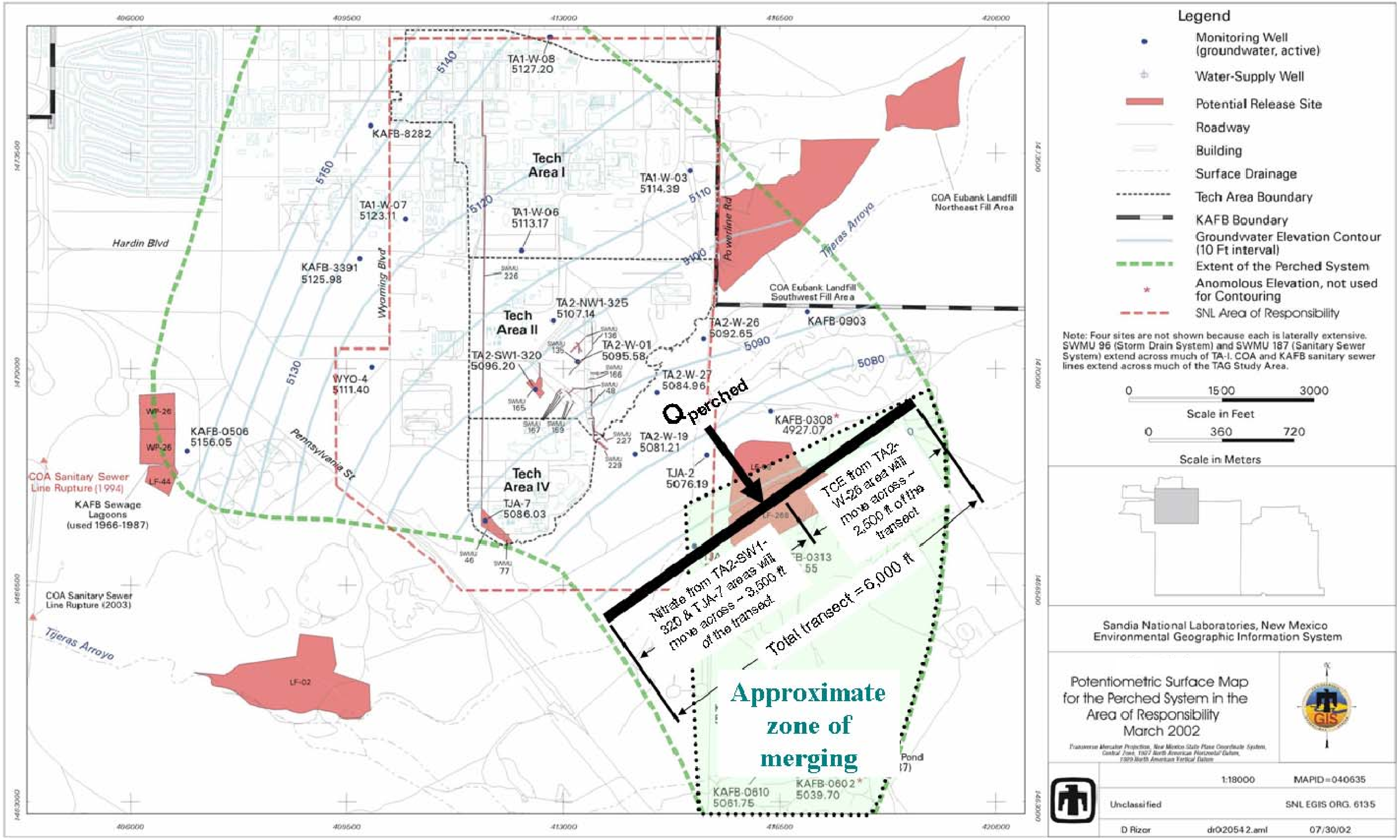

Figure 3-3. Perched system illustration.

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3.1.1 Estimate of Perched Groundwater System Discharge

Contaminants in the perched groundwater system will continue to move with ambient groundwater flow southeast to the zone of merging. At the zone of merging groundwater from the perched groundwater system discharges into the alluvial fan lithofacies of the regional aquifer. A conservative approach to estimating this discharge is based on the following assumptions:

- Groundwater from the perched system was assumed to move instantaneously into the regional aquifer where flow lines cross the transect (shown on Figure 3-3) as if the perching layer suddenly ended. It is recognized that the zone of merging more likely occurs gradually as the perching horizon becomes more permeable. However, the assumption is conservative with respect to downgradient solute concentration and travel time because the transect was chosen to intentionally minimize the total distance of the flow path in both the perched system and the regional aquifer.

- The width (W) over which the merging occurs is approximately 6,000 ft, which is based on the distribution of nitrate and TCE and the extent of the perched system. This width is shown in Figure 3-3 as the cross-gradient transect of the perched system at the northern end of the zone of merging. The potential contribution of TCE and nitrate contaminated groundwater to the total flux across the 6,000-ft transect is also illustrated in Figure 3-3, which is used for interpretations in Section 4.2.

- The saturated thickness (D) of the perched groundwater system at the zone of merging ranges from 10 to 30 ft (see Section 2.0).

- The hydraulic gradient (i) within the perched system is 0.008 ft/ft. This estimate is based on the distance between the 5,090-ft and the 5,070-ft potentiometric surface elevation contours, but the estimated gradient is also the same as the overall average gradient for the perched system (see Section 2.0).

- Horizontal hydraulic conductivity (K_H) ranges from 0.05 to 3.1 ft/day (see Section 2.0).

Given the assumptions listed above, the discharge of groundwater out of the perched groundwater system was estimated using the following equation derived from Darcy’s Law (Equation 1):

$$Q = K_H\, iA = K_H iWD \qquad \text{Equation 1.}$$

where

Q = flow in ft^3/ day

K_H = horizontal hydraulic conductivity in ft/day

i = hydraulic gradient

A = area in ft^2

W = width in ft

D = saturated thickness in ft.

Considering the range of hydraulic conductivity and saturated thickness, the discharge from the perched system ranges from 24 ft^3/day (D = 10 ft and K_H = 0.05 ft/day) to 4,460 ft^3/day (D = 30 ft and K_H = 3.1 ft/day) across the 6,000 ft wide transect. The value used as flow input into the alluvial fan model section is 4,460 ft^3/day. The highest estimated value was used for subsequent model inputs in order to intentionally estimate the upper limit of perched groundwater system discharge to the regional aquifer. As a consequence, the overall transport evaluation is made more conservative (i.e., intentionally estimates the upper limit of solute concentration) because the upper limit of solute flux into the alluvial fan section is used.

The concentration in the simulated flow from the perched system into the alluvial fan model section was 1 unit concentration for the duration of the simulation. This approach allows for a conservative evaluation of solute concentration reduction as it is transported to potential receptors but is recognized to overestimate the mass of both TCE and nitrate, as neither of these contaminants is distributed at the maximum concentration over the 6,000-ft cross-gradient length. The results of the transport simulation were interpreted using actual observed concentrations in Section 4.2.

3.1.2 Estimate of Transport Time

An estimate of transport time of contaminants through the perched system was made using the same assumptions stated in Section 3.1.1. Additional assumptions necessary for this estimate are:

- The porosity (η) of the material is 25%, which is the accepted value for the perched system materials (SNL/NM 2004a) and is assumed to represent effective porosity.
- The length of travel (L) of contaminants is the shortest distance between the three monitoring wells of concern (TA2-W-26 [TCE], TJA-7 [nitrate], and TA2-SW1-320 [nitrate]) and the transect shown in Figure 3-3. The estimated distances are shown in Table 3-2.
- Contaminants are conservatively transported with ambient groundwater flow without retardation.

The groundwater velocity is estimated using the following equation:

$$\nu = \frac{K_H i}{\eta} \qquad \text{Equation 2.}$$

where

ν = velocity of the groundwater and contaminants in the groundwater, ft/day

K_H = Horizontal hydraulic conductivity, ft/day

i = hydraulic gradient, ft/ft

η = porosity.

The travel time is then given by solving the equation for velocity (v = L / time) for time. As shown on Table 3-2, the estimated travel times range from less than 100 years to several thousand years based on the horizontal hydraulic conductivity used. In order to be conservative (intentionally estimate the minimum travel time), the minimum travel times for each contaminant have been used for the interpretations summarized in Section 4.2. These travel times are 70 years for TCE and 60 years for nitrate.

Table 3-2. Estimate of contaminant travel time in the perched system.

	Horizontal Hydraulic Conductivity (K_H), ft/day	Velocity (v), ft/day	Length (L), ft	Time, years
TJA-7 area (nitrate)	0.05	0.002	2,200	3,800
TA2-SW1-320 area (nitrate)	0.05	0.002	3,500	6,000
TA2-W26 area (TCE)	0.05	0.002	2,700	4,600
TJA-7 area (nitrate)	3.1	0.10	2,200	60
TA2-SW1-320 area (nitrate)	3.1	0.10	3,500	96
TA2-W26 area (TCE)	3.1	0.10	2,700	70

3.2 Alluvial Fan Model Section

The alluvial fan model section represents the groundwater flow system that extends west and northwest through the low-permeability alluvial fan lithofacies of the Albuquerque Basin from the mountain front to the high-permeability ARG lithofacies, as observed on the local potentiometric surface map (Figure 3-2). Flow through the alluvial fan lithofacies is horizontally preferential because of the layered, lenticular nature of these deposits. Water along this flowpath generally originates from mountain-front recharge to the east and infiltrating recharge in the vicinity of the zone of merging from Tijeras Arroyo and other sources.

Model Grid—The numerical model represents a groundwater flowpath that extends 1.4 miles northwest from an arbitrary location in the zone of merging to a location representing the junction between the alluvial fan and the ARG, as shown in Figure 3-2. The model section consists of a single layer, with the top approximately 10 ft above the altitude of the simulated potentiometric surface and the bottom at an altitude 100 ft lower than the top (approximately 90 ft of saturated thickness). The model section consists of a single row (with 15 cell columns from southeast to northwest) with cell dimensions 500 ft long (in the direction of flow) and 6,000 ft wide.

Model Boundaries and Hydrologic Properties—The flow system was simulated with an average horizontal hydraulic gradient of 0.009 ft/ft. An upgradient constant head boundary (4,944 ft) represented mountain front recharge, and a downgradient constant head boundary (4,880 ft) represented the intersection of the alluvial fan lithofacies and the ARG lithofacies. Actual observations of the potentiometric heads at these locations were not available and were furthermore complicated by the anomalous water levels in the zone of merging monitoring wells. Therefore, the constant heads at the boundaries were interpolated from the observed water levels in five monitoring wells (KAFB-0311, KAFB-0307, TA2-W-24, TA2-NW1-595, and TA1-W-02).

The horizontal hydraulic conductivity of 14.1 ft/day was determined by adjusting the model to produce the calibrated flow into the ARG model cells, which represents underflow into the ARG lithofacies from mountain front recharge (see Section 3.3). This hydraulic conductivity value is considered a reasonable representation given that the horizontal hydraulic conductivity in the alluvial fan lithofacies of the regional aquifer is expected to range from 0.001 to 44.7 ft/day (SNL/NM 2002). In addition, a United States Geological Survey (USGS) regional flow model used an east-west range of hydraulic conductivity ranging from 8 to 15 ft/day in cells simulating alluvial fan deposits (Bexfield and McAda 2003).

Calibration—Simulated heads were compared to observed water levels in five monitoring wells (see Figure 3-4). The constant head elevations were intentionally chosen to produce a hydraulic gradient of approximately 0.009 ft/ft and simulate a gradient approximated by these water level observations. The relatively minor deviation in observed water levels from simulated head is likely a result of heterogeneity of the alluvial fan lithofacies, while the model assumed homogeneous properties. The cross-sectional flow model permitted a reasonable representation of flow and transport.

Flow Model Results—Simulated flow through the cross-sectional model moved from southeast to northwest. An average flow of approximately 70,000 ft^3/day moved out of the model at the downgradient constant-head boundary during the simulation, representing flow out of a 6,000-ft wide section of the alluvial fan deposits into the ARG.

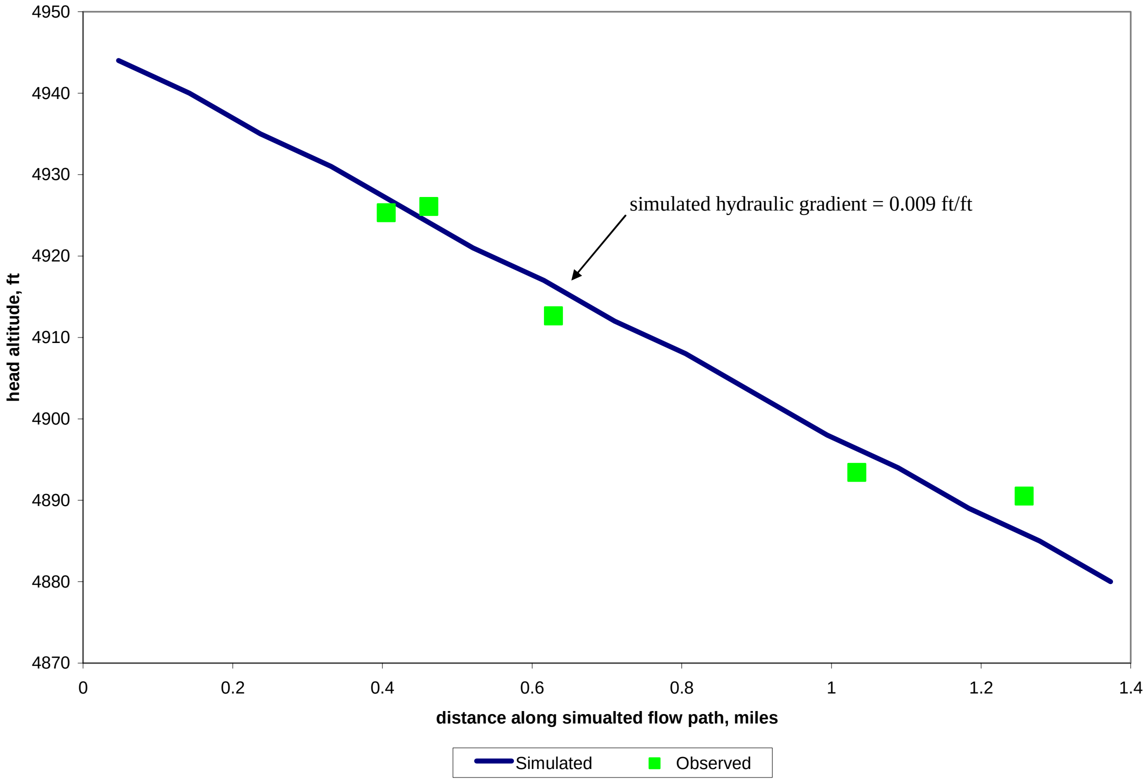

Figure 3-4. Comparison of simulated and observed potentiometric head along the alluvial fan model section.

3.3 Ancestral Rio Grande Model Section

The ARG model section begins south and west of KAFB near an estimated groundwater divide separating flow toward pumping centers to the north from natural system flow to the south. The section represents flow northward through the high-permeability ARG lithofacies, as inferred from water-table contour maps (Figure 3-1). Groundwater along this flowpath generally accretes from underflow out of alluvial fan deposits to the east and recharge from the Rio Grande to the west. The ARG model section simulated accretion of underflow out of the alluvial fan lithofacies to the east.

Grid—The ARG model section represents a groundwater flowpath that extends 10 miles north from the estimated groundwater flow divide to the Ridgecrest well field. The model section consists of one layer, with the bottom at an altitude of 4,400 ft. This bottom elevation includes most of the aquifer thickness presently utilized by pumping wells but does not account for flow within underlying Santa Fe Group sediments.

The model section consists of 88 cells, with cell dimensions 600 ft long (direction of groundwater flow) and 6,000 ft wide (cross-gradient). The width dimension represents most of the flow through the ARG that would be derived from accreted flows from the east.

Model Boundaries and Hydrologic Properties—The estimated groundwater divide to the south was simulated as a no-flow boundary. The cumulative cone of depression in the water table in the vicinity of the Ridgecrest well field has steadily developed over time because of continuous pumpage to meet municipal requirements. In the cross-sectional model, this well field was represented at the northern terminus of the flowpath by a constant head at an altitude of 4,850 ft, which was the approximate water level in well Ridgecrest 4 in 2000. Accreted underflow originating from mountain fronts east of the ARG was represented by injection wells in each cell along the section.

A previous regional flow model used a hydraulic conductivity of 150 ft/day to represent the ARG (Bexfield and McAda 2003). This hydraulic conductivity was used uniformly in the steady-state ARG model section. Horizontal to vertical anisotropy was not represented in the one-layer model. An effective porosity of 25% was assigned to model cells based on the regional numerical model.

Calibration—The model was calibrated to observed water levels by adjusting injection-well contributions representing accreted underflow in each cell. Simulated heads were compared to observed water levels in five wells along the section (Figure 3-5). The cross-sectional flow model was not calibrated further because the intent was not to exactly reproduce distribution of head but to permit a reasonable, representation of flow and transport to the Ridgecrest well field. The calibrated injection rate representing underflow was 7,000 ft^3/day into each cell.

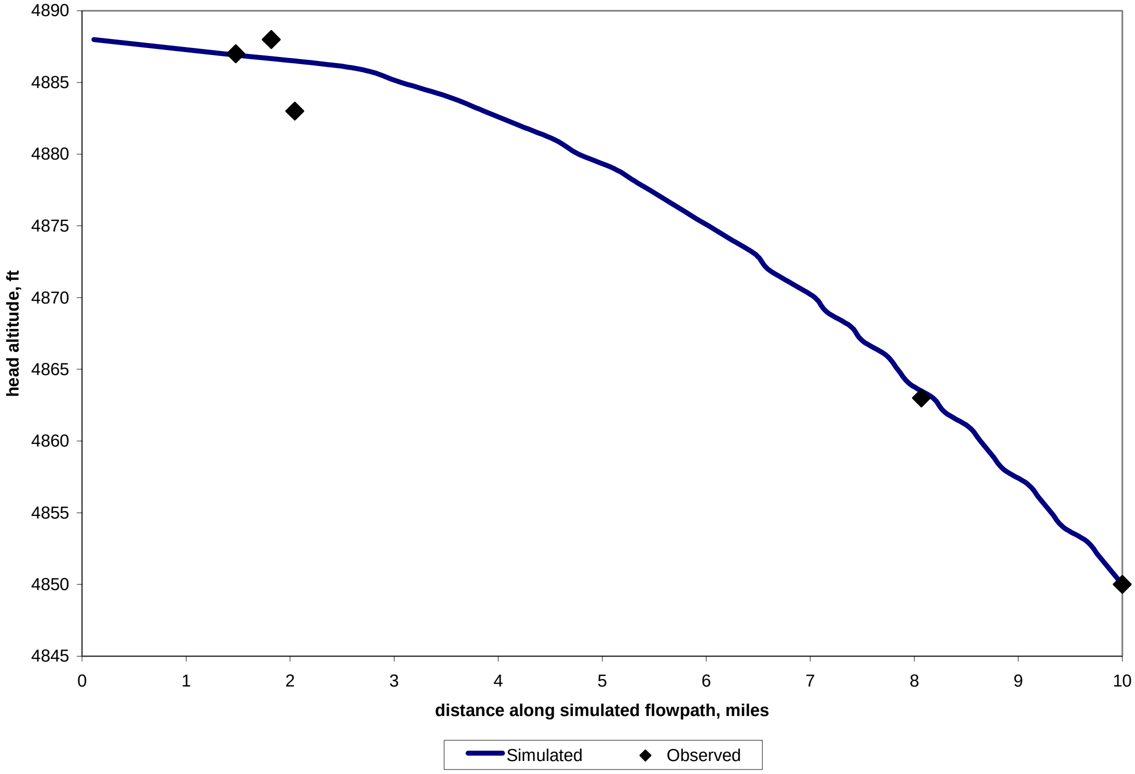

Figure 3-5. Comparison of simulated and observed potentiometric head along the ARG model section

Simulation of the Alluvial Fan/ARG Model Section Interface—Groundwater flow and solute transport from the alluvial fan into the ARG were simulated by using the flow and concentration out of the alluvial fan model section as direct input into the ARG model section. This was possible due to the following characteristics of these two flow models:

- Flow out of the alluvial fan model section was approximately 70,000 ft^3/day,
- Calibrated injection rate into each ARG model section cell was 7,000 ft^3/day, which was meant to simulate underflow from alluvial fan lithofacies,
- Width (cross-gradient) of the alluvial fan model section was 6,000 ft, and
- Length (with the gradient) of the ARG model section cells was 600 ft.

Therefore, the flow out of the alluvial fan model section into the ARG model section was simulated as 7,000 ft^3/day into imaginary injection wells located in 10 cells of the ARG model section. These 10 cells were between 0.8 and 1.9 miles upgradient of the Ridgecrest well field. This location is shown in Figures 3-1 and 3-2.

This simulated solute bearing underflow represents the flux of contaminants from the alluvial fan lithofacies into the ARG lithofacies. As shown in Figure 3-6, the solute flux out of the alluvial fan model section into the ARG model section was simulated by stepping concentrations up throughout the breakthrough period and holding constant at the maximum concentration for the rest of the simulation. Solute injected into the ARG wells was assumed to mix completely with ambient water in the cell. This mixing will more likely occur as the solute is transported downgradient or during withdrawal at pumping centers. The assumption was not considered to be conservative with respect to downgradient concentrations but provided a qualitative assessment of the overall effect of dilution in the ARG prior to reaching potential receptors where groundwater is withdrawn.

Flow Model Results—Simulated flow through the ARG model section moved from south to north. A flux of 609,000 ft^3/day moved out of the model at the downgradient constant-head boundary, representing flow out of a 6,000-ft wide strip of the ARG deposits into the area of influence of the Ridgecrest well field. For comparison, the annual withdrawal for all COA municipal wells for 2000 was estimated to be 110,000 acre-ft, or 13.1 million ft^3/day. The model of ARG groundwater flow represented less than 5% of total COA withdrawals. This representation was considered to be reasonable given the known distribution of head, hydraulic conductivity values, and water-withdrawal data.

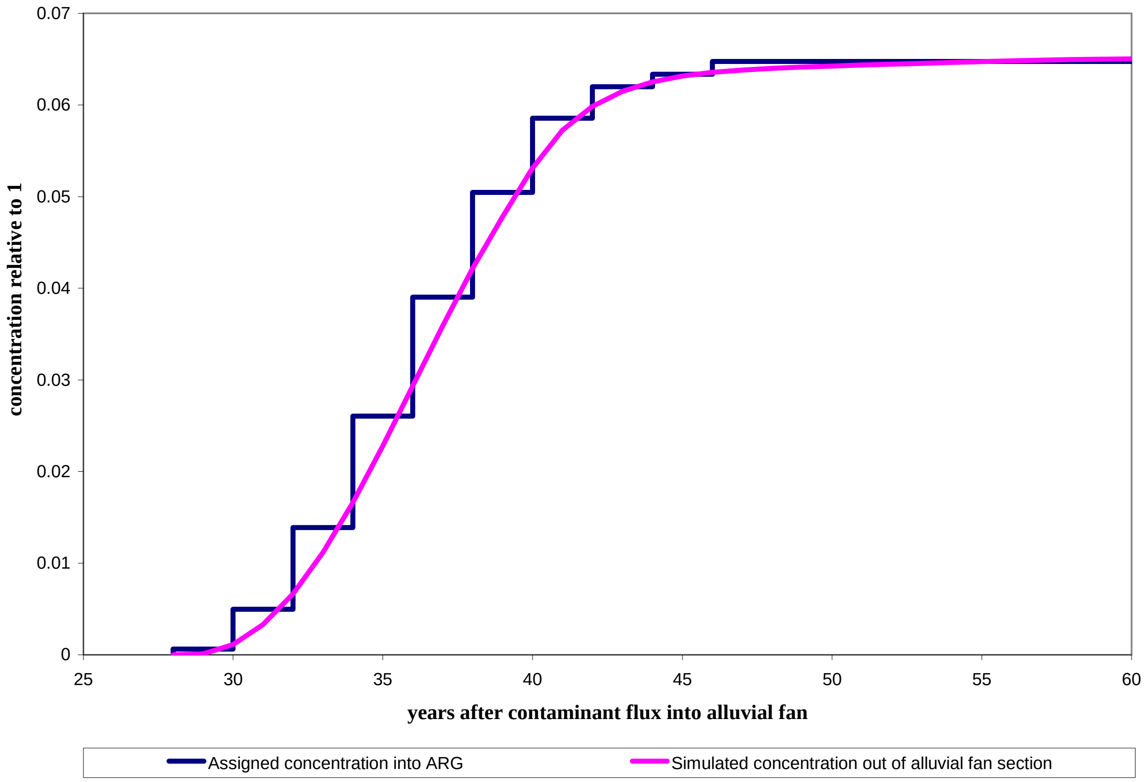

Figure 3-6. Illustration of solute flux simulation from the alluvial fan model section into the ARG model section.

4.0 RESULTS AND INTERPRETATIONS

The modeling approach outlined in Section 3.0 incorporates the conceptual model summarized in Section 2.0 into a conservative numerical model for evaluating reduction in a simulated solute concentration. This section presents results of transport modeling using the alluvial fan and ARG model sections. Section 4.1 presents results of the conservative solute transport, and Section 4.2 presents interpretation of these results relative to observed contaminant concentration and distribution in the SNL/NM AOR.

4.1 Simulation of Solute Transport to Production Wells

The numerical model of groundwater flow was used to simulate a conservative solute that moves out of the perched system through the alluvial fan and ARG lithofacies of the regional aquifer and is extracted in production wells located in the ARG lithofacies. The solute concentration in flow from the perched system into the regional aquifer was simulated at a constant concentration of 1 unit for the duration of the simulation.

Figure 4-1 illustrates the simulated solute arrival at two locations. The first is the location where the maximum solute concentration is observed, which is adjacent to the intersection of the alluvial fan and the ARG model sections. The second is the downgradient boundary of the ARG model section, which represents the Ridgecrest well field.

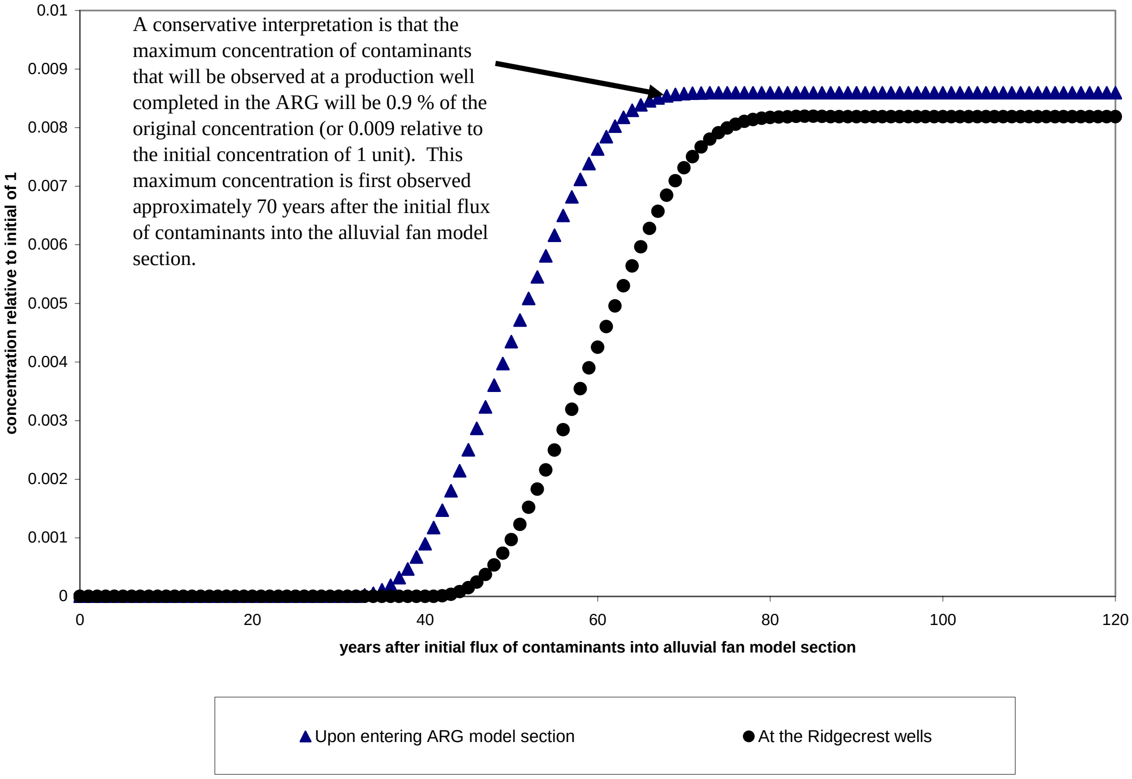
A conservative interpretation is that the maximum concentration of contaminants that will be observed at a production well completed in the ARG will be 0.9 % of the original concentration (or 0.009 relative to the initial concentration of 1 unit). This maximum concentration is first observed approximately 70 years after the initial flux of contaminants into the alluvial fan model section.

Figure 4-1. Plot of solute arrival at the ARG/ alluvial fan model section interface and at the Ridgecrest well field.

The maximum concentration of solute observed in the ARG model section was 0.009 or 0.9% of the initial concentration of 1 unit in the perched groundwater system discharge. The solute was further attenuated to 0.008 (0.8%) before reaching the downgradient boundary of the ARG model section. A conservative estimate of the solute concentration reduction before withdrawal at any production well completed in the ARG lithofacies is 0.9% of the original concentration in the perched groundwater system discharge to the regional aquifer.

Travel time estimated through the alluvial fan model section and the ARG model section does not account for travel through the perched system, which was estimated in Section 3.1. Simulated concentrations of solute began to breakthrough into the ARG model section after about 35 years after the initial flux of contaminants into the alluvial fan model section. The maximum concentration occurred in the ARG model section after approximately 70 years. The maximum concentration moved across the downgradient ARG model section boundary approximately 80 years after initial flux of contaminants into the alluvial fan model section.

4.2 Interpretations of Modeling Relative to Observed Concentrations

The simulated relative solute concentrations presented in Section 4.1 can be compared to actual observed concentrations of nitrate and TCE in samples from various wells completed in the perched groundwater system of the SNL/NM AOR. This comparison provides an estimate of the contribution of nitrate and TCE derived from the AOR that might be expected at production wells. A very conservative interpretation neglects travel through the perched system and assumes that all of the flow out of the perched system (estimated in Section 3.1) contains dissolved TCE or nitrate at the historical maximum observed concentration in any perched system monitoring well. Therefore, an estimate of the maximum concentration that would be expected at the production wells can be obtained by multiplying the maximum relative concentration simulated in the ARG (0.009) by the historical maximum observed concentrations. Interpretation of concentrations and travel time in this manner overestimates the total mass of contaminants within the perched system and underestimates the travel time but is included in the summary of interpretations shown in Table 4-1 as the most conservative estimate.

Based on observed distribution of TCE and nitrate in the perched system, these contaminants are distributed over smaller areas that would not be transported across the entire 6,000-ft transect used to estimate the total flow out of the perched system. As part of the modeling approach, it is assumed that the solute is instantaneously mixed with the ambient flow in the alluvial fan model section. This assumption is only valid if the results are interpreted at the point of groundwater withdrawal. Given this assumption, a more accurate interpretation of the solute transport results relative to nitrate and TCE concentrations would account for the fraction of contaminated water relative to the total flow across the 6,000-ft transect used to estimate perched system discharge (see Section 3.1). The 6,000-ft transect was divided into two zones: a 3,500-ft section representing the portion of the total transect through which nitrate will move and a 2,500-ft section representing the portion through which TCE will be transported (see Figure 3-3). Thus, an additional multiplication factor of 0.6 (3,500 ft/6,000 ft) should be applied when interpreting the solute transport results relative to nitrate and 0.4 (2,500 ft/6,000 ft) should be applied when interpreting relative to TCE.

Maximum historical concentrations of both nitrate and TCE were used when interpreting the solute transport results presented in Section 4.1, even though more recent observations suggest that concentrations have declined. Maximum historical concentrations of TCE and nitrate are 9.6 μg/L and 44 mg/L (as nitrogen), respectively. As shown in Tables 4-1 and 4-2, the most conservative estimate (i.e., concentrations are intentionally overestimated) of nitrate and TCE concentrations that might be observed at production wells in the ARG are 0.40 mg/L (as nitrogen) and 0.09 μg/L, respectively. If observed distribution of contaminant in the perched zone is accounted for, the simulated concentrations of nitrate and TCE at the production wells are 0.24 mg/L (as nitrogen) and 0.03 μg/L, respectively. The actual concentrations are expected to be lower given the conservative assumptions built into the numerical model.

Travel time estimates are also shown on Tables 4-1 and 4-2 for each contaminant. The estimates are the arrival time of the maximum concentration of contaminant in the ARG deposits where production wells are located. The most conservative estimate of the travel time is 70 years, which only accounts for travel through the alluvial fan model section. When travel through the perched system is accounted for, travel times for nitrate and TCE are 140 and 130 years, respectively, which are also conservative estimates. The estimated travel times are slightly different because the contaminants are in two different locations and must travel different distances through the perched groundwater system.

Table 4-1. Interpretations of solute transport simulation relative to nitrate contamination.

	Relative simulated solute concentration	Maximum contaminant concentration, mg/L as nitrogen	Fraction of total perched flow	Maximum concentration in production well, mg/L (as nitrogen)	Time of maximum concentration arrival into ARG model section, years
Most conservative	0.009	44	1[a]	0.40	70[b]
Less conservative	0.009	44	0.6	0.24	130

a. Assumes that all flow out of the perched system contains 44 mg/L (as nitrogen) nitrate.
b. Neglects travel time through the perched system.

Table 4-2. Interpretations of solute transport simulation relative to TCE contamination.

	Relative simulated solute concentration	Maximum contaminant concentration, µg/L	Fraction of total perched flow	Maximum concentration in production well, µg/L	Time of maximum concentration arrival into ARG model section, years
Most conservative	0.009	9.6	1[a]	0.09	70[b]
Less conservative	0.009	9.6	0.4	0.03	140

a. Assumes that all flow out of the perched system contains 9.6 µg/L TCE.
b. Neglects travel time through the perched system.

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5.0 CONCLUSIONS

A cross-sectional modeling approach was used to simulate transport and dilution of a conservative solute between the SNL/NM AOR in the perched zone to production wells completed in the ARG lithofacies. The simulated concentration of a conservative solute at these production wells was 0.9% of the original concentration in the perched system. When compared to observed concentrations in the perched system, these results led to the following conclusions:

- Nitrate originating from the SNL/NM AOR will be reduced to 0.24 mg/L (as nitrogen) before reaching production wells in the ARG lithofacies. For comparison, the MCL for nitrate is 10 mg/L (as nitrogen).
- TCE originating from the SNL/NM AOR will be reduced to 0.03 µg/L before reaching production wells in the ARG. For comparison, the MCL for TCE is 5 µg/L.

These estimates represent conservative estimates of concentration that intentionally neglect the effects of dispersion, degradation, and sorption on contaminant concentrations.

The travel time from the current location of contaminants in the perched groundwater system to the ARG lithofacies where production wells are completed is at least 130 years for nitrate and at least 140 years for TCE. The estimated travel times are slightly different because the contaminants are currently in two different locations in the perched groundwater system. These travel times represent minimum or conservative estimates, because retardation, travel time through the zone of merging, and travel time through the ARG are intentionally neglected.

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Attachment D
Investigation of Intrinsic Anaerobic Biodegradation

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Investigation of Intrinsic Anaerobic Biodegradation in Tijeras Arroyo Groundwater at Sandia National Laboratories/ New Mexico

June 2005

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Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of Energy's
National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Sandia National Laboratories

CONTENTS

TABLES

ACRONYMS AND ABBREVIATIONS

COC	contaminant of concern
COOC	Compliance Order on Consent
DO	dissolved oxygen
DOC	dissolved organic carbon
FY	fiscal year
KAFB	Kirtland Air Force Base
MNA	monitored natural attenuation
NMED	New Mexico Environment Department
ORP	oxidation reduction potential
SNL/NM	Sandia National Laboratories/New Mexico
TAG	Tijeras Arroyo groundwater
TCE	trichloroethene
TKN	Total Kjeldahl Nitrogen
TOC	total organic carbon
VOC	volatile organic compound

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1.0 INTRODUCTION

The *Corrective Measures Evaluation Work Plan Tijeras Arroyo Groundwater* (SNL/NM 2004) was prepared as directed by the Compliance Order on Consent (COOC) issued by the New Mexico Environment Department (NMED) (NMED 2004). This Work Plan outlines a process for evaluation of remedial alternatives in order to identify a corrective measure for the contaminants of concern (COCs) in Sandia National Laboratories/New Mexico (SNL/NM) Tijeras Arroyo groundwater (TAG). The COCs include trichloroethene (TCE) and nitrate. The Corrective Measures Evaluation Work Plan (SNL/NM 2004) identifies data gathering activities to be carried out in four stages. These stages consist of the Paper Study, Numerical Modeling, Laboratory Studies, and Field Scale Studies. In order to determine the effectiveness of implementing monitored natural attenuation (MNA), the Field Scale Studies stage includes investigating natural attenuation mechanisms in TAG.

Sampling is conducted by the SNL/NM Environmental Restoration Project as part of a voluntary monitoring program. Additional sampling work was performed under the *Sandia National Laboratories Tijeras Arroyo Groundwater Investigation Work Plan* (SNL/NM 2003), referred to in this report as the TAG Investigation Work Plan. The purpose of the additional sampling was to characterize the nature and extent of TCE and nitrate contamination. A total of six quarterly sampling events are described in the TAG Investigation Work Plan. The information from these sampling events is used to provide data for a volatile organic compound (VOC) anaerobic biodegradation screening assessment, as defined by the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (EPA 1998), and for an assessment of the potential for nitrate biodegradation via denitrification.

The purpose of this document is to present the biodegradation screening assessment for VOCs and nitrate as applied to TAG sampling and analyses results. The data used to perform this assessment are presented in Section 2.0 and Appendix A, the biodegradation screening assessment is presented in Section 3.0, and conclusions are presented in Section 4.0.

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2.0 CONTAMINANT BIODEGRADATION ASSESSMENT DATA

Water samples were collected under the TAG Investigation Work Plan during the quarterly sampling rounds beginning with the fourth quarter of Fiscal Year (FY) 2003 and ending with the first quarter of FY 2005. Data collected under the TAG Investigation Work Plan include:

- VOCs,
- Alkalinity,
- Oxidation reduction potential (ORP),
- Dissolved oxygen (DO),
- pH,
- Temperature,
- Nitrate (as nitrogen),
- Nitrate plus nitrite (as nitrogen),
- Ammonia (as nitrogen),
- Total Kjeldahl Nitrogen (TKN),
- Chloride,
- Sulfate,
- Orthophosphate (as phosphorous),
- Manganese II,
- Ferrous iron, and
- Other anions and cations.

The sampling results for all these analyses are presented in Appendix A. For each parameter used in the assessment of contaminant biodegradation, the significance of the data relative to the assessment and general observations are presented in Table 2-1.

Table 2-1. Parameters for assessment of contaminant biodegradation.

Parameters	Data Significance	Data Observation	Table in Appendix A
VOCs (PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, and VC)	Contaminants and dechlorination products; required to assess chlorinated solvent biodegradation	PCE was detected at a maximum concentration of 2.63 μg/L; TCE was detected at a maximum concentration of 7.7 μg/L; DCE was detected at a maximum concentration of 3.4 μg/L; VC was not detected.	Tables A-1 to A-6
Nitrate (as nitrogen)	Contaminant (compliance requirement) and redox parameter	Nitrate was detected above the MCL of 10 mg/L in three wells TA2-SW1-320 (25 mg/L), TJA-4 (26 mg/L), and TJA-7 (27 mg/L). All other wells had nitrate detections below the MCL.	Tables A-7 to A-12
Chloride	Dechlorination product; released during chlorinated solvent biodegradation	Chloride results ranged from 11.5 to 263 mg/L.	Tables A-14 to A-19
TOC	Measure for bioavailable electron donor	TOC is present in all samples at less than 2 mg/L.	Table A-20
Ferrous Iron	Redox parameter; electron acceptor (ferric iron) is reduced to the product (ferrous iron); required to assess active anaerobic reaction pathways	Ferrous iron results ranged from 0.0 to 0.57 mg/L.	Table A-13
Manganese II	Redox parameter; required to assess active anaerobic oxidation pathways	Manganese II results ranged from 0.0 to 0.098 mg/L.	Table A-21
Sulfate	Redox parameter; electron acceptor; required to assess active anaerobic reaction pathways	Sulfate results ranged from 8 to 672 mg/L. These results are similar to historic average concentrations for each well.	Tables A-14 to A-19
ORP	Redox parameter; required to assess active anaerobic reaction pathways	ORP ranged between 97.9 to 346.1 mV.	Table A-22
DO	Redox parameter; required to assess active anaerobic reaction pathways	DO ranged between 0.28 to 11.92 mg/L.	Table A-22

Table 2-1. (continued).

Parameters	Data Significance	Data Observation	Table in Appendix A
Orthophosphate	Microbial nutrient; required to assess potential nutrient limitations	All orthophosphate (as phosphorus) results were below the PQL.	Table A-20
Ammonia (as nitrogen)	Microbial nutrient; required to assess potential nutrient limitations	All ammonia results were below the MDL except for one detection at TJA-7 of 0.080 mg/L.	Table A-20
Alkalinity	Indicator of microbial respiration; may be useful for evaluating biostimulation	Alkalinity results ranged from 44.8 to 289 mg/L.	Tables A-14 to A-19
pH and Temperature	Water quality parameters; may be useful for evaluating biostimulation and suitability of conditions for anaerobic reductive dechlorination	The range for pH was from 6.81 to 8.48. Temperature ranged from 13.29 to 22.40°C.	Table A-22

mg/L = milligrams per liter, µg/L = micrograms per liter
mV = millivolt
°C = degrees Celsius

COD = chemical oxygen demand
DCE = dichloroethene
DO = dissolved oxygen
DOC = dissolved organic carbon
MCL = maximum contaminant level
MDL = method detection limit
ORP = oxidation reduction potential
PCE = tetrachloroethene
TCE = trichloroethene
TOC = total organic carbon
VC = vinyl chloride
VOC = volatile organic compound

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3.0 CONTAMINANT BIODEGRADATION SCREENING ASSESSMENT

The contaminant biodegradation assessment data, presented in Section 2.0 and Appendix A, and historical data were used to perform the VOC contaminant biodegradation screening assessment described in the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (EPA 1998). This section details the biodegradation screening assessment process (Section 3.1) and summarizes the results of the VOC screening using data from TAG monitoring (Section 3.2). An assessment of nitrate biodegradation is presented in Section 3.3.

3.1 VOC Biodegradation Screening Assessment Process

The purpose of this screening is to determine if evidence is available to show that anaerobic biodegradation of VOCs is occurring in TAG. This biodegradation screening assessment process consists of analyzing the data using the information presented in Table 3-1. For each parameter, a concentration criterion, interpretation of the criterion, and a scoring value are listed. For the perched system and regional aquifer wells, a value was assigned for each parameter. The sentry/background wells were used as a basis of comparison for some of the parameters. The total scoring value for all parameters at each well was compared to the interpretation information presented in Table 3-2.

Table 3-1. Analytical Parameters and Weighting for Anaerobic Biodegradation Screening Assessment Processes (modified from EPA 1998).

Parameters	Concentration in Most Contaminated Zone	Interpretation	Value
Oxygen	<0.5 mg/L	Tolerated, suppresses the reductive pathway at higher concentrations	3
	>5 mg/L	Not tolerated; however, VC may be oxidized aerobically	-3
Nitrate	<1 mg/L	At higher concentrations may compete with reductive pathway	2
Iron II	>1 mg/L	Reductive pathway possible; VC may be oxidized under Fe (III)-reducing conditions	3
Sulfate	<20 mg/L	At higher conditions may compete with reductive pathway	2
ORP against Ag/AgCl electrode	<50 mV	Reductive pathway possible	1
	<-100 mV	Reductive pathway likely	2
pH	5 < pH < 9	Optimal range for reductive pathway	0
	pH < 5 or pH> 9	Outside optimal range for reductive pathway	-2
TOC	> 20 mg/L	Carbon and energy source; drives dechlorination; can be natural or anthropogenic	2

Table 3-1. (continued).

Parameters	Concentration in Most Contaminated Zone	Interpretation	Value
Temperature	> 20°C	At T >20°C biochemical process is accelerated	1
Alkalinity	>2× background	Results from interaction between CO_2 and aquifer minerals	1
Chloride	>2× background	Daughter product of organic chlorine	2
BTEX	>0.1 mg/L	Carbon and energy source; drives dechlorination	2
PCE	Not Applicable	Material release	0
TCE	Not Applicable	Material release Daughter product of PCE	0 2*
DCE	Not Applicable	Material release Daughter product of TCE If cis is > 80% of total DCE it is likely a daughter product	0 2*
VC	Not Applicable	Material release Daughter product of DCE	0 2*

*Points awarded only if it can be shown that the compound is a daughter product.

mg/L = milligrams per liter
mV = millivolt
°C = degrees Celsius

BTEX = benzene, toluene, ethyl benzene, xylene
DCE = dichloroethene
ORP = oxidation reduction potential
PCE = tetrachloroethene
TCE = trichloroethene
TOC = total organic carbon
VC = vinyl chloride

Table 3-2. Interpretation of Points Awarded During Screening.

Score	Interpretation
0 to 5	Inadequate evidence for anaerobic biodegradation (reductive dechlorination)
6 to 14	Limited evidence for anaerobic biodegradation (reductive dechlorination)
15 to 20	Adequate evidence for anaerobic biodegradation (reductive dechlorination)
>20	Strong evidence for anaerobic biodegradation (reductive dechlorination)

3.2 VOC Biodegradation Screening Assessment and Results

The biodegradation screening was performed for both perched system and regional aquifers in the Tijeras Arroyo area. Perched system and regional aquifer wells are identified in the Tijeras Arroyo Groundwater Investigation Work Plan (SNL/NM 2003) and Tables 3-3 and 3-4. Groundwater monitoring data from regional aquifer wells Eubank-1, Eubank-2, Eubank-3, Eubank-5, PGS-2, TA1-W-04, and TA1-W-05 were used to represent background conditions. When available, historical data, along with the most recent data, were analyzed against the evaluation criteria (Table 3-1) in order to make general assessments of conditions within each well. Kirtland Air Force Base (KAFB) wells were sampled but the data were not used in this evaluation.

Table 3-3 summarizes the results of the VOC biodegradation screening assessment. This table presents a scoring value for each parameter at each well and a general explanation for the scoring value assignments. The total scoring value for each well is also shown. Total scores range from –3 to 2. Comparisons of these total values to the interpretations of the values presented in Table 3-2 show that all wells fall within or below the scoring range of 0 to 5. This leads to the interpretation that there is inadequate evidence to demonstrate that biodegradation, through anaerobic processes of reductive dechlorination, is occurring in TAG. Because there is inadequate evidence to demonstrate anaerobic biodegradation and the observed aerobic conditions are not conducive to anaerobic biodegradation of VOCs, it is concluded that anaerobic biodegradation will not be a significant mechanism of natural attenuation.

3.3 Biodegradation of Nitrate

Transformation of nitrate in the environment is part of the natural nitrogen cycle. Under the right environmental conditions, nitrate can be transformed to nitrogen gas through the biologically mediated process of denitrification. Denitrification can occur in low oxygen environments and in the presence of an electron donor where nitrate can act as an electron acceptor in the microbial respiration process (ITRC 2002). Oxygen is a more thermodynamically favorable electron acceptor than nitrate. In the presence of oxygen, aerobically respiring organisms will constitute the dominant microbial community; therefore, DO is inhibitory to the process of denitrification. Denitrification also requires the presence of both carbon and energy sources to sustain biological activity within groundwater.

There is not a biodegradation screening assessment for nitrate similar to the screening presented for VOCs (Section 3.2). However, a qualitative evaluation of the data demonstrates that denitrification is not likely to act as a natural attenuation mechanism. This is confirmed by the following observations:

- DO inhibits the process of denitrification. DO concentrations in samples from most of the wells were greater than 5 mg/L.

- A source of carbon and energy must be available to sustain biological activity. Very low dissolved organic carbon (DOC) concentrations (< 2 mg/L) and low total organic carbon (TOC) concentrations (<4 mg/L) suggest that organic carbon and energy sources are limited.

Table 3-3. Anaerobic biodegradation screening for TAG perched system wells.

	Perched System Wells											Reason for Scoring
Parameters	TA1-W-03	TA1-W-06	TA1-W-08	TA2-SW1-320	TA2-W-01	TA2-W-19	TA2-W-26	TA2-W-27	TJA-2	TJA-7	WYO-4	
Dissolved Oxygen	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	All wells in the perched system had average DO concentrations of >5 mg/L.
Nitrate	0	0	0	0	0	0	0	0	0	0	0	All wells in the perched system had average nitrate concentrations of >1 mg/L.
Iron II	0	0	0	0	0	0	0	0	0	0	0	All wells in the perched system had average ferrous iron concentrations of <1 mg/L.
Sulfate	0	0	0	2	0	0	0	0	0	2	0	Average sulfate concentrations are >20 mg/L in all perched system wells except two (TA2-SW1-320 and TJA-7).
ORP	0	0	0	0	0	0	0	0	0	0	0	All wells in the perched system had average ORP of >50 mV.
pH	0	0	0	0	0	0	0	0	0	0	0	The pH in all wells has remained within the optimal range for the reductive pathway.
TOC	0	0	0	0	0	0	0	0	0	0	0	Very low average TOC concentrations (< 1 mg/L) for all wells.
Temperature	0	0	0	0	0	0	0	0	0	0	0	During seasonal temperature variations, the groundwater temperature has been >20^{o}C. However, the average temperature was not >20^{o}C in any of the perched system wells.
Alkalinity	0	0	0	0	0	0	0	0	0	0	0	Alkalinity is less than two times the average concentration in background wells (Eubank-1, Eubank-2, Eubank-3, Eubank-5, PGS-2, TA1-W-04, and TA1-W-05).

Table 3-3. (continued).

Parameters	Perched System Wells											Reason for Scoring
	TA1-W-03	TA1-W-06	TA1-W-08	TA2-SW1-320	TA2-W-01	TA2-W-19	TA2-W-26	TA2-W-27	TJA-2	TJA-7	WYO-4	
Chloride	0	0	0	0	0	0	0	0	0	0	0	Chloride concentrations are variable in different wells. Although some chloride concentrations are greater than two times background, chloride is not believed to be a result of chlorinated organic compound degradation.
BTEX	0	0	0	0	0	0	0	0	0	0	0	No BTEX constituents were detected above 0.1 mg/L in any of the perched system wells.
PCE	0	0	0	0	0	0	0	0	0	0	0	PCE in groundwater is a material released from the source.
TCE	0	0	0	0	0	0	0	0	0	0	0	TCE in groundwater is a material released from the source and is not suspected to be a degradation product of PCE reduction.
DCE	0	0	0	0	0	2	2	0	2	0	2	DCE has been detected in various wells; however, cis-DCE was > 80% of total DCE in only four wells.
VC	0	0	0	0	0	0	0	0	0	0	0	VC was not detected above the MDL.
Total Score	**-3**	**-3**	**-3**	**-1**	**-3**	**-1**	**-1**	**-3**	**-1**	**-1**	**-1**	

BTEX = benzene, toluene, ethylbenzene, and xylene
DCE = dichloroethene
DO = dissolved oxygen
MDL = method detection limit
ORP = oxidation reduction potential
PCE = tetrachloroethene
TCE = trichloroethene
TOC = total organic carbon
VC = vinyl chloride

Table 3-4. Anaerobic biodegradation screening for TAG regional aquifer wells.

Parameters	Regional Aquifer Wells							Sentry/Background Wells							Reason for Scoring
	TA1-W-01	TA1-W-02	TA2-NW1-595	TJA-3	TJA-4	TJA-6	WYO-3	EUBANK-1	EUBANK-2	EUBANK-3	EUBANK-5	PGS-2	TA1-W-04	TA1-W-05	
Dissolved Oxygen	-3	-3	-3	-3	0	0	0	-3	-3	-3	-3	0	-3	-3	Most wells in the regional aquifer had average DO concentrations >5 mg/L, and none had DO concentrations <0.5 mg/L.
Nitrate	0	0	0	0	0	0	0	0	0	0	0	2	0	0	All wells in the regional aquifer had average nitrate concentrations of >1 mg/L, except for PGS-2 (0.85 mg/L).
Iron II	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Ferrous iron has not been detected in any wells >1 mg/L.
Sulfate	0	0	0	0	2	0	0	0	0	0	0	0	0	0	Average sulfate concentrations are >20 mg/L in all perched system wells except one (TJA-4).
ORP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	The ORP for all wells is greater than 50 mV.
pH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	The pH in all wells has remained within the optimal range for the reductive pathway.
TOC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Very low TOC concentrations (< 1 mg/L) for all wells.
Temperature	1	0	0	0	0	1	0	0	0	0	0	0	0	0	During seasonal temperature variations, the groundwater temperature has been >20°C. However, the average temperature was >20°C in only two wells (TA1-W-01 and TJA-6).
Alkalinity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Alkalinity is less than two times the average concentration in background wells (Eubank-1, Eubank-2, Eubank-3, Eubank-5, PGS-2, TA1-W-04, and TA1-W-05).

Table 3-4. (continued).

Parameters	Regional Aquifer Wells							Sentry/Background Wells							Reason for Scoring
	TA1-W-01	TA1-W-02	TA2-NW1-595	TJA-3	TJA-4	TJA-6	WYO-3	EUBANK-1	EUBANK-2	EUBANK-3	EUBANK-5	PGS-2	TA1-W-04	TA1-W-05	
Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Chloride concentrations are variable in different wells. Although some chloride concentrations are greater than two times background, chloride is not believed to be a result of chlorinated organic compound degradation.
BTEX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No BTEX were detected above >0.1 mg/L.
PCE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	PCE in groundwater is a material released from the source.
TCE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	TCE in groundwater is a material released from the source and is not suspected to be a degradation product of PCE reduction.
DCE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	cis-DCE was not detected in any of the regional aquifer/sentry wells.
VC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	VC was not detected above the MDL.
Total Score	**-2**	**-3**	**-3**	**-3**	**2**	**1**	**0**	**-3**	**-3**	**-3**	**-3**	**2**	**-3**	**-3**	

BTEX = benzene, toluene, ethylbenzene, and xylene
DCE = dichloroethene
DO = dissolved oxygen
MDL = method detection limit
ORP = oxidation reduction potential

PCE = tetrachloroethene
TCE = trichloroethene
TOC = total organic carbon
VC = vinyl chloride

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4.0 CONCLUSIONS AND RECOMMENDATIONS

The purpose of this document is to present the biodegradation screening assessment for VOCs and nitrate at TAG. The results of this screening will be used in the Tijeras Arroyo Groundwater CME Report. Based on the screening process, the conclusions of this report are as follows:

1. Conditions in Tijeras Arroyo groundwater are not conducive to anaerobic biodegradation of VOCs; therefore, anaerobic biodegradation is not a significant natural attenuation mechanism.

2. Conditions conducive to denitrification are not present in Tijeras Arroyo groundwater; therefore, natural attenuation via denitrification is not is not a significant natural attenuation mechanism.

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5.0 REFERENCES

5. EPA, 1998, “Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water,” United States Environmental Protection Agency, Office of Research and Development, Washington DC.

6. ITRC, 2002, Interstate Technology and Regulatory Cooperation (ITRC) Work Group, 2002. “Technical and Regulatory Guidance for In Situ Bioremediation in Groundwater,” 129 pp.

7. NMED, 2004, “Compliance Order on Consent Pursuant to the New Mexico Hazardous Waste Act 74-4-10: Sandia National Laboratories Consent Order,” New Mexico Environment Department, April 24, 2004.

8. SNL/NM, 2003, *Tijeras Arroyo Groundwater Investigation Work Plan*, Sandia National Laboratories/New Mexico, June 2003.

9. SNL/NM, 2004, *Corrective Measures Evaluation Work Plan Tijeras Arroyo Groundwater*, Sandia National Laboratories/New Mexico.

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Appendix A

Last quarter FY 2003 to first Quarter FY 2005

Biodegradation Assessment Data

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Table A-1
Summary of Detected Volatile Organic Compounds

(EPA Method 8260)

Tijeras Arroyo Groundwater Investigation

4th Quarter 2003

Well ID	Analyte	Result (µg/L)	MDL (µg/L)	PQL (µg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
TA1-W-03 24-Jul-03	Acetone	13.1	4.5	5		J	062684-001
TA1-W-06 29-Jul-03	1,1-Dichloroethene	0.48	0.41	1	J		062690-001
TA2-W-01 07-Aug-03	Trichloroethene	1.29	0.36	1			062700-001
TA2-W-19 23-Sep-03	Trichloroethene	3.77	0.36	1			063272-001
	cis-1,2-Dichloroethene	0.661	0.3	1	J		063272-001
TA2-W-26 04-Aug-03	Tetrachloroethene	2.67	0.33	1			062704-001
	Trichloroethene	1.9	0.36	1			062704-001
	cis-1,2-Dichloroethene	0.925	0.3	1	J		062704-001
TA2-W-27 06-Aug-03	Tetrachloroethene	0.421	0.33	1	J		062707-001
TJA-2 31-Jul-03	Trichloroethene	2.59	0.36	1			062709-001
TJA-7 12-Aug-03	Trichloroethene	1.46	0.36	1			062717-001
WYO-4 14-Aug-03	1,1-Dichloroethane	0.709	0.41	1	J		062721-001
	Trichloroethene	6.57	0.36	1			062721-001
	cis-1,2-Dichloroethene	1.63	0.3	1			062721-001
WYO-4 (Duplicate) 14-Aug-03	1,1-Dichloroethane	0.757	0.41	1	J		062722-001
	Trichloroethene	6.39	0.36	1			062722-001
	cis-1,2-Dichloroethene	1.66	0.3	1			062722-001

µg/L = micrograms per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.

Table A-2
Summary of Detected Volatile Organic Compounds

(EPA Method 8260)

Tijeras Arroyo Groundwater Investigation

1st Quarter 2004

Well ID	Analyte	Result (µg/L)	MDL (µg/L)	PQL (µg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
TA1-W-03 13-Oct-03	Chloroform	0.364	0.36	1	J		063281-001
TA1-W-06 09-Oct-03	Trichloroethene	0.438	0.36	1	J		063284-001
TA2-W-01 01-Dec-03	Trichloroethene	1.96	0.36	1		J	063290-001
TA2-W-19 07-Oct-03	1,1-Dichloroethane	0.725	0.41	1	J		063291-001
	Trichloroethene	4.54	0.36	1			063291-001
	cis-1,2-Dichloroethene	0.845	0.3	1	J		063291-001
TA2-W-26 16-Oct-03	Tetrachloroethene	2.50	0.33	1			063292-001
	Trichloroethene	1.98	0.36	1		J	063292-001
	cis-1,2-Dichloroethene	0.820	0.3	1	J		063292-001
TA2-W-26 (Duplicate) 16-Oct-03	Tetrachloroethene	2.59	0.33	1			063293-001
	Trichloroethene	2.13	0.36	1		J	063293-001
	cis-1,2-Dichloroethene	0.770	0.3	1	J		063293-001
TA2-W-27 23-Oct-03	Tetrachloroethene	0.436	0.33	1	J		063294-001
TJA-2 15-Oct-03	Trichloroethene	2.36	0.36	1		J	063295-001
WYO-4 03-Nov-03	Trichloroethene	6.06	0.36	1		J	063301-001
	cis-1,2-Dichloroethene	1.43	0.3	1			063301-001
WYO-4 (Duplicate) 03-Nov-03	Trichloroethene	7.05	0.36	1		J	063302-001
	cis-1,2-Dichloroethene	1.55	0.3	1			063302-001

µg/L = micrograms per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.

Table A-3
Summary of Detected Volatile Organic Compounds

(EPA Method 8260)

Tijeras Arroyo Groundwater Investigation

2nd Quarter 2004

Well ID	Analyte	Result (µg/L)	MDL (µg/L)	PQL (µg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
Eubank-5 19-Feb-04	Acetone	5.52	4.5	5		5.52 U, B1	063911-001
TA1-W-06 *09-Feb-04*	1,1-Dichloroethene	0.784	0.41	1	J		063864-001
	Trichloroethene	0.362	0.36	1	J	J	063864-001
TA2-W-01 12-Jan-04	Trichloroethene	1.63	0.36	1			063876-001
TA2-W-19 13-Jan-04	Trichloroethene	4.19	0.36	1			063878-001
	cis-1,2-Dichloroethene	0.886	0.3	1	J		063878-001
TA2-W-26 20-Jan-04	Tetrachloroethene	2.31	0.33	1			063880-001
	Trichloroethene	1.81	0.36	1		J	063880-001
	cis-1,2-Dichloroethene	0.726	0.3	1	J		063880-001
TA2-W-26 (Duplicate) 20-Jan-04	Tetrachloroethene	2.04	0.33	1			063881-001
	Trichloroethene	1.56	0.36	1		J	063881-001
	cis-1,2-Dichloroethene	0.724	0.3	1	J		063881-001
TA2-W-27 15-Jan-04	Tetrachloroethene	0.577	0.33	1	J		063885-001
	Trichloroethene	0.519	0.36	1	J	J	063885-001
TJA-2 19-Jan-04	Trichloroethene	3.08	0.36	1		J	063887-001
	cis-1,2-Dichloroethene	0.626	0.626	1	J		063887-001
TJA-7 22-Jan-04	Trichloroethene	0.430	0.36	1	J	J	063895-001
WYO-4 03-Feb-04	1,1-Dichloroethane	0.773	0.41	1	J		063899-001
	Trichloroethene	6.99	0.36	1		J	063899-001
	cis-1,2-Dichloroethene	1.58	0.3	1			063899-001
WYO-4 (Duplicate) 03-Feb-04	1,1-Dichloroethane	0.729	0.41	1	J		063900-001
	Trichloroethene	6.60	0.36	1		J	063900-001
	cis-1,2-Dichloroethene	1.62	0.3	1			063900-001

µg/L = micrograms per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
B1 = Analyte present in associated trip blank sample.
#U = Analyte was qualified as not detected at the listed value.

Table A-4
Summary of Detected Volatile Organic Compounds

(EPA Method 8260)

Tijeras Arroyo Groundwater Investigation

3rd Quarter 2004

Well ID	Analyte	Result (µg/L)	MDL (µg/L)	PQL (µg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
Eubank-1 20-May-04	Acetone	4.2	1.3	20	B, J	20UJ, B, B1, P2	064600-001
Eubank-2 *06-May-04*	Acetone	4.6	1.3	20	J	J	064602-001
	Toluene	0.72	0.59	5	J		064602-001
Eubank-3 *04-May-04*	Acetone	4.3	1.3	20	J	20UJ, B1	064604-001
	Chloromethane	0.32	0.23	10	J	10U, B1	064604-001
Eubank-5 03-May-04	Methylene chloride	14	2.6	5		14UJ, A2, B1	064607-001
PGS-2 *12-May-04*	Acetone	6.5	1.3	20	B, J	20UJ, B, B1	064551-001
	Methylene chloride	4.0	2.6	5	B, J	5.0UJ, B, B1	064551-001
TA1-W-01 10-May-04	Acetone	3.9	1.3	20	J	20UJ, B1	064553-001
TA1-W-02 11-May-04	Acetone	4.5	1.3	20	B, J	20UJ, B, B1, P1	064556-001
TA1-W-03 28-Apr-04	Acetone	3.8	1.3	20	B, J	20UJ, B	064558-001
	Chloroform	0.60	0.12	5	J	5.0U, B3	064558-001
	Toluene	1.0	0.59	5	B, J	5.0U, B	064558-001
TA1-W-04 26-Apr-04	Acetone	6.5	1.3	20	B, J	20UJ, B	064560-001
	Trichloroethene	0.30	0.06	5	J		064560-001
	1,2-Dichloroethene (total)	0.73	0.61	10	J	10UJ, A2, B3	064560-001
	trans-1,2-Dichloroethene	0.73	0.31	5	J	5.0U, B3	064560-001
TA1-W-05 07-May-04	Acetone	4.7	1.3	20	J	20UJ, B1	064562-001
TA1-W-06 *21-May-04*	Acetone	4.9	1.3	20	B, J	20UJ, A1, B, B1	064564-001
	Chloroform	0.30	0.12	5	J	J, A1	064564-001
	1,1-Dichloroethene	1.0	0.68	5	J	J, A1	064564-001

Well ID	Analyte	Result (µg/L)	MDL (µg/L)	PQL (µg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
TA1-W-08 *23-Apr-04*	Acetone	5.3	1.3	20	B, J	20UJ, B, B1	064566-001
	Chloroform	0.22	0.12	5	J	5.0UJ, A2, B1, P1	064566-001
	Trichloroethene	0.44	0.06	5	J		064566-001
	1,2-Dichloroethene (total)	0.64	0.61	10	J		064566-001
	trans-1,2-Dichloroethene	0.64	0.31	5	J		064566-001
TA2-NW1-595 (QED) 13-May-04	Acetone	7.9	1.3	20	B, J	20U, B	064568-001
	Chloroform	0.42	0.12	5	J	5.0U, B1	064568-001
	Methylene chloride	6.4	2.6	5		6.4UJ, B1	064568-001
TA2-NW1-595 (Bennett) 19-May-04	Acetone	4.4	1.3	20	B, J	20U, B, P2	064571-001
	Chloroform	0.28	0.12	5	J	P2	064571-001
TA2-SW1-320 14-May-04	Acetone	11	1.3	20	B, J	20UJ, B, B1	064573-001
	Chloromethane	0.38	0.23	10	J		064573-001
	Methylene chloride	5.7	2.6	5		5.7UJ, B1	064573-001
TA2-W-01 17-May-04	Acetone	9.6	1.3	20	B, J	20UJ, B, B1	064575-001
	Chloroform	0.30	0.12	5	J		064575-001
	Methylene chloride	6.7	2.6	5		6.7UJ, B1	064575-001
	Trichloroethene	1.8	0.06	5	J		064575-001
TA2-W-19 27-Apr-04	Acetone	5.1	1.3	20	B, J	20UJ, B	064577-001
	Trichloroethene	5.2	0.06	5			064577-001
	1,1-Dichloroethane	0.92	0.21	5	J		064577-001
	1,2-Dichloroethene (total)	1.7	0.61	10	J	10U, B3	064577-001
	cis-1,2-Dichloroethene	0.99	0.20	5	J		064577-001
	trans-1,2-Dichloroethene	0.70	0.31	5	J		064577-001
TA2-W-19 (Duplicate) 27-Apr-04	Acetone	4.5	1.3	20	B, J	20UJ, B	064578-001
	Trichloroethene	5.1	0.06	5			064578-001
	1,1-Dichloroethane	0.96	0.21	5	J		064578-001
	1,2-Dichloroethene (total)	1.7	0.61	10	J	10U, B3	064578-001
	cis-1,2-Dichloroethene	1.0	0.20	5	J		064578-001
	trans-1,2-Dichloroethene	0.62	0.31	5	J		064578-001
TA2-W-26 21-Apr-04	Acetone	4.1	1.3	20	B, J	20UJ, B	064580-001
	Carbon tetrachloride	0.87	0.14	5	B, J	5.0U, B	064580-001

Well ID	Analyte	Result (µg/L)	MDL (µg/L)	PQL (µg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
	Chloroform	0.32	0.12	5	J		064580-001
	Tetrachloroethene	1.9	0.20	5	J		064580-001
	Trichloroethene	3.1	0.06	5	B, J	5.0U, B	064580-001
	1,2-Dichloroethene (total)	0.69	0.61	10	J		064580-001
	cis-1,2-Dichloroethene	0.69	0.20	5	J		064580-001
TA2-W-26 (Duplicate) 21-Apr-04	Acetone	4.1	1.3	20	B, J	20UJ, B	064581-001
	Carbon tetrachloride	0.88	0.14	5	B, J	5.0U, B	064581-001
	Chloroform	0.37	0.12	5	J		064581-001
	Tetrachloroethene	2.0	0.20	5	J		064581-001
	Trichloroethene	3.0	0.06	5	B, J	5.0U, B	064581-001
	1,2-Dichloroethene (total)	0.70	0.61	10	J		064581-001
	cis-1,2-Dichloroethene	0.70	0.20	5	J		064581-001
TA2-W-27 19-Apr-04	Acetone	4.6	1.3	20	J	20UJ, B1	064583-001
	Chloromethane	0.46	0.23	10	J	J	064583-001
	Methylene chloride	6.1	2.6	5	B	5.0U, B	064583-001
	Tetrachloroethene	0.62	0.20	5	J		064583-001
	Trichloroethene	1.3	0.06	5	J	5.0U, B1	064583-001
	4-Methyl-2-pentanone	3.6	0.90	20	J	20UJ, B1	064583-001
TJA-2 05-May-04	Acetone	3.3	1.3	20	J	20UJ, B1	064585-001
	Chloromethane	0.38	0.23	10	J	10U, B1	064585-001
	Trichloroethene	3.3	0.06	5	J		064585-001
	1,1-Dichloroethane	0.50	0.21	5	J		064585-001
	1,2-Dichloroethene (total)	0.67	0.61	10	J		064585-001
	cis-1,2-Dichloroethene	0.67	0.20	5	J		064585-001
TJA-3 27-Apr-04	Acetone	4.3	1.3	20	B, J	20UJ, B	064587-001
TJA-4 20-Apr-04	Acetone	5.7	1.3	20	J	20UJ, A1, B1	064589-001
	Methylene chloride	2.9	2.6	5	B, J	5.0UJ, A1, B	064589-001
	4-Methyl-2-pentanone	3.0	0.90	20	J	20UJ, B1, A1	064589-001
TJA-6	Acetone	5.0	1.3	20	B, J	20UJ, B	064591-001

Well ID	Analyte	Result (µg/L)	MDL (µg/L)	PQL (µg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
22-Apr-04	Carbon tetrachloride	0.88	0.14	5	B, J	5.0U, B	064591-001
	Trichloroethene	1.2	0.06	5	B, J	5.0U, B	064591-001
TJA-7 30-Apr-04	Acetone	4.4	1.3	20	B, J	20UJ, B, B1	064593-001
	Methylene chloride	23	2.6	5		23UJ, A2, B1	064593-001
WYO-3 28-Apr-04	Acetone	4.0	1.3	20	B, J	20UJ, B	064595-001
	Chloromethane	0.35	0.23	10	J	10U, B3	064595-001
	Toluene	1.0	0.59	5	B, J	5.0U, B	064595-001
WYO-4 30-Apr-04	Acetone	3.8	1.3	20	B, J	20UJ, B, B1	064597-001
	Methylene chloride	3.2	2.6	5	J	5.0UJ, A2, B1	064597-001
	Trichloroethene	7.7	0.06	5			064597-001
	1,1-Dichloroethane	0.99	0.21	5	J		064597-001
	1,2-Dichloroethene (total)	2.1	0.61	10	J		064597-001
	cis-1,2-Dichloroethene	2.1	0.20	5	J		064597-001
WYO-4 (Duplicate) 30-Apr-04	Acetone	3.7	1.3	20	B, J	20UJ, B, B1	064598-001
	Methylene chloride	3.2	2.6	5	J	5.0UJ, A2, B1	064598-001
	Trichloroethene	7.6	0.06	5			064598-001
	1,1-Dichloroethane	0.95	0.21	5	J		064598-001
	1,2-Dichloroethene (total)	1.9	0.61	10	J		064598-001
	cis-1,2-Dichloroethene	1.9	0.20	5	J		064598-001

µg/L = micrograms per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
A1 = Laboratory accuracy and/or bias measurements for the associated surrogate spike do not meet acceptance criteria.
A2 = Laboratory accuracy and/or bias measurements for the associated matrix spike and/or duplicate do not meet acceptance criteria.
B = Analyte is detected in associated laboratory method blank.
B1 = Analyte present in associated trip blank sample.
B3 = Analyte present in associated continuing calibration blank.
P1 = Laboratory precision measurement for the associated matrix spike and/or duplicate samples do not meet acceptance criteria.
P2 = Insufficient quality control data to determine laboratory precision.
UJ = Associated value is an estimate and may be inaccurate or imprecise.
#U = Analyte was qualified as not detected at the listed value.

Table A-5
Summary of Detected Volatile Organic Compounds

(EPA Method 8260)

Tijeras Arroyo Groundwater Investigation

4th Quarter 2004

Well ID	Analyte	Result (μg/L)	MDL (μg/L)	PQL (μg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
Eubank-1 19-Aug-04	Methylene chloride	4.5	2.6	5	B, J	5.0UJ, A, B, B1	065416-001
PGS-2 28-Jul-04	Acetone	3.7	1.3	20	B, J	20UJ, B	065360-001
TA1-W-01 17-Aug-04	Methylene chloride	4.8	2.6	5	B, J	5.0UJ, A, B, B1	065362-001
TA1-W-02 13-Aug-04	Acetone	4.9	1.3	20	J	20UJ, B1	065364-001
	Chloromethane	0.49	0.23	10	J	10U, B1	065364-001
	Methylene chloride	4.8	2.6	5	J	5.0U, B1	065364-001
TA1-W-03 18-Aug-04	Chloroform	0.47	0.12	5	J		065366-001
	Methylene chloride	4.5	2.6	5	B, J	5.0UJ, A, B, B1	065366-001
TA1-W-04 26-Jul-04	Acetone	3.9	1.3	20	B, J	20UJ, B, B1	065368-001
	Chloromethane	0.48	0.23	10	J	J, P1	065368-001
	Methylene chloride	2.7	2.6	5	B, J	5.0UJ, B	065368-001
TA1-W-06 06-Aug-04	1,1-Dichloroethene	0.92	0.68	5	J		065372-001
	Bromomethane	4.1	0.89	10	B, J	10UJ, B	065372-001
	Chloroform	0.35	0.12	5	J		065372-001
	Methylene chloride	4.2	2.6	5	B, J	5.0UJ, B	065372-001
	Trichloroethene	0.32	0.06	5	J		065372-001
TA1-W-08 13-Aug-04	Methylene chloride	8.3	2.6	5	B	8.3UJ, B, B1	065374-001
TA2-NW1-595 (QED) 26-Jul-04	Acetone	4.1	1.3	20	J	J	065377-001
	Methylene chloride	3.8	2.6	5	J	5.0UJ, B1	065377-001
TA2-SW1-320 27-Jul-04	Acetone	4.3	1.3	20	B, J	20UJ, B	065381-001
TA2-W-01 12-Aug-04	Trichloroethene	1.3	0.06	5	J		065383-001
TA2-W-19 27-Jul-04	1,1-Dichloroethane	0.73	0.21	5	J	P1, UJ	065385-001
	Chloromethane	0.49	0.23	10	J	10UJ, B1, P1	065385-001
	Trichloroethene	4.2	0.06	5	J		065385-001
TA2-W-26 30-Jul-04	1,2-Dichloroethene	0.61	0.18	10	J	P2	065387-001
	Acetone	4.1	0.21	20	J	20UJ, B1, P2	065387-001
	Bromomethane	1.2	0.1	10	J	J, P2	065387-001
	Methylene chloride	1.8	0.17	5	J	5.0UJ, B1, P2	065387-001
	Tetrachloroethene	2.0	0.08	5	J	P2	065387-001
	Trichloroethene	1.4	0.09	5	J	P2	065387-001
	cis-1,2-Dichloroethene	0.61	0.1	5	J	P2	065387-001
TA2-W-26	1,2-Dichloroethene	0.6	0.18	10	J	P2	065388-001

Well ID	Analyte	Result (µg/L)	MDL (µg/L)	PQL (µg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
30-Jul-04 (Duplicate)	Bromomethane	1.2	0.1	10	J	J, P2	065388-001
	Methylene chloride	2.1	0.17	5	J	5.0UJ, B1, P2	065388-001
	Tetrachloroethene	2.0	0.08	5	J	P2	065388-001
	Trichloroethene	1.3	0.09	5	J	P2	065388-001
	cis-1,2-Dichloroethene	0.6	0.1	5	J	P2	065388-001
TAG-W-27 28-Jul-04	Acetone	3.8	1.3	20	B, J	20UJ, B	065392-001
	Chloroform	0.24	0.12	5	J	5.0U, B1	065392-001
	Methylene chloride	2.8	2.6	5	B, J	5.0UJ, B	065392-001
	Tetrachloroethene	0.65	0.2	5	J	P1, UJ	065392-001
	Trichloroethene	0.51	0.06	5	J		065392-001
TJA-2 16-Aug-04	1,1-Dichloroethane	0.53	0.21	5	J	A, J	065394-001
	1,2-Dichloroethene	0.63	0.61	10	J		065394-001
	Methylene chloride	3.6	2.6	5	B, J	5.0UJ, A, B, B1	065394-001
	Trichloroethene	3.1	0.06	5	J		065394-001
	cis-1,2-Dichloroethene	0.63	0.2	5	J		065394-001
TJA-3 09-Aug-04	Methylene chloride	8.9	2.6	5		8.9UJ, A, B1	065397-001
TJA-6 04-Aug-04	Bromomethane	1.7	0.1	10	B, J	10UJ, B	065401-001
	Methylene chloride	2.6	0.17	5	B, J	5.0UJ, B, B1	065401-001
TJA-7 6-Aug-04 (Duplicate)	Acetone	2.7	1.3	20	B, J, H	20UJ, B, HT	065403-R01
	Acetone	4.7	1.3	20	J	20UJ, B1	065403-001
	Bromomethane	4.1	0.89	10	B, J	10UJ, B	065403-001
	Methylene chloride	3.5	2.6	5	B, J	5.0UJ, B	065403-001
	Trichloroethene	0.53	0.06	5	J		065403-001
TJA-7 06-Aug-04	Methylene chloride	3.7	2.6	5	B, J	5.0UJ, B	065404-001
	Trichloroethene	0.55	0.06	5	J		065404-001
WYO-4 03-Aug-04	1,2-Dichloroethene	1.7	0.18	10	J		065411-001
	Bromomethane	1.6	0.1	10	B, J	10UJ, B, B1	065411-001
	Methylene chloride	2.6	0.17	5	B, J	5.0UJ, B, B1, B2	065411-001
	Trichloroethene	6.7	0.09	5			065411-001
	cis-1,2-Dichloroethene	1.7	0.1	5	J		065411-001
WYO-4 03-Aug-04 (Duplicate)	1,2-Dichloroethene	1.5	0.18	10	J		065412-001
	Methylene chloride	2.7	0.17	5	B, J	5.0UJ, B, B1, B2	065412-001
	Trichloroethene	6.0	0.09	5			065412-001
	cis-1,2-Dichloroethene	1.5	0.1	5	J		065412-001

µg/L = micrograms per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
A = Laboratory accuracy and/or bias measurements do not meet acceptance criteria.
B = Analyte is detected in associated laboratory method blank.
B1 = Analyte present in associated trip blank sample.
B2 = Analyte present in associated equipment blank sample.
H = The holding time was exceeded for the associated sample analysis.
P1 = Laboratory precision measurement for the associated matrix spike and/or duplicate samples do not meet acceptance criteria.
P2 = Insufficient quality control data to determine laboratory precision.
UJ = Associated value is an estimate and may be inaccurate or imprecise.
#U = Analyte was qualified as not detected at the listed value.

Table A-6
Summary of Detected Volatile Organic Compounds

(EPA Method 8260)

Tijeras Arroyo Groundwater Investigation

1st Quarter 2005

Well ID	Analyte	Result (μg/L)	MDL (μg/L)	PQL (μg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
Eubank-1 20-Oct-04	Acetone	6.5	4.5	5.0		6.50 UJ	066077-001
TA1-W-03 19-Oct-04	Chloroform	0.372	0.36	1.0	J		066031-001
TA2-W-01 18-Oct-04	Trichloroethene	1.38	0.36	1.0			066048-001
TA2-W-19 04-Oct-04	Trichloroethene	4.56	0.36	1.0		J	066050-001
	cis-1,2-Dichloroethene	0.866	0.30	1.0	J		066050-001
TA2-W-19 (Duplicate) 04-Oct-04	1,1-Dichloroethane	0.722	0.41	1.0	J		066051-001
	Trichloroethene	4.65	0.36	1.0		J	066051-001
	cis-1,2-Dichloroethene	0.873	0.30	1.0	J		066051-001
TA2-W-27 14-Oct-04	Tetrachloroethene	0.631	0.33	1.0	J		066056-001
	Trichloroethene	0.412	0.36	1.0	J		066056-001
TJA-2 11-Oct-04	Trichloroethene	3.1	0.36	1.0		J	066059-001
	cis-1,2-Dichloroethene	0.504			J		066059-001
TJA-6 13-Oct-04	Bromodichloromethane	0.445	0.38	1.0	J		066065-001
	Bromoform	0.83	0.50	1.0	J		066065-001
	Dibromochloromethane	0.832	0.29	1.0	J		066065-001
WYO-4 06-Oct-04	Trichloroethene	7.35	0.36	1.0			066073-001
	cis-1,2-Dichloroethene	1.61	0.30	1.0			066073-001
WYO-4 (Duplicate) 06-Oct-04	Trichloroethene	7.43	0.36	1.0			066074-001
	cis-1,2-Dichloroethene	1.69	0.30	1.0			066074-001

μg/L = micrograms per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
UJ = Associated value is an estimate and may be inaccurate or imprecise.

Table A-7
Summary of Nitrate and Nitrate plus Nitrite Results

Tijeras Arroyo Groundwater Investigation

Fiscal Year 2003, 4th Quarter

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
EUBANK-1 18-Aug-03	Nitrate	2.07	0.0341	0.1			062724-045	SW846 9056
	Nitrate	3.5	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	2.55	0.03	0.15			062724-016	EPA 353.1
PGS-2 22-Jul-03	Nitrate	0.828	0.0341	0.1	H	HT, J	062678-045	SW846 9056
	Nitrate	ND	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	0.89	0.01	0.05	B		062678-016	EPA 353.1
TA1-W-01 22-Jul-03	Nitrate	2.23	0.0341	0.1	H	HT, J	062680-045	SW846 9056
	Nitrate	3.1	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	2.46	0.02	0.1	B		062680-016	EPA 353.1
TA1-W-02 23-Jul-03	Nitrate	0.993	0.0341	0.1	H	HT, J	062682-045	SW846 9056
	Nitrate	0.2	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	1	0.01	0.05			062682-016	EPA 353.1
TA1-W-03 24-Jul-03	Nitrate	6.83	0.0341	0.1			062684-045	SW846 9056
	Nitrate	0.6	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	7.3	0.05	0.25			062684-016	EPA 353.1
TA1-W-04 29-Jul-03	Nitrate	1.7	0.0341	0.1			062686-045	SW846 9056
	Nitrate	2.5	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	1.68	0.01	0.05			062686-016	EPA 353.1
TA1-W-05 28-Jul-03	Nitrate	0.997	0.0341	0.1			062688-045	SW846 9056
	Nitrate	ND	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	1.06	0.01	0.05		B2, J	062688-016	EPA 353.1
TA1-W-06 29-Jul-03	Nitrate	3.05	0.0341	0.1			062690-045	SW846 9056
	Nitrate	2.9	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	2.59	0.01	0.05			062690-016	EPA 353.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TA1-W-08 30-Jul-03	Nitrate	6.92	0.0341	0.1			062692-045	SW846 9056
	Nitrate	5.5	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	7.35	0.05	0.25			062692-016	EPA 353.1
TA1-W-08 (Duplicate) 30-Jul-03	Nitrate plus nitrite as N	7.3	0.05	0.25			062693-016	EPA 353.1
TA2-NW1-595 30-Jul-03	Nitrate	3.09	0.0341	0.1			062695-A45	SW846 9056
	Nitrate	3.9	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	2.7	0.01	0.05			062695-A16	EPA 353.1
TA2-NW1-595 05-Aug-03	Nitrate	3.02	0.0341	0.1			062695-045	SW846 9056
	Nitrate	3.4	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	2.76	0.01	0.05			062695-016	EPA 353.1
TA2-SW1-320 24-Jul-03	Nitrate	22.9	0.171	0.5	H	HT, J	062698-045	SW846 9056
	Nitrate	17.2	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	25	0.25	1.25			062698-016	EPA 353.1
TA2-W-01 07-Aug-03	Nitrate	5.14	0.0341	0.1			062700-045	SW846 9056
	Nitrate	4.3	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	5.58	0.03	0.15			062700-016	EPA 353.1
TA2-W-19 04-Aug-03	Nitrate	9.58	0.0341	0.1	H		062702-045	SW846 9056
	Nitrate	7.4	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	10.4	0.1	0.5			062702-016	EPA 353.1
TA2-W-26 04-Aug-03	Nitrate	4.67	0.0341	0.1			062704-045	SW846 9056
	Nitrate	5.2	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	5.22	0.03	0.15			062704-016	EPA 353.1
TA2-W-26 (Duplicate) 04-Aug-03	Nitrate plus nitrite as N	5.1	0.03	0.15			062705-016	EPA 353.1
TA2-W-27 06-Aug-03	Nitrate	4.14	0.0341	0.1			062707-045	SW846 9056
	Nitrate	3.2	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	4.53	0.03	0.15			062707-016	EPA 353.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TJA-2 31-Jul-03	Nitrate	9.34	0.0341	0.1			062709-045	SW846 9056
	Nitrate	9.8	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	10.1	0.1	0.5			062709-016	EPA 353.1
TJA-3 06-Aug-03	Nitrate	2.52	0.0341	0.1			062711-045	SW846 9056
	Nitrate	3.7	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	2.55	0.01	0.05		B2, J	062711-016	EPA 353.1
TJA-4 11-Aug-03	Nitrate	23.2	0.171	0.5			062713-045	SW846 9056
	Nitrate	20.5	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	25	0.25	1.25			062713-016	EPA 353.1
TJA-6 11-Aug-03	Nitrate	2.17	0.0341	0.1			062715-045	SW846 9056
	Nitrate	0.4	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	2.49	0.03	0.15			062715-016	EPA 353.1
TJA-7 12-Aug-03	Nitrate	22.9	0.0341	0.1	H	HT, J	062717-045	SW846 9056
	Nitrate	21.7	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	26	0.5	2.5			062717-016	EPA 353.1
WYO-3 13-Aug-03	Nitrate	1.71	0.0341	0.1	H	HT, J	062719-045	SW846 9056
	Nitrate	2.0	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	1.92	0.01	0.05			062719-016	EPA 353.1
WYO-4 14-Aug-03	Nitrate	2.54	0.0341	0.1			062721-045	SW846 9056
	Nitrate	1.7	0.5	NA		None	Field	HACH 8039
	Nitrate plus nitrite as N	2.72	0.01	0.05			062721-016	EPA 353.1
WYO-4 (Duplicate) 14-Aug-03	Nitrate plus nitrite as N	2.7	0.01	0.05			062722-016	EPA 353.1

mg/L = milligrams per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
B = Analyte is detected in associated laboratory method blank.
B2 = Analyte is detected in associated equipment blank sample.
HT/H = The holding time was exceeded for the associated sample analysis.

Table A-8
Summary of Nitrate and Nitrate plus Nitrite Results

Tijeras Arroyo Groundwater Investigation

Fiscal Year 2004, 1st Quarter

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
Eubank-1 10-Nov-03	Nitrate	1.99	0.0341	0.1	H	HT, J	063303-045	SW846 9056
	Nitrate	2.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.50	0.05	0.25			063303-016	EPA 353.1
Eubank-1 (Sample Split) 10-Oct-03	Nitrate	2.40	0.1	0.1			063302-A45	EPA 300.0
Eubank-2 12-Nov-03	Nitrate	1.23	0.0341	0.1			063304-045	SW846 9056
	Nitrate	1.0	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	0.950	0.01	0.050			063304-016	EPA 353.1
Eubank-3 18-Nov-03	Nitrate	3.03	0.0341	0.1	H	HT, J	063305-045	SW846 9056
	Nitrate	4.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.40	0.05	0.25			063305-016	EPA 353.1
Eubank-5 19-Nov-03	Nitrate	3.02	0.0341	0.1	H	HT, J	063306-045	SW846 9056
	Nitrate	3.6	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.70	0.05	0.25			063306-016	EPA 353.1
PGS-2 10-Nov-03	Nitrate	0.628	0.0341	0.1	H	HT, J	063278-045	SW846 9056
	Nitrate	0.2	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	0.710	0.01	0.05			063278-016	EPA 353.1
TA1-W-01 06-Nov-03	Nitrate	2.27	0.0341	0.1			063279-045	SW846 9056
	Nitrate	2.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.50	0.05	0.25			063279-016	EPA 353.1
TA1-W-02 08-Oct-03	Nitrate	0.921	0.0341	0.1	H	HT, J	063280-045	SW846 9056
	Nitrate	1.5	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.00	0.05	0.25			063280-016	EPA 353.1
TA1-W-03 13-Oct-03	Nitrate	6.79	0.0341	0.1			063281-045	SW846 9056
	Nitrate	5.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	6.40	0.05	0.25			063281-016	EPA 353.1
TA1-W-04 14-Oct-03	Nitrate	1.54	0.0341	0.1			063282-045	SW846 9056
	Nitrate	2.5	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.39	0.01	0.05			063282-016	EPA 353.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TA1-W-05 20-Oct-03	Nitrate	0.967	0.0341	0.1			063283-045	SW846 9056
	Nitrate	0.9	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.05	0.05	0.25			063283-016	EPA 353.1
TA1-W-06 09-Oct-03	Nitrate	2.96	0.0341	0.1			063284-045	SW846 9056
	Nitrate	3.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.30	0.05	0.25			063284-016	EPA 353.1
TA1-W-08 21-Oct-03	Nitrate	7.00	0.0341	0.1			063285-045	SW846 9056
	Nitrate	5.6	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	6.25	0.05	0.25			063285-016	EPA 353.1
TA1-W-08 (Duplicate) 21-Oct-03	Nitrate plus nitrite as N	6.25	0.05	0.25			063286-016	EPA 353.1
TA2-NW1-595 12-Nov-03	Nitrate	3.34	0.0341	0.1			063287-045	SW846 9056
	Nitrate	3.0	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.40	0.05	0.25			063287-016	EPA 353.1
TA2-NW1-595 11-Nov-03	Nitrate	2.96	0.0341	0.1			063288-045	SW846 9056
	Nitrate	3.6	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.20	0.05	0.25			063288-016	EPA 353.1
TA2-SW1-320 11-Nov-03	Nitrate	22.4	0.171	0.5	H	HT, J	063289-045	SW846 9056
	Nitrate	19.8	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	24.0	0.5	2.5			063289-016	EPA 353.1
TA2-W-01 01-Dec-03	Nitrate	5.16	0.0341	0.1			063290-045	SW846 9056
	Nitrate	6.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	5.70	0.05	0.25			063290-016	EPA 353.1
TA2-W-19 07-Oct-03	Nitrate	9.35	0.0682	0.2	H	HT, J	063291-045	SW846 9056
	Nitrate	10.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	9.50	0.1	0.5			063291-016	EPA 353.1
TA2-W-26 16-Oct-03	Nitrate	4.84	0.0341	0.1			063292-045	SW846 9056
	Nitrate	3.5	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	5.00	0.05	0.25			063292-016	EPA 353.1
TA2-W-26 (Duplicate) 16-Oct-03	Nitrate plus nitrite as N	4.75	0.05	0.25			063293-016	EPA 353.1
TA2-W-27 23-Oct-03	Nitrate	4.19	0.0341	0.1			063294-045	SW846 9056
	Nitrate	4.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	4.50	0.05	0.25			063294-016	EPA 353.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TJA-2 15-Oct-03	Nitrate	9.32	0.0341	0.1			063295-045	SW846 9056
	Nitrate	9.6	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	9.70	0.1	0.5			063295-016	EPA 353.1
TJA-3 22-Oct-03	Nitrate	2.51	0.0341	0.1			063296-045	SW846 9056
	Nitrate	3.8	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.75	0.05	0.25			063296-016	EPA 353.1
TJA-4 27-Oct-03	Nitrate	22.8	0.341	1.0	H		063297-045	SW846 9056
	Nitrate	17.7	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	25.8	0.25	1.25			063297-016	EPA 353.1
TJA-6 05-Nov-03	Nitrate	2.26	0.0341	0.1			063298-045	SW846 9056
	Nitrate	2.6	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.50	0.05	0.25		B2, J	063298-016	EPA 353.1
TJA-7 28-Oct-03	Nitrate	24.5	0.341	1.00	H	HT, J	063299-045	SW846 9056
	Nitrate	20.4	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	25.0	0.250	1.25			063299-016	EPA 353.1
TJA-7 (Sample Split) 28-Oct-03	Nitrate	26.0	0.5	0.5		P2	063299-A45	EPA 300.0
WYO-3 29-Oct-03	Nitrate	1.80	0.0341	0.1			063300-045	SW846 9056
	Nitrate	2.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.61	0.01	0.05			063300-016	EPA 353.1
WYO-3 (Sample Split) 29-Oct-03	Nitrate	2.0	0.1	0.1		P2	063300-A45	EPA 300.0
WYO-4 03-Nov-03	Nitrate	2.86	0.0341	0.1			063301-045	SW846 9056
	Nitrate	2.2	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.20	0.01	0.05			063301-016	EPA 353.1
WYO-4 (Duplicate) 03-Nov-03	Nitrate plus nitrite as N	2.21	0.01	0.05			063302-016	EPA 353.1
WYO-4 (Sample Split) 03-Nov-03	Nitrate	3.0	0.1	0.1			063301-A45	EPA 300.0

mg/L = milligrams per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
B = Analyte is detected in associated laboratory method blank.
B2 = Analyte is detected in associated equipment blank sample.
P2 = Insufficient quality control data to determine laboratory precision.
HT/H = The holding time was exceeded for the associated sample analysis.

Table A-9
Summary of Nitrate and Nitrate plus Nitrite Results

Tijeras Arroyo Groundwater Investigation

Fiscal Year 2004, 2nd Quarter

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
Eubank-1	Nitrate	2.3	0.054	0.1			063904-016	EPA 300.0
16-Feb-04	Nitrate	4.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.20	0.05	0.25			063904-015	EPA 353.1
Eubank-2	Nitrate	1.3	0.054	0.1			063906-016	EPA 300.0
18-Feb-04	Nitrate	1.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.03	0.01	0.05			063906-015	EPA 353.1
Eubank-3	Nitrate	3.2	0.054	0.1			063909-016	EPA 300.0
17-Feb-04	Nitrate	2.7	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.34	0.01	0.05			063909-015	EPA 353.1
Eubank-5	Nitrate	3.3	0.054	0.1			063911-016	EPA 300.0
19-Feb-04	Nitrate	3.6	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.40	0.05	0.25			063911-015	EPA 353.1
PGS-2	Nitrate	0.85	0.054	0.1			063851-016	EPA 300.0
03-Feb-04	Nitrate	1.7	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	0.80	0.01	0.05		A2, J	063851-015	EPA 353.1
	Nitrate plus nitrite as N (lab re-analysis)	0.73	0.01	0.05			063851-R15	EPA 353.1
TA1-W-01	Nitrate	2.5	0.054	0.1			063853-016	EPA 300.0
05-Feb-04	Nitrate	2.0	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.85	0.01	0.05		A2, J	063853-015	EPA 353.1
	Nitrate plus nitrite as N (lab re-analysis)	2.40	0.05	0.25			063853-R15	EPA 353.1
TA1-W-02	Nitrate	1.0	0.054	0.1			063855-016	EPA 300.0
28-Jan-04	Nitrate	1.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.00	0.05	0.25			063855-015	EPA 353.1
TA1-W-03	Nitrate	6.8	0.054	0.1			063857-016	EPA 300.0
07-Jan-04	Nitrate	5.6	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.09	0.01	0.05		A2, J	063857-015	EPA 353.1
TA1-W-04	Nitrate	1.6	0.054	0.1			063860-016	EPA 300.0
06-Jan-04	Nitrate	2.7	0.5	NA	None	None	Field	HACH 8039

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Nitrate plus nitrite as N	1.30	0.01	0.05		A2, J	063860-015	EPA 353.1
TA1-W-05	Nitrate	1.0	0.054	0.1			063862-016	EPA 300.0
12-Feb-04	Nitrate	0.4	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.0	0.05	0.25			063862-015	EPA 353.1
TA1-W-06	Nitrate	3.2	0.054	0.1			063864-016	EPA 300.0
09-Feb-04	Nitrate	2.29	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.96	0.01	0.05		A2, J	063864-015	EPA 353.1
	Nitrate plus nitrite as N (lab re-analysis)	3.25	0.05	0.25			063864-R15	EPA 353.1
TA1-W-08	Nitrate	7.1	0.054	0.1			063866-016	EPA 300.0
10-Feb-04	Nitrate	5.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	7.00	0.05	0.25			063866-015	EPA 353.1
TA1-W-08 (Duplicate)	Nitrate	7.0	0.054	0.1			063867-016	EPA 300.0
10-Feb-04	Nitrate plus nitrite as N	7.10	0.05	0.25			063867-015	EPA 353.1
TA2-NW1-595	Nitrate	3.3	0.054	0.1			063869-016	EPA 300.0
26-Jan-04	Nitrate	3.4	0.5	NA	None	None	Field	HACH 8039
(Bennett)	Nitrate plus nitrite as N	1.85	0.05	0.25			063869-015	EPA 353.1
TA2-NW1-595	Nitrate	3.3	0.054	0.1			063871-016	EPA 300.0
04-Feb-04	Nitrate	2.9	0.5	NA	None	None	Field	HACH 8039
(QED)	Nitrate plus nitrite as N	3.25	0.05	0.25			063871-015	EPA 353.1
TA2-SW1-320	Nitrate	23.0	0.27	0.50			063873-016	EPA 300.0
29-Jan-04	Nitrate	17.5	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	25.0	0.5	2.5			063873-015	EPA 353.1
TA2-W-01	Nitrate	5.1	0.054	0.1			063876-016	EPA 300.0
12-Jan-04	Nitrate	4.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	4.50	0.05	0.25		A2, J	063876-015	EPA 353.1
TA2-W-19	Nitrate	9.2	0.054	0.1			063878-016	EPA 300.0
13-Jan-04	Nitrate	7.8	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	10	0.1	0.5		A2, J	063878-015	EPA 353.1
TA2-W-26	Nitrate	4.8	0.054	0.1			063880-016	EPA 300.0
20-Jan-04	Nitrate	4.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	5.15	0.05	0.25			063880-015	EPA 353.1
TA2-W-26 (Duplicate)	Nitrate	4.9	0.054	0.1			063881-016	EPA 300.0
20-Jan-04	Nitrate plus nitrite as N	5.30	0.05	0.25			063881-015	EPA 353.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TA2-W-27	Nitrate	4.4	0.054	0.1			063885-016	EPA 300.0
15-Jan-04	Nitrate	3.8	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.16	0.01	0.05		A2, B2, J	063885-015	EPA 353.1
TJA-2	Nitrate	9.3	0.054	0.1		A2, J	063887-016	EPA 300.0
19-Jan-04	Nitrate	6.0	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	10	0.05	0.25			063887-015	EPA 353.1
TJA-3	Nitrate	2.9	0.054	0.1			063889-016	EPA 300.0
22-Oct-03	Nitrate	2.6	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.89	0.01	0.25			063889-015	EPA 353.1
TJA-4	Nitrate	26.0	0.27	0.50			063891-016	EPA 300.0
29-Jan-04	Nitrate	17.4	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	27.0	0.25	1.25			063891-015	EPA 353.1
TJA-6	Nitrate	2.5	0.054	0.1			063893-016	EPA 300.0
04-Feb-04	Nitrate	2.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.35	0.05	0.25			063893-015	EPA 353.1
TJA-7	Nitrate	27.0	0.27	0.50			063895-016	EPA 300.0
22-Jan-04	Nitrate	15	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	29.8	0.250	1.25			063895-015	EPA 353.1
WYO-3	Nitrate	2.0	0.054	0.1			063897-016	EPA 300.0
21-Jan-04	Nitrate	1.9	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.38	0.01	0.05		B2, J	063897-015	EPA 353.1
WYO-4	Nitrate	2.9	0.054	0.1			063899-016	EPA 300.0
03-Feb-04	Nitrate	3.6	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.06	0.01	0.05		A2, J	063899-015	EPA 353.1
	Nitrate plus nitrite as N (lab re-analysis)	2.11	0.01	0.05			063899-R15	EPA 353.1
WYO-4 (Duplicate)	Nitrate	2.9	0.054	0.1			063900-016	EPA 300.0
03-Feb-04	Nitrate plus nitrite as N	2.09	0.01	0.05		A2, J	063900-015	EPA 353.1
	Nitrate plus nitrite as N (lab re-analysis)	2.12	0.01	0.05			063900-R15	EPA 353.1

mg/L = milligrams per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
A2= Laboratory accuracy and/or bias measurements for the associated matrix spike and/or duplicate do not meet acceptance criteria.
B2 = Analyte is detected in associated equipment blank sample.

Table A-10
Summary of Nitrate and Nitrate plus Nitrite Results

Tijeras Arroyo Groundwater Investigation

Fiscal Year 2004, 3rd Quarter

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
Eubank-1	Nitrate	2.3	0.054	0.10			064600-016	EPA 300.0
20-May-04	Nitrate	3.2	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.34	0.0144	0.20			064600-015	EPA 353.1
Eubank-2	Nitrate	1.2	0.054	0.10			064602-016	EPA 300.0
06-May-04	Nitrate	1.7	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.29	0.0144	0.20			064602-015	EPA 353.1
Eubank-3	Nitrate	3.1	0.054	0.10			064604-016	EPA 300.0
04-May-04	Nitrate	3.8	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.18	0.0359	0.05			064604-015	EPA 353.1
Eubank-5	Nitrate	3.3	0.054	0.10			064607-016	EPA 300.0
03-May-04	Nitrate	3.0	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.51	0.0359	0.05			064607-015	EPA 353.1
PGS-2	Nitrate	0.90	0.054	0.10			064551-016	EPA 300.0
12-May-04	Nitrate	1.7	0.50	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	0.837	0.0144	0.20			064551-015	EPA 353.1
TA1-W-01	Nitrate	2.4	0.054	0.10			064553-016	EPA 300.0
10-May-04	Nitrate	2.7	0.50	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.34	0.0144	0.20			064553-015	EPA 353.1
TA1-W-02	Nitrate	1.0	0.054	0.10			064556-016	EPA 300.0
11-May-04	Nitrate	0.8	0.50	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.04	0.0144	0.20			064556-015	EPA 353.1
TA1-W-03	Nitrate	6.5	0.054	0.10			064558-016	EPA 300.0
28-Apr-04	Nitrate	5.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	7.4	0.0359	0.50			064558-015	EPA 353.1
TA1-W-04	Nitrate	1.6	0.054	0.10			064560-016	EPA 300.0
26-Apr-04	Nitrate	2.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.61	0.0359	0.05	N		064560-015	EPA 353.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TA1-W-05	Nitrate	1.1	0.054	0.10			064562-016	EPA 300.0
07-May-04	Nitrate	3.0	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	0.923	0.0144	0.20			064562-015	EPA 353.1
TA1-W-06	Nitrate	3.2	0.054	0.10			064564-016	EPA 300.0
21-May-04	Nitrate	3.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.14	0.0144	0.20			064564-015	EPA 353.1
TA1-W-08	Nitrate	6.9	0.054	0.10			064566-016	EPA 300.0
23-Apr-04	Nitrate	6.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	6.59	0.0359	0.50			064566-015	EPA 353.1
TA2-NW1-595	Nitrate	3.3	0.054	0.10			064568-016	EPA 300.0
13-May-04	Nitrate	3.3	0.5	NA	None	None	Field	HACH 8039
(QED)	Nitrate plus nitrite as N	3.12	0.0144	0.20			064568-015	EPA 353.1
TA2-NW1-595	Nitrate	3.3	0.054	0.10			064571-016	EPA 300.0
19-May-04	Nitrate	4.0	0.5	NA	None	None	Field	HACH 8039
(Bennett)	Nitrate plus nitrite as N	3.24	0.0144	0.20			064571-015	EPA 353.1
TA2-SW1-320	Nitrate	22	0.27	0.50			064573-016	EPA 300.0
14-May-04	Nitrate	16.5	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	24.2	0.144	2	H	HT, J	064573-015	EPA 353.1
TA2-W-01	Nitrate	4.9	0.054	0.10			064575-016	EPA 300.0
17-May-04	Nitrate	2.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.46	0.0359	0.50			064575-015	EPA 353.1
TA2-W-19	Nitrate	9.3	0.054	0.10			064577-016	EPA 300.0
27-Apr-04	Nitrate	7.6	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	9.23	0.0359	0.50			064577-015	EPA 353.1
TA2-W-19 (Duplicate)	Nitrate	9.3	0.054	0.10			064578-016	EPA 300.0
27-Apr-04	Nitrate plus nitrite as N	9.39	0.0359	0.50			064578-015	EPA 353.1
TA2-W-26	Nitrate	4.8	0.054	0.10			064580-016	EPA 300.0
21-Apr-04	Nitrate	3.8	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	4.70	0.0359	0.50		J, B2	064580-015	EPA 353.1
TA2-W-26 (Duplicate)	Nitrate	4.7	0.054	0.10			064581-016	EPA 300.0
21-Apr-04	Nitrate plus	4.80	0.0359	0.50		J, B2	064581-015	EPA 353.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	nitrite as N							
TA2-W-27	Nitrate	5.0	0.054	0.10			064583-016	EPA 300.0
19-Apr-04	Nitrate	4.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	4.17	0.0359	0.50			064583-015	EPA 353.1
TJA-2	Nitrate	9.1	0.054	0.10			064585-016	EPA 300.0
05-May-04	Nitrate	8.0	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	8.65	0.144	0.05			064585-015	EPA 353.1
TJA-3	Nitrate	2.5	0.054	0.10			064587-016	EPA 300.0
27-Apr-04	Nitrate	4.0	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.8	0.0359	0.50			064587-015	EPA 353.1
TJA-4	Nitrate	24	0.27	0.50			064589-016	EPA 300.0
20-Apr-04	Nitrate	17.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	26.4	0.144	2			064589-015	EPA 353.1
TJA-6	Nitrate	2.4	0.054	0.10			064591-016	EPA 300.0
22-Apr-04	Nitrate	2.5	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.42	0.0359	0.05		J, B2	064591-015	EPA 353.1
TJA-7	Nitrate	24	0.27	0.50			064593-016	EPA 300.0
30-Apr-04	Nitrate	16.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	17.9	0.287	4			064593-015	EPA 353.1
WYO-3	Nitrate	1.9	0.054	0.10			064595-016	EPA 300.0
28-Apr-04	Nitrate	2.8	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.12	0.0359	0.50			064595-015	EPA 353.1
WYO-4	Nitrate	2.7	0.054	0.10			064597-016	EPA 300.0
30-Apr-04	Nitrate	2.7	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.81	0.0359	0.50			064597-015	EPA 353.1
WYO-4 (Duplicate)	Nitrate	2.7	0.054	0.10			064598-016	EPA 300.0
30-Apr-04	Nitrate plus nitrite as N	2.86	0.0359	0.05			064598-015	EPA 353.1

mg/L = milligrams per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
B2 = Analyte is detected in associated equipment blank sample.
HT/H = The holding time was exceeded for the associated sample analysis.

Table A-11
Summary of Nitrate and Nitrate plus Nitrite Results

Tijeras Arroyo Groundwater Investigation

Fiscal Year 2004, 4th Quarter

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
Eubank-1	Nitrate	2.3	2.8	0.054			065416-016	EPA 300.0
19-Aug-04	Nitrate	1.7	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.17	0.0144	0.20			065416-015	EPA 353.1
PGS-2	Nitrate	0.82	0.054	0.10			065360-016	EPA 300.0
28-Jul-04	Nitrate	1.6	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	0.62	0.0036	0.05			065360-015	EPA 353.1
TA1-W-01	Nitrate	2.6	0.054	0.10			065362-016	EPA 300.0
17-Aug-04	Nitrate	2.5	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.32	0.0144	0.20			065362-015	EPA 353.1
TA1-W-02	Nitrate	1.0	0.054	0.10		A2, J	065364-016	EPA 300.0
13-Aug-04	Nitrate	1.7	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	0.921	0.0144	0.20			065364-015	EPA 353.1
TA1-W-03	Nitrate	6.8	0.054	0.10			065366-016	EPA 300.0
18-Aug-04	Nitrate	5.4	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	6.53	0.0144	0.20			065366-015	EPA 353.1
TA1-W-04	Nitrate	1.6	0.054	0.10			065368-016	EPA 300.0
26-Jul-04	Nitrate	1.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.53	0.0036	0.05			065368-015	EPA 353.1
TA1-W-05	Nitrate	1.1	0.054	0.10			065370-016	EPA 300.0
20-Aug-04	Nitrate	2.7	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	0.596	0.0036	0.05			065370-015	EPA 353.1
TA1-W-06	Nitrate	3.2	0.054	0.10			065372-016	EPA 300.0
06-Aug-04	Nitrate	4.5	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.72	0.0144	0.20			065372-015	EPA 353.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TA1-W-08	Nitrate	6.8	0.054	0.10		A2, J	065374-016	EPA 300.0
13-Aug-04	Nitrate	3.7	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	7.31	0.144	2.0			065374-015	EPA 353.1
TA2-NW1-595	Nitrate	3.3	0.054	0.10			065377-016	EPA 300.0
26-Jul-04	Nitrate	4.7	0.5	NA	None	None	Field	HACH 8039
(QED)	Nitrate plus nitrite as N	3.21	0.0036	0.05			065377-015	EPA 353.1
TA2-NW1-595	Nitrate	3.3	0.054	0.10			065379-016	EPA 300.0
23-Aug-04	Nitrate	2.7	0.5	NA	None	None	Field	HACH 8039
(Bennett)	Nitrate plus nitrite as N	3.01	0.0144	0.20			065379-015	EPA 353.1
TA2-SW1-320	Nitrate	24.0	0.27	0.50		A2, J	065381-016	EPA 300.0
27-Jul-04	Nitrate	34.2	0.5	NA			Field	HACH 8039
	Nitrate plus nitrite as N	24.0	0.0036	0.05			065381-015	EPA 353.1
TA2-W-01	Nitrate	5.0	0.054	0.10			065383-016	EPA 300.0
12-Aug-04	Nitrate	3.8	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	4.71	0.144	2.0			065383-015	EPA 353.1
TA2-W-19	Nitrate	9.4	0.054	0.10		A2, J	065385-016	EPA 300.0
27-Jul-04	Nitrate	8.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	9.53	0.0036	0.05			065385-015	EPA 353.1
TA2-W-26	Nitrate	4.7	0.054	0.10		P2	065387-016	EPA 300.0
30-Jul-04	Nitrate	5.0	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.55	0.144	2.0			065387-015	EPA 353.1
TA2-W-26 (Duplicate)	Nitrate	4.6	0.054	0.10		P2	065388-016	EPA 300.0
30-Jul-04	Nitrate plus nitrite as N	3.31	0.144	2.0			065388-015	EPA 353.1
TA2-W-27	Nitrate	4.3	0.054	0.10			065392-016	EPA 300.0
28-Jul-04	Nitrate	3.8	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	4.32	0.0359	0.50			065392-015	EPA 353.1
TJA-2	Nitrate	9.3	0.054	0.10		A2, J	065394-016	EPA 300.0
16-Aug-04	Nitrate	8.5	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	9.96	0.144	2.0			065394-015	EPA 353.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TJA-3	Nitrate	2.7	0.054	0.10			065397-016	EPA 300.0
09-Aug-03	Nitrate	2.6	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.52	0.0144	0.20			065397-015	EPA 353.1
TJA-4	Nitrate	26.0	0.27	0.50		A2, J	065399-016	EPA 300.0
10-Aug-04	Nitrate	21.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	25.4	0.144	2.0			065399-015	EPA 353.1
TJA-6	Nitrate	2.5	0.054	0.10			065401-016	EPA 300.0
09-Aug-04	Nitrate	2.9	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.20	0.0144	0.20			065397-015	EPA 353.1
TJA-7	Nitrate	27.0	0.054	0.10	E	J	065403-016	EPA 300.0
06-Aug-04	Nitrate (re-analysis)	24.0	0.27	0.50	H	HT, J	065403-R16	EPA 300.0
	Nitrate	20.9	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	24.3	0.144	2.0			065403-015	EPA 353.1
TJA-7 (Duplicate)	Nitrate	27.0	0.054	0.10	E	J	065404-016	EPA 300.0
06-Aug-04	Nitrate (re-analysis)	25.0	0.27	0.50	H	HT, J	065404-R16	EPA 300.0
	Nitrate plus nitrite as N	24.6	0.144	2.0			065404-015	EPA 353.1
WYO-3	Nitrate	2.0	0.054	0.10			065408-016	EPA 300.0
11-Aug-04	Nitrate	2.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.89	0.0144	0.20			065408-015	EPA 353.1
WYO-4	Nitrate	2.8	0.054	0.10			065411-016	EPA 300.0
03-Aug-04	Nitrate	1.9	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.04	0.0144	0.20		B2, J	065411-015	EPA 353.1
WYO-4 (Duplicate)	Nitrate	2.8	0.054	0.10			065412-016	EPA 300.0
03-Aug-04	Nitrate plus nitrite as N	2.71	0.0144	0.20		B2, J	065412-015	EPA 353.1

mg/L = milligrams per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
B2 = Analyte is detected in associated equipment blank sample.
P2 = Insufficient quality control data to determine laboratory precision.
HT/H = The holding time was exceeded for the associated sample analysis.
E = Concentration exceeds calibration range of instrument and/or estimated quantity due to matrix interference.

Table A-12
Summary of Nitrate and Nitrate plus Nitrite Results

Tijeras Arroyo Groundwater Investigation

Fiscal Year 2005, 1st Quarter

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
Eubank-1	Nitrate	2.3	0.054	0.10			066077-016	EPA 300.0
20-Oct-04	Nitrate	1.8	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.62	0.003	0.02			066077-015	EPA 353.1
Eubank-2	Nitrate	1.3	0.054	0.10			066080-016	EPA 300.0
21-Oct-04	Nitrate	1.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	0.689	0.03	0.20			066080-015	EPA 353.1
Eubank-3	Nitrate	3.2	0.054	0.10			066082-016	EPA 300.0
20-Oct-04	Nitrate	3.5	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.49	0.003	0.02			066082-015	EPA 353.1
Eubank-5	Nitrate	3.2	0.054	0.10			066084-016	EPA 300.0
25-Oct-04	Nitrate	3.0	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.61	0.003	0.02			066084-015	EPA 353.1
PGS-2	Nitrate	1.1	0.054	0.10			066025-016	EPA 300.0
05-Oct-04	Nitrate	1.7	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.02	0.003	0.02		A2, J	066025-015	EPA 353.1
TA1-W-01	Nitrate	2.5	0.054	0.10		P2	066027-016	EPA 300.0
06-Oct-04	Nitrate	3.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.97	0.003	0.02			066027-015	EPA 353.1
TA1-W-02	Nitrate	1.1	0.054	0.10			066029-016	EPA 300.0
11-Oct-04	Nitrate	1.0	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.24	0.003	0.02			066029-015	EPA 353.1
TA1-W-03	Nitrate	7.0	0.054	0.10			066031-016	EPA 300.0
19-Oct-04	Nitrate	5.4	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	0.545	0.003	0.02			066031-015	EPA 353.1
TA1-W-04	Nitrate	1.6	0.054	0.10		P2	066033-016	EPA 300.0
07-Oct-04	Nitrate	2.7	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus	1.82	0.003	0.02			066033-015	EPA 353.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	nitrite as N							
TA1-W-05	Nitrate	1.1	0.054	0.10			066035-016	EPA 300.0
26-Oct-04	Nitrate	1.4	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	1.16	0.003	0.02			066035-015	EPA 353.1
TA1-W-06	Nitrate	3.2	0.054	0.10			066037-016	EPA 300.0
26-Oct-04	Nitrate	3.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.54	0.003	0.02			066037-015	EPA 353.1
TA1-W-08	Nitrate	7.0	0.054	0.10		P2	066039-016	EPA 300.0
08-Oct-04	Nitrate	5.3	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	0.337	0.003	0.020			066039-015	EPA 353.1
TA2-NW1-595	Nitrate	3.3	0.054	0.10			066042-016	EPA 300.0
25-Oct-04	Nitrate	2.5	0.5	NA	None	None	Field	HACH 8039
(QED)	Nitrate plus nitrite as N	2.57	0.03	0.20			066042-015	EPA 353.1
TA2-NW1-595	Nitrate	3.3	0.054	0.10		P2	066044-016	EPA 300.0
07-Oct-04	Nitrate	3.3	0.5	NA	None	None	Field	HACH 8039
(Bennett)	Nitrate plus nitrite as N	3.38	0.003	0.02		B2, J	066044-015	EPA 353.1
TA2-SW1-320	Nitrate	25	0.27	0.50			066046-016	EPA 300.0
04-Oct-04	Nitrate	17.4	0.5	NA			Field	HACH 8039
	Nitrate plus nitrite as N	25.1	0.03	0.20		A2, J	066046-015	EPA 353.1
TA2-W-01	Nitrate	4.8	0.054	0.10			066048-016	EPA 300.0
18-Oct-04	Nitrate	3.7	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	4.75	0.003	0.02			066048-015	EPA 353.1
TA2-W-19	Nitrate	10	0.054	0.10			066050-016	EPA 300.0
04-Oct-04	Nitrate	7.4	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	10.3	0.03	0.20		A2, J	066050-015	EPA 353.1
TA2-W-19 (Duplicate)	Nitrate	10	0.054	0.10			066051-016	EPA 300.0
04-Oct-04	Nitrate plus nitrite as N	9.93	0.03	0.20		A2, J	066051-015	EPA 353.1
TA2-W-26	Nitrate	4.6	0.054	0.10			066053-016	EPA 300.0
13-Oct-04	Nitrate	4.0	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.32	0.003	0.02			066053-015	EPA 353.1
TA2-W-27	Nitrate	4.2	0.054	0.10			066056-016	EPA 300.0

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
14-Oct-04	Nitrate	3.4	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.91	0.03	0.20			066056-015	EPA 353.1
TJA-2	Nitrate	9.6	0.054	0.10			066059-016	EPA 300.0
11-Oct-04	Nitrate	14.9	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	7.51	0.03	0.20			066059-015	EPA 353.1
TJA-3	Nitrate	2.6	0.054	0.10			066061-016	EPA 300.0
12-Oct-04	Nitrate	3.0	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.12	0.003	0.02			066061-015	EPA 353.1
TJA-4	Nitrate	25	0.27	0.50			066063-016	EPA 300.0
12-Oct-04	Nitrate	15.9	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	20.2	0.03	0.20			066063-015	EPA 353.1
TJA-6	Nitrate	2.5	0.054	0.10			066065-016	EPA 300.0
13-Oct-04	Nitrate	2.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.94	0.003	0.02			066065-015	EPA 353.1
TJA-7	Nitrate	25	0.27	0.50			066067-016	EPA 300.0
15-Oct-04	Nitrate	5.6	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	27.1	0.03	0.20			066067-015	EPA 353.1
TJA-7 (Duplicate)	Nitrate	25	0.27	0.50			066068-016	EPA 300.0
15-Oct-04	Nitrate plus nitrite as N	23.2	0.03	0.20			066068-015	EPA 353.1
WYO-3	Nitrate	2.0	0.054	0.10			066071-016	EPA 300.0
08-Oct-04	Nitrate	2.4	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	2.38	0.003	0.02			066071-015	EPA 353.1
WYO-4	Nitrate	2.8	0.054	0.10		P2	066073-016	EPA 300.0
06-Oct-04	Nitrate	2.1	0.5	NA	None	None	Field	HACH 8039
	Nitrate plus nitrite as N	3.30	0.003	0.02			066073-015	EPA 353.1
WYO-4 (Duplicate)	Nitrate	2.8	0.054	0.10		P2	066074-016	EPA 300.0
06-Oct-04	Nitrate plus nitrite as N	3.29	0.003	0.02			066074-015	EPA 353.1

mg/L = milligrams per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
A2 = Laboratory accuracy and/or bias measurements for the associated matrix spike and/or duplicate do not meet acceptance criteria.
B2 = Analyte is detected in associated equipment blank sample.
P2 = Insufficient quality control data to determine laboratory precision.

Table A-13
Summary of Ferrous Iron Results

Tijeras Arroyo Groundwater Investigation

July 2003 through December 2004

Well ID	Sample Date	Ferrous Iron Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
Eubank-1	18-Aug-03	ND	0.0284	0.05	U, H	None	062724-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	10-Nov-03	ND	0.0284	0.05	U, H	None	063303-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	16-Feb-04	ND	0.028	0.10		None	063904-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	20-May-04	ND	0.028	0.10	U	None	064600-012	3500 Fe2+
		0.02	0.03	NA	None	None	Field	HACH 8146
	19-Aug-04	ND	0.028	0.10		None	065416-012	3500 Fe2+
	20-Oct-04	ND	0.028	0.10		None	066077-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
Eubank-2	09-Jul-03	ND	0.0284	0.05	U, H	None	062585-040	SM 3500-Fe
	12-Nov-03	ND	0.0284	0.05	U, H	None	063304-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	18-Feb-04	ND	0.028	0.10		None	063906-012	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
	06-May-04	ND	0.028	0.10	U	None	064602-012	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
	13-Jul-04	ND	0.028	0.10	None	None	065418-012	3500 Fe2+
	21-Oct-04	ND	0.028	0.10		None	066080-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
Eubank-3	10-Jul-03	ND	0.0284	0.05	U, H	None	062586-040	SM 3500-Fe
	18-Nov-03	ND	0.0284	0.05	U, H	None	063305-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	17-Feb-04	ND	0.028	0.10		None	063909-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	04-May-04	ND	0.028	0.10	U	None	064604-012	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
	13-Jul-04	ND	0.028	0.10	None	None	065419-012	3500 Fe2+
	20-Oct-04	ND	0.028	0.10		None	066082-012	3500 Fe2+

Well ID	Sample Date	Ferrous Iron Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
		ND	0.03	NA	None	None	Field	HACH 8146
Eubank-5	09-Jul-03	ND	0.0284	0.05	U, H	None	062587-040	SM 3500-Fe
	19-Nov-03	ND	0.0284	0.05	U, H	None	063306-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	19-Feb-04	ND	0.028	0.10		None	063911-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	03-May-04	ND	0.028	0.10	U	None	064607-012	3500 Fe2+
		0.03	0.03	NA	None	None	Field	HACH 8146
	13-Jul-04	ND	0.028	0.10	None	None	065420-012	3500 Fe2+
	25-Oct-04	ND	0.028	0.10		None	066084-012	3500 Fe2+
		0.02	0.03	NA	None	None	Field	HACH 8146
PGS-2	22-Jul-03	ND	0.0284	0.05	U, H	None	062678-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	10-Nov-03	0.040	0.0284	0.05	H, J	None	063278-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	03-Feb-04	ND	0.028	0.10		None	063851-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	12-May-04	ND	0.028	0.10	U	None	064551-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	28-Jul-04	ND	0.028	0.10		None	065360-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	05-Oct-04	ND	0.028	0.10		None	066025-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
TA1-W-01	22-Jul-03	ND	0.0284	0.05	U, H	None	062680-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	06-Nov-03	ND	0.0284	0.05	U	None	063279-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	05-Feb-04	ND	0.028	0.10		None	063853-012	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
	10-May-04	ND	0.028	0.10	U	None	064553-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	17-Aug-04	ND	0.028	0.10		None	065362-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	06-Oct-04	ND	0.028	0.10		None	066027-012	3500 Fe2+
		0.04	0.03	NA	None	None	Field	HACH 8146

Well ID	Sample Date	Ferrous Iron Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TA1-W-02	23-Jul-03	ND	0.0284	0.05	U, H	None	062682-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	08-Oct-03	0.0536	0.0284	0.05	H	None	063280-040	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
	28-Jan-04	ND	0.028	0.10		None	063855-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	11-May-04	ND	0.028	0.10	U	None	064556-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	13-Aug-04	ND	0.028	0.10		None	065364-012	3500 Fe2+
		0.08	0.03	NA	None	None	Field	HACH 8146
	11-Oct-04	ND	0.028	0.10		None	066029-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
TA1-W-03	24-Jul-03	ND	0.0284	0.05	U, H	None	062684-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	13-Oct-03	ND	0.0284	0.05	U, H	None	063281-040	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
	07-Jan-04	ND	0.028	0.10		None	063857-012	3500 Fe2+
		0.26	0.03	NA	None	None	Field	HACH 8146
	28-Apr-04	ND	0.028	0.10	U	None	064558-012	3500 Fe2+
		0.06	0.03	NA	None	None	Field	HACH 8146
	18-Aug-04	ND	0.028	0.10		None	065366-012	3500 Fe2+
		0.29	0.03	NA	None	None	Field	HACH 8146
	19-Oct-04	ND	0.028	0.10		None	066031-012	3500 Fe2+
		0.12	0.03	NA	None	None	Field	HACH 8146
TA1-W-04	29-Jul-03	ND	0.0284	0.05	U, H	None	062686-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	14-Oct-03	ND	0.0284	0.05	U, H	None	063282-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	06-Jan-04	ND	0.028	0.10		None	063860-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	26-Apr-04	ND	0.028	0.10	U	None	064560-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	26-Jul-04	ND	0.028	0.10		None	065368-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	07-Oct-04	ND	0.028	0.10		None	066033-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146

Well ID	Sample Date	Ferrous Iron Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TA1-W-05	28-Jul-03	ND	0.0284	0.05	U	None	062688-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	20-Oct-03	ND	0.0284	0.05	U, H	None	063283-040	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
	12-Feb-04	ND	0.028	0.10		None	063862-012	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
	07-May-04	ND	0.028	0.10	U	None	064562-012	3500 Fe2+
		0.03	0.03	NA	None	None	Field	HACH 8146
	20-Aug-04	ND	0.028	0.10		None	065370-012	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
	26-Oct-04	ND	0.028	0.10		None	066035-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
TA1-W-06	29-Jul-03	ND	0.0284	0.05	U	None	062690-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	09-Oct-03	ND	0.0284	0.05	U, H	None	063284-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	09-Feb-04	ND	0.028	0.10		None	063864-012	3500 Fe2+
		0.03	0.03	NA	None	None	Field	HACH 8146
	21-May-04	ND	0.028	0.10	U	None	064564-012	3500 Fe2+
		0.03	0.03	NA	None	None	Field	HACH 8146
	06-Aug-04	ND	0.028	0.10		None	065372-012	3500 Fe2+
		0.04	0.03	NA	None	None	Field	HACH 8146
	26-Oct-04	ND	0.028	0.10		None	066037-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
TA1-W-08	30-Jul-03	ND	0.0284	0.05	U, H	None	062692-040	SM 3500-Fe
		0.15	0.03	NA		None	Field	HACH 8146
	21-Oct-03	ND	0.0284	0.05	U	None	063285-040	3500 Fe2+
		0.02	0.03	NA	None	None	Field	HACH 8146
	10-Feb-04	ND	0.028	0.10		None	063866-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	23-Apr-04	ND	0.028	0.10	U	None	064566-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	13-Aug-04	ND	0.028	0.10		None	065374-012	3500 Fe2+
		0.14	0.03	NA	None	None	Field	HACH 8146
	08-Oct-04	ND	0.028	0.10		None	066039-012	3500 Fe2+
		0.03	0.03	NA	None	None	Field	HACH 8146

Well ID	Sample Date	Ferrous Iron Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TA2-NW1-595 (QED)	30-Jul-03	ND	0.0284	0.05	U, H	None	062695-A40	SM 3500-Fe
		0.01	0.03	NA		None	Field	HACH 8146
	12-Nov-03	ND	0.0284	0.05	U, H	None	063287-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	04-Feb-04	ND	0.028	0.10		None	063871-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	13-May-04	ND	0.028	0.10	U	None	064568-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	26-Jul-04	ND	0.028	0.10		None	065377-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	25-Oct-04	ND	0.028	0.10		None	066042-012	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
TA2-NW1-595 (Bennett)	05-Aug-03	ND	0.0284	0.05	U, H	None	062695-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	11-Nov-03	ND	0.0284	0.05	U, H	None	063288-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	26-Jan-04	ND	0.028	0.10		None	063869-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	19-May-04	ND	0.028	0.10	U	None	064568-012	3500 Fe2+
		0.02	0.03	NA	None	None	Field	HACH 8146
	23-Aug-04	ND	0.028	0.10		None	065379-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	07-Oct-04	ND	0.028	0.10		None	066044-012	3500 Fe2+
		0.04	0.03	NA	None	None	Field	HACH 8146
TA2-SW1-320	24-Jul-03	ND	0.0284	0.05	U, H	None	062698-040	SM 3500-Fe
		0.02	0.03	NA		None	Field	HACH 8146
	11-Nov-03	ND	0.0284	0.05	U, H	None	063289-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	29-Jan-04	ND	0.028	0.10		None	063873-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	14-May-04	ND	0.028	0.10	U	None	064573-012	3500 Fe2+
		0.02	0.03	NA	None	None	Field	HACH 8146
	27-Jul-04	ND	0.028	0.10		None	065381-012	3500 Fe2+
		0.57	0.03	NA	None	None	Field	HACH 8146

Well ID	Sample Date	Ferrous Iron Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	04-Oct-04	ND	0.028	0.10		None	066046-012	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
TA2-W-01	07-Aug-03	ND	0.0284	0.05	U, H	None	062700-040	SM 3500-Fe
		0.01	0.03	NA		None	Field	HACH 8146
	01-Dec-03	ND	0.0284	0.05	U	None	063290-040	3500 Fe2+
		0.02	0.03	NA	None	None	Field	HACH 8146
	12-Jan-04	ND	0.028	0.10		None	063876-012	3500 Fe2+
		0.03	0.03	NA	None	None	Field	HACH 8146
	17-May-04	ND	0.028	0.10	U	None	064575-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	12-Aug-04	ND	0.028	0.10		None	065383-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	18-Oct-04	ND	0.028	0.10		None	066048-012	3500 Fe2+
		0.06	0.03	NA	None	None	Field	HACH 8146
TA2-W-19	04-Aug-03	ND	0.0284	0.05	U, H	None	062702-040	SM 3500-Fe
		0.01	0.03	NA		None	Field	HACH 8146
	07-Oct-03	ND	0.0284	0.05	U, H	None	063291-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	13-Jan-04	ND	0.028	0.10		None	063878-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	27-Apr-04	ND	0.028	0.10	U	None	064577-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	27-Jul-04	ND	0.028	0.10		None	065385-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	04-Oct-04	ND	0.028	0.10		None	066050-012	3500 Fe2+
		0.03	0.03	NA	None	None	Field	HACH 8146
TA2-W-26	04-Aug-03	ND	0.0284	0.05	U, H	None	062704-040	SM 3500-Fe
		0.19	0.03	NA		None	Field	HACH 8146
	16-Oct-03	ND	0.0284	0.05	U, H	None	063292-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	20-Jan-04	ND	0.028	0.10		None	063880-012	3500 Fe2+
		0.05	0.03	NA	None	None	Field	HACH 8146
	21-Apr-04	ND	0.028	0.10	U	None	064580-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	30-Jul-04	ND	0.028	0.10		None	065387-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146

Well ID	Sample Date	Ferrous Iron Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	13-Oct-04	ND	0.028	0.10		None	066053-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
TA2-W-27	06-Aug-03	ND	0.0284	0.05	U, H	None	062707-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	23-Oct-03	ND	0.0284	0.05	U, H	None	063294-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	15-Jan-04	ND	0.028	0.10		None	063885-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	19-Apr-04	ND	0.028	0.10	U	None	064583-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	28-Jul-04	ND	0.028	0.10		None	065392-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	14-Oct-04	ND	0.028	0.10		None	066056-012	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
TJA-2	31-Jul-03	ND	0.0284	0.05	U, H	None	062709-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	15-Oct-03	ND	0.0284	0.05	U, H	None	063295-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	19-Jan-04	ND	0.028	0.10		None	063887-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	05-May-04	ND	0.028	0.10	U	None	064585-012	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
	16-Aug-04	ND	0.028	0.10		None	065394-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	11-Oct-04	ND	0.028	0.10		None	066059-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
TJA-3	06-Aug-03	ND	0.0284	0.05	U, H	None	062711-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	22-Oct-03	ND	0.0284	0.05	U	None	063296-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	27-Jan-04	ND	0.028	0.10		None	063889-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	27-Apr-04	ND	0.028	0.10	U	None	064587-012	3500 Fe2+
		0.02	0.03	NA	None	None	Field	HACH 8146
	09-Aug-04	ND	0.028	0.10		None	065397-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146

Well ID	Sample Date	Ferrous Iron Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	12-Oct-04	ND	0.028	0.10		None	066061-012	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
TJA-4	06-Aug-03	ND	0.0284	0.05	U, H	None	062713-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	27-Oct-03	ND	0.0284	0.05	U	None	063297-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	29-Jan-04	ND	0.028	0.10		None	063891-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	20-Apr-04	ND	0.028	0.10	U	None	064589-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	10-Aug-04	ND	0.028	0.10		None	065399-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	12-Oct-04	ND	0.028	0.10		None	066063-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
TJA-6	11-Aug-03	ND	0.0284	0.05	U, H	None	062715-040	SM 3500-Fe
		0.10	0.03	NA		None	Field	HACH 8146
	05-Nov-03	ND	0.0284	0.05	U, H	None	063298-040	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
	04-Feb-04	ND	0.028	0.10		None	063893-012	3500 Fe2+
		0.11	0.03	NA	None	None	Field	HACH 8146
	22-Apr-04	ND	0.028	0.10	U	None	064591-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	04-Aug-04	ND	0.028	0.10		None	065401-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	13-Oct-04	ND	0.028	0.10		None	066065-012	3500 Fe2+
		0.06	0.03	NA	None	None	Field	HACH 8146
TJA-7	12-Aug-03	ND	0.0284	0.05	U, H	None	062717-040	SM 3500-Fe
		0.05	0.03	NA		None	Field	HACH 8146
	28-Oct-03	ND	0.0284	0.05	U, H	None	063299-040	3500 Fe2+
		0.02	0.03	NA	None	None	Field	HACH 8146
	22-Jan-04	ND	0.028	0.10		None	063895-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	30-Apr-04	ND	0.028	0.10	U	None	064593-012	3500 Fe2+
		0.03	0.03	NA	None	None	Field	HACH 8146
	06-Aug-04	ND	0.028	0.10		None	065403-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146

Well ID	Sample Date	Ferrous Iron Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	15-Oct-04	ND	0.028	0.10		None	066067-012	3500 Fe2+
		0.04	0.03	NA	None	None	Field	HACH 8146
WYO-3	13-Aug-03	ND	0.0284	0.05	U, H	None	062719-040	SM 3500-Fe
		ND	0.03	NA		None	Field	HACH 8146
	29-Oct-03	ND	0.0284	0.05	U, H	None	063300-040	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	21-Jan-04	ND	0.028	0.10		None	063897-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	28-Apr-04	ND	0.028	0.10	U	None	064595-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	11-Aug-04	ND	0.028	0.10		None	065408-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	08-Oct-04	ND	0.028	0.10		None	066071-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
WYO-4	14-Aug-03	ND	0.0284	0.05	U, H	None	062721-040	SM 3500-Fe
		0.06	0.03	NA		None	Field	HACH 8146
	03-Nov-03	0.0288	0.0284	0.05	B, H, J	None	063301-040	3500 Fe2+
		0.01	0.03	NA	None	None	Field	HACH 8146
	03-Feb-04	ND	0.028	0.10		None	063899-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	30-Apr-04	ND	0.028	0.10	U	None	064597-012	3500 Fe2+
		0.02	0.03	NA	None	None	Field	HACH 8146
	03-Aug-04	ND	0.028	0.10		None	065411-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146
	06-Oct-04	ND	0.028	0.10		None	066073-012	3500 Fe2+
		ND	0.03	NA	None	None	Field	HACH 8146

mg/L = milligrams per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
B = Analyte is detected in associated laboratory method blank.
H = The holding time was exceeded for the associated sample analysis.
U = Analyte not detected above the MDL.

Table A-14
Summary of Anion, Cation, and Alkalinity Results

Tijeras Arroyo Groundwater Investigation

Fiscal Year 2003, 4th Quarter

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
EUBANK-1	Bromide	0.141	0.0978	0.2	J		062724-013	SW846 9056
18-Aug-03	Chloride	12.3	0.0322	0.2			062724-013	SW846 9056
	Fluoride	0.318	0.0553	0.1			062724-013	SW846 9056
	Sulfate	85.4	0.965	2			062724-013	SW846 9056
	Calcium	70.9	0.04	0.1			062724-009	SW846 3005
	Magnesium	9.76	0.00633	0.01		J	062724-009	SW846 3005
	Potassium	1.65	0.0151	0.3	B		062724-009	SW846 3005
	Sodium	22.8	0.00968	0.25		J	062724-009	SW846 3005
	Alkalinity as CaCO3	133	1.45	2			062724-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	133	1.45	2			062724-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062724-014	EPA 310.1
PGS-2	Bromide	0.243	0.0978	0.2			062678-013	SW846 9056
22-Jul-03	Chloride	14.2	0.0322	0.2			062678-013	SW846 9056
	Fluoride	0.212	0.0553	0.1			062678-013	SW846 9056
	Sulfate	59	0.965	2			062678-013	SW846 9056
	Calcium	56.7	0.04	0.1			062678-009	SW846 3005
	Magnesium	12.1	0.00633	0.01			062678-009	SW846 3005
	Potassium	2.59	0.0151	0.3			062678-009	SW846 3005
	Sodium	34.4	0.00968	0.25			062678-009	SW846 3005
	Alkalinity as CaCO3	168	1.45	2			062678-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	165	1.45	2			062678-014	EPA 310.1
	carb as CaCO3 Alkalinity	2.58	1.45	2			062678-014	EPA 310.1
TA1-W-01	Bromide	0.275	0.0978	0.2			062680-013	SW846 9056
22-Jul-03	Chloride	14.7	0.0322	0.2			062680-013	SW846 9056
	Fluoride	0.444	0.0553	0.1			062680-013	SW846 9056
	Sulfate	78.3	0.965	2			062680-013	SW846 9056
	Calcium	72.7	0.04	0.1			062680-009	SW846 3005
	Magnesium	14.5	0.00633	0.01			062680-009	SW846 3005
	Potassium	2.15	0.0151	0.3			062680-009	SW846 3005
	Sodium	28	0.00968	0.25			062680-009	SW846 3005

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Alkalinity as CaCO3	170	1.45	2			062680-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	170	1.45	2			062680-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062680-014	EPA 310.1
TA1-W-02	Bromide	0.226	0.0978	0.2			062682-013	SW846 9056
23-Jul-03	Chloride	14.1	0.0322	0.2			062682-013	SW846 9056
	Fluoride	0.407	0.0553	0.1			062682-013	SW846 9056
	Sulfate	79.7	0.965	2			062682-013	SW846 9056
	Calcium	76.8	0.2	0.5	B		062682-009	SW846 3005
	Magnesium	14.3	0.0317	0.05			062682-009	SW846 3005
	Potassium	2.33	0.0753	1.5			062682-009	SW846 3005
	Sodium	26.5	0.0484	1.25			062682-009	SW846 3005
	Alkalinity as CaCO3	178	1.45	2			062682-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	177	1.45	2			062682-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062682-014	EPA 310.1
TA1-W-03	Bromide	3	0.0978	0.2			062684-013	SW846 9056
24-Jul-03	Chloride	234	1.61	10			062684-013	SW846 9056
	Fluoride	0.247	0.0553	0.1			062684-013	SW846 9056
	Sulfate	469	9.65	20			062684-013	SW846 9056
	Calcium	299	0.2	0.5	B		062684-009	SW846 3005
	Magnesium	32.7	0.0317	0.05			062684-009	SW846 3005
	Potassium	2.8	0.0753	1.5			062684-009	SW846 3005
	Sodium	51	0.0484	1.25			062684-009	SW846 3005
	Alkalinity as CaCO3	74	1.45	2			062684-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	73.8	1.45	2			062684-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062684-014	EPA 310.1
TA1-W-04	Bromide	0.256	0.0978	0.2			062686-013	SW846 9056
29-Jul-03	Chloride	16.8	0.0322	0.2			062686-013	SW846 9056
	Fluoride	0.372	0.0553	0.1			062686-013	SW846 9056
	Sulfate	65.4	0.965	2			062686-013	SW846 9056
	Calcium	70.7	0.04	0.1	B		062686-009	SW846 3005
	Magnesium	13.1	0.00633	0.01			062686-009	SW846 3005
	Potassium	2.62	0.0151	0.3			062686-009	SW846 3005
	Sodium	27	0.00968	0.25	B		062686-009	SW846 3005
	Alkalinity as	173	1.45	2			062686-014	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	CaCO3							
	bicarb as CaCO3 Alkalinity	172	1.45	2			062686-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062686-014	EPA 310.1
TA1-W-05	Bromide	0.204	0.0978	0.2			062688-013	SW846 9056
28-Jul-03	Chloride	11.5	0.0322	0.2			062688-013	SW846 9056
	Fluoride	0.301	0.0553	0.1			062688-013	SW846 9056
	Sulfate	101	0.965	2			062688-013	SW846 9056
	Calcium	87.6	0.04	0.1			062688-009	SW846 3005
	Magnesium	13.2	0.00633	0.01			062688-009	SW846 3005
	Potassium	2.08	0.0151	0.3			062688-009	SW846 3005
	Sodium	31.8	0.00968	0.25			062688-009	SW846 3005
	Alkalinity as CaCO3	207	1.45	2			062688-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	207	1.45	2			062688-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062688-014	EPA 310.1
TA1-W-06	Bromide	1.23	0.0978	0.2			062690-013	SW846 9056
29-Jul-03	Chloride	98.1	0.322	2			062690-013	SW846 9056
	Fluoride	0.309	0.0553	0.1			062690-013	SW846 9056
	Sulfate	206	1.93	4			062690-013	SW846 9056
	Calcium	130	0.04	0.1	B		062690-009	SW846 3005
	Magnesium	16.9	0.00633	0.01			062690-009	SW846 3005
	Potassium	1.96	0.0151	0.3			062690-009	SW846 3005
	Sodium	33.8	0.00968	0.25	B		062690-009	SW846 3005
	Alkalinity as CaCO3	98.7	1.45	2			062690-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	98.3	1.45	2			062690-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062690-014	EPA 310.1
TA1-W-08	Bromide	2.55	0.0978	0.2			062692-013	SW846 9056
30-Jul-03	Chloride	215	1.61	10			062692-013	SW846 9056
	Fluoride	0.27	0.0553	0.1			062692-013	SW846 9056
	Sulfate	672	9.65	20			062692-013	SW846 9056
	Calcium	330	0.2	0.5			062692-009	SW846 3005
	Magnesium	38	0.00633	0.01			062692-009	SW846 3005
	Potassium	2.95	0.0151	0.3	B		062692-009	SW846 3005
	Sodium	70.7	0.00968	0.25		J	062692-009	SW846 3005
	Alkalinity as CaCO3	94.5	1.45	2			062692-014	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	bicarb as CaCO3 Alkalinity	94.2	1.45	2			062692-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062692-014	EPA 310.1
TA2-NW1-595	Bromide	1.19	0.0978	0.2			062695-A13	SW846 9056
30-Jul-03	Chloride	85.1	0.322	2			062695-A13	SW846 9056
	Fluoride	0.344	0.0553	0.1			062695-A13	SW846 9056
	Sulfate	120	1.93	4			062695-A13	SW846 9056
	Calcium	106	0.04	0.1			062695-A09	SW846 3005
	Magnesium	17	0.00633	0.01			062695-A09	SW846 3005
	Potassium	2.36	0.0151	0.3	B		062695-A09	SW846 3005
	Sodium	32	0.00968	0.25		J	062695-A09	SW846 3005
	Alkalinity as CaCO3	188	1.45	2			062695-A14	EPA 310.1
	bicarb as CaCO3 Alkalinity	187	1.45	2			062695-A14	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062695-A14	EPA 310.1
TA2-NW1-595	Bromide	0.985	0.0978	0.2			062695-013	SW846 9056
05-Aug-03	Chloride	65.9	0.322	2			062695-013	SW846 9056
	Fluoride	0.216	0.0553	0.1			062695-013	SW846 9056
	Sulfate	92.2	1.93	4			062695-013	SW846 9056
	Calcium	106	0.04	0.1			062695-009	SW846 3005
	Magnesium	15.9	0.00633	0.01			062695-009	SW846 3005
	Potassium	2.34	0.0151	0.3	B		062695-009	SW846 3005
	Sodium	29.2	0.00968	0.25		J	062695-009	SW846 3005
	Alkalinity as CaCO3	154	1.45	2			062695-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	154	1.45	2			062695-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062695-014	EPA 310.1
TA2-SW1-320	Bromide	0.421	0.0978	0.2			062698-013	SW846 9056
24-Jul-03	Chloride	26.3	0.0644	0.4			062698-013	SW846 9056
	Fluoride	0.454	0.0553	0.1			062698-013	SW846 9056
	Sulfate	14.1	0.193	0.4			062698-013	SW846 9056
	Calcium	66.3	0.2	0.5	B		062698-009	SW846 3005
	Magnesium	11.6	0.0317	0.05			062698-009	SW846 3005
	Potassium	2.05	0.0753	1.5			062698-009	SW846 3005
	Sodium	19.8	0.0484	1.25			062698-009	SW846 3005
	Alkalinity as CaCO3	109	1.45	2			062698-014	EPA 310.1
	bicarb as CaCO3	108	1.45	2			062698-014	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Alkalinity							
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062698-014	EPA 310.1
TA2-W-01 07-Aug-03	Bromide	1.43	0.0978	0.2			062700-013	SW846 9056
	Chloride	108	0.322	2			062700-013	SW846 9056
	Fluoride	0.318	0.0553	0.1			062700-013	SW846 9056
	Sulfate	40.3	1.93	4			062700-013	SW846 9056
	Calcium	85.6	0.04	0.1			062700-009	SW846 3005
	Magnesium	11	0.00633	0.01			062700-009	SW846 3005
	Potassium	1.78	0.0151	0.3	B		062700-009	SW846 3005
	Sodium	21.4	0.00968	0.25			062700-009	SW846 3005
	Alkalinity as CaCO3	114	1.45	2			062700-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	113	1.45	2			062700-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062700-014	EPA 310.1
TA2-W-19 04-Aug-03	Bromide	0.835	0.0978	0.2			062702-013	SW846 9056
	Chloride	72.9	0.322	2			062702-013	SW846 9056
	Fluoride	0.262	0.0553	0.1			062702-013	SW846 9056
	Sulfate	55.6	1.93	4			062702-013	SW846 9056
	Calcium	83.9	0.04	0.1			062702-009	SW846 3005
	Magnesium	11.6	0.00633	0.01			062702-009	SW846 3005
	Potassium	1.83	0.0151	0.3	B		062702-009	SW846 3005
	Sodium	23.9	0.00968	0.25		J	062702-009	SW846 3005
	Alkalinity as CaCO3	101	1.45	2			062702-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	101	1.45	2			062702-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062702-014	EPA 310.1
TA2-W-26 04-Aug-03	Bromide	1.49	0.0978	0.2			062704-013	SW846 9056
	Chloride	106	0.322	2			062704-013	SW846 9056
	Fluoride	0.207	0.0553	0.1			062704-013	SW846 9056
	Sulfate	197	1.93	4			062704-013	SW846 9056
	Calcium	156	0.04	0.1			062704-009	SW846 3005
	Magnesium	19.1	0.00633	0.01			062704-009	SW846 3005
	Potassium	2.21	0.0151	0.3	B		062704-009	SW846 3005
	Sodium	31	0.00968	0.25		J	062704-009	SW846 3005
	Alkalinity as CaCO3	95.5	1.45	2			062704-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	95.2	1.45	2			062704-014	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062704-014	EPA 310.1
TA2-W-27	Bromide	1.63	0.0978	0.2			062707-013	SW846 9056
06-Aug-03	Chloride	126	0.322	2			062707-013	SW846 9056
	Fluoride	0.292	0.0553	0.1			062707-013	SW846 9056
	Sulfate	168	1.93	4			062707-013	SW846 9056
	Calcium	134	0.04	0.1	B		062707-009	SW846 3005
	Magnesium	18.7	0.00633	0.01		J	062707-009	SW846 3005
	Potassium	2.46	0.0151	0.3	B		062707-009	SW846 3005
	Sodium	32.7	0.00968	0.25		J	062707-009	SW846 3005
	Alkalinity as CaCO3	100	1.45	2			062707-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	99.9	1.45	2			062707-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062707-014	EPA 310.1
TJA-2	Bromide	0.912	0.0978	0.2			062709-013	SW846 9056
31-Jul-03	Chloride	70.9	0.161	1			062709-013	SW846 9056
	Fluoride	0.365	0.0553	0.1			062709-013	SW846 9056
	Sulfate	58.2	0.965	2			062709-013	SW846 9056
	Calcium	80.4	0.04	0.1			062709-009	SW846 3005
	Magnesium	13.1	0.00633	0.01			062709-009	SW846 3005
	Potassium	1.81	0.0151	0.3	B		062709-009	SW846 3005
	Sodium	24.4	0.00968	0.25		J	062709-009	SW846 3005
	Alkalinity as CaCO3	134	1.45	2			062709-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	134	1.45	2			062709-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062709-014	EPA 310.1
TJA-3	Bromide	0.204	0.0978	0.2			062711-013	SW846 9056
06-Aug-03	Chloride	13.6	0.0322	0.2			062711-013	SW846 9056
	Fluoride	0.352	0.0553	0.1			062711-013	SW846 9056
	Sulfate	74.3	0.965	2			062711-013	SW846 9056
	Calcium	69	0.04	0.1	B		062711-009	SW846 3005
	Magnesium	11	0.00633	0.01		J	062711-009	SW846 3005
	Potassium	2.07	0.0151	0.3	B		062711-009	SW846 3005
	Sodium	26.5	0.00968	0.25		J	062711-009	SW846 3005
	Alkalinity as CaCO3	184	1.45	2			062711-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	184	1.45	2			062711-014	EPA 310.1
	carb as CaCO3	ND	1.45	2	U		062711-014	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Alkalinity							
TJA-4	Bromide	0.355	0.0978	0.2			062713-013	SW846 9056
11-Aug-03	Chloride	21.6	0.0644	0.4			062713-013	SW846 9056
	Fluoride	0.403	0.0553	0.1			062713-013	SW846 9056
	Sulfate	19	0.193	0.4			062713-013	SW846 9056
	Calcium	64.5	0.04	0.1			062713-009	SW846 3005
	Magnesium	12.5	0.00633	0.01			062713-009	SW846 3005
	Potassium	3.11	0.0151	0.3	B		062713-009	SW846 3005
	Sodium	22.9	0.00968	0.25			062713-009	SW846 3005
	Alkalinity as CaCO3	110	1.45	2			062713-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	110	1.45	2			062713-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062713-014	EPA 310.1
TJA-6	Bromide	0.227	0.0978	0.2			062715-013	SW846 9056
11-Aug-03	Chloride	14.8	0.0322	0.2			062715-013	SW846 9056
	Fluoride	0.409	0.0553	0.1			062715-013	SW846 9056
	Sulfate	62.1	0.965	2			062715-013	SW846 9056
	Calcium	61.3	0.04	0.1			062715-009	SW846 3005
	Magnesium	11.5	0.00633	0.01			062715-009	SW846 3005
	Potassium	2.21	0.0151	0.3	B		062715-009	SW846 3005
	Sodium	22.3	0.00968	0.25			062715-009	SW846 3005
	Alkalinity as CaCO3	115	1.45	2			062715-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	115	1.45	2			062715-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062715-014	EPA 310.1
TJA-7	Bromide	0.373	0.978	2			062717-013	SW846 9056
12-Aug-03	Chloride	30.3	0.322	2			062717-013	SW846 9056
	Fluoride	0.273	0.0553	0.1			062717-013	SW846 9056
	Sulfate	15.7	0.193	0.4			062717-013	SW846 9056
	Calcium	71.4	0.04	0.1	B		062717-009	SW846 3005
	Magnesium	11.3	0.00633	0.01		J	062717-009	SW846 3005
	Potassium	2.14	0.0151	0.3			062717-009	SW846 3005
	Sodium	19.7	0.00968	0.25			062717-009	SW846 3005
	Alkalinity as CaCO3	44.8	1.45	2			062717-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	44.8	1.45	2			062717-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062717-014	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
WYO-3 13-Aug-03	Bromide	0.147	0.0978	0.2	J		062719-013	SW846 9056
	Chloride	15.2	0.0322	0.2			062719-013	SW846 9056
	Fluoride	0.309	0.0553	0.1			062719-013	SW846 9056
	Sulfate	82	0.965	2			062719-013	SW846 9056
	Calcium	66.5	0.04	0.1	B		062719-009	SW846 3005
	Magnesium	11.6	0.00633	0.01		J	062719-009	SW846 3005
	Potassium	2.22	0.0151	0.3			062719-009	SW846 3005
	Sodium	25.9	0.00968	0.25			062719-009	SW846 3005
	Alkalinity as CaCO3	189	1.45	2			062719-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	188	1.45	2			062719-014	EPA 310.1
	carb as CaCO3 Alkalinity	1.69	1.45	2	J		062719-014	EPA 310.1
WYO-4 14-Aug-03	Bromide	1.04	0.0978	0.2			062721-013	SW846 9056
	Chloride	101	0.322	2			062721-013	SW846 9056
	Fluoride	0.264	0.0553	0.1			062721-013	SW846 9056
	Sulfate	57	1.93	4			062721-013	SW846 9056
	Calcium	81.8	0.04	0.1	B		062721-009	SW846 3005
	Magnesium	11.8	0.00633	0.01		J	062721-009	SW846 3005
	Potassium	1.93	0.0151	0.3			062721-009	SW846 3005
	Sodium	20.2	0.00968	0.25			062721-009	SW846 3005
	Alkalinity as CaCO3	97.8	1.45	2			062721-014	EPA 310.1
	bicarb as CaCO3 Alkalinity	97.5	1.45	2			062721-014	EPA 310.1
	carb as CaCO3 Alkalinity	ND	1.45	2	U		062721-014	EPA 310.1

mg/L = milligrams per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
B = Analyte is detected in associated laboratory method blank.
U = Analyte not detected above the MDL.

Table A-15
Summary of Anion, Cation, and Alkalinity Results

Tijeras Arroyo Groundwater Investigation

Fiscal Year 2004, 1st Quarter

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
Eubank-1	Bromide	0.104	0.0978	0.2	J		063303-013	SW846 9056
10-Nov-03	Chloride	12.1	0.0322	0.2			063303-013	SW846 9056
	Fluoride	0.334	0.0553	0.1			063303-013	SW846 9056
	Sulfate	76.2	0.965	2			063303-013	SW846 9056
	Calcium	71.1	0.04	0.1			063303-009	SW846 3005
	Magnesium	10.5	0.00633	0.01		J	063303-009	SW846 3005
	Potassium	1.63	0.0151	0.3			063303-009	SW846 3005
	Sodium	24.2	0.00968	0.25			063303-009	SW846 3005
	Total Alkalinity as CaCO3	171	1.45	2			063303-014	EPA 310.1
	Alkalinity as HCO3	169	1.45	2			063303-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063303-014	EPA 310.1
Eubank-2	Bromide	0.110	0.0978	0.2	J		063304-013	SW846 9056
12-Nov-03	Chloride	12.4	0.0322	0.2			063304-013	SW846 9056
	Fluoride	0.264	0.0553	0.1			063304-013	SW846 9056
	Sulfate	91.6	1.93	4			063304-013	SW846 9056
	Calcium	80.8	0.04	0.1			063304-009	SW846 3005
	Magnesium	12.4	0.00633	0.01		J	063304-009	SW846 3005
	Potassium	2.04	0.0151	0.3			063304-009	SW846 3005
	Sodium	32.8	0.00968	0.25			063304-009	SW846 3005
	Total Alkalinity as CaCO3	237	1.45	2			063304-014	EPA 310.1
	Alkalinity as HCO3	237	1.45	2			063304-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063304-014	EPA 310.1
Eubank-3	Bromide	0.143	0.0978	0.2	J		063305-013	SW846 9056
18-Nov-03	Chloride	21.2	0.0644	0.4			063305-013	SW846 9056
	Fluoride	0.322	0.0553	0.1			063305-013	SW846 9056
	Sulfate	93.0	0.965	2			063305-013	SW846 9056
	Calcium	82.6	0.04	0.1			063305-009	SW846 3005
	Magnesium	12.9	0.00633	0.01			063305-009	SW846 3005
	Potassium	2.03	0.0151	0.3	B		063305-009	SW846 3005
	Sodium	32.1	0.00968	0.25	B		063305-009	SW846 3005
	Total Alkalinity as CaCO3	200	1.45	2			063305-014	EPA 310.1
	Alkalinity as HCO3	200	1.45	2			063305-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063305-014	EPA 310.1
Eubank-5	Bromide	0.250	0.0978	0.2			063306-013	SW846 9056
19-Nov-03	Chloride	24.3	0.161	1			063306-013	SW846 9056
	Fluoride	0.310	0.0553	0.1			063306-013	SW846 9056
	Sulfate	90.9	0.965	2			063306-013	SW846 9056
	Calcium	86.4	0.04	0.1	B		063306-009	SW846 3005
	Magnesium	11.1	0.00633	0.01			063306-009	SW846 3005

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Potassium	1.79	0.0151	0.3			063306-009	SW846 3005
	Sodium	28.8	0.00968	0.25	B		063306-009	SW846 3005
	Total Alkalinity as CaCO3	199	1.45	2			063306-014	EPA 310.1
	Alkalinity as HCO3	198	1.45	2			063306-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063306-014	EPA 310.1
PGS-2	Bromide	0.107	0.0978	0.2	J		063278-013	SW846 9056
10-Nov-03	Chloride	13.1	0.0322	0.2			063278-013	SW846 9056
	Fluoride	0.107	0.0553	0.1			063278-013	SW846 9056
	Sulfate	58.6	0.965	2			063278-013	SW846 9056
	Calcium	50.9	0.04	0.1			063278-009	SW846 3005
	Magnesium	10.8	0.00633	0.01		J	063278-009	SW846 3005
	Potassium	2.41	0.0151	0.3			063278-009	SW846 3005
	Sodium	33.4	0.00968	0.25			063278-009	SW846 3005
	Total Alkalinity as CaCO3	159	1.45	2			063278-014	EPA 310.1
	Alkalinity as HCO3	155	1.45	2			063278-014	EPA 310.1
	Alkalinity as CO3	3.34	1.45	2			063278-014	EPA 310.1
TA1-W-01	Bromide	0.190	0.0978	0.2	J	B3, J	063279-013	SW846 9056
06-Nov-03	Chloride	14.9	0.0322	0.2			063279-013	SW846 9056
	Fluoride	0.419	0.0553	0.1			063279-013	SW846 9056
	Sulfate	77.7	0.965	2			063279-013	SW846 9056
	Calcium	71.7	0.04	0.1			063279-009	SW846 3005
	Magnesium	12.6	0.00633	0.01			063279-009	SW846 3005
	Potassium	2.44	0.0151	0.3			063279-009	SW846 3005
	Sodium	28.6	0.00968	0.25	B	J	063279-009	SW846 3005
	Total Alkalinity as CaCO3	176	1.45	2			063279-014	EPA 310.1
	Alkalinity as HCO3	175	1.45	2			063279-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063279-014	EPA 310.1
TA1-W-02	Bromide	0.137	0.0978	0.2	J		063280-013	SW846 9056
08-Oct-03	Chloride	13.8	0.0322	0.2			063280-013	SW846 9056
	Fluoride	0.323	0.0553	0.1			063280-013	SW846 9056
	Sulfate	78.8	1.93	4			063280-013	SW846 9056
	Calcium	72.0	0.04	0.1		J	063280-009	SW846 3005
	Magnesium	13.2	0.00633	0.01			063280-009	SW846 3005
	Potassium	2.08	0.0151	0.3			063280-009	SW846 3005
	Sodium	23.4	0.00968	0.25			063280-009	SW846 3005
	Total Alkalinity as CaCO3	165	1.45	2			063280-014	EPA 310.1
	Alkalinity as HCO3	165	1.45	2			063280-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063280-014	EPA 310.1
TA1-W-03	Bromide	3.03	0.0978	0.2			063281-013	SW846 9056
13-Oct-03	Chloride	234	1.61	10			063281-013	SW846 9056
	Fluoride	0.261	0.0553	0.1			063281-013	SW846 9056
	Sulfate	461	9.65	20			063281-013	SW846 9056
	Calcium	298	0.2	0.5			063281-009	SW846 3005
	Magnesium	31.8	0.00633	0.01			063281-009	SW846 3005
	Potassium	2.61	0.0151	0.3			063281-009	SW846 3005
	Sodium	45.0	0.00968	0.25	B		063281-009	SW846 3005

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Total Alkalinity as CaCO3	67.1	1.45	2			063281-014	EPA 310.1
	Alkalinity as HCO3	66.8	1.45	2			063281-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063281-014	EPA 310.1
TA1-W-04	Bromide	0.213	0.0978	0.2			063282-013	SW846 9056
14-Oct-03	Chloride	16.7	0.0322	0.2			063282-013	SW846 9056
	Fluoride	0.360	0.0553	0.1			063282-013	SW846 9056
	Sulfate	65.0	0.965	2			063282-013	SW846 9056
	Calcium	68.2	0.04	0.1			063282-009	SW846 3005
	Magnesium	11.9	0.00633	0.01			063282-009	SW846 3005
	Potassium	2.39	0.0151	0.3			063282-009	SW846 3005
	Sodium	24.5	0.00968	0.25	B		063282-009	SW846 3005
	Total Alkalinity as CaCO3	186	1.45	2			063282-014	EPA 310.1
	Alkalinity as HCO3	185	1.45	2			063282-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063282-014	EPA 310.1
TA1-W-05	Bromide	0.121	0.0978	0.2	J		063283-013	SW846 9056
20-Oct-03	Chloride	12.3	0.0322	0.2			063283-013	SW846 9056
	Fluoride	0.224	0.0553	0.1			063283-013	SW846 9056
	Sulfate	99.5	0.965	2			063283-013	SW846 9056
	Calcium	81.6	0.04	0.1			063283-009	SW846 3005
	Magnesium	11.0	0.00633	0.01		J	063283-009	SW846 3005
	Potassium	2.0	0.0151	0.3			063283-009	SW846 3005
	Sodium	26.1	0.00968	0.25			063283-009	SW846 3005
	Total Alkalinity as CaCO3	236	1.45	2			063283-014	EPA 310.1
	Alkalinity as HCO3	236	1.45	2			063283-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063283-014	EPA 310.1
TA1-W-06	Bromide	1.19	0.0978	0.2			063284-013	SW846 9056
09-Oct-03	Chloride	100	0.322	2			063284-013	SW846 9056
	Fluoride	0.291	0.0553	0.1			063284-013	SW846 9056
	Sulfate	192	1.93	4			063284-013	SW846 9056
	Calcium	126	0.04	0.1		J	063284-009	SW846 3005
	Magnesium	15.6	0.00633	0.01			063284-009	SW846 3005
	Potassium	2.02	0.0151	0.3			063284-009	SW846 3005
	Sodium	31.7	0.00968	0.25			063284-009	SW846 3005
	Total Alkalinity as CaCO3	85.1	1.45	2			063284-014	EPA 310.1
	Alkalinity as HCO3	84.7	1.45	2			063284-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063284-014	EPA 310.1
TA1-W-08	Bromide	2.51	0.0978	0.2			063285-013	SW846 9056
21-Oct-03	Chloride	198	3.22	20			063285-013	SW846 9056
	Fluoride	0.167	0.0553	0.1			063285-013	SW846 9056
	Sulfate	600	19.3	40			063285-013	SW846 9056
	Calcium	321	0.2	0.5			063285-009	SW846 3005
	Magnesium	40.6	0.00633	0.01		J	063285-009	SW846 3005
	Potassium	2.93	0.0151	0.3			063285-009	SW846 3005
	Sodium	75.3	0.00968	0.25			063285-009	SW846 3005
	Total Alkalinity as CaCO3	97.8	1.45	2			063285-014	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Alkalinity as HCO3	97.3	1.45	2			063285-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063285-014	EPA 310.1
TA2-NW1-595 (QED) 12-Nov-03	Bromide	0.914	0.0978	0.2			063287-013	SW846 9056
	Chloride	88.0	0.322	2			063287-013	SW846 9056
	Fluoride	0.247	0.0553	0.1			063287-013	SW846 9056
	Sulfate	121	1.93	4			063287-013	SW846 9056
	Calcium	110	0.04	0.1			063287-009	SW846 3005
	Magnesium	18.5	0.00633	0.01		J	063287-009	SW846 3005
	Potassium	2.24	0.0151	0.3			063287-009	SW846 3005
	Sodium	35.4	0.00968	0.25			063287-009	SW846 3005
	Total Alkalinity as CaCO3	147	1.45	2			063287-014	EPA 310.1
	Alkalinity as HCO3	146	1.45	2			063287-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063287-014	EPA 310.1
TA2-NW1-595 (Bennett) 11-Nov-03	Bromide	0.929	0.0978	0.2			063288-013	SW846 9056
	Chloride	85.8	0.322	2			063288-013	SW846 9056
	Fluoride	0.235	0.0553	0.1			063288-013	SW846 9056
	Sulfate	120	1.93	4			063288-013	SW846 9056
	Calcium	107	0.04	0.1			063288-009	SW846 3005
	Magnesium	17.8	0.00633	0.01		J	063288-009	SW846 3005
	Potassium	2.11	0.0151	0.3			063288-009	SW846 3005
	Sodium	32.0	0.00968	0.25			063288-009	SW846 3005
	Total Alkalinity as CaCO3	289	2.90	4			063288-014	EPA 310.1
	Alkalinity as HCO3	288	2.90	4			063288-014	EPA 310.1
	Alkalinity as CO3	ND	2.90	4	U		063288-014	EPA 310.1
TA2-SW1-320 11-Nov-03	Bromide	0.267	0.0978	0.2			063289-013	SW846 9056
	Chloride	24.4	0.161	1			063289-013	SW846 9056
	Fluoride	0.379	0.0553	0.1			063289-013	SW846 9056
	Sulfate	15.9	0.193	0.4			063289-013	SW846 9056
	Calcium	64.9	0.04	0.1			063289-009	SW846 3005
	Magnesium	11.5	0.00633	0.01		J	063289-009	SW846 3005
	Potassium	1.78	0.0151	0.3			063289-009	SW846 3005
	Sodium	19.6	0.00968	0.25			063289-009	SW846 3005
	Total Alkalinity as CaCO3	229	2.90	4			063289-014	EPA 310.1
	Alkalinity as HCO3	228	2.90	4			063289-014	EPA 310.1
	Alkalinity as CO3	ND	2.90	4	U		063289-014	EPA 310.1
TA2-W-01 01-Dec-03	Bromide	1.34	0.0978	0.2			063290-013	SW846 9056
	Chloride	110	0.322	2			063290-013	SW846 9056
	Fluoride	ND	0.0553	0.1	U		063290-013	SW846 9056
	Sulfate	47.1	1.93	4			063290-013	SW846 9056
	Calcium	82.1	0.04	0.1			063290-009	SW846 3005
	Magnesium	9.77	0.00633	0.01			063290-009	SW846 3005
	Potassium	1.80	0.0151	0.3	B		063290-009	SW846 3005
	Sodium	19.5	0.00968	0.25	B	J	063290-009	SW846 3005
	Total Alkalinity as CaCO3	88.8	1.45	2			063290-014	EPA 310.1
	Alkalinity as	88.2	1.45	2			063290-014	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	HCO3							
	Alkalinity as CO3	ND	1.45	2	U		063290-014	EPA 310.1
TA2-W-19 07-Oct-03	Bromide	0.904	0.0978	0.2		B3, J	063291-013	SW846 9056
	Chloride	78.8	0.322	2			063291-013	SW846 9056
	Fluoride	0.287	0.0553	0.1			063291-013	SW846 9056
	Sulfate	48.3	1.93	4			063291-013	SW846 9056
	Calcium	83.9	0.04	0.1		J	063291-009	SW846 3005
	Magnesium	12.2	0.00633	0.01			063291-009	SW846 3005
	Potassium	1.82	0.0151	0.3			063291-009	SW846 3005
	Sodium	22.8	0.00968	0.25			063291-009	SW846 3005
	Total Alkalinity as CaCO3	98.1	1.45	2			063291-014	EPA 310.1
	Alkalinity as HCO3	97.7	1.45	2			063291-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063291-014	EPA 310.1
TA2-W-26 16-Oct-03	Bromide	1.62	0.0978	0.2			063292-013	SW846 9056
	Chloride	134	0.322	2			063292-013	SW846 9056
	Fluoride	0.218	0.0553	0.1			063292-013	SW846 9056
	Sulfate	248	1.93	4			063292-013	SW846 9056
	Calcium	164	0.04	0.1	B		063292-009	SW846 3005
	Magnesium	19.8	0.00633	0.01		J	063292-009	SW846 3005
	Potassium	2.08	0.0151	0.3			063292-009	SW846 3005
	Sodium	29.8	0.00968	0.25	B		063292-009	SW846 3005
	Total Alkalinity as CaCO3	89.8	1.45	2			063292-014	EPA 310.1
	Alkalinity as HCO3	89.3	1.45	2			063292-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063292-014	EPA 310.1
TA2-W-27 23-Oct-03	Bromide	1.62	0.0978	0.2			063294-013	SW846 9056
	Chloride	129	0.322	2			063294-013	SW846 9056
	Fluoride	0.311	0.0553	0.1			063294-013	SW846 9056
	Sulfate	164	1.93	4			063294-013	SW846 9056
	Calcium	135	0.04	0.1			063294-009	SW846 3005
	Magnesium	17.5	0.00633	0.01		J	063294-009	SW846 3005
	Potassium	2.12	0.0151	0.3			063294-009	SW846 3005
	Sodium	32.0	0.00968	0.25			063294-009	SW846 3005
	Total Alkalinity as CaCO3	98.8	1.45	2			063294-014	EPA 310.1
	Alkalinity as HCO3	98.2	1.45	2			063294-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063294-014	EPA 310.1
TJA-2 15-Oct-03	Bromide	0.915	0.0978	0.2			063295-013	SW846 9056
	Chloride	72.2	0.161	1			063295-013	SW846 9056
	Fluoride	0.352	0.0553	0.1			063295-013	SW846 9056
	Sulfate	56.1	0.965	2			063295-013	SW846 9056
	Calcium	85.0	0.04	0.1	B		063295-009	SW846 3005
	Magnesium	12.8	0.00633	0.01		J	063295-009	SW846 3005
	Potassium	1.74	0.0151	0.3			063295-009	SW846 3005
	Sodium	22.9	0.00968	0.25	B		063295-009	SW846 3005
	Total Alkalinity as CaCO3	114	1.45	2			063295-014	EPA 310.1
	Alkalinity as HCO3	113	1.45	2			063295-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063295-014	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TJA-3	Bromide	0.126	0.0978	0.2	J		063296-013	SW846 9056
22-Oct-03	Chloride	13.4	0.0322	0.2			063296-013	SW846 9056
	Fluoride	0.278	0.0553	0.1			063296-013	SW846 9056
	Sulfate	73.4	0.965	2			063296-013	SW846 9056
	Calcium	68.4	0.04	0.1			063296-009	SW846 3005
	Magnesium	11.7	0.00633	0.01		J	063296-009	SW846 3005
	Potassium	1.82	0.0151	0.3			063296-009	SW846 3005
	Sodium	24.4	0.00968	0.25			063296-009	SW846 3005
	Total Alkalinity as CaCO3	169	1.45	2			063296-014	EPA 310.1
	Alkalinity as HCO3	168	1.45	2			063296-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063296-014	EPA 310.1
TJA-4	Bromide	0.243	0.0978	0.2			063297-013	SW846 9056
27-Oct-03	Chloride	21.1	0.0644	0.4			063297-013	SW846 9056
	Fluoride	0.322	0.0553	0.1			063297-013	SW846 9056
	Sulfate	19.4	0.193	0.4			063297-013	SW846 9056
	Calcium	65.3	0.04	0.1			063297-009	SW846 3005
	Magnesium	12.0	0.00633	0.01			063297-009	SW846 3005
	Potassium	3.0	0.0151	0.3	B		063297-009	SW846 3005
	Sodium	24.1	0.00968	0.25	B		063297-009	SW846 3005
	Total Alkalinity as CaCO3	140	1.45	2			063297-014	EPA 310.1
	Alkalinity as HCO3	139	1.45	2			063297-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063297-014	EPA 310.1
TJA-6	Bromide	ND	0.0978	0.2	U		063298-013	SW846 9056
05-Nov-03	Chloride	14.6	0.0322	0.2			063298-013	SW846 9056
	Fluoride	0.322	0.0553	0.1			063298-013	SW846 9056
	Sulfate	61.1	0.965	2			063298-013	SW846 9056
	Calcium	63.2	0.04	0.1			063298-009	SW846 3005
	Magnesium	11.2	0.00633	0.01			063298-009	SW846 3005
	Potassium	2.43	0.0151	0.3			063298-009	SW846 3005
	Sodium	24.7	0.00968	0.25	B	J	063298-009	SW846 3005
	Total Alkalinity as CaCO3	174	1.45	2			063298-014	EPA 310.1
	Alkalinity as HCO3	173	1.45	2			063298-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063298-014	EPA 310.1
TJA-7	Bromide	0.344	0.0978	0.2			063299-013	SW846 9056
28-Oct-03	Chloride	30.8	0.161	1			063299-013	SW846 9056
	Fluoride	0.294	0.0553	0.1			063299-013	SW846 9056
	Sulfate	15.9	0.193	0.4			063299-013	SW846 9056
	Calcium	71.0	0.04	0.1			063299-009	SW846 3005
	Magnesium	12.3	0.00633	0.01			063299-009	SW846 3005
	Potassium	2.06	0.0151	0.3	B		063299-009	SW846 3005
	Sodium	19.1	0.00968	0.25	B		063299-009	SW846 3005
	Total Alkalinity as CaCO3	135	1.45	2			063299-014	EPA 310.1
	Alkalinity as HCO3	134	1.45	2			063299-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063299-014	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
WYO-3	Bromide	ND	0.0978	0.2	U		063300-013	SW846 9056
29-Oct-03	Chloride	16.8	0.0322	0.2			063300-013	SW846 9056
	Fluoride	0.376	0.0553	0.1			063300-013	SW846 9056
	Sulfate	93.8	0.965	2			063300-013	SW846 9056
	Calcium	68.3	0.04	0.1			063300-009	SW846 3005
	Magnesium	13.3	0.00633	0.01			063300-009	SW846 3005
	Potassium	2.19	0.0151	0.3	B		063300-009	SW846 3005
	Sodium	25.6	0.00968	0.25	B		063300-009	SW846 3005
	Total Alkalinity as CaCO3	172	1.45	2			063300-014	EPA 310.1
	Alkalinity as HCO3	171	1.45	2			063300-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063300-014	EPA 310.1
WYO-4	Bromide	1.05	0.0978	0.2			063301-013	SW846 9056
03-Nov-03	Chloride	104	0.322	2			063301-013	SW846 9056
	Fluoride	0.319	0.0553	0.1			063301-013	SW846 9056
	Sulfate	54.3	1.93	4			063301-013	SW846 9056
	Calcium	81.3	0.04	0.1	B		063301-009	SW846 3005
	Magnesium	11.7	0.00633	0.01		J	063301-009	SW846 3005
	Potassium	1.69	0.0151	0.3			063301-009	SW846 3005
	Sodium	21.3	0.00968	0.25			063301-009	SW846 3005
	Total Alkalinity as CaCO3	95.8	1.45	2			063301-014	EPA 310.1
	Alkalinity as HCO3	95.2	1.45	2			063301-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063301-014	EPA 310.1

mg/L = milligrams per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
B = Analyte is detected in associated laboratory method blank.
B3 = Analyte is detected in associated laboratory calibration blank.
U = Analyte not detected above the MDL.

Table A-16
Summary of Anion, Cation, and Alkalinity Results

Tijeras Arroyo Groundwater Investigation

Fiscal Year 2004, 2nd Quarter

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
Eubank-1	Bromide	0.243	0.0978	0.2			063904-013	SW846 9056
16-Feb-04	Chloride	13.0	0.0322	0.2			063904-013	SW846 9056
	Fluoride	0.430	0.0553	0.1			063904-013	SW846 9056
	Sulfate	74.2	1.93	4			063904-013	SW846 9056
	Calcium	70.0	0.04	0.1			063904-014	SW846 3005
	Magnesium	8.77	0.00633	0.01		J	063904-014	SW846 3005
	Potassium	1.67	0.0151	0.3			063904-014	SW846 3005
	Sodium	22.2	0.00968	0.25	B	J	063904-014	SW846 3005
	Total Alkalinity as CaCO3	161	1.45	2			063904-018	EPA 310.1
	Alkalinity as HCO3	160	1.45	2			063904-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063904-018	EPA 310.1
Eubank-2	Bromide	0.217	0.0978	0.2			063906-013	SW846 9056
18-Feb-04	Chloride	11.7	0.0322	0.2			063906-013	SW846 9056
	Fluoride	0.271	0.0553	0.1			063906-013	SW846 9056
	Sulfate	83.2	1.93	4			063906-013	SW846 9056
	Calcium	82.0	0.04	0.1			063906-014	SW846 3005
	Magnesium	11.3	0.00633	0.01			063906-014	SW846 3005
	Potassium	2.22	0.0151	0.3	B		063906-014	SW846 3005
	Sodium	28.3	0.00968	0.25			063906-014	SW846 3005
	Total Alkalinity as CaCO3	202	1.45	2			063906-018	EPA 310.1
	Alkalinity as HCO3	201	1.45	2			063906-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063906-018	EPA 310.1
Eubank-3	Bromide	ND	0.0978	0.2	U		063909-013	SW846 9056
17-Feb-04	Chloride	2.56	0.0322	0.2			063909-013	SW846 9056
	Fluoride	0.795	0.0553	0.1			063909-013	SW846 9056
	Sulfate	8.07	0.193	0.4			063909-013	SW846 9056
	Calcium	86.4	0.04	0.1			063909-014	SW846 3005
	Magnesium	11.4	0.00633	0.01		J	063909-014	SW846 3005
	Potassium	1.89	0.0151	0.3			063909-014	SW846 3005
	Sodium	31.8	0.00968	0.25	B		063909-014	SW846 3005
	Total Alkalinity as CaCO3	189	1.45	2			063909-018	EPA 310.1
	Alkalinity as HCO3	188	1.45	2			063909-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063909-018	EPA 310.1
Eubank-5	Bromide	0.277	0.0978	0.2			063911-013	SW846 9056
19-Feb-04	Chloride	22.6	0.161	1			063911-013	SW846 9056
	Fluoride	0.348	0.0553	0.1			063911-013	SW846 9056
	Sulfate	85.6	0.965	2			063911-013	SW846 9056
	Calcium	86.1	0.04	0.1	B		063911-014	SW846 3005
	Magnesium	11.5	0.00633	0.01		J	063911-014	SW846 3005

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Potassium	2.11	0.0151	0.3	B		063911-014	SW846 3005
	Sodium	30.2	0.00968	0.25			063911-014	SW846 3005
	Total Alkalinity as CaCO3	190	1.45	2			063911-018	EPA 310.1
	Alkalinity as HCO3	189	1.45	2			063911-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063911-018	EPA 310.1
PGS-2	Bromide	0.204	0.0978	0.2			063851-013	SW846 9056
03-Feb-04	Chloride	14.0	0.0322	0.2			063851-013	SW846 9056
	Fluoride	0.089	0.0553	0.1	J		063851-013	SW846 9056
	Sulfate	63.1	0.965	2			063851-013	SW846 9056
	Calcium	52.7	0.04	0.1			063851-014	SW846 3005
	Magnesium	12.8	0.00633	0.01			063851-014	SW846 3005
	Potassium	2.96	0.0151	0.3			063851-014	SW846 3005
	Sodium	41.3	0.00968	0.25			063851-014	SW846 3005
	Total Alkalinity as CaCO3	129	1.45	2			063851-018	EPA 310.1
	Alkalinity as HCO3	129	1.45	2			063851-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063851-018	EPA 310.1
TA1-W-01	Bromide	0.240	0.0978	0.2			063853-013	SW846 9056
05-Feb-04	Chloride	15.1	0.0322	0.2			063853-013	SW846 9056
	Fluoride	0.429	0.0553	0.1			063853-013	SW846 9056
	Sulfate	79.9	0.965	2			063853-013	SW846 9056
	Calcium	64.0	0.04	0.1	B	J	063853-014	SW846 3005
	Magnesium	10.9	0.00633	0.01		J	063853-014	SW846 3005
	Potassium	2.01	0.0151	0.3			063853-014	SW846 3005
	Sodium	21.7	0.00968	0.25		J	063853-014	SW846 3005
	Total Alkalinity as CaCO3	167	1.45	2			063853-018	EPA 310.1
	Alkalinity as HCO3	167	1.45	2			063853-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063853-018	EPA 310.1
TA1-W-02	Bromide	0.906	0.0978	0.2	B		063855-013	SW846 9056
28-Jan-04	Chloride	14.3	0.0322	0.2			063855-013	SW846 9056
	Fluoride	0.320	0.0553	0.1			063855-013	SW846 9056
	Sulfate	82.1	0.965	2			063855-013	SW846 9056
	Calcium	68.2	0.04	0.1	B		063855-014	SW846 3005
	Magnesium	11.1	0.00633	0.01		J	063855-014	SW846 3005
	Potassium	2.20	0.0151	0.3			063855-014	SW846 3005
	Sodium	20.4	0.00968	0.25		J	063855-014	SW846 3005
	Total Alkalinity as CaCO3	165	1.45	2			063855-018	EPA 310.1
	Alkalinity as HCO3	165	1.45	2			063855-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063855-018	EPA 310.1
TA1-W-03	Bromide	2.50	0.0978	0.2			063857-013	SW846 9056
07-Jan-04	Chloride	226	1.61	10			063857-013	SW846 9056
	Fluoride	0.152	0.0553	0.1			063857-013	SW846 9056
	Sulfate	473	9.65	20			063857-013	SW846 9056
	Calcium	286	0.2	0.5			063857-014	SW846 3005
	Magnesium	28.9	0.00633	0.01		J	063857-014	SW846 3005
	Potassium	2.74	0.0151	0.3	B		063857-014	SW846 3005
	Sodium	42.3	0.00968	0.25	B		063857-014	SW846 3005

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Total Alkalinity as CaCO3	109	1.45	2			063857-018	EPA 310.1
	Alkalinity as HCO3	108	1.45	2			063857-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063857-018	EPA 310.1
TA1-W-04	Bromide	0.242	0.0978	0.2		B3, J	063860-013	SW846 9056
06-Jan-04	Chloride	16.6	0.0322	0.2			063860-013	SW846 9056
	Fluoride	0.322	0.0553	0.1			063860-013	SW846 9056
	Sulfate	63.6	0.965	2			063860-013	SW846 9056
	Calcium	63.5	0.04	0.1	B		063860-014	SW846 3005
	Magnesium	10.6	0.00633	0.01		J	063860-014	SW846 3005
	Potassium	2.37	0.0151	0.3			063860-014	SW846 3005
	Sodium	22.3	0.00968	0.25			063860-014	SW846 3005
	Total Alkalinity as CaCO3	193	1.45	2			063860-018	EPA 310.1
	Alkalinity as HCO3	193	1.45	2			063860-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063860-018	EPA 310.1
TA1-W-05	Bromide	0.988	0.0978	0.2	B		063862-013	SW846 9056
12-Feb-04	Chloride	11.5	0.0322	0.2			063862-013	SW846 9056
	Fluoride	0.253	0.0553	0.1			063862-013	SW846 9056
	Sulfate	98.7	0.965	2			063862-013	SW846 9056
	Calcium	82.1	0.04	0.1			063862-014	SW846 3005
	Magnesium	11.0	0.00633	0.01			063862-014	SW846 3005
	Potassium	2.20	0.0151	0.3			063862-014	SW846 3005
	Sodium	28.5	0.00968	0.25	B		063862-014	SW846 3005
	Total Alkalinity as CaCO3	199	1.45	2			063862-018	EPA 310.1
	Alkalinity as HCO3	198	1.45	2			063862-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063862-018	EPA 310.1
TA1-W-06	Bromide	1.23	0.0978	0.2			063864-013	SW846 9056
09-Feb-04	Chloride	94.4	0.322	2			063864-013	SW846 9056
	Fluoride	0.298	0.0553	0.1			063864-013	SW846 9056
	Sulfate	194	1.93	4			063864-013	SW846 9056
	Calcium	133	0.04	0.1	B		063864-014	SW846 3005
	Magnesium	15.9	0.00633	0.01		J	063864-014	SW846 3005
	Potassium	2.12	0.0151	0.3			063864-014	SW846 3005
	Sodium	31.7	0.00968	0.25		J	063864-014	SW846 3005
	Total Alkalinity as CaCO3	87.1	1.45	2			063864-018	EPA 310.1
	Alkalinity as HCO3	86.5	1.45	2			063864-018	EPA 310.1
TA1-W-08	Alkalinity as CO3	ND	1.45	2	U		063864-018	EPA 310.1
10-Feb-04	Bromide	2.52	0.0978	0.2			063866-013	SW846 9056
	Chloride	202	1.61	10			063866-013	SW846 9056
	Fluoride	0.230	0.0553	0.1			063866-013	SW846 9056
	Sulfate	641	9.65	20			063866-013	SW846 9056
	Calcium	348	0.4	1	B		063866-014	SW846 3005
	Magnesium	40.8	0.00633	0.01		J	063866-014	SW846 3005
	Potassium	3.18	0.0151	0.3			063866-014	SW846 3005
	Sodium	74.2	0.00968	0.25		J	063866-014	SW846 3005
	Total Alkalinity as CaCO3	82.0	1.45	2			063866-018	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Alkalinity as HCO3	81.2	1.45	2			063866-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063866-018	EPA 310.1
TA2-NW1-595 26-Jan-04 (Bennett)	Bromide	1.76	0.0978	0.2	B		063869-013	SW846 9056
	Chloride	88.0	0.322	2			063869-013	SW846 9056
	Fluoride	0.223	0.0553	0.1			063869-013	SW846 9056
	Sulfate	119	1.93	4			063869-013	SW846 9056
	Calcium	107	0.04	0.1	B		063869-014	SW846 3005
	Magnesium	16.9	0.00633	0.01			063869-014	SW846 3005
	Potassium	2.43	0.0151	0.3			063869-014	SW846 3005
	Sodium	28.2	0.00968	0.25	B		063869-014	SW846 3005
	Total Alkalinity as CaCO3	143	1.45	2			063869-018	EPA 310.1
	Alkalinity as HCO3	142	1.45	2			063869-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063869-018	EPA 310.1
TA2-NW1-595 04-Feb-04 (QED)	Bromide	1.12	0.0978	0.2			063871-013	SW846 9056
	Chloride	85.2	0.322	2			063871-013	SW846 9056
	Fluoride	0.307	0.0553	0.1			063871-013	SW846 9056
	Sulfate	114	1.93	4			063871-013	SW846 9056
	Calcium	98.0	0.04	0.1		J	063871-014	SW846 3005
	Magnesium	15.2	0.00633	0.01			063871-014	SW846 3005
	Potassium	2.19	0.0151	0.3			063871-014	SW846 3005
	Sodium	24.8	0.00968	0.25	B	J	063871-014	SW846 3005
	Total Alkalinity as CaCO3	140	1.45	2			063871-018	EPA 310.1
	Alkalinity as HCO3	139	1.45	2			063871-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063871-018	EPA 310.1
TA2-SW1-320 29-Jan-04	Bromide	0.397	0.0978	0.2			063873-013	SW846 9056
	Chloride	26.2	0.0644	0.4			063873-013	SW846 9056
	Fluoride	0.444	0.0553	0.1			063873-013	SW846 9056
	Sulfate	13.6	0.193	0.4			063873-013	SW846 9056
	Calcium	67.3	0.04	0.1			063873-014	SW846 3005
	Magnesium	11.3	0.00633	0.01			063873-014	SW846 3005
	Potassium	2.02	0.0151	0.3			063873-014	SW846 3005
	Sodium	19.6	0.00968	0.25	B	J	063873-014	SW846 3005
	Total Alkalinity as CaCO3	109	1.45	2			063873-018	EPA 310.1
	Alkalinity as HCO3	108	1.45	2			063873-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063873-018	EPA 310.1
TA2-W-01 12-Jan-04	Bromide	1.57	0.0978	0.2			063876-013	SW846 9056
	Chloride	103	0.322	2			063876-013	SW846 9056
	Fluoride	0.300	0.0553	0.1			063876-013	SW846 9056
	Sulfate	45.5	1.93	4			063876-013	SW846 9056
	Calcium	89.9	0.04	0.1	B		063876-014	SW846 3005
	Magnesium	11.5	0.00633	0.01			063876-014	SW846 3005
	Potassium	2.11	0.0151	0.3	B		063876-014	SW846 3005
	Sodium	24.2	0.00968	0.25		J	063876-014	SW846 3005
	Total Alkalinity as CaCO3	94.1	1.45	2			063876-018	EPA 310.1
	Alkalinity as HCO3	93.2	1.45	2			063876-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063876-018	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TA2-W-19	Bromide	0.966	0.0978	0.2			063878-013	SW846 9056
13-Jan-04	Chloride	71.9	0.322	2			063878-013	SW846 9056
	Fluoride	0.333	0.0553	0.1			063878-013	SW846 9056
	Sulfate	56.8	1.93	4			063878-013	SW846 9056
	Calcium	81.4	0.04	0.1			063878-014	SW846 3005
	Magnesium	11.0	0.00633	0.01			063878-014	SW846 3005
	Potassium	1.75	0.0151	0.3			063878-014	SW846 3005
	Sodium	20.1	0.00968	0.25			063878-014	SW846 3005
	Total Alkalinity as CaCO3	100	1.45	2			063878-018	EPA 310.1
	Alkalinity as HCO3	99.1	1.45	2			063878-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063878-018	EPA 310.1
TA2-W-26	Bromide	1.83	0.0978	0.2	B		063880-013	SW846 9056
20-Jan-04	Chloride	146	0.322	2			063880-013	SW846 9056
	Fluoride	0.216	0.0553	0.1			063880-013	SW846 9056
	Sulfate	268	1.93	4			063880-013	SW846 9056
	Calcium	175	0.2	0.5			063880-014	SW846 3005
	Magnesium	23.2	0.00633	0.01		J	063880-014	SW846 3005
	Potassium	2.51	0.0151	0.3			063880-014	SW846 3005
	Sodium	32.0	0.00968	0.25		J	063880-014	SW846 3005
	Total Alkalinity as CaCO3	93.1	1.45	2			063880-018	EPA 310.1
	Alkalinity as HCO3	92.7	1.45	2			063880-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063880-018	EPA 310.1
TA2-W-27	Bromide	2.19	0.0978	0.2	B		063885-013	SW846 9056
15-Jan-04	Chloride	118	0.644	4			063885-013	SW846 9056
	Fluoride	0.220	0.0553	0.1			063885-013	SW846 9056
	Sulfate	160	3.86	8			063885-013	SW846 9056
	Calcium	128	0.04	0.1	B		063885-014	SW846 3005
	Magnesium	15.9	0.00633	0.01			063885-014	SW846 3005
	Potassium	2.11	0.0151	0.3			063885-014	SW846 3005
	Sodium	28.3	0.00968	0.25	B		063885-014	SW846 3005
	Total Alkalinity as CaCO3	92	1.45	2			063885-018	EPA 310.1
	Alkalinity as HCO3	91.7	1.45	2			063885-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063885-018	EPA 310.1
TJA-2	Bromide	1.41	0.0978	0.2	B		063887-013	SW846 9056
19-Jan-04	Chloride	70.2	0.322	2			063887-013	SW846 9056
	Fluoride	0.278	0.0553	0.1			063887-013	SW846 9056
	Sulfate	54.6	1.93	4			063887-013	SW846 9056
	Calcium	81.1	0.04	0.1			063887-014	SW846 3005
	Magnesium	12.8	0.00633	0.01			063887-014	SW846 3005
	Potassium	1.85	0.0151	0.3	B		063887-014	SW846 3005
	Sodium	25	0.00968	0.25			063887-014	SW846 3005
	Total Alkalinity as CaCO3	107	1.45	2			063887-018	EPA 310.1
	Alkalinity as HCO3	106	1.45	2			063887-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063887-018	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TJA-3	Bromide	0.824	0.0978	0.2	B		063889-013	SW846 9056
27-Jan-04	Chloride	13.6	0.0322	0.2			063889-013	SW846 9056
	Fluoride	0.280	0.0553	0.1			063889-013	SW846 9056
	Sulfate	74.1	0.965	2			063889-013	SW846 9056
	Calcium	67.6	0.04	0.1	B		063889-014	SW846 3005
	Magnesium	10.3	0.00633	0.01		J	063889-014	SW846 3005
	Potassium	1.86	0.0151	0.3	B		063889-014	SW846 3005
	Sodium	21.6	0.00968	0.25			063889-014	SW846 3005
	Total Alkalinity as CaCO3	160	1.45	2			063889-018	EPA 310.1
	Alkalinity as HCO3	160	1.45	2			063889-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063889-018	EPA 310.1
TJA-4	Bromide	0.354	0.0978	0.2			063891-013	SW846 9056
29-Jan-04	Chloride	21.7	0.0644	0.4			063891-013	SW846 9056
	Fluoride	0.404	0.0553	0.1			063891-013	SW846 9056
	Sulfate	18.5	0.193	0.4			063891-013	SW846 9056
	Calcium	73.6	0.04	0.1			063891-014	SW846 3005
	Magnesium	15.4	0.00633	0.01			063891-014	SW846 3005
	Potassium	3.46	0.0151	0.3			063891-014	SW846 3005
	Sodium	27.8	0.00968	0.25	B	J	063891-014	SW846 3005
	Total Alkalinity as CaCO3	133	1.45	2			063891-018	EPA 310.1
	Alkalinity as HCO3	133	1.45	2			063891-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063891-018	EPA 310.1
TJA-6	Bromide	0.255	0.0978	0.2			063893-013	SW846 9056
04-Feb-04	Chloride	15.1	0.0322	0.2			063893-013	SW846 9056
	Fluoride	0.418	0.0553	0.1			063893-013	SW846 9056
	Sulfate	61.5	0.965	2			063893-013	SW846 9056
	Calcium	60.7	0.04	0.1		J	063893-014	SW846 3005
	Magnesium	10.9	0.00633	0.01			063893-014	SW846 3005
	Potassium	2.24	0.0151	0.3			063893-014	SW846 3005
	Sodium	20.4	0.00968	0.25	B	J	063893-014	SW846 3005
	Total Alkalinity as CaCO3	160	1.45	2			063893-018	EPA 310.1
	Alkalinity as HCO3	160	1.45	2			063893-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063893-018	EPA 310.1
TJA-7	Bromide	0.565	0.0978	0.2	B	B, B3, J	063895-013	SW846 9056
22-Jan-04	Chloride	30.9	0.322	2			063895-013	SW846 9056
	Fluoride	0.310	0.0553	0.1			063895-013	SW846 9056
	Sulfate	18.2	0.193	0.4			063895-013	SW846 9056
	Calcium	72.1	0.04	0.1	B	J	063895-014	SW846 3005
	Magnesium	12.5	0.00633	0.01		J	063895-014	SW846 3005
	Potassium	2.14	0.0151	0.3	B		063895-014	SW846 3005
	Sodium	17.6	0.00968	0.25	B	J	063895-014	SW846 3005
	Total Alkalinity as CaCO3	130	1.45	2			063895-014	EPA 310.1
	Alkalinity as HCO3	130	1.45	2			063895-014	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063895-014	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
WYO-3 21-Jan-04	Bromide	0.900	0.0978	0.2	B	B, J	063897-013	SW846 9056
	Chloride	16.3	0.0322	0.2			063897-013	SW846 9056
	Fluoride	0.398	0.0553	0.1			063897-013	SW846 9056
	Sulfate	88.6	1.93	4			063897-013	SW846 9056
	Calcium	67.4	0.04	0.1			063897-014	SW846 3005
	Magnesium	13.3	0.00633	0.01			063897-014	SW846 3005
	Potassium	2.25	0.0151	0.3			063897-014	SW846 3005
	Sodium	24.3	0.00968	0.25			063897-014	SW846 3005
	Total Alkalinity as CaCO3	172	1.45	2			063897-018	EPA 310.1
	Alkalinity as HCO3	171	1.45	2			063897-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063897-018	EPA 310.1
WYO-4 03-Feb-04	Bromide	1.15	0.0978	0.2			063899-013	SW846 9056
	Chloride	97.2	0.322	2			063899-013	SW846 9056
	Fluoride	0.365	0.0553	0.1			063899-013	SW846 9056
	Sulfate	49.2	1.93	4			063899-013	SW846 9056
	Calcium	89.3	0.04	0.1			063899-014	SW846 3005
	Magnesium	15.5	0.00633	0.01			063899-014	SW846 3005
	Potassium	2.01	0.0151	0.3			063899-014	SW846 3005
	Sodium	21.6	0.00968	0.25			063899-014	SW846 3005
	Total Alkalinity as CaCO3	95.1	1.45	2			063899-018	EPA 310.1
	Alkalinity as HCO3	94.3	1.45	2			063899-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2	U		063899-018	EPA 310.1

mg/L = milligrams per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
B = Analyte is detected in associated laboratory method blank.
B3 = Analyte is detected in associated laboratory calibration blank.
U = Analyte not detected above the MDL.

Table A-17
Summary of Anion, Cation, and Alkalinity Results

Tijeras Arroyo Groundwater Investigation

Fiscal Year 2004, 3rd Quarter

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
Eubank-1	Bromide	0.14	0.02	0.25	J		064600-013	SW846 9056
20-May-04	Chloride	12.7	0.43	2			064600-013	SW846 9056
	Fluoride	0.35	0.0032	0.10			064600-013	SW846 9056
	Sulfate	78.9	0.37	5			064600-013	SW846 9056
	Calcium	65.8	0.035	0.50			064600-014	SW846 6020
	Magnesium	9.8	0.0022	0.10	B		064600-014	SW846 6020
	Potassium	1.6	0.013	0.50	B		064600-014	SW846 6020
	Sodium	24.6	0.0064	0.50	B		064600-014	SW846 6020
	Total Alkalinity as CaCO3	164	1.2	5			064600-018	EPA 310.1
	Alkalinity as HCO3	164	1.2	5			064600-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		064600-018	EPA 310.1
Eubank-2	Bromide	0.15	0.02	0.25	J		064602-013	SW846 9056
06-May-04	Chloride	11.9	0.43	2			064602-013	SW846 9056
	Fluoride	0.23	0.0032	0.10			064602-013	SW846 9056
	Sulfate	93.1	0.37	5			064602-013	SW846 9056
	Calcium	73	0.035	0.50		J	064602-014	SW846 6020
	Magnesium	11.3	0.0022	0.10			064602-014	SW846 6020
	Potassium	2.1	0.013	0.50			064602-014	SW846 6020
	Sodium	29.9	0.0064	0.50			064602-014	SW846 6020
	Total Alkalinity as CaCO3	199	1.2	5			064602-018	EPA 310.1
	Alkalinity as HCO3	199	1.2	5			064602-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		064602-018	EPA 310.1
Eubank-3	Bromide	0.19	0.02	0.25	J		064604-013	SW846 9056
04-May-04	Chloride	18.1	0.43	2			064604-013	SW846 9056
	Fluoride	0.31	0.0032	0.10			064604-013	SW846 9056
	Sulfate	82.6	0.37	5			064604-013	SW846 9056
	Calcium	72.9	0.035	0.50		J	064604-014	SW846 6020
	Magnesium	11.8	0.0022	0.10			064604-014	SW846 6020
	Potassium	1.8	0.013	0.50			064604-014	SW846 6020
	Sodium	29.8	0.0064	0.50			064604-014	SW846 6020
	Total Alkalinity as CaCO3	188	1.2	5			064604-018	EPA 310.1
	Alkalinity as HCO3	188	1.2	5			064604-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		064604-018	EPA 310.1
Eubank-5	Bromide	0.22	0.02	0.25	J		064607-013	SW846 9056
03-May-04	Chloride	23.4	0.43	2			064607-013	SW846 9056
	Fluoride	0.28	0.0032	0.10			064607-013	SW846 9056
	Sulfate	84.7	0.37	5			064607-013	SW846 9056
	Calcium	77.0	0.035	0.50			064607-014	SW846 6020
	Magnesium	11.8	0.0022	0.10			064607-014	SW846 6020

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Potassium	1.9	0.013	0.50			064607-014	SW846 6020
	Sodium	30.9	0.0064	0.50			064607-014	SW846 6020
	Total Alkalinity as CaCO3	195	1.2	5			064607-018	EPA 310.1
	Alkalinity as HCO3	195	1.2	5			064607-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		064607-018	EPA 310.1
PGS-2	Bromide	0.18	0.02	0.25	J		064551-013	SW846 9056
12-May-04	Chloride	14.1	0.43	2	B		064551-013	SW846 9056
	Fluoride	ND	0.0032	0.10	U		064551-013	SW846 9056
	Sulfate	64.1	0.37	5			064551-013	SW846 9056
	Calcium	50.9	0.035	0.50	B		064551-014	SW846 6020
	Magnesium	11.5	0.0022	0.10		J	064551-014	SW846 6020
	Potassium	2.7	0.013	0.50			064551-014	SW846 6020
	Sodium	39.9	0.0064	0.50			064551-014	SW846 6020
	Total Alkalinity as CaCO3	179	1.2	5.0			064551-018	EPA 310.1
	Alkalinity as HCO3	179	1.2	5.0			064551-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064551-018	EPA 310.1
TA1-W-01	Bromide	0.18	0.02	0.25	J		064553-013	SW846 9056
10-May-04	Chloride	14.7	0.43	2			064553-013	SW846 9056
	Fluoride	0.40	0.0032	0.10			064553-013	SW846 9056
	Sulfate	78.0	0.37	5			064553-013	SW846 9056
	Calcium	61.0	0.035	0.50		J	064553-014	SW846 6020
	Magnesium	12.4	0.0022	0.10			064553-014	SW846 6020
	Potassium	2.2	0.013	0.50			064553-014	SW846 6020
	Sodium	24.7	0.0064	0.50			064553-014	SW846 6020
	Total Alkalinity as CaCO3	165	1.2	5.0			064553-018	EPA 310.1
	Alkalinity as HCO3	165	1.2	5.0			064553-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064553-018	EPA 310.1
TA1-W-02	Bromide	0.16	0.02	0.25	J		064556-013	SW846 9056
11-May-04	Chloride	13.7	0.43	2			064556-013	SW846 9056
	Fluoride	0.34	0.0032	0.10			064556-013	SW846 9056
	Sulfate	81.0	0.37	5			064556-013	SW846 9056
	Calcium	67.3	0.035	0.50	B		064556-014	SW846 6020
	Magnesium	12.8	0.0022	0.10		J	064556-014	SW846 6020
	Potassium	2.1	0.013	0.50			064556-014	SW846 6020
	Sodium	23.2	0.0064	0.50			064556-014	SW846 6020
	Total Alkalinity as CaCO3	173	1.2	5.0			064556-018	EPA 310.1
	Alkalinity as HCO3	173	1.2	5.0			064556-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064556-018	EPA 310.1
TA1-W-03	Bromide	3.0	0.02	0.25			064558-013	SW846 9056
28-Apr-04	Chloride	230	4.3	20			064558-013	SW846 9056
	Fluoride	0.21	0.0032	0.10			064558-013	SW846 9056
	Sulfate	449	3.7	50			064558-013	SW846 9056
	Calcium	227	0.01745	0.50	N		064558-014	SW846 6020
	Magnesium	29.9	0.001099	0.10			064558-014	SW846 6020
	Potassium	2.6	0.006374	0.50	E		064558-014	SW846 6020
	Sodium	44.4	0.003203	0.50			064558-014	SW846 6020

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Total Alkalinity as CaCO3	70	1.2	5.0			064558-018	EPA 310.1
	Alkalinity as HCO3	70	1.2	5.0			064558-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064558-018	EPA 310.1
TA1-W-04	Bromide	0.15	0.02	0.25	B		064560-013	SW846 9056
26-Apr-04	Chloride	14.3	0.43	2			064560-013	SW846 9056
	Fluoride	0.31	0.0032	0.10			064560-013	SW846 9056
	Sulfate	60.3	0.37	5			064560-013	SW846 9056
	Calcium	61.2	0.01745	0.50	N		064560-014	SW846 6020
	Magnesium	10.9	0.001099	0.10			064560-014	SW846 6020
	Potassium	2.4	0.006374	0.50	E		064560-014	SW846 6020
	Sodium	23.2	0.003203	0.50			064560-014	SW846 6020
	Total Alkalinity as CaCO3	170	1.2	5.0			064560-018	EPA 310.1
	Alkalinity as HCO3	170	1.2	5.0			064560-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064560-018	EPA 310.1
TA1-W-05	Bromide	0.13	0.02	0.25	J		064562-013	SW846 9056
07-May-04	Chloride	11.5	0.43	2			064562-013	SW846 9056
	Fluoride	0.27	0.0032	0.10			064562-013	SW846 9056
	Sulfate	99.2	0.37	5			064562-013	SW846 9056
	Calcium	75.9	0.035	0.50		J	064562-014	SW846 6020
	Magnesium	11.7	0.0022	0.10			064562-014	SW846 6020
	Potassium	2.1	0.013	0.50			064562-014	SW846 6020
	Sodium	29.9	0.0064	0.50			064562-014	SW846 6020
	Total Alkalinity as CaCO3	201	1.2	5.0			064562-018	EPA 310.1
	Alkalinity as HCO3	201	1.2	5.0			064562-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064562-018	EPA 310.1
TA1-W-06	Bromide	1.2	0.02	0.25			064564-013	SW846 9056
21-May-04	Chloride	101	4.3	20			064564-013	SW846 9056
	Fluoride	0.32	0.0032	0.10			064564-013	SW846 9056
	Sulfate	195	3.7	50			064564-013	SW846 9056
	Calcium	98.7	0.035	0.50			064564-014	SW846 6020
	Magnesium	12.2	0.0022	0.10	B		064564-014	SW846 6020
	Potassium	1.7	0.013	0.50	B		064564-014	SW846 6020
	Sodium	27.3	0.0064	0.50	B		064564-014	SW846 6020
	Total Alkalinity as CaCO3	85	1.2	5.0			064564-018	EPA 310.1
	Alkalinity as HCO3	85	1.2	5.0			064564-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064564-018	EPA 310.1
TA1-W-08	Bromide	2.4	0.02	0.25			064566-013	SW846 9056
23-Apr-04	Chloride	190	4.3	20			064566-013	SW846 9056
	Fluoride	0.19	0.0032	0.10			064566-013	SW846 9056
	Sulfate	570	3.7	50			064566-013	SW846 9056
	Calcium	285	0.01745	0.50	N		064566-014	SW846 6020
	Magnesium	37.3	0.001099	0.10			064566-014	SW846 6020
	Potassium	3.0	0.006374	0.50	E		064566-014	SW846 6020
	Sodium	69.9	0.003203	0.50			064566-014	SW846 6020
	Total Alkalinity as CaCO3	86	1.2	5.0			064566-018	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Alkalinity as HCO3	86	1.2	5.0			064566-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064566-018	EPA 310.1
TA2-NW1-595 13-May-04 (QED)	Bromide	1.2	0.02	0.25			064568-013	SW846 9056
	Chloride	92.8	4.3	20			064568-013	SW846 9056
	Fluoride	0.26	0.0032	0.10			064568-013	SW846 9056
	Sulfate	117	3.7	50			064568-013	SW846 9056
	Calcium	99.3	0.035	0.50	B		064568-014	SW846 6020
	Magnesium	16.4	0.0022	0.10			064568-014	SW846 6020
	Potassium	2.3	0.013	0.50			064568-014	SW846 6020
	Sodium	30	0.0064	0.50			064568-014	SW846 6020
	Total Alkalinity as CaCO3	144	1.2	5.0			064568-018	EPA 310.1
	Alkalinity as HCO3	144	1.2	5.0			064568-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064568-018	EPA 310.1
TA2-NW1-595 19-May-04 (Bennett)	Bromide	1.2	0.02	0.25			064571-013	SW846 9056
	Chloride	86.2	4.3	20			064571-013	SW846 9056
	Fluoride	0.25	0.0032	0.10			064571-013	SW846 9056
	Sulfate	111	3.7	50			064571-013	SW846 9056
	Calcium	98.1	0.035	0.50			064571-014	SW846 6020
	Magnesium	15.9	0.0022	0.10	B		064571-014	SW846 6020
	Potassium	2.2	0.013	0.50	B		064571-014	SW846 6020
	Sodium	28.9	0.0064	0.50	B		064571-014	SW846 6020
	Total Alkalinity as CaCO3	137	1.2	5.0			064571-018	EPA 310.1
	Alkalinity as HCO3	137	1.2	5.0			064571-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064571-018	EPA 310.1
TA2-SW1-320 14-May-04	Bromide	0.38	0.02	0.25			064573-013	SW846 9056
	Chloride	27.1	0.87	4			064573-013	SW846 9056
	Fluoride	0.39	0.0032	0.10			064573-013	SW846 9056
	Sulfate	14.8	0.75	10			064573-013	SW846 9056
	Calcium	56.9	0.035	0.50			064573-014	SW846 6020
	Magnesium	10	0.0022	0.10	B		064573-014	SW846 6020
	Potassium	1.7	0.013	0.50	B		064573-014	SW846 6020
	Sodium	17	0.0064	0.50	B		064573-014	SW846 6020
	Total Alkalinity as CaCO3	109	1.2	5.0			064573-018	EPA 310.1
	Alkalinity as HCO3	109	1.2	5.0			064573-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064573-018	EPA 310.1
TA2-W-01 17-May-04	Bromide	1.8	0.02	0.25			064575-013	SW846 9056
	Chloride	108	4.3	20			064575-013	SW846 9056
	Fluoride	0.42	0.0032	0.10			064575-013	SW846 9056
	Sulfate	52.3	0.37	5.0			064575-013	SW846 9056
	Calcium	82.7	0.035	0.50			064575-014	SW846 6020
	Magnesium	11.1	0.0022	0.10	B		064575-014	SW846 6020
	Potassium	1.8	0.013	0.50	B		064575-014	SW846 6020
	Sodium	20.9	0.0064	0.50	B		064575-014	SW846 6020
	Total Alkalinity as CaCO3	95	1.2	5.0			064575-018	EPA 310.1
	Alkalinity as HCO3	95	1.2	5.0			064575-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064575-018	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TA2-W-19	Bromide	0.90	0.02	0.25			064577-013	SW846 9056
27-Apr-04	Chloride	74.6	0.87	4			064577-013	SW846 9056
	Fluoride	0.28	0.0032	0.10			064577-013	SW846 9056
	Sulfate	57.5	0.75	10			064577-013	SW846 9056
	Calcium	71.5	0.01745	0.50	N		064577-014	SW846 6020
	Magnesium	11.3	0.001099	0.10			064577-014	SW846 6020
	Potassium	1.8	0.006374	0.50	E		064577-014	SW846 6020
	Sodium	22	0.003203	0.50			064577-014	SW846 6020
	Total Alkalinity as CaCO3	104	1.2	5.0			064577-018	EPA 310.1
	Alkalinity as HCO3	104	1.2	5.0			064577-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064577-018	EPA 310.1
TA2-W-26	Bromide	1.7	0.02	0.25			064580-013	SW846 9056
21-Apr-04	Chloride	130	4.3	20			064580-013	SW846 9056
	Fluoride	0.23	0.0032	0.10			064580-013	SW846 9056
	Sulfate	246	3.7	50			064580-013	SW846 9056
	Calcium	175	0.01745	0.50			064580-014	SW846 6020
	Magnesium	21.6	0.001099	0.10			064580-014	SW846 6020
	Potassium	2.3	0.006374	0.50			064580-014	SW846 6020
	Sodium	33.8	0.003203	0.50	B		064580-014	SW846 6020
	Total Alkalinity as CaCO3	104	1.2	5.0			064580-018	EPA 310.1
	Alkalinity as HCO3	104	1.2	5.0			064580-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064580-018	EPA 310.1
TA2-W-27	Bromide	1.6	0.02	0.25			064583-013	SW846 9056
19-Apr-04	Chloride	200	4.3	20			064583-013	SW846 9056
	Fluoride	0.24	0.0032	0.10			064583-013	SW846 9056
	Sulfate	164	3.7	50			064583-013	SW846 9056
	Calcium	131	0.01745	0.50			064583-014	SW846 6020
	Magnesium	17.2	0.001099	0.10			064583-014	SW846 6020
	Potassium	2.1	0.006374	0.50			064583-014	SW846 6020
	Sodium	29.1	0.003203	0.50	B		064583-014	SW846 6020
	Total Alkalinity as CaCO3	93	1.2	5			064583-018	EPA 310.1
	Alkalinity as HCO3	93	1.2	5			064583-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		064583-018	EPA 310.1
TJA-2	Bromide	1.1	0.02	0.25			064585-013	SW846 9056
05-May-04	Chloride	69.8	0.87	4			064585-013	SW846 9056
	Fluoride	0.28	0.0032	0.10			064585-013	SW846 9056
	Sulfate	52.9	0.75	10			064585-013	SW846 9056
	Calcium	70.8	0.035	0.50		J	064585-014	SW846 6020
	Magnesium	11.7	0.0022	0.10			064585-014	SW846 6020
	Potassium	1.7	0.013	0.50			064585-014	SW846 6020
	Sodium	22	0.0064	0.50			064585-014	SW846 6020
	Total Alkalinity as CaCO3	104	1.2	5.0			064585-018	EPA 310.1
	Alkalinity as HCO3	104	1.2	5.0			064585-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064585-018	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TJA-3	Bromide	0.17	0.02	0.25	B		064587-013	SW846 9056
27-Apr-04	Chloride	12.5	0.43	2			064587-013	SW846 9056
	Fluoride	0.30	0.0032	0.10			064587-013	SW846 9056
	Sulfate	71.1	0.37	5			064587-013	SW846 9056
	Calcium	60.9	0.01745	0.50	N		064587-014	SW846 6020
	Magnesium	11.1	0.001099	0.10			064587-014	SW846 6020
	Potassium	1.9	0.006374	0.50	E		064587-014	SW846 6020
	Sodium	23.4	0.003203	0.50			064587-014	SW846 6020
	Total Alkalinity as CaCO3	98	1.2	5.0			064587-018	EPA 310.1
	Alkalinity as HCO3	98	1.2	5.0			064587-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064587-018	EPA 310.1
TJA-4	Bromide	0.30	0.02	0.25			064589-013	SW846 9056
20-Apr-04	Chloride	20	0.43	2			064589-013	SW846 9056
	Fluoride	0.34	0.0032	0.10			064589-013	SW846 9056
	Sulfate	19.1	0.037	0.50			064589-013	SW846 9056
	Calcium	93.4	0.01745	0.50			064589-014	SW846 6020
	Magnesium	39.1	0.001099	0.10			064589-014	SW846 6020
	Potassium	28.3	0.006374	0.50			064589-014	SW846 6020
	Sodium	50.6	0.003203	0.50	B		064589-014	SW846 6020
	Total Alkalinity as CaCO3	134	1.2	5			064589-018	EPA 310.1
	Alkalinity as HCO3	134	1.2	5			064589-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		064589-018	EPA 310.1
TJA-6	Bromide	0.18	0.02	0.25	J		064591-013	SW846 9056
22-Apr-04	Chloride	14.6	0.43	2			064591-013	SW846 9056
	Fluoride	0.33	0.0032	0.10			064591-013	SW846 9056
	Sulfate	61.8	0.37	5			064591-013	SW846 9056
	Calcium	65.2	0.01745	0.50			064591-014	SW846 6020
	Magnesium	11.7	0.001099	0.10			064591-014	SW846 6020
	Potassium	2.3	0.006374	0.50			064591-014	SW846 6020
	Sodium	23.5	0.003203	0.50	B		064591-014	SW846 6020
	Total Alkalinity as CaCO3	158	1.2	5			064591-018	EPA 310.1
	Alkalinity as HCO3	158	1.2	5			064591-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		064591-018	EPA 310.1
TJA-7	Bromide	0.42	0.02	0.25			064593-013	SW846 9056
30-Apr-04	Chloride	29.0	0.43	2			064593-013	SW846 9056
	Fluoride	0.30	0.0032	0.10			064593-013	SW846 9056
	Sulfate	16.2	0.037	0.50			064593-013	SW846 9056
	Calcium	63.6	0.035	0.50			064593-014	SW846 6020
	Magnesium	12.1	0.0022	0.10			064593-014	SW846 6020
	Potassium	1.9	0.013	0.50			064593-014	SW846 6020
	Sodium	18.4	0.0064	0.50			064593-014	SW846 6020
	Total Alkalinity as CaCO3	128	1.2	5			064593-018	EPA 310.1
	Alkalinity as HCO3	128	1.2	5			064593-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		064593-018	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
WYO-3 28-Apr-04	Bromide	0.18	0.02	0.25	B		064595-013	SW846 9056
	Chloride	14.1	0.43	2			064595-013	SW846 9056
	Fluoride	0.37	0.0032	0.10			064595-013	SW846 9056
	Sulfate	82.8	0.37	5			064595-013	SW846 9056
	Calcium	63.8	0.01745	0.50	N		064595-014	SW846 6020
	Magnesium	11.8	0.001099	0.10			064595-014	SW846 6020
	Potassium	2.2	0.006374	0.50	E		064595-014	SW846 6020
	Sodium	24.4	0.003203	0.50			064595-014	SW846 6020
	Total Alkalinity as CaCO3	156	1.2	5.0			064595-018	EPA 310.1
	Alkalinity as HCO3	156	1.2	5.0			064595-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064595-018	EPA 310.1
WYO-4 30-Apr-04	Bromide	0.49	0.02	0.25			064597-013	SW846 9056
	Chloride	84.4	0.87	4			064597-013	SW846 9056
	Fluoride	0.14	0.0032	0.10			064597-013	SW846 9056
	Sulfate	38	0.75	10			064597-013	SW846 9056
	Calcium	75.2	0.035	0.50			064597-014	SW846 6020
	Magnesium	12.6	0.0022	0.10			064597-014	SW846 6020
	Potassium	1.8	0.013	0.50			064597-014	SW846 6020
	Sodium	19.2	0.0064	0.50			064597-014	SW846 6020
	Total Alkalinity as CaCO3	96	1.2	5.0			064597-018	EPA 310.1
	Alkalinity as HCO3	96	1.2	5.0			064597-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5.0	U		064597-018	EPA 310.1

mg/L = milligrams per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
B = Analyte is detected in associated laboratory method blank.
U = Analyte not detected above the MDL.
E = Concentration exceeds calibration range of instrument and/or estimated quantity due to matrix interference.

Table A-18
Summary of Anion, Cation, and Alkalinity Results

Tijeras Arroyo Groundwater Investigation

Fiscal Year 2004, 4th Quarter

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
Eubank-1	Bromide	0.17	0.02	0.25	J		065416-013	SW846 9056
18-Aug-04	Chloride	12.3	0.43	2			065416-013	SW846 9056
	Fluoride	0.34	0.01	0.10			065416-013	SW846 9056
	Sulfate	75.5	0.37	5			065416-013	SW846 9056
	Calcium	66.6	0.035	0.50	B		065416-014	SW846 6020
	Magnesium	9.7	0.0022	0.10	B		065416-014	SW846 6020
	Potassium	1.6	0.013	0.50	B		065416-014	SW846 6020
	Sodium	24.6	0.0064	0.50	B		065416-014	SW846 6020
	Total Alkalinity as CaCO3	166	1.2	5			065416-018	EPA 310.1
	Alkalinity as HCO3	166	1.2	5			065416-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065416-018	EPA 310.1
PGS-2	Bromide	0.18	0.02	0.25	J		065360-013	SW846 9056
28-Jul-04	Chloride	14.6	0.43	2			065360-013	SW846 9056
	Fluoride	0.089	0.01	0.10	J		065360-013	SW846 9056
	Sulfate	61.4	0.37	5			065360-013	SW846 9056
	Calcium	50	0.035	0.50	B	J	065360-014	SW846 6020
	Magnesium	2.3	0.0022	0.10	B	J	065360-014	SW846 6020
	Potassium	10.5	0.013	0.50	B		065360-014	SW846 6020
	Sodium	30.6	0.0064	0.50	B	J	065360-014	SW846 6020
	Total Alkalinity as CaCO3	98	1.2	5			065360-018	EPA 310.1
	Alkalinity as HCO3	98	1.2	5			065360-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065360-018	EPA 310.1
TA1-W-01	Bromide	0.16	0.02	0.25	J		065362-013	SW846 9056
17-Aug-04	Chloride	14.1	0.43	2	B		065362-013	SW846 9056
	Fluoride	0.35	0.01	0.10			065362-013	SW846 9056
	Sulfate	76.1	0.37	5			065362-013	SW846 9056
	Calcium	64.7	0.035	0.50	B		065362-014	SW846 6020
	Magnesium	12.6	0.0022	0.10	B		065362-014	SW846 6020
	Potassium	2.2	0.013	0.50	B		065362-014	SW846 6020
	Sodium	25.3	0.0064	0.50	B		065362-014	SW846 6020
	Total Alkalinity as CaCO3	170	1.2	5			065362-018	EPA 310.1
	Alkalinity as HCO3	170	1.2	5			065362-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065362-018	EPA 310.1
TA1-W-02	Bromide	0.16	0.02	0.25	J		065364-013	SW846 9056
13-Aug-04	Chloride	13.9	0.43	2	B		065364-013	SW846 9056
	Fluoride	0.32	0.01	0.10			065364-013	SW846 9056
	Sulfate	82.4	0.37	5			065364-013	SW846 9056
	Calcium	67.5	0.035	1	B	A2, J, P1	065364-014	SW846 6020
	Magnesium	13.1	0.0022	0.2	B	A, J, P1	065364-014	SW846 6020
	Potassium	2.0	0.013	1	B		065364-014	SW846 6020

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Sodium	23.2	0.0064	1	B		065364-014	SW846 6020
	Total Alkalinity as CaCO3	171	1.2	5			065364-018	EPA 310.1
	Alkalinity as HCO3	171	1.2	5			065364-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065364-018	EPA 310.1
TA1-W-03	Bromide	3.5	0.02	0.25			065366-013	SW846 9056
18-Aug-04	Chloride	245	4.3	20			065366-013	SW846 9056
	Fluoride	0.25	0.01	0.10			065366-013	SW846 9056
	Sulfate	470	3.7	50			065366-013	SW846 9056
	Calcium	280	0.035	0.50	B		065366-014	SW846 6020
	Magnesium	33.1	0.0022	0.10	B		065366-014	SW846 6020
	Potassium	2.7	0.013	0.50	B		065366-014	SW846 6020
	Sodium	49.9	0.0064	0.50	B		065366-014	SW846 6020
	Total Alkalinity as CaCO3	65	1.2	5			065366-018	EPA 310.1
	Alkalinity as HCO3	65	1.2	5			065366-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065366-018	EPA 310.1
TA1-W-04	Bromide	0.16	0.02	0.25	J		065368-013	SW846 9056
26-Jul-04	Chloride	16.2	0.43	2			065368-013	SW846 9056
	Fluoride	0.27	0.01	0.10			065368-013	SW846 9056
	Sulfate	61.7	0.37	5			065368-013	SW846 9056
	Calcium	61.9	0.035	0.50	B		065368-014	SW846 6020
	Magnesium	9.6	0.0022	0.10	B	J	065368-014	SW846 6020
	Potassium	2.1	0.013	0.50	B		065368-014	SW846 6020
	Sodium	22.5	0.0064	0.50	B		065368-014	SW846 6020
	Total Alkalinity as CaCO3	168	1.2	5			065368-018	EPA 310.1
	Alkalinity as HCO3	168	1.2	5			065368-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065368-018	EPA 310.1
TA1-W-05	Bromide	0.13	0.02	0.25	J		065370-013	SW846 9056
20-Aug-04	Chloride	11.5	0.43	2			065370-013	SW846 9056
	Fluoride	0.24	0.01	0.10			065370-013	SW846 9056
	Sulfate	97.2	0.37	5			065370-013	SW846 9056
	Calcium	78.6	0.035	0.50	B		065370-014	SW846 6020
	Magnesium	12.2	0.0022	0.10	B		065370-014	SW846 6020
	Potassium	2.2	0.013	0.50	B		065370-014	SW846 6020
	Sodium	31.2	0.0064	0.50	B		065370-014	SW846 6020
	Total Alkalinity as CaCO3	202	1.2	5			065370-018	EPA 310.1
	Alkalinity as HCO3	202	1.2	5			065370-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065370-018	EPA 310.1
TA1-W-06	Bromide	1.4	0.02	0.25			065372-013	SW846 9056
06-Aug-04	Chloride	98.1	4.3	20			065372-013	SW846 9056
	Fluoride	0.28	0.01	0.10			065372-013	SW846 9056
	Sulfate	188	0.037	50			065372-013	SW846 9056
	Calcium	150	0.035	1	B	A2, J	065372-014	SW846 6020
	Magnesium	19.2	0.0022	0.2	B	J	065372-014	SW846 6020
	Potassium	2.3	0.013	1	B		065372-014	SW846 6020
	Sodium	39.5	0.0064	1	B		065372-014	SW846 6020
	Total Alkalinity as	87	1.2	5			065372-018	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	CaCO3							
	Alkalinity as HCO3	87	1.2	5			065372-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065372-018	EPA 310.1
TA1-W-08 13-Aug-04	Bromide	2.8	0.02	0.25			065374-013	SW846 9056
	Chloride	213	4.3	20	B		065374-013	SW846 9056
	Fluoride	0.38	0.01	0.10			065374-013	SW846 9056
	Sulfate	666	3.7	50			065374-013	SW846 9056
	Calcium	336	0.035	1	B	A2, J, P1	065374-014	SW846 6020
	Magnesium	44.7	0.0022	0.2	B	A, J, P1	065374-014	SW846 6020
	Potassium	3.2	0.013	1	B		065374-014	SW846 6020
	Sodium	83	0.0064	1	B	J	065374-014	SW846 6020
	Total Alkalinity as CaCO3	82	1.2	5			065374-018	EPA 310.1
	Alkalinity as HCO3	82	1.2	5			065374-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065374-018	EPA 310.1
TA2-NW1-595 26-Jul-04 (QED)	Bromide	1.1	0.02	0.25			065377-013	SW846 9056
	Chloride	0.88	0.43	2			065377-013	SW846 9056
	Fluoride	0.23	0.01	0.10			065377-013	SW846 9056
	Sulfate	122	0.37	5			065377-013	SW846 9056
	Calcium	96.7	0.035	0.50	B		065377-014	SW846 6020
	Magnesium	14.6	0.0022	0.10	B	J	065377-014	SW846 6020
	Potassium	2.0	0.013	0.50	B		065377-014	SW846 6020
	Sodium	26.9	0.0064	0.50	B	J	065377-014	SW846 6020
	Total Alkalinity as CaCO3	149	1.2	5			065377-018	EPA 310.1
	Alkalinity as HCO3	149	1.2	5			065377-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065377-018	EPA 310.1
TA2-NW1-595 23-Aug-04 (Bennett)	Bromide	1.2	0.02	0.25			065379-013	SW846 9056
	Chloride	90.7	4.3	20			065379-013	SW846 9056
	Fluoride	0.24	0.01	0.10			065379-013	SW846 9056
	Sulfate	113	3.7	50			065379-013	SW846 9056
	Calcium	99.2	0.035	0.50	B		065379-014	SW846 6020
	Magnesium	18.4	0.0022	0.10	B		065379-014	SW846 6020
	Potassium	2.4	0.013	0.50	B		065379-014	SW846 6020
	Sodium	32.9	0.0064	0.50	B		065379-014	SW846 6020
	Total Alkalinity as CaCO3	140	1.2	5			065379-018	EPA 310.1
	Alkalinity as HCO3	140	1.2	5			065379-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065379-018	EPA 310.1
TA2-SW1-320 27-Jul-04	Bromide	0.38	0.02	0.25			065381-013	SW846 9056
	Chloride	27.2	0.43	2			065381-013	SW846 9056
	Fluoride	0.36	0.01	0.10			065381-013	SW846 9056
	Sulfate	14.9	0.037	0.50			065381-013	SW846 9056
	Calcium	59.5	0.035	0.50	B	J	065381-014	SW846 6020
	Magnesium	9.5	0.0022	0.10	B	J	065381-014	SW846 6020
	Potassium	1.6	0.013	0.50	B		065381-014	SW846 6020
	Sodium	16.4	0.0064	0.50	B	J	065381-014	SW846 6020
	Total Alkalinity as CaCO3	114	1.2	5			065381-018	EPA 310.1
	Alkalinity as	114	1.2	5			065381-018	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	HCO3							
	Alkalinity as CO3	ND	1.2	5	U		065381-018	EPA 310.1
TA2-W-01	Bromide	1.5	0.02	0.25			065383-013	SW846 9056
12-Aug-04	Chloride	105	4.3	20			065383-013	SW846 9056
	Fluoride	0.23	0.01	0.10			065383-013	SW846 9056
	Sulfate	48.1	0.37	5			065383-013	SW846 9056
	Calcium	93.2	0.035	1	B	A2, J	065383-014	SW846 6020
	Magnesium	13	0.0022	0.2	B	J	065383-014	SW846 6020
	Potassium	2.0	0.013	1	B		065383-014	SW846 6020
	Sodium	23.9	0.0064	1	B		065383-014	SW846 6020
	Total Alkalinity as CaCO3	106	1.2	5			065383-018	EPA 310.1
	Alkalinity as HCO3	106	1.2	5			065383-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065383-018	EPA 310.1
TA2-W-19	Bromide	1.0	0.02	0.25			065385-013	SW846 9056
27-Jul-04	Chloride	75.6	4.3	20			065385-013	SW846 9056
	Fluoride	0.26	0.01	0.10			065385-013	SW846 9056
	Sulfate	58.5	0.37	5			065385-013	SW846 9056
	Calcium	75.8	0.035	0.50	B	J	065385-014	SW846 6020
	Magnesium	10.3	0.0022	0.10	B	J	065385-014	SW846 6020
	Potassium	1.6	0.013	0.50	B		065385-014	SW846 6020
	Sodium	19.8	0.0064	0.50	B	J	065385-014	SW846 6020
	Total Alkalinity as CaCO3	106	1.2	5			065385-018	EPA 310.1
	Alkalinity as HCO3	106	1.2	5			065385-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065385-018	EPA 310.1
TA2-W-26	Bromide	1.9	0.02	0.25			065387-013	SW846 9056
30-Jul-04	Chloride	140	4.3	20			065387-013	SW846 9056
	Fluoride	0.22	0.01	0.10			065387-013	SW846 9056
	Sulfate	245	3.7	50			065387-013	SW846 9056
	Calcium	161	0.035	0.50	B		065387-014	SW846 6020
	Magnesium	18.9	0.0022	0.10	B	J	065387-014	SW846 6020
	Potassium	2.0	0.013	0.50	B		065387-014	SW846 6020
	Sodium	30.1	0.0064	0.50	B	J	065387-014	SW846 6020
	Total Alkalinity as CaCO3	90	1.2	5			065387-018	EPA 310.1
	Alkalinity as HCO3	90	1.2	5			065387-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065387-018	EPA 310.1
TA2-W-27	Bromide	1.7	0.02	0.25			065392-013	SW846 9056
28-Jul-04	Chloride	119	4.3	20			065392-013	SW846 9056
	Fluoride	0.26	0.01	0.10			065392-013	SW846 9056
	Sulfate	172	0.37	5			065392-013	SW846 9056
	Calcium	120	0.035	0.50	B	J	065392-014	SW846 6020
	Magnesium	15.1	0.0022	0.10	B	J	065392-014	SW846 6020
	Potassium	1.8	0.013	0.50	B		065392-014	SW846 6020
	Sodium	26.2	0.0064	0.50	B	J	065392-014	SW846 6020
	Total Alkalinity as CaCO3	159	1.2	5			065392-018	EPA 310.1
	Alkalinity as HCO3	159	1.2	5			065392-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065392-018	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TJA-2	Bromide	0.93	0.02	0.25			065394-013	SW846 9056
16-Aug-04	Chloride	66.3	4.3	20	B		065394-013	SW846 9056
	Fluoride	0.25	0.01	0.10			065394-013	SW846 9056
	Sulfate	55.2	0.37	5			065394-013	SW846 9056
	Calcium	76.1	0.035	1	B	A2, J, P1	065394-014	SW846 6020
	Magnesium	12.5	0.0022	0.2	B	A, J, P1	065394-014	SW846 6020
	Potassium	1.7	0.013	1	B		065394-014	SW846 6020
	Sodium	24.4	0.0064	1	B		065394-014	SW846 6020
	Total Alkalinity as CaCO3	104	1.2	5			065394-018	EPA 310.1
	Alkalinity as HCO3	104	1.2	5			065394-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065394-018	EPA 310.1
TJA-3	Bromide	0.15	0.02	0.25	J		065397-013	SW846 9056
09-Aug-04	Chloride	13.1	0.43	2			065397-013	SW846 9056
	Fluoride	0.26	0.01	0.10			065397-013	SW846 9056
	Sulfate	71.6	0.37	5			065397-013	SW846 9056
	Calcium	68.7	0.035	1	B	A2, J, P1	065397-014	SW846 6020
	Magnesium	11.8	0.0022	0.2	B	A, J, P1	065397-014	SW846 6020
	Potassium	1.8	0.013	1	B		065397-014	SW846 6020
	Sodium	25.6	0.0064	1	B		065397-014	SW846 6020
	Total Alkalinity as CaCO3	165	1.2	5			065397-018	EPA 310.1
	Alkalinity as HCO3	165	1.2	5			065399-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065399-018	EPA 310.1
TJA-4	Bromide	0.28	0.02	0.25			065399-013	SW846 9056
10-Aug-04	Chloride	20.9	0.43	2			065399-013	SW846 9056
	Fluoride	0.26	0.01	0.10			065399-013	SW846 9056
	Sulfate	17.9	0.37	5			065399-013	SW846 9056
	Calcium	65.8	0.035	1	B	A2, J, P1	065399-014	SW846 6020
	Magnesium	14.1	0.0022	0.2	B	A, J, P1	065399-014	SW846 6020
	Potassium	3.0	0.013	1	B	J	065399-014	SW846 6020
	Sodium	25.4	0.0064	1	B	J	065399-014	SW846 6020
	Total Alkalinity as CaCO3	135	1.2	5			065399-018	EPA 310.1
	Alkalinity as HCO3	135	1.2	5		J, P1	065399-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065399-018	EPA 310.1
TJA-6	Bromide	0.15	0.02	0.25	J		065401-013	SW846 9056
04-Aug-04	Chloride	14.5	0.43	2			065401-013	SW846 9056
	Fluoride	0.30	0.01	0.10			065401-013	SW846 9056
	Sulfate	61.8	0.37	5			065401-013	SW846 9056
	Calcium	58.2	0.035	0.50	B		065401-014	SW846 6020
	Magnesium	10.1	0.0022	0.10	B	J	065401-014	SW846 6020
	Potassium	2.0	0.013	0.50	B		065401-014	SW846 6020
	Sodium	20.4	0.0064	0.50	B		065401-014	SW846 6020
	Total Alkalinity as CaCO3	161	1.2	5			065401-018	EPA 310.1
	Alkalinity as HCO3	161	1.2	5			065401-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065401-018	EPA 310.1
TJA-7	Bromide	0.43	0.02	0.25			065403-013	SW846 9056
06-Aug-04	Chloride	31.8	0.43	2			065403-013	SW846 9056

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Fluoride	0.30	0.01	0.10			065403-013	SW846 9056
	Sulfate	20.4	0.37	5			065403-013	SW846 9056
	Calcium	72.5	0.035	1	B	A2, J	065403-014	SW846 6020
	Magnesium	13.9	0.0022	0.2	B	J	065403-014	SW846 6020
	Potassium	1.9	0.013	1	B		065403-014	SW846 6020
	Sodium	20.3	0.0064	1	B		065403-014	SW846 6020
	Total Alkalinity as CaCO3	124	1.2	5			065403-018	EPA 310.1
	Alkalinity as HCO3	124	1.2	5			065403-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065403-018	EPA 310.1
WYO-3	Bromide	ND	0.02	0.25	U		065408-013	SW846 9056
11-Aug-04	Chloride	15	0.43	2			065408-013	SW846 9056
	Fluoride	0.31	0.01	0.10			065408-013	SW846 9056
	Sulfate	86.5	0.37	5			065408-013	SW846 9056
	Calcium	70.4	0.035	1	B	A2, J, P1	065408-014	SW846 6020
	Magnesium	13.9	0.0022	0.2	B	A, J, P1	065408-014	SW846 6020
	Potassium	2.2	0.013	1	B		065408-014	SW846 6020
	Sodium	27.1	0.0064	1	B		065408-014	SW846 6020
	Total Alkalinity as CaCO3	173	1.2	5			065408-018	EPA 310.1
	Alkalinity as HCO3	173	1.2	5			065408-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065408-018	EPA 310.1
WYO-4	Bromide	1.2	0.02	0.25			065411-013	SW846 9056
03-Aug-04	Chloride	105	4.3	20			065411-013	SW846 9056
	Fluoride	0.28	0.01	0.10			065411-013	SW846 9056
	Sulfate	45.7	0.37	5			065411-013	SW846 9056
	Calcium	79.1	0.035	0.50	B		065411-014	SW846 6020
	Magnesium	12.4	0.0022	0.10	B	J	065411-014	SW846 6020
	Potassium	1.6	0.013	0.50	B		065411-014	SW846 6020
	Sodium	18.9	0.0064	0.50	B		065411-014	SW846 6020
	Total Alkalinity as CaCO3	93	1.2	5			065411-018	EPA 310.1
	Alkalinity as HCO3	93	1.2	5			065411-018	EPA 310.1
	Alkalinity as CO3	ND	1.2	5	U		065411-018	EPA 310.1

mg/L = milligrams per liter
A = Laboratory accuracy and/or bias measurements do not meet acceptance criteria.
A2 = Laboratory accuracy and/or bias measurements for the associated matrix spike and/or duplicate do not meet acceptance criteria.
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
B = Analyte is detected in associated laboratory method blank.
B3 = Analyte is detected in associated laboratory calibration blank.
P1 = Laboratory precision measurement for the associated matrix spike and/or duplicate samples do not meet acceptance criteria.
U = Analyte not detected above the MDL.

Table A-19
Summary of Anion, Cation, and Alkalinity Results

Tijeras Arroyo Groundwater Investigation

Fiscal Year 2005, 1st Quarter

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
Eubank-1	Bromide	ND	0.0978	0.20	U		066077-013	SW846 9056
20-Oct-04	Chloride	13.0	0.0322	0.20			066077-013	SW846 9056
	Fluoride	0.294	0.0553	0.10			066077-013	SW846 9056
	Sulfate	78.4	0.965	2.0			066077-013	SW846 9056
	Calcium	70.9	0.010	0.10			066077-014	SW846 6020
	Magnesium	10.1	0.00633	0.01		J	066077-014	SW846 6020
	Potassium	1.72	0.0151	0.30			066077-014	SW846 6020
	Sodium	27.2	0.00968	0.25	B		066077-014	SW846 6020
	Total Alkalinity as CaCO3	160	1.45	2.0			066077-018	EPA 310.1
	Alkalinity as HCO3	159	1.45	2.0			066077-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066077-018	EPA 310.1
Eubank-2	Bromide	ND	0.0978	0.20	U		066080-013	SW846 9056
21-Oct-04	Chloride	11.6	0.0322	0.20			066080-013	SW846 9056
	Fluoride	0.158	0.0553	0.10			066080-013	SW846 9056
	Sulfate	90.9	0.965	2.0			066080-013	SW846 9056
	Calcium	80.1	0.040	0.10			066080-014	SW846 6020
	Magnesium	12.0	0.00633	0.01			066080-014	SW846 6020
	Potassium	2.21	0.0151	0.30			066080-014	SW846 6020
	Sodium	31.7	0.00968	0.25	B		066080-014	SW846 6020
	Total Alkalinity as CaCO3	205	1.45	2.0			066080-018	EPA 310.1
	Alkalinity as HCO3	205	1.45	2.0			066080-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066080-018	EPA 310.1
Eubank-3	Bromide	ND	0.0978	0.20	U		066082-013	SW846 9056
20-Oct-04	Chloride	18.6	0.161	1.0			066082-013	SW846 9056
	Fluoride	0.240	0.0553	0.10			066082-013	SW846 9056
	Sulfate	88.4	0.965	2.0			066082-013	SW846 9056
	Calcium	81.8	0.010	0.10			066082-014	SW846 6020
	Magnesium	12.1	0.00633	0.01		J	066082-014	SW846 6020
	Potassium	1.93	0.0151	0.30			066082-014	SW846 6020
	Sodium	34.7	0.00968	0.25	B		066082-014	SW846 6020
	Total Alkalinity as CaCO3	190	1.45	2.0			066082-018	EPA 310.1
	Alkalinity as HCO3	189	1.45	2.0			066082-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066082-018	EPA 310.1
Eubank-5	Bromide	ND	0.0978	0.20	U		066084-013	SW846 9056
25-Oct-04	Chloride	24.6	0.161	1.0			066084-013	SW846 9056
	Fluoride	0.216	0.0553	0.10			066084-013	SW846 9056
	Sulfate	91.2	0.965	2.0			066084-013	SW846 9056
	Calcium	83.9	0.040	0.10			066084-014	SW846 6020
	Magnesium	12.7	0.00633	0.01		J	066084-014	SW846 6020

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Potassium	2.01	0.0151	0.30			066084-014	SW846 6020
	Sodium	32.6	0.00968	0.25	B		066084-014	SW846 6020
	Total Alkalinity as CaCO3	186	1.45	2.0			066084-018	EPA 310.1
	Alkalinity as HCO3	186	1.45	2.0			066084-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066084-018	EPA 310.1
PGS-2	Bromide	0.253	0.0978	0.20			066025-013	SW846 9056
05-Oct-04	Chloride	13.1	0.0322	0.20			066025-013	SW846 9056
	Fluoride	0.213	0.0553	0.10			066025-013	SW846 9056
	Sulfate	57.5	0.965	2.0			066025-013	SW846 9056
	Calcium	46.5	0.040	0.10			066025-014	SW846 6020
	Magnesium	10.5	0.00633	0.01			066025-014	SW846 6020
	Potassium	2.34	0.0151	0.30			066025-014	SW846 6020
	Sodium	28.3	0.00968	0.25			066025-014	SW846 6020
	Total Alkalinity as CaCO3	147	1.45	2.0			066025-018	EPA 310.1
	Alkalinity as HCO3	145	1.45	2.0			066025-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066025-018	EPA 310.1
TA1-W-01	Bromide	0.247	0.0978	0.20			066027-013	SW846 9056
06-Oct-04	Chloride	14.6	0.0322	0.20			066027-013	SW846 9056
	Fluoride	0.432	0.0553	0.10			066027-013	SW846 9056
	Sulfate	75.0	0.965	2.0			066027-013	SW846 9056
	Calcium	69.0	0.040	0.10			066027-014	SW846 6020
	Magnesium	13.6	0.00633	0.01			066027-014	SW846 6020
	Potassium	2.16	0.0151	0.30			066027-014	SW846 6020
	Sodium	25.9	0.00968	0.25			066027-014	SW846 6020
	Total Alkalinity as CaCO3	166	1.45	2.0			066027-018	EPA 310.1
	Alkalinity as HCO3	165	1.45	2.0			066027-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066027-018	EPA 310.1
TA1-W-02	Bromide	0.254	0.0978	0.20			066029-013	SW846 9056
11-Oct-04	Chloride	13.8	0.0322	0.20			066029-013	SW846 9056
	Fluoride	0.423	0.0553	0.10			066029-013	SW846 9056
	Sulfate	78.2	0.965	2.0			066029-013	SW846 9056
	Calcium	68.8	0.040	0.10			066029-014	SW846 6020
	Magnesium	13.5	0.00633	0.01			066029-014	SW846 6020
	Potassium	2.29	0.0151	0.30			066029-014	SW846 6020
	Sodium	23.3	0.00968	0.25			066029-014	SW846 6020
	Total Alkalinity as CaCO3	177	104	1.45			066029-018	EPA 310.1
	Alkalinity as HCO3	177	104	1.45			066029-018	EPA 310.1
	Alkalinity as CO3	ND	104	1.45	U		066029-018	EPA 310.1
TA1-W-03	Bromide	2.63	0.0978	0.20			066031-013	SW846 9056
19-Oct-04	Chloride	263	0.644	4.0			066031-013	SW846 9056
	Fluoride	0.076	0.0553	0.10	J		066031-013	SW846 9056
	Sulfate	505	3.86	8.0			066031-013	SW846 9056
	Calcium	294	0.20	0.50			066031-014	SW846 6020
	Magnesium	30.7	0.00633	0.01		J	066031-014	SW846 6020
	Potassium	2.61	0.0151	0.30			066031-014	SW846 6020
	Sodium	48.2	0.00968	0.25	B		066031-014	SW846 6020

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Total Alkalinity as CaCO3	68.0	1.45	2.0			066031-018	EPA 310.1
	Alkalinity as HCO3	67.7	1.45	2.0			066031-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066031-018	EPA 310.1
TA1-W-04	Bromide	0.276	0.0978	0.20			066033-013	SW846 9056
07-Oct-04	Chloride	15.5	0.0322	0.20			066033-013	SW846 9056
	Fluoride	0.382	0.0553	0.10			066033-013	SW846 9056
	Sulfate	59.3	0.965	2.0			066033-013	SW846 9056
	Calcium	65.9	0.040	0.10			066033-014	SW846 6020
	Magnesium	11.5	0.00633	0.01			066033-014	SW846 6020
	Potassium	2.39	0.0151	0.30			066033-014	SW846 6020
	Sodium	23.5	0.00968	0.25			066033-014	SW846 6020
	Total Alkalinity as CaCO3	168	1.45	2.0			066033-018	EPA 310.1
	Alkalinity as HCO3	167	1.45	2.0			066033-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066033-018	EPA 310.1
TA1-W-05	Bromide	ND	0.0978	0.20	U		066035-013	SW846 9056
26-Oct-04	Chloride	11.7	0.0322	0.20			066035-013	SW846 9056
	Fluoride	0.198	0.0553	0.10			066035-013	SW846 9056
	Sulfate	102	0.965	2.0			066035-013	SW846 9056
	Calcium	79.8	0.040	0.10	B		066035-014	SW846 6020
	Magnesium	10.9	0.00633	0.01		J	066035-014	SW846 6020
	Potassium	2.02	0.0151	0.30			066035-014	SW846 6020
	Sodium	33.6	0.00968	0.25	B		066035-014	SW846 6020
	Total Alkalinity as CaCO3	199	1.45	2.0			066035-018	EPA 310.1
	Alkalinity as HCO3	198	1.45	2.0			066035-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066035-018	EPA 310.1
TA1-W-06	Bromide	0.880	0.0978	0.20			066037-013	SW846 9056
26-Oct-04	Chloride	103	0.322	2.0			066037-013	SW846 9056
	Fluoride	0.206	0.0553	0.10			066037-013	SW846 9056
	Sulfate	211	1.93	4.0			066037-013	SW846 9056
	Calcium	119	0.040	0.10	B		066037-014	SW846 6020
	Magnesium	14.8	0.00633	0.01		J	066037-014	SW846 6020
	Potassium	1.91	0.0151	0.30			066037-014	SW846 6020
	Sodium	34.6	0.00968	0.25	B		066037-014	SW846 6020
	Total Alkalinity as CaCO3	88.9	1.45	2.0			066037-018	EPA 310.1
	Alkalinity as HCO3	88.4	1.45	2.0			066037-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066037-018	EPA 310.1
TA1-W-08	Bromide	ND	0.0978	0.20	U		066039-013	SW846 9056
08-Oct-04	Chloride	202	1.61	10.0			066039-013	SW846 9056
	Fluoride	0.260	0.0553	0.10			066039-013	SW846 9056
	Sulfate	650	9.65	20.0			066039-013	SW846 9056
	Calcium	334	0.20	0.50			066039-014	SW846 6020
	Magnesium	41.1	0.00633	0.01			066039-014	SW846 6020
	Potassium	3.25	0.0151	0.30			066039-014	SW846 6020
	Sodium	76.7	0.00968	0.25			066039-014	SW846 6020
	Total Alkalinity as CaCO3	53.6	1.45	2.0			066039-018	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Alkalinity as HCO3	53.5	1.45	2.0			066039-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066039-018	EPA 310.1
TA2-NW1-595	Bromide	0.761	0.0978	0.20			066042-013	SW846 9056
25-Oct-04 (QED)	Chloride	89.4	0.322	2.0			066042-013	SW846 9056
	Fluoride	0.183	0.0553	0.10			066042-013	SW846 9056
	Sulfate	119	1.93	4.0			066042-013	SW846 9056
	Calcium	103	0.040	0.10			066042-014	SW846 6020
	Magnesium	17.0	0.00633	0.01		J	066042-014	SW846 6020
	Potassium	2.40	0.0151	0.30			066042-014	SW846 6020
	Sodium	31.3	0.00968	0.25	B		066042-014	SW846 6020
	Total Alkalinity as CaCO3	137	1.45	2.0			066042-018	EPA 310.1
	Alkalinity as HCO3	137	1.45	2.0			066042-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066042-018	EPA 310.1
TA2-NW1-595	Bromide	ND	0.0978	0.20	U		066044-013	SW846 9056
07-Oct-04 (Bennett)	Chloride	83.3	0.322	2.0			066044-013	SW846 9056
	Fluoride	0.299	0.0553	0.10			066044-013	SW846 9056
	Sulfate	118	1.93	4.0			066044-013	SW846 9056
	Calcium	104	0.040	0.10			066044-014	SW846 6020
	Magnesium	17.4	0.00633	0.01			066044-014	SW846 6020
	Potassium	2.32	0.0151	0.30			066044-014	SW846 6020
	Sodium	29.5	0.00968	0.25			066044-014	SW846 6020
	Total Alkalinity as CaCO3	138	1.45	2.0			066044-018	EPA 310.1
	Alkalinity as HCO3	137	1.45	2.0			066044-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066044-018	EPA 310.1
TA2-SW1-320	Bromide	0.467	0.0978	0.20			066046-013	SW846 9056
04-Oct-04	Chloride	28.2	0.161	1.0			066046-013	SW846 9056
	Fluoride	0.444	0.0553	0.10			066046-013	SW846 9056
	Sulfate	13.7	0.193	0.40			066046-013	SW846 9056
	Calcium	60.9	0.040	0.10			066046-014	SW846 6020
	Magnesium	11.2	0.00633	0.01			066046-014	SW846 6020
	Potassium	1.70	0.0151	0.30			066046-014	SW846 6020
	Sodium	17.5	0.00968	0.25			066046-014	SW846 6020
	Total Alkalinity as CaCO3	104	1.45	2.0	H	HT, J	066046-018	EPA 310.1
	Alkalinity as HCO3	104	1.45	2.0	H	HT, J	066046-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	H, U	HT, UJ	066046-018	EPA 310.1
TA2-W-01	Bromide	1.19	0.0978	0.20			066048-013	SW846 9056
18-Oct-04	Chloride	113	0.322	2.0			066048-013	SW846 9056
	Fluoride	0.145	0.0553	0.10			066048-013	SW846 9056
	Sulfate	81.4	1.93	4.0			066048-013	SW846 9056
	Calcium	84.2	0.040	0.10			066048-014	SW846 6020
	Magnesium	10.8	0.00633	0.01		J	066048-014	SW846 6020
	Potassium	1.72	0.0151	0.30			066048-014	SW846 6020
	Sodium	21.9	0.00968	0.25	B		066048-014	SW846 6020
	Total Alkalinity as CaCO3	81.6	1.45	2.0			066048-018	EPA 310.1
	Alkalinity as HCO3	81.4	1.45	2.0			066048-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066048-018	EPA 310.1

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TA2-W-19	Bromide	0.966	0.0978	0.20			066050-013	SW846 9056
04-Oct-04	Chloride	70.2	0.322	2.0			066050-013	SW846 9056
	Fluoride	0.343	0.0553	0.10			066050-013	SW846 9056
	Sulfate	58.4	1.93	4.0			066050-013	SW846 9056
	Calcium	76.7	0.040	0.10			066050-014	SW846 6020
	Magnesium	11.3	0.00633	0.01			066050-014	SW846 6020
	Potassium	1.61	0.0151	0.30			066050-014	SW846 6020
	Sodium	21.1	0.00968	0.25			066050-014	SW846 6020
	Total Alkalinity as CaCO3	100	1.45	2.0			066050-018	EPA 310.1
	Alkalinity as HCO3	99.9	1.45	2.0			066050-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066050-018	EPA 310.1
TA2-W-26	Bromide	1.38	0.0978	0.20			066053-013	SW846 9056
13-Oct-04	Chloride	143	0.644	4.0			066053-013	SW846 9056
	Fluoride	0.146	0.0553	0.10			066053-013	SW846 9056
	Sulfate	268	3.86	8.0			066053-013	SW846 9056
	Calcium	160	0.040	0.10	B		066053-014	SW846 6020
	Magnesium	21.6	0.00633	0.01			066053-014	SW846 6020
	Potassium	2.26	0.0151	0.30			066053-014	SW846 6020
	Sodium	31.4	0.00968	0.25	B	J	066053-014	SW846 6020
	Total Alkalinity as CaCO3	66.8	1.45	2.0			066053-018	EPA 310.1
	Alkalinity as HCO3	66.6	1.45	2.0			066053-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066053-018	EPA 310.1
TA2-W-27	Bromide	1.27	0.0978	0.20			066056-013	SW846 9056
14-Oct-04	Chloride	132	0.322	2.0			066056-013	SW846 9056
	Fluoride	0.109	0.0553	0.10			066056-013	SW846 9056
	Sulfate	174	1.93	4.0			066056-013	SW846 9056
	Calcium	123	0.040	0.10	B		066056-014	SW846 6020
	Magnesium	18.9	0.00633	0.01			066056-014	SW846 6020
	Potassium	1.99	0.0151	0.30	B		066056-014	SW846 6020
	Sodium	29.8	0.00968	0.25	B		066056-014	SW846 6020
	Total Alkalinity as CaCO3	74.6	1.45	2.0			066056-018	EPA 310.1
	Alkalinity as HCO3	74.2	1.45	2.0			066056-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066056-018	EPA 310.1
TJA-2	Bromide	ND	0.0978	0.20	U		066059-013	SW846 9056
11-Oct-04	Chloride	70.1	0.161	1.0			066059-013	SW846 9056
	Fluoride	0.343	0.0553	0.10			066059-013	SW846 9056
	Sulfate	53.2	0.965	2.0			066059-013	SW846 9056
	Calcium	79.3	0.040	0.10			066059-014	SW846 6020
	Magnesium	12.5	0.00633	0.01			066059-014	SW846 6020
	Potassium	1.86	0.0151	0.30			066059-014	SW846 6020
	Sodium	24.0	0.00968	0.25			066059-014	SW846 6020
	Total Alkalinity as CaCO3	98.2	1.45	2.0			066059-018	EPA 310.1
	Alkalinity as HCO3	97.6	1.45	2.0			066059-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066059-018	EPA 310.1
TJA-3	Bromide	0.267	0.0978	0.20			066061-013	SW846 9056
12-Oct-04	Chloride	13.0	0.0322	0.20			066061-013	SW846 9056

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Fluoride	0.353	0.0553	0.10			066061-013	SW846 9056
	Sulfate	71.7	0.965	2.0			066061-013	SW846 9056
	Calcium	65.3	0.040	0.10			066061-014	SW846 6020
	Magnesium	11.6	0.00633	0.01			066061-014	SW846 6020
	Potassium	1.83	0.0151	0.30			066061-014	SW846 6020
	Sodium	24.4	0.00968	0.25			066061-014	SW846 6020
	Total Alkalinity as CaCO3	187	1.45	2.0			066061-018	EPA 310.1
	Alkalinity as HCO3	187	1.45	2.0			066061-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066061-018	EPA 310.1
TJA-4	Bromide	0.418	0.0978	0.20			066063-013	SW846 9056
12-Oct-04	Chloride	20.1	0.0553	0.10			066063-013	SW846 9056
	Fluoride	0.402	0.0553	0.10			066063-013	SW846 9056
	Sulfate	18.0	0.193	0.40			066063-013	SW846 9056
	Calcium	65.5	0.040	0.10			066063-014	SW846 6020
	Magnesium	13.7	0.00633	0.01			066063-014	SW846 6020
	Potassium	3.08	0.0151	0.30			066063-014	SW846 6020
	Sodium	25.2	0.00968	0.25			066063-014	SW846 6020
	Total Alkalinity as CaCO3	98.2	1.45	2.0			066063-018	EPA 310.1
	Alkalinity as HCO3	97.9	1.45	2.0			066063-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066063-018	EPA 310.1
TJA-6	Bromide	ND	0.0978	0.20	U		066065-013	SW846 9056
13-Oct-04	Chloride	15.2	0.0322	0.20			066065-013	SW846 9056
	Fluoride	0.165	0.0553	0.10			066065-013	SW846 9056
	Sulfate	65.9	0.965	2.0			066065-013	SW846 9056
	Calcium	63.8	0.040	0.10	B		066065-014	SW846 6020
	Magnesium	12.6	0.00633	0.01			066065-014	SW846 6020
	Potassium	2.37	0.0151	0.30			066065-014	SW846 6020
	Sodium	24.9	0.00968	0.25	B	J	066065-014	SW846 6020
	Total Alkalinity as CaCO3	127	1.45	2.0			066065-018	EPA 310.1
	Alkalinity as HCO3	126	1.45	2.0			066065-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066065-018	EPA 310.1
TJA-7	Bromide	ND	0.0978	0.20	U		066067-013	SW846 9056
15-Oct-04	Chloride	30.7	0.161	1.0			066067-013	SW846 9056
	Fluoride	0.137	0.0553	0.10			066067-013	SW846 9056
	Sulfate	16.9	0.193	0.40			066067-013	SW846 9056
	Calcium	68.7	0.040	0.10			066067-014	SW846 6020
	Magnesium	12.7	0.00633	0.01		J	066067-014	SW846 6020
	Potassium	1.90	0.0151	0.30			066067-014	SW846 6020
	Sodium	20.9	0.00968	0.25	B		066067-014	SW846 6020
	Total Alkalinity as CaCO3	98.4	1.45	2.0			066067-018	EPA 310.1
	Alkalinity as HCO3	97.6	1.45	2.0			066067-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066067-018	EPA 310.1
WYO-3	Bromide	0.263	0.0978	0.20			066071-013	SW846 9056
08-Oct-04	Chloride	14.7	0.0322	0.20			066071-013	SW846 9056
	Fluoride	0.415	0.0553	0.10			066071-013	SW846 9056
	Sulfate	84.9	0.965	2.0			066071-013	SW846 9056

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Calcium	71.3	0.040	0.10			066071-014	SW846 6020
	Magnesium	14.7	0.00633	0.01			066071-014	SW846 6020
	Potassium	2.41	0.0151	0.30			066071-014	SW846 6020
	Sodium	25.7	0.00968	0.25			066071-014	SW846 6020
	Total Alkalinity as CaCO3	169	1.45	2.0			066071-018	EPA 310.1
	Alkalinity as HCO3	168	1.45	2.0			066071-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066071-018	EPA 310.1
WYO-4	Bromide	1.24	0.0978	0.20			066073-013	SW846 9056
06-Oct-04	Chloride	99.4	0.322	2.0			066073-013	SW846 9056
	Fluoride	0.368	0.0553	0.10			066073-013	SW846 9056
	Sulfate	51.4	1.93	4.0			066073-013	SW846 9056
	Calcium	80.3	0.040	0.10			066073-014	SW846 6020
	Magnesium	13.6	0.00633	0.01			066073-014	SW846 6020
	Potassium	1.88	0.0151	0.30			066073-014	SW846 6020
	Sodium	21.1	0.00968	0.25			066073-014	SW846 6020
	Total Alkalinity as CaCO3	95.1	1.45	2.0			066073-018	EPA 310.1
	Alkalinity as HCO3	94.5	1.45	2.0			066073-018	EPA 310.1
	Alkalinity as CO3	ND	1.45	2.0	U		066073-018	EPA 310.1

mg/L = milligrams per liter
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
B = Analyte is detected in associated laboratory method blank.
U = Analyte not detected above the MDL.
H/HT = The holding time was exceeded for the associated sample analysis.

Table A-20
Summary of Ammonia, Total Kjeldahl Nitrogen, Total Organic Carbon, and Phosphate Detections

Tijeras Arroyo Groundwater Investigation

July 2003 through December 2004

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
TA1-W-03	Total Organic carbon	0.764	0.025	0.2	B		062684-048	EPA 415.1
24-Jul-03	Total Phosphate as phosphorus	0.0448	0.0162	0.05	J, B	B, B3, J	062684-042	EPA 365.4
TA1-W-08	Total Organic carbon	0.924	0.025	0.2	B		062692-048	SW846 9060
30-Jul-03	Total Phosphate as phosphorus	ND	0.0162	0.05	U, B		062692-042	EPA 365.4
TJA-7	Ammonia	ND	0.024	0.05	U		062717-019	EPA 350.1
12-Aug-03	Total Kjeldahl Nitrogen	0.338	0.0375	0.125			062717-046	EPA 351.2
	Total Organic carbon	0.431	0.025	0.2	B		062717-048	EPA 415.1
	Total Phosphate as phosphorus	0.0449	0.0162	0.05	J, B	B, B3, J	062717-042	EPA 365.4
TJA-7	Ammonia	ND	0.024	0.05	U		063299-019	EPA 350.1
28-Oct-03	Total Kjeldahl Nitrogen	3.33	0.09	0.3			063299-046	EPA 351.2
TA1-W-03	Total Organic Carbon	0.790	0.025	0.2			063857-004	EPA 415.1
07-Jan-04	Total Phosphorus	0.011	0.011	0.05	B, J	B, B3, J	063857-024	EPA 365.4
TA1-W-08	Total Organic Carbon	0.599	0.025	0.2	B	B3, J	063866-004	EPA 415.1
10-Feb-04	Total Phosphorus	0.016	0.011	0.05	J		063866-024	EPA 365.4
TJA-7	Total Organic Carbon	0.335	0.025	0.2			063895-004	EPA 415.1
22-Jan-04	Ammonia	0.080	0.024	0.05			063895-017	EPA 350.1
	Total Kjeldahl Nitrogen	0.560	0.030	0.1			063895-019	EPA 351.2

Well ID	Analyte	Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.	Analytical Method
	Total Phosphorus	ND	0.011	0.05	U		063895-024	EPA 365.4
TJA-7	Total Kjeldahl Nitrogen	ND	0.061	0.10	U		064593-017	EPA 350.1
30-Apr-04	Ammonia	ND	0.0216	0.05	U	UJ, A2	064593-019	EPA 351.2
TA1-W-03	Total Organic Carbon	0.64	0.39	1.0	J		065366-004	EPA 415.1
18-Aug-04	Total Phosphorus	0.0288	0.010	0.050	J		065366-024	EPA 365.4
TA1-W-08	Total Organic Carbon	1.1	0.39	1.0			065374-004	EPA 415.1
13-Aug-04	Total Phosphorus	0.0237	0.010	0.050	J		065374-024	EPA 365.4
TJA-7	Total Organic Carbon	ND	0.39	1.0	U		065403-004	EPA 415.1
06-Aug-04	Ammonia	ND	0.0216	0.050	U		065403-019	EPA 350.1
	Total Kjeldahl Nitrogen	ND	0.061	0.10	U	A2, R	065403-017	EPA 351.2
	Total Phosphorus	0.0361	0.010	0.050	J		065403-024	EPA 365.4
TJA-7	Ammonia	ND	0.0159	0.05	U	B3, UJ	066067-019	EPA 350.1
15-Oct-04	Total Kjeldahl Nitrogen	0.130	0.044	0.10			066067-017	EPA 351.2

mg/L = milligrams per liter
A2 = Laboratory accuracy and/or bias measurements for the associated matrix spike and/or duplicate do not meet acceptance criteria.
J = Amount detected is below the practical quantitation limit. The associated value is an estimated quantity.
B = Analyte is detected in associated laboratory method blank.
B3 = Analyte is detected in associated laboratory calibration blank.
U = Analyte not detected above the MDL.
R = Data rejected.

Table A-21
Summary of Manganese 2+ Results (Method C2_150.mtw)

Tijeras Arroyo Groundwater Investigation

July 2003 through December 2004

Well ID	Sample Date	Manganese 2+ Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
Eubank-1	18-Aug-03	0.002	0.0007	NR		None	062724-040
	10-Nov-03	ND	0.05	NR	U	None	063303-041
	16-Feb-04	ND	0.05	NR	U	None	063904-011
	20-May-04	ND	0.05	NR	U	None	064600-011
	19-Aug-04	ND	0.05	NR	U	None	065416-011
	20-Oct-04	ND	0.05	NR	U	None	066077-011
Eubank-2	09-Jul-03	ND	0.05	NR	U	None	062585-040
	12-Nov-03	ND	0.05	NR	U	None	063304-041
	18-Feb-04	ND	0.05	NR	U	None	063906-011
	06-May-04	ND	0.05	NR	U	None	064602-011
	07-Jul-04	ND	0.05	NR	U	None	065418-011
	21-Oct-04	ND	0.05	NR	U	None	066080-011
Eubank-3	10-Jul-03	ND	0.05	NR	U	None	062586-040
	18-Nov-03	ND	0.05	NR	U	None	063305-041
	17-Feb-04	ND	0.05	NR	U	None	063909-011
	04-May-04	ND	0.05	NR	U	None	064604-011
	07-Jul-04	ND	0.05	NR	U	None	065419-011
	20-Oct-04	ND	0.05	NR	U	None	066082-011
Eubank-5	09-Jul-03	ND	0.05	NR	U	None	062587-040
	19-Nov-03	ND	0.05	NR	U	None	063306-041
	19-Feb-04	ND	0.05	NR	U	None	063911-011
	03-May-04	ND	0.05	NR	U	None	064607-011

Well ID	Sample Date	Manganese 2+ Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
	07-Jul-04	ND	0.05	NR	U	None	065420-011
	25-Oct-04	ND	0.05	NR	U	None	066084-011
PGS-2	22-Jul-03	ND	0.05	NR	U	None	062678-041
	10-Nov-03	ND	0.05	NR	U	None	063278-041
	03-Feb-04	ND	0.05	NR	U	None	063851-011
	12-May-04	ND	0.05	NR	U	None	064551-011
	28-Jul-04	ND	0.05	NR	U	None	065360-011
	05-Oct-04	ND	0.05	NR	U	None	066025-011
TA1-W-01	22-Jul-03	ND	0.05	NR	U	None	062680-041
	06-Nov-03	ND	0.05	NR	U	None	063279-041
	05-Feb-04	ND	0.05	NR	U	None	063853-011
	10-May-04	ND	0.05	NR	U	None	064553-011
	17-Aug-04	ND	0.05	NR	U	None	065362-011
	06-Oct-04	ND	0.05	NR	U	None	066027-011
TA1-W-02	23-Jul-03	ND	0.05	NR	U	None	062682-041
	08-Oct-03	ND	0.05	NR	U	None	063280-041
	28-Jan-04	ND	0.05	NR	U	None	063855-011
	11-May-04	ND	0.05	NR	U	None	064556-011
	13-Aug-04	ND	0.05	NR	U	None	065364-011
	11-Oct-04	ND	0.05	NR	U	None	066029-011
TA1-W-03	24-Jul-03	ND	0.05	NR	U	None	062684-041
	13-Oct-03	ND	0.05	NR	U	None	063281-041
	07-Jan-04	ND	0.05	NR	U	None	063857-011
	28-Apr-04	ND	0.05	NR	U	None	064558-011
	18-Aug-04	ND	0.05	NR	U	None	065366-011
	19-Oct-04	ND	0.05	NR	U	None	066031-011
TA1-W-04	29-Jul-03	ND	0.05	NR	U	None	062686-041
	14-Oct-03	ND	0.05	NR	U	None	063282-041
	06-Jan-04	ND	0.05	NR	U	None	063860-011
	26-Apr-04	ND	0.05	NR	U	None	064560-011
	26-Jul-04	ND	0.05	NR	U	None	065368-011

Well ID	Sample Date	Manganese 2+ Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
	07-Oct-04	ND	0.05	NR	U	None	066033-011
TA1-W-05	28-Jul-03	ND	0.05	NR	U	None	062688-041
	20-Oct-03	ND	0.05	NR	U	None	063283-041
	12-Feb-04	ND	0.05	NR	U	None	063862-011
	07-May-04	ND	0.05	NR	U	None	064562-011
	20-Aug-04	ND	0.05	NR	U	None	065370-011
	26-Oct-04	ND	0.05	NR	U	None	066035-011
TA1-W-06	29-Jul-03	ND	0.05	NR	U	None	062690-041
	09-Oct-03	ND	0.05	NR	U	None	063284-041
	09-Feb-04	ND	0.05	NR	U	None	063864-011
	21-May-04	ND	0.05	NR	U	None	064564-011
	06-Aug-04	ND	0.05	NR	U	None	065372-011
	26-Oct-04	ND	0.05	NR	U	None	066037-011
TA1-W-08	30-Jul-03	ND	0.05	NR	U	None	062692-041
	21-Oct-03	ND	0.05	NR	U	None	063285-041
	10-Feb-04	ND	0.05	NR	U	None	063866-011
	23-Apr-04	ND	0.05	NR	U	None	064566-011
	13-Aug-04	ND	0.05	NR	U	None	065374-011
	08-Oct-04	ND	0.05	NR	U	None	066039-011
TA2-NW1-595 (QED)	12-Nov-03	ND	0.05	NR	U	None	063287-041
	04-Feb-04	ND	0.05	NR	U	None	063871-011
	13-May-04	ND	0.05	NR	U	None	064568-011
	26-Jul-04	ND	0.05	NR	U	None	065377-011
	25-Oct-04	ND	0.05	NR	U	None	066042-011
TA2-NW1-595 (Bennett)	05-Aug-03	ND	0.05	NR	U	None	062695-041
	11-Nov-03	ND	0.05	NR	U	None	063288-041
	26-Jan-04	ND	0.05	NR	U	None	063869-011
	19-May-04	ND	0.05	NR	U	None	064568-011
	23-Aug-04	ND	0.05	NR	U	None	065379-011
	07-Oct-04	ND	0.05	NR	U	None	066044-011
TA2-SW1-320	24-Jul-03	ND	0.05	NR	U	None	062698-041
	11-Nov-03	ND	0.05	NR	U	None	063289-041
	29-Jan-04	ND	0.05	NR	U	None	063873-011

Well ID	Sample Date	Manganese 2+ Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
	14-May-04	ND	0.05	NR	U	None	064573-011
	27-Jul-04	ND	0.05	NR	U	None	065381-011
	04-Oct-04	ND	0.05	NR	U	None	066046-011
TA2-W-01	07-Aug-03	ND	0.05	NR	U	None	062700-041
	01-Dec-03	ND	0.05	NR	U	None	063290-041
	12-Jan-04	ND	0.05	NR	U	None	063876-011
	17-May-04	ND	0.05	NR	U	None	064575-011
	12-Aug-04	ND	0.05	NR	U	None	065383-011
	18-Oct-04	ND	0.05	NR	U	None	066048-011
TA2-W-19	04-Aug-03	ND	0.05	NR	U	None	062702-041
	07-Oct-03	ND	0.05	NR	U	None	063291-041
	13-Jan-04	ND	0.05	NR	U	None	063878-011
	27-Apr-04	ND	0.05	NR	U	None	064577-011
	27-Jul-04	ND	0.05	NR	U	None	065385-011
	04-Oct-04	ND	0.05	NR	U	None	066050-011
TA2-W-26	04-Aug-03	ND	0.05	NR	U	None	062704-041
	16-Oct-03	0.031	0.05	NR		None	063292-041
	20-Jan-04	ND	0.05	NR	U	None	063880-011
	21-Apr-04	ND	0.05	NR	U	None	064580-011
	30-Jul-04	ND	0.05	NR	U	None	065387-011
	13-Oct-04	ND	0.05	NR	U	None	066053-011
TA2-W-27	06-Aug-03	ND	0.05	NR	U	None	062707-041
	23-Oct-03	ND	0.05	NR	U	None	063294-041
	15-Jan-04	ND	0.05	NR	U	None	063885-011
	19-Apr-04	ND	0.05	NR	U	None	064583-011
	28-Jul-04	ND	0.05	NR	U	None	065392-011
	14-Oct-04	ND	0.05	NR	U	None	066056-011
TJA-2	31-Jul-03	0.06	0.05	NR		None	062709-041
	15-Oct-03	ND	0.05	NR	U	None	063295-041
	19-Jan-04	ND	0.05	NR	U	None	063887-011
	05-May-04	ND	0.05	NR	U	None	064585-011
	16-Aug-04	ND	0.05	NR	U	None	065394-011

Well ID	Sample Date	Manganese 2+ Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
	11-Oct-04	ND	0.05	NR	U	None	066059-011
TJA-3	06-Aug-03	0.078	0.05	NR		None	062711-041
	22-Oct-03	ND	0.05	NR	U	None	063296-041
	27-Jan-04	ND	0.05	NR	U	None	063889-011
	27-Apr-04	ND	0.05	NR	U	None	064587-011
	09-Aug-04	ND	0.05	NR	U	None	065397-011
	12-Oct-04	ND	0.05	NR	U	None	066061-011
TJA-4	11-Aug-03	ND	0.05	NR	U	None	062713-041
	27-Oct-03	ND	0.05	NR	U	None	063297-041
	29-Jan-04	ND	0.05	NR	U	None	063891-011
	20-Apr-04	ND	0.05	NR	U	None	064589-011
	10-Aug-04	ND	0.05	NR	U	None	065399-011
	12-Oct-04	ND	0.05	NR	U	None	066063-011
TJA-6	11-Aug-03	ND	0.05	NR	U	None	062715-041
	05-Nov-03	ND	0.05	NR	U	None	063298-041
	04-Feb-04	ND	0.05	NR	U	None	063893-011
	22-Apr-04	ND	0.05	NR	U	None	064591-011
	04-Aug-04	ND	0.05	NR	U	None	065401-011
	13-Oct-04	ND	0.05	NR	U	None	066065-011
TJA-7	12-Aug-03	ND	0.05	NR	U	None	062717-041
	28-Oct-03	ND	0.05	NR	U	None	063299-041
	22-Jan-04	ND	0.05	NR	U	None	063895-011
	30-Apr-04	ND	0.05	NR	U	None	064593-011
	06-Aug-04	ND	0.05	NR	U	None	065403-011
	15-Oct-04	ND	0.05	NR	U	None	066067-011
WYO-3	13-Aug-03	ND	0.05	NR	U	None	062719-041
	29-Oct-03	ND	0.05	NR	U	None	063300-041
	21-Jan-04	ND	0.05	NR	U	None	063897-011
	28-Apr-04	ND	0.05	NR	U	None	064595-011
	11-Aug-04	ND	0.05	NR	U	None	065408-011

Well ID	Sample Date	Manganese 2+ Result (mg/L)	MDL (mg/L)	PQL (mg/L)	Laboratory Qualifier	Validation Qualifier	Sample No.
	08-Oct-04	ND	0.05	NR	U	None	066071-011
WYO-4	14-Aug-03	0.098	0.05	NR		None	062721-041
	03-Nov-03	ND	0.05	NR	U	None	063301-041
	03-Feb-04	ND	0.05	NR	U	None	063899-011
	30-Apr-04	ND	0.05	NR	U	None	064597-011
	03-Aug-04	ND	0.05	NR	U	None	065411-011
	06-Oct-04	ND	0.05	NR	U	None	066073-011

mg/L = milligrams per liter
U = Analyte not detected above the MDL.

Table A-22
Summary of Field parameters

Tijeras Arroyo Groundwater Investigation

Last Quarter 2003 to First Quarter 2005

Well ID	Sample Date	Temperature (^{0}C)	Oxidation Reduction Potential (mV)	pH	Dissolved Oxygen (mg/L)
Eubank-1	18-Aug-03	20.55	230.5	7.48	7.40
	10-Nov-03	19.00	328.1	7.44	6.34
	16-Feb-04	18.60	193.5	7.73	7.73
	20-May-04	20.76	133.8	7.43	7.07
	19-Aug-04	19.93	169.7	7.81	4.67
	20-Oct-04	19.59	187.8	7.06	7.93
Eubank-2	12-Nov-03	17.93	309.5	7.30	7.03
	18-Feb-04	16.96	187.3	7.56	7.53
	6-May-04	20.74	152.1	7.16	6.95
	21-Oct-04	18.74	193.3	6.87	5.20
Eubank-3	18-Nov-03	15.50	262.9	7.29	8.75
	17-Feb-04	17.31	178.7	7.54	7.99
	4-May-04	18.67	117.0	7.14	7.60
	20-Oct-04	18.27	134.8	7.19	6.39
Eubank-5	19-Nov-03	16.70	305.7	7.26	8.19
	19-Feb-04	16.44	191.4	7.56	8.14
	3-May-04	18.70	130.9	7.14	7.88
	25-Oct-04	18.33	182.9	6.91	1.72
PGS-2	22-Jul-03	22.00	128.8	8.31	NM
	10-Nov-03	17.25	170.1	8.48	1.15
	3-Feb-04	14.01	120.7	8.27	1.60
	12-May-04	19.04	129.5	7.85	0.99
	28-Jul-04	20.95	133.4	8.16	1.28
	5-Oct-04	17.44	125.4	8.47	2.60
TA1-W-01	22-Jul-03	21.40	187.2	7.11	NM
	6-Nov-03	19.89	346.1	7.33	6.23
	5-Feb-04	17.90	249.3	7.32	NM
	10-May-04	22.07	169.2	7.27	6.21
	17-Aug-04	21.46	189.6	7.70	6.42
	6-Oct-04	18.98	216.2	7.51	7.32
TA1-W-02	23-Jul-03	21.80	223.4	7.17	5.89
	8-Oct-03	18.68	224.1	7.28	6.24
	28-Jan-04	17.51	268.2	7.27	4.01
	11-May-04	21.19	148.5	7.23	5.00

Well ID	Sample Date	Temperature (^0C)	Oxidation Reduction Potential (mV)	pH	Dissolved Oxygen (mg/L)
	13-Aug-04	21.38	130.9	7.32	5.83
	11-Oct-04	18.48	190.6	7.25	6.41
TA1-W-03	24-Jul-03	19.96	168.3	7.26	7.60
	13-Oct-03	17.60	229.2	7.34	7.39
	7-Jan-04	15.22	190.7	7.39	5.39
	28-Apr-04	17.84	102.1	7.23	7.17
	18-Aug-04	18.41	158.7	7.65	7.89
	19-Oct-04	16.96	174.3	6.94	8.05
TA1-W-04	29-Jul-03	21.01	192.8	7.32	6.09
	14-Oct-03	18.50	229.0	7.33	5.60
	6-Jan-04	17.46	247.8	7.08	5.02
	26-Apr-04	19.37	97.9	7.26	5.53
	26-Jul-04	19.86	180.0	7.49	2.78
	7-Oct-04	18.55	224.3	7.51	6.89
TA1-W-05	28-Jul-03	21.91	194.1	7.26	5.38
	20-Oct-03	19.80	257.9	7.20	7.46
	12-Feb-04	17.01	202.3	7.47	7.29
	7-May-04	20.04	174.8	7.11	6.69
	20-Aug-04	20.94	173.7	7.47	6.51
	26-Oct-04	18.72	196.0	6.89	1.66
TA1-W-06	29-Jul-03	21.41	205.4	7.45	7.35
	9-Oct-03	18.89	184.1	7.45	7.31
	9-Feb-04	16.05	175.3	7.79	7.27
	21-May-04	20.44	146.9	7.46	6.54
	6-Aug-04	20.09	143.6	7.44	6.98
	26-Oct-04	17.40	128.4	7.43	6.87
TA1-W-08	30-Jul-03	19.57	206.2	7.30	7.22
	21-Oct-03	17.48	242.0	7.32	7.49
	10-Feb-04	14.97	172.3	7.57	6.29
	23-Apr-04	16.84	109.9	7.16	7.80
	13-Aug-04	18.60	173.1	7.53	7.35
	8-Oct-04	17.31	180.4	7.24	9.04
TA2-NW1-595	30-Jul-03	20.30	187.2	7.07	7.61
TA2-NW1-595	5-Aug-03	20.86	189.1	7.31	6.98
TA2-NW1-595 (Bennett)	11-Nov-03	19.45	269.9	7.30	6.92
	26-Jan-04	16.55	218.7	7.29	4.30
	19-May-04	19.98	139.9	7.28	7.19
	23-Aug-04	20.02	170.7	7.64	7.49
	7-Oct-04	18.78	220.7	6.81	6.51
TA2-NW1-595	12-Nov-03	16.20	245.3	7.48	8.53

Well ID	Sample Date	Temperature (^{0}C)	Oxidation Reduction Potential (mV)	pH	Dissolved Oxygen (mg/L)
(QED)					
	4-Feb-04	13.29	142.7	7.59	8.45
	13-May-04	16.78	208.6	7.19	7.47
	26-Jul-04	17.87	180.3	7.14	6.56
	25-Oct-04	15.79	109.9	7.40	5.74
TA2-SW1-320	24-Jul-03	21.60	147.3	7.70	8.52
	11-Nov-03	16.80	233.9	7.77	8.53
	29-Jan-04	14.08	158.4	7.91	11.92
	14-May-04	15.99	163.6	7.50	8.20
	27-Jul-04	19.28	168.0	7.49	7.36
	4-Oct-04	18.39	191.5	7.76	10.61
TA2-W-01	7-Aug-03	19.92	203.6	7.54	7.83
	1-Dec-03	16.63	290.3	7.53	8.74
	12-Jan-04	17.13	224.8	7.52	4.17
	17-May-04	22.03	182.2	7.40	7.32
	12-Aug-04	20.40	177.6	7.82	7.81
	18-Oct-04	17.91	159.7	7.12	7.21
TA2-W-19	4-Aug-03	19.64	211.5	7.52	7.99
	23-Sep-03	19.71	205.9	7.61	8.29
	7-Oct-03	18.12	216.6	7.41	8.08
	13-Jan-04	17.16	234.7	7.54	4.91
	27-Apr-04	18.43	152.4	7.77	8.61
	27-Jul-04	19.76	181.5	7.26	7.65
	4-Oct-04	18.75	183.4	7.00	2.07
TA2-W-26	4-Aug-03	20.51	197.4	7.41	7.88
	16-Oct-03	17.79	232.1	7.39	7.65
	20-Jan-04	15.98	226.6	7.43	4.54
	21-Apr-04	17.36	103.6	7.28	8.76
	30-Jul-04	19.24	147.5	7.18	7.58
	13-Oct-04	18.17	176.2	6.95	5.23
TA2-W-27	6-Aug-03	20.14	204.2	7.43	8.22
	23-Oct-03	18.77	234.7	7.44	8.32
	15-Jan-04	16.19	233.9	7.44	4.91
	19-Apr-04	18.01	117.9	7.29	8.51
	28-Jul-04	18.82	166.5	7.19	8.50
	14-Oct-04	17.49	200.9	7.32	8.25
TJA-2	31-Jul-03	19.52	204.9	7.49	7.37
	15-Oct-03	17.74	238.7	7.49	7.42
	19-Jan-04	15.98	217.1	7.54	6.48
	5-May-04	19.30	144.6	7.40	7.47
	16-Aug-04	18.99	181.1	7.92	7.67

Well ID	**Sample Date**	**Temperature (^{0}C)**	**Oxidation Reduction Potential (mV)**	**pH**	**Dissolved Oxygen (mg/L)**
	11-Oct-04	16.51	168.3	7.10	5.71
TJA-3	6-Aug-03	20.97	194.5	7.41	6.68
	22-Oct-03	18.73	249.0	7.41	6.35
	27-Jan-04	16.89	250.1	7.36	4.28
	27-Apr-04	18.93	126.8	7.29	6.38
	9-Aug-04	20.78	209.7	7.65	6.93
	12-Oct-04	17.77	208.1	7.27	6.72
TJA-4	11-Aug-03	19.32	206.4	7.52	5.19
	27-Oct-03	17.58	225.7	7.49	5.41
	29-Jan-04	16.76	235.1	7.49	1.68
	20-Apr-04	16.83	154.0	7.33	5.51
	10-Aug-04	19.20	170.5	7.75	5.06
	12-Oct-04	17.88	196.0	6.98	4.16
TJA-6	11-Aug-03	22.32	217.0	7.47	4.48
	5-Nov-03	19.55	329.5	7.42	4.47
	4-Feb-04	17.90	232.0	7.39	2.31
	22-Apr-04	20.64	112.5	7.25	4.66
	4-Aug-04	21.60	171.4	7.18	4.91
	13-Oct-04	19.21	224.5	7.29	4.95
TJA-7	12-Aug-03	22.40	233.9	7.54	7.60
	28-Oct-03	17.11	234.6	7.53	8.08
	22-Jan-04	13.68	229.5	7.51	5.13
	30-Apr-04	17.39	136.6	7.40	7.64
	6-Aug-04	18.80	158.4	7.28	8.07
	15-Oct-04	16.86	154.9	7.20	4.10
WYO-3	13-Aug-03	20.05	227.5	7.48	0.28
	29-Oct-03	18.89	323.7	7.42	7.20
	21-Jan-04	16.51	233.1	7.42	4.24
	28-Apr-04	19.43	119.7	7.68	7.14
	11-Aug-04	20.00	171.3	7.74	7.04
	8-Oct-04	19.27	177.2	7.00	1.06
WYO-4	14-Aug-03	19.12	173.4	7.65	7.45
	3-Nov-03	16.85	263.7	7.63	8.15
	3-Feb-04	14.90	194.3	7.72	3.81
	30-Apr-04	17.20	157.7	7.88	8.21
	3-Aug-04	19.50	158.7	7.42	7.61
	6-Oct-04	16.11	145.8	7.39	7.09

mg/L = milligrams per liter
mV = millivolt
^{o}C = degrees Celsius

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Attachment E
Evaluation of an Intrinsic Aerobic Degradation Mechanism

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Evaluation of an Intrinsic Aerobic Degradation Mechanism in Tijeras Arroyo Groundwater, Sandia National Laboratories / New Mexico

April 2005

Prepared by
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Sandia National Laboratories

ABSTRACT

This evaluation is an informal report that documents the application of enzyme activity probes and control studies to evaluate the potential for cometabolic activity to degrade trichloroethene (TCE) at the Sandia National Laboratories/New Mexico (SNL/NM) Tijeras Arroyo Groundwater area of responsibility. The contaminants of concern include nitrate and TCE. Positive results from the application of probes to samples from both the perched groundwater system and the regional aquifer provide direct evidence of cometabolic enzymatic activity in all but one of the wells sampled. The enzyme activity probe data provide defensible, direct evidence that intrinsic aerobic cometabolism by indigenous microbial populations is an existing mechanism for natural attenuation of TCE in Tijeras Arroyo Groundwater.

CONTENTS

Appendix A. Enzyme Probe Data

FIGURES

TABLES

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ACRONYMS AND ABBREVIATIONS

3HPA	3-hydroxyphenylacetylene
Cinn	*trans*-cinnamonitrile
CME	Corrective Measures Evaluation
COC	chain of custody
COOC	Compliance Order on Consent
DAPI	4,6-diamindino-phenylindole
DCE	dichloroethene
DNA	deoxyribonucleic acid
F1	*Pseudomonas putida*
G4	*Burkholderia cepacia*
MCL	maximum contaminant level
MNA	monitored natural attenuation
NMED	New Mexico Environment Department
Ob3B	*Methylosinus trichosporium*
PA	phenylacetylene
PCE	tetrachloroethene
PCR	polymerase chain reaction
PHE	phenol monooxygenase
PK01	*Ralstonia picketti*
RMO	toluene monooxygenase
sMMO	soluble methane monooxygenase
SNL/NM	Sandia National Laboratories/New Mexico

TAG	Tijeras Arroyo Groundwater
TCE	trichloroethene
TOD	toluene dioxygenase
UV	ultraviolet light
VC	vinyl chloride
VOC	volatile organic compounds
W31	*Pseudomonas sp.*

1.0 INTRODUCTION

The *Corrective Measures Evaluation (CME) Work Plan Tijeras Arroyo Groundwater* (SNL/NM 2004a) was prepared as directed by the Compliance Order on Consent (COOC) issued by the New Mexico Environment Department (NMED) (NMED 2004). The CME Work Plan outlines a process for evaluating remedial alternatives in order to identify a corrective measure for the contaminants of concern at the Sandia National Laboratories/New Mexico (SNL/NM) Tijeras Arroyo Groundwater (TAG) area of responsibility. The contaminants of concern at TAG include the volatile organic compound (VOC) trichloroethene (TCE) and nitrate. The CME Work Plan identified a four stage data collection and interpretation process: (1) paper study, (2) numerical modeling, (3) laboratory studies, and (4) field scale studies. The field-scale studies stage includes establishing mechanisms for contaminant degradation at TAG. One such mechanism is aerobic cometabolic oxidation, a process by which a microbial cell metabolizes a substrate (in this case, TCE) in the presence of a second organic compound that is used as the primary source of carbon and energy. This paper presents results and interpretations of enzyme probe analyses applied to TAG samples. Enzyme activity probes are research tools that provide direct evidence of aerobic cometabolic oxidation of contaminants, including VOCs such as TCE.

2.0 SUMMARY OF ENZYME PROBE METHODS

Studies have shown that subsurface microbial communities are metabolically active and produce enzymes that catalyze diverse biochemical reactions, including cometabolism of a wide variety of chlorinated hydrocarbons (Wilson and Wilson, 1985; Fogel et al., 1986; Little et al., 1988; Oldenhuis et al., 1989; 1991; Tsien et al., 1989; Alvarez-Cohen and McCarty, 1991; Speitel and Alley, 1991; Brockman et al., 1995; Pfiffner et al., 1997). In contrast to anaerobic microbial populations that reductively dechlorinate TCE, many aerobic microorganisms cometabolically degrade TCE via oxygenase-catalyzed reactions, including organisms that use methane, propane, benzene, phenol, toluene, and ammonia as natural growth substrates (Ensley, 1991). Thus, aerobic cometabolism requires the presence of a primary substrate and oxygen but can fortuitously transform a cometabolic substrate if both requirements are met. If the primary substrate is absent, the enzyme required for cometabolic transformation will not be induced and the cometabolic transformation will not occur. TCE, *cis*-dichloroethene (DCE), *trans*-DCE, and vinyl chloride (VC) have all been shown to be susceptible to cometabolic oxidation under aerobic conditions (Wilson and Wilson, 1985; Semprini et al., 1990). For more details of cometabolic enzyme and pathways, refer to *Final Quick Win Vertical Profile Sampling Effort* (Wymore et al., 2004).

Enzyme activity probes are research tools that provide direct evidence that the mechanism for aerobic cometabolic oxidation of chlorinated ethenes, most notably TCE, is present and active in the aquifer. Enzyme activity probes that serve as alternative substrates for TCE-cometabolizing enzymes have been developed for four separate toluene oxygenases (Keener and Watwood, 1997; Keener et al., 1998; Kauffman et al., 2003; Clingenpeel et al., 2005a) and for the soluble methane monooxygenase (sMMO; Miller et al., 2002). These non-fluorescent probes are transformed by either the toluene or methane oxygenase enzymes into strongly fluorescent products. A clear, quantifiable signal (i.e., fluorescent probe product) is detected only when the enzyme of interest is actively functioning. If the appropriate enzyme is not present or is present but not active in a given sample, then the probes will not be transformed and no fluorescence will be detected. This class of probes provides direct evidence of specific cometabolic enzyme activity toward chlorinated solvents at remediation sites; this evidence is useful for documenting that intrinsic bioremediation is occurring in a given environment (Madsen, 1991; Madsen, 1998).

The nomenclature “toluene oxygenase” is derived from early laboratory studies and the presence of these enzymes is not an indication that toluene is present in the groundwater. The toluene enzymes may, under ambient conditions, be induced by the presence of any number of aromatic substances. Genes that code for toluene oxygenases have highly conserved overlap regions with genes for other aromatic oxygenases, including phenol and benzene (Fries et al., 1997; Mesarch et al., 2000; Parales et al., 2000; Baldwin et al., 2003). While the activity detected with the enzyme probe is derived from toluene induced pathways (fluorescent products are specific to degradation by the toluene induced enzymes), laboratory studies have suggested that these enzymes are not limited to degradation of or induction by toluene (Wackett, 1984; Parales et al., 2000).

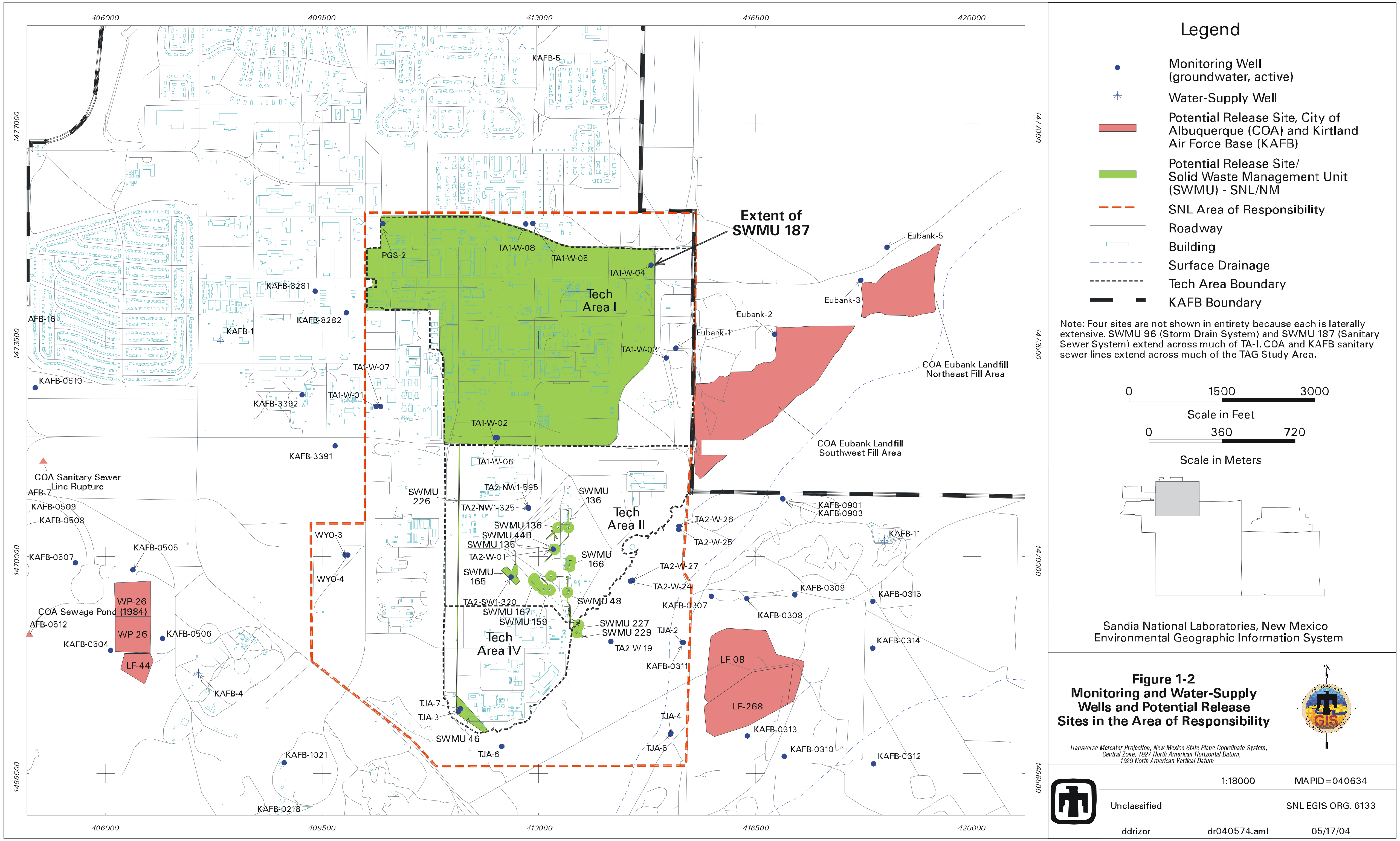
2.1 Sample Collection

Water samples were collected from 12 TAG monitoring wells (Figure 1) in conjunction with the current voluntary monitoring program for TAG by SNL/NM sampling crews. One third of the samples originated in the regional aquifer (TJA-3, TJA-6, TA1-W-02, and TA1-W-05), while two-thirds were from the perched groundwater system (TA2-W-19, WYO-4, TA2-W-01, TA2-W-26, TA1-W-08, TJA-2, TA2-SW1-320, and TJA-7). Samples were shipped to Northern Arizona University for analysis.

2.2 Laboratory Methods

This section describes the analytical techniques used, including enzyme probe analysis, total cell count (DAPI), and control studies. DAPI (4,6-diamindino-phenylindole) staining provides a total microbial cell count for a given sample. This number provides a relative means of quantifying the number of cells that have active enzymes, as determined by enzyme probe analysis. Enzyme probes provide a direct measure of the activity of both the toluene and methane monooxygenases, while the control studies further provide evidence of the targeted enzyme. The following techniques are widely accepted for use in laboratory studies (Keener et al., 1998; 2001; Miller et al., 2002; Kauffman et al., 2003; Clingenpeel et al., 2005a) but have been modified herein for assessment of a contaminated field site (Wymore et al., 2004; Howard et al., 2005). The sequence for analysis is as follows:

1. Enzyme activity probe analysis,
2. Negative and positive control studies,
3. DAPI staining,
4. DNA analysis, and
5. Inhibition control studies.



Note: Four sites are not shown in entirety because each is laterally extensive. SWMU 96 (Storm Drain System) and SWMU 187 (Sanitary Sewer System) extend across much of TA-I. COA and KAFB sanitary sewer lines extend across much of the TAG Study Area.

Sandia National Laboratories, New Mexico
Environmental Geographic Information System

Figure 1-2
Monitoring and Water-Supply Wells and Potential Release Sites in the Area of Responsibility

Transverse Mercator Projection, New Mexico State Plane Coordinate System, Central Zone, 1927 North American Horizontal Datum, 1929 North American Vertical Datum

1:18000 MAPID=040634
Unclassified SNL EGIS ORG. 6133
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Figure 1. Monitoring and Water Supply Wells and Potential Release Sites in the Area of Responsibility.

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2.2.1 Enzyme Activity Determination

Enzyme activity was determined using two methods, toluene probes and the sMMO probe, for 12 TAG monitoring locations. Evaluation with the toluene probes is performed by filtering 10 mL of groundwater onto black, polycarbonate filters on a vacuum manifold. One mL of an enzyme activity probe (5mM phenylacetylene (PA), 5mM *trans*-cinnamonitrile (Cinn), and 5mM 3-hydroxyphenylacetylene (3HPA)) was pipetted onto the surface of the filter and incubated at room temperature for 10 minutes. PA and 3HPA label cells, with varying affinities, that express the following toluene enzymes: 2,3 dioxygenase, toluene 2-monooxygenase, and toluene 3-monooxygenase (Keener et al., 1998; Kauffman et al., 2003), while *trans*-cinnamonitrile labels cells with active toluene-2,3 dioxygenase enzymes with the highest affinity and cells with the toluene-3-monooxygenase to a lesser degree. A separate filter was used for each of the three probes. After 10 minutes, vacuum was reapplied to remove the solution and the filter was washed with buffer to remove any residual substrate that could potentially interfere with epifluorescent imaging. The filter was mounted on a glass microscope slide and examined for fluorescent cells by epifluorescent microscopy. If any of the toluene enzymes were active, a clear fluorescent signal would be seen when looking at the filter under the microscope. However, if no enzyme was active, the filter would appear black and no fluorescent signal would be seen.

Evaluation with the sMMO probe was similar to the toluene probes with the following modifications. Water samples were filtered onto Supor filters to prevent background interference from polycarbonate filters. In addition, the product of coumarin transformation by the sMMO enzyme is highly soluble (7-hydroxycoumarin, Miller et al., 2002); therefore, the fluorescence was measured fluorometrically (i.e., in solution) rather than by epifluorescent microscopy.

2.2.2 Control Studies

Both negative and positive controls were carried out for the enzyme activity probe analysis. The negative controls were as follows:

1. Cells filtered onto a black polycarbonate filter with no stain or probe added,
2. Filtering each of the enzyme probes onto black polycarbonate filters, with no bacterial cells, and
3. 1 mL of stationary-phase *Escherichia coli* cells, which do not express any toluene oxygenase gene, exposed to each of the enzyme probes as described above.

Positive controls consisted of exposing laboratory grown strains (expressing various toluene oxygenases or sMMO), under toluene or methane induction conditions, to the appropriate enzyme probe. Specifically, *Burkholderia cepacia* (G4), which has the toluene-2-monoxygenase, and *Ralstonia picketti* (PK01), which has the toluene-3-monooxygenase as controls for the 3HPA probe; *Pseudomonas putida* (F1), which has the 2,3-dioxygenase, and *Pseudomonas sp.* (W31), having the toluene-3-monooxygenase, as positive test organisms for the PA probe; F1 as a positive test organism for the cinnamonitrile probe; and *Methylosinus trichosporium* (OB3b) as a positive control for the coumarin probe (sMMO).

2.2.3 DAPI Staining

DAPI is a general fluorescent stain that binds to the DNA of bacterial cells. The total number of cells is determined by the number of cells that can be stained and counted using epifluorescent microscopy. Groundwater samples (10 mL) were filtered onto black polycarbonate filters. DAPI was added onto the surface of the filter and incubated for 5 minutes (60 μl/ml; final concentration 3 μg/ml) at room temperature. Following the staining protocol, samples were washed with 1 mL of nanopure water and vacuum-filter dried. Filters were mounted on glass microscope slides, covered with immersion oil and a coverslip, and viewed using an epifluorescent microscope equipped with ultraviolet (UV) capabilities.

2.2.4 DNA Analysis

In addition to the enzyme probes, a series of molecular probes have been developed or adapted to investigate the genetic potential of toluene and methane-oxidizing microbial populations (McDonald et al., 1995; Baldwin et al., 2003). These techniques are designed to look for the presence of the genes coding for toluene or methane oxygenases and are considered indirect or supporting evidence for the enzyme activity measurements. Enzyme activity probes provide direct evidence of degradative activity, while DNA analysis determines the potential for degradative activity. A sufficient amount of DNA could not be extracted from the volume of groundwater taken at TAG wells; therefore, this supporting evidence for the enzyme activity is not available.

2.2.5 Inhibition Control Studies

In addition to the control studies discussed in Section 2.2.2, several inhibitory controls were performed to support the enzyme activity probe findings. Phenylacetylene, an irreversible inhibitor, was applied to a sub-set of TAG samples (TJA-3, TJA-6, TA1-W-02, TA2-W-26, TA2-SW1-320, and TA1-W-05). Groundwater samples (~900 mL) were filtered onto a 47-mm Supor filter. Filters were cut, using a sterile razor blade, into four quadrants. One of the quadrants was exposed to 250 μM PA at room temperature for 10 minutes. The filter was placed onto the tower, washed with 1 mL of nanopure water, and then exposed to the enzyme probe (coumarin), as described above. The filters were viewed and counted with an epifluorescent microscope.

Many of the toluene pathways are irreversibly inhibited by the presence of 1-pentyne (10% v/v), the only exception being the toluene dioxygenase enzyme (Keener et al., 2001). Select samples (TA2-W-19, TJA-6, TJA-2, TA2-SW1-320, TJA-7, and TA1-W-05) were incubated in the presence of 1-pentyne and subsequently assessed for enzyme activity. Briefly, 5 mL of groundwater was filtered onto two Supor filters. One filter was exposed to 1-pentyne (vapor form) for 2 hours, the other for 2 days; both in a vacuum desiccator. Following exposure, filters were assessed for enzyme probe response, as described in Section 2.2.1.

3.0 RESULTS

This section presents the enzyme probe and control study results. Section 3.1 presents the results of the enzyme probe (fluorescence data), while Section 3.2 presents the results of the control studies.

3.1 Enzyme Probe Sample Results

Table 1 presents the results of the enzyme probe sample analyses. For each result, the sample date, well location, Administrative Record/Chain of Custody (COC) number, and SNL/NM Sample ID are listed. For the toluene probes (3HPA, PA, Cinn) and sMMO probe (coumarin), a positive response with the probe and the presence of active enzymes in the sample is designated as yes (Y). A no (N) indicates there was no probe response detected. More details, primarily about the fraction of the total cells that were probe positive, can be found in Appendix A. The DAPI column shows the total number of microorganisms in a given groundwater sample, as determined by DAPI staining.

Figure 2 shows the results of applying enzyme probes to a sample from well TJA-2 (Sample ID 066763-042); the figure shows both a negative (PA) and positive (3HPA) response to application of the toluene enzyme probes. The micrograph on the left represents the DAPI-stained or total number of microbial cells present in the sample, the center micrograph shows a negative response, and the right micrograph represents the cells that transformed the probe into a fluorescent product.

Figure 2. Micrographs of Sample TJA-2 within the perched groundwater system.

3.2 Control Studies

Since a sufficient amount of microbial DNA could not be extracted from the volume of groundwater taken, control studies were performed to confirm that observed results were not artificial or influenced by outside factors (i.e., inducers). The series of negative controls were designed to determine if the probes provided a false positive response. The results for two of the three controls are presented in Table 2. Enzyme probes pipetted onto filters without cells resulted in no fluorescent signal. *E.coli* cells (no toluene oxygenase enzymes) exposed to each of the enzyme probes also resulted in no fluorescent signal (Table 2 rows 1 and 2). The third negative control consisted of filtering every sample onto a black polycarbonate filter to determine if there was background fluorescence (data not shown). In all cases, no fluorescence was observed in the absence of the enzyme probes. These results show that the probes did not give a false positive result.

Table 1. Results of enzyme probe analysis.

					Toluene probes[a]			**sMMO probe**[a]	**DAPI**
Date	**Well Location**	**Aquifer**	**COC #**	**Sample ID**	**3HPA**	**PA**	**Cinn**	**Coumarin**	**Cells/mL**
01.04.05	TA2-W-19	Perched	608124	066752-042	Y	Y	Y	N	3.20E+03
01.05.05	TJA-3	Regional	608132	066765-042	Y	N	Y	Y	5.00E+03
01.06.05	TJA-6	Regional	608135	066769-042	Y	Y	Y	Y	2.30E+04
01.11.05	WYO-4	Perched	608143	066778-042	N	N	N	N	2.34E+03
01.11.05	TA1-W-02	Regional	608109	066731-042	N	Y	Y	Y	1.19E+04
01.12.05	TA2-W-01	Perched	608122	066750-042	N	N	Y	N	4.60E+03
01.12.05	TA1-W-08	Perched	608116	066742-042	N	Y	Y	N	5.50E+03
01.13.05	TA2-W-26	Perched	608126	066755-042	Y	N	Y	Y	7.10E+03
01.13.05	TJA-2	Perched	608130	066763-042	Y	N	Y	N	2.37E+03
01.17.05	TA2-SW1-320	Perched	608120	066748-042	Y	Y	Y	Y	2.35E+03
01.20.05	TJA-7	Perched	608139	066771-042	Y	Y	Y	N	9.65E+03
01.25.05	TA1-W-05	Regional	608113	066737-042	Y	Y	Y	Y	7.54E+03

a- Yes (Y) indicates the presence of an active toluene or sMMO enzyme in the groundwater sample; no (N) indicates no probe response.

Table 2. Results of control studies from wells at the TAG wells.

Control/Bacterial Strain	**Enzyme**	**PA**	**3HPA**	**Cinn**	**Coumarin**
Filter[a]	N/A	-	-	-	-
E.coli[b]	N/A	-	-	-	-
G4[c]	2-monooxygenase	+	+	-	-
PK01[c]	3-monooxygenase	-	+	-	-
F1[c]	2,3-dioxygenase	+	+	+	-
W31[c]	3-monooxygenase	+	-	+	-
OB3b[d]	sMMO	-	-	-	+

a- Cells on a black filter, no probe.
b- E.coli cells (no toluene genes) exposed to enzyme probes specific for toluene oxygenases.
c- Laboratory strains with toluene oxygenase enzymes and exposed to enzyme probes.
d- Laboratory strains with sMMO enzyme and exposed to the coumarin probe.
The + symbol designates that a positive response (fluorescent signal) was achieved. The – symbol means that there was no response.

The second series of controls were those which used laboratory strains exposed to enzyme probes to provide confirmation that each of the probes was functioning as expected (i.e., that a positive response is produced in actively degrading organisms with the appropriate enzyme). In all cases, the bacterial cells with the appropriate enzyme responded positively (fluorescent signal) to the application of the enzyme probe (Table 2). Each of these strains also responded negatively to probes targeted at other toluene oxygenase enzymes. The results show that the probes were accurately detecting active enzymes.

In addition to these controls, several other inhibitory controls were performed. PA, an irreversible inhibitor, was applied to TAG samples that showed activity as determined by the coumarin assay. At the chosen concentration, PA has been shown to differentially inhibit the soluble versus the particulate form of the enzyme as well as the methane oxygenase enzyme in comparison to other enzymes (Lontoh et al., 2000). Deactivation of the sMMO enzyme by exposure to PA should therefore result in the loss of the fluorescent response to coumarin. Table 3 indicates that inhibition of the fluorescent signal (I) was observed in all of the samples to which the inhibitor was applied.

Table 3. Results of the sMMO inhibitor study from TAG wells.

Date	Well Location	Aquifer	COC #	Sample ID	sMMO activity	PA[a]
01/05/05	TJA-3	Regional	608132	066765-042	Y	I
01/06/05	TJA-6	Regional	608135	066769-042	Y	I
01/11/05	TA1-W-02	Regional	608109	066731-042	Y	I
01/13/05	TA2-W-26	Perched	608126	066755-042	Y	I
01/17/05	TA2-SW1-320	Perched	608120	066748-042	Y	I
01/25/05	TA1-W-05	Regional	608113	066737-042	Y	I

a- Phenylacetylene was used as an inhibitor of the sMMO enzyme; Inhibition (I) indicates that the sample was inhibited and no fluorescent signal was detected; Yes (Y) indicates the presence of an active sMMO enzyme in the groundwater sample.

A study based on laboratory cultures showed that many of the toluene pathways are irreversibly inhibited by the presence of 1-pentyne (Keener et al., 2001). Select samples were incubated in the presence of 1-pentyne and subsequently assessed for enzyme activity with the probes. Table 4 shows the results of the inhibition of the toluene enzymes; all of the samples were inhibited and showed no fluorescent signal following exposure.

Table 4. Results of the toluene inhibitor study from TAG wells.

Date	Well Location	Aquifer	COC #	Sample ID	Toluene activity	1-pentyne[a]
01/04/05	TA2-W-19	Perched	608124	066752-042	Y	I
01/06/05	TJA-6	Regional	608135	066769-042	Y	I
01/13/05	TJA-2	Perched	608130	066763-042	Y	I
01/17/05	TA2-SW1-320	Perched	608120	066748-042	Y	I
01/20/05	TJA-7	Perched	608139	066771-042	Y	I
01/25/05	TA1-W-05	Regional	608113	066737-042	Y	I

a- 1-pentyne was used as an inhibitor of the toluene oxygenase enzymes. Inhibition (I) indicates that the sample was inhibited and no fluorescent signal was detected; Yes (Y) indicates the presence of an active toluene enzyme in the groundwater sample.

4.0 SUMMARY AND CONCLUSIONS

The purpose of these studies was to investigate biodegradation of TCE in the perched groundwater system. The primary goal was to identify an active aerobic degradation mechanism through the use of enzyme activity probes.

A suite of probes has been developed that indicate activity of enzymes responsible for cometabolic degradation of TCE. Three toluene degradation pathways and the sMMO degradation pathway were evaluated. Enzymes responsible for degradation of these compounds have been shown to cometabolically degrade TCE and have been found in all groundwater systems investigated thus far, including the Test Area North site of the Idaho National Laboratory, Technical Area V (TA-V) site of the Sandia National Laboratories, and the Arizona Department of Environmental Quality Park-Euclid WQARF (PE) site (Wymore et al., 2004; Clingenpeel et al., 2005b; Howard et al., 2005).

The results of the TAG enzyme probe analysis ascertains the presence and activity of at least one toluene oxygenase or sMMO enzyme in all but one of the wells sampled (WYO-4) based on the application of enzyme activity probes. Fifty percent of the wells showed activity with the sMMO enzyme probe, while 92% (11 out of 12) showed a response with the toluene probes. Any positive response, even with one probe, provides direct evidence of enzyme activity in the groundwater sample. Control studies confirmed the findings of the enzyme probe data, specifically that the probes accurately and efficiently targeted specific oxidative pathways. Inhibition studies confirmed that the activity measured was a result of the enzyme targeted and not as a result of other oxygenase enzymes.

The detection of both sMMO and toluene oxygenase enzyme activity (as determined by enzyme activity probes) in TAG samples identifies cometabolism as a mechanism of natural attenuation. Active enzymes were found throughout the tested area, including samples taken from both inside and outside the TCE contamination area, in the perched groundwater system and at all regional aquifer wells. This demonstrates that the process is not driven by constituents in the contaminated groundwater but by the presence of the enzymes and oxygen. These data provide conclusive evidence of active enzyme systems capable of TCE degradation at the TAG SNL/NM are of responsibility and more importantly represent an active mechanism for the natural attenuation of contaminants.

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Appendix A

Enzyme Probe Data

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Table A-1. Results of enzyme probe analysis.

				Toluene probes[a]			**sMMO probe**	**Total DAPI count**
Date	**Well Location**	**COC #**	**Sample ID**	**3HPA**	**PA**	**Cinn**	**Coumarin**[b]	**Cells/mL**
01/04/05	TA2-W-19	608124	066752-042	++	+	+	-	3.20E+03
01/05/05	TJA-3	608132	066765-042	+	-	+	+	5.00E+03
01/06/05	TJA-6	608135	066769-042	+++	++	+++	+	2.30E+04
01/11/05	WYO-4	608143	066778-042	-	-	-	-	2.34E+03
01/11/05	TA1-W-02	608109	066731-042	-	+	+	+	1.19E+04
01/12/05	TA2-W-01	608122	066750-042	-	-	+	-	4.60E+03
01/12/05	TA1-W-08	608116	066742-042	-	+	+	-	5.50E+03
01/13/05	TA2-W-26	608126	066755-042	+	-	+	+	7.10E+03
01/13/05	TJA-2	608130	066763-042	++	-	+	-	2.37E+03
01/17/05	TA2-SW1-320	608120	066748-042	++	+	+	+	2.35E+03
01/20/05	TJA-7	608139	066771-042	+	+	++	-	9.65E+03
01/25/05	TA1-W-05	608113	066737-042	+	+	+	+	7.54E+03

[a] The number of plus signs designated the percentage of positive response resulting from each probe. For example, a single plus sign indicates that between 10-25% of the total cells in the sample demonstrated a clear quantifiable response when exposed to that particular probe; Two plus signs represents 25-50%; three, 50-75%; and four 75-100% of the total microbial population were probe positive, verifying enzyme activity.

[b] A plus sign indicates that sMMO activity was detected. A minus sign indicates that no enzyme activity was determined; no fluorescence was detected.

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