Sandia National Laboratories, New Mexico Environmental Restoration Operations

Revised Tijeras Arroyo Groundwater Current Conceptual Model and Corrective Measures Evaluation Report

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TABLE OF CONTENTS

LIST OF FIGURES v
LIST OF TABLES ix
LIST OF APPENDICES xi
LIST OF ATTACHMENTS xi
ACRONYMS AND ABBREVIATIONS xiii
EXECUTIVE SUMMARY ES-1

1.0 INTRODUCTION 1-1

1.1 TAG Background and Status of the CCM and CME Report 1-3
1.2 Objectives 1-5
1.3 Organization 1-5

2.0 REGIONAL GEOLOGY AND HYDROGEOLOGY 2-1

2.1 Regional Geologic Setting 2-1
2.2 Regional Hydrogeologic Setting 2-3
2.3 Regional Stratigraphic Framework 2-6
2.4 Regional Hydrology 2-8
2.5 Regional Aquifer 2-10

2.5.1 Aquifer Geometry 2-10
2.5.2 Hydrostratigraphic Characteristics 2-10
2.5.3 Regional Recharge 2-11
2.5.4 Regional Groundwater Flow 2-11
2.5.5 Regional Discharge 2-14

3.0 GEOLOGY AND HYDROGEOLOGY OF THE TAG AOC 3-1

3.1 Geologic Setting of TAG AOC Vicinity 3-1

3.1.1 Structural Framework 3-1
3.1.2 Stratigraphic Framework 3-2

3.1.2.1 Alluvial Fan Lithofacies 3-5
3.1.2.2 Ancestral Rio Grande Deposits 3-5

3.2 Monitoring Well Network 3-8

3.2.1 Monitoring Well Network 3-8

3.3 Hydrogeologic Conditions at the TAG AOC 3-13

3.3.1 Potentiometric Surfaces 3-13

3.3.1.1 Potentiometric Surface of the Perched Groundwater System 3-13
3.3.1.2 Potentiometric Surface of the Regional Aquifer 3-13

TABLE OF CONTENTS (Continued)

3.3.2 Groundwater Geochemistry 3-21

3.3.2.1 Piper Diagrams 3-23
3.3.2.2 Stiff Diagrams 3-23

3.3.3 Geochemical Modeling 3-33
3.3.4 Geochemical Ratios 3-33
3.3.5 Hydraulic Properties 3-37

3.3.5.1 Horizontal Hydraulic Conductivity 3-37
3.3.5.2 Vertical Hydraulic Conductivity 3-38
3.3.5.3 Horizontal Hydraulic Gradients 3-38
3.3.5.4 Vertical Hydraulic Gradients 3-39
3.3.5.5 Effective Porosity 3-39
3.3.5.6 Groundwater Velocities 3-39

3.4 Groundwater Recharge and Discharge 3-40

3.4.1 Wastewater Disposal 3-41
3.4.2 Precipitation 3-41
3.4.3 Infiltration and Recharge 3-41
3.4.4 Local Discharge and Production Wells 3-41
3.4.5 Local Recharge 3-42

3.5 Water Level Fluctuations 3-42
3.6 Groundwater Flow Modeling 3-57

3.6.1 Capture Zone Modeling for Production Wells 3-57
3.6.2 Contaminant Transport Modeling 3-58
3.6.3 Conceptual Modeling of Recharge Features and Stratigraphic Controls 3-60

3.7 Stable Isotopes 3-63
3.8 Perching Horizon and Interpretation of Downhole Geophysical Logs 3-71
3.9 Mass Balance Modeling of Vertical and Lateral Flow in the Perched Groundwater System 3-77

4.0 SITE HISTORY, CORRECTIVE ACTIONS, AND POTENTIAL RELEASE SITES 4-1

4.1 Operational History 4-1

4.1.1 Co-located Operations 4-1
4.1.2 KAFB Operations 4-3
4.1.3 ABCWUA/COA Operations 4-7

4.2 SNL/NM Corrective Actions in the TAG AOC 4-8

TABLE OF CONTENTS (Continued)

4.3 SNL/NM Historical Releases with the Potential to Impact Groundwater 4-10

4.3.1 SWMU 46 (Old Acid Waste Line Outfall) 4-10
4.3.2 Multiple SWMUs at TA-II 4-12
4.3.3 TA-I Sanitary Sewer System (SWMU 187) 4-12

4.4 Federal SWMUs and Municipal Sites with Potential for Creating Groundwater Contamination 4-13

5.0 GROUNDWATER MONITORING AT THE TAG AOC 5-1

5.1 Nitrate 5-1
5.2 Nature and Extent of Nitrate Contamination 5-6
5.3 Time-Series Plots of NPN Concentrations in Groundwater 5-6
5.4 Trichloroethene (TCE) 5-13
5.5 Other Groundwater Analytes 5-15

6.0 CONCEPTUAL SITE MODEL 6-1

6.1 TAG Conceptual Site Model 6-1
6.2 Nitrate Occurrence in the Environment 6-5
6.3 Health Effects Associated with Nitrate 6-6
6.4 Potential Receptors of Groundwater Contamination 6-6
6.5 Summary of the Conceptual Site Model 6-7

7.0 CORRECTIVE MEASURES EVALUATION 7-1

7.1 Remedial Technology Identification and Screening 7-1

7.1.1 Monitored Natural Attenuation 7-2
7.1.2 In-Situ Bioremediation 7-2
7.1.3 Groundwater Extraction and Treatment 7-2
7.1.4 Other Remedial Technologies 7-3

7.2 Identification and Description of Remedial Alternatives 7-3

7.2.1 Alternative 1: Monitored Natural Attenuation 7-4
7.2.2 Alternative 2: In-Situ Bioremediation 7-6
7.2.3 Alternative 3: Groundwater Extraction and Treatment 7-12

7.3 Evaluation of Remedial Alternatives 7-16

7.3.1 Evaluation of Alternative 1: Monitored Natural Attenuation 7-16

7.3.1.1 Alternative 1 Threshold Criteria 7-16
7.3.1.2 Alternative 1 Balancing Criteria 7-20

TABLE OF CONTENTS (Continued)

7.3.2 Evaluation of Alternative 2: In-Situ Bioremediation 7-21

7.3.2.1 Alternative 2 Threshold Criteria 7-21
7.3.2.2 Alternative 2 Balancing Criteria..... 7-22

7.3.3 Evaluation of Alternative 3: Groundwater Extraction and Treatment 7-23

7.3.3.1 Alternative 3 Threshold Criteria 7-23
7.3.3.2 Alternative 3 Balancing Criteria..... 7-24

7.3.4 Sustainability Evaluation..... 7-25

7.3.4.1 Scope of the Alternatives Relevant to Sustainability..... 7-26
7.3.4.2 Sustainability Evaluation Methodology 7-27
7.3.4.3 Results..... 7-27

7.4 Preferred Remedy 7-34
7.5 Remedial Alternative Design Criteria..... 7-36
7.6 Corrective Measures Implementation Plan..... 7-37

7.6.1 Corrective Measures Implementation Plan Outline 7-37
7.6.2 Estimated Schedule for Initiating Corrective Measures Implementation and Associated Deliverables..... 7-38

8.0 CONCLUSIONS..... 8-1

9.0 REFERENCES..... 9-1

LIST OF FIGURES

Figure		Page
1-1	TAG AOC and the TAG Study Area Location in Southeast Albuquerque	1-2
2-1	Principal Geologic Features of the Albuquerque Basin	2-2
2-2	Generalized Geology near SNL/NM and KAFB (Van Hart 2003)	2-4
2-3	Hydrogeologically Distinct Regions near KAFB (SNL/NM June 2016)	2-5
2-4	Schematic of Typical Alluvial Fan Sedimentation Packages (Spearing 1974)	2-7
2-5	Production Wells and Springs (perennial and ephemeral) Located on KAFB	2-9
2-6	Groundwater Elevations that Represent Predevelopment Conditions in the Santa Fe Group Regional Aquifer in the Middle Rio Grande Basin (Bartolino and Cole 2002)	2-12
2-7	Production Well Influence on the Potentiometric Surface for the Regional Aquifer in 1995 near KAFB (Bartolino and Cole 2002)	2-13
3-1	Geophysical Cross-Section across the TAG AOC (Van Hart June 2003)	3-3
3-2	Isopach Map of the Vertical Distance between the Perched Groundwater System and the Regional Aquifer, modified from Van Hart, June 2001 (SNL/NM November 2002)	3-6
3-3	SNL/NM Groundwater Monitoring Wells in the TAG AOC	3-9
3-4	Potentiometric Surface Map for the Perched Groundwater System near the TAG AOC, October 2015	3-17
3-5	Potentiometric Surface Map for the Regional Aquifer near the TAG AOC, October 2015	3-19
3-6	Piper Diagrams for Samples Collected in 2015 from Monitoring Wells Screened in the Perched Groundwater System and the Regional Aquifer	3-24
3-7	Piper Diagrams for Samples Collected in 2003 from Monitoring Wells Screened in the Perched Groundwater System and the Regional Aquifer	3-25
3-8	Stiff Diagrams for Samples Collected in 2015 from Monitoring Wells Screened in the Perched Groundwater System and the Regional Aquifer	3-26

LIST OF FIGURES (Continued)

Figure **Page**

3-9 Stiff Diagrams for Samples Collected in 2003 from Monitoring Wells Screened in the Perched Groundwater System and the Regional Aquifer 3-27

3-10 Examples of Stiff Diagrams for Nitrate-Contaminated Groundwater in New Mexico (McQuillan April 2016) 3-28

3-11 Stiff Diagrams for Groundwater Samples Collected by KAFB at Monitoring Wells Screened in the Perched Groundwater System and the Regional Aquifer (McQuillan [April 2016] from an unpublished KAFB report) 3-31

3-12 NPN versus Chloride Concentrations for Groundwater Samples Collected near the TAG AOC 3-35

3-13 Recharge Features near the TAG AOC 3-43

3-14 Hydrographs for All Monitoring Wells Completed in the TAG AOC 3-44

3-15 Hydrographs for Six Monitoring Wells Completed in the Perched Groundwater at the TAG AOC 3-45

3-16 Hydrographs for Nine Monitoring Wells Completed in the Perched Groundwater System at the TAG AOC 3-46

3-17 Hydrographs for Monitoring Wells Completed in the Regional Aquifer at the TAG AOC 3-47

3-18 Hydrologic Section Depicting the Merging Zone between the Perched Groundwater System and the Regional Aquifer using October 2015 Data 3-49

3-19 Annual Change in Groundwater Elevations at Monitoring Wells Screened in the Perched Groundwater System in the TAG AOC 3-53

3-20 Annual Change in Groundwater Elevations at Monitoring Wells Screened in the Regional Aquifer in the TAG AOC 3-54

3-21 Estimated Years When Groundwater Elevations Will Decline Below Perched Groundwater System Well Screens in the TAG AOC 3-55

3-22 Modeled Capture Zones for Production Wells Used by KAFB and the ABCWUA (SNL/NM February 2001) 3-59

3-23 Depiction of the Primary Modeling Constraints and the Simulated Results for the Water-Bearing Units near the TAG AOC (BGW September 2002) 3-62

LIST OF FIGURES (Continued)

Figure **Page**

3-24 Dual-Isotope Plot of Nitrate Isotopic Composition for Monitoring Wells Screened in the Regional Aquifer in the TAG AOC, TA-V AOC, and the Burn Site AOC 3-64

3-25 Isotopic Composition of $\delta^{18}O$ in Water versus $\delta^{18}O$ in Nitrate for Groundwater Samples Collected in 2012 at the Three SNL/NM AOCs 3-65

3-26 Isotopic Composition (δDeuterium versus $\delta^{18}O$) of Groundwater Along Tijeras Arroyo in SNL/NM Monitoring Wells 3-67

3-27 Isotopic Composition (δDeuterium versus $\delta^{18}O$) of Groundwater Along Tijeras Arroyo in KAFB Monitoring and Production Wells 3-69

3-28 Structure-Contour Map for the Perching Horizon that Underlies the Perched Groundwater System 3-75

3-29 Perching Horizon Thickness Underlying the Perched Groundwater System 3-76

3-30 Perched Groundwater System Thickness below Each Well Screen 3-79

3-31 Total Perched Groundwater System Thickness, October 2015 3-80

3-32 Vertical Distance from the Base of the Perching Horizon to the Regional Aquifer Potentiometric Surface, October 2015 3-81

4-1 Historical Commercial and Military Aircraft Operations in the TAG AOC 4-2

4-2 Monitoring Wells and Potential Nitrate Release Sites near the TAG AOC 4-5

4-3 Potential Nitrate Release Sites in the TAG AOC 4-11

5-1 Monitoring Wells Used for Sampling Purposes by Personnel from SNL/NM, KAFB, and the COA EHD near the TAG AOC prior to 2018 5-2

5–2 Time-Series Plot of NPN Concentrations in Groundwater Samples Collected from SNL/NM Monitoring Wells in the TAG AOC 5-5

5-3 Maximum NPN Concentrations in Groundwater Samples Collected in 2015 from Monitoring Wells Screened in the Perched Groundwater System 5-7

5-4 Maximum NPN Concentrations in Groundwater Samples Collected in 2015 from Monitoring Wells Screened in the Regional Aquifer 5-8

LIST OF FIGURES (Concluded)

Figure		Page
5–5	Time-Series Plot of NPN Concentrations in Perched Groundwater Samples Collected from Monitoring Well TA2-W-19	5-9
5–6	Time-Series Plot of NPN Concentrations in Perched Groundwater Samples Collected from Monitoring Wells TA2-SW1-320 and TA2-W-28 (replacement)	5-10
5–7	Time-Series Plot of NPN Concentrations in Perched Groundwater Samples Collected from Monitoring Well TJA-2	5-11
5–8	Time-Series Plot of NPN Concentrations in Perched Groundwater Samples Collected from Monitoring Well TJA-7	5-12
5–9	Time-Series Plot of NPN Concentrations in Merging-Zone Groundwater Samples Collected from Monitoring Well TJA-4	5-14
6-1	Conceptual Site Model for TAG Area, View to Northeast, Not to Scale	6-2
7-1	Conceptual Design for Alternative 1: Monitored Natural Attenuation	7-5
7-2	Conceptual Design for Alternative 2: In-Situ Bioremediation	7-7
7-3	Conceptual Cross-Section of In-Situ Bioremediation Treatment Areas	7-10
7-4	Conceptual Plan View of ISB Treatment Areas Surrounding Injection Wells	7-11
7-5	Conceptual Design for Alternative 3: Groundwater Extraction and Treatment	7-13
7-6	Results of the Sustainability Evaluation for the TAG AOC Remedial Alternatives (greenhouse gas and energy use)	7-29
7-7	Results of the Sustainability Evaluation for the TAG AOC Remedial Alternatives (water consumption and electricity usage)	7-30
7-8	Results of the Sustainability Evaluation for the TAG AOC Remedial Alternatives (emissions)	7-31
7-9	Results of the Sustainability Evaluation for the TAG AOC Remedial Alternatives (fatality and injury risk)	7-32
7-10	Normalized Sustainability Impacts for the TAG AOC Remedial Alternatives	7-33

LIST OF TABLES

Table		Page
1-1	Cross Walk of Consent Order (NMED April 2004) Requirements versus this Report	1-6
3-1	Calculated Estimates of Hydraulic Conductivities for Core Samples Collected from TA-II Boreholes (SNL/NM 1995)	3-7
3-2	Summary of Well Construction and Hydrogeologic Data for Active Groundwater Monitoring Wells in the TAG AOC	3-11
3-3	Comparison of Water-bearing Units Characteristics and Properties in the TAG AOC	3-14
3-4	Geochemical Data Sources Used for Generating Piper and Stiff Diagrams	3-22
3-5	Estimates of Groundwater Horizontal Velocities in the TAG AOC	3-40
3-6	Average Annual Changes in Groundwater Elevations and the Estimated Time When Groundwater Elevations Decline Below the Perched Groundwater System Well Screens at the TAG AOC	3-52
3-7	Average Annual Changes in Groundwater Elevations for Monitoring Wells Screened in the Regional Aquifer at the TAG AOC	3-57
3-8	Simulated Recharge Rates in the TAG AOC Model (BGW September 2002)	3-61
3-9	Geophysical Logging Dates and Applicable Logs for Monitoring Wells near the TAG AOC	3-72
3-10	Well Pairs Used for Interpreting Geophysical Logs near the TAG AOC.	3-73
3-11	Structure Contour Elevations and Thickness of the Perching Horizon as Estimated from Downhole Geophysical Logs	3-74
3-12	Total Perched Groundwater System Thickness the Vertical Distance from the Base of Perching Horizon to the Regional Aquifer as Estimated from Downhole Geophysical Logs	3-78
4-1	Corrective Action Complete Approval Dates for SWMUs in the TAG AOC (NMED January 2015)	4-9
4-2	SNL/NM SWMUs in the TAG AOC that Potentially Released Water Containing Nitrogenous Compounds	4-10

LIST OF TABLES (Concluded)

Table **Page**

4-3 Potential Nitrate Release Sites that may have Impacted Groundwater near the TAG AOC 4-15

5-1 Maximum NPN Concentration for Groundwater Samples Collected in 2015 from Monitoring Wells near the TAG AOC 5-3

5-2 Evaluation of Trends for NPN Concentrations and Groundwater Elevations for Monitoring Wells in the Perched Groundwater System that Exceed the Nitrate MCL 5-13

7-1 Summary of the Remedial Alternatives Evaluation for the TAG AOC 7-17

7-2 Results of the Sustainability Evaluation for the TAG AOC Remedial Alternatives 7-28

7-3 Preliminary Schedule for the TAG AOC Corrective Action 7-39

LIST OF APPENDICES

A Tijeras Arroyo Groundwater Investigation Historical Timeline

B Construction Details for Monitoring, Production, and Remediation Wells near the TAG AOC

C Groundwater Elevations Measured in 2015 at Monitoring Wells near the TAG AOC

D Evaluation of Contaminant Transport (SNL/NM August 2005)

E Cost Estimates and Design Assumptions for the Remedial Alternatives

LIST OF ATTACHMENTS

1 Stratigraphic Cross-Sections for the TAG AOC

2 Index of Downhole Geophysical Logging Conducted near the TAG AOC

3 Geophysical Logs for the TAG AOC

4 Index of Borehole Lithologic Logs for Monitoring Wells Installed in the TAG AOC

5 Lithologic Logs for the TAG AOC

6 Well Diagrams for Monitoring Wells near the TAG AOC

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ACRONYMS AND ABBREVIATIONS

ABCWUA	Albuquerque Bernalillo County Water Utility Authority
amsl	above mean sea level
AOC	Area of Concern
AOR	Area of Responsibility
ARCH	air rotary casing hammer
ARCH&S	air rotary casing hammer and sonic
ARG	Ancestral Rio Grande
ATSDR	Agency for Toxic Substances and Disease Registry
BFF	Bulk Fuels Facility
bgs	below ground surface
BGW	Balleau Groundwater, Inc.
BTU	British Thermal Units
BYU	Brigham Young University
CAC	Corrective Action Complete
CCM	Current Conceptual Model
CEARP	Comprehensive Environmental Assessment and Response Program
CIR	Continuing Investigation Report
cm/s	centimeter(s) per second
CME	Corrective Measures Evaluation
CMIP	Corrective Measures Implementation Plan
COA	City of Albuquerque
COC	Constituent of Concern
Consent Order	Compliance Order on Consent
CSM	Conceptual Site Model
D/H	deuterium/hydrogen
DBS&A	Daniel B. Stephens & Associates
DHS	Department of Health Services
DOE	U.S. Department of Energy
DSS	drain and septic system
E	Exponential function
EHD	Environmental Health Department
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
ERCL	Environmental Restoration Chemistry Laboratory
ERP	Environmental Restoration Program (KAFB)
ft	foot (feet)
ft/day	feet per day
ft/ft	foot (feet) per foot
ft/yr	foot (feet) per year
FY	fiscal year (used only on tables)
GAC	granular activated carbon
GEL	General Engineering Laboratories, LLC
GMWL	Global Mean Water Line
GMS	Department of Defense Groundwater Modeling System
gpm	gallon(s) per minute
GWQB	Ground Water Quality Bureau
HE	high explosive(s)

ACRONYMS AND ABBREVIATIONS (Continued)

HPT	High Performing Team
HWB	Hazardous Waste Bureau
IDW	investigation-derived waste
IR	Investigation Report
IRP	Installation Restoration Program (KAFB)
ISB	In-Situ Bioremediation (used only on figures or tables)
IT	IT Corporation (used only on tables)
KAFB	Kirtland Air Force Base
K_{sat}	K-saturated
LF	Landfill (used only on tables)
LLNL	Lawrence Livermore National Laboratory
LMWL	local mean water line
M	million (when used with a number)
M&O	Management and Operating
MCL	Maximum Contaminant Level
meq/L	milliequivalent(s) per liter
MFB	mud-filled borehole (only used on tables)
μg/L	microgram(s) per liter (approximately equivalent to parts per billion)
mg/L	milligram(s) per liter (approximately equivalent to parts per million)
MR	mud rotary (only used on tables)
NAVFAC	Naval Facilities Engineering Command
NFA	No Further Action
NMED	New Mexico Environment Department
NMOSE	New Mexico Office of the State Engineer
NNSA	National Nuclear Security Administration
NO_3	nitrate
NOD	Notice of Disapproval
NPN	nitrate plus nitrite
n.s.	Not sampled in 2015 (only used on tables)
n.t.	Not tested (only used on tables)
NTESS	National Technology & Engineering Solutions of Sandia, LLC
OB	Oversight Bureau
OMB	Office of Management and Budget
PGS	Parade Ground South (monitoring well designation only)
PGWS	Perched Groundwater System (only used on figures or tables)
PRB	Permeable Reactive Barrier
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
Sandia	Sandia Corporation
SBA	Strong-base anion (ion-exchange resin)
SFG	Santa Fe Group
SNL	Sandia National Laboratories
SNL/NM	Sandia National Laboratories, New Mexico
sq. mi.	square mile(s)
ss	stainless steel or split spoon (used only on tables, definition specific to table)
SWHC	Site-Wide Hydrogeologic Characterization Project

ACRONYMS AND ABBREVIATIONS (Concluded)

SWMU	solid waste management unit
TA	Technical Area
TA1-W	Technical Area-I (Well) (monitoring well designation only)
TA2-NW	Technical Area-II (Northwest) (monitoring well designation only)
TA2-SW	Technical Area-II (Southwest) (monitoring well designation only)
TA2-W	Technical Area-II (Well) (monitoring well designation only)
TAG	Tijeras Arroyo Groundwater
TBD	to be determined
TCE	trichloroethene (trichloroethylene)
TJA	Tijeras Arroyo (monitoring well designation only)
unk	unknown (used only on figures or tables)
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VA	Veterans Administration
WYO	Wyoming (monitoring well designation only)

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EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) and the management and operating (M&O) contractor for Sandia National Laboratories beginning on May 1, 2017, National Technology & Engineering Solutions of Sandia, LLC (NTESS), hereinafter collectively referred to as DOE/NTESS, prepared this Revised Tijeras Arroyo Groundwater Current Conceptual Model (CCM) and Corrective Measures Evaluation (CME) Report , referred to as the Revised CCM/CME Report, to meet requirements under the Sandia National Laboratories-New Mexico (SNL/NM) Compliance Order on Consent (Consent Order). The Consent Order became effective on April 29, 2004. The Consent Order identifies the Tijeras Arroyo Groundwater (TAG) Area of Concern (AOC) as an area of groundwater contamination requiring further characterization and corrective action.

In November 2004, New Mexico Environment Department (NMED) approved the July 2004 CME Work Plan. In April 2005, DOE and the SNL M&O contractor at the time, Sandia Corporation (Sandia), hereinafter collectively referred to as DOE/Sandia, submitted a CME Report, but NMED did not finalize review of that document. In December 2016, DOE/Sandia submitted a combined and updated CCM/CME Report. NMED issued a disapproval letter in May 2017 that included comments on the December 2016 CCM/CME Report. In August 2017, NMED and DOE/NTESS staff held a meeting to discuss and clarify outstanding issues. This Revised CCM/CME Report addresses (1) the issues presented in the NMED May 2017 disapproval letter and (2) findings from the August 2017 meeting.

Conceptual Site Model

This report includes an updated Conceptual Site Model (CSM) of the TAG AOC and describes the contaminant release sites, the geological and hydrogeological setting, and the distribution and migration of contaminants in the subsurface. The dataset used for this report includes analytical results from groundwater samples collected through December 2015.

Two primary water-bearing units of interest underlie the TAG AOC: 1) a Perched Groundwater System, and 2) the underlying Regional Aquifer. A merging zone that partially extends under the southeast corner of the TAG AOC appears to connect these two units. Nitrate is the sole contaminant used for evaluating the remedial alternatives. Nitrate concentrations, as measured by a nitrate plus nitrite (NPN) analytical method, exceed the Maximum Contaminant Level (MCL) of 10 milligrams per liter (mg/L) in five Perched Groundwater System monitoring wells located in the southern end of the TAG AOC, and one well completed in the upper portion of the Regional Aquifer within the merging zone. In 2015, the highest NPN concentrations detected in the TAG AOC were 27.8 mg/L and 33 mg/L in the Perched Groundwater System and the Regional Aquifer, respectively. Other Perched Groundwater System wells located south of the TAG AOC have detected higher NPN concentrations (up to 70 mg/L). The Kirtland Air Force Base Installation Restoration Program owns these wells and samples them as part of their investigation into other more widespread nitrate contamination that is likely to have multiple sources located outside of the TAG AOC.

There is no current or anticipated use of groundwater from the Perched Groundwater System in the TAG AOC's vicinity. The nearest receptor in the Regional Aquifer is the Ridgecrest Well Field, located approximately 5 miles from the TAG AOC along the groundwater flow path.

Modeling predicts any nitrate reaching the well field after a travel time of 130 years would be attenuated by over two orders of magnitude. Thus, there is no foreseeable risk to human health or threat to beneficial use of groundwater from historical SNL/NM operations.

The focus of the TAG AOC investigation is the Perched Groundwater System, which is a thin, dissipating water-bearing unit that formed because of historical anthropogenic discharges of wastewater and septic water. Declining water level trends indicate that nearly the entire extent of the Perched Groundwater System will naturally dewater in the TAG AOC within approximately 41 years from 2018. Some areas in the TAG AOC will dewater much sooner. Approximately 25 percent of the total groundwater loss from the Perched Groundwater System is due to lateral flow towards the southeast where it merges with the underlying Regional Aquifer. The remaining 75 percent likely flows vertically downward through the Perching Horizon and dissipates in the upper portion of over 200 feet of unsaturated sediments present between the Perched Groundwater System and the Regional Aquifer. Geochemical data indicates that the Regional Aquifer has not been impacted by nitrate or other contaminants in the 70+ years since wastewater discharges began in the TAG AOC.

The original sources of nitrate (wastewater outfall ditches and sanitary waste leach fields/seepage pits) are no longer in operation (the greatest discharge ceased in 1974 and all discharges ceased as of 1992). There is no longer a driving force for downward migration of nitrate through the vadose zone to groundwater.

Nitrate concentrations in the Perched Groundwater System are expected to decrease as a result of natural groundwater transport mechanisms (advection, dispersion, and diffusion).

Corrective Measures Evaluation

After an initial screening of potential remedial technologies, three remedial alternatives were developed and evaluated in this CME:

- Alternative 1: Monitored Natural Attenuation
- Alternative 2: In-Situ Bioremediation
- Alternative 3: Groundwater Extraction and Treatment

Alternative 1: Monitored Natural Attenuation

DOE/NTESS would sample monitoring wells completed in the TAG AOC Perched Groundwater System semiannually until meeting remedial objectives or the Perched Groundwater System has naturally dewatered. In addition, DOE/NTESS would sample selected TAG AOC Regional Aquifer wells annually.

DOE/NTESS would conduct annual remedy performance reviews and would identify any required modifications or optimization measures for the remedy. This process would include a review of land use controls.

DOE/NTESS would implement and maintain land use controls to mitigate potential exposure to contaminated groundwater. Most of these controls are already in place, including maintaining existing site access controls.

The estimated timeframe to achieve remedial objectives for this alternative (or for most of the Perched Groundwater System to naturally dewater) is approximately 41 years, assuming remedy implementation in 2018.

The estimated total cost of the Monitored Natural Attenuation Alternative (in 2018 dollars) is $7,772,000; the present value is $6,789,000.

Alternative 2: In-Situ Bioremediation

Alternative 2's objective is to reduce nitrate concentrations in all TAG AOC groundwater to below the MCL within 20 years by implementing an in-situ bioremediation remedy. This would be accomplished by injecting a bioremediation substrate solution into multiple, closely spaced injection wells throughout the area where nitrate exceeds the MCL. This would create a series of Permeable Reactive Barriers (PRBs). As nitrate-contaminated groundwater flows through the PRBs, denitrification by indigenous microbes would occur, converting the nitrate to non-toxic nitrogen gas.

DOE/NTESS would construct nine PRBs by installing 575 injection wells spaced 50 feet apart. Multiple PRBs are needed because of the slow groundwater velocity. Each PRB would be oriented perpendicular to the groundwater flow direction, with no more than 20 years of groundwater travel time between each PRB. The spacing between each PRB would be 300 to 500 feet, depending on the groundwater flow rate in the area.

The injected bioremediation substrate mixture would consist of potable water, an electron donor (such as ethyl lactate), biological nutrients, buffering agents, and tracers. Each well would be injected with an average of 20,000 gallons of substrate-amended potable water. The average nitrate concentration would be reduced to below the MCL downgradient of each PRB because of the in-situ mixing of treated and untreated groundwater as it moves downgradient. The injection wells would be re-dosed, as necessary, with smaller volumes of substrate mixture (500 gallons per well) to maintain denitrifying conditions in the PRBs.

The estimated total cost of the In-Situ Bioremediation Alternative (in 2018 dollars) is $173,266,000; the present value is $167,579,000.

Alternative 3: Groundwater Extraction and Treatment

Alternative 3's objective is to extract all TAG AOC groundwater with a nitrate concentration exceeding the MCL within 20 years. This would be accomplished by installing multiple groundwater extraction wells, a nitrate treatment system, a reinjection well, and associated infrastructure (pipelines). The objective would require a minimum of 73 groundwater extraction wells.

DOE/NTESS estimates approximately 100 gallons per minute (gpm) as the total extraction rate and estimates individual extraction well yields to be 0.5 to 2 gpm, which are dependent on lateral variability in hydraulic conductivity and saturated thickness.

DOE/NTESS would pump groundwater from the extraction wells and convey the water to a treatment facility via a network of double-contained piping. The extracted water would be treated with strong-base anion (SBA) ion-exchange resin to reduce nitrate concentrations to below the

10 mg/L MCL prior to discharge into a reinjection well completed in the Regional Aquifer. Ion-exchange resin would be regenerated offsite.

The estimated total cost of the Groundwater Extraction and Treatment Alternative (in 2018 dollars) is $61,542,000; the present value is $57,822,000.

Evaluation of Alternatives 1 through 3

This CME Report evaluates the three remedial alternatives using the four threshold and five balancing evaluation criteria prescribed by Section VII.C.3 of the Consent Order. Table ES-1 summarizes the evaluation.

Table ES-1
Remedial Alternative Evaluation Summary for the TAG AOC

	Alternative 1: Monitored Natural Attenuation	**Alternative 2: In-Situ Bioremediation**	**Alternative 3: Groundwater Extraction and Treatment**
Threshold Criteria			
1. Protective of Human Health and the Environment	Protective. No potential exposure for human or ecological receptors at concentrations of concern.	Protective. No potential exposure for human or ecological receptors to at concentrations of concern.	Protective. No potential exposure for human or ecological receptors at concentrations of concern.
2. Attain Media Cleanup Standard (nitrate MCL)	Attained by dispersion, dilution, and advection.	Attained by in-situ destruction of nitrate by denitrification.	Attained by extracting nitrate-contaminated groundwater exceeding the nitrate MCL.
3. Control the Source of Releases	Original sources of nitrate (sanitary waste and wastewater discharges) eliminated.	Original sources of nitrate (sanitary waste and wastewater discharges) eliminated.	Original sources of nitrate (sanitary waste and wastewater discharges) eliminated.
4. Comply with Standards for Management of Wastes	Would comply with all standards for the management of wastes.	Would comply with all standards for the management of wastes.	Would comply with all standards for the management of wastes.
Balancing Criteria			
1. Long-Term Reliability and Effectiveness	Groundwater elevations in the Perched Groundwater System declining steadily because of cessation of wastewater discharges.	Demonstrated technology effectively creates denitrifying conditions in the subsurface. Denitrification irreversible.	Proven technology for the remediation of nitrate-contaminated groundwater.
2. Reduction of Toxicity, Mobility, or Volume	Would not reduce toxicity, mobility, or volume of nitrate.	Would destroy nitrate in groundwater, reducing toxicity and volume. Mobility of nitrate not affected.	Would not reduce the toxicity or mobility of nitrate. Volume of nitrate in groundwater reduced by transfer to ion-exchange resin.

Table ES-1 (Concluded)
Remedial Alternative Evaluation Summary for the TAG AOC

	Alternative 1: Monitored Natural Attenuation	Alternative 2: In-Situ Bioremediation	Alternative 3: Groundwater Extraction and Treatment
Balancing Criteria (Continued)			
3. Short-Term Effectiveness	Risk of worker exposure to contaminants during remedy implementation is manageable.	Risk of worker exposure to contaminants during remedy implementation is manageable.	Risk of worker exposure to contaminants during remedy implementation is manageable.
4. Feasibility	Feasible and easily implemented. The monitoring network is in place.	Infeasible due to installing 575 injection wells and using 11.5M gallons of substrate-amended potable water amended initially injected. Infrastructure and disruption to facility operations may prohibit implementation.	Infeasible due to installing 73 extraction wells and over 3 miles of trenches. Infrastructure and disruption to facility operations may prohibit implementation.
5. Cost	Moderate. Total cost is $7.8M.	Extremely expensive. Total cost is $173.3M.	Extremely expensive. Total cost is $61.5M.

Sustainability Evaluation

As required by DOE Order 436.1, *Departmental Sustainability* and consistent with U.S. Environmental Protection Agency sustainability guidance, sustainability metrics were calculated for the three remedial alternatives presented in this CME. The *SiteWise™ Tool for Green and Sustainable Remediation* modeled sustainability. The following sustainability metrics were estimated:

- Greenhouse gas emissions, including carbon dioxide, methane, and nitrous oxide. These emissions result from transportation, consumables, and material production.
- Energy usage, primarily from manufacturing, fuels, and electricity.
- Water consumption.
- Nitrogen oxide, sulfur oxide, and particulate matter emissions from transportation.
- Accident risk (injury and fatality), based on published transportation-related statistics.

The sustainability evaluation indicates that the Monitored Natural Attenuation Alternative would be the most sustainable (have a far smaller environmental footprint) than either the In-Situ Bioremediation or Groundwater Extraction and Treatment Alternatives. This is primarily because:

- The Monitored Natural Attenuation Alternative would have the lowest greenhouse gas emissions, lowest emissions from vehicles, and lowest injury/fatality risk.
- The In-Situ Bioremediation Alternative would have the highest greenhouse gas emissions, highest emissions from vehicles, and highest injury risk.
- The Groundwater Extraction and Treatment Alternative would have the highest electrical usage due to the operation of extraction pumps and the highest fatality risk due to the transportation of ion-exchange resin to a regeneration facility.

Preferred Remedy

The preferred remedy for nitrate in groundwater at the TAG AOC is the Monitored Natural Attenuation Alternative. It meets the threshold evaluation criteria, is readily implementable, and projected to meet the remedial objectives in a reasonable timeframe.

Monitored Natural Attenuation is the preferred remedy because:

1. There is no unacceptable risk to receptors and / or foreseeable groundwater beneficial use. There is no current or anticipated use of groundwater from the Perched Groundwater System in the TAG AOC vicinity. The nearest receptor is the Ridgecrest Well Field located approximately 5 miles from the TAG AOC along the groundwater flow path. Modeling predicts any nitrate reaching the well field would be attenuated by over two orders of magnitude. Thus, there is no foreseeable risk to human health or threat to beneficial use of groundwater.

2. There are no remaining active sources of contamination release at the TAG AOC. The original sources of nitrate (wastewater drain field, seepage pits, and surface impoundments) are no longer in operation (discharges ceased as of 1992).

3. Nitrate concentrations are relatively low, only slightly exceeding the MCL. The nitrate plume is dilute with no distinct areas of high concentrations except in the far southeast corner of the TAG AOC where the nitrate plume commingles with higher nitrate concentrations associated with Kirtland Air Force Base (KAFB) and/or City of Albuquerque operations.

4. Attenuation is projected to occur within a reasonable timeframe. Natural processes are predicted to reduce concentrations to below the MCL in a reasonable timeframe (41 years from 2018), primarily through natural dewatering of the Perched Groundwater System.

5. Land use controls can be controlled, maintained, or implemented. DOE expects to retain stewardship of the site for the foreseeable future. If land use changes at the TAG AOC, or transfer of the property from DOE control were to occur in the future, DOE would reevaluate the protectiveness of the remedy.

6. The remedy is readily implementable. The monitoring well network is already in place.

7. The remedy is sustainable. Compared to the In-Situ Bioremediation and Groundwater Extraction and Treatment Alternatives, the Monitored Natural Attenuation remedy would generate far less greenhouse gas, have lower energy and water use, emit fewer particulates, and have the lowest risk of accidents or fatalities during remedy implementation.

8. Performance assurance measures are included. A Contingency Plan would include measures to be implemented if the remedy does not proceed as anticipated. DOE/NTESS would keep the public informed of the remedy progress by remedial progress reports and public meetings.

9. The remedy is cost effective. The estimated total cost of the Monitored Natural Attenuation Alternative is $7,772,000, compared to $173,266,000 for the In-Situ Bioremediation Alternative, and $61,542,000 for the Groundwater Extraction and Treatment Alternative.

10. The Monitored Natural Attenuation remedy is fully protective of human health and the environment.

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1.0 INTRODUCTION

Sandia National Laboratories (SNL) is a multimission laboratory which is presently managed and operated by National Technology & Engineering Solutions of Sandia, LLC (NTESS), a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's (DOE) National Nuclear Security Administration (NNSA). SNL personnel conduct groundwater monitoring and site-specific investigations through Environmental Restoration (ER) Operations (formerly the ER Project) and Long-Term Stewardship. SNL New Mexico (SNL/NM) is located on Kirtland Air Force Base (KAFB), in Albuquerque, New Mexico (Figure 1-1). The Tijeras Arroyo Groundwater (TAG) Area of Concern (AOC) is located in the north-central portion of KAFB and involves three SNL/NM technical areas (TAs) (TA-I, TA-II, and TA-IV). Prior to 2000, the TAG investigation was known as the Sandia North investigation. The TAG AOC encompasses approximately 1.82 square miles (sq. mi.) and is analogous with the previous term "TAG Area of Responsibility (AOR)" (SNL/NM August 2005).

The New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB) provides regulatory oversight of SNL/NM ER Operations, as well as implements and enforces regulations mandated by the Resource Conservation and Recovery Act (RCRA). The TAG investigation groundwater monitoring activities are not associated with a single Solid Waste Management Unit (SWMU), but have a broader scope. DOE and SNL/NM personnel originally conducted groundwater characterization activities for TAG voluntarily as proposed in the Groundwater Investigation Plan (SNL/NM March 1996a). Beginning in October 2000, the TAG High Performing Team (HPT) meetings served as a forum for discussing a diverse set of groundwater issues. During these HPT meetings, staff from SNL/NM, KAFB, City of Albuquerque (COA), the NMED, and the U.S. Environmental Protection Agency (EPA) debated the validity of using groundwater analytical results previously collected using low-flow sampling devices. Because of the perceived inadequacy of the sampling method, groundwater sampling activities were temporarily suspended at SNL/NM until an alternative sampling method was implemented. In June 2003, the TAG Investigation Work Plan (SNL/NM June 2003) was submitted to the NMED. Groundwater sampling resumed in July 2003 using NMED-approved conventional groundwater purging/sampling techniques.

Starting in October 2000, at the request of NMED, several HPT meetings served as a forum for discussing groundwater issues that span multiple institutional boundaries, specifically the properties controlled by DOE/SNL management and operating (M&O) contractor, KAFB, and the COA. Representatives of DOE, SNL/NM ER Project, KAFB Installation Restoration Program (IRP), EPA Region 6, NMED/HWB, NMED DOE Oversight Bureau (OB), NMED Ground Water Quality Bureau (GWQB), Bernalillo County, and the COA Environmental Health Department (EHD) regularly attended the HPT meetings. HPT defined the TAG Study Area to facilitate discussion between the entities. Figure 1-1 depicts the TAG Study Area and covers approximately 40 sq. mi. in the north-central portion of KAFB and the southeastern portion of the COA. Remediation responsibility within the historical TAG area was assigned to three separate potentially responsible parties: DOE/ SNL M&O contractor, the COA, and KAFB.

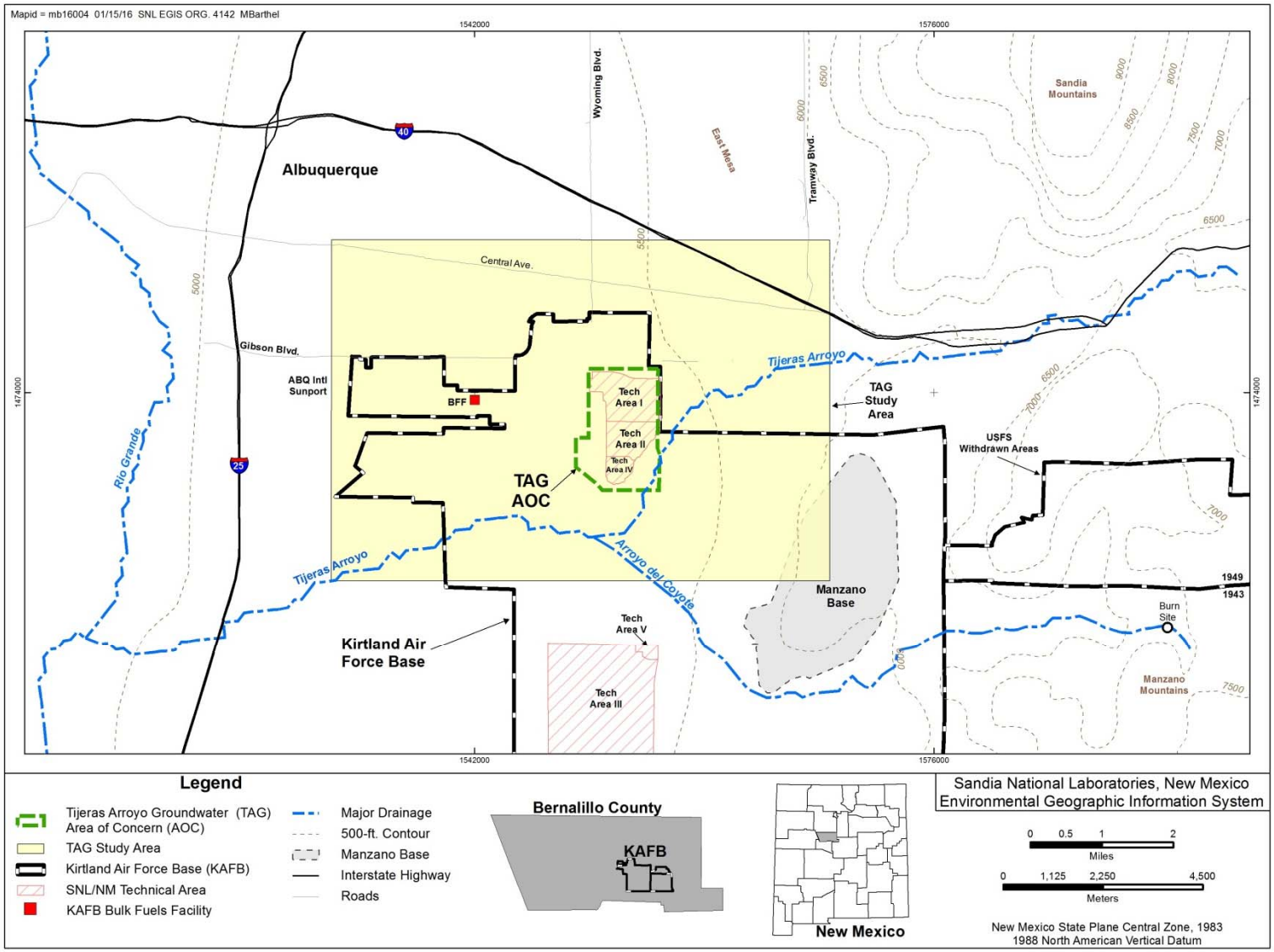


Figure 1-1
TAG AOC and the TAG Study Area Location in Southeast Albuquerque

In 2004, the Compliance Order on Consent (the Consent Order) became effective (NMED April 2004). The Consent Order identified the TAG AOC as an area of groundwater contamination requiring further characterization and corrective action. In response to the Consent Order, DOE/Sandia submitted the TAG Corrective Measures Evaluation (CME) Work Plan to the NMED in July 2004 (SNL/NM July 2004). NMED approved the work plan later that same year (NMED October 2004). After fulfilling the requirements of the CME Work Plan, DOE/Sandia submitted the CME Report to the NMED (SNL/NM August 2005). However, the NMED did not finalize its review of the 2005 CME Report review. The December 2016 Current Conceptual Model/CME (CCM/CME) Report superseded the 2005 CME Report.

Groundwater monitoring has been conducted in the TAG AOC since 1992. NMED identified the TAG AOC in the Consent Order because nitrate and trichloroethene (TCE) had concentrations in groundwater that exceeded the respective Maximum Contaminant Levels (MCLs). When the Consent Order was issued, nitrate and TCE were specified as constituents of concern (COCs) because 1) the Perched Groundwater System contained concentrations of nitrate and TCE that exceeded the corresponding MCLs and 2) the Regional Aquifer contained nitrate concentrations that exceeded the MCL. TCE did not exceed the MCL in the Regional Aquifer when the Consent Order was issued and has not exceeded the MCL since then. TCE has not exceeded the MCL in the Perched Groundwater System since March 2002, except at upgradient background monitoring well WYO-4. This well is screened in the Perched Groundwater System near the western edge of the TAG AOC. The Perched Groundwater System has been gradually dewatering and the water level in well WYO-4 has declined to the point where collecting a representative sample is no longer feasible.

DOE/NTESS and NMED discussed the status of monitoring well WYO-4 in the August 2017 meeting. NMED management stated that the well no longer needs to be considered to be the responsibility of DOE/Sandia for groundwater sampling or remedial purposes. Responsibility for well WYO-4 will transfer to the KAFB Environmental Restoration Program.

DOE/NTESS reiterates here that well WYO-4 is located west of Wyoming Boulevard on land managed by the U.S. Air Force (not leased or owned by DOE). The well was not installed for investigating DOE/Sandia SWMUs. Because the background concentrations of nitrate plus nitrite (NPN) have not exceeded the MCL at WYO-4, the detections of TCE appear to have originated from a source upgradient of DOE/Sandia operations.

1.1 TAG Background and Status of the CCM and CME Report

The TAG AOC is located in the north-central portion of KAFB (Figure 1-1) and is contained within the much larger TAG Study Area, which HPT defined for purposes of discussion. As shown on Figure 1-1, the TAG Study Area covers approximately 40 sq. mi. and contains much of the north-central portion of KAFB in the southeastern portion of the COA.

The boundary of the TAG AOC relative to the TAG Study Area evolved over time. Work described in the TAG Continuing Investigation Report (CIR) (SNL/NM November 2002) was performed in the TAG Study Area by multiple parties (KAFB, COA, and DOE/Sandia) and was reviewed by multiple parties (KAFB, DOE/Sandia, NMED/HWB, NMED/GWQB, NMED/DOE OB, EPA, Bernalillo County, and the COA). DOE/Sandia agreed to prepare the TAG Study Area Investigation Report (IR) and combine the information provided by all parties. There are no current, negotiated agreements among the members of the HPT, and the NMED HWB has not re-convened the HPT since October 2003.

DOE/Sandia defined the TAG AOR/AOC as a smaller 1.82 sq. mi. subset of the TAG Study Area in the NMED-approved CME Work Plan (SNL/NM July 2004) and the CME Report (SNL/NM August 2005) after the IR was submitted in November 2002. The DOE/Sandia TAG AOC boundary encompasses 47 SWMUs and related monitoring wells at SNL/NM. The Consent Order (NMED April 2004) requires completion of a CME Report for the TAG AOC.

There are three TAs within the TAG AOC at SNL/NM. Combined, TA-I, TA-II, and TA-IV cover approximately 641 acres (approximately 1 sq. mi.). SNL/NM research operations began at TA-I and TA-II in 1947. TA-IV research operations began in 1978. TA-I has historically been the administrative headquarters for SNL/NM and includes numerous office buildings, in addition to research laboratories and small machine shops. During the early stages of the Cold War, TA-II was the primary assembly facility for nuclear weapons. TA-II currently contains shipping facilities, waste management operations, and office buildings. TA-IV houses office buildings and large linear accelerators for studying nuclear fusion. About 7,600 employees and contractors work in the 470 structures that are located in the three TAs (DOE October 1999). Section 4.0 discusses additional details for SNL/NM facilities, as well as nearby KAFB facilities.

Since 1989, site-specific environmental investigations have been conducted at the 47 SWMUs in the TAG AOC. These investigations included a review of background information/process knowledge, and as necessary, the implementation of characterization and remedial activities including soil sampling, soil-vapor sampling, and the excavation of contaminated soil and debris. No Further Action (NFA) proposals submitted over a period of more than 20 years, beginning in 1995, summarized findings for each SWMU. To facilitate the timely regulatory review of the NFA proposals, the groundwater issues associated with the TAG AOC were decoupled from the individual SWMUs. By the end of 2014, NMED had approved Corrective Action Complete (CAC) status for each of the 47 SWMUs. Twenty-four of the SWMUs were approved for CAC status after the TAG IR was submitted in November 2014. Section 4 discusses the relevancy of specific SWMUs to potential groundwater impacts.

The Consent Order stipulated that DOE/SNL M&O contractor prepare a TAG CCM to support a TAG CME Report that would address remedial alternatives. The CCM objective was to provide NMED with sufficient information characterizing the hydrogeologic setting to allow DOE/ SNL M&O contractor to proceed with preparing the CME Report. Appendix A provides the Historical Timeline for the TAG AOC, which lists various compliance plans, reports, and activities.

At the time NMED issued the Consent Order, DOE/Sandia was updating the TAG CIR (SNL/NM November 2002) using groundwater monitoring data from multiple organizations. The final version, known as the IR (SNL/NM November 2005), discussed all CCM-related items as specified in the Consent Order (NMED April 2004). NMED subsequently referred to the IR as being “an updated conceptual model” in a 2008 letter (NMED August 2008). NMED approved the IR in 2010 (NMED February 2010) after DOE/Sandia submitted responses (SNL/NM February 2009 and January 2010) for two Notice of Disapproval (NOD) letters (NMED August 2008 and August 2009). The NOD responses clarified information such as the number of soil samples collected per SMWU and construction details for monitoring wells.

NMED approval of the IR demonstrates that DOE/Sandia fulfilled the CCM characterization requirements. The NMED approval letter stated that NMED would begin review of the August 2005 TAG CME Report, but by early 2015, NMED had not finalized their review. DOE/Sandia requested a meeting with NMED to discuss the schedule of future work, which was held in July 2015. All parties agreed that a substantial amount of new groundwater data (both groundwater elevations and analytical) acquired over the intervening years needed to be

incorporated in an updated CCM. Specifically, KAFB had installed 18 monitoring wells near the TAG AOC as part of their nitrate abatement program (KAFB December 2015 and January 2016). To document the meeting, NMED prepared a letter titled "Summary of Agreements and Proposed Milestones" requiring an updated CCM and CME Report for TAG be submitted to NMED by December 2, 2016 (NMED April 2016). The December 2016 CCM/CME Report addressed this requirement.

The December 2016 CCM/CME Report included an updated Conceptual Site Model (CSM), incorporating approximately 10 additional years of groundwater monitoring data and additional interpretations of the hydrogeologic setting. DOE/Sandia's *Annual Groundwater Monitoring Reports* routinely report ongoing groundwater monitoring activities. The Calendar Year 2016 report was submitted to NMED in June 2017 (SNL/NM June 2017) and NMED approved it in July 2017 (NMED August 2017).

In May 2017, NMED issued a disapproval letter (NMED May 2017) for the December 2016 CCM/CME Report. The NMED letter specified that a Revised CCM/CME Report be submitted before November 30, 2017. However, NMED staff identified additional topics during an August 2017 meeting with DOE/NTESS staff. In order to address the additional issues, DOE/NTESS requested that the submittal date be extended to February 15, 2018 (DOE September 2017). NMED subsequently approved this proposed extension date for the Revised CCM/CME Report (NMED October 2017). This Revised CCM/CME Report addresses 1) the issues presented in the NMED May 2017 letter and 2) the additional issues that were discussed in the August 2017 meeting.

1.2 Objectives

This report presents an updated CSM of the TAG AOC that describes the geological and hydrogeological setting, the contaminant release sites, and the distribution and migration of contaminants in the subsurface. The dataset used for this Revised CCM/CME Report includes the analytical results for groundwater samples collected through December 2015. Subsequent sampling results are presented in *Annual Groundwater Monitoring Reports.*

1.3 Organization

The Consent Order identified nine characterization requirements for satisfactorily evaluating the hydrogeologic setting for the TAG AOC (NMED April 2004). This Revised CCM/CME Report is organized into nine sections:

- Section 1.0: Introduction,
- Section 2.0: Regional Geology and Hydrogeology,
- Section 3.0: Geology and Hydrogeology of the TAG AOC,
- Section 4.0: Site History, Corrective Actions, and Potential Release Sites,
- Section 5.0: Groundwater Monitoring at the TAG AOC,
- Section 6.0: Conceptual Site Model,
- Section 7.0: Corrective Measures Evaluation,
- Section 8.0: Conclusions, and
- Section 9.0: References.

Table 1-1 summarizes the Consent Order requirements and lists the corresponding sections in this Revised CCM/CME Report.

Table 1-1
Cross Walk of Consent Order (NMED April 2004) Requirements versus this Revised Report

Site Characterization (CCM) Requirements from Section IV.C of the Consent Order	**CCM/CME Report Sections**
1. Nature, rate of transport, and extent of contamination	5.0 Groundwater Monitoring at the TAG AOC
2. Regional and perched aquifer boundaries	3.3 Hydrogeologic Conditions at the TAG AOC
3. Depth to water, water levels, water table, potentiometric surface, and any seasonal variations	3.3 Hydrogeologic Conditions at the TAG AOC
4. Flow directions and velocities	3.3 Hydrogeologic Conditions at the TAG AOC
5. Geologic, hydrostratigraphic, and structural relationships	3.1 Geologic Setting of the TAG AOC.
6. Water supply well pumping influences, seasonal pumping rates, and annual amounts of water withdrawn	3.4.4 Local Discharge and Production Wells
7. Saturated hydraulic conductivity, porosity, effective porosity, permeability, transmissivity, particle size, storage coefficients, and estimated fracture/secondary porosity	3.3 Hydrogeologic Conditions at the TAG AOC
8. Contaminant concentrations in soil, rock, sediment, vapor, and water (as appropriate)	5.2 Nature and Extent of Contamination
9. General water chemistry	3.3.2 Groundwater Geochemistry
CME Report Requirements from Section X.F of the Consent Order	**CCM/CME Report Sections**
I. Title Page and Signature Block	Title Page and Transmittal Letter
II. Executive Summary	Executive Summary
III. Table of Contents	Table of Contents
IV. Figures	Incorporated into applicable sections of text
V. Tables	Incorporated into applicable sections of text
VI. Introduction	1.0 Introduction
VII. Background Information	2.0 Regional Geology and Hydrogeology
VIII. Site Conditions	3.0 Geology and Hydrogeology of the TAG AOC 4.0 Site History, Corrective Actions, and Potential Release Sites 5.0 Groundwater Monitoring at the TAG AOC
IX. Potential Receptors	6.0 Conceptual Site Model
X. Regulatory Criteria	1.1 TAG Background and Status of the CCM and CME Report
XI. Identification of Corrective Measure Options	7.1 Remedial Technology Identification and Screening 7.2 Identification and Description of Remedial Alternatives
XII. Evaluation of Corrective Measure Options	7.3 Evaluation of Remedial Alternatives
XIII. Selection of Preferred Corrective Measure	7.4 Preferred Remedy
XIV. Design Criteria to Meet Cleanup Objectives	7.5 Remedial Alternative Design Criteria
XV. Schedule	7.6 Corrective Measures Implementation Plan
XVI. Appendices	Appendices A – E, and Attachments 1 - 6.

2.0 REGIONAL GEOLOGY AND HYDROGEOLOGY

This section summarizes the regional geologic and hydrogeologic setting near the TAG AOC. Site-Wide Hydrogeologic Characterization Project (SWHC) reports describe the regional hydrology near SNL/NM (SNL/NM February 1998 and February 2001). Portions of the material presented below were obtained from the *Annual Groundwater Monitoring Report Calendar Year 2016* (SNL/NM June 2017), combined with a current understanding of the site-specific conditions.

2.1 Regional Geologic Setting

SNL/NM is located near the east-central edge of the Albuquerque Basin (SNL/NM June 2016). The Albuquerque Basin (also known as the Middle Rio Grande Basin) is one of a series of north-south–trending basins formed during the extension of the Rio Grande Rift. The basin is approximately 70 miles long and up to 40 miles wide near the center of the basin (~3,000 sq. mi.), and the COA and KAFB rely heavily on this basin's groundwater as their principal water supply. Rift formation began in the late Oligocene and continued into the early Pleistocene, with the primary period of extension occurring between 30- and 5-million years ago. Tectonic activity, which began uplifting the Sandia, Manzanita, and Manzano Mountains, was most prevalent from about 15- to 5-million years ago (Thorn et al. 1993). The rift today extends from south-central Colorado to northern Mexico. The vertical displacement between the rock units exposed at the top of Sandia Crest, and the equivalent units located at the bottom of the Albuquerque Basin, is more than 3 miles.

Figure 2-1 shows the structural boundaries of the Albuquerque Basin are as follows:

- Colorado Plateau on the west,
- Nacimiento uplift and the Jemez Mountains to the north,
- La Bajada Escarpment to the northeast,
- Sandia, Manzanita, Manzano, and Los Pinos Mountains to the east,
- Joyita and Socorro uplifts to the south, and the
- Ladron and Lucero uplifts to the southwest.

As the Rio Grande Rift continued to expand, the Albuquerque Basin subsided. The Ancestral Rio Grande (ARG) meandered across the valley formed by the subsidence and deposited sediments in broad stream channels and floodplains. The basin also filled with aeolian deposits and alluvial materials shed from surrounding uplifts (Hawley and Haase 1992). This sequence of sediments is called the Santa Fe Group (SFG). The thickness of the SFG is up to 16,400 feet (ft) at the deepest part of the basin (Lozinsky 1994). The entire sequence consists of unconsolidated sediments, which thin toward the edge of the basin and are truncated by normal faults at the basin-bounding uplifts (Hawley January 2016).

Units overlying the SFG include Pliocene Ortiz gravel and Rio Grande fluvial deposits interbedded with Tertiary and Quaternary basaltic and pyroclastic materials. Based on recent geophysical models, the Albuquerque Basin has been further divided into three, 2 to 4 miles deep, interconnected structural depressions from north to south: Santo Domingo, Calabacillas,

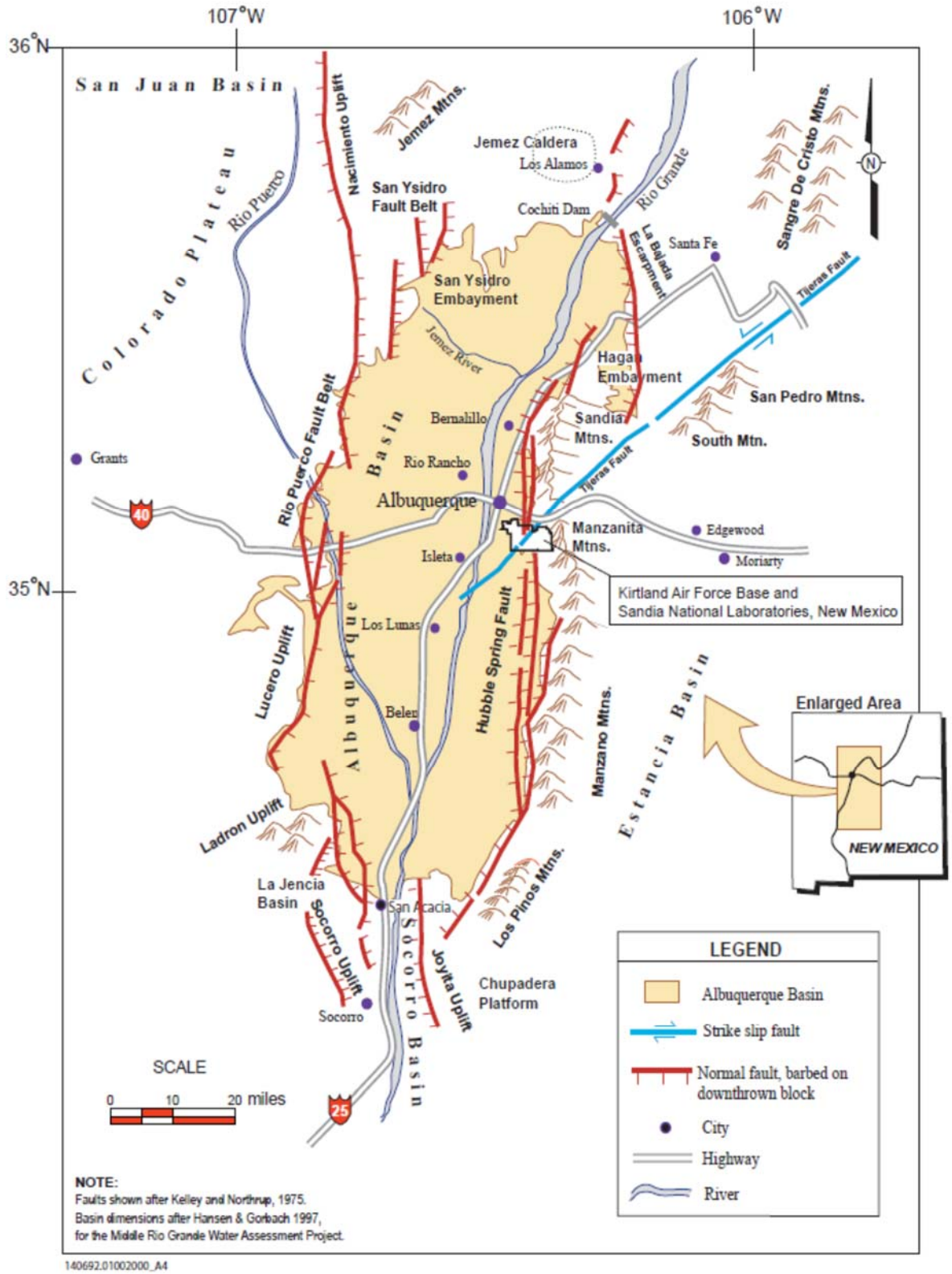


Figure 2-1
Principal Geologic Features of the Albuquerque Basin

and Belen sub-basins. KAFB lies near the intersection of the Calabacillas and Belen sub-basins along a broad, northwest elongate structural high called the Mountainview prong that separates the two sub-basins (Grauch and Connell 2013). These tectonic/sedimentation features contribute greatly to the complex structural setting described below.

Figure 2-2 shows the four primary faults on the east side of KAFB are: 1) the Sandia Fault, 2) the buried West Sandia Fault with no surface expression, 3) the Hubbell Spring Fault (West, Central, and East fault segments), and 4) the Tijeras Fault.

The primary structural boundary between the Sandia Mountains and the Albuquerque Basin is the Sandia Fault. The Hubbell Spring Fault extends northward from Socorro County and terminates on KAFB near the Tijeras Fault. The Sandia Fault and the Hubbell Spring Fault are north-south-trending, down-to-the-west, *en echelon* normal faults bounding the east margin of the Albuquerque Basin.

The Tijeras Fault is an ancient strike-slip fault that developed in the Precambrian or early Paleozoic (approximately 600-million years ago) Periods and reactivated in association with the Laramide Orogeny during the Cretaceous Period (Kelley 1954). The fault also demonstrates Quaternary movement at locations 20 to 30 miles northeast of KAFB (Kelson et al. 1999, and SNL/NM February 1998). This fault has been traced as far north as Madrid, New Mexico, and continues into the Sangre de Cristo Mountains as the Cañoncito Fault. Preferential erosion along the fault formed Tijeras Canyon, which divides the Sandia and Manzanita Mountains. The fault trends southwest from Tijeras Canyon, intersects the northeast boundary of KAFB, and crosses KAFB east and south of Manzano Base. Manzano Base occupies an uplift of four peaks defined by the Tijeras Fault on the east side and the Sandia Fault on the west side. The Sandia, Hubbell Spring, and Tijeras Faults converge near the southeast end of TA-III. This complicated system of faults, defining the east edge of the basin, is referred to collectively as the Tijeras Fault Complex.

2.2 Regional Hydrogeologic Setting

Figure 2-3 shows the three distinct hydrogeologic regions for the KAFB area: 1) the Albuquerque Basin, 2) the Tijeras Fault Complex, and 3) the Foothills and Canyons Area. The Tijeras Fault Complex is a transitional zone between the Regional Aquifer of the Albuquerque Basin and the fractured bedrock system in the Foothills and Canyons Area. The TAG AOC lies solely with the Albuquerque Basin west of the fault system, and characterized by Upper SFG sediments. The Tijeras Fault Complex and the Foothills and Canyons Area hydrologic regions have little bearing on the TAG Study Area; therefore, are only briefly discussed in this report.

East of the Tijeras Fault Complex, a thin layer of alluvium covers Pennsylvanian and Precambrian bedrock, which has been fractured due to multiple stages of regional deformation. The depth-to-groundwater ranges from about 45 to 325 feet (ft) below ground surface (bgs). Most groundwater is non-potable due to naturally elevated concentrations of metals such as arsenic. Groundwater occurs in the fractured bedrock on the east side of KAFB and well yields are relatively low. Groundwater generally flows westward from the canyons toward the Tijeras Fault Complex. The groundwater gradient is relatively steep across the Tijeras Fault Complex, which suggests that westward groundwater flow is restricted.

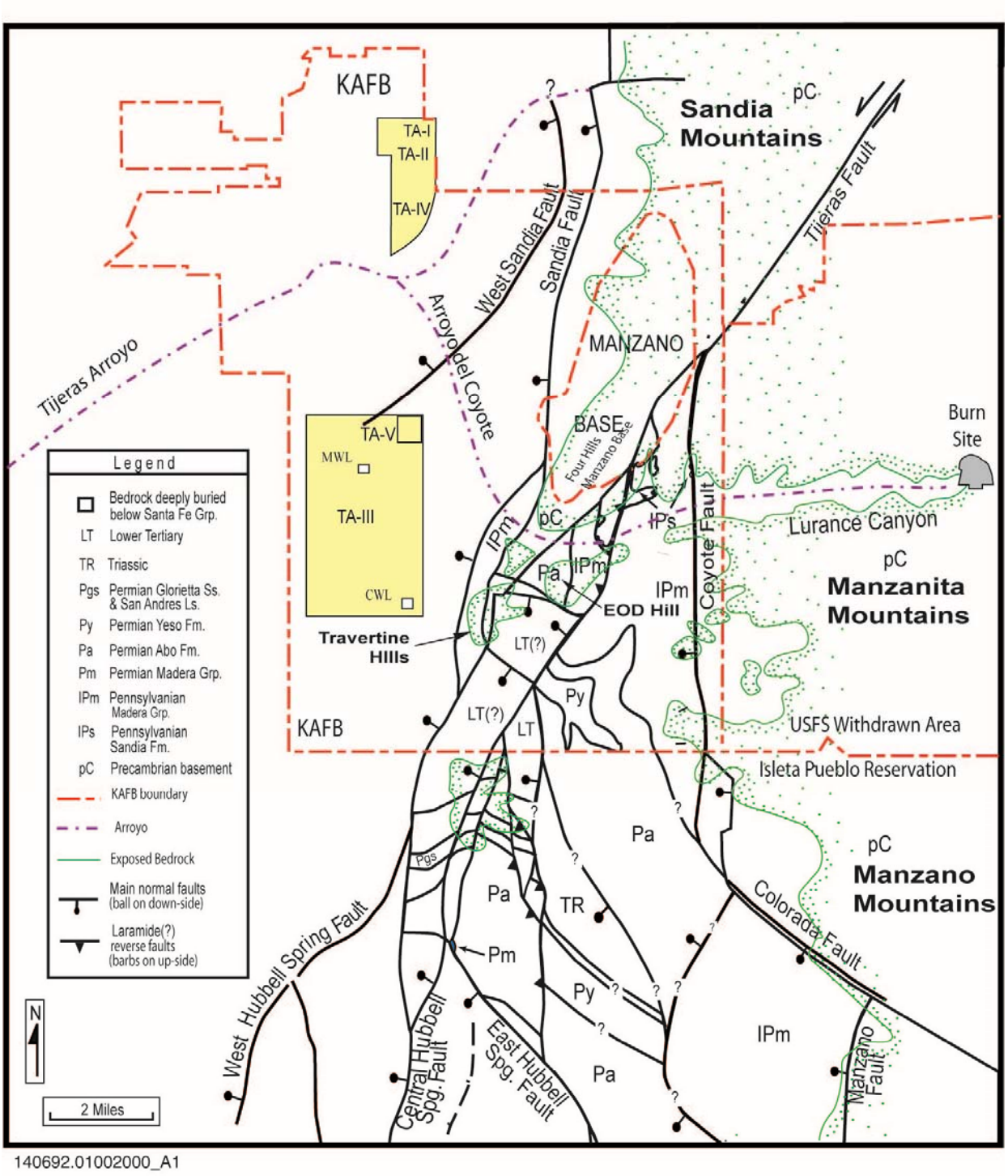


Figure 2-2
Generalized Geology near SNL/NM and KAFB (Van Hart 2003)

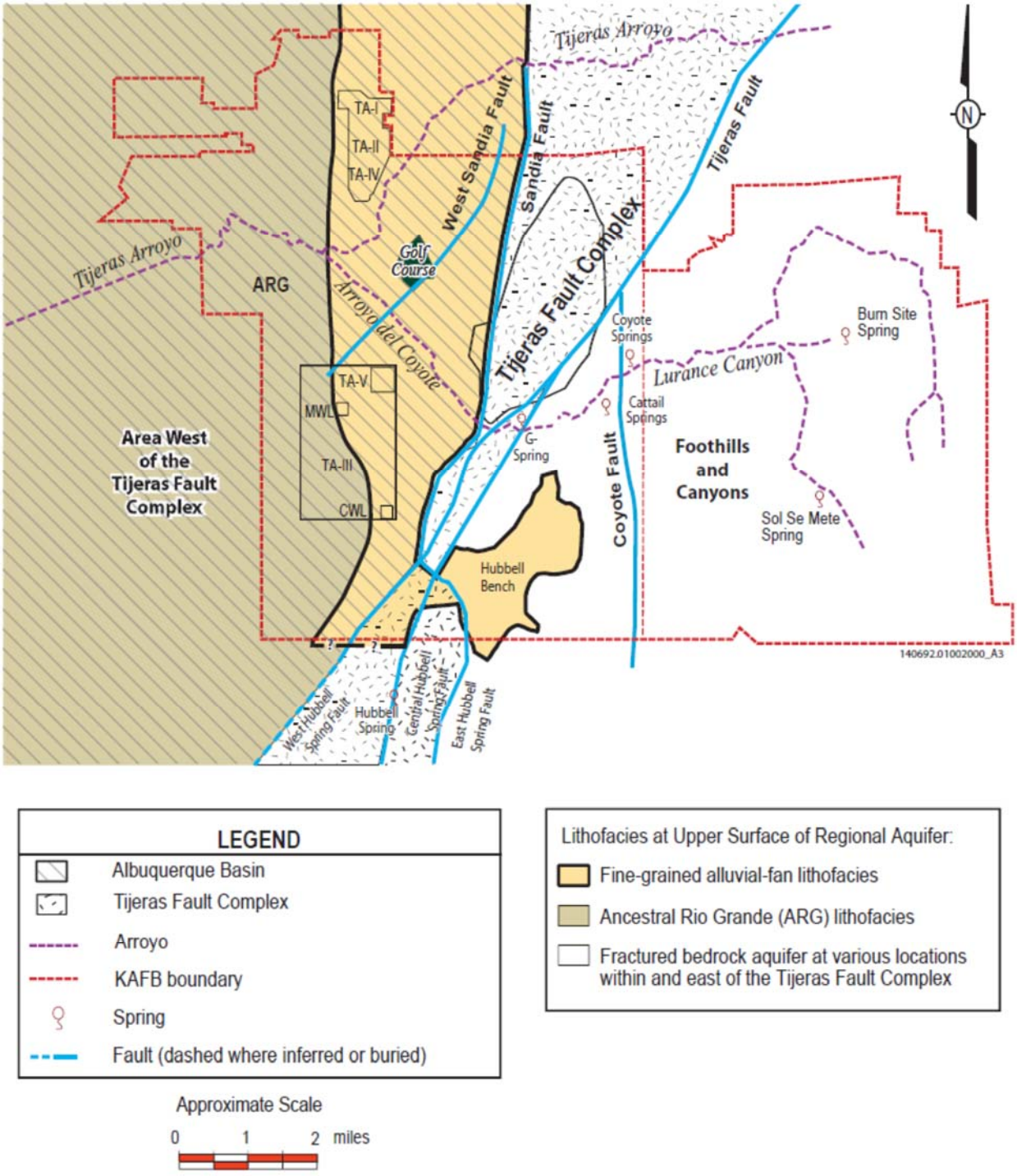


Figure 2-3
Hydrogeologically Distinct Regions near KAFB (SNL/NM June 2016)

Within the sediments of the Albuquerque Basin on KAFB, the hydraulic gradient of the Regional Aquifer is relatively flat. The historical direction of regional groundwater flow within the basin was westward from the mountains toward the Rio Grande. However, groundwater pumping at KAFB, Veterans Administration (VA), and Albuquerque Bernalillo County Water Utility Authority (ABCWUA) production wells, located near the northern boundary of KAFB, have created a broad trough in the potentiometric surface along the western boundary of KAFB.

2.3 Regional Stratigraphic Framework

The interaction between faulting and concurrent sedimentary processes within the structural basins along the Rio Grande Rift resulted in a complex accumulation of interfingering, lenticular units of sand, gravel, silt, and clay (Bartolino and Cole 2002). Sedimentary units in the basin are truncated, commonly displaced by faults, and are hundreds to thousands of feet thick. As adjoining fault blocks were uplifted, eroded detritus was deposited within the basins formed by the subsiding blocks. Uplift and subsidence also shifted internal stream drainages and forced migration of the different depositional environments within sub-basins. These basin-fill sediments are unconsolidated to partially cemented, and consist primarily of fluvial and alluvial fan deposits.

Fluvial deposits in the Albuquerque Basin were derived from stream flows that transported sediments from source areas. In the early stages of rifting, the sub-basins were internally drained and fluvial deposits were locally derived. Uplift of adjacent mountain ranges resulted in erosion and formation of coalescing alluvial fan and piedmont deposits along mountain fronts. These deposits are lenticular, poorly sorted, and highly variable in texture, with coarser cobble-size sediments deposited near the mountain front and finer sands, silts, and clays deposited in the distal parts of the fans and piedmonts. A period of increased precipitation, beginning approximately 5-million years ago, resulted in increased stream flows and transport of coarser sediments into the sub-basins of the Albuquerque Basin (Bartolino and Cole 2002).

Approximately 2.7-million years ago, regional integration of stream drainage basins developed the through-flowing ARG drainage (Bartolino and Cole 2002). Increases in stream flows and regional integration of the Rio Grande resulted in deposition of fluvial, coarse-grained sands and gravels derived from distant source areas to the north, including large quantities of volcanic detritus from the Jemez Mountain region. These medium to coarse sand and gravel deposits formed an irregular sheet-like zone that is locally several hundred feet thick and distributed in a broad band that follows the modern Rio Grande (Bartolino and Cole 2002). These deposits are identified as the ARG lithofacies and form a hydrostratigraphic unit, which is one of the most productive groundwater units within the Albuquerque Basin, including the western portion of KAFB.

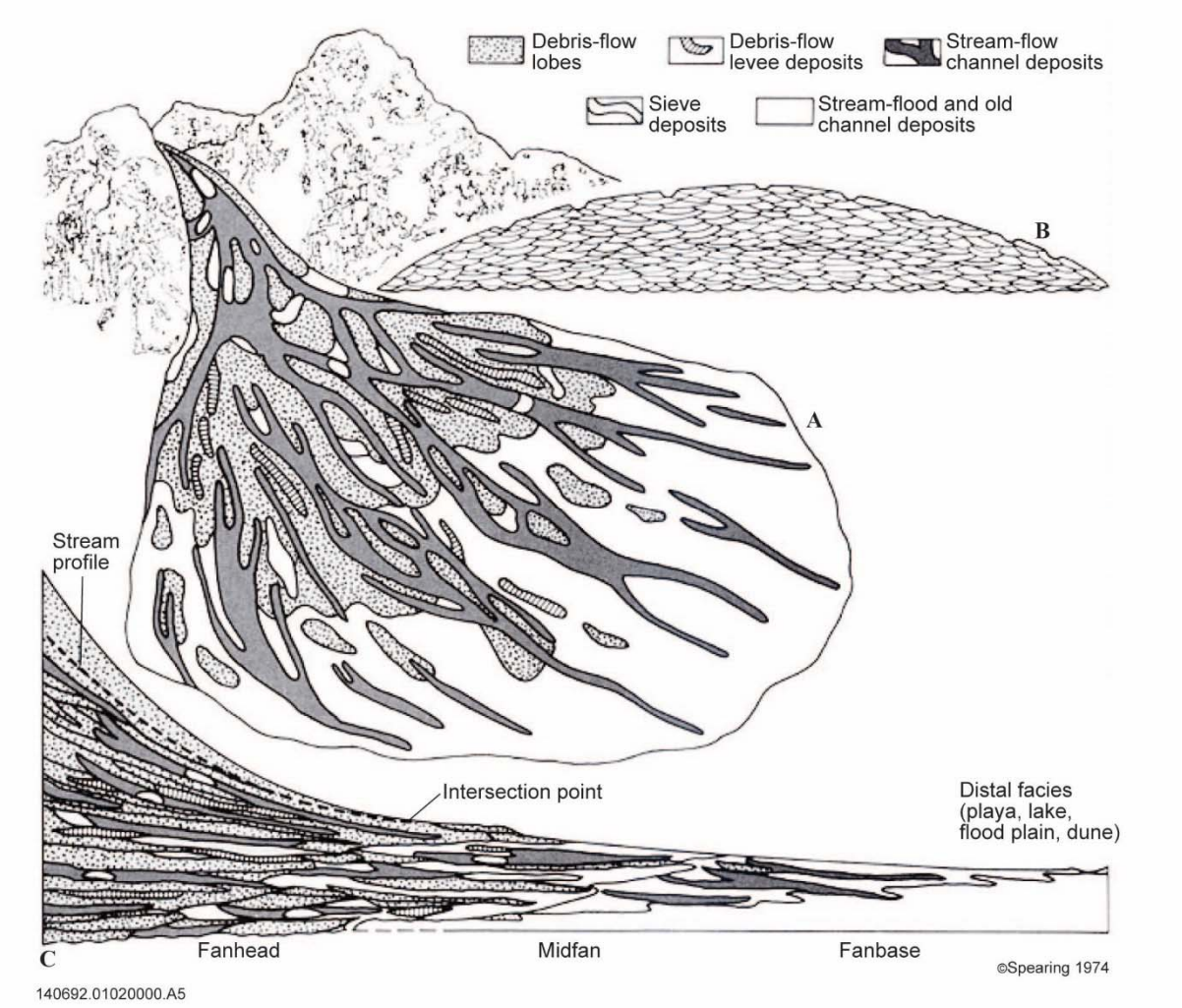
Concurrent deposition of locally derived erosional detritus continued to build alluvial fans and piedmonts to the east of the Rio Grande. Aggradation of the ARG flood plain continued until about 1 million years ago. Subsequently, the modern Rio Grande began to incise the Albuquerque Basin deposits in response to lowering of the stream base level associated with the integration of the Rio Grande to the Gulf of Mexico.

Persistent volcanic eruptions in the Jemez Mountains, north of the Albuquerque Basin, produced thick deposits of volcanic rocks. These rocks provided a source of transported volcanoclastic debris (sediments derived from volcanic rock). Volcanic ash and pumice is commonly observed in younger ARG lithofacies. Volcanic activity along rift zone faults within the

Albuquerque Basin also contributed to the basin-fill process. These volcanic deposits consist largely of locally derived basalt flows and ash deposits. This volcanic activity modified stream drainages and local sedimentary depositional processes.

Fluvial sediments deposited within active stream channels commonly are coarse-grained and of relatively uniform size (Bartolino and Cole 2002). Areas of overbank floodplain deposition are characterized by fine-grained sediments typically found in a lower-velocity environment. Stratigraphic deposits derived from perennial stream flow are relatively extensive and uniform.

Alluvial fan deposits derived from local, ephemeral stream flow are more poorly sorted, lenticular, and variably distributed. Figure 2-4 shows the types of sedimentary deposits associated with a typical alluvial fan. Most alluvial fan deposits encountered by drilling in the TAG AOC appear to correspond to a mid-fan setting.



View A depicts a plan view. View B depicts a transverse cross-section. View C is a longitudinal cross-section.

Figure 2-4
Schematic of Typical Alluvial Fan Sedimentation Packages (Spearing 1974)

2.4 Regional Hydrology

The Rio Grande, located approximately 6.1 miles west of the TAG AOC, is the major surface water (hydrologic) feature in central New Mexico. The Rio Grande originates in Colorado's San Juan Mountains and terminates at the Gulf of Mexico, near Brownsville, Texas. The Rio Grande has a total length of 1,900 miles and is ranked as the fourth longest river system in the United States, but its meager and discontinuous flow in some stretches negates the river from being realistically ranked concerning discharge (U.S. Geological Survey [USGS] May 1990).

Surface water (with the exception of a few springs) within the boundaries of KAFB is found only as ephemeral streams (arroyos) that flow for short periods due to runoff from thunderstorms. Occasionally, flow occurs after the spring melt of mountain snowpack. The primary surface water feature that drains the eastern foothills on KAFB is the Tijeras Arroyo. The Arroyo del Coyote joins Tijeras Arroyo approximately 0.5 miles southwest of the TAG AOC (Figure 2-3). Both Tijeras Arroyo and Arroyo del Coyote carry significant runoff after heavy thunderstorms that usually occur from June through August. The Tijeras Arroyo, above the confluence with Arroyo del Coyote, drains about 80 sq. mi., while Arroyo del Coyote drains about 39 sq. mi. on KAFB (U.S. Army Corps of Engineers 1979). The total watershed for Tijeras Arroyo, which includes the Sandia and Manzanita Mountains and eastern portion of KAFB, is approximately 126 sq. mi. All active SNL/NM facilities are located outside the 100-year floodplains of both Tijeras Arroyo and Arroyo del Coyote.

Tijeras Arroyo is the most significant surface water drainage feature on KAFB and trends southwest across KAFB and eventually drains into the Rio Grande, approximately 3 miles west of KAFB. Surface water flows in the arroyo several times per year because of significant thunderstorms. The average annual precipitation for the area, as measured at Albuquerque International Sunport, is 8.5 inches (SNL/NM September 2015). During most rainfall events, rainfall quickly infiltrates into the soil in the study area. However, virtually all moisture subsequently undergoes evapotranspiration. Estimates of evapotranspiration for the KAFB area range from 95 to 99 percent of the annual rainfall (SNL/NM February 1998).

The TAG AOC overlies the eastern margin of the Albuquerque Basin where the basin-bounding faults mostly trend parallel to the Sandia-Manzanita-Manzano mountain front. The stratigraphic unit of greatest interest is the Upper SFG, which is primarily composed of two interfingering lithofacies: alluvial fan lithofacies and the ARG fluvial lithofacies. Both lithofacies are less than 5 Mega Annum and are composed of unconsolidated to poorly cemented gravel, sand, silt, and clay (Stone et al. February 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 ARG fluvial lithofacies is derived from northern sources and typically composed of well-sorted, medium- to coarse-grained sands with higher hydraulic conductivities.

Figure 2-5 shows several springs on KAFB associated with the uplifts in the Tijeras Fault Complex and Foothills and Canyons Hydrogeologic Area: 1) Coyote Springs, Cattail Spring, and G Spring within Arroyo del Coyote, 2) Burn Site Spring in Lurance Canyon, and 3) Sol se Mete Spring within the Manzanita Mountains. Coyote Springs and Sol se Mete are perennial springs (continuously flowing), while the others are ephemeral springs. Hubbell Spring (a perennial spring) is located approximately 1 mile to the south of KAFB on Isleta Pueblo. The wetland areas created by these springs, though very limited in extent, provide a unique ecological niche in an otherwise arid habitat.

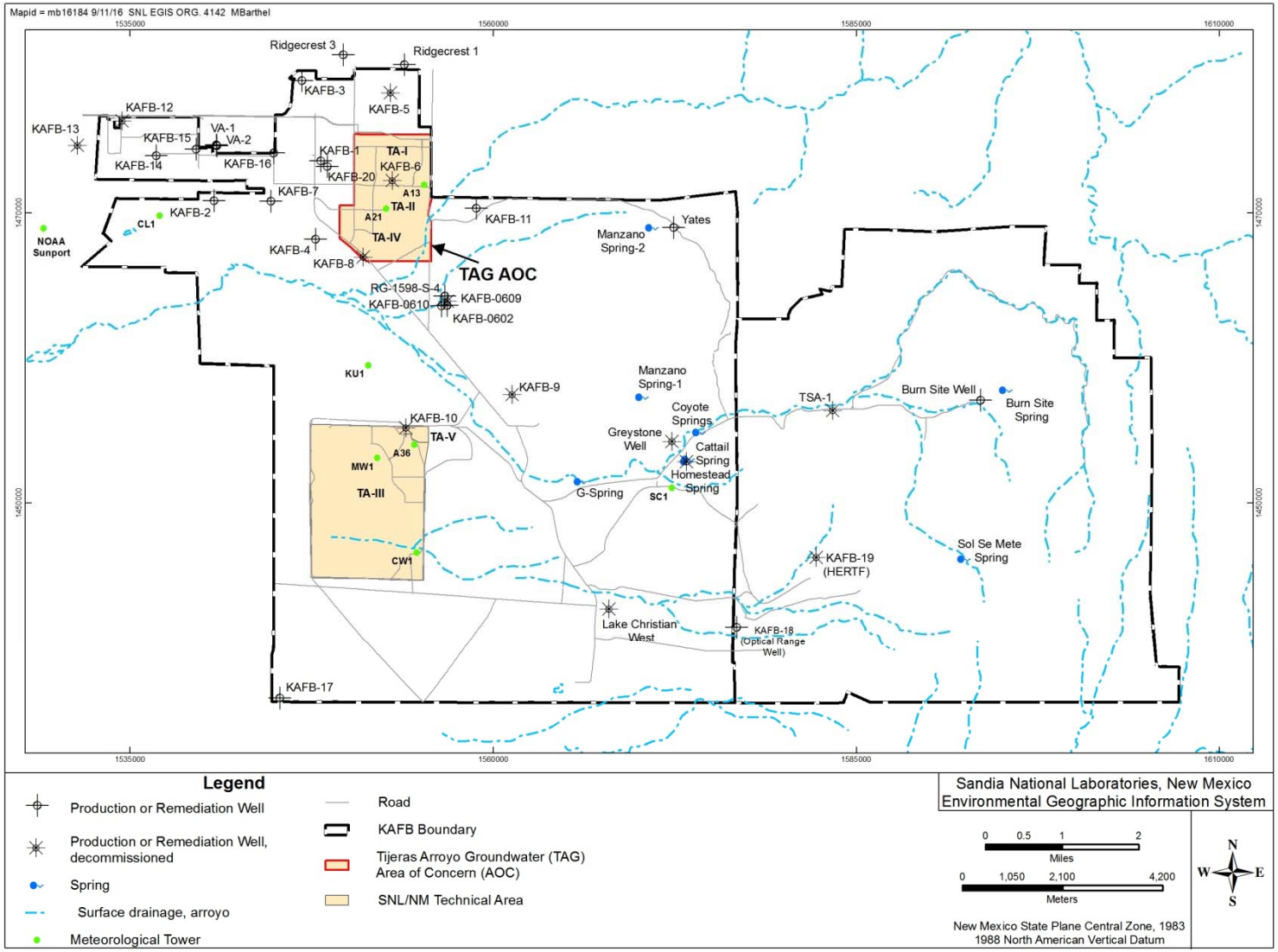


Figure 2-5
Production Wells and Springs (perennial and ephemeral) Located on KAFB

2.5 Regional Aquifer

The major fresh water aquifers in the basin are located within the Upper SFG sediments, specifically within the fluvial and alluvial fan facies. This section describes the regional SFG Aquifer within the Albuquerque Basin, including aquifer geometry, distribution and characteristics of hydrostratigraphic units, sources of recharge to the aquifer, regional groundwater flow, and locations of discharge from the aquifer. SFG Aquifer and Regional Aquifer will be used interchangeably in this document.

2.5.1 Aquifer Geometry

The sedimentary deposits of the SFG and overlying alluvium that fill the Albuquerque Basin contain the SFG Regional Aquifer. This aquifer is the primary source of municipal, domestic, and industrial water in the Albuquerque area.

The present day structure of the aquifer system within the Middle Rio Grande Basin is complex (Bartolino and Cole 2002). The major hydrostratigraphic units in the aquifer are tabular and wedge-shaped bodies that are truncated and displaced by numerous faults. Few major units are present continuously throughout all three sub-basins and most pinch out against the subsurface basement blocks that separate the sub-basins. These major units are hundreds to thousands of feet thick, extend over tens of square miles, and primarily consist of unconsolidated and partially cemented deposits that interfingered in complex arrangements. The diverse rock types and intricate interbedding relationships indicate that the hydrologic characteristics of these units can be defined only in general terms.

2.5.2 Hydrostratigraphic Characteristics

Hydrostratigraphic units within the SFG Regional Aquifer consist of sediments that are derived from similar depositional environments and have similar hydraulic properties (Bartolino and Cole 2002). These units consist predominantly of unconsolidated to partially cemented sand and silt with lesser amounts of clay and gravel. Regional groundwater flow is controlled in part by the distribution and thickness of these hydrostratigraphic units and by their capacity to store and transmit water. The numerous depositional processes, modifications attributed to continued uplift and subsidence, and the varied sources of sediment combine to form a complex, three-dimensional framework of truncated and overlapping sedimentary units exhibiting hydrologic properties that vary both laterally and vertically.

Alluvial fan lithofacies occur extensively along the eastern boundary of the Albuquerque Basin, and include a thick section of older fine-grained piedmont and younger, coarser-grained, alluvial fan lithofacies. Older piedmont deposits are characterized by lower hydraulic conductivity because of their fine-grained texture. Younger alluvial fan deposits are coarser and have higher hydraulic conductivity. These deposits are locally thousands of feet thick.

Grain sizes in the alluvial fan lithofacies typically decrease with depth and distance from the sediment source areas. Figure 2-4 shows variations in grain size that occur within short lateral distances also are attributed to the lenticular nature of deposits typically found in an alluvial fan. As a result of the highly variable texture, a large range of hydraulic conductivities can be anticipated in the vadose zone and the aquifer.

The youngest sedimentary deposits of the SFG consist of materials that are coarser-grained than most of the earlier basin fill (Bartolino and Cole 2002). These deposits include locally derived alluvial fan deposits and other deposits laid down by the ARG. Coarse sand and gravel are common in these deposits, indicating a more energetic depositional environment. The transition in grain size is evident on a regional scale and consistent with global evidence of substantial increase in precipitation. These younger, coarser-grained deposits comprise the productive zones of the Regional Aquifer in the Albuquerque Basin. The deposits are not laterally extensive and are only a small percentage of the basin-fill deposits. These deposits are currently eroding in the Rio Grande drainage.

2.5.3 Regional Recharge

Regional recharge occurs from infiltration of stream flow from the Rio Grande and arroyos, from infiltration of areal precipitation, and from underflow originating from mountain front recharge. On KAFB, Tijeras Arroyo and Arroyo del Coyote provide limited recharge, as does mountain-front recharge. The amount of recharge occurring in the foothills and canyons is not well characterized. The estimated recharge for that portion of Tijeras Arroyo on KAFB is estimated to be up to 2.2 million cubic feet per year (ft/yr) (50-acre ft/yr). The best estimate for the groundwater recharge associated with Arroyo del Coyote is 0.4 million cubic ft/yr (9.2-acre ft/yr). Infiltration studies conducted by the SWHC (GRAM and Lettis December 1995) determined that recharge is negligible from areal precipitation due to the high rate of evapotranspiration (95 to 99 percent) for most areas on KAFB, especially on alluvial fan slopes and other relatively flat areas.

2.5.4 Regional Groundwater Flow

Prior to development of water resources in the Albuquerque area, groundwater flow in the Albuquerque Basin was generally from the north to the south paralleling the Rio Grande (Figure 2-6) (Bartolino and Cole 2002). Beneath KAFB, the predominant groundwater flow was westward prior to water resources development. As the SFG Regional Aquifer was developed as a source for municipal and industrial water supplies, the natural groundwater flow directions were significantly altered toward production wells to the northeast that are operated by the KAFB, VA, and ABCWUA. The ABCWUA began operation of the San Juan-Chama Drinking Water Project in December 2008 for recharging the Regional Aquifer beneath Albuquerque (Powell and McKean 2014).

Figure 2-5 shows the locations of production wells that pump groundwater from the Regional Aquifer near KAFB. Appendix B lists construction details for the production wells. In 2016, KAFB operated five production wells (KAFB-3, KAFB-4, KAFB-14, KAFB-15, and KAFB-20) for potable water-supply purposes (SNL/NM June 2016). Well KAFB-16 was off-line for maintenance purposes. Production well KAFB-7 was modified from being a recovery well for nitrate-impacted groundwater to an injection well for treated water obtained from the Bulk Fuels Facility (BFF) remediation project. The VA operated production well VA-2 for potable water-supply purposes. The ABCWUA also operates production wells such as Ridgecrest 1 and Ridgecrest 2 near the northern edge of KAFB. Figure 2-7 shows the combined pumping effects of the wells discussed above, in addition to dozens of more wells in the Albuquerque Basin, upon the regional groundwater flow. The base-wide potentiometric surface map (Plate 1) in the *Annual Groundwater Monitoring Report Calendar Year 2016* (Plate 1, SNL/NM June 2017) also shows the effect of drawdown across the western portion of KAFB.

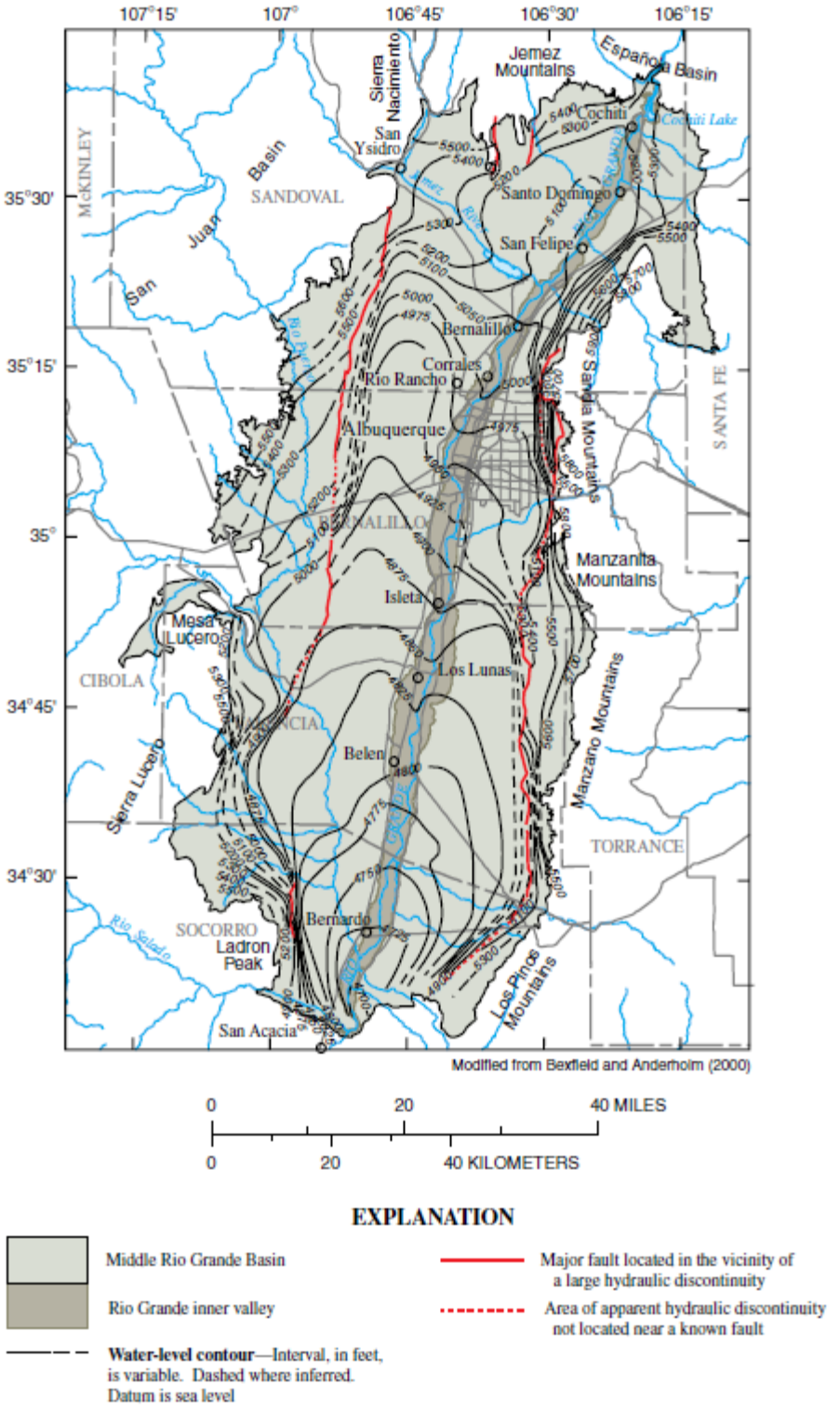


Figure 2-6
Groundwater Elevations that Represent Predevelopment Conditions in the Santa Fe Group Regional Aquifer in the Middle Rio Grande Basin (Bartolino and Cole 2002)

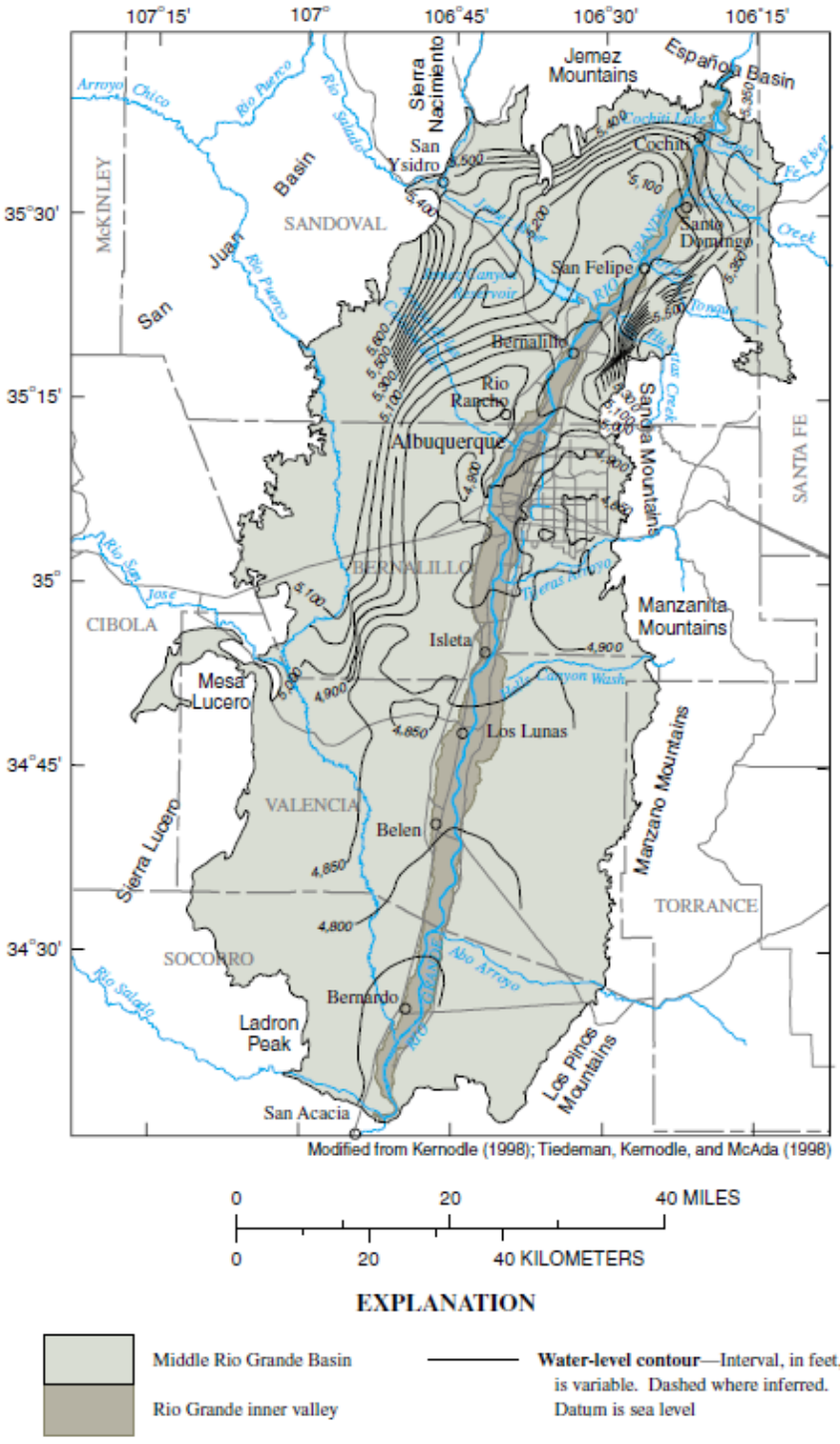


Figure 2-7
Production Well Influence on the Potentiometric Surface for the Regional Aquifer in 1995 for the Vicinity of KAFB (Bartolino and Cole 2002)

2.5.5 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. Groundwater discharge also occurs as pumping from the KAFB, VA, and ABCWUA production wells near SNL/NM.

3.0 GEOLOGY AND HYDROGEOLOGY OF THE TAG AOC

Sections 3.1, 3.2, and 3.3 discuss the geologic setting, monitoring well network, and the hydrogeologic setting for the TAG AOC vicinity, respectively.

3.1 Geologic Setting of TAG AOC Vicinity

The SWHC Project at SNL/NM provided the framework for the geologic and hydrogeologic interpretation of the TAG AOC (GRAM and Lettis December 1995, SNL/NM February 1998). The TAG CIR (SNL/NM November 2002) and the TAG IR (SNL/NM November 2005) presented material specific to the TAG AOC. The geologic information used to better define the site geology included geologic mapping of surface deposits, surface geophysical surveys, borehole geologic descriptions for cuttings and cores, and borehole geophysical logs.

3.1.1 Structural Framework

The TAG AOC 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 System. The Albuquerque Basin is a segment of the tectonic, hydrologic, and topographic basins extending from central Colorado to the border of Mexico at El Paso, Texas. North-south–trending fault systems control these basins (Hawley and Haase 1992). The faults on the eastern margin of the Albuquerque Basin nearest to the TAG AOC primarily trend parallel to the Sandia-Manzanita mountain front. These faults are down-to-the-west, normal faults that offset Precambrian through Holocene strata. The overall hydrologic effect of faults near the AOC is not completely understood. At other locations in the Albuquerque Basin, normal faults affect the basin hydrogeology by: 1) influencing the distribution of the higher conductivity sediments; 2) partitioning the aquifer by juxtaposition of sediments with contrasting hydraulic properties; and 3) possibly providing planes of preferential cementation (Smith and Kuhle February 1998). Investigations conducted immediately south of the TAG AOC show that the effects of normal faults range from sealing off groundwater flow to acting as preferential pathways. Groundwater flow across the faults may be localized, both horizontally and vertically (Reiter March 1998).

Figure 2-3 shows the TAG AOC is located near numerous rift-zone faults. The Sandia Fault is located approximately two miles east of the TAG AOC. The eastern upthrown block of this fault consists of Precambrian and Paleozoic rocks at the land surface. The relatively low hydraulic conductivity of the Precambrian and Paleozoic rocks on the eastern side of the Sandia Fault serves to partially limit groundwater flow. Figure 2-3 shows the buried West Sandia Fault is tentatively located approximately 1.4 miles east the TAG AOC based on seismic data.

Over a period of several years, Van Hart (June 2003) constructed an extensive interpretation of the structural setting of KAFB. His findings were also reported in SNL/NM (November 2002), Van Hart (June 2001), Van Hart et al. (October 1999), and Fritts and Van Hart (March 1997). These reports contained interpretations based on borehole cuttings/cores, geophysical logs from monitoring wells, water level data, aeromagnetic data, aerial photography, seismic-reflection surveys, gravity measurements, magnetotelluric surveys, and outcrop mapping.

3.1.2 Stratigraphic Framework

The TAG AOC overlies the eastern margin of the Albuquerque Basin. Geologic studies have focused primarily on the Upper SFG, which is composed mostly of two interfingering facies: alluvial fan facies and fluvial ARG facies. Both facies are less than 5 million years old and are composed of unconsolidated to poorly cemented gravel, sand, silt, and clay (Stone et al. February 2000). The alluvial fan facies consist of poorly sorted piedmont-slope deposits derived from the Sandia, Manzanita, and Manzano Mountains east of the AOC. The alluvial fan facies has a predominantly east to west depositional fabric. The fluvial facies is derived from the ARG to the north and are typically well-sorted coarser-grained sediments with correspondingly high hydraulic conductivity, and are located in the subsurface, just west of Wyoming Boulevard. Poorly developed soil covers much of the Upper SFG in the TAG AOC. Conversely, the depth to bedrock underlying the Upper SFG is estimated to be approximately 3,500 ft near the center of the AOC.

As part of Van Hart's (June 2001) work, a geophysical-log correlation net (similar to a fence diagram) was constructed using borehole geophysical logs. Six cross-sections with broad stratigraphic correlations across KAFB were constructed using the correlation net (SNL/NM November 2002). Figure 3-1 presents the most useful cross-section for the TAG AOC. Depicted on the cross-section is the coarse-grained/fine-grained datum that was used to construct the structure map. The vertical transition from predominantly coarse-grained to fine-grained sediments has wide regional significance, and probably formed by both tectonic and climatic events (Pazzaglia et al. September 1999; Van Hart June 2001).

The TAG AOC, located on a partially dissected piedmont surface, was formed by coalescing Holocene and Pleistocene alluvial fans originating from the Sandia and Manzanita Mountains. The alluvial fan deposits are primarily derived from Tijeras Canyon, which divides the Sandia and Manzanita Mountains. Tijeras Arroyo extends westward from Tijeras Canyon and across the southern portion of the area. The alluvial fan deposits consist of poorly sorted, weakly stratified sand and gravel in a silt/clay matrix. The sources of these clastic materials are the granitic and sedimentary lithologies of the Sandia Mountains, and the metamorphic and sedimentary lithologies from the Manzanita Mountains. Fine-grained facies in the alluvial fan deposits produce low-permeability zones that significantly influence water movement in both the unsaturated (vadose) and saturated zones.

The strata penetrated in boreholes during the installation of monitoring wells in the TAG AOC were highly variable, consisting of alternating layers of gravels, sands, silts, and clays. Gravelly sand lenses, up to 20 ft in thickness, were present at various depths. The lithology of these coarse fractions mainly consisted of limestone, granite, and various metamorphic rock types. Layers of clayey-silty sand, ranging from 2 to 10 ft in thickness, were present throughout the drilled sequence, but were more prevalent and thicker at depths below 300 ft bgs. The low vertical permeability of these fine-grained units is suspected of being able to perch groundwater.

The stratigraphy of the upper portion of the SFG has been studied using borehole cuttings, cores, and geophysical logging of monitoring wells. The characteristics for the alluvial fan lithofacies and ARG lithofacies are discussed in more detail below.

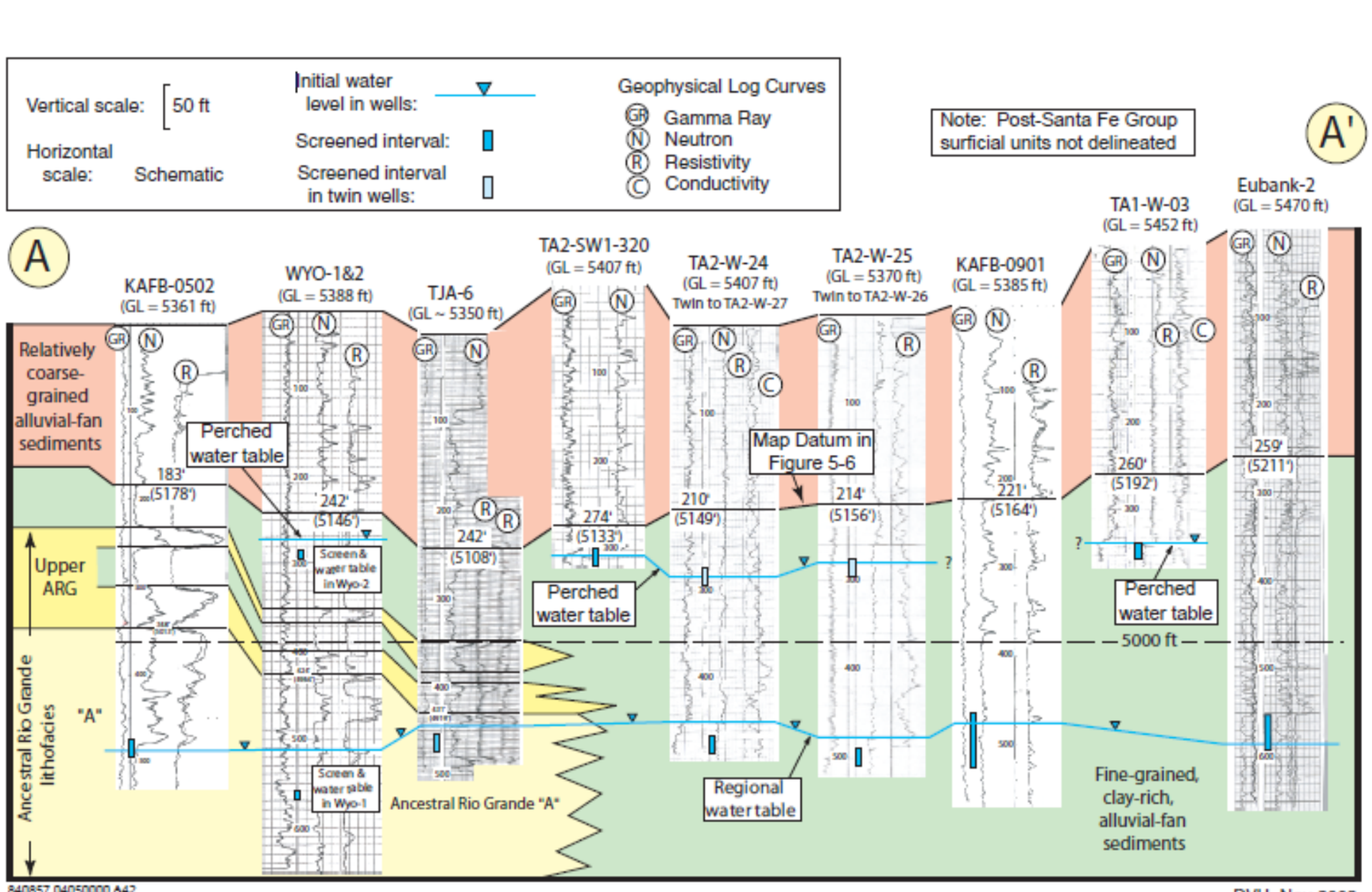


Figure 3-1
Geophysical Cross-Section across the TAG AOC (Van Hart June 2003)

3.1.2.1 Alluvial Fan Lithofacies

A thick section of alluvial fan deposits underlay the TAG AOC. These deposits are part of the alluvial fan lithofacies of the SFG and have a predominantly east-to-west depositional fabric reflecting an anastomosing sequence of braided channels set within lobes of debris flows (Figure 2-4). Figure 3-1 shows the alluvial fan lithofacies is subdivided into lower and upper sections. The upper section consists of relatively coarse-grained sediments that were most likely deposited in a higher energy environment. The lower section consists of a fine-grained, clay-rich unit. This unit has been identified as low energy piedmont deposits derived from upland soil that developed during a pre-glacial humid climate. Under the TAG AOC, the Perched Groundwater System and the Regional Aquifer are present in the fine-grained lower unit of alluvial fan lithofacies.

3.1.2.2 Ancestral Rio Grande Deposits

The ARG deposits interfingered with the alluvial fan deposits near the western edge of the TAG AOC. The ARG deposits consist predominantly of well-sorted sands and gravels that were deposited during the integration of the Rio Grande Drainage System (SNL/NM July 2004). The ARG deposits have a predominantly north-to-south depositional fabric. The ARG facies, with its distinctive pebbles of tuffaceous material, was encountered at depths of approximately 350 and 345 ft bgs at the boreholes for monitoring wells WYO-1 and TJA-6, respectively (Van Hart June 2003). Figure 3-1 shows the water table for the Perched Groundwater System is above the ARG facies.

Figure 3-2 presents an isopach map showing the thickness of the sedimentary package between the Perched Groundwater System and the Regional Aquifer (Van Hart June 2001; SNL/NM November 2002). Section 3.8 contains an updated figure. This intervening thickness decreases from approximately 260 ft in the northwest portion of the TAG AOC to less than 160 ft in the southeast portion, as the two water-bearing units merge. Within this sedimentary package, three perching layers identified by laboratory testing of core samples obtained from two adjacent boreholes in TA-II. In 1993, continuous coring conducted from the ground surface to 300 ft bgs at the borehole for well TA2-NW1-325, and from 325 to 625 ft bgs at the borehole for well TA2-NW1-595. Core samples from 20-ft intervals were tested in the Environmental Restoration Chemistry Laboratory's hydrologic laboratory using ASTM D422-63 for particle size analysis (SNL/NM 1995) and K–saturated (K_{sat}) values were calculated using the computer code of Vukovic and Soro (1992). Table 3-1 shows the 300-ft-bgs core sample corresponded to the water table and had a K_{sat} of 1.88 E-4 centimeters per second (cm/s). The 320-ft bgs and 340-ft bgs core samples had K_{sat} values of 3.45 E-5 and 6.19 E-7 cm/s, respectively, and likely represent the Perching Horizon underlying the Perched Groundwater System. The cores from 380 and 440 ft bgs produced K_{sat} values of 2.04 E-7 and 3.80 E-7 cm/s, respectively, and also visually appeared to be representative of aquitards (Fritts and Van Hart March 1997). Figure 2-4 illustrates the perching layer probably has variable hydraulic conductivities across the TAG AOC because of inconsistent geometry commonly associated with alluvial fan deposits.

The depth to the Regional Aquifer was approximately 523 ft bgs at the time of drilling for well TA2-NW1-595. The hydraulic conductivity values for samples collected from 540 to 620 ft bgs show that the Regional Aquifer has variable hydraulic conductivities ranging from 2.59 E-04 to 1.17 E-07 cm/s.

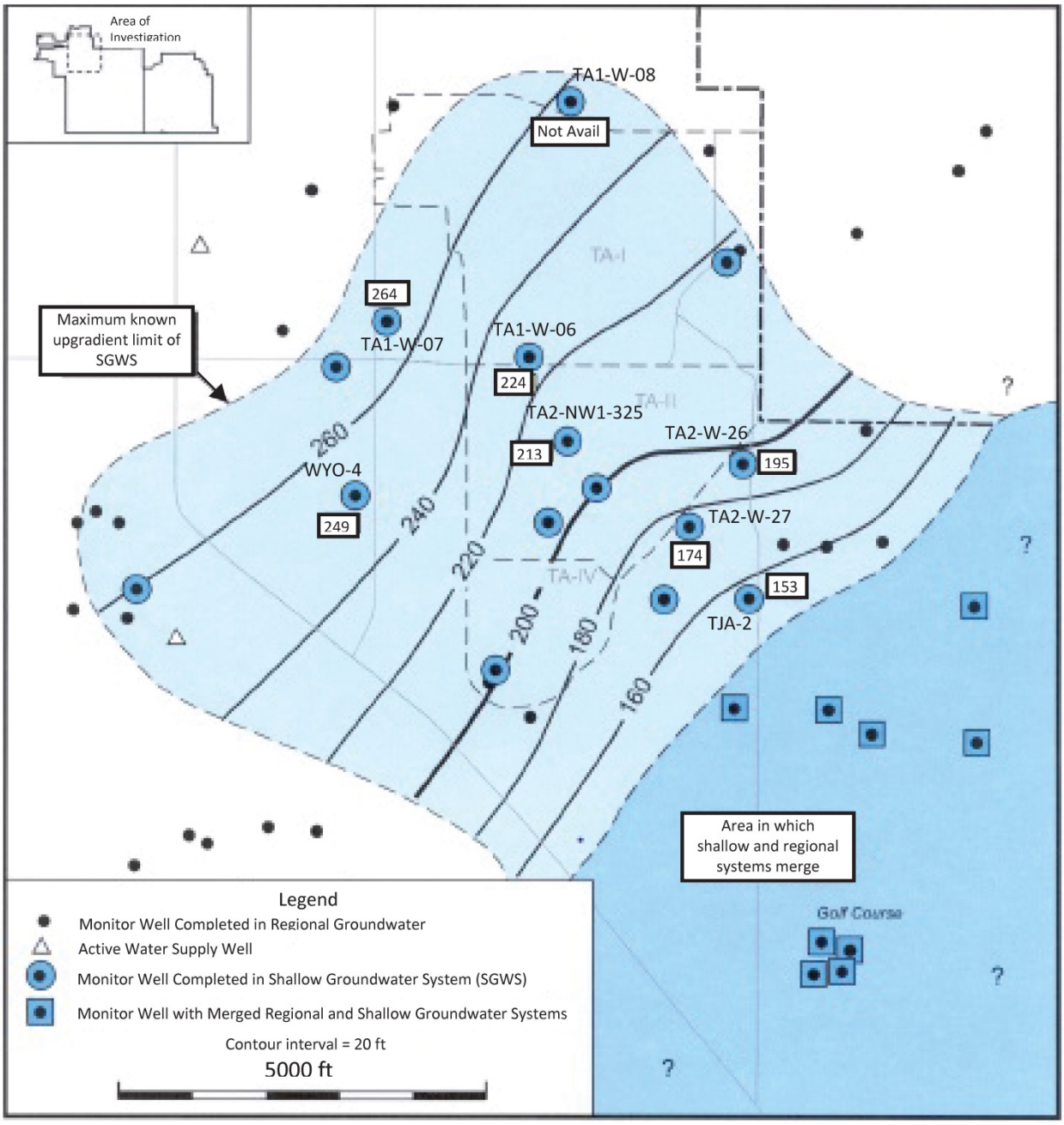


Figure 3-2
Isopach Map of the Vertical Distance between the Perched Groundwater System and the Regional Aquifer, modified from Van Hart, June 2001 (SNL/NM November 2002)

Table 3-1
Calculated Estimates of Hydraulic Conductivities for
Core Samples Collected from TA-II Boreholes (SNL/NM 1995)

Borehole	Sample Depth (ft bgs)	Ksat (cm/s)
TA2-NW1-325	18	4.44 E-05
TA2-NW1-325	40	2.70 E-05
TA2-NW1-325	60	5.64 E-05
TA2-NW1-325	80	1.94 E-05
TA2-NW1-325	119	3.86 E-05
TA2-NW1-325	140	5.55 E-05
TA2-NW1-325	159	6.81 E-06
TA2-NW1-325	160	2.46 E-06
TA2-NW1-325	177	1.43 E-05
TA2-NW1-325	200	2.96 E-07
TA2-NW1-325	220	1.76 E-06
TA2-NW1-325	240	2.45 E-06
TA2-NW1-325	280	1.61 E-06
TA2-NW1-325	300 top of saturation for the Perched Groundwater System	1.88 E-04
TA2-NW1-595	320	3.45 E-05
TA2-NW1-595	340	6.19 E-07
TA2-NW1-595	360	7.29 E-05
TA2-NW1-595	380	2.04 E-07
TA2-NW1-595	400	3.06 E-06
TA2-NW1-595	420	9.64 E-08
TA2-NW1-595	440	3.80 E-07
TA2-NW1-595	460	2.08 E-05
TA2-NW1-595	520	9.64 E-08
TA2-NW1-595	523 top of saturation for the Regional Aquifer	n.t.
TA2-NW1-595	540	2.59 E-04
TA2-NW1-595	560	1.56 E-04
TA2-NW1-595	580	1.17 E-07
TA2-NW1-595	620	1.03 E-06

Notes:
Top of saturation for both water-bearing units is from drilling observations (Fritts and Van Hart March 1997).
bgs = Below ground surface.
cm/s = Centimeter(s) per second.
E = Exponential function.
ft = Foot (feet).
n.t. = Not tested.
SNL/NM = Sandia National Laboratories, New Mexico.
TA = Technical Area.
TA2-NW = Technical Area-II (Northwest).

3.2 Monitoring Well Network

Figure 3-3 shows the 31 groundwater monitoring wells installed by the DOE/SNL M&O contractor in the TAG AOC for studying the hydrogeologic setting. Another well, Eubank-1, is also located in the TAG AOC. COA EHD installed this well for evaluating the municipal Eubank Landfill. When installed, Eubank-1 was located on city property. In 2001, the base boundary was adjusted and this well fell within the KAFB fence line. The COA EHD continues to sample this well.

KAFB and the COA EHD have also installed numerous monitoring wells near the TAG AOC. Data from these non-SNL/NM wells have been used to develop a broader understanding of the hydrogeologic setting. No production wells are located within the TAG AOC boundary.

3.2.1 Monitoring Well Network

Table 3-2 summarizes the construction details for monitoring wells in the TAG AOC. Twenty-seven wells are currently used for monitoring purposes. Fourteen wells are screened in the Perched Groundwater System while 13 monitoring wells are screened in the Regional Aquifer. The topographic relief across the TAG AOC is approximately 120 ft, as measured near the well pads. Ground surface elevations are lower on the floodplain of Tijeras Arroyo and the highest ground surface elevations are located in the northeast corner of the TAG AOC.

Appendix B contains the construction details for active and decommissioned (plugged and abandoned) monitoring and production wells near the TAG AOC. Five SNL/NM monitoring wells have been decommissioned. In April 1998, Regional Aquifer well PGS-1 was decommissioned because of insufficient yield for sampling purposes. Monitoring wells WYO-1 and WYO-2 were decommissioned in July 2001 because the two well casings had been installed in a single borehole and the annular seal was later determined to be ineffective. These two wells were replaced that same month with Regional Aquifer well WYO-3 and Perched Groundwater System well WYO-4, respectively. Monitoring well TJA-1 was decommissioned shortly after installation in July 1994 because the well casing failed during well development. Well TJA-2 replaced TJA-1 in the same month. Perched Groundwater System well TA2-SW1-320 was decommissioned in December 2014 after video logging showed that joints in the polyvinyl chloride (PVC) well casing were fractured in two places above the water table. Well TA2-W-28 was installed in December 2014 to replace well TA2-SW1-320. The screen interval of well TA2-SW1-320 was 299.6 to 319.6 ft bgs whereas the screen for well TA2-W-28 was set at 310.45 to 330.45 ft bgs. Based upon the groundwater level that was measured immediately after well development, it is anticipated that the poorly sorted, silty sand interval present from 317 to 320 ft bgs yields the majority of groundwater in well TA2-W-28.

Appendix B lists the wells owned by other agencies (KAFB and the COA EHD) near the TAG AOC. Groundwater investigations at KAFB are conducted as part of both RCRA corrective action investigations and an NMED-mandated Nitrate Abatement Program (Montgomery Watson August 2000). The COA EHD has also conducted groundwater investigations at the closed Eubank Landfill. Data from these wells are used throughout this report.



Figure 3-3
SNL/NM Groundwater Monitoring Wells in the TAG AOC

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Table 3-2
Summary of Well Construction and Hydrogeologic Data for Active Groundwater Monitoring Wells in the TAG AOC

Monitoring Well	Screened Depth (ft bgs)	Depth to Water, October 2015 (ft bgs)	Groundwater Elevation October 2015 (ft amsl)	Date of Well Development After Casing Installation	Casing Type	Water Level Change (ft/yr)[a]	Hydraulic Conductivity (ft/day)[b]	Sampling Frequency in 2015
Perched Groundwater System Monitoring Wells								
TA1-W-03	337.0 – 357.0	350.94	5103.96	27-Jan-1998	PVC	-1.17		Annual
TA1-W-06	300.0 – 320.0	308.39	5109.01	27-Feb-1998	PVC	-0.44		Semiannual
TA1-W-07	268.6 – 288.6	284.12	5118.68	03-Dec-1998	PVC	-0.15	3.8 E-01	n.s.
TA1-W-08	302.0 – 322.0	311.86	5122.84	10-Oct-2001	PVC	-0.52	2.92	Annual
TA2-NW1-325	295.0 – 325.0	316.90	5103.10	01-Apr-1993	PVC	-0.53		n.s.
TA2-W-01	312.0 – 332.0	326.26	5091.14	27-Jun-1994	PVC	-0.70		Semiannual
TA2-W-19	265.9 – 285.9	270.21	5078.79	29-Nov-1995	PVC	-0.50		Quarterly
TA2-W-26	276.0 – 296.0	285.95	5087.85	19-Jan-1998	PVC	-0.75	3.06	Quarterly
TA2-W-27	275.0 – 295.0	278.57	5082.23	09-Feb-1998	PVC	-0.56		Semiannual
TA2-W-28[c]	310.5 – 330.5	317.40	5092.60	10-Dec-2014	PVC	-0.55		Quarterly
TJA-2[d]	275.0 – 295.0	275.85	5075.45	12-Jul-1994	PVC	-0.43		Quarterly
TJA-5	267.0 – 287.0	267.26	5071.24	02-Dec-1998	PVC	-0.02		Annual by KAFB
TJA-7	290.5 – 310.5	300.93	5087.47	12-Mar-2001	PVC	-0.27	1.73	Quarterly
WYO-4	275.0 – 295.0	291.17	5099.03	16-Oct-2001	PVC	-0.68	5.32 E-02	Quarterly
Regional Aquifer Monitoring Wells								
Eubank-1	550.0 – 610.0	548.92	4911.10	16-Jul-1988	SS	0.59		Annual by COA
PGS-2[e]	535.0 – 645.0[f]	542.64	4866.26	22-Sep-1995	SS	2.65		Annual
TA1-W-01	575.0 – 595.0	536.69	4865.11	22-Mar-1997	PVC	1.25	3.14	Annual
TA1-W-02	540.0 – 560.0	522.82	4894.08	27-Feb-1998	PVC	0.60		Annual
TA1-W-04	576.0 – 596.0	566.65	4891.65	06-Oct-1998	PVC	0.59		Annual
TA1-W-05	597.5 – 617.5	565.14	4869.06	16-Nov-1998	PVC	2.24	7.75	Annual
TA2-NW1-595	535.0 – 595.0[g]	521.07	4898.93	27-Jul-1993	PVC	0.66		Annual
TJA-3	496.0 – 516.0	496.47	4891.33	04-Dec-1998	PVC	-0.04	4.53	Quarterly
TJA-4	360.0 – 380.0	298.12	5040.38	01-Dec-1998	PVC	0.41		Quarterly
TJA-6	454.9 – 474.9	448.88	4891.72	04-Feb-2001	PVC	-0.07		Semiannual
WYO-3	520.0 – 540.0	524.73	4865.27	10-Oct-2001	PVC	1.08	1.77	Annual
TA2-W-24	465.0 – 485.0	440.52	4921.28	09-Feb-1998	PVC	0.41		n.s.
TA2-W-25	492.0 – 512.0	466.37	4906.13	28-Apr-1997	PVC	0.69	1.66	n.s.

Refer to footnotes at end of table.

Table 3-2 (Concluded)
Summary of Well Construction and Hydrogeologic Data for Active Groundwater Monitoring Wells in the TAG AOC

Notes:
[a] Calculated for the 5-year period (October 2010 to October 2015).
[b] Value is average of the two mathematical solutions cited in Skelly et al May 2004.
[c] Well TA2-W-28 is the replacement well for TA2-SW1-320. The 5-year average was calculated using the October 2010 water elevation for well TA2-SW1-320, and the October 2015 water elevation for well TA2-W-28.
[d] Well TJA-2 is the replacement well for TJA-1. The well casing for TJA-1 failed during well development.
[e] Well PGS-2 is the replacement well for PGS-1. The water level in PGS-1 had declined below the screen.
[f] Well PGS-2 has three screens: 535 to 565 ft bgs, 585 to 595 ft bgs, and 625 to 645 ft bgs. To isolate the screens, annular seals (bentonite chips) were installed at 567 to 580 ft bgs, and from 596 to 616 ft bgs. Groundwater samples are collected from the upper screen. No packer was installed.
[g] Well TA2-NW1-595 has two screens: 535 to 555 ft bgs and 585 to 595 ft bgs. To isolate the screens, an annular seal of grout was installed from 562 to 572 ft bgs. Groundwater samples are collected from the upper screen. No packer was installed.
amsl = Above mean sea level.
bgs = Below ground surface.
COA = City of Albuquerque Environmental Health Department.
ft = Foot (feet).
ft/day = Feet per day.
ft/yr = Feet per year.
KAFB = Kirtland Air Force Base.
n.s. = Not sampled in 2015 in accordance with work plans.
PVC = Polyvinyl chloride.
SS = Stainless steel.
TA1-W = Technical Area-I (Well) (monitoring well designation).
TA2-NW = Technical Area-II (Northwest) (monitoring well designation).
TA2-W = Technical Area-II (Well) (monitoring well designation).
TJA = Tijeras Arroyo (monitoring well designation).
WYO = Wyoming (monitoring well designation).

3.3 Hydrogeologic Conditions at the TAG AOC

This section discusses hydrogeologic characteristics and properties for the two water-bearing units in the TAG AOC. Table 3-3 summarizes these characteristics and properties. The following section discusses the details.

3.3.1 Potentiometric Surfaces

Groundwater is present in two water-bearing units in the TAG AOC: the Perched Groundwater System and the Regional Aquifer. At TA-II in the central part of the TAG AOC, the depth to the Perched Groundwater System is approximately 330 ft bgs and the depth to the Regional Aquifer is approximately 520 ft bgs. Groundwater elevations from 101 monitoring wells were used to create potentiometric surface maps (Figures 3-4 and 3-5) for these two water-bearing units near the TAG AOC. The data were obtained from SNL/NM, KAFB, and the COA EHD monitoring wells (Appendix C). Figures 3-4 and 3-5 are discussed below and both figures depict a broader area than presented in the 2016 *Annual Groundwater Monitoring Report* (SNL/NM June 2017).

Based on October 2015 water levels in monitoring wells and the interpretation of geophysical logs, the estimated thickness of the saturated sediments in the Perched Groundwater System ranges from approximately 7 to 20 ft across the northern and central portions of the TAG AOC. The thickness reaches 40 ft in the southeast corner of the TAG AOC (see Section 3.8).

3.3.1.1 Potentiometric Surface of the Perched Groundwater System

The Perched Groundwater System is the uppermost water-bearing unit and covers approximately 4.43 sq. mi. Figure 3-4 presents the October 2015 potentiometric surface of the Perched Groundwater System. The direction of groundwater flow in the Perched Groundwater System is inferred from the potentiometric surface to be principally to the east and southeast near the TAG AOC, with an average horizontal gradient of approximately 0.01 feet per foot (ft/ft). The horizontal gradient of the Perched Groundwater System varies from 0.004 to 0.0125 ft/ft. Groundwater mounding to the northwest of the Tijeras Arroyo Golf Course is likely a result of merging groundwater from smaller, stratigraphically higher perching layers and possibly local, historical surface-water recharge.

3.3.1.2 Potentiometric Surface of the Regional Aquifer

Figure 3-5 depicts the October 2015 potentiometric surface of the Regional Aquifer. The direction of groundwater flow in the Regional Aquifer is inferred to be primarily to the northwest across the TAG AOC towards the KAFB, VA, and ABCWUA production wells. The horizontal gradient of the Regional Aquifer across the TAG AOC varies from approximately 0.006 to 0.0125 ft/ft, with an average of approximately 0.01 ft/ft. The horizontal gradient is steeper to the east of the TAG AOC at 0.03 to 0.045 ft/ft where flow is more westerly and southwesterly. To the west of the AOC, the gradient is nearly flat. Groundwater mounding at the Tijeras Arroyo Golf Course produces localized radial flow. Three monitoring wells (KAFB-0904, ST105-MW005, and ST105-MW007) were not contoured due to anomalous water levels that may reflect isolated water zones that are located to the southwest of the TAG AOC.

Table 3-3
Comparison of Water-bearing Units Characteristics and Properties in the TAG AOC

Characteristic or Property	Perched Groundwater System	Regional Aquifer
Potentiometric Surface	Surface is inferred to slope primarily to the southeast.	Surface is inferred to slope primarily to the west and northwest.
Pressure Head	Unconfined (water table) conditions.	Unconfined to semi-confined conditions.
Lithofacies Distribution	Restricted to the alluvial fan lithofacies.	Contained within both the alluvial fan lithofacies and the ARG fluvial lithofacies.
Flow Direction	Primarily to the east and southeast.	Primarily to the west and northwest.
Horizontal Gradient	Varies from approximately 0.004 to 0.0125 ft/ft across the TAG AOC with an average of 0.01 ft/ft.	Varies from approximately 0.006 to 0.0125 ft/ft across the TAG AOC with an average of 0.01 ft/ft. Much steeper east of Powerline Road at 0.03 to 0.045 ft/ft. Nearly flat to the west of Wyoming Blvd.
Horizontal hydraulic conductivity (Kh) from slug tests	A wide range from 0.0532 ft/day to 3.06 ft/day, with an average of 1.63 ft/day.	A narrow range of 1.66 to 7.75 ft/day, with an average of 3.77 ft/day.
Vertical hydraulic conductivity (Kv)	0.0163 to 0.163 ft/day.	0.0377 to 0.377 ft/day.
Groundwater velocity, horizontal	0.002 to 0.122 ft/day. Equivalent to 0.778 to 44.68 ft/yr.	0.066 to 0.310 ft/day. Equivalent to 24.24 to 113.15 ft/yr.
Groundwater velocity, horizontal average	Approximately 24 ft/yr, based on five wells.	Approximately 55 ft/yr, based on five wells.
Usage	Not used for water supply purposes.	Utilized for potable water supply by KAFB, VA, and the ABCWUA outside of the TAG AOC.
Lateral extent	Approximately 4.43 sq. mi. across north-central KAFB.	Laterally extensive across the Albuquerque Basin.
Saturated Thickness	Estimated from geophysical logs to range from approximately 7 to 20 ft across the northern and central portions of the TAG AOC. In the far southeast corner, the saturated thickness reaches approximately 40 ft.	In excess of 1,000 ft in thickness across much of the area.
Geochemical Variability	Geochemical signatures variable between monitoring wells.	Geochemical signatures consistent between monitoring wells.
Geochemical Uniqueness	High chloride, nitrate, and sulfate concentrations.	Low calcium concentrations, but high bicarbonate/alkalinity concentrations.

Refer to footnotes at end of table.

Table 3-3 (Concluded)
Comparison of Water-bearing Units Characteristics and Properties in the TAG AOC

Characteristic or Property	Perched Groundwater System	Regional Aquifer
Effective porosity	0.25	0.25
Water levels	Steadily declining groundwater elevations across the entire TAG AOC, except in southeast corner (well TJA-5), annual declining rate ranges from 0.06 to 1.17 ft/yr.	Increasing water across entire TAG AOC, except for southwest corner. Variable rate ranges from a declining 0.07 to an increasing 2.65 ft/yr.
Recharge	Historically recharged by anthropogenic sources (leaking water supply/sewer lines, irrigated lawns, the Tijeras Arroyo Golf Course, the former KAFB Sewage Lagoons), and natural sources such as Tijeras Arroyo.	Recharged by natural sources including upstream reaches of the Rio Grande, mountain front recharge, and Tijeras Arroyo. Also, some anthropogenic recharge from the Perched Groundwater System via the merging zone.
Principal Hydrogeologic Controls	Stratigraphic dip of Perching Horizon to the southeast coupled with lesser effect of depositional fabric trending westward from mountain flank.	Combined drawdown of KAFB, VA, and ABCWUA production wells. North to South trending paleochannels, have high conductivities.

Notes:
ABCWUA = Albuquerque Bernalillo County Water Utility Authority.
AOC = Area of Concern.
ARG = Ancestral Rio Grande (lithofacies).
ft = Foot (feet).
ft/ft = Feet per foot.
ft/yr = Feet per year.
KAFB = Kirtland Air Force Base.
sq. mi. = Square mile(s).
TAG = Tijeras Arroyo Groundwater.
VA = Veterans Administration.

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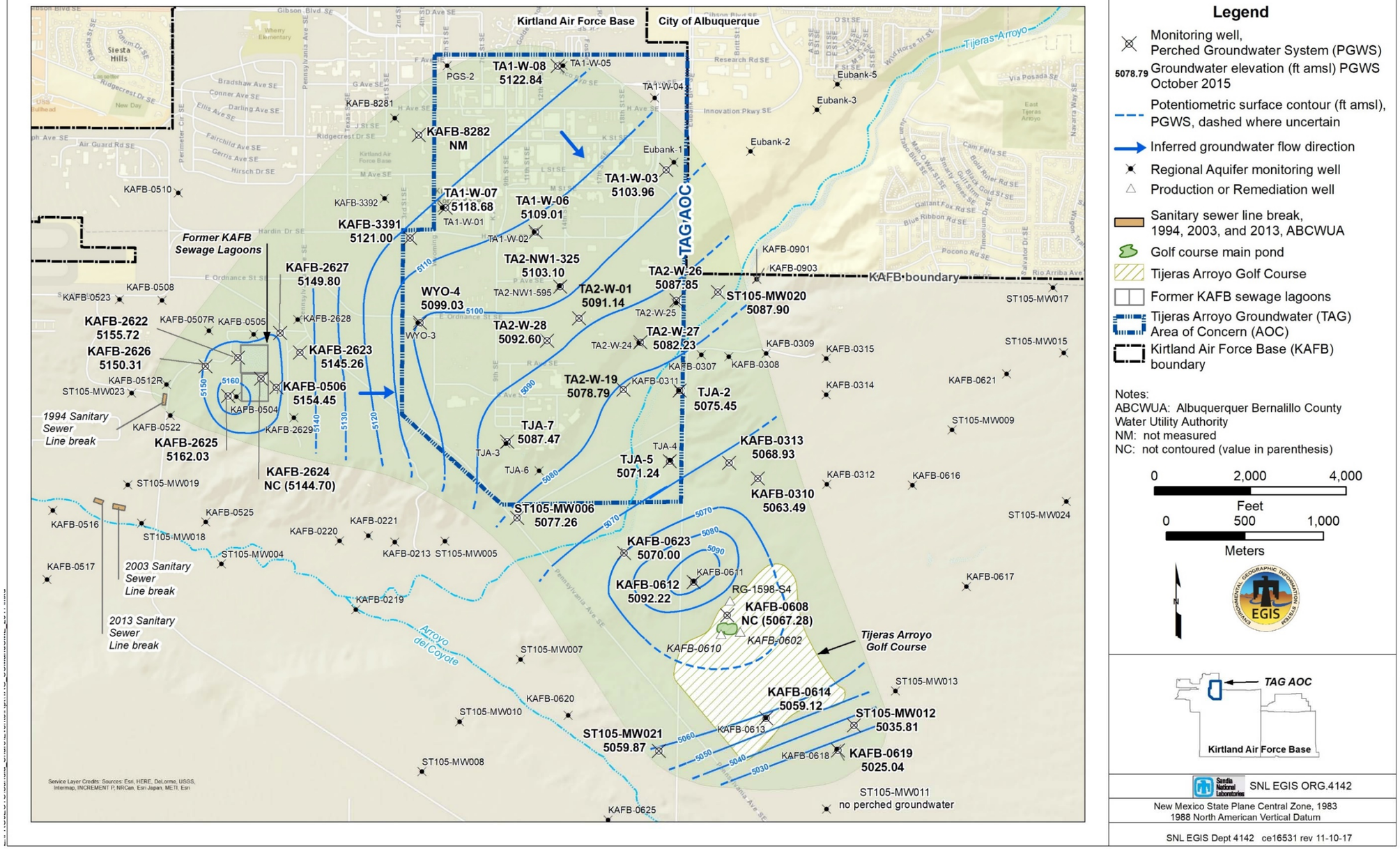


Figure 3-4
Potentiometric Surface Map for the Perched Groundwater System near the TAG AOC, October 2015

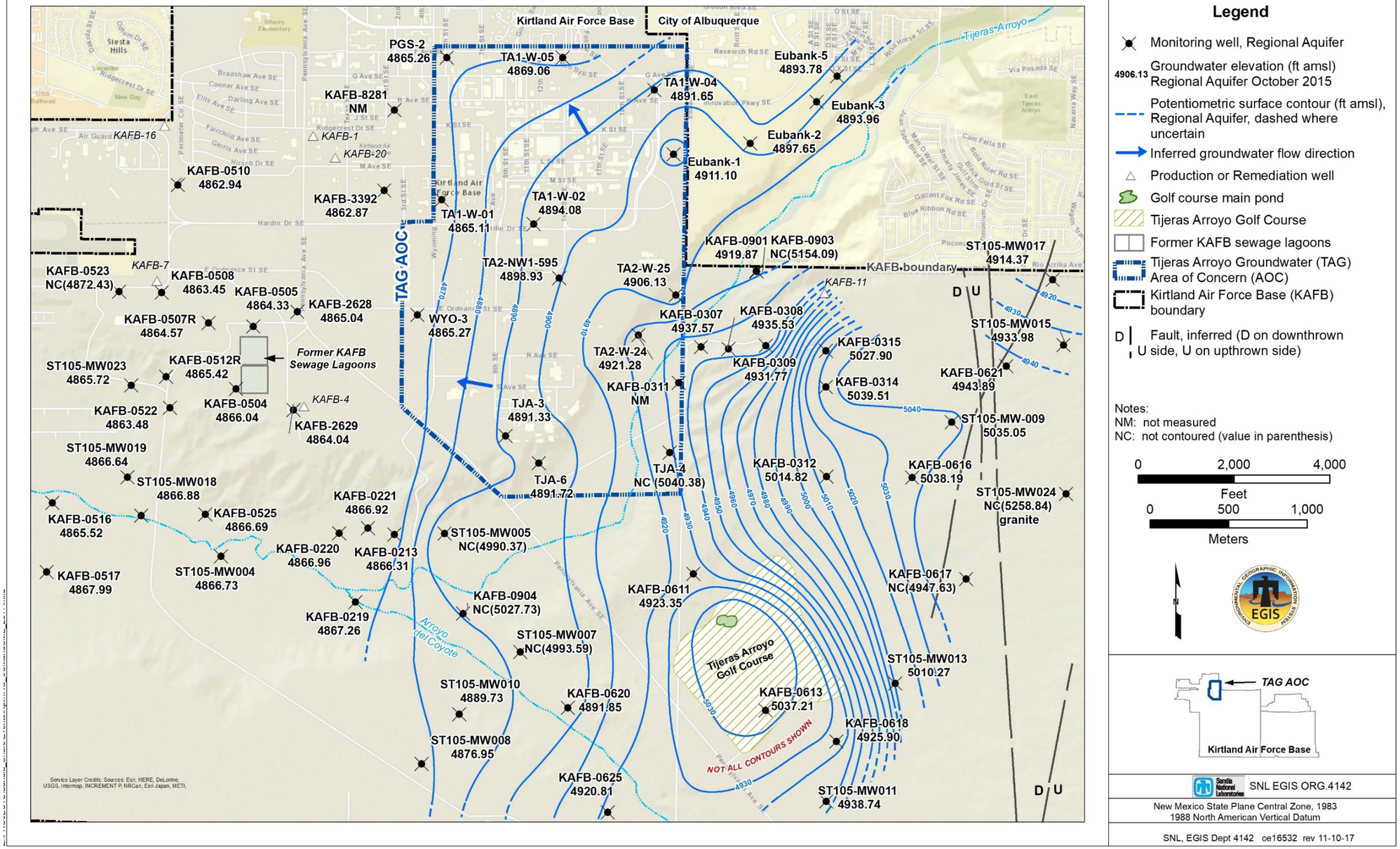


Figure 3-5
Potentiometric Surface Map for the Regional Aquifer near the TAG AOC, October 2015

3.3.2 Groundwater Geochemistry

The geochemistry discussion for groundwater samples collected from the TAG AOC monitoring wells is based on the interpretation of Piper and Stiff diagrams. The depiction of major ions is typically useful as a diagnostic tool for evaluating sources of groundwater recharge and groundwater flow patterns. Table 3-4 lists the sampling dates and corresponding analytical laboratories. As much as possible, analytical results from the most recent (2015) sampling events were used. Geochemical data from 2003 were used for comparative purposes because that is the most complete historical dataset. Geochemical modeling is also discussed below.

Several factors should be considered when evaluating the geochemical diagrams.

- Anthropogenic recharge at the TAG AOC (for example, landscaping, septic, and wastewater) was originally sourced from KAFB production wells completed in the Regional Aquifer. Subsequent subsurface mixing with residual pore water within the Perched Groundwater System may have altered the geochemical signature of this discharged water.

- Prior to anthropogenic recharge, sediments in the Perched Groundwater System were most likely at residual saturation due to natural drainage, and these sediments would not have contained sufficient water to fill a well casing (Brady and Domski 2001). Brady and Domski postulated that a “triggering effect” was created by the input of anthropogenic water that artificially created a water-bearing zone. Thus, water produced by a well may contain a significant portion of natural (pre-recharge) water and a minor portion of the anthropogenic recharge water.

- Well TA2-NW1-595 has two well screens (535 to 555 ft bgs and 585 to 595 ft bgs). Groundwater samples have historically been collected from the upper screen, but some contribution is possible from the lower-screened formation. An annular seal separates the two screens (see footnote for Table 3-2).

- Well PGS-2 has three well screens (535 to 565 ft bgs, 585 to 595 ft bgs, and 625 to 645 ft bgs). Annular seals separate the three screens (see Table 3-2 footnote). Samples have historically been collected from the upper screen, but some contribution is possible from the lower screens.

Table 3-4
Geochemical Data Sources Used for Generating Piper and Stiff Diagrams

Monitoring Well	Most Recent Sampling Event	Laboratory	Historical Sampling Event	Laboratory
Perched Groundwater System				
TA1-W-03	August 2015	GEL	July 2003	GEL
TA1-W-06	September 2015	GEL	July 2003	GEL
TA1-W-07	March 2002	ERCL	July 1999	ERCL
TA1-W-08	August 2015	GEL	July 2003	GEL
TA2-NW1-325	March 2002	ERCL	June 1997	ERCL
TA2-W-01	September 2015	GEL	August 2003	GEL
TA2-W-19	September 2015	GEL	August 2003	GEL
TA2-W-26	September 2015	GEL	August 2003	GEL
TA2-W-27	September 2015	GEL	August 2003	GEL
TA2-W-28[a]	September 2015	GEL	July 2003	GEL
TJA-2	September 2015	GEL	July 2003	GEL
TJA-5	March 2002	ERCL	July 1999	ERCL
TJA-7	September 2015	GEL	October 2003	GEL
WYO-4	August 2014	GEL	August 2003	GEL
Regional Aquifer				
Eubank-1	March 2010	GEL	June 2001	GEL
PGS-2	August 2015	GEL	June 2001	GEL
TA1-W-01	August 2015	GEL	July 2003	GEL
TA1-W-02	August 2015	GEL	July 2003	GEL
TA1-W-04	August 2015	GEL	June 2001	GEL
TA1-W-05	September 2015	GEL	June 2001	GEL
TA2-NW1-595	August 2015	GEL	July 2003	GEL
TJA-3	September 2015	GEL	August 2003	GEL
TJA-4	September 2015	GEL	August 2003	GEL
TJA-6	August 2015	GEL	August 2003	GEL
WYO-3	August 2015	GEL	August 2003	GEL
TA2-W-24	March 2002	ERCL	June 1999	ERCL
TA2-W-25	March 2002	ERCL	April 2000	GEL

Notes:
[a] Well TA2-W-28 replaced well TA2-SW1-320, which was plugged and abandoned in December 2014.
ERCL = Environmental Restoration Chemistry Laboratory.
GEL = General Engineering Laboratories, Inc.
PGS = Parade Ground South (monitoring well designation).
TA1-W = Technical Area-I (Well) (monitoring well designation).
TA2-NW = Technical Area-II (Northwest) (monitoring well designation).
TA2-W = Technical Area-II (Well) (monitoring well designation).
TJA = Tijeras Arroyo (monitoring well designation).
WYO = Wyoming (monitoring well designation).

3.3.2.1 Piper Diagrams

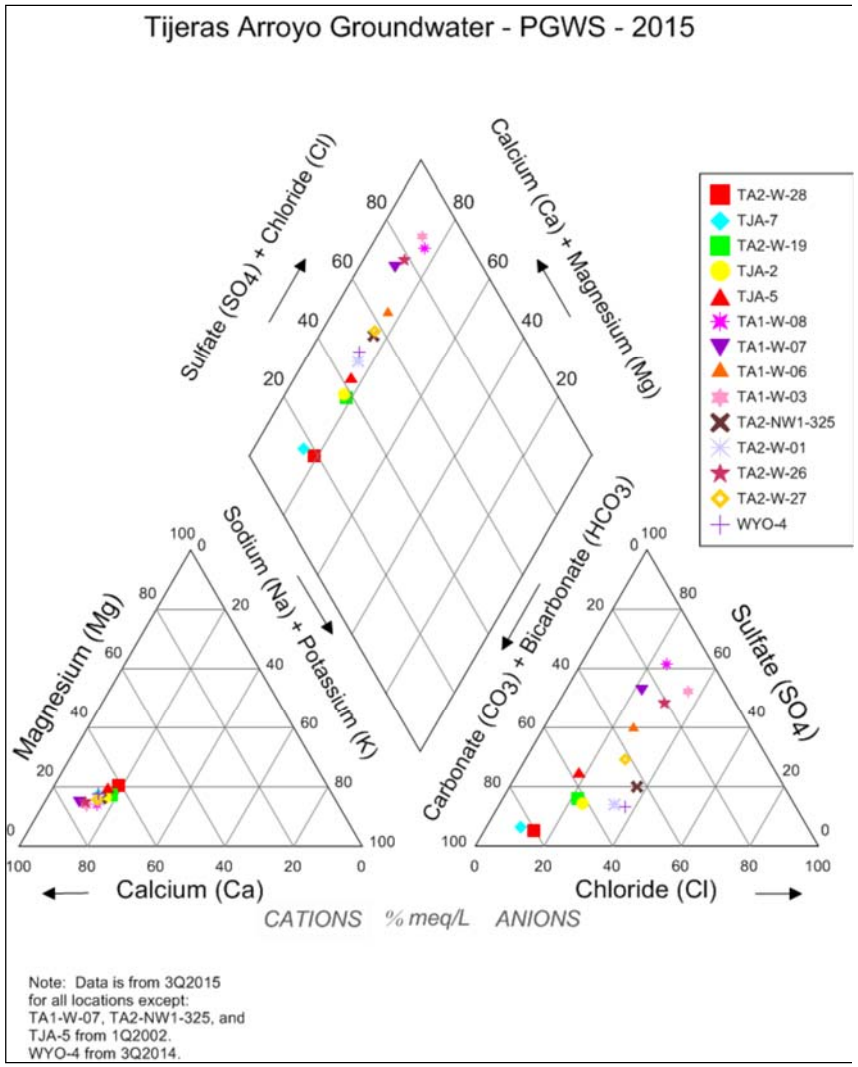
Figure 3-6 presents two Piper diagrams depicting the 2015 geochemical data for Perched Groundwater System wells and Regional Aquifer wells, respectively. For comparative purposes, Figure 3-7 presents the geochemical data for samples collected in 2003. Several interpretations can be gleaned from the Piper diagrams:

- The two water-bearing units have distinctive geochemical signatures.
- Water samples from the Perched Groundwater System exhibit a wide range of geochemistry that as a group does not correspond to a dominant type.
- Water samples from the Regional Aquifer exhibit a more consistent groundwater chemistry that is classified as a calcium-bicarbonate type. Calcium is the dominant cation and bicarbonate is the dominant anion. The clustering of data points on the plot shows a consistent range of geochemistry.
- Water from the Perched Groundwater System exhibits relatively higher concentrations of chloride and sulfate.
- Water from the Regional Aquifer exhibits higher bicarbonate concentrations.
- The variability in geochemistry from the Perched Groundwater System appears to indicate several sources of recharge.
- The tight grouping of the Regional Aquifer data points indicates that the wells are screened in the same hydrostratigraphic interval (groundwater from all wells is chemically similar; therefore, in direct hydraulic communication). The water appears to have a single source.

3.3.2.2 Stiff Diagrams

Figures 3-8 and 3-9 present a series of Stiff diagrams for the TAG AOC for monitoring wells sampled in 2015 and 2003, respectively. Figure 3-10 shows the Stiff diagrams were constructed using seven apexes for the major ions in a manner similar to the style employed by McQuillan (April 2016). In addition to the typical six apexes (chloride, carbonate plus bicarbonate, sulfate, sodium plus potassium, calcium, and magnesium), a seventh apex at the bottom of each Stiff diagram shows the NPN concentration. The milliequivalent per liter (meq/L) scales for the two water-bearing units differ because water in the Perched Groundwater System has greater ion concentrations than the Regional Aquifer.

As shown on Figures 3-8 and 3-9, the slightly elevated NPN concentrations in the Perched Groundwater System are evident on the plots for wells TA2-W-28, TJA-7, TA2-W-19, and TJA-2. These wells are grouped together on the right side of the diagram series.



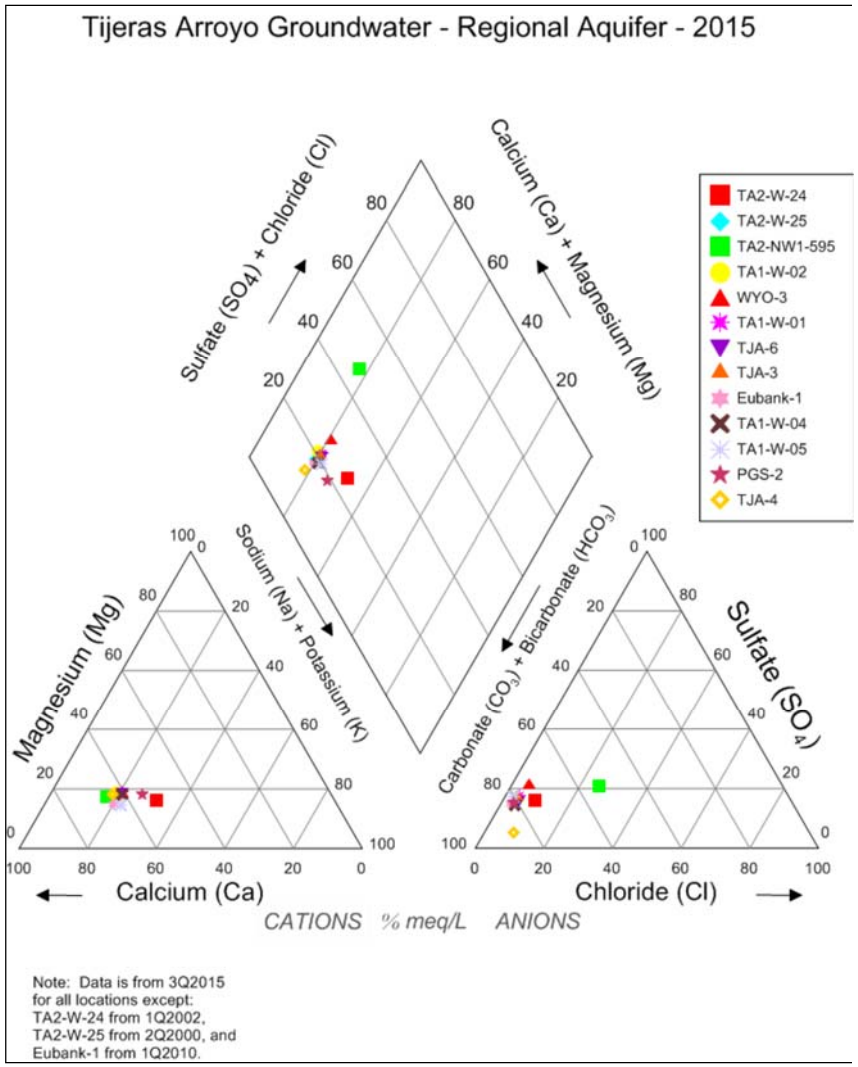
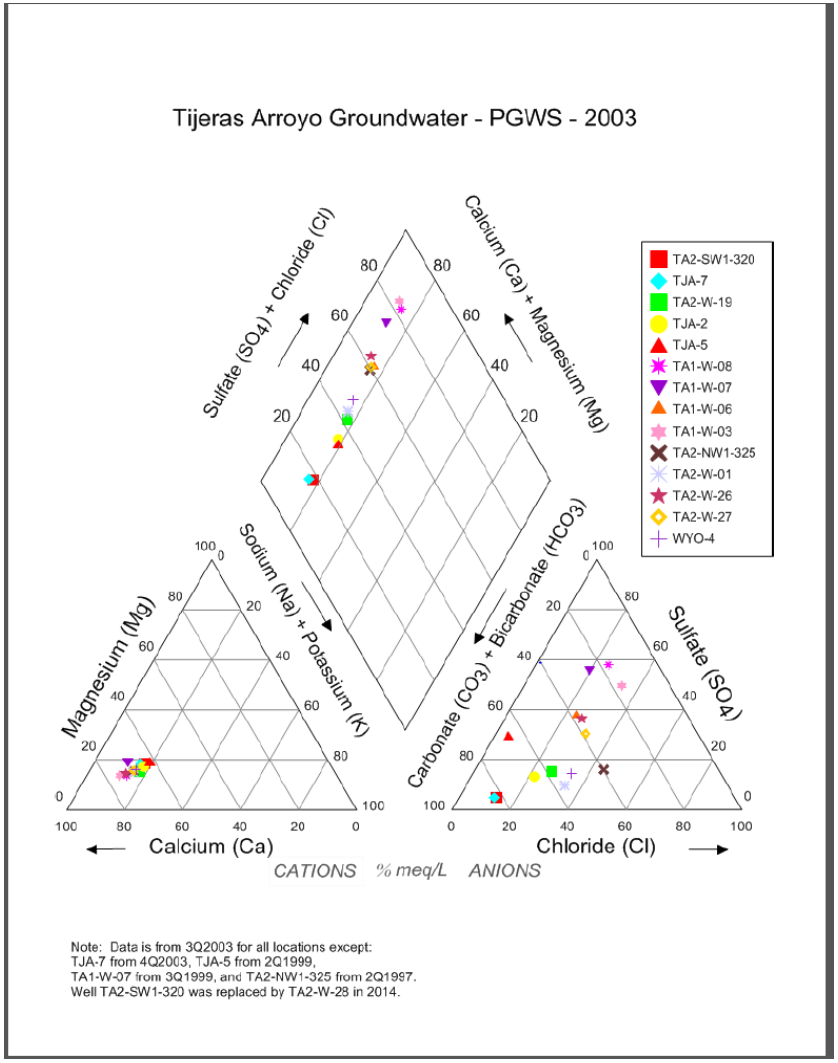


Figure 3-6
Piper Diagrams for Samples Collected in 2015 from
Monitoring Wells Screened in the Perched Groundwater System and the Regional Aquifer



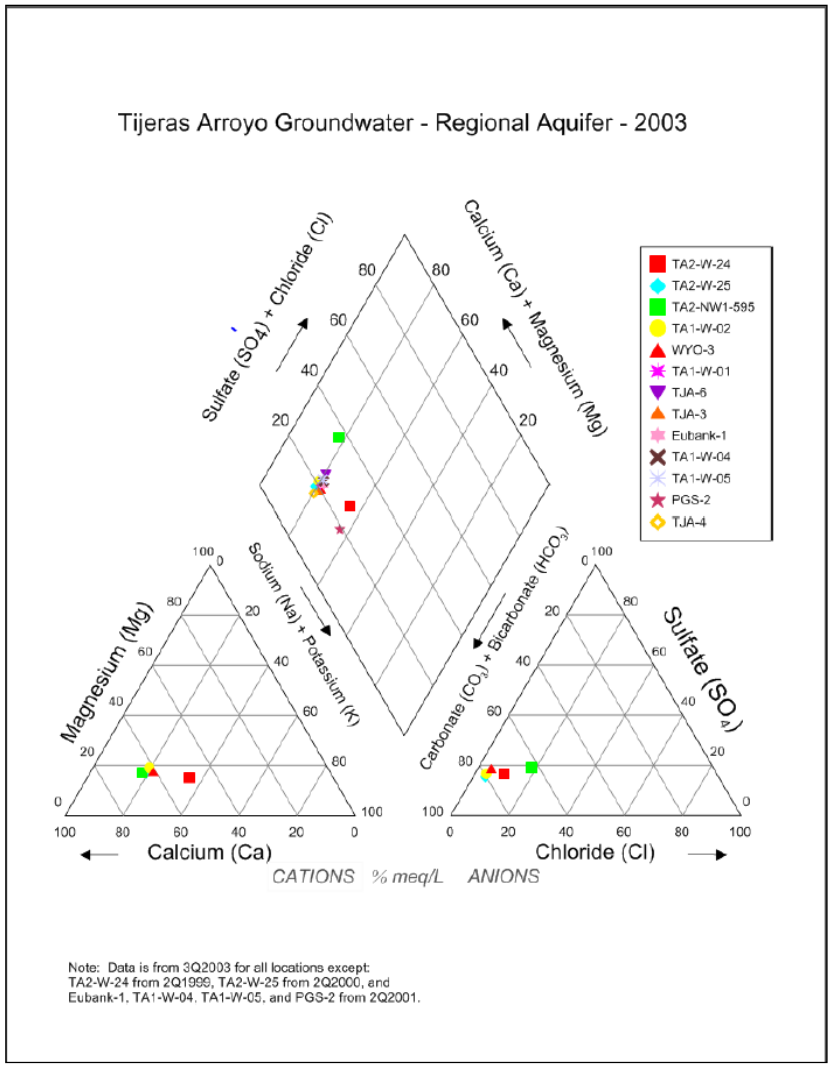
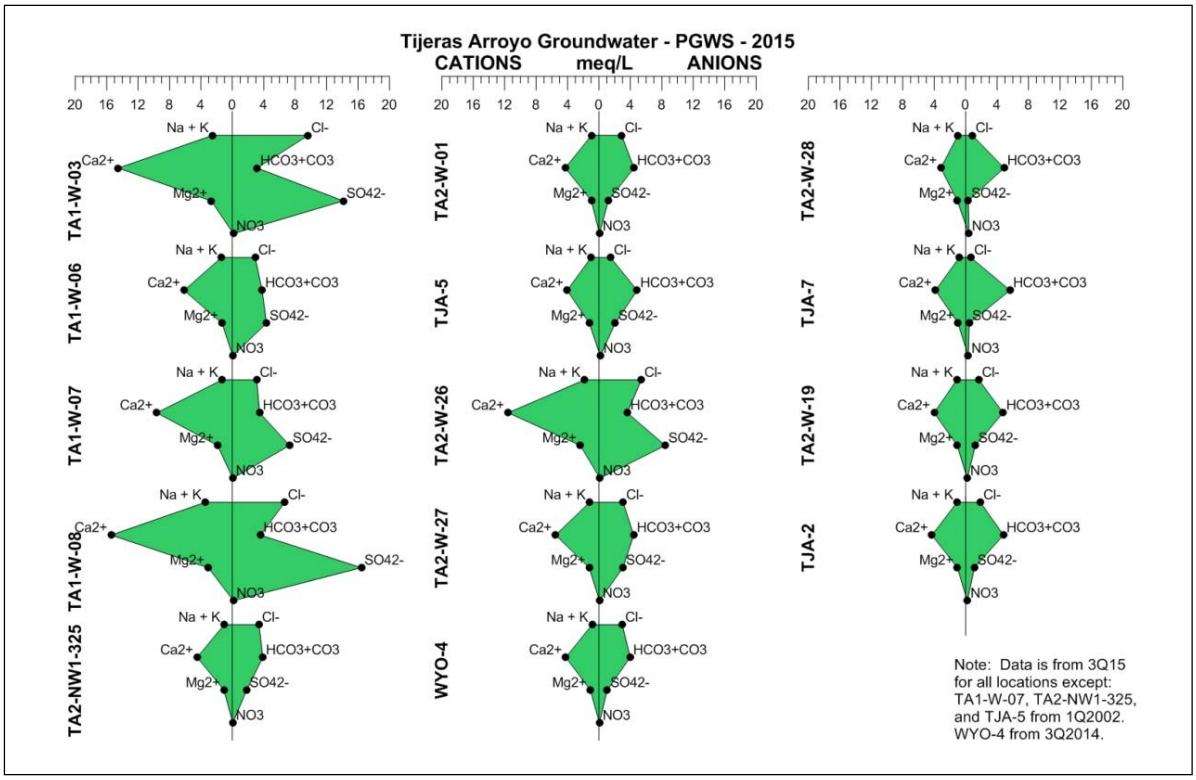


Figure 3-7
Piper Diagrams for Samples Collected in 2003 from Monitoring Wells Screened in the Perched Groundwater System and the Regional Aquifer



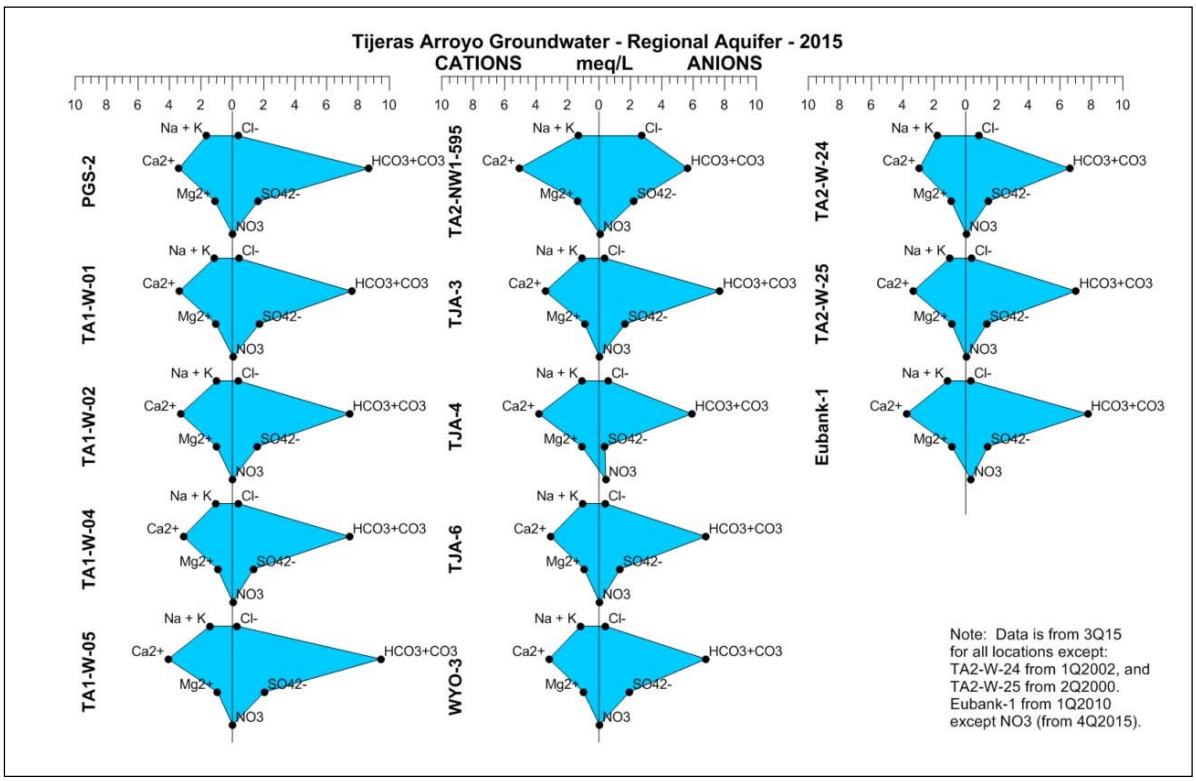
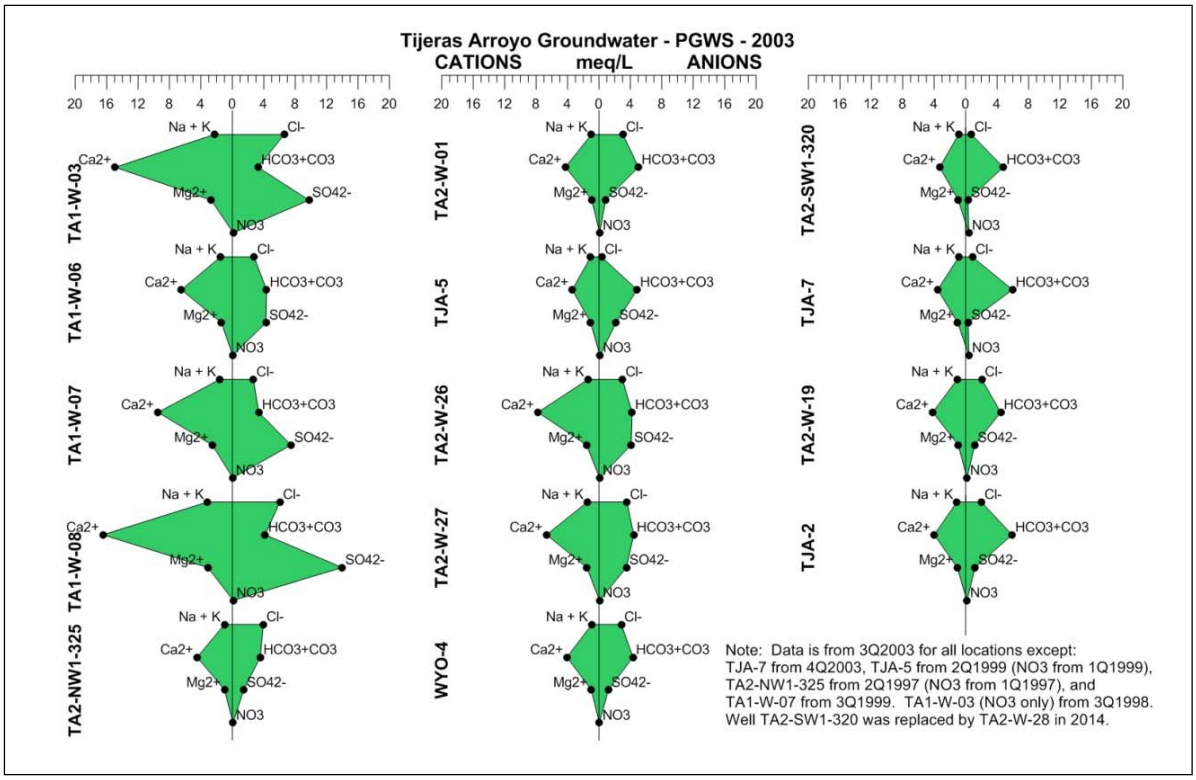


Figure 3-8
Stiff Diagrams for Samples Collected in 2015 from
Monitoring Wells Screened in the Perched Groundwater System and the Regional Aquifer



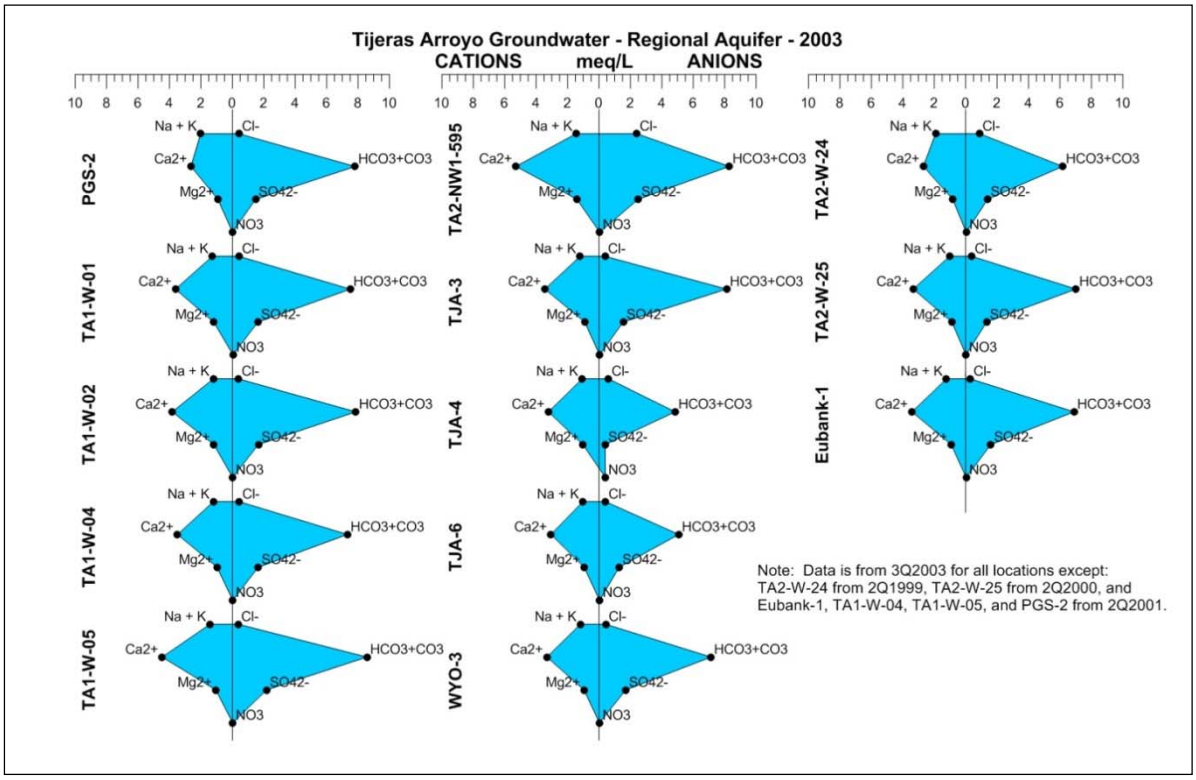


Figure 3-9
Stiff Diagrams for Samples Collected in 2003 from
Monitoring Wells Screened in the Perched Groundwater System and the Regional Aquifer

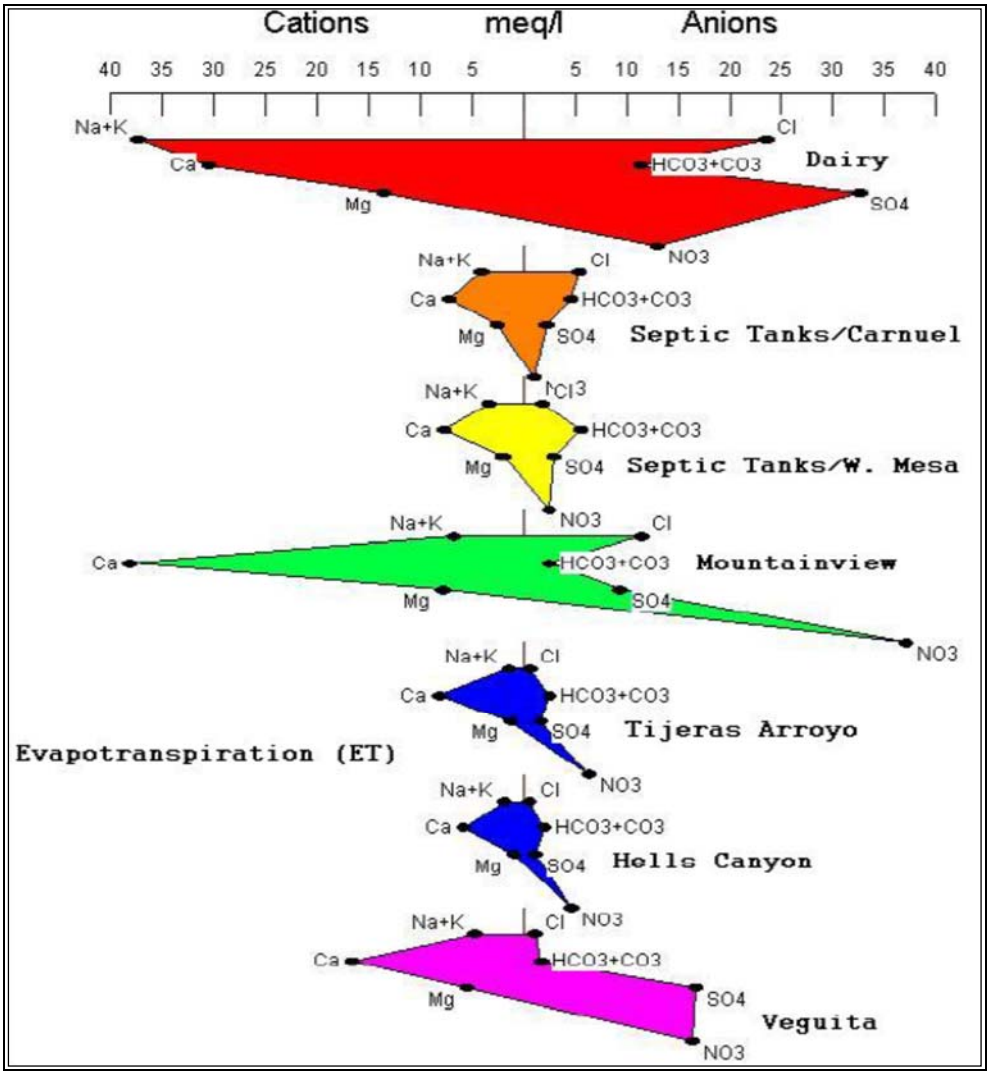


Figure 3-10
Examples of Stiff Diagrams for Nitrate-Contaminated Groundwater in New Mexico
(McQuillan April 2016)

Several interpretations can be gleaned from the Stiff diagrams:

- The two water-bearing units have distinctive geochemical signatures.
- Water in the Perched Groundwater System has greater ion concentrations than water in the Regional Aquifer.
- Water in the Perched Groundwater System is dominated by the calcium cation. No anion is consistently dominant. Chloride, bicarbonate, and sulfate concentrations are variable.
- Water from the Regional Aquifer wells exhibits a consistent geochemistry. Calcium and bicarbonate are consistently the dominant ions.
- The variable water quality from the Perched Groundwater System wells indicates several sources of recharge.
- The similarity of Stiff diagrams for water from the Regional Aquifer wells indicates that they are screened in the same hydrostratigraphic interval (groundwater from all of the wells is chemically similar; therefore, in direct hydraulic communication) and represent a single/broader source and/or more ancient water.
- Only 1 of 14 Perched Groundwater System monitoring wells appears to show a significant change in water quality between the 2003 and 2015 sampling events. Well TA2-W-26 had slightly higher concentrations of calcium, chloride, and sulfate in 2015. However, the overall conclusion is that the geochemistry in the Perched Groundwater System has been relatively stable since 2003.
- Three Regional Aquifer wells (TA2-NW1-595, TJA-4, and WYO-3) appear to have greater concentrations of carbonate plus bicarbonate in 2015. However, the overall conclusion is that the geochemistry in the Regional Aquifer has been relatively stable since 2003.
- Wells screened in the Perched Groundwater System mimic the pattern shown by McQuillan (April 2016) as representing groundwater affected by septic systems. Natural sources are possible too.
- Except for well TJA-4, none of the wells screened in the Regional Aquifer have elevated NPN concentrations that are useful for comparison with the McQuillan (April 2016) diagrams.
- Monitoring well TJA-4 (screened in the merging zone) is plotted on the Regional Aquifer diagrams to be consistent with interpretations presented in reports prepared by both DOE/SNL M&O contractor and KAFB. Water from well TJA-4 is similar to the pattern shown by McQuillan (April 2016) as representing groundwater affected by septic systems.

KAFB has also used the McQuillan (April 2016) format for interpreting groundwater geochemistry on base. Figure 3-11 shows the Stiff diagrams are relatively consistent across the northern part of KAFB and primarily show a septic influence on water quality.

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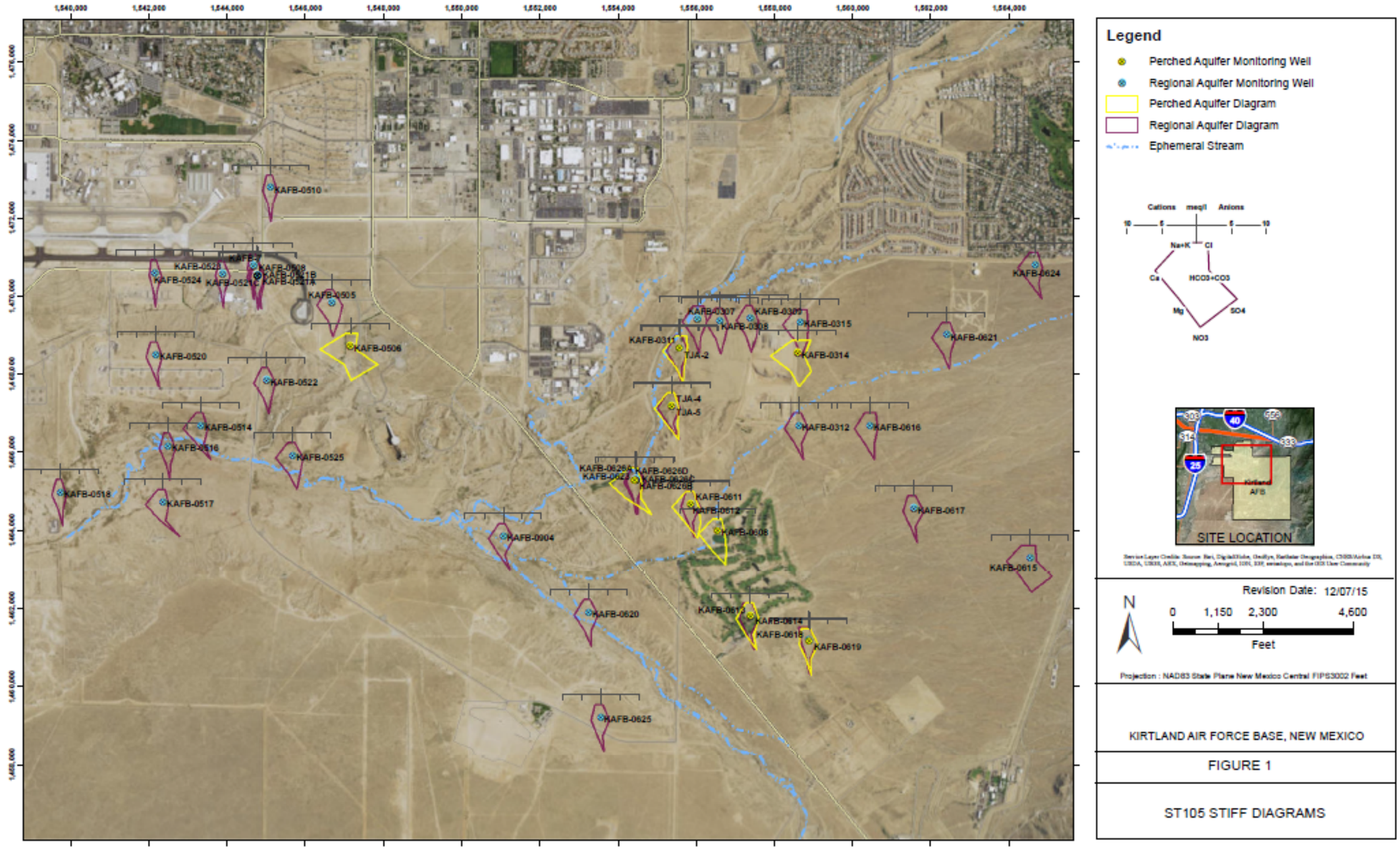


Figure 3-11
Stiff Diagrams for Groundwater Samples Collected by KAFB at Monitoring Wells Screened in the Perched Groundwater System and the Regional Aquifer (McQuillan [April 2016] from an unpublished KAFB report)

In 2003, KAFB collected groundwater samples for $\delta^{15}N$ analyses at two SNL/NM monitoring wells. The $\delta^{15}N$ results for wells TA2-SW1-320 and TJA-2 were 3.6 and 5.6, respectively, and are within the ranges typically associated with natural sources such as decaying vegetation or organic-nitrogen fertilizer (KAFB August 2005). However, the results are contradictory to known modern nitrate sources in the TAG AOC. The $\delta^{15}N$ results may indicate that consideration should be made concerning the triggering effect postulated by Brady and Domski (2001).

3.3.3 Geochemical Modeling

In a geochemical study conducted for the TAG AOC investigation, Brady and Domski (2001) presented several points for consideration.

- Geochemical evidence indicates that the Perched Groundwater System is distinct from the underlying Regional Aquifer. For example, while the waters in the Perched Groundwater System and the Regional Aquifer are reasonably dilute (ionic strengths were calculated to be approximately 0.01 Molar), water in the Perched Groundwater System contains higher concentrations of calcium, sulfate, chloride, and nitrate than the water in the Regional Aquifer.

- Mixing of the Perched Groundwater System with the Regional Aquifer is not evident from groundwater samples collected within the TAG AOC.

- Regional Aquifer water is of the calcium-bicarbonate type; calcium is the dominant cation while bicarbonate is the dominant anion. Dissolution of limestone is the primary reaction that accounts for the chemistry of such waters. Calcium-bicarbonate waters are common in the Middle Rio Grande Basin and acquire their major element character most notably in passing through the Madera Limestone exposed in the Sandia and Manzanita Mountains. Sulfate enters the Regional Aquifer through dissolution of gypsum along various flow paths such as Tijeras Arroyo.

- Geochemical modeling using the SNORM computer code (Bodine and Jones 1986) indicates that the chemical composition of the Perched Groundwater System is broadly similar to present-day Tijeras Canyon recharge suggesting that the natural component was substantial prior to the input from anthropogenic sources.

3.3.4 Geochemical Ratios

The geochemistry of the two water-bearing units has been studied using a plot of chloride concentrations versus NPN concentrations. Figure 3-12 depicts the analytical results from SNL/NM and KAFB wells. Monitoring wells screened in the Regional Aquifer plot in a narrow cluster indicative of low chloride and low NPN concentrations.

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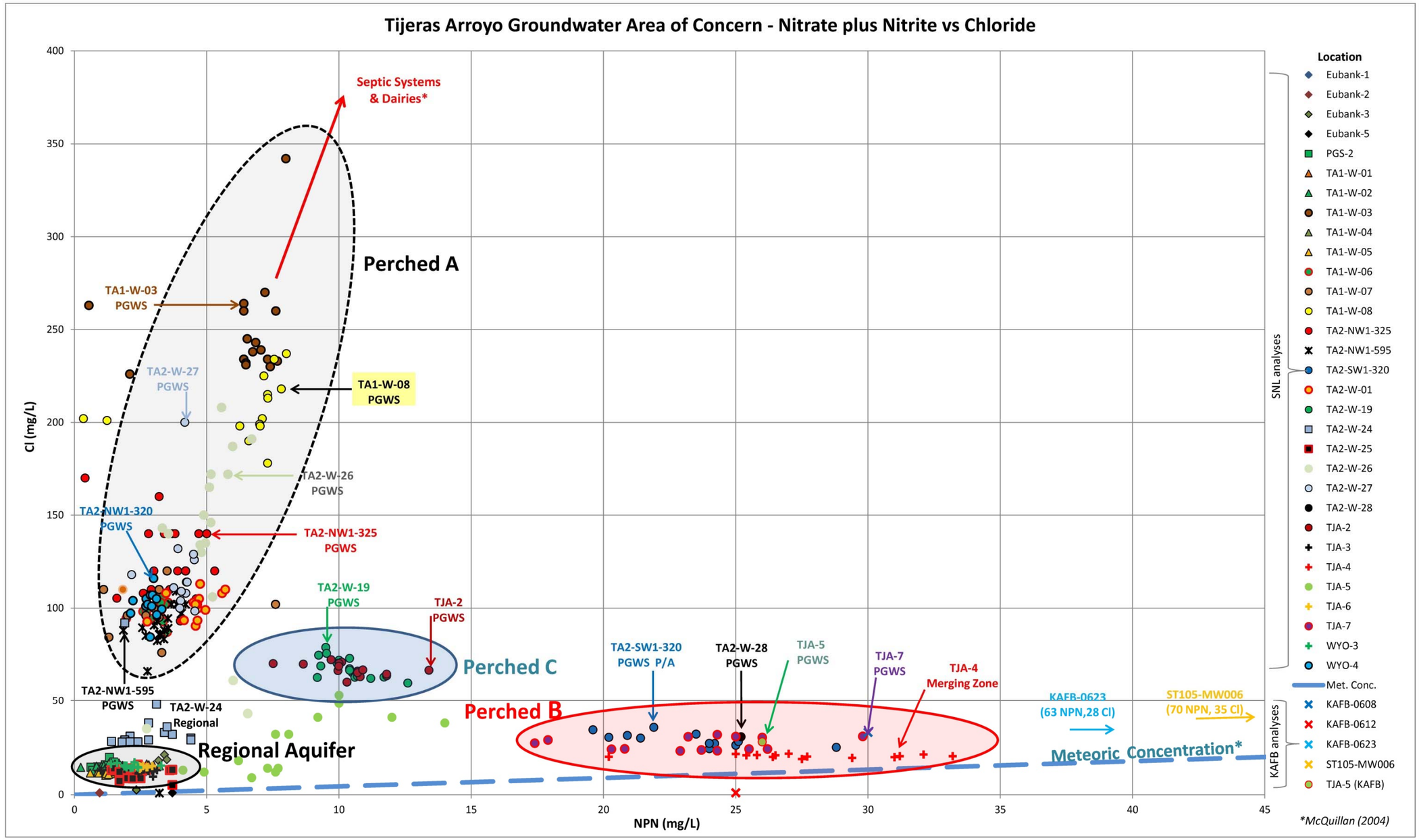


Figure 3-12
NPN versus Chloride Concentrations for Groundwater Samples Collected near the TAG AOC

The monitoring wells screened in the Perched Groundwater System fall into three compositional groupings. This suggests that the groups are the result of differing or multiple water sources. For purposes of discussion, these wells are identified as Perched A, Perched B, and Perched C. The characteristics of these three groups and other wells are:

- The majority of the TAG AOC monitoring wells correspond to Perched A with elevated chloride and relatively low NPN concentrations that are similar to naturally occurring background concentrations. Perched A wells are mostly located in the northern part of the TAG AOC.

- Perched B wells exhibit lower chloride concentrations and slightly higher NPN concentrations. Monitoring wells TA2-W-19 and TJA-2 in the south-central part of the TAG AOC exhibit this signature.

- Perched C wells exhibit intermediate values of NPN and chloride and are located in the southern part of the TAG AOC. Wells TJA-7 and TA2-W-28 (the replacement for TA2-SW1-320) exhibit these greater NPN concentrations.

- Well TJA-4 is screened at an intermediate depth (in the merging zone) and exhibits low chloride concentrations and high NPN concentrations.

- KAFB wells such as ST105-MW006 exhibit low chloride (less than 40 milligrams per liter [mg/L]), but high NPN concentrations (up to 70 mg/L).

3.3.5 Hydraulic Properties

The following subsections discuss hydraulic properties of the Perched Groundwater System and the Regional Aquifer for the TAG AOC and are summarized in Table 3-3.

3.3.5.1 Horizontal Hydraulic Conductivity

Slug tests were performed in late 2003 and early 2004 at 10 monitoring wells to determine the hydraulic conductivity of the water-bearing units in the TAG AOC (Skelly et al. May 2004). No aquifer pumping tests were conducted due to the low yield of the wells and waste management considerations. AquaTest™ Software developed by Waterloo Hydrogeologic, Inc. analyzed the slug-test data. This software employs analytical methods developed by Hvorslev (1951) and Bouwer and Rice (1976) to produce graphical solutions of hydraulic conductivity. Table 3-2 lists averaged solutions from both methods. Ten monitoring wells in the TAG AOC were evaluated.

Five monitoring wells screened in the Perched Groundwater System were evaluated: TA1-W-07, TA1-W-08, TA2-W-26, TJA-7, and WYO-4. The calculated hydraulic conductivities show a wide range of values from 0.0532 ft/day to 3.06 ft/day, with an average of 1.63 ft/day (Skelly et al. May 2004). This range covers nearly two orders of magnitude and likely results from anisotropy of the sediments.

Recent well-maintenance work at four monitoring wells provides some yield estimates for the Perched Groundwater System. Monitoring well TA1-W-03 was redeveloped in 2010 (Sanders and Skelly February 2010). Monitoring wells TA2-W-01 and TA2-W-19 were redeveloped in 2011 (Copland and Skelly September 2011). In 2014, well TA2-W-28 was

developed soon after installation (SNL/NM April 2015). After each well was swabbed and bailed to remove silt from the well screen, a submersible pump was used to develop the well. At each of the four wells, a pumping rate of approximately 1 gallon per minute (gpm) was sustainable for about 30 to 60 minutes. The wells could not sustain a rate of 1.5 gpm without encountering excessive drawdown and going dry.

Five Regional Aquifer monitoring wells were slug tested in 2003-2004 to obtain hydraulic conductivity values: TA1-W-01, TA1-W-05, TA2-W-25, TJA-3, and WYO-3. The calculated hydraulic conductivities for the Regional Aquifer ranged from 1.66 to 7.75 ft/day, with an average of 3.77 ft/day. This range is much narrower than observed in the Perched Groundwater System. In the TAG AOC, the Regional Aquifer generally has slightly higher hydraulically conductivity values than the Perched Groundwater System. However, the Regional Aquifer has much higher hydraulic conductivity to the west of the TAG AOC.

3.3.5.2 Vertical Hydraulic Conductivity

The commonly accepted ratio of vertical to horizontal hydraulic conductivity of a layered heterogeneous sequence is approximately 1:100 (Freeze and Cherry 1979). The vertical hydraulic conductivity of the unconsolidated SFG sediments was estimated to be one-hundredth the horizontal hydraulic conductivity. The estimated vertical hydraulic conductivities for both TAG AOC water-bearing units were derived using their respective average horizontal hydraulic conductivities. For the Perched Groundwater System, the range of vertical hydraulic conductivity is 0.0163 to 0.163 ft/day. For the Regional Aquifer, the range of vertical hydraulic conductivity is estimated to range from 0.0377 to 0.377 ft/day.

Monitoring well TA2-W-28 was installed as a replacement for monitoring well TA2-SW1-320 in December 2014. The borehole was spudded in the alluvial fan lithofacies. Interfingering layers consisting mostly of poorly sorted, silty sands and poorly sorted, gravelly sands were encountered to 320 ft bgs. Starting at 320 ft bgs, the drilling became increasingly more difficult in a sequence of medium-plasticity clay. Slightly clayey sand was encountered at 325 ft bgs. The cuttings consisted of slightly clayey sand at 330 ft bgs. A clay horizon was encountered at 336 ft bgs. Based upon the high number of casing-hammer blows needed to advance the drive casing, this clay exhibits the geotechnical definition of dense clay. This dense clay was encountered to the borehole total depth of 338 ft bgs. The screen for monitoring well TA2-W-28 was set at 310.45 to 330.45 ft bgs. Based upon the groundwater level that was measured after well development, it is anticipated that the majority of groundwater in the foreseeable future will be derived from the poorly sorted, silty sand interval present from 317 to 320 ft bgs. This interval consists of a visually estimated 70 percent very fine to medium sand, 10 percent coarse sand, and 20 percent silt/clay. Clay below this silty sand interval at 328 ft bgs likely serves as the Perching Horizon. This is especially true for the dense clay encountered from 336 to 338 ft bgs.

3.3.5.3 Horizontal Hydraulic Gradients

As noted earlier in Section 3.2, horizontal hydraulic gradients were estimated using the October 2015 potentiometric surface maps. The horizontal gradient of the Perched Groundwater System across the TAG AOC varies from 0.004 to 0.0125 ft/ft; the average gradient is approximately 0.01 ft/ft.

The horizontal gradient of the Regional Aquifer across the TAG AOC varies from 0.006 to 0.0125 ft/ft; the average gradient is approximately 0.01 ft/ft. The horizontal gradient is steeper to the east of the TAG AOC at 0.03 to 0.045 ft/ft. To the west of the TAG AOC, the gradient is nearly flat in the more permeable sediments.

3.3.5.4 Vertical Hydraulic Gradients

The vertical gradient in the Perched Groundwater System is likely downward. A specific value could not be determined because this water-bearing unit consists of a thin zone of saturation and no well clusters were installed.

Because Regional Aquifer wells in the TAG AOC are completed within only the upper part of the aquifer, no well clusters were installed in this water-bearing unit. However, flow within the Regional Aquifer is most likely downward in the TAG AOC in a manner similar to the hydrogeologic setting at TA-V (SNL/NM September 2015). At TA-V, the vertical gradient measured at three well clusters in the Regional Aquifer was downward and ranged from 0.04 to 0.12 ft/ft in 2014. TA-V is located approximately 2.1 miles south of the TAG AOC.

3.3.5.5 Effective Porosity

An effective porosity of 0.25 for the sediments in the TAG AOC is based upon studies conducted at TA-V (SNL/NM September 2015).

3.3.5.6 Groundwater Velocities

The range of horizontal groundwater flow velocities for the TAG AOC was estimated using the Darcy flow equation, as follows:

$$V = K\,(dh/dx)/n_e$$

where:

V = linear, or pore, velocity (ft/day)
K = hydraulic conductivity (ft/day)
dh/dx = horizontal hydraulic gradient (unitless)
n_e = effective porosity

The velocity estimates for the Perched Groundwater System were calculated using a horizontal hydraulic gradient of 0.01 ft/ft (an inferred average from the potentiometric surface), an effective porosity of 0.25, and the range of horizontal hydraulic conductivities (0.0532 to 3.06 ft/day) from slug tests. Table 3-5 shows the calculated horizontal groundwater flow velocities for the Perched Groundwater System range from 0.78 to 44.68 ft/yr. The average is approximately 24 ft/yr.

Table 3-5
Estimates of Groundwater Horizontal Velocities in the TAG AOC

Hydraulic Conductivity (ft/day)	Horizontal Gradient (ft/ft)	Effective Porosity	Velocity (ft/day)	Velocity (ft/yr)	Velocity Note
Perched Groundwater System					
0.0532	0.01	0.25	0.002	0.78	lowest
3.06	0.01	0.25	0.122	44.68	highest
1.63	0.01	0.25	0.065	23.80	average of five wells
Regional Aquifer					
1.66	0.01	0.25	0.066	24.24	lowest
7.75	0.01	0.25	0.310	113.15	highest
3.77	0.01	0.25	0.151	55.04	average of five wells

Notes:
Hydraulic conductivity is the mean value for multiple slug tests per well (SNL/NM November 2005).
Assumed effective porosity.
Horizontal groundwater gradient, average across the TAG AOC.
AOC = Area of Concern.
ft/day = Feet per day.
ft/ft = Feet per foot.
ft/yr = Feet per year.
TAG = Tijeras Arroyo Groundwater.
SNL/NM = Sandia National Laboratories, New Mexico.

In June 1999, a colloidal borescope was used to determine groundwater flow directions and velocities in 18 SNL/NM and KAFB wells in the Perched Groundwater System (AquaVISION July 1999). The colloidal borescope was placed in each well screen and directly imaged colloids (particles generally 1 to 10 microns in diameter) with a computer-controlled video system to infer real-time local groundwater flow direction and velocity. Near the TAG AOC, the mean of the groundwater vectors for the Perched Groundwater System was southward at 0.043 cm/s. Using the AquaVISION "order-of-magnitude" rule, the groundwater velocity was inferred to be approximately 0.004 cm/s (equivalent to 11 ft/day). However, the velocity measurements inferred from the colloidal borescope represent those in preferential pathways within the screened intervals, and can be expected to be significantly higher than the average flow velocity of the Perched Groundwater System. The maximum value reported per well often corresponds to just a few slots in the screen.

The velocity estimates for the Regional Aquifer were calculated using a horizontal hydraulic gradient of 0.01 ft/ft (an inferred average from the potentiometric surface), an assumed effective porosity of 0.25, and the range of horizontal hydraulic conductivities (1.66 to 7.75 ft/day). Table 3-5 shows the calculated horizontal groundwater flow velocities for the Regional Aquifer range from 24.24 to 113.15 ft/yr. The average is approximately 55 ft/yr.

3.4 Groundwater Recharge and Discharge

The subsections below discuss groundwater inflow and outflow from the Perched Groundwater System.

3.4.1 Wastewater Disposal

Historical releases of wastewater are associated with several SWMUs. Section 4.3 discuss these release sites.

3.4.2 Precipitation

The long-term average precipitation is 9.45 inches per year (30-year norm based on 1981-2010 data) at the Albuquerque International Sunport (SNL/NM September 2015). Thundershowers during July through September produce much of this precipitation. No measurable correlation is observed between precipitation and groundwater elevations in the TAG AOC monitoring wells. Several field studies conducted in 1995 as part of the Tijeras Arroyo Infiltration Experiment and the natural recharge rates were estimated to range from 0.04 to 0.24 inches per year (GRAM and Lettis December 1995). Because the rate of evapotranspiration (95 to 99 percent) for most areas on KAFB greatly exceeds precipitation, this source of recharge is considered minimal as a mechanism for transporting contaminants or recharging groundwater.

3.4.3 Infiltration and Recharge

Tijeras Arroyo trends across the southeastern-most corner of the TAG AOC and directs sporadic, brief, ephemeral stream flows from mountainous drainages in the east towards the Rio Grande. In response to heavy rains a few times per year, the width of flowing water in the active channel can be 10 to 20 ft. These flows are typically of brief duration. Much of the potential recharge returns to the atmosphere through evapotranspiration. Some water that infiltrates the arroyo channel may move past the root zone and provide some local recharge. This type of local recharge does not produce an observable effect upon groundwater elevations. Based upon infiltration tests conducted on the northern rim (escarpment) of Tijeras Arroyo (SNL/NM March 1996b), SNL/NM concluded that 95 to 99 percent of the annual rainfall is lost to evapotranspiration (SNL/NM February 1998).

3.4.4 Local Discharge and Production Wells

No examples of local discharge, such as production wells or springs, are located within the TAG AOC boundary. However, KAFB operates several production wells near the TAG AOC. In addition to the KAFB production wells, Figure 2-5 depicts the locations of the VA and ABCWUA operated production wells near the TAG AOC.

As mentioned in Section 2.5.4, KAFB operated five production wells (KAFB-3, KAFB-4, KAFB-14, KAFB-15, and KAFB-20) for potable water-supply purposes in 2016 (SNL/NM June 2017). Typically, the wells operated once or twice per week depending on seasonal demand. Wells KAFB-4 and KAFB-20 are located nearest the TAG AOC and extracted 171 and 263 million gallons in 2016, respectively. Farther afield to the west, wells KAFB-3 and KAFB-14 extracted 110 and 192 million gallons in 2016, respectively. Well KAFB-15 returned to service in September 2016 and pumped 1 million gallons. To the north of the TAG AOC, the entire Ridgecrest well field (five wells) pumped 177 million gallons in the first six months of 2016 (New Mexico Office of the State Engineer [NMOSE] September 2017).

3.4.5 Local Recharge

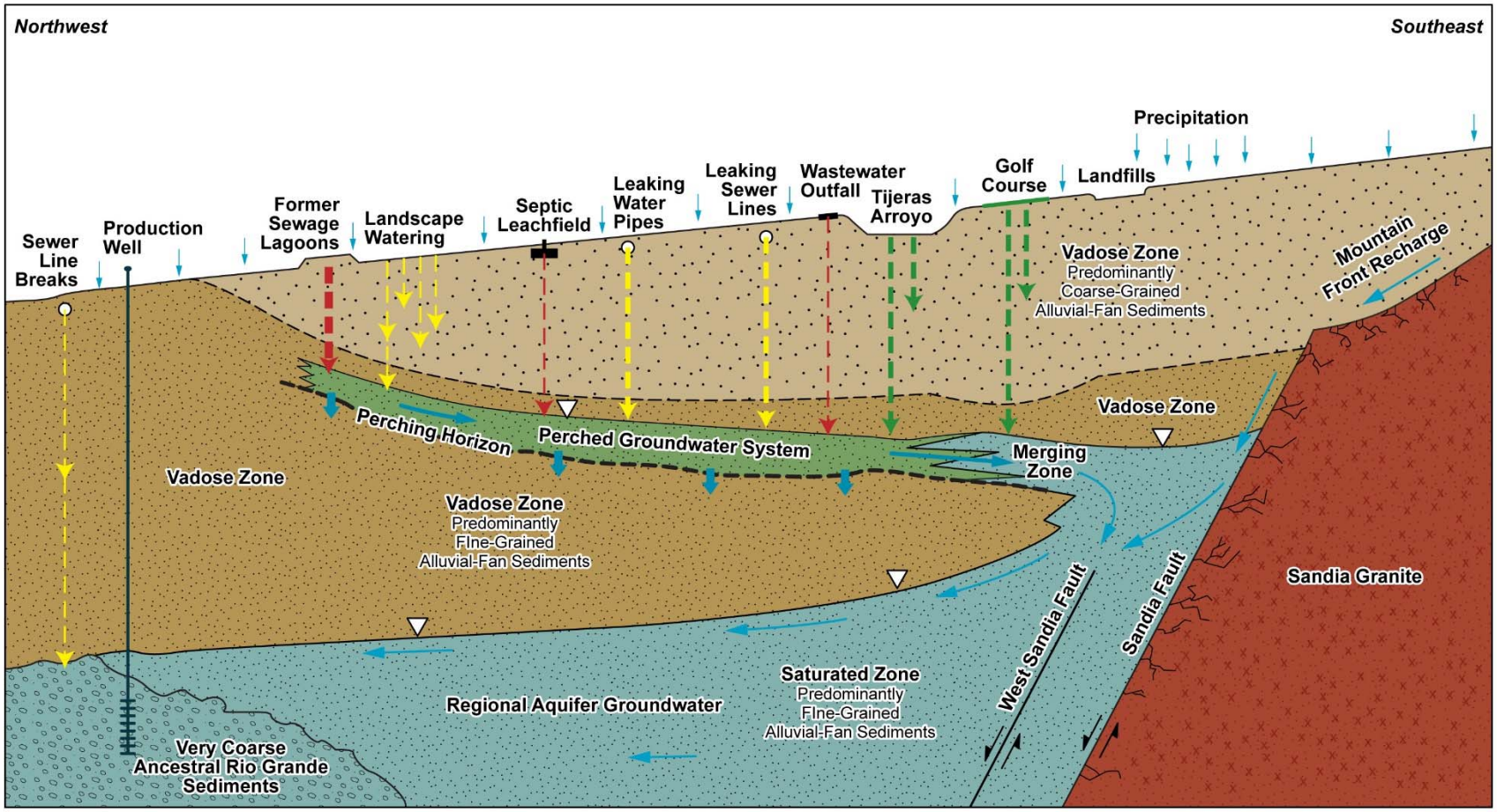
Figure 3-13 shows the variety of recharge sources (active and inactive) that are located near the TAG AOC. These recharge sources likely affected the Perched Groundwater System:

- Landscape watering of grassy areas such as the Parade Ground north of TA-I,
- A buried ancestral Tijeras Arroyo channel with relatively older groundwater, flowing from Tijeras Canyon,
- Ongoing surface and base flow along Tijeras Arroyo,
- Leaking water lines and sewer lines,
- Wastewater outfall (now inactive),
- Septic systems (now inactive),
- The KAFB former Sewage Lagoons (now inactive), and
- The Tijeras Arroyo Golf Course operated by KAFB.

3.5 Water Level Fluctuations

The hydrographs on Figures 3-14 through 3-17 show the historical trends of groundwater elevations in the TAG AOC. No seasonality, such as a response to the summer monsoon season, is apparent. However, some wells (TA1-W-05 and PGS-2) show a cycle related to the pumping of ABCWUA production wells.

Figure 3-18 presents a hydrologic cross-section using the 2015 groundwater elevation data. The cross-section approximates a northwest-to-southeast–trending line of projection across the TAG AOC. Depicted on the cross-section is the ground surface, location of the wells, depth of the screened intervals, the Perching Horizon, and groundwater elevations. Several monitoring wells have been projected into the line of section. The cross-section clearly demonstrates that the Perched Groundwater System potentiometric surface dips to the southeast while the Regional Aquifer potentiometric surface dips to the northwest. The merging zone between the two water-bearing units is evident at the southeastern end of the cross-section near the golf course.



Recharge Schematic for TAG Area Showing Principal Recharge and Discharge Features, View to Northeast, Not to Scale. Width of recharge arrow signifies relative volume. Color signifies the duration: green arrow denotes ongoing recharge, yellow arrow denotes a reduced rate of discharge, red arrow signifies that recharge was eliminated. (Precipitation and groundwater arrows are not scaled.)

Figure 3-13
Recharge Features near the TAG AOC

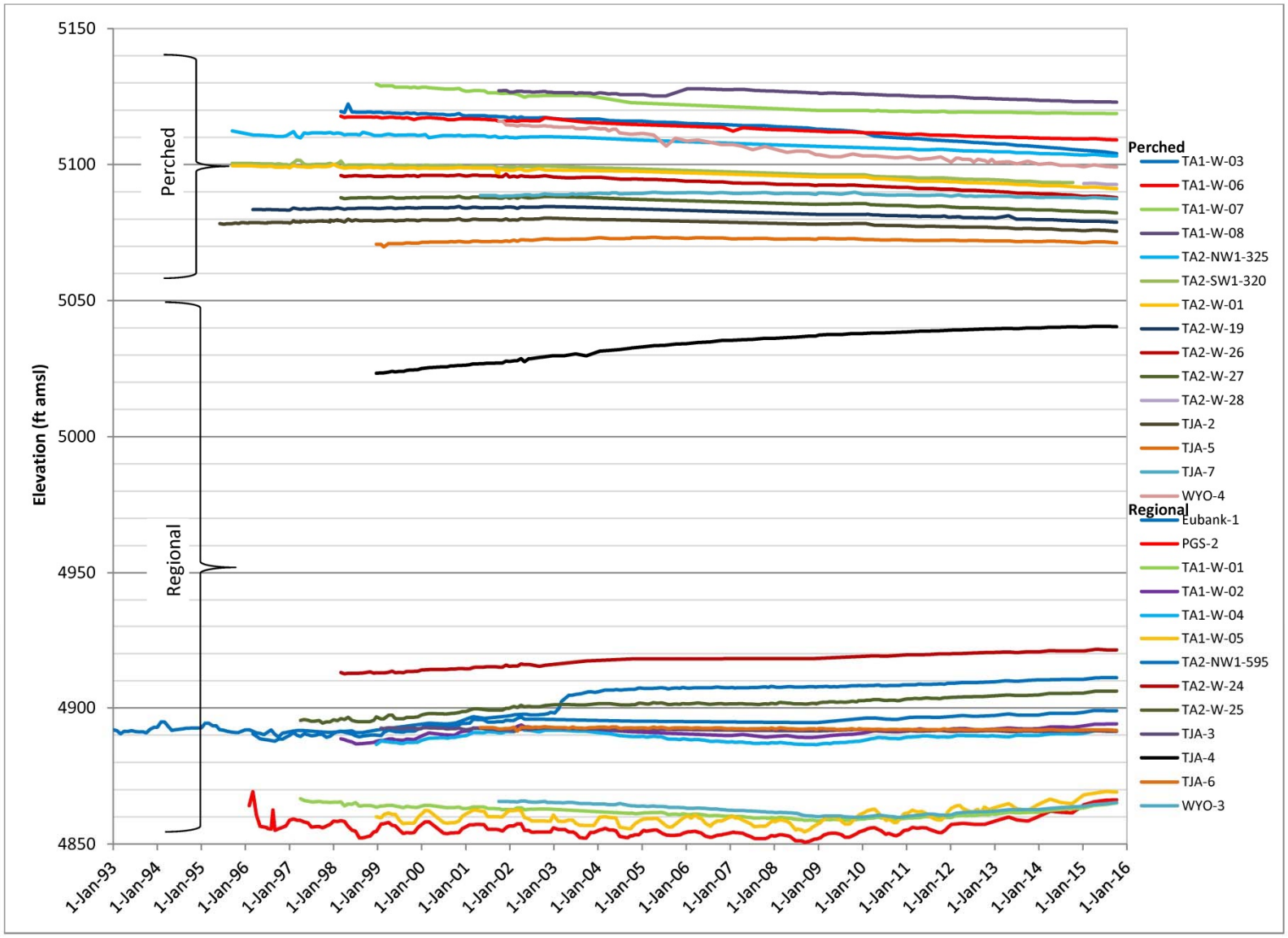


Figure 3-14
Hydrographs for All Monitoring Wells Completed in the TAG AOC

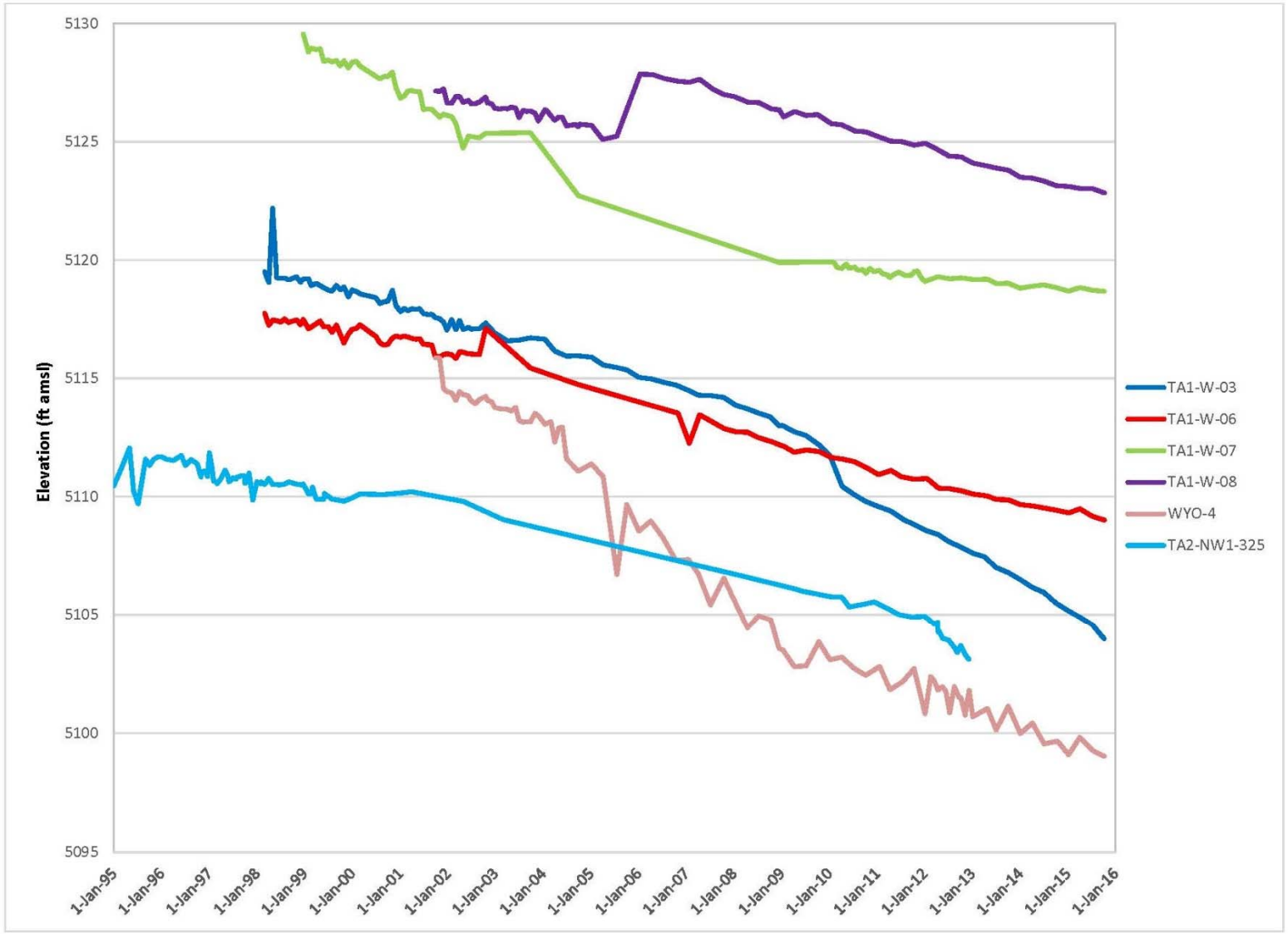


Figure 3-15
Hydrographs for Six Monitoring Wells Completed in the Perched Groundwater at the TAG AOC

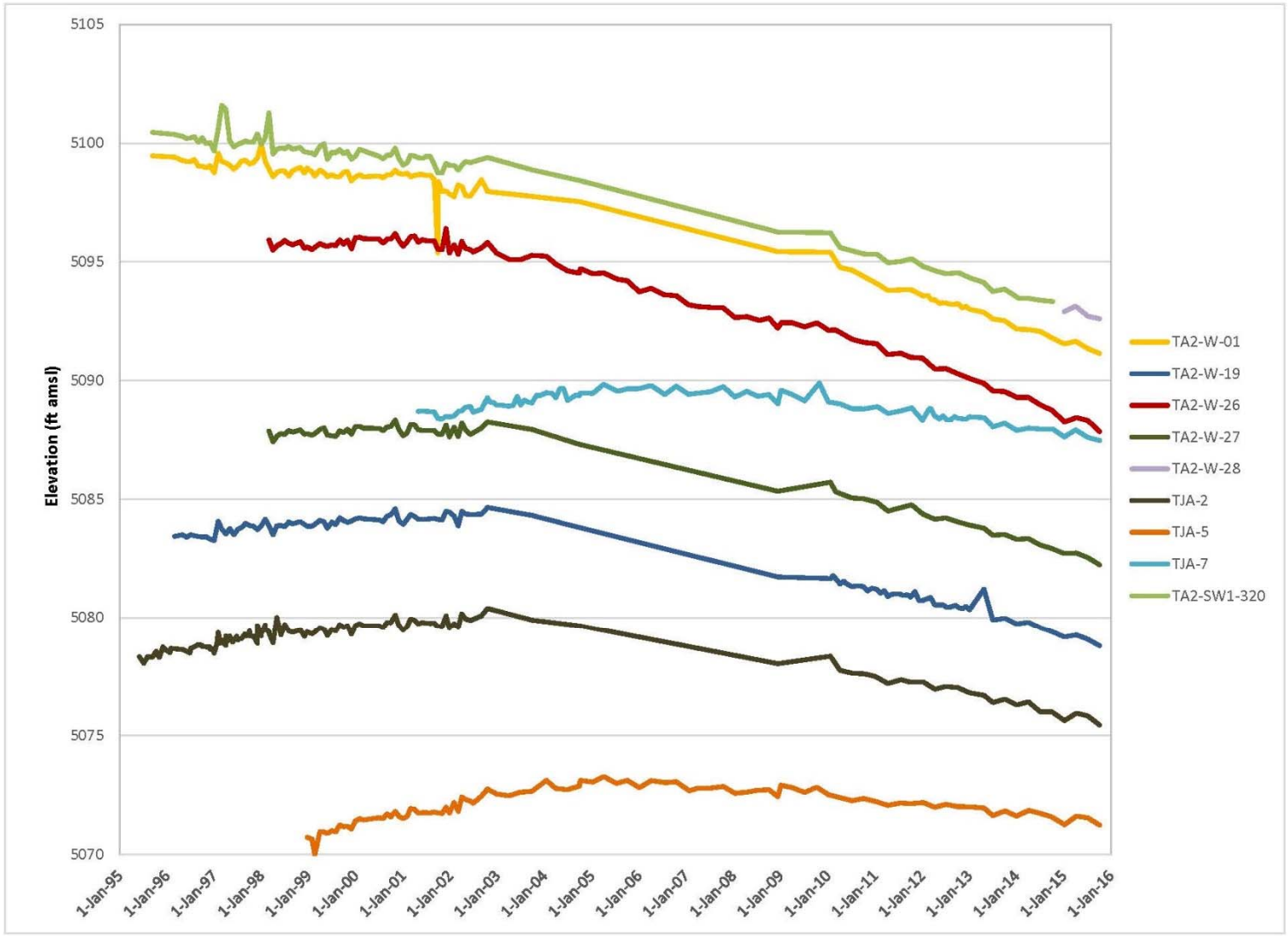


Figure 3-16
Hydrographs for Nine Monitoring Wells Completed in the Perched Groundwater System at the TAG AOC

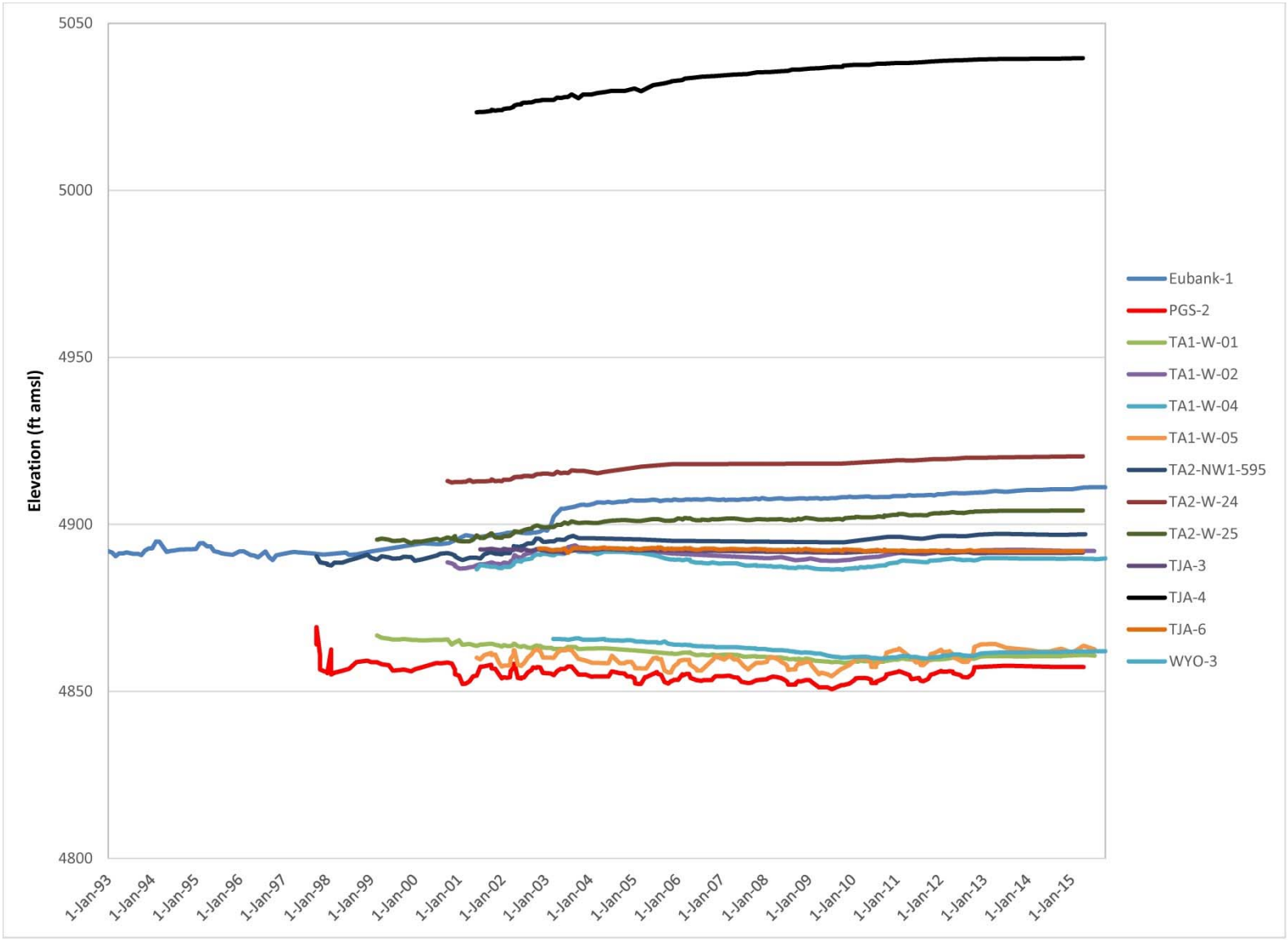


Figure 3-17
Hydrographs for Monitoring Wells Completed in the Regional Aquifer at the TAG AOC

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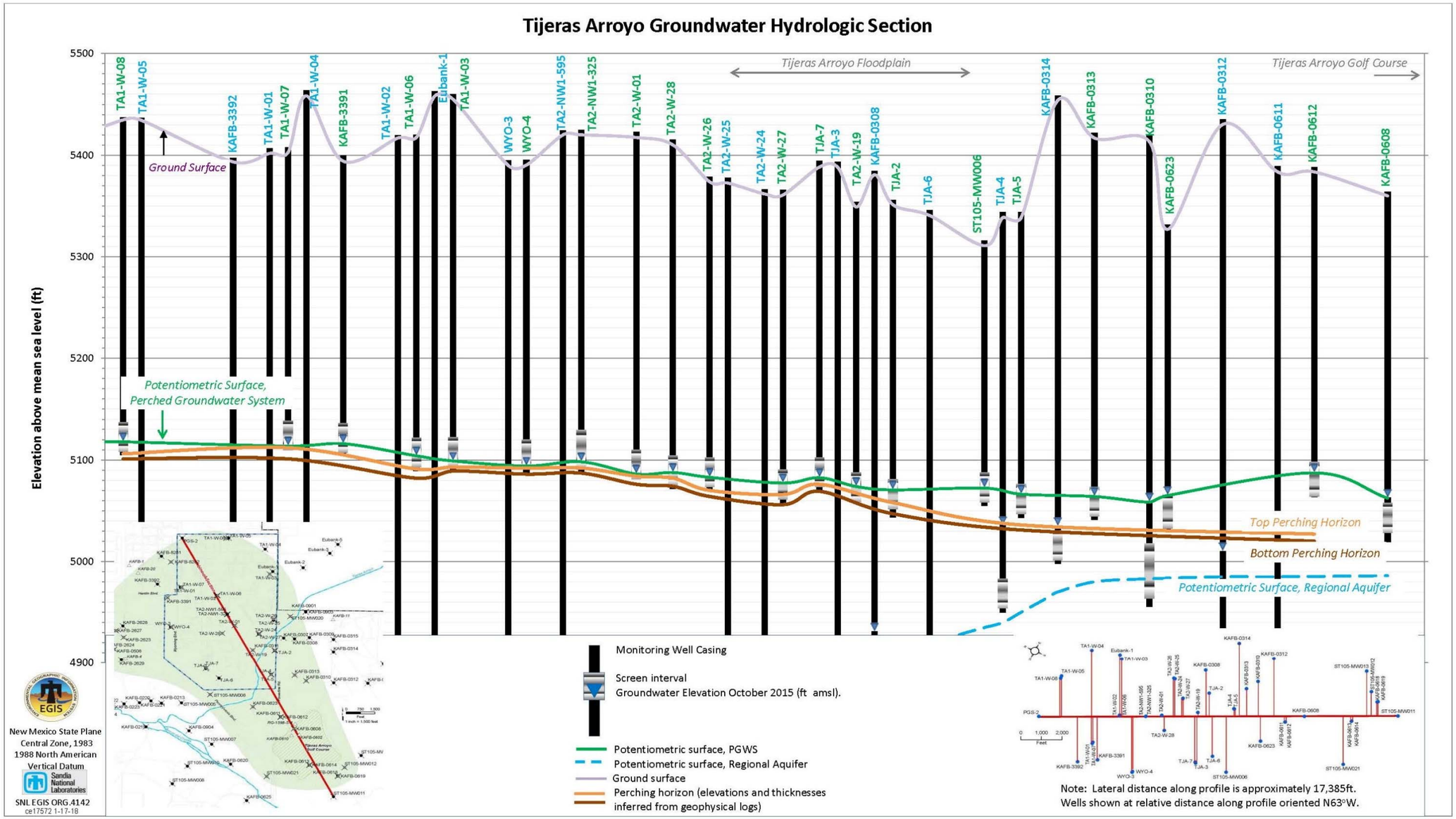


Figure 3-18
Hydrologic Section Depicting the Merging Zone between the Perched Groundwater System and the Regional Aquifer using October 2015 Data

Table 3-6 lists the average annual change in groundwater elevations of the Perched Groundwater System for the five-year period from October 2010 to October 2015. Groundwater elevations declined in 14 monitoring wells. The average decline was 0.48 ft within a range of approximately 0.02 to 1.17 ft. Figure 3-19 shows the spatial distribution of annual groundwater elevation change in Perched Groundwater System monitoring wells. Figure 3-20 depicts the Regional Aquifer wells.

Table 3-6 also lists an estimate of when water levels will decline to the bottom of the Perched Groundwater System well screens as extrapolated from this five-year rate of decline. Except for well TJA-5, the range of useful years (starting in 2015) for measuring groundwater elevations is estimated to be approximately 5 to 44 years for wells screened in the Perched Groundwater System. Figure 3-21 shows that monitoring wells located near the center of the TAG AOC have the shortest expected remaining lifespans.

Table 3-7 lists the average annual change in groundwater elevations of monitoring wells screened in the Regional Aquifer for the most recent five-year period (October 2010 to October 2015). Figure 3-20 shows these data. Groundwater elevations increased in 11 of the 13 Regional Aquifer wells. The greatest increases were in the northern portion of the TAG AOC. Monitoring well PGS-2 had the greatest average annual increase at 2.65 ft. Wells TJA-3 and TJA-6, located near the edge of the arroyo, have shown slight decreases (less than 0.1 ft). The average annual rise in groundwater elevations for the 13 wells screened in the Regional Aquifer was 0.85 ft.

Groundwater elevations for Regional Aquifer wells in the northern part of the KAFB show an increasing trend in groundwater elevations since 2009. This is presumably in response to the ABCWUA transitioning to the use of more surface water and decreasing dependence on production wells in the Ridgecrest Well Field north of KAFB as shown in Figure 2-5.

Table 3-6
Annual Changes in Groundwater Elevations and the Estimated Time When Groundwater Elevations Decline Below Perched Groundwater System Well Screens at the TAG AOC

Monitoring Well	October 2010 Groundwater Elevation (ft amsl)	October 2015 Groundwater Elevation (ft amsl)	Annual Change for Five-Year Period	Estimated Number of Years Before Water Level Declines to Bottom of Screen	Estimated Year When Water Level Declines to Bottom of Screen
TA1-W-03	5109.80	5103.96	-1.17	5.2	2020
TA1-W-06	5111.23	5109.01	-0.44	26.5	2041
TA1-W-07	5119.44	5118.68	-0.15	29.4	2044
TA1-W-08	5125.42	5122.84	-0.52	19.7	2035
TA2-NW1-325	5105.77	5103.10	-0.53	15.2	2030
TA2-W-01	5094.07	5091.14	-0.59	9.8	2025
TA2-W-19	5081.31	5078.79	-0.50	31.1	2046
TA2-W-26	5091.61	5087.85	-0.75	13.4	2028
TA2-W-27	5085.02	5082.23	-0.56	29.4	2044
TA2-W-28 [a]	5095.33	5092.60	-0.06	28.6	2044
TJA-2	5077.61	5075.45	-0.43	44.3	2059
TJA-5	5071.36	5071.24	-0.02	n.a. [b]	n.a.
TJA-7	5088.80	5087.47	-0.27	36.0	2051
WYO-4	5102.43	5099.03	-0.68	5.6	2021

Notes:
[a] Well TA2-W-28 is a replacement well for TA2-SW1-320. The five-year average was calculated using the October 2010 water elevation for well TA2-SW1-320, and the October 2015 water elevation for well TA2-W-28.
[b] The numerical estimate for TJA-5 was calculated to be 823 years. For all practical purposes, the well is not expected to go dry.
amsl = Above mean sea level.
AOC = Area of Concern.
ft = Foot (feet).
n.a. = Not applicable.
PGS = Parade Ground South (monitoring well designation).
TA1-W = Technical Area-I (Well) (monitoring well designation).
TA2-NW = Technical Area-II (Northwest) (monitoring well designation).
TA2-SW = Technical Area-II (Southwest) (monitoring well designation).
TA2-W = Technical Area-II (Well) (monitoring well designation).
TAG = Tijeras Arroyo Groundwater.
TJA = Tijeras Arroyo (monitoring well designation).
WYO = Wyoming (monitoring well designation).

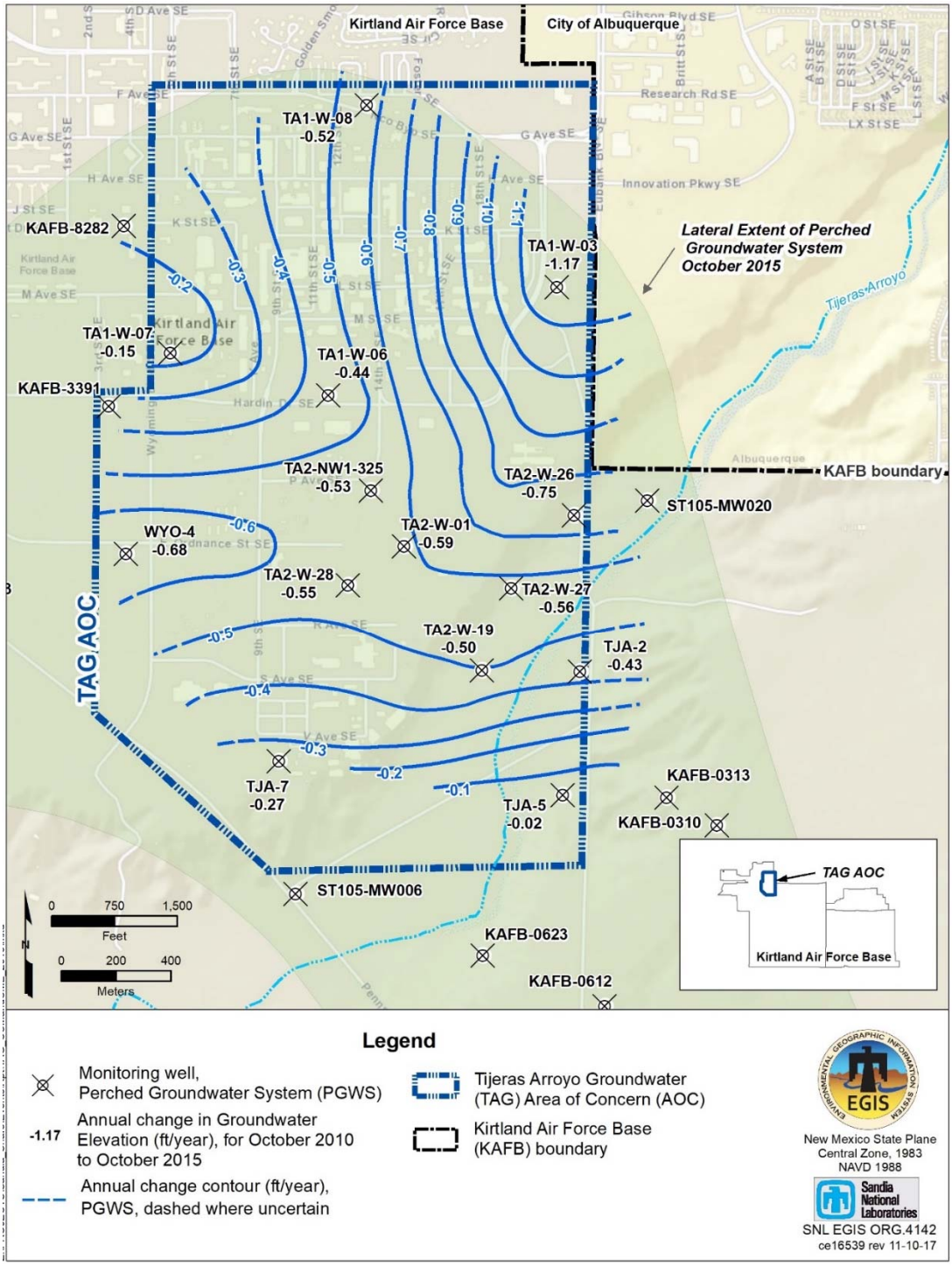


Figure 3-19
Annual Change in Groundwater Elevations at
Monitoring Wells Screened in the Perched Groundwater System in the TAG AOC

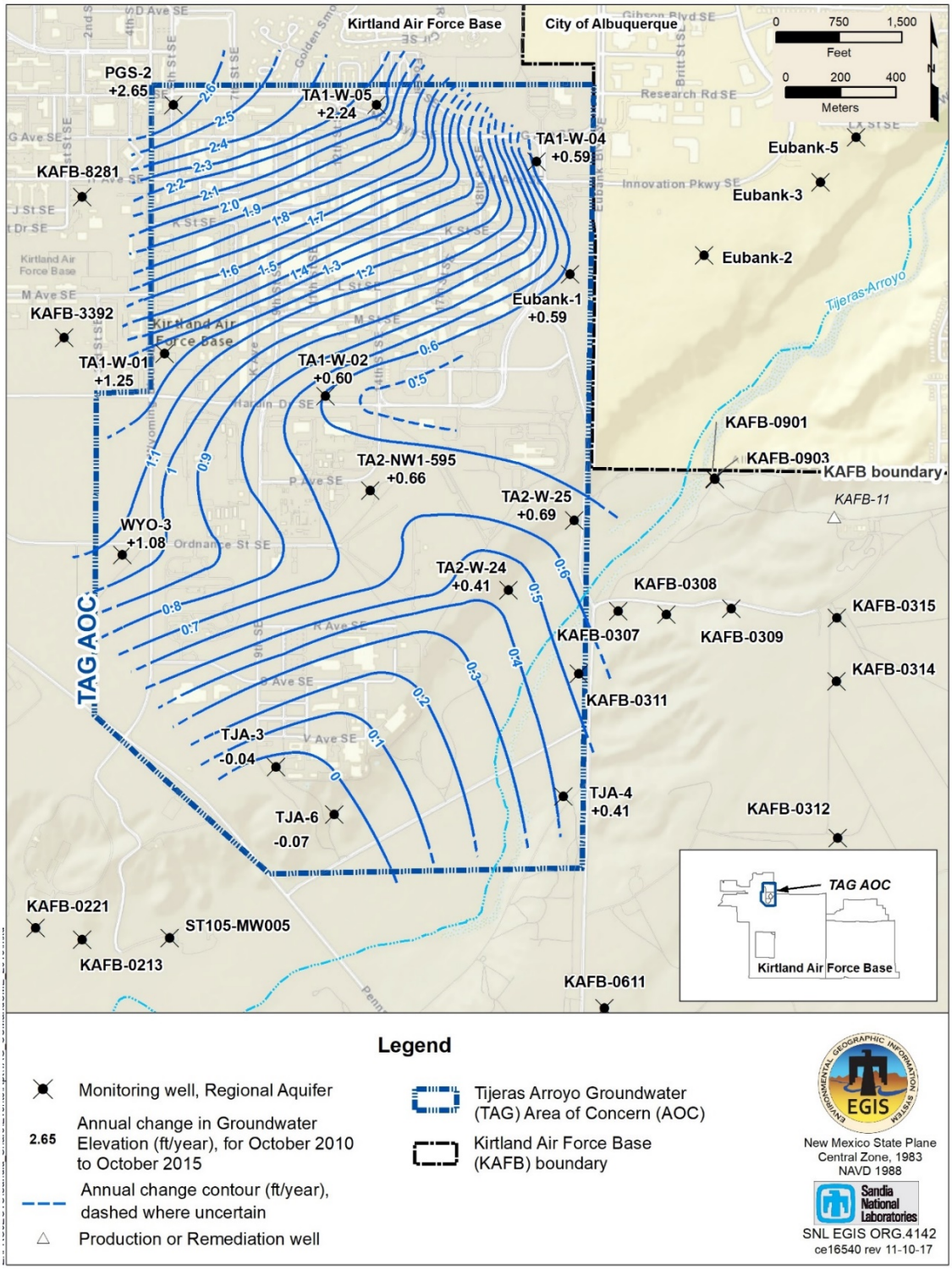
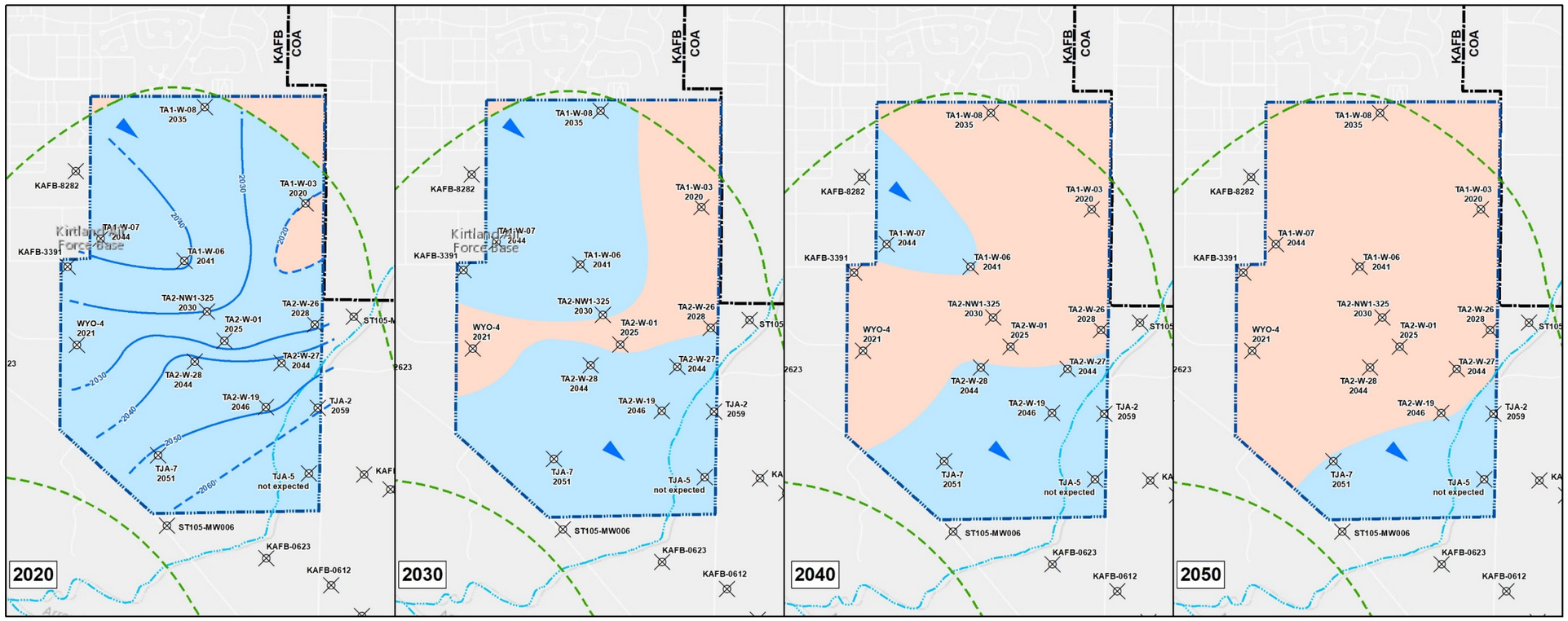
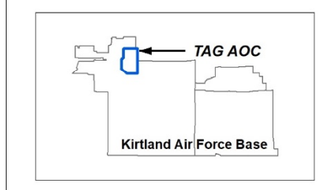


Figure 3-20
Annual Change in Groundwater Elevations at
Monitoring Wells Screened in the Regional Aquifer in the TAG AOC



Predicted lateral extent of the Perched Groundwater System (Years 2020-2050) when water level is estimated to decline to bottom of well screen.



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Legend

- Monitoring well, Perched Groundwater System (PGWS)
- 2020 — Estimated year when water level declines to bottom of well screen
- Estimated year of decline contour, dashed where uncertain shown at Year 2020 only
- Predicted remaining extent
- Water below screen in SNL/NM well
- Lateral extent of PGWS, October 2015
- Groundwater Flow direction, inferred from potentiometric surface
- Surface drainage, arroyo
- Tijeras Arroyo Groundwater (TAG) Area of Concern (AOC)
- Kirtland Air Force Base (KAFB) boundary

COA: City of Albuquerque
SNL/NM: Sandia National Laboratories/New Mexico

0 1,250 2,500
Feet
0 300 600
Meters

SNL EGIS ORG.4142
New Mexico State Plane Central Zone, 1983
1988 North American Vertical Datum
SNL, EGIS Dept 4142 ce17573 11-10-17

Figure 3-21
Estimated Years When Groundwater Elevations Will Decline Below the Perched Groundwater System Wells in the TAG AOC

Table 3-7
Average Annual Changes in Groundwater Elevations for
Monitoring Wells Screened in the Regional Aquifer at the TAG AOC

Monitoring Well	October 2010 Groundwater Elevation (ft amsl)	October 2015 Groundwater Elevation (ft amsl)	Annual Change for the Five-Year Period (ft)
Eubank-1	4908.14	4911.10	0.59
PGS-2	4852.99	4866.26	2.65
TA1-W-01	4858.84	4865.11	1.25
TA1-W-02	4891.07	4894.08	0.60
TA1-W-04	4888.69	4891.65	0.59
TA1-W-05	4857.84	4869.06	2.24
TA2-NW1-595	4895.65	4898.93	0.66
TJA-3	4891.53	4891.33	-0.04
TJA-4	5038.33	5040.38	0.41
TJA-6	4892.07	4891.72	-0.07
WYO-3	4859.86	4865.27	1.08
TA2-W-24	4919.21	4921.28	0.41
TA2-W-25	4902.70	4906.13	0.69

amsl = Above mean sea level.
AOC = Area of Concern.
ft = Foot (feet).
PGS = Parade Ground South (monitoring well designation).
TA1-W = Technical Area-I (Well) (monitoring well designation).
TA2-NW = Technical Area-II (Northwest) (monitoring well designation).
TA2-W = Technical Area-II (Well) (monitoring well designation).
TAG = Tijeras Arroyo Groundwater.
TJA = Tijeras Arroyo (monitoring well designation).
WYO = Wyoming (monitoring well designation).

3.6 Groundwater Flow Modeling

Three numerical modeling efforts were discussed in the December 2016 CCM/CME Report:

- Capture zone analysis for production wells (SNL/NM February 2001),
- Contaminant transport modeling (SNL/NM August 2005), and
- Conceptual groundwater modeling incorporating recharge features and stratigraphic controls (Balleau Groundwater, Inc. [BGW] September 2002).

Recent MODFLOW modeling using a mass balance approach is presented in Section 3.9.

3.6.1 Capture Zone Modeling for Production Wells

To evaluate the capture zone of production wells completed in the Regional Aquifer, DOE/Sandia modified the Albuquerque Basin model developed by the USGS (Tiedeman et al. 1998). The 2001 modeling (SNL/NM February 2001) used the MODPATH code (Pollock 1994) to perform particle tracking for estimating groundwater travel times and the capture zones of production wells. Simulated particles of water released around a series of potable water supply (production) wells and the computer model was run backwards in time for

a maximum of 100 years. The wells consisted of five ABCWUA wells (Ridgecrest 1, 2, 3, 4, and 5) and three on-base wells (KAFB-4, KAFB-11, and KAFB-15). Figure 3-22 shows the modeling results and shows that the capture zones trend approximately from south to north paralleling the more transmissive ARG facies in the Regional Aquifer.

Groundwater contamination in the southeast corner of the TAG AOC could potentially be captured by off-base production wells Ridgecrest 1 and Ridgecrest 2. These two wells capture Regional Aquifer groundwater underlying and to the immediate west of the TAG AOC, respectively, intercepting it before it could potentially be captured through the intermittent use of KAFB or VA production wells located physically closer to TAG AOC. However, this capture of contamination could only occur after groundwater from the Perched Groundwater System had migrated into the Regional Aquifer either via the merging zone to the southeast or by percolating through the approximately 200-ft thick layer of unsaturated sediments located between the base of the Perching Horizon and the Regional Aquifer. In the unlikely scenario that contaminated groundwater from SNL/NM historical operations reached the Regional Aquifer, the capture zones for Ridgecrest 1 and Ridgecrest 2 would prevent the contaminated groundwater from migrating far enough westward to reach on-base KAFB and VA production wells.

3.6.2 Contaminant Transport Modeling

The 2001 capture zone analysis was updated in 2005 by incorporating additional data for the hydrogeologic setting (SNL/NM August 2005). The modeling is summarized below with Appendix C presenting the entire report. Contaminant transport was simulated to estimate contaminant concentrations at the production wells and contaminant arrival time. Refinements included increasing the hydraulic conductivity of the ARG deposits, moving the eastern ARG boundary farther east, and decreasing the hydraulic conductivity of the alluvial fan deposits. A cross-sectional modeling approach used as a means to further evaluate the potential for nitrate contamination in the Perched Groundwater System to reach the production wells that are screened in the Regional Aquifer. The transport analysis included three hydrogeologic regions: Perched Groundwater System, an Alluvial Fan Model Section of the Regional Aquifer, and the ARG Model Section of the Regional Aquifer. Numerical models were developed using the Department of Defense Groundwater Modeling System (GMS), employing the MODFLOW groundwater flow simulator (Harbaugh et al. 2000) and the MT3DMS transport simulator (Zheng and Wang 1999) with GMS processors (Brigham Young University [BYU] 2003). The modeling effort used a historical maximum NPN concentration of 44 mg/L. It should be noted that this concentration has not been exceeded since conducting the modeling. The 2005 modeling effort concluded that:

- Nitrate (as nitrogen) originating from the Perched Groundwater System in the TAG AOC will be reduced to 0.24 mg/L before reaching production wells in the ARG lithofacies of the Regional Aquifer. This is a conservative estimate that intentionally over-predicts contaminant concentrations by neglecting dispersion, degradation, and sorption, which would further attenuate contaminant concentrations.

- The estimated travel time for nitrate contamination in the TAG AOC Perched Groundwater System to reach the production wells in the Regional Aquifer is at least 130 years.

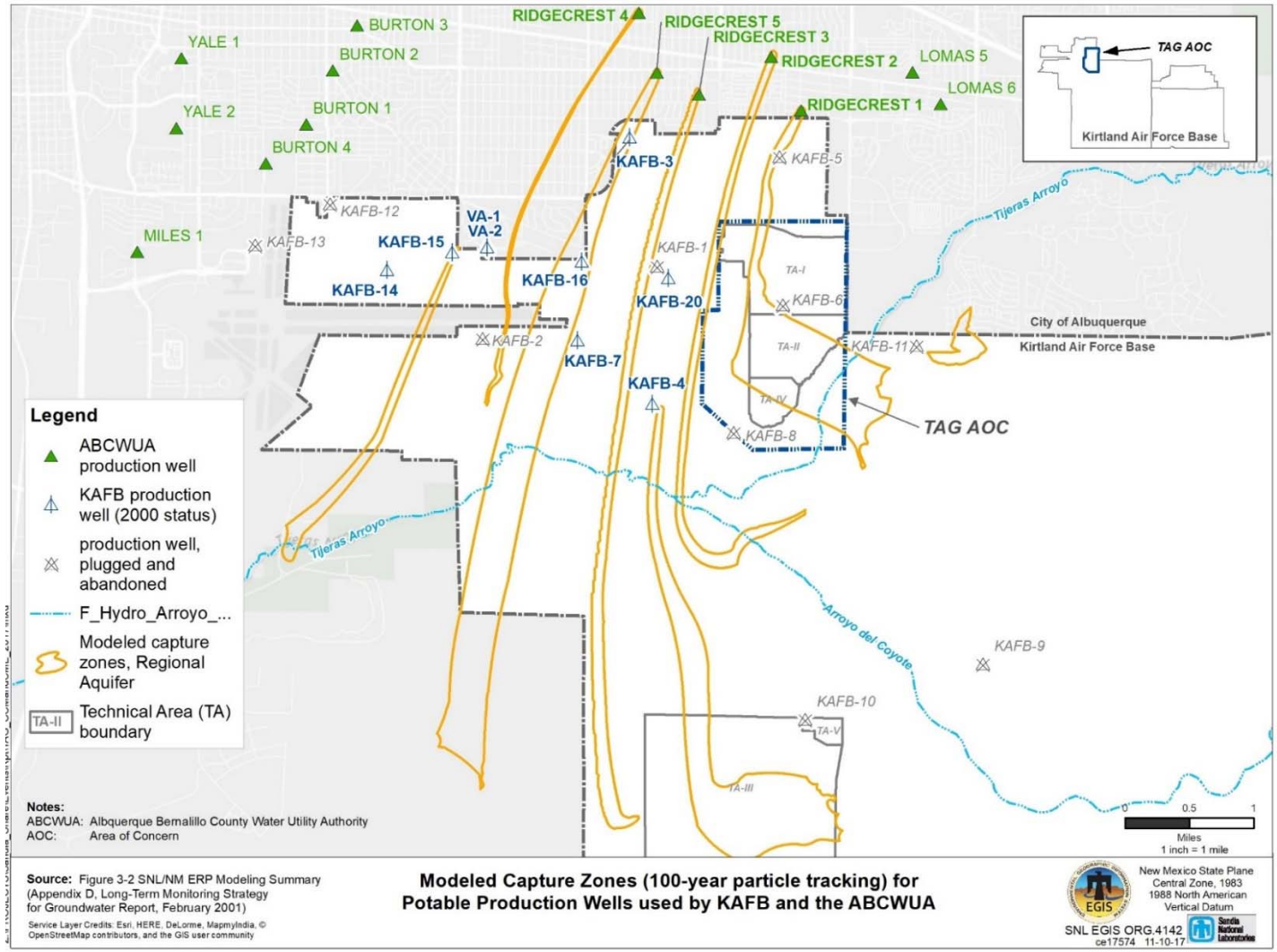


Figure 3-22
Modeled Capture Zones for Production Wells Used by KAFB and the ABCWUA
(SNL/NM February 2001)

3.6.3 Conceptual Modeling of Recharge Features and Stratigraphic Controls

In 2002, BGW refined and calibrated the recharge modeling effort of Wolford (September 1996) and BGW (February 2001) by using a more realistic numerical code (BGW September 2002). The initial model was incorporated into a three-dimensional, variably saturated, finite-element flow and transport model using FEMWATER (Hsin-Chi et al. 1997). The modeling grid was based upon stratigraphy of the alluvial fan lithofacies of the Upper SFG as described in GRAM and Lettis (December 1995). Various simulations were applied to determine the rate and volumes for several sources of recharge to the Perched Groundwater System. The sources of recharge were:

- The former KAFB Sewage Lagoons,
- Leaking water-supply lines in base housing and operational areas,
- Subsurface flow within a buried ancestral channel of Tijeras Arroyo,
- Surface water recharge from Tijeras Arroyo and Arroyo del Coyote on KAFB,
- Irrigation at the Tijeras Arroyo Golf Course,
- Watering of base housing lawns near the Gibson and Wyoming gates,
- Irrigation of the Parade Grounds (a grassy park),
- Infiltration from the Tijeras Arroyo Golf Course Main Pond,
- Leaking sewer lines in base housing and operational areas,
- Sewer line break (1994) and associated ponding on floodplain,
- The Acid Waste Line Outfall (SWMU 46),
- TA-II personnel shower (SWMU 165), and
- TA-II wastewater outfalls (SWMUs 227 and 229).

BGW (September 2002) endorsed the supposition of Brady and Domski (2001) that sediments in the Perched Groundwater System were most likely at residual saturation due to natural drainage prior to the addition of anthropogenic sources. Thus, the sediments would not have contained sufficient natural water to fill a well casing. However, water inputs from anthropogenic sources subsequently created a “triggering effect” that resulted in the artificial creation of the Perched Groundwater System. Table 3-8 lists water sources included in the model for simulating the recharge inputs. Figure 3-23 depicts the primary constraints (such as the southeasterly dip of stratigraphic units) used in the groundwater model and the simulated results for the water-bearing units near the TAG AOC (BGW September 2002).

Table 3-8
Simulated Recharge Rates in the TAG AOC Model (BGW September 2002)

Source	Input Start Date	Input End Date	Total Volume (acre feet)	Percentage of Calibrated Input
Sewage Lagoons	1967	1987	11,567	31.20
Leaky Water Lines	1947	2002	6,720	18.12
Tijeras Arroyo and Arroyo del Coyote	Pre-existing	2002	6,720	18.12
Tijeras Arroyo Golf Course	1967	2002	5,489	14.80
Base Housing Lawns	1947	2002	1,722	4.64
Parade Grounds	1947	2002	1,568	4.23
Tijeras Arroyo Golf Course Main Pond	1967	1987	2,425	6.54
Leaky Sewer Lines	1947	2002	284	0.77
Sewer Line Break Ponding area	9/14/1994	10/7/1994	259	0.70
Acid Waste Outfall (SWMU 46)	1947	1973	224	0.60
TA-II Shower Leach Field (SWMU 165)	1947	1992	52	0.14
SWMUs 227 and 229	1947	1992	38	0.10
Sewer Line Break Site	9/14/1993	9/13/1994	8	0.02
Total	--	--	37,076	~100

AOC = Area of Concern.
BGW = Balleau Groundwater, Inc.
ft = Foot (feet).
TAG = Tijeras Arroyo Groundwater.
SWMU = Solid Waste Management Unit.
TA = Technical Area.

BGW (September 2002) offered several conclusions:

- Model calibration produced a reasonable match of simulated to historical hydrographs.
- The model reproduced the areal extent of the Perched Groundwater System and demonstrated that a large fraction of perched water is derived from past and ongoing anthropogenic sources.
- The most significant recharge sources were the sewage lagoons, leaking water lines, ancestral arroyos, and the modern-day golf course.
- Other sources had a minor effect.
- The model also demonstrated that the Perched Groundwater System has a net discharge (drains and merges) to the Regional Aquifer.
- The lateral extent of the Perched Groundwater System is shrinking due to the lagoons being taken out of service.

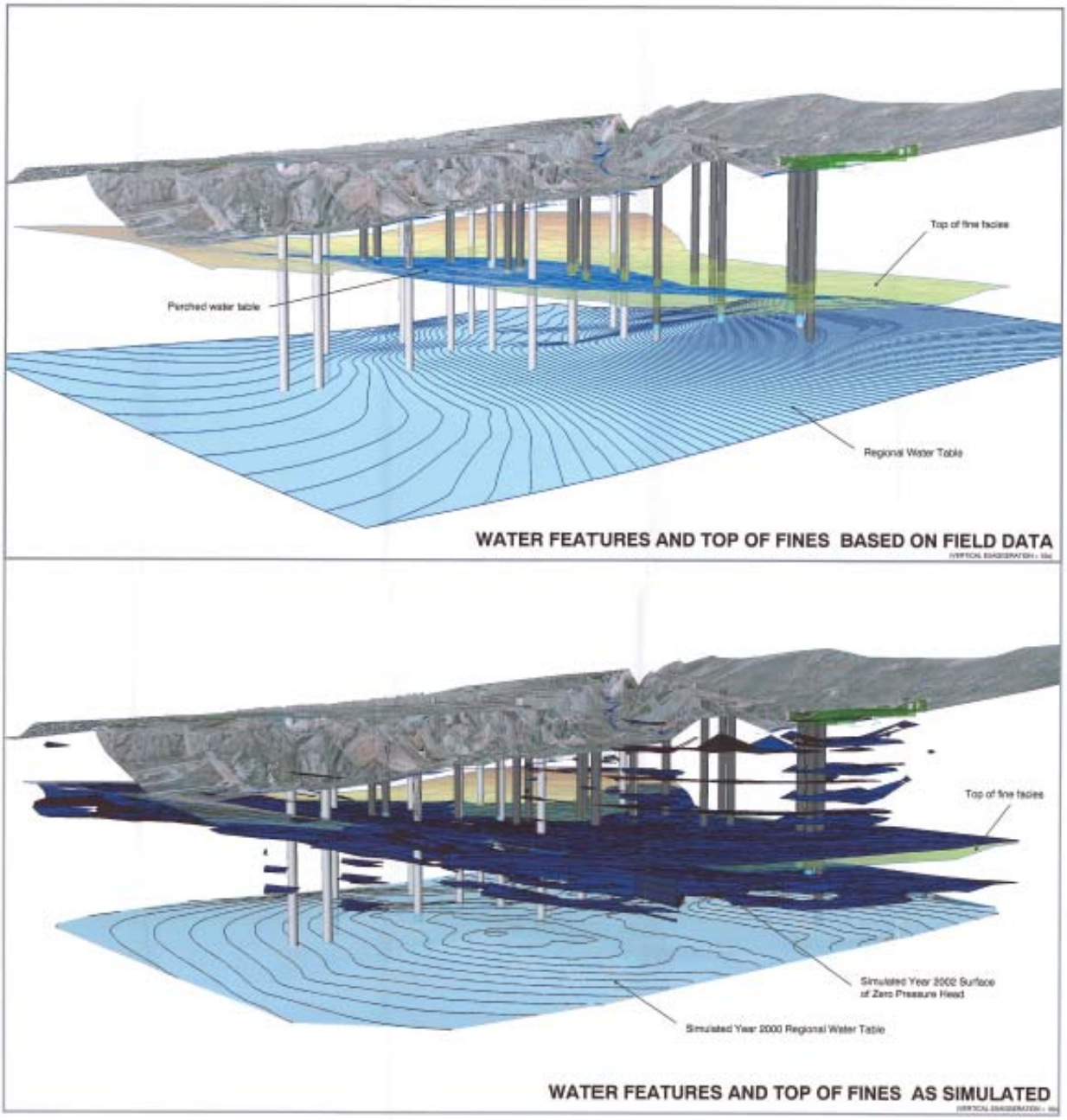


Figure 3-23
Depiction of the Primary Modeling Constraints and the Simulated Results for the Water-Bearing Units near the TAG AOC (BGW September 2002)
[Well casings diameters are exaggerated for clarity.]

3.7 Stable Isotopes

A variety of stable (non-radioactive) isotopes for nitrogen (N) and oxygen (O) were used to evaluate the genesis of nitrate in groundwater for the TAG AOC. In accordance with common usage, delta (δ) is used to refer to isotopic ratios. For example, $\delta^{15}N$ refers to the ratio of ^{15}N to ^{14}N. The following discussion presents data for the overall isotopic ratios in water. Specific isotopic ratios for the nitrate molecules extracted from the water matrix are also discussed. For example, $\delta^{15}N\text{-}NO_3$ refers to the ratio of ^{15}N to ^{14}N for the extracted nitrate (NO_3) molecules.

In 2003 and 2004, $\delta^{15}N$ analyses were conducted for five Perched Groundwater System monitoring wells (TA1-W-03, TA1-W-08, TA2-SW1-320, TJA-2, and TJA-7). The $\delta^{15}N$ values in water ranged from 3.6 to 7.0 (SNL/NM November 2004), which is indicative of natural soil and septic waste (Kendall 1998).

Figure 3-24 presents a dual-isotope plot of nitrate isotopic composition in groundwater samples collected in 2012. The values of $\delta^{18}O\text{-}NO_3$ versus $\delta^{15}N\text{-}NO_3$ were obtained from Madrid et al. (June 2013). Figure 3-24 also shows the commonly cited fields of various nitrate sources from Kendall (1998). For comparative purposes, groundwater samples from all the three groundwater AOCs at SNL/NM are shown. The clustering of the isotopic results for TAG groundwater samples collected from the Regional Aquifer wells predominantly indicate that the nitrate sources likely consist of natural (unfertilized) soil and manure/septic waste. The theoretical denitrification trend is also depicted. Samples from the Regional Aquifer do not fall in this trend indicating that denitrification is not occurring. The nitric-acid point on Figure 3-24 is derived from Beller et al. (2004) who studied the DOE Site 300 High Explosive (HE) research and testing facility. Samples from the TAG AOC Regional Aquifer do not plot near the nitric-acid point, which suggests that wastewater from SWMU 46 has not affected the Regional Aquifer.

Figure 3-25 presents the isotopic composition of $\delta^{18}O$ in water versus $\delta^{18}O$ in the nitrate molecules using data from Madrid et al. (June 2013). As shown, the Local Mean Water Line (LMWL) was calculated by Lawrence Livermore National Laboratory (LLNL) (Madrid et al. June 2013). The TAG monitoring wells do not plot along the LMWL, which indicates that evaporative concentration is not apparent for the wells screened in the Regional Aquifer. Similar analyses have not been conducted for wells screened in the Perched Groundwater System.

Figure 3-26 depicts the isotopic composition (δdeuterium [^2H] versus $\delta^{18}O$) for groundwater samples collected from numerous SNL/NM wells located along Tijeras Arroyo. As noted on the figure, the data were obtained from multiple entities (LLNL, KAFB, and USGS) for samples collected at various times between 1999 and 2012. Figure 3-27 shows a similar plot for the KAFB wells. As noted on the two figures, groundwater samples were collected from the Perched Groundwater System and the Regional Aquifer. The calculated linear regressions can be compared to the Global Mean Water Line (GMWL). The groundwater analyses for SNL/NM monitoring wells screened in both the Perched Groundwater System and the Regional Aquifer do not plot directly along the GMWL, which indicates a lack of modern recharge. The KAFB wells show more variability and may suggest some influence of modern recharge.

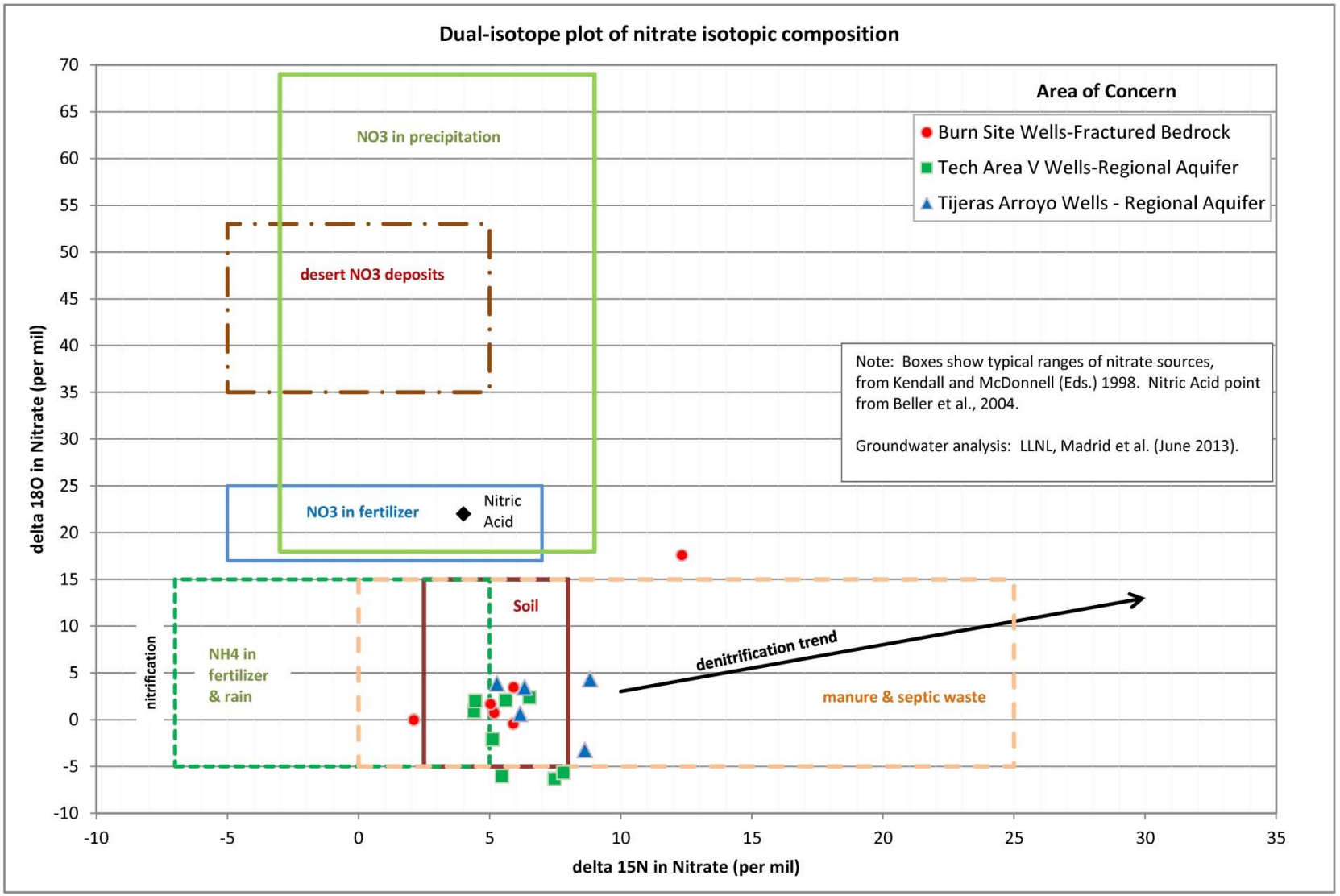


Figure 3-24
Dual-Isotope Plot of Nitrate Isotopic Composition for Monitoring Wells Screened in the Regional Aquifer in the TAG AOC, TA-V AOC, and the Burn Site AOC

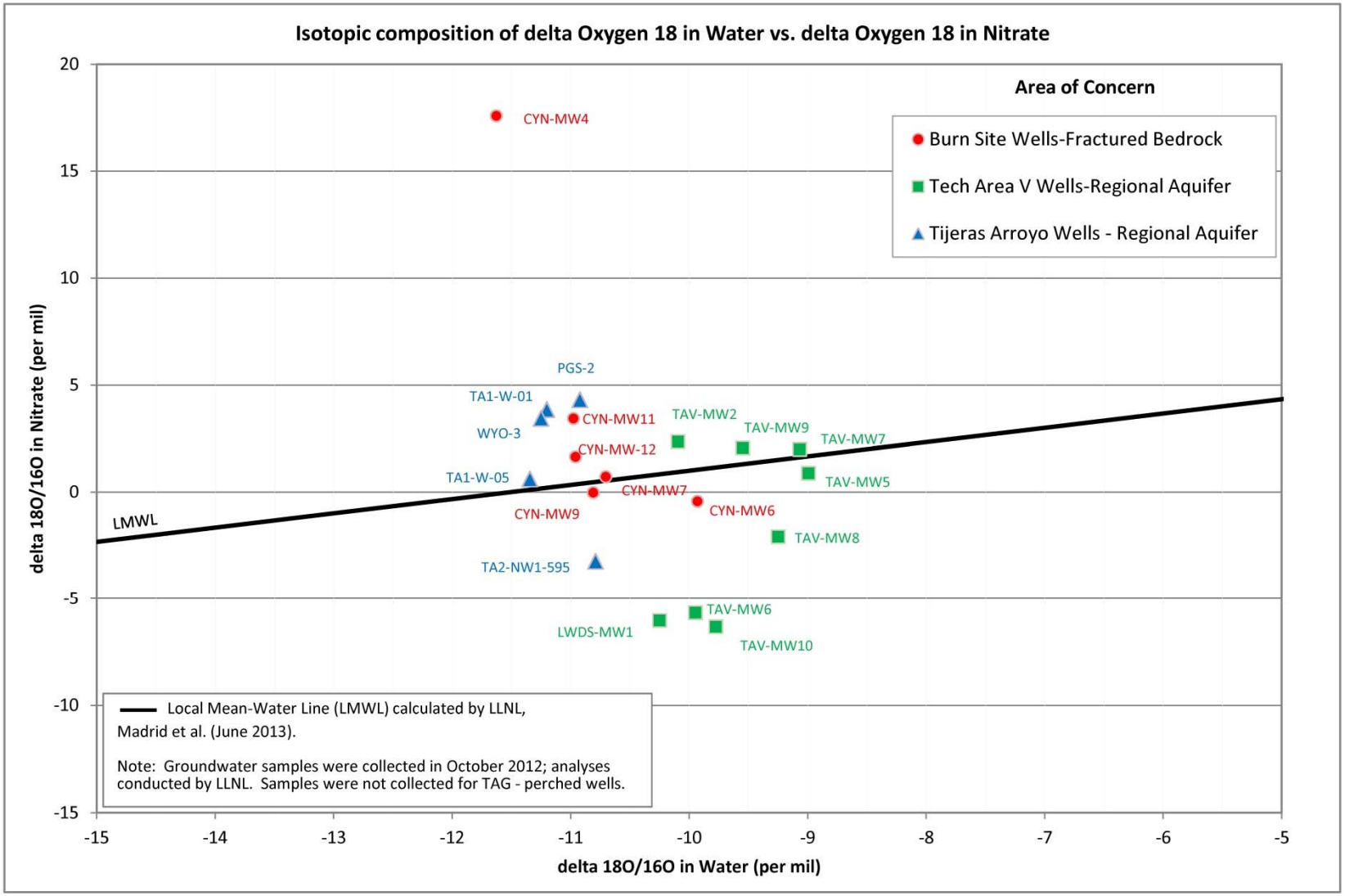


Figure 3-25
Isotopic Composition of $\delta^{18}O$ in Water versus $\delta^{18}O$ in Nitrate for Groundwater Samples Collected in 2012 at the Three SNL/NM AOCs

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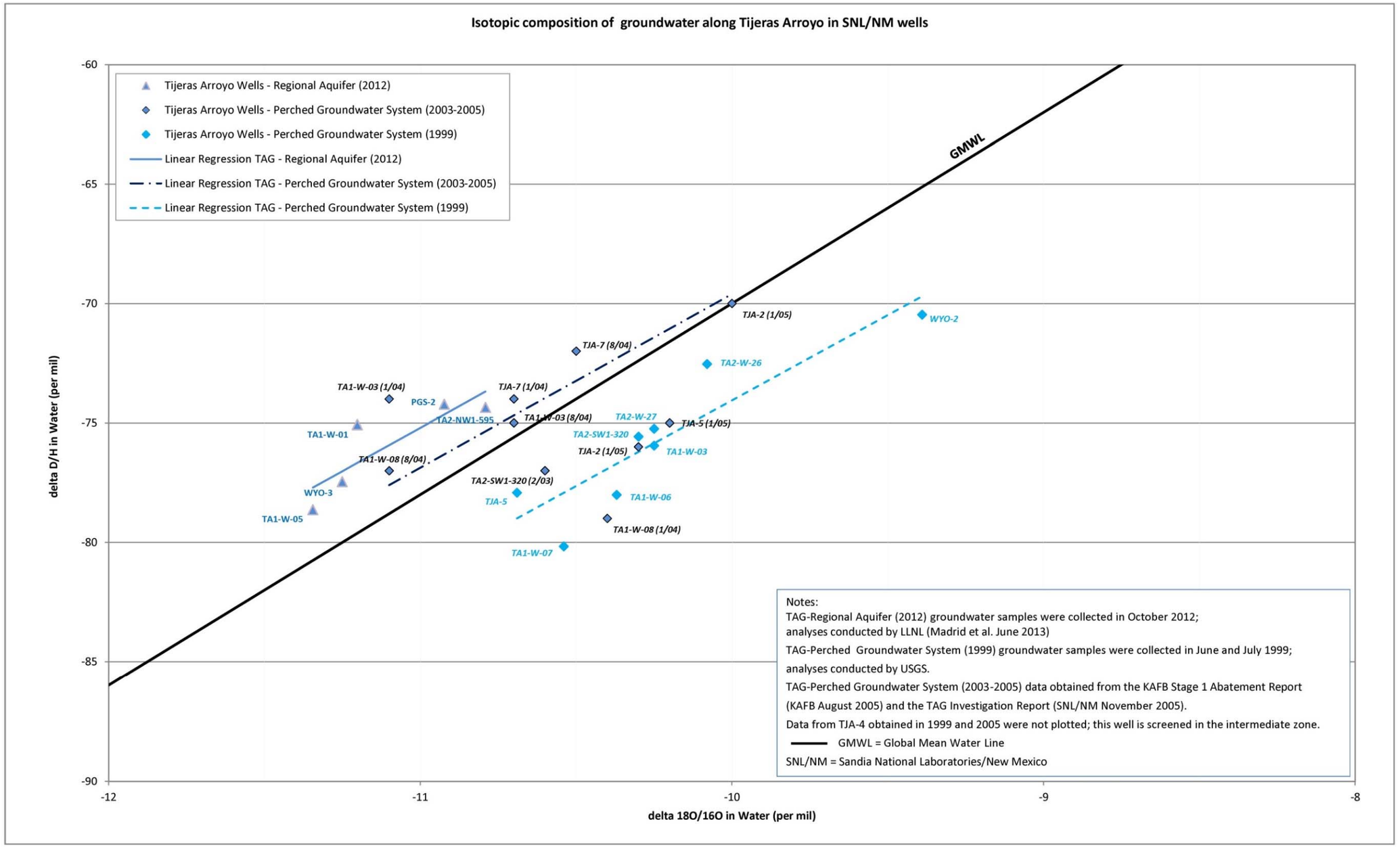


Figure 3-26
Isotopic Composition (δDeuterium versus $\delta^{18}O$) of Groundwater Along Tijeras Arroyo in SNL/NM Monitoring Wells

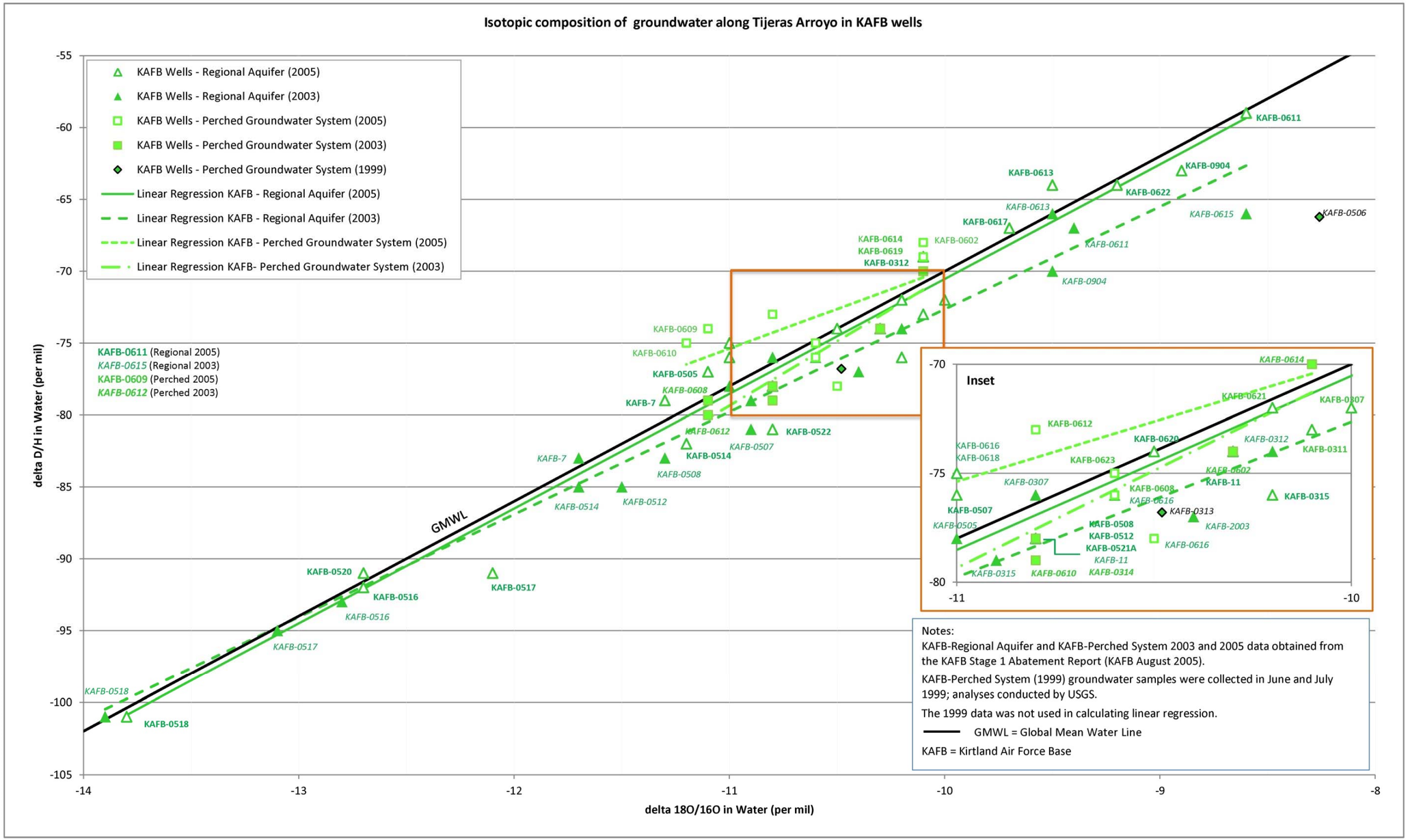


Figure 3-27
Isotopic Composition (δDeuterium versus $\delta^{18}O$) of Groundwater Along Tijeras Arroyo in KAFB Monitoring and Production Wells

3.8 Perching Horizon and Interpretation of Downhole Geophysical Logs

Interpretation of TAG AOC hydrogeology was refined in this Revised CCM/CME Report to support development of remedial alternatives for nitrate contamination in the Perched Groundwater System. Downhole geophysical logs from monitoring wells located throughout the TAG AOC coupled with mapping previously conducted by Van Hart (June 2001 and June 2003) were used to thoroughly describe the lateral and vertical extent of the Perching Horizon underlying the Perched Groundwater System.

The Van Hart mapping was the culmination of a nearly 10-year comprehensive effort conducted by the SNL SWHC Project to describe primary hydrostratigraphic units throughout the approximately 80-sq. mi. KAFB. The SWHC project was quasi-regional in scale and not designed to define the extent of contaminants at individual SWMUs. The SWHC findings were presented in a base-wide conceptual model report (GRAM and Lettis December 1995), which was slightly updated in in 1998 (SNL/NM February 1998). Van Hart was the lead interpreter of geologic structures by integrating borehole lithologic logs, downhole geophysical logs, aquifer conditions, outcrops, seismic sections, and aeromagnetic surveys. Van Hart described a general “Top Fine-grained Unit” as being prevalent across much of KAFB. However, alluvial fan sediments are difficult to correlate due to interfingering sedimentary packages that have a high degree of vertical and lateral variability in grain sizes. Van Hart also evaluated the stratigraphic and tectonic relationship within the Regional Aquifer and prepared two TAG-specific reports (Fritts and Van Hart March 1997, Van Hart June 2001).

Attachment 1 presents seven cross-sections from Van Hart (June 2001 and June 2003) extending across most or part of the TAG AOC. Van Hart referred to the cross-sections as “Geophysical-Log Correlation Sections” that are similar to fence diagrams. His stratigraphic interpretations (picks) for the “Top Fine-grained Unit” are shown on the recently digitized geophysical logs listed and presented in Attachments 2 and 3, respectively. The picks for the Perching Horizon shown in Attachment 3 were interpreted for this report.

Table 3-9 lists the monitoring wells where downhole geophysical logging was conducted. Attachment 2 lists the specific dates and logging conditions for the geophysical logging conducted at 24 well locations in and adjacent to the TAG AOC. Geophysical logs were acquired from DOE/SNL M&O contractor, KAFB, and COA sources. In several cases, geophysical plots from a deeper (Regional Aquifer) monitoring well were extrapolated to an adjacent Perched Groundwater System monitoring well. Thus, a well pair was used to interpret the depth and thickness of the Perching Horizon. Table 3-10 lists the well pairs located throughout the TAG AOC. For example, the well log for Regional Aquifer monitoring well TA1-W-02 applies to itself and to the adjacent Perched Groundwater System monitoring well TA1-W-06.

Attachment 4 contains a listing of borehole lithologic descriptions. These logs were used to support geophysical log interpretation. Three boreholes logs include detailed core descriptions prepared by USGS rig geologists. For example, the boreholes for paired wells TA2-NW1-325 and TA2-NW1-595 were continuously cored and logged in detail (35 pages total) to a depth of 650 ft bgs. The borehole for nearby well TA2-SW1-320 was continuously cored to a depth of 330 ft bgs and has a 17-page description. These three wells are centrally located in the TAG AOC. Attachment 4 lists core-depth intervals for all TAG boreholes. Attachment 5 presents lithologic logs and Attachment 6 presents well diagrams.

Table 3-9
Geophysical Logging Dates and Applicable Logs for Monitoring Wells near the TAG AOC

Monitoring Well	Date of Geophysical Logging	Applicable Geophysical Log
PGS-1 [a]	5 Aug 1994	PGS-1
PGS-2 [a]	Not logged	See PGS-1
TA1-W-01	4 Aug 1997	TA1-W-01
TA1-W-02	29 Apr 1999	TA1-W-02
TA1-W-03	29 Apr 1999	TA1-W-03
TA1-W-04	28 Apr 1999	TA1-W-04
TA1-W-05	29 Apr 1999	TA1-W-05
TA1-W-06	29 Apr 1999	See TA1-W-02
TA1-W-07	Not logged	See TA1-W-01
TA1-W-08	Not logged	See TA1-W-05
TA2-NW1-325	Not logged	See TA2-NW1-595
TA2-NW1-595	26 June 1993	TA2-NW1-595
TA2-SW1-320	14 Sep 1994	TA2-SW1-320
TA2-W-01	14 Sep 1994	TA2-W-01
TA2-W-19	12 Oct 2017	TA2-W-19
TA2-W-24	28 Apr 1999	TA2-W-24
TA2-W-25	11 Aug 1997	TA2-W-25
TA2-W-26	Not logged	See TA2-W-25
TA2-W-27	28 Apr 1999	See TA2-W-24
TA2-W-28 [b]	12 Oct 2017	TA2-W-28
TJA-1 [c]	Not logged	See TJA-2
TJA-2	12 Aug 1997	TJA-2 and KAFB-0311
TJA-3	27 Apr 1999	TJA-3
TJA-4	28 Apr 1999	TJA-4
TJA-5	Not logged	See TJA-4
TJA-6	31 Jan 2001	TJA-6
TJA-7	Not logged	See TJA-3
WYO-1 [d]	12 Aug 1997	WYO-1
WYO-2 [d]	Not logged	See WYO-1
WYO-3 [d]	Not logged	See WYO-1
WYO-4 [d]	Not logged	See WYO-1
Eubank-1	July 1998	Eubank-1
KAFB-0213	6 Aug 1997	KAFB-0213
KAFB-0311	24 July 1992	KAFB-0311
KAFB-0611	5 Feb 2003	KAFB-0612

Green rows are Perched Groundwater System monitoring wells.
[a] Well PGS-2 is the replacement well for well PGS-1. Located 29 feet apart.
[b] Well TA2-W-28 is the replacement well for TA2-SW1-320. Located 24 ft apart.
[c] Well TJA-1 is the replacement well for well TJA-2. Located 25 ft apart.
[d] Monitoring wells WYO-1 and WYO-2 comprised a well cluster. In 1995, the two wells were installed in the same borehole. In 2001, the wells were plugged and abandoned because the annular seal between the two well screens was not effective. Two replacement wells (WYO-3 and WYO-4) were subsequently installed in individual boreholes.
AOC = Area of Concern.
KAFB = Kirtland Air Force Base.
n.a. = not applicable.
PGS = Parade Ground South (monitoring well designation).
TA1-W = Technical Area-I (Well) (monitoring well designation).
TA2-NW = Technical Area-II (Northwest) (monitoring well designation).
TA2-SW = Technical Area-II (Southwest) (monitoring well designation).
TA2-W = Technical Area-II (Well) (monitoring well designation).
TAG = Tijeras Arroyo Groundwater.
TJA = Tijeras Arroyo (monitoring well designation).
WYO = Wyoming (monitoring well designation).

Table 3-10
Well Pairs Used for Interpreting Geophysical Logs near the TAG AOC

Well Screened in Perched Groundwater System	Well Screened in Regional Aquifer	Distance Between Wells (ft)
TA1-W-06	TA1-W-02	38
TA1-W-07	TA1-W-01	73
TA1-W-08	TA1-W-05	116
TA2-NW1-325	TA2-NW1-595	17
TA2-W-26	TA2-W-25	50
TA2-W-27	TA2-W-24	36
TJA-2	KAFB-0311	15
TJA-5	TJA-4	19
TJA-7	TJA-3	52
WYO-3	WYO-1 and WYO-2 well cluster	92
WYO-4	WYO-1 and WYO-2 well cluster	48
KAFB-0612	KAFB-0611	22

AOC = Area of Concern.
ft = Foot (feet).
KAFB = Kirtland Air Force Base.
PGS = Parade Ground South (monitoring well designation).
TA1-W = Technical Area-I (Well) (monitoring well designation).
TA2-NW = Technical Area-II (Northwest) (monitoring well designation).
TA2-SW = Technical Area-II (Southwest) (monitoring well designation).
TA2-W = Technical Area-II (Well) (monitoring well designation).
TAG = Tijeras Arroyo Groundwater.
TJA = Tijeras Arroyo (monitoring well designation).
WYO = Wyoming (monitoring well designation).

The observed depth to the top of the Perching Horizon ranges from approximately 282 to 362 ft bgs (Table 3-11). Elevations for the top of the horizon range from a high of 5,112 ft above mean sea level (amsl) at well TA1-W-07 in the northwest corner of the TAG AOC to 5,036 ft amsl at well TJA-5 in the southeast corner. Figure 3-28 shows a structural-contour map for the top of the Perching Horizon. Across the TAG AOC, the Perching Horizon declines in elevation by approximately 80 ft. The contour spacing shows a uniform dip to the southeast that mimics the orientation of the potentiometric surface for the Perched Groundwater System. The Perching Horizon dips to the southeast at approximately 0.5 degrees, but appears to steepen as it nears the merging zone in the southeast corner of the TAG AOC.

The thickness of the Perching Horizon is inferred from the geophysical logs to range from approximately 4 to 11 ft across the TAG AOC (Table 3-11). The thickness of the Perching Horizon was determined by averaging the three geophysical responses (induction, neutron, and gamma) per well. No appreciable pattern is evident on Figure 3-29 for the Perching Horizon thickness. The thickness of the Perching Horizon averages approximately 7 ft across the TAG AOC.

Table 3-11
Structural Elevations and Perching Horizon Thickness
as Estimated from Downhole Geophysical Logs

Monitoring Well	Depth to Perching Horizon (ft bgs)	Structural Elevation for top of Perching Horizon (ft amsl)	Thickness of Perching Horizon (ft)
TA1-W-03	362	5093	4[a]
TA1-W-04	347	5111	4
TA1-W-06	326	5091	9
TA1-W-07	290	5112	11
TA1-W-08	328	5106	5
TA2-NW1-325	328	5092	5
TA2-W-26	303	5070	6
TA2-W-27	296	5066	10
TA2-W-28	328	5082	unk
TJA-2	294	5057	11
TJA-5	303	5036	5
TJA-6	282	5059	10
TJA-7	312	5076	7
WYO-4	298	5092	6
Range for the TAG AOC	282 to 362	5036 to 5112	4 to 11
Average for the TAG AOC	314	5082	7
KAFB-0213	202	5080	3?
KAFB-0611	357	5027	7?

[a] Value obtained from well TA1-W-04.

Green shading indicates that well is screened in the Perched Groundwater System.

amsl = Above mean sea level.
AOC = Area of Concern.
bgs = Below ground surface.
ft = Foot (feet).
KAFB = Kirtland Air Force Base.
TA1-W = Technical Area-I (Well) (monitoring well designation).
TA2-NW = Technical Area-II (Northwest) (monitoring well designation).
TA2-W = Technical Area-II (Well) (monitoring well designation).
TAG = Tijeras Arroyo Groundwater.
TJA = Tijeras Arroyo (monitoring well designation).
unk = Unknown, well casing was not deep enough for logging tool to image the base of the Perching Horizon.
WYO = Wyoming (monitoring well designation).



Figure 3-28
Structure-Contour Map for the Top of the Perching Horizon that Underlies the Perched Groundwater System

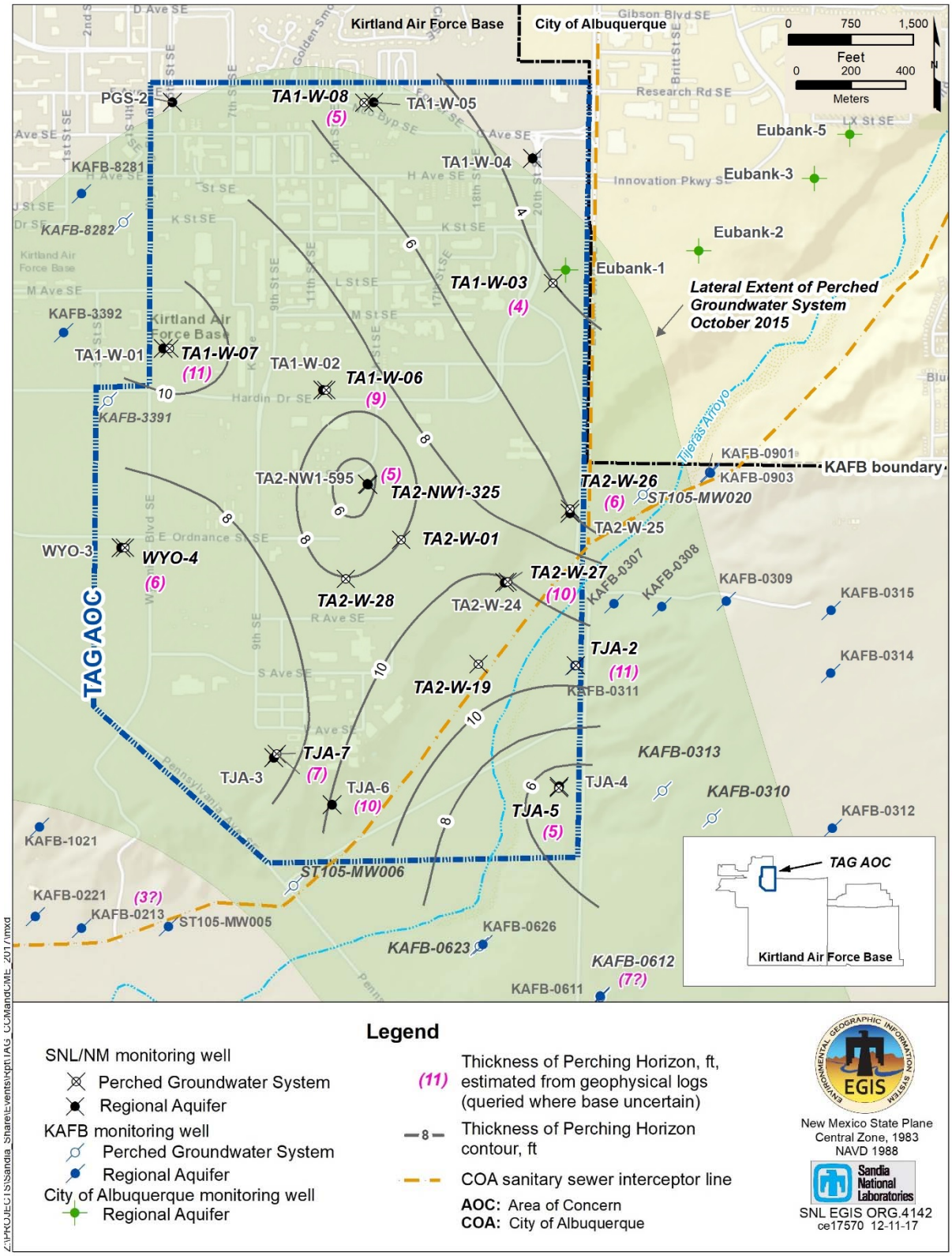


Figure 3-29
Perching Horizon Thickness Underlying the Perched Groundwater System

Table 3-12 lists the estimated thickness of the Perched Groundwater System saturated sediments below each well screen. This unscreened (but saturated) thickness sits directly above the Perching Horizon. Across the TAG AOC, this unscreened thickness ranges from a negative 3 ft at well WYO-4 to a maximum of 16 ft at well TJA-5 (Figure 3-30). The water column at well WYO-4 has historically been thin. The well screen for WYO-4 partially extends into the Perching Horizon, which does not yield water to the well. The monitoring wells were constructed with 20-ft long screens that straddle the water table. As a result, some well screens are not sufficiently long enough to both straddle the water table and extend to the top of the Perching Horizon.

The amount of unscreened saturated thickness in the Perched Groundwater System was calculated per well by adding the October 2015 water column to the estimated thickness of the underlying unscreened saturated sediments (Table 3-12). The thickness of this unscreened portion of the Perched Groundwater System averages approximately 4 ft for wells located in the TAG AOC ranging from approximately 7 ft at the western edge of the TAG AOC to approximately 35 ft in the southeast corner. The isopach contours shown on Figure 3-31 show a generally increasing saturated thickness towards the southeast. Some mounding appears in the north-central portion of the TAG AOC coincidental with wells with the slowest rate of water level decline.

A review of lithologic borehole descriptions and the geophysical logs indicates that the sediments sandwiched between the base of the Perching Horizon and the Regional Aquifer are mostly composed of moist sediments that will not yield groundwater to a well. Figure 3-32 shows this unsaturated thickness of sediments below the Perching Horizon averaged approximately 202 ft thick as of October 2015, decreasing from approximately 258 ft in the northwest corner of the TAG AOC to 177 ft in the southeast corner near the merging zone (Table 3-12).

3.9 Mass Balance Modeling of Vertical and Lateral Flow in the Perched Groundwater System

Using a mass balance approach, the volume of groundwater flowing laterally to the southeast out of the Perched Groundwater System was compared to the volume flowing vertically downward through the Perching Horizon. The total volume of water lost from the Perched Groundwater System between 2012 and 2015 was calculated by contouring the difference in groundwater elevations using a kriging algorithm. The volume of groundwater flowing laterally out of the Perched Groundwater System during that same period was estimated using the mass balance function of the numerical modeling program MODFLOW. This analysis indicates that approximately 25 percent of the total groundwater loss from the Perched Groundwater System is due to lateral flow, while 75 percent is downward vertical flow through the Perching Horizon. This is consistent with the very low horizontal hydraulic gradient (0.004 to 0.0125) and the slow groundwater velocity (24 ft/yr) in the Perched Groundwater System. However, as discussed in Section 3.3.2, there is no geochemical indication that groundwater flowing downward through the Perching Horizon has reached the Regional Aquifer, except in the merging zone southeast of the TAG AOC.

Table 3-12
Total Perched Groundwater System Thickness and the Vertical Distance from the Base of Perching Horizon to the Regional Aquifer as Estimated from Downhole Geophysical Logs

Monitoring Well	Thickness of Saturated PGWS Sediments Below Well Screen (ft)	Total Thickness of the Perched Groundwater System - October 2015 (ft)*	Unsaturated Thickness Between the Base of Perching Horizon to the Regional Aquifer Potentiometric Surface - October 2015 (ft)
TA1-W-03	5	11	unk
TA1-W-04	n.a.[1]	n.a.[1]	224
TA1-W-06	6	18	206
TA1-W-07	1	7	258
TA1-W-08	6	17	242
TA2-NW1-325	3	11	199
TA2-W-26	7	18	169
TA2-W-27	1	16	155
TA2-W-28	-3	11	unk
TJA-2	-1	17	n.c.
TJA-5	16	35	n.a.[2]
TJA-6	n.a.[1]	n.a.[1]	177
TJA-7	2	11	191
WYO-4	3	7	233
Range for the TAG AOC	-3 to 16	7 to 35	177 to 258
Average for the TAG AOC	4	15	202
KAFB-0213	n.a.[3]	n.a.[3]	n.a.[3]
KAFB-0612	n.a.[2]	65	n.a.[2]

Green shading indicates that well is screened in the Perched Groundwater System.
Negative values denote well screen extending below the top of the Perching Horizon.
*Combined value for water column in well (October 2015) and the estimated thickness of saturated sediments (from geophysical logs) below the screen.
AOC = Area of Concern.
ft = Foot (feet).
KAFB = Kirtland Air Force Base.
n.a.[1] = Not applicable (well is screened in the Regional Aquifer).
n.a.[2] = Not applicable (well is screened in the merging zone).
n.a.[3] = Not applicable (Perched Groundwater System is not present in this area).
n.c. = Not calculated (water level was not available for paired well KAFB-0311).
TA1-W = Technical Area-I (Well) (monitoring well designation).
TA2-NW = Technical Area-II (Northwest) (monitoring well designation).
TA2-W = Technical Area-II (Well) (monitoring well designation).
TAG = Tijeras Arroyo Groundwater.
TJA = Tijeras Arroyo (monitoring well designation).
unk = Unknown (Perching Horizon not sufficiently imaged by geophysical tool for a conclusive result).
WYO = Wyoming (monitoring well designation).



Figure 3-30
Perched Groundwater System Thickness below Each Well Screen

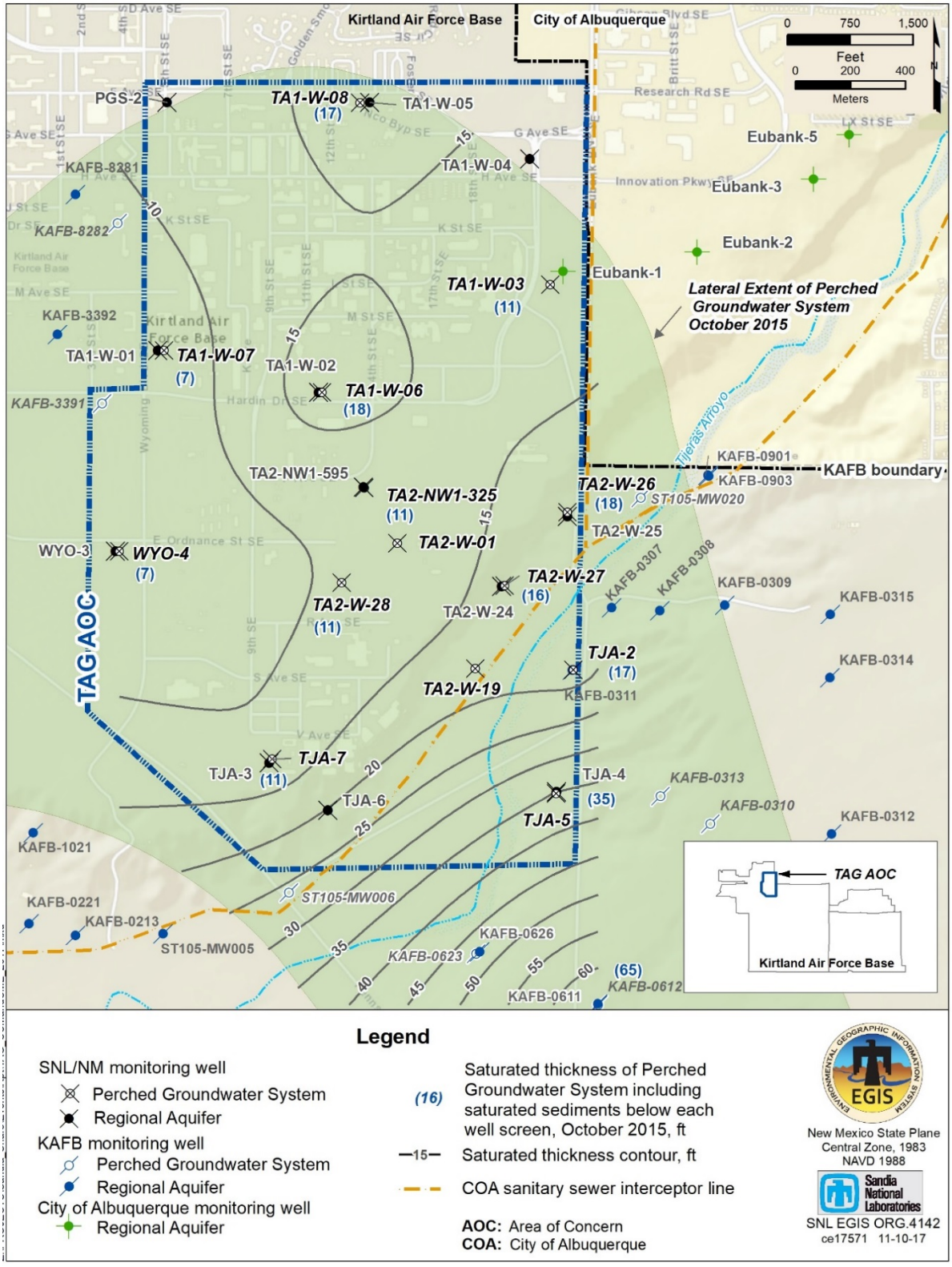


Figure 3-31
Total Perched Groundwater System Thickness, October 2015

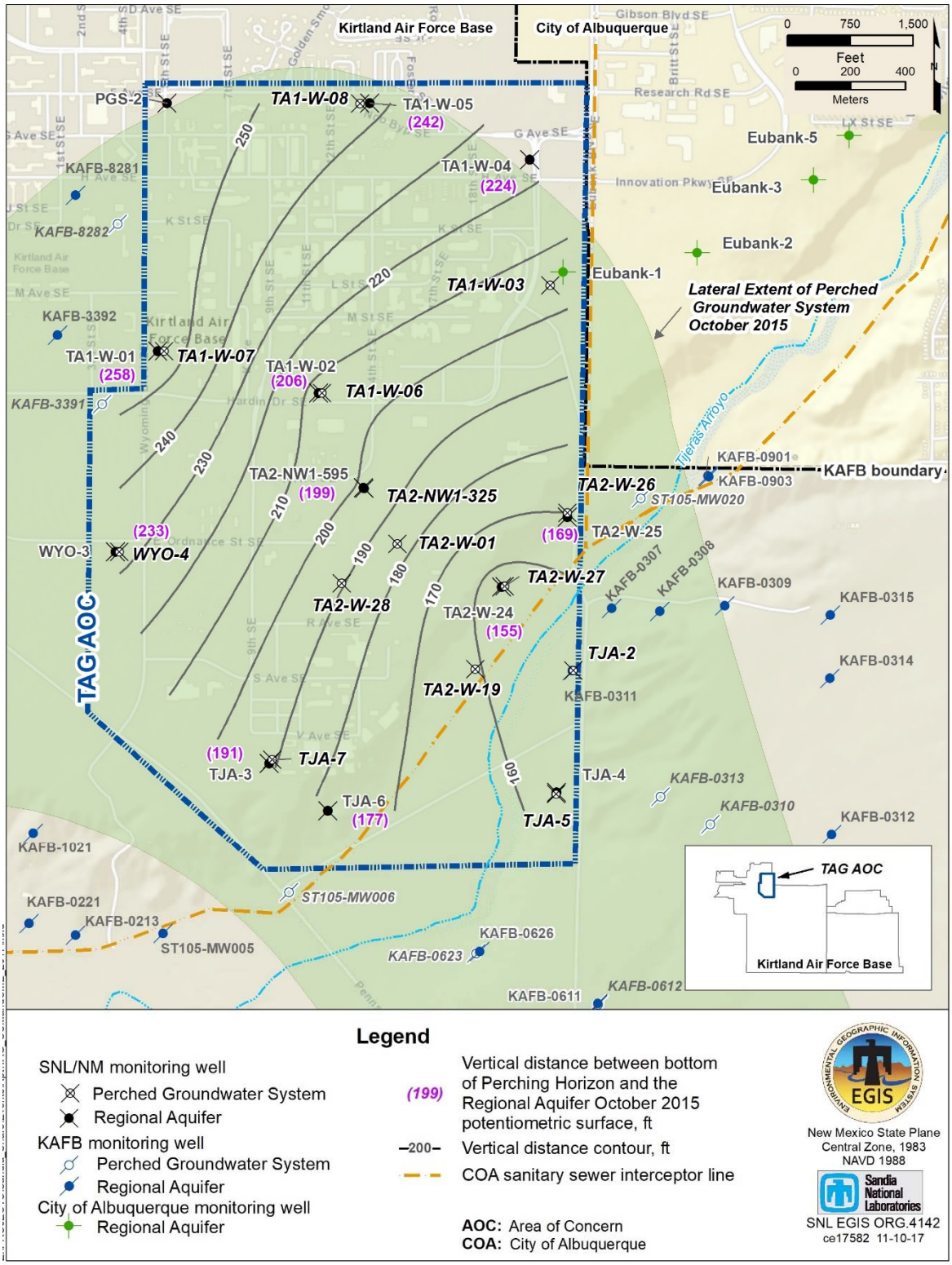


Figure 3-32
Vertical Distance from the Base of the Perching Horizon to the Regional Aquifer Potentiometric Surface, October 2015

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4.0 SITE HISTORY, CORRECTIVE ACTIONS, AND POTENTIAL RELEASE SITES

This section provides background information on the history of operational activities near the TAG AOC, a summary of the corrective actions conducted by DOE/SNL M&O contractor and a discussion of the potential nitrate-release sites.

The water-type terminology used in this report is as follows. Wastewater refers to water derived from activities such as research/testing operations, machine workshops, photographic development, and foundries. Septic water refers to sewage (sanitary waste) from restrooms and bathing showers. Stormwater consists of precipitation and ephemeral overland flow.

4.1 Operational History

The parties identified as potentially responsible for groundwater contamination near the TAG AOC include DOE/SNL M&O contractor, KAFB, and ABCWUA/COA.

4.1.1 Co-located Operations

The SNL/NM facilities at TA-I, TA-II, and TA-IV were built on land that had been previously developed by commercial operators and to a much larger degree by the military (CE2 Corporation September 2016). Land-use development began in 1928 when the public Albuquerque Airport was built on the East Mesa. Renamed Oxnard Field in 1929, the airport covered approximately 490 acres and was used until late 1939 when the vicinity of Oxnard Field was purchased by the federal government for use as an Army Air Depot Training Station, later to be known as Sandia Base (www.airfields-freeman.com). After World War II, the old Oxnard Field runways and an extensive grid of taxiways were used for parking aircraft (Figure 4-1). Starting in 1946, the War Assets Administration managed the sale or dismantlement of approximately 2,250 surplus military aircraft. Approximately 1,500 planes were dismantled and smelted down adjacent to the Oxnard taxiways (www.militarymediainc.com). In addition to the smelter, numerous maintenance and machine shops were operated for several years in the air depot area (34 acres). Figure 4-1 shows that surplus aircraft were parked at several areas that covered a combined 280 acres. The known extent of the nearby aircraft parking grid covered an additional area that totaled approximately 210 acres, but most of this area appears to have not been used.

In 1939, public airline service was moved approximately four miles to the west of Oxnard Field where the Albuquerque Municipal Airport was built. Using the set of municipal runways, the Albuquerque Army Air Base began operations in 1941. The air base was later dedicated as Kirtland Army Air Field and subsequently renamed as KAFB. In 1971, the operations of KAFB, Sandia Base, and Manzano Base were combined under the Air Force Materiel Command. The municipal airfield is now identified as the Albuquerque International Sunport.

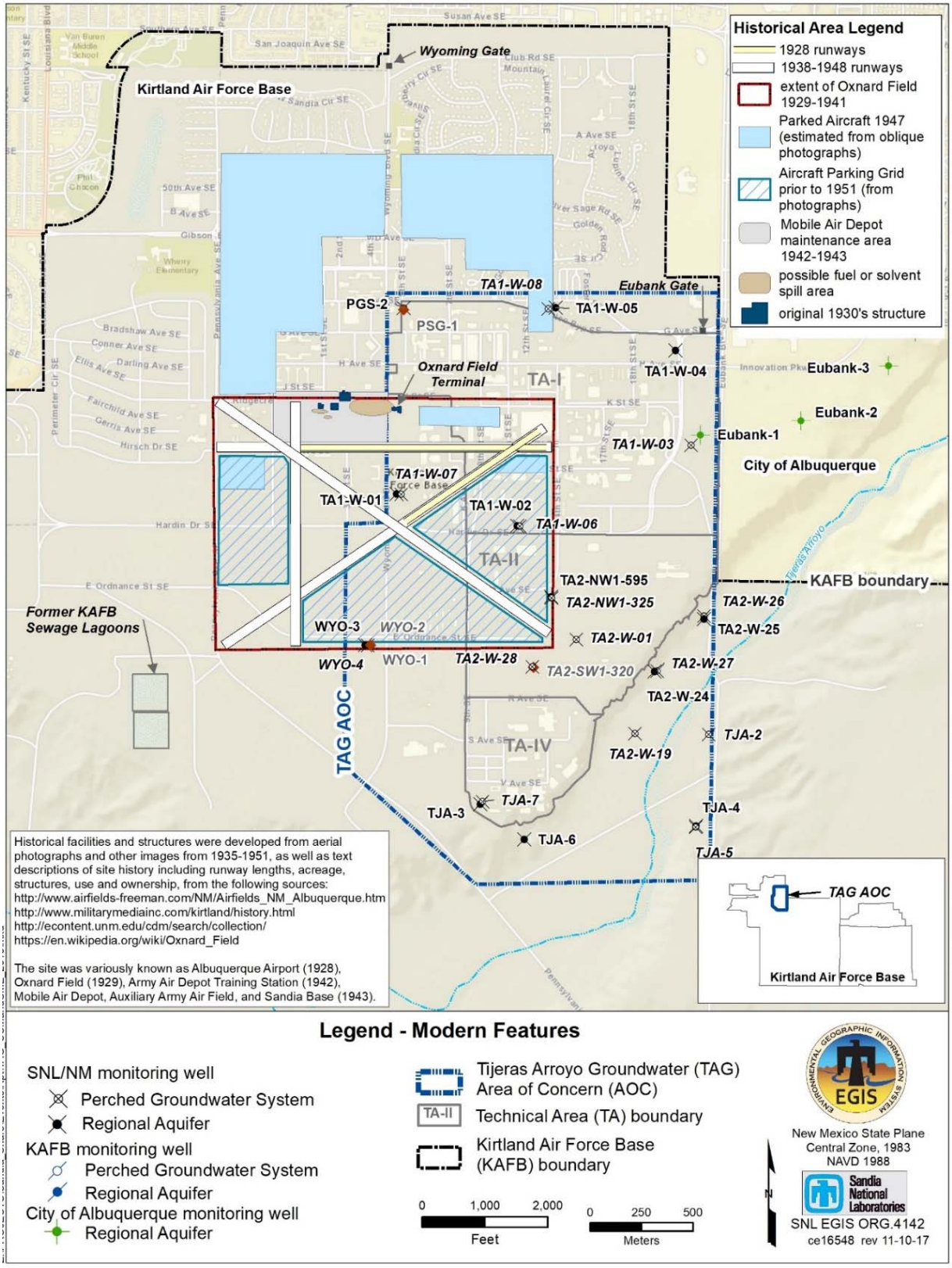


Figure 4-1
Historical Commercial and Military Aircraft Operations in the TAG AOC

In July 1945, the “Z Division” of the Manhattan Engineers District, an extension of the original Los Alamos Laboratory, was established at Sandia Base in the area that would become known as TA-I (Furman 1990). The primary mission of the Z Division was to provide engineering, production, stockpiling, and testing support for nuclear weapon systems. In 1949, the independent “Sandia Laboratory” was established at TA-I and TA-II. The total number of employees that year was 549. The primary management and administrative operations have historically been conducted in several of the TA-I office buildings. TA-I has historically been the administrative headquarters and includes numerous office buildings, in addition to research laboratories and small machine shops.

Construction of TA-IV began in 1977. TA-IV houses office buildings and large linear accelerators for studying nuclear fusion. Over the years, operations at the three TAs have evolved to include a wide variety of research and development activities including weapons design, high-performance computing, and energy research programs.

During the early stages of the Cold War, TA-II was the primary facility in the U.S. for assembling nuclear weapons (Furman 1990) and a few hundred employees worked there. TA-II currently contains shipping facilities, waste management operations, and small office buildings. At TA-II, septic water and wastewater releases to the site-specific (SWMU) features such as leach fields and seepage pits occurred prior to installation of a collection system in 1993 that was connected to the COA (now the ABCWUA) sanitary sewer system. During the Cold War, the principal structures at TA-II were Buildings 904, 907, and 919. These buildings, and all the other Cold War-era TA-II buildings, have been demolished.

Tijeras Arroyo trends across the southern AOC boundary with a defined 100-year floodplain that varies in width from approximately 2,500 to 3,000 ft. The northern rim (escarpment) of the arroyo is quite steep, with slopes averaging approximately 40 degrees. The topographic relief averages about 50 ft between the arroyo floodplain and the East Mesa on which nearby TA-II and TA-IV are located. In response to storms, surface water flows sporadically in Tijeras Arroyo approximately 12 days per year along a narrow channel that varies in width from approximately 50 to 100 ft (SNL/NM November 2005). The nearest spring (Echo Canyon Spring) is located upstream of the TAG AOC in Tijeras Canyon, approximately 4 miles east of the KAFB Eubank Gate. No springs are located within or downstream of the TAG AOC. Most of Tijeras Arroyo in the AOC is undeveloped except for utilities and roads. DOE/NTESS does not manage any occupied buildings on the floodplain near the TAG AOC.

4.1.2 KAFB Operations

KAFB controls properties with varied land uses and facilities near the TAG AOC. The land located along the northern and western sides of the TAG AOC is developed and contains base housing, office buildings, emergency response facilities, training schools, machine workshops, storage yards, a brig, a diesel-fuel tank farm, an electromagnetic research facility, and the former sewage lagoons. Bordering the southern and southeastern edges of the TAG AOC are undeveloped open spaces, active landfills, and closed landfills (Figure 4-2).

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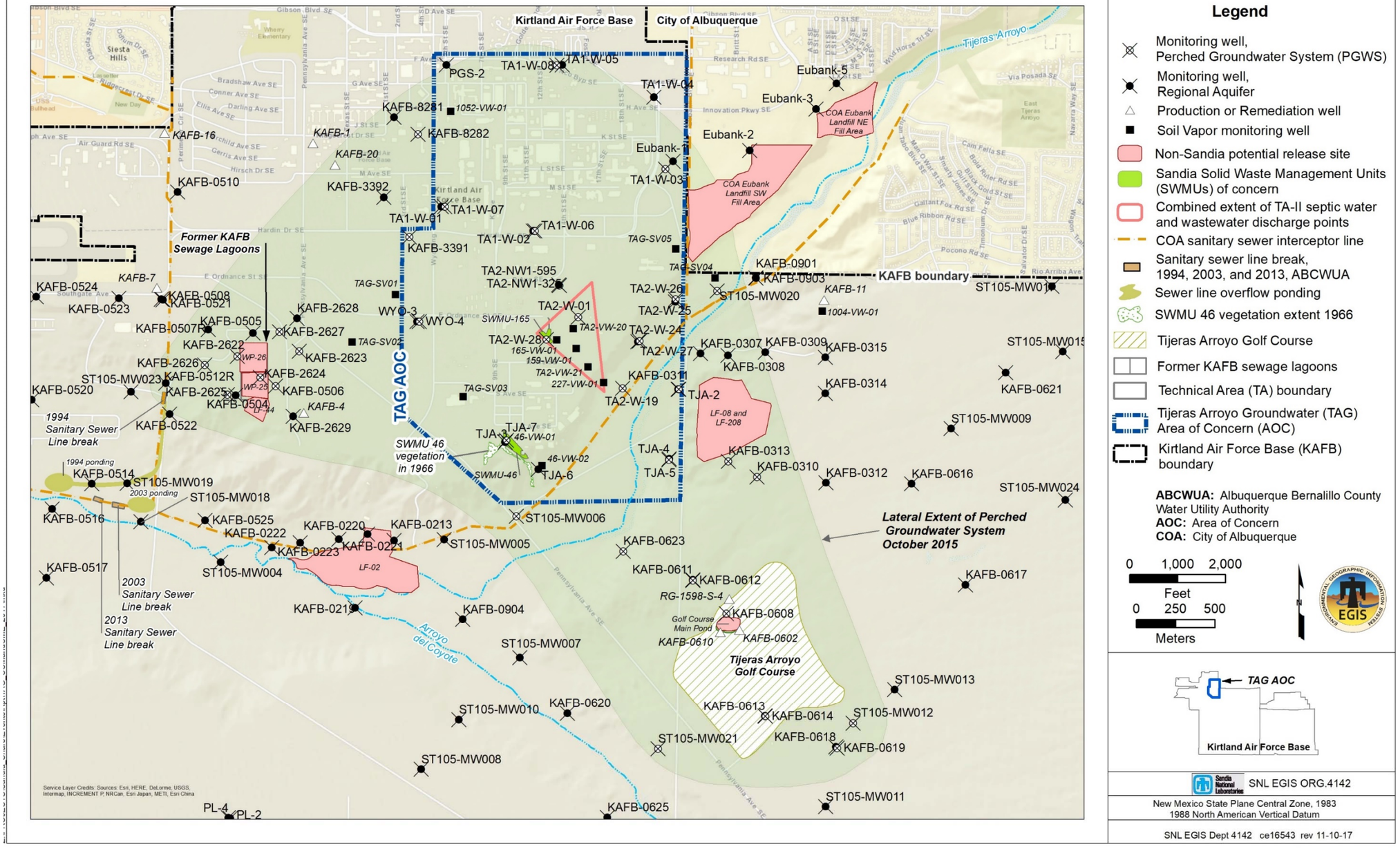


Figure 4-2
Monitoring Wells and Potential Nitrate Release Sites near the TAG AOC

The U.S. Air Force IRP manages the environmental characterization and remediation projects at KAFB. KAFB conducts groundwater investigations as part of both RCRA corrective action investigations and an NMED-mandated Nitrate Abatement Program. NMED-HWB and NMED-GWQB oversee various aspects of these projects. KAFB submits groundwater reports to the NMED on a quarterly basis (KAFB February 2005 and June 2005). Approximately forty KAFB SWMUs (formerly referred to as Corrective Action Units) are located within one mile of the TAG AOC. The SWMUs include oil/water separators, surface spills, oil-storage tanks, septic systems, drum-storage yards, ordnance-training sites, landfills, sewage lagoons, and a contractor yard (KAFB 2000b). KAFB has installed numerous monitoring wells across the area, including wells at landfills and the former sewage lagoons (Figure 4-2).

The KAFB Sewage Lagoons and the KAFB Golf Course Main Pond are a nitrate concern because 8.3 billion gallons (KAFB February 2015) of wastewater and septic water are estimated to have been disposed at the two sites. In the 1980s, nitrate was detected in water that was discharging at both the KAFB Sewage Lagoons and the Golf Course Main Pond.

The KAFB Sewage Lagoons and the Golf Course Main Pond together comprise SWMU WP-26 (Montgomery Watson August 2000). Nitrate was detected in sediment samples from the lagoons and pond. Combined, the two adjacent lagoons cover approximately 14 acres. Figure 4-2 shows the lagoons are located approximately 0.9 miles west of the TAG AOC. During the irrigation season (April through October) of the 25 years of use, approximately 330 million gallons of raw sewage was “handled” at the sewage lagoons (KAFB February 2015). Most sewage, including some industrial wastewater, percolated into the ground. KAFB operated the lagoons, which received untreated sewage from both KAFB and SNL/NM, through an interconnected sanitary sewer system. The lagoons were used seasonally during the golf-course irrigation as settling basins for the untreated (raw) sewage (Montgomery Watson August 2000). Over a period of 25 years, such a rate would equate to 8.3 billion gallons. The volume of water that percolated into the soil is not known. Some fraction evaporated and some fraction was diverted from the lagoons to the golf course. As discussed in Section 3.6, modeling results indicate that approximately half (3.8 of the 8.3 billion gallons) of the “handled” volume of septic water infiltrated through the upper vadose zone.

The 15-inch diameter pipeline that linked the former sewage lagoons with the golf course Main Pond had a rupture in 1983 that released approximately 110,000 gallons of septic water near the Pennsylvania Street Bridge (KAFB December 2004). This release site is tracked as KAFB SWMU 6-14. The pipeline had a length of 2.5 miles and was taken out of service in 1987. After refurbishment in 2015, the pipeline was returned to service for transferring treated groundwater from the BFF remediation (activated carbon) unit to the golf course.

4.1.3 ABCWUA/COA Operations

Figure 4-2 shows the Eubank Landfill, which is located approximately 0.5 miles east of the KAFB Eubank Gate and the TAG AOC. The Eubank Landfill is managed by the COA EHD and consists of two inactive disposal areas, the Northeast Fill Area and the Southwest Fill Area (COA July 2016, Earp January 2002). Section 4.4 discusses additional details for the disposal areas and a sewer interceptor line.

4.2 SNL/NM Corrective Actions in the TAG AOC

The initial environmental investigations at SNL/NM were conducted under the Comprehensive Environmental Assessment and Response Program (CEARP) (DOE September 1987). DOE/Sandia built on the CEARP findings and conducted a wide range of activities to determine the nature and extent of contamination. Site characterization for the SWMUs has included the following activities:

- Acquisition of background information/process knowledge,
- Collection of soil samples,
- Conducting passive soil-vapor surveys,
- Installation and sampling of soil-vapor monitoring wells,
- Excavation of debris at SWMUs 1, 2, 50, and 228,
- Installation and sampling of groundwater monitoring wells, and
- Conducting ongoing groundwater monitoring (sampling and measuring water levels).

The potential release sites for nitrate-impacted waters were evaluated in the TAG IR (SNL/NM November 2005). Forty-seven SWMUs are located in the TAG AOC. The IR and corresponding responses to the two NODs presented a comprehensive summary of the environmental investigations and corrective actions that were conducted by the DOE/Sandia in the TAG AOC. CAC status approval has been obtained for 24 SWMUs since the IR was submitted in November 2002. Table 4-1 shows NMED has approved CAC status for each of the 47 SWMUs (NMED January 2015). After the NMED approves an NFA proposal, the site need not be considered as an ongoing potential source of groundwater contamination (Moats November 2001). Therefore, none of SNL/NM SWMUs are suspected of being an ongoing source of groundwater contamination in accordance with NMED guidance. Table 4-1 lists the status for each site in accordance with the Hazardous Waste Facility Operating Permit (NMED January 2015). Groundwater at the TAG AOC is addressed separately in accordance with the Consent Order (NMED April 2004).

NMED has not required any additional vadose zone monitoring since the last round of soil-vapor samples were collected in January 2005. Analytical results for the VOC analyses were previously submitted in the IR (SNL/NM November 2005) and in the two NODs (SNL/NM February 2009 and January 2010). As mentioned earlier, the IR report was approved by NMED in 2010 (NMED February 2010).

Table 4-1
Corrective Action Complete Approval Dates for SWMUs in the TAG AOC
(NMED January 2015)

SWMU Number	SWMU Name	CAC Approval	With Controls
1	Radioactive Waste Landfill and SWMU 3 Chemical Disposal Pit	February 2008	Yes
2	Classified Waste Landfill	June 2006	Yes
30	Reclamation Yard	April 2005	No
32	Steam Plant Oil Spill	December 1995	No
33	Motor Pool	April 2005	No
41	Building 838 Mercury Release	December 1995	No
42	Building 870 Water Treatment Facility	September 2000	No
43	Radioactive Material Storage Yard	September 2000	No
44	44A Uranium Calibration Pits and 44B Decontamination Areas	July 2000	No
45	Liquid Discharge	February 2008	Yes
46	Old Acid Waste Line Outfall	December 2014	Yes
48	Building 904 Septic System	June 2006	No
50	Old Centrifuge Site	September 2000	No
77	Oil Surface Impoundment	July 2000	No
96	Storm Drain System	June 2006	Yes
98	Building 863 Trichloroethane and Photochemical Releases	November 2005	Yes
113	Area II Firing Sites	November 2001	No
114	Explosive Burn Pit	April 2005	No
135	Building 906 Septic System	June 2006	Yes
136	Building 907 Septic System	June 2006	No
159	Building 935 Septic System	June 2006	No
165	Building 901 Septic System	June 2006	No
166	Building 919 Septic System	June 2006	No
167	Building 940 Septic System	June 2006	No
186	Building 859 Trichloroethene (TCE) Disposal	September 2000	No
187	Technical Area (TA)-I Sanitary Sewer System	June 2006	Yes
190	Steam Plant Tank Farm	June 2006	Yes
192	TA-I Waste Oil Tank	July 2000	No
211	Building 840 Former Underground Storage Tank 840-1	September 2000	No
226	Old Acid Waste Line	June 2006	Yes
227	Building 904 Outfall	June 2006	No
228	Centrifuge Dump Site (SWMUs 228A and 228B)	September 2000 November 2001	No
229	Storm Drain System Outfall	June 2006	Yes
230	Storm Drain System Outfall (for TA-IV)	April 2005	No
231	Storm Drain System Outfall (for TA-IV)	April 2005	No
232	Storm Drain System Outfall	April 2005	No
233	Storm Drain System Outfall	July 2012	No
234	Storm Drain System Outfall	July 2012	No
235	Storm Drain System Outfall	September 2000	No
276	Former Building 829X Silver Recovery Sump	February 2008	No
1001	Building 898 Septic System (TA-I) (drain and septic system [DSS] Site 1001)	November 2005	No
1003	Former Building 915/922 Septic System (TA-II) (DSS Site 1003)	November 2005	No
1004	Building 6969 Septic System (Robotic Vehicle Range) (DSS Site 1004)	February 2008	No
1052	Building 803 Seepage Pit (TA-II) (DSS Site 1052)	February 2008	No
1101	Building 885 Septic System (TA-I) (DSS Site 1101)	December 2014	No
1102	Former Building 889 Septic System (TA-I) (DSS Site 1102)	February 2008	No

AOC = Area of Concern.
CAC = Corrective Action Complete.
NMED = New Mexico Environment Department.
SWMU = Solid Waste Management Unit.
TAG = Tijeras Arroyo Groundwater.

4.3 SNL/NM Historical Releases with the Potential to Impact Groundwater

Table 4-2 lists the years of discharge for septic water and wastewater from the TA-I and TA-II sites. Details for these sites are discussed below.

Table 4-2
SNL/NM SWMUs in the TAG AOC that Potentially Released
Water Containing Nitrogenous Compounds

SWMU Number	SWMU Name	Years of Discharge	Wastewater Source	Septic Water Source
46	SWMU 46, Old Acid Waste Line Outfall	1948–1974	TA-I	TA-I, possibly
48	SWMU 48, Building 904 Septic System	1947–1992	TA-II	TA-II
135	SWMU 135, Building 906 Septic System	1950–1992	TA-II	TA-II
136	SWMU 136, Building 907 Septic System	1948–1992	TA-II	TA-II
159	SWMU 159, Building 935 Septic System	1963–1991	TA-II	TA-II
165	SWMU 165, Building 901 Septic System	1948–1992	TA-II	TA-II
166	SWMU 166, Building 919 Septic System	1969–1990	TA-II	TA-II
167	SWMU 167, Building 940 Septic System	1965–1990	TA-II	TA-II
187	SWMU 187, TA-I Sanitary Sewer System	1948–Present	TA-I	TA-I
227	SWMU 227, Building 904 Outfall	1947–1992	TA-II	None
229	SWMU 229, Storm Drain System Outfall	1947–1992	TA-II	None

AOC = Area of Concern.
SNL/NM = Sandia National Laboratories, New Mexico.
SWMU = Solid Waste Management Unit.
TA = Technical Area.
TAG = Tijeras Arroyo Groundwater.

4.3.1 SWMU 46 (Old Acid Waste Line Outfall)

During 1947 to 1974, an estimated 1.3 billion gallons of wastewater from six TA-I buildings discharged sequentially into three outfall ditches (SWMU 46) at the southern end of a buried 8-inch diameter sewer line (SWMU 226). The line ended approximately 700 ft to the north of the arroyo rim in a relatively flat area. Initially, one ditch was used, but the ditch was prone to becoming clogged with weeds and aeolian sand, so two additional ditches were constructed. Each ditch was about 3-ft deep, 5-ft wide, and about 700-ft long.

The amount of water that discharged from the wastewater line was not metered or routinely documented. The CEARP (DOE September 1987) is the only historical document that cites a wastewater discharge rate. The cited rate was 130,000 gallons of acid wastewater per day (DOE September 1987) and presumably applies to the last year of operation. Assuming that this rate is applicable for the entire 27 years of operation, the cumulative discharge could have been approximately 1.3 billion gallons of wastewater. This total conservatively assumes that the daily rate applied to each day of year, neglecting weekends and holidays. Field inspections and review of historical aerial photography have not identified a significant amount of erosion where the line discharged. However, the amount of water was sufficient to create vegetation that extended for approximately 1,400 ft to the south and southwest of the ditch end points (Figure 4-3).

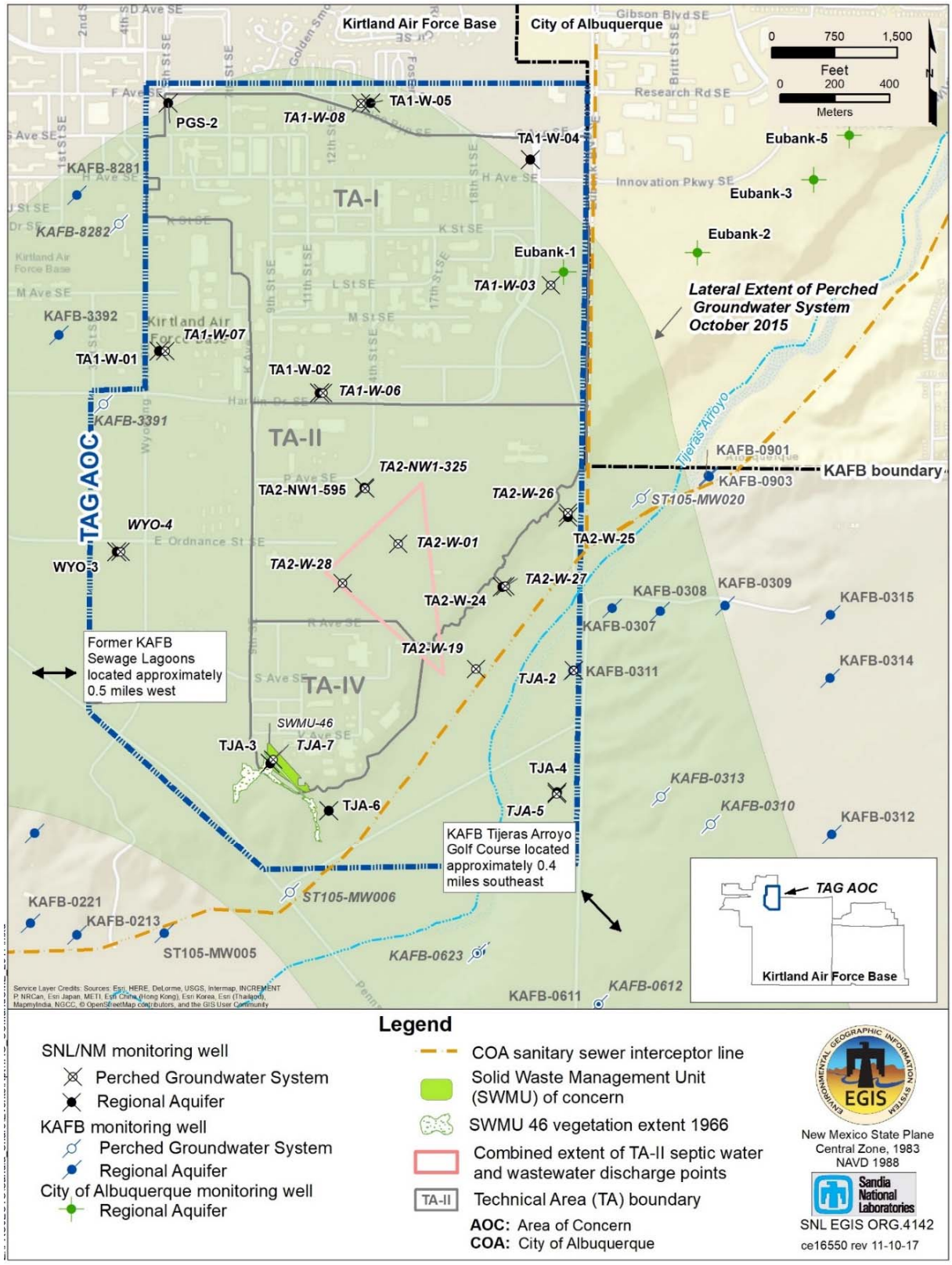


Figure 4-3
Potential Nitrate Release Sites in the TAG AOC

The wastewater may have contained nitric and other acids from chemistry laboratories and possibly nitrate from inadvertent plumbing cross-connects between the buried SWMU 226 line and nearby sanitary sewer lines in TA-I. The disposal of large amounts of TA-I water containing nitrate at SWMU 46 is possible, but not highly probable. The disposal of significant amounts of septic waste into open ditches was unlikely to have occurred because of obvious odor and health issues. However, inadvertent cross-connects at various sewer lines have been uncovered in TA-I. Similar cross-connects may have led to sanitary waste entering the Acid Waste Line (SWMU 226) and thus discharging at SWMU 46. The wastewater may have contained dilute concentrations of nitric acid. However, nitric acid would likely not have been persistent at SWMU 46. Nitric acid is photosensitive and exposure to sunlight in the outfall ditches would have degraded the acid. The soils in the TAG AOC vicinity are alkaline with caliche layers, which would have likely neutralized the acid solutions to some degree.

4.3.2 Multiple SWMUs at TA-II

From 1947 to 1992, numerous leach fields, seepage pits, and dry wells were used at TA-II to dispose of sanitary waste and wastewater. The water was derived from a variety of operations including a shower/laundry facility, restrooms in several buildings, small research laboratories, and a machine shop. These releases occurred prior to installation of a sanitary sewer collection system in 1993. TA-II had seven wastewater disposal sites and six septic disposal sites (SNL/NM August 1994). The TA-II septic systems were excavated to confirm the locations of distribution boxes and leach fields (Galloway 2001a, 2001b). Individually, these disposal sites had a small areal extent, such as seepage pits, that were only 5 ft in diameter. Figure 4-3 depicts a triangular area that contains all of the disposal sites.

SWMUs 48 and 136 were designed to handle more water than other TA-II systems. Instead of only being connected to buried disposal components (leach fields, seepage pits, and/or dry wells), these two SWMUs also discharged into open ditches. The disposal ditches were used only for the disposal of wastewater, not septic water, because of the obvious odor and health problems inherent in exposure to sanitary waste.

During the Cold War, the historical 45-acre, diamond-shaped fenced area contained about 25 structures consisting of small research laboratories, storage yards, warehouses, office trailers, and shipping facilities. A few hundred workers were employed at TA-II during this era. Several phases of excavation work were conducted at TA-II as part of voluntary corrective measures including the excavation of two small landfills (the Radioactive Waste Landfill - SWMU 1, and the Classified Waste Landfill - SWMU 2). Debris was also excavated to the east of TA-II at SWMUs 50 and 228. As mentioned above, CAC was approved for these SWMUs.

No SNL/NM testing or disposal activities involving HE material are suspected of releasing nitrate to the environment. The potential for HE to degrade to nitrate in this area is low because of the lack of detected HE compounds in soil samples collected at TA-II SWMUs (for example, SWMUs 113 and 114). Furthermore, plastic explosives do not typically contain nitrate-based compounds. All TA-II sites have been approved for CAC status.

4.3.3 TA-I Sanitary Sewer System (SWMU 187)

Construction of the TA-I sanitary sewer system (SWMU 187) began in 1948. The sanitary sewer system is connected to numerous buildings in TA-I and is tied into the KAFB sewer system that

discharged at the sewage lagoons from 1966 to 1987 before being connected to the ABCWUA system. Over the years, the TA-I sanitary sewer system has been expanded and upgraded. However, the buried lines may have leaked septic water in the subsurface and may possibly have had inadvertent plumbing cross-connects with wastewater lines. As detailed in the NFA proposal, numerous soil samples were collected at locations along the buried lines. No significant contamination was identified concerning potential groundwater contamination. CAC status was approved in June 2006 for SWMU 187.

4.4 Federal SWMUs and Municipal Sites with Potential for Creating Groundwater Contamination

Table 4-3 summarizes the nitrate release sites that have potentially affected groundwater near the TAG AOC. The table lists 11 SNL/NM sites previously discussed above in this section. Also discussed are 14 sites owned by KAFB, 4 sites owned by the COA and ABCWUA, and 4 off-base sites. Table 4-3 also summarizes details for each site, such as the types of water, years of operation, and relevant comments.

Of particular concern is the ABCWUA sanitary-sewer interceptor line that crosses the TAG AOC (Figure 4-3). This 24-inch concrete line trends along the arroyo floor and passes near monitoring wells TA2-W-19 and TJA-6. To the west of the TAG AOC, this line has experienced three known structural failures (1994, 2003, and 2013) where the line diameter is 96 inches. The corrosive effect of sewer gases upon the concrete line is suspected of causing the failure.

In 1994, approximately 100 million gallons spilled from a line break and created ponding on the floodplain (Figure 4-2) (Montgomery Watson August 2000). Some portion of the sewage was pumped back into the sewer system, but an unknown volume was allowed to evaporate or infiltrate. Deposits consisting of sewage sludge were 2 to 3 ft thick in some places. Inspection of the sewer line revealed that leakage may have occurred for a prolonged time before rupturing. This suggests that septic leakage from sanitary-sewer lines may be an ongoing problem elsewhere.

A sewer-line break in 2003 also caused ponding, and a 2013 break created sinkholes, but no ponding (KAFB April 2014). In a 2009 letter, KAFB requested that the ABCWUA supply their ‘sewage line inspection reports’ because of the Air Force’s concern that leaking lines were contaminating groundwater (KAFB July 2009). To date, this ongoing concern has not been addressed by the ABCWUA.

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Table 4-3
Potential Nitrate Release Sites that may have Impacted Groundwater near the TAG AOC

Potential Source of Nitrate	Years of Use	Type of Water Release	Summary of Process Knowledge
SNL/NM SWMU 46, Old Acid Waste Line Outfall	1948 to 1974	TA-I wastewater and possibly septic water	Estimated 1.3 billion gallons of wastewater from six TA-I research/office buildings (839, 840, 841, 860, 863, 892) discharged year-round into the three outfall ditches (SWMU 46) at the south end of SWMU 226. Septic water from possible cross-connects between the SWMU 226 waste line and sewer lines may have discharged at SWMU 46. During 1948 through 1974, the average number of employees per year was 5,693.
SNL/NM SWMU 48, Building 904 Septic System	1947 to 1992	TA-II septic and wastewater	Two types of systems were connected to large research/office Building 904. First system (leach field/seepage pit) discharged septic water near center of TA-II. Second system (pair of outfall ditches at SWMUs 227 and 229) discharged wastewater outside the southern apex of TA-II.
SNL/NM SWMU 135, Building 906 Septic System	1950 to1992	TA-II wastewater	Leach field (dry well previously) for wastewater was connected to small research Building 906.
SNL/NM SWMU 136, Building 907 Septic System	1948 to1992	TA-II septic and wastewater	Two systems connected to large research/office Building 907. First system (leach field/seepage pit) discharged septic water west of Building 907. Second system (ditch in center of TA-II) discharged wastewater.
SNL/NM SWMU 159, Building 935 Septic System	1963 to 1991	TA-II waste and septic water	Dry wells and seepage pit connected to small research/office Building 935.
SNL/NM SWMU 165, Building 901 Septic System	1948 to 1992	TA-II septic and wastewater	Leach field connected to personnel shower/laundry facility (Building 901) and small research/machine shop Building 902.
SNL/NM SWMU 166, Building 919 Septic System	1969 to 1990	TA-II waste and septic water	Leach field, seepage pit, and dry well connected to large office/research Building 919.
SNL/NM SWMU 167, Building 940 Septic System	1965 to 1990	TA-II waste and septic water	Seepage pits connected to small research/office Building 940.
SNL/NM SWMU 187, TA-I Sanitary Sewer System	1948 to present	TA-I septic and wastewater	Possibly leaking sewer lines and several cross-connects with wastewater lines. System connected to numerous research/office buildings in TA-I.
SNL/NM SWMU 227, Building 904 Outfall	1947 to 1992	TA-II wastewater	Wastewater from SWMU 48 system discharged into outfall ditch at SWMU 227. The volume of wastewater is unknown, but is estimated from historical aerial photography to have been just a small percentage of what was discharged at SWMU 46.
SNL/NM SWMU 229, Storm Drain System Outfall (second outlet for Building 904 Outfall)	1947 to 1992	TA-II wastewater	Wastewater from SWMU 48 discharged into outfall ditch at SWMU 229. The site name is misleading. The volume of wastewater is unknown, but is estimated from historical aerial photography to have been a small percentage of what was discharged at SWMU 46.
KAFB Sewage Lagoons	1962 to 1987	KAFB and TA-I septic and wastewater	During the irrigation season (April through October) of the 25 years of use, approximately 330 million gallons of raw sewage was handled at the sewage lagoons (KAFB February 2015). Together, the two lagoons covered 14 acres. Most of the sewage, including some industrial wastewater percolated into the ground. One reference states that a small portion of the water was piped to the golf course Main Pond (Montgomery Watson August 2000). However, KAFB (February 2015) states that 40 to 100 percent of the 8.3 billion gallons of raw sewage was diverted from the lagoons to the pond during 1962 to 1987. The modeling conducted by BGW (September 2002) indicates that 3.8 billion gallons of water (approximately 46 percent of the 8.3 billion gallons) percolated into the ground beneath the lagoons.
KAFB Golf Course Main Pond	1966 to 1987	KAFB and TA-I septic water and wastewater	A 2.6-acre lined pond was built in 1962 and received raw sewage from the sewage lagoons until 1987. The 15-inch diameter transfer line had a rupture in 1983. The sewage water was blended with stormwater and KAFB-4 potable water, and was used for turf irrigation (Montgomery Watson August 2000; KAFB February 2015). The pond and liner were refurbished in 1998 and currently stores groundwater obtained from a nearby remediation well. Three nearby monitoring wells were converted in 1999 to operate as remediation wells. This groundwater was blended with KAFB-4 potable water and used for turf irrigation. Groundwater obtained from nitrate-recovery well KAFB-7 was also used. Starting in 2016, treated groundwater from the BFF remediation project has been piped to the pond.
KAFB Golf Course Club House	1966 to present	Septic	Sanitary waste from the clubhouse discharges into a leach field at the Tijeras Arroyo Golf Course.
KAFB Golf Course Fertilization	1966 to present	Irrigation	Ongoing application of fertilizer to fairways and greens at 18-hole golf course and the driving range.
KAFB Sanitary Sewer Lines	1940s to present	KAFB septic water	Leaking sewers lines are possibly an ongoing problem across KAFB in a manner similar to most municipal systems.
KAFB Landfill LF-02	1945 to 1967	Leachate	Industrial and residential waste, landscape debris; unlined landfill covers 50 acres (KAFB 2000a). Estimated debris volume is 1,000,000 cubic yards.
KAFB Landfill LF-08	1960 to 1989	Leachate	Industrial and residential waste, landscape debris, unlined landfill covers 30 acres; Estimated debris volume is 600,000 cubic yards (KAFB 2000a).
KAFB Landfill LF-44	1979 to 1988	Leachate	Landscape debris; unlined landfill covers 2 acres; debris volume is not known. Most debris removed in 1992 and 1993 (KAFB 2000a).
KAFB Landfill LF-268	1989 to present	Leachate	Construction/demolition debris, landscape debris; landfill covers 45 acres; debris volume is not known (KAFB 2000a).
KAFB Horse Stables	1950s? to 2006	Septic water	Two types of waste: manure spreading and a leach field for sanitary waste from office trailer. Located approximately 0.7 miles southeast of the Tijeras Arroyo Golf Course. Nearby radioactive-waste disposal trenches were excavated in 2009 to 2011.
Oxnard Field and Sandia Air Base	1928 to 1950s		Scattered septic systems were likely used across what is now operational areas for KAFB and SNL/NM. Historical uses for barracks, machine shops, offices, aircraft parking, and post World War II aircraft smelting extended across approximately 1.3 square miles.
KAFB Manzano Base Operations	1950s to 1992	Septic water	Prior to 1993, sanitary waste from the Central Training Academy was discharged to the ground surface approximately 0.8 miles southeast of the golf course.
KAFB Manzano Base Construction	1950s	Stormwater	Excavating and blasting (ammonium nitrate fuel/oil [ANFO] and dynamite?) associated with construction of storage bunkers in granite may have left residual explosive material that has degraded to nitrate. Misfires typically occur in blasting work resulting in scattered explosives in the muck.
ABCWUA Sanitary-Sewer Interceptor Line Breaks / Temporary Sewage Ponds	1994, 2003, 2013	ABCWUA septic water	Approximately 100 million gallons spilled from sewer-line break in 1994 created ponding on the floodplain. An unknown volume of septic water recovered from temporary pond on floodplain (Montgomery Watson August 2000). A sewer-line break in 2003 caused ponding and a 2013 break created sinkholes but no ponding (KAFB April 2014).
COA Eubank Landfill – Northeast Fill Area	1963 to 1973	Stormwater and septic water	Northeast Fill Area covers approximately 21 acres with a waste thickness ranging from 30 to 40 ft (COA July 2016). Residential and industrial waste was dumped in unlined landfill (Nelson June 1997). Landfill covers 27 acres, waste depth of 30 to 40 ft. Estimated debris volume is 1,000,000 cubic yards. Residential sewage lagoons were used nearby for mobile home park (CH2M Hill April 1996). The Perched Groundwater System does not extend under the landfill.
COA Eubank Landfill – Southwest Fill Area	1974 to 1984	Stormwater	Southwest Fill Area covers approximately 27 acres with a waste thickness ranging from 36 to 40 ft. Residential and industrial waste was dumped in unlined landfill (Nelson June 1997). Landfill covers 60 acres; maximum waste depth of 36 to 40 ft. Volume of debris is unknown (Daniel B. Stephens & Associates [DBS&A] April 2002).

Refer to footnotes at end of table.

Table 4-3 (Concluded)
Potential Nitrate Release Sites that may have Impacted Groundwater near the TAG AOC

Potential Source of Nitrate	Years of Use	Type of Water Release	Summary of Process Knowledge
ABCWUA Sanitary Sewer Lines	1940s to present	Septic water	Leaking sewer lines may be ongoing problem near the base.
COA Montessa Park/Tree Nursery	1950s to present	Septic water/ Irrigation water	Sewage lagoon used at Montessa Park Correctional Facility. Irrigation ponds and fertilizer used at tree nursery operated by U.S. Department of Agriculture from approximately 1959 until mid-1990s. In the 1950s, farming activities (manure spreading) used up to 10 tons per acre per year of manure (Gould 1992). The Perched Groundwater System does not extend as far west as Montessa Park.
Canyon Club (formerly Four Hills Golf Course)	1960s? to present	Irrigation water	Western edge of golf course is located approximately 1.7 miles east of the Eubank Gate. Fairways and greens are typically heavily watered and fertilized.
Gulton Industries	1956 to 1979	Wastewater	Electronics plant discharged wastewater containing chlorinated solvents and heavy metals into leach fields and unlined evaporation lagoons. Groundwater contamination, primarily TCE, detected in samples from monitoring wells (Carlson February 2011), but distant at approximately 2.8 miles east-northeast of the Eubank Gate.
Cement Plant / Limestone Quarry	1950s to present	Stormwater	In operation since the 1950's, the cement plant uses locally excavated limestone. The plant is located approximately 6.8 miles east-northeast of the Eubank Gate. The blasting uses ammonium nitrate fuel. Aerial photography show that 10 to 15 ft grids are commonly used to blast the limestone strata.
Carnuel community in Tijeras Canyon	1793 to present	Septic Water	Small community of approximately 1,200 people with no centralized sewage handling system or treatment plant. Homes have septic systems, but are distant at approximately 2.8 miles east-northeast of the Eubank Gate. McQuillan (April 2016) reported NPN concentrations up to 132 mg/L in domestic well water.

Notes:
ABCWUA = Albuquerque Bernalillo County Water Utility Authority.
AOC = Area of Concern.
BFF = Bulk Fuels Facility.
bgs = Below ground surface.
BGW = Balleau Groundwater, Inc.
COA = City of Albuquerque.
ft = Foot (feet).
KAFB = Kirtland Air Force Base.
LF = Landfill.
mg/L = Milligrams per liter.
NPN = Nitrate plus nitrite.
SNL/NM = Sandia National Laboratories, New Mexico.
SWMU = Solid Waste Management Unit.
TA = Technical Area.
TAG = Tijeras Arroyo Groundwater.
TCE = Trichloroethene.

5.0 GROUNDWATER MONITORING AT THE TAG AOC

Groundwater quality in the TAG AOC has been monitored since November 1992. The SNL/NM monitoring well network was discussed previously in Section 3.2. Supplementing the corresponding analytical database for the SNL/NM monitoring wells are the nearby monitoring wells that are sampled by KAFB and the COA EHD. Figure 5-1 shows the set of monitoring wells used for evaluating the distribution of NPN in the two water-bearing units (the Perched Groundwater System and the Regional Aquifer).

5.1 Nitrate

Nitrate is a COC for the TAG AOC. The MCL for nitrate is 10 mg/L. NMED has specified 4 mg/L as the maximum approved background value for nitrate at KAFB, including SNL/NM (Dinwiddie September 1997). The presence of nitrogen in water may be reported by analytical laboratories in various formats such as nitrate, nitrite, NPN, total nitrogen, or Total Kjeldahl Nitrogen. Care must be taken in evaluating nitrogen values. Dinwiddie (September 1997) set a NPN background concentration of 4 mg/L for SNL/NM based upon Moats and Winn (January 1995). However, this value was not “reliably established” (Moats and Winn January 1995). The KAFB Nitrate Abatement Program uses the background NPN concentration of 4 mg/L (Montgomery Watson August 2000).

Historical groundwater analyses have demonstrated that nitrite concentrations are below method detection limits and are considered as non-contributory to the analytical results of NPN analyses. Therefore, NPN (as nitrogen) results are used directly to represent nitrate concentrations in this report. The NPN analytical results discussed in this section were obtained from off-site certified laboratories that consistently use EPA Method 353.2 (or its equivalent).

In 2015, DOE/Sandia sampled 21 monitoring wells at the TAG AOC. KAFB sampled an additional 10 monitoring wells in the vicinity including SNL/NM well TJA-5. The COA EHD also sampled four nearby monitoring wells (Table 5-1). Table 3-2 lists the sampling frequencies.

Figure 5-1 shows the sampling frequency for the SNL/NM wells. Each well is sampled at a frequency (either quarterly, semiannually, or annually) in accordance with a variety of approved work plans. In light of the August 2017 meeting, Figure 5-1 shows that DOE/NTESS does not anticipate sampling well WYO-4 in 2018 or later years. Responsibility for this well is anticipated to transfer to the KAFB ERP.

Table 5-1 lists the maximum NPN concentrations for 2015. For a historical perspective, Figure 5–2 presents a time-series plot of NPN concentrations in groundwater samples collected from SNL/NM monitoring wells since 1998. The *Annual Groundwater Monitoring Reports* provide complete analytical data results and discussions.

For 2015, the maximum NPN concentrations per well ranged from 3.56 to 27.8 mg/L in the Perched Groundwater System at the TAG AOC. Nearby KAFB monitoring wells had NPN concentrations up to 70 mg/L.



Figure 5-1
Monitoring Wells Used for Sampling Purposes by Personnel from
SNL/NM, KAFB, and the COA EHD near the TAG AOC prior to 2018

Table 5-1
Maximum NPN Concentration for 2015 Groundwater Samples from
Monitoring Wells near the TAG AOC

Monitoring Well	Maximum NPN Concentration in 2015 (mg/L)	Screened Interval (ft bgs)	Data Source
Perched Groundwater System			
TA1-W-03	7.99	337.0 – 357.0	SNL/NM June 2016
TA1-W-06	3.76	300.0 – 320.0	SNL/NM June 2016
TA1-W-07	3.2[a]	268.6 – 288.6	SNL/NM database 2016
TA1-W-08	8.01	302.0 – 322.0	SNL/NM June 2016
TA2-NW1-325	3.9[a]	295.0 – 325.0	SNL/NM database 2016
TA2-W-01	5.38	312.0 – 332.0	SNL/NM June 2016
TA2-W-19	**12.8**	265.9 – 285.9	SNL/NM June 2016
TA2-W-26	6.7	276.0 – 296.0	SNL/NM June 2016
TA2-W-27	4.58	275.0 – 295.0	SNL/NM June 2016
TA2-W-28	**27.8**	310.5 – 330.5	SNL/NM June 2016
TJA-2	**13.4**	275.0 – 295.0	SNL/NM June 2016
TJA-5	**26**	267.0 – 287.0	KAFB December 2015
TJA-7	**25.0**	290.5 – 310.5	SNL/NM June 2016
WYO-4	3.56	275.0 – 295.0	SNL/NM June 2016
KAFB-0612	**25**	290.0 – 315.0	KAFB December 2015
KAFB-0623	**63**	265.0 – 290.0	KAFB December 2015
ST105-MW006	**70**	228.0 – 248.0	KAFB December 2015
ST105-MW020	5.6	281.0 – 301.0	KAFB December 2015
Regional Aquifer			
Eubank-1	2.0	550.0 – 610.0	COA September 2016
Eubank-2	1.2	552.0 – 592.0	COA September 2016
Eubank-3	1.9	590.0 – 650.0	COA September 2016
Eubank-5	3.6	605.0 – 665.0	COA September 2016
PGS-2	1.56	535.0 – 565.0	SNL/NM June 2016
TA1-W-01	2.69	575.0 – 595.0	SNL/NM June 2016
TA1-W-02	1.15	540.0 – 560.0	SNL/NM June 2016
TA1-W-04	2.04	576.0 – 596.0	SNL/NM June 2016
TA1-W-05	1.29	597.5 – 617.5	SNL/NM June 2016
TA2-NW1-595	4.03	535.0 – 555.0	SNL/NM June 2016
TJA-3	2.76	496.0 – 516.0	SNL/NM June 2016
TJA-4	**33.0**	360.0 – 380.0	SNL/NM June 2016
TJA-6	2.80	454.9 – 474.6	SNL/NM June 2016
WYO-3	2.41	520.0 – 540.0	SNL/NM June 2016
TA2-W-24	2.8[a]	465.0 – 485.0	SNL/NM database 2016
TA2-W-25	2.1[a]	492.0 – 512.0	SNL/NM database 2016
KAFB-0307	7.9	405.0 – 450.0	KAFB December 2015

Refer to footnotes at end of table.

Table 5-1 (Concluded)
Maximum NPN Concentration for 2015 Groundwater Samples from
Monitoring Wells near the TAG AOC

Monitoring Well	Maximum NPN Concentration in 2015 (mg/L)	Screened Interval (ft bgs)	Data Source
Regional Aquifer (Continued)			
KAFB-0312	**17**	503.0 – 528.0	KAFB December 2015
KAFB-0314	5.4	428.0 – 448.0	KAFB December 2015
KAFB-0315	6.8	447.0 – 472.0	KAFB December 2015
KAFB-0611	**12**	498.0 – 508.0	KAFB December 2015

Notes:
[a] Value from 2002. The well is not routinely sampled.
Bold value exceeds the nitrate MCL (10 mg/L).
Analytical method is EPA 353.2. The SNL/NM and KAFB contract laboratories have differing reporting requirements.
AOC = Area of Concern.
bgs = Below ground surface.
ft = Foot (feet).
EPA = U.S. Environmental Protection Agency.
KAFB = Kirtland Air Force Base.
mg/L = Milligrams per liter.
NPN = Nitrate plus nitrite.
PGS = Parade Ground South (monitoring well designation).
SNL/NM = Sandia National Laboratories, New Mexico.
TA1-W = Technical Area-I (Well) (monitoring well designation).
TA2-NW = Technical Area-II (Northwest) (monitoring well designation).
TA2-SW = Technical Area-II (Southwest) (monitoring well designation).
TA2-W = Technical Area-II (Well) (monitoring well designation).
TAG = Tijeras Arroyo Groundwater.
TJA = Tijeras Arroyo (monitoring well designation).
WYO = Wyoming (monitoring well designation).

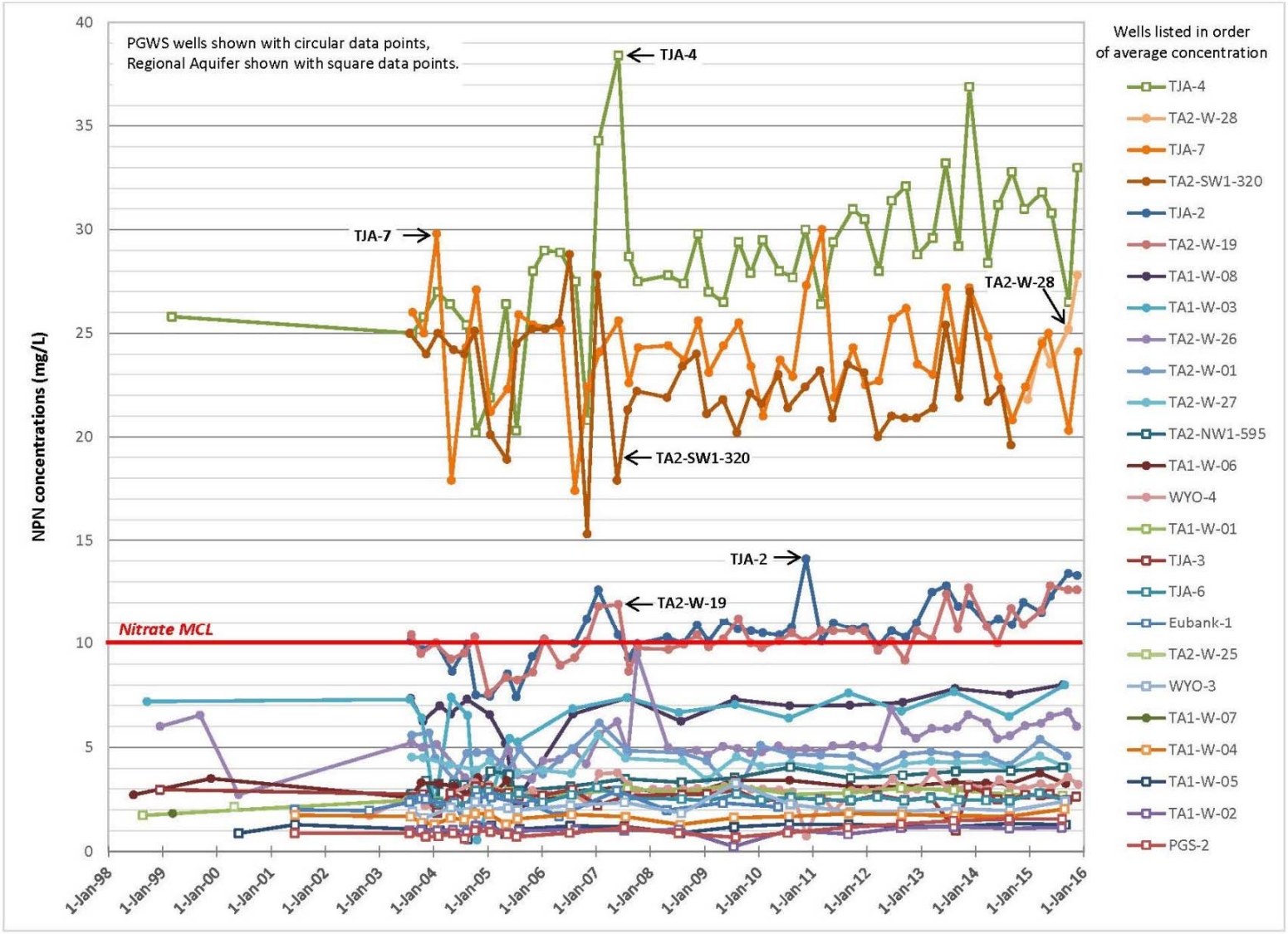


Figure 5–2
Time-Series Plot of NPN Concentrations in Groundwater Samples Collected from SNL/NM Monitoring Wells in the TAG AOC

The maximum historical concentration of NPN reported for the Perched Groundwater System within the TAG AOC is 27.8 mg/L was obtained from monitoring well TA2-SW1-320 in January 2007. Due to casing integrity issues, this well was replaced by well TA2-W-28 in December 2014. Coincidentally, replacement well TA2-W-28 has had a maximum NPN concentration of 27.8 mg/L. This maximum occurred in November 2015.

Except for well TJA-4, the NPN concentrations in the Regional Aquifer ranged from 1.15 to 4.03 mg/L in 2015. These concentrations are below the nitrate MCL (10 mg/L) and within the range of natural nitrate background concentrations (Moats and Winn January 1995). Monitoring well TJA-4 is located in the extreme southeast corner to the TAG AOC and based on its intermediate groundwater elevations, is believed to be screened in a merging zone and not representative of the Regional Aquifer. Well TJA-4 had a maximum 2015 NPN concentration of 33.0 mg/L.

5.2 Nature and Extent of Nitrate Contamination

In addition to the SNL/NM analytical results, data from KAFB and the COA EHD were used to create Figures 5-3 and 5-4 showing NPN concentrations detected in the Perched Groundwater System and the Regional Aquifer, respectively. Data from these additional monitoring wells help evaluate the distribution of NPN concentrations in the two water-bearing units. Table 5-1 lists the NPN analytical results obtained from KAFB and the COA EHD for the 2015 samples.

DOE/SNL M&O contractor personnel have routinely sampled four of the five Perched Groundwater System wells where the nitrate MCL is exceeded (TA2-W-19, TA2-SW1-320 [replacement TA2-W-28], TJA-2, and TJA-7). KAFB samples SNL/NM well TJA-5. On Figure 5-3, a red line defines the western and northern area within the TAG AOC, which exceeds the MCL. Wells to the southeast (and downgradient) of SNL/NM release sites have greater NPN concentrations. Higher NPN concentrations in the Perched Groundwater System are evident at wells located downgradient of the TAG AOC. Monitoring well ST105-MW006 had a NPN concentration of 70 mg/L and well KAFB-0623 had a NPN concentration of 63 mg/L. These two wells were installed by KAFB for their nitrate-abatement program (KAFB December 2015).

5.3 Time-Series Plots of NPN Concentrations in Groundwater

Figures 5-5 through 5-8 shows detailed time-series plots for SNL/NM wells TA2-W-19, TA2-SW1-320/TA2-W-28, TJA-2, and TJA-7. These four wells are screened in the Perched Groundwater System and have consistently exceeded the MCL. Table 5-2 lists an evaluation of the trends for NPN concentrations and groundwater elevations for the Perched Groundwater System. Groundwater elevations are consistently declining while NPN trends are either relatively stable or are slightly increasing. No correlation is apparent between trends in groundwater elevations and NPN concentrations.

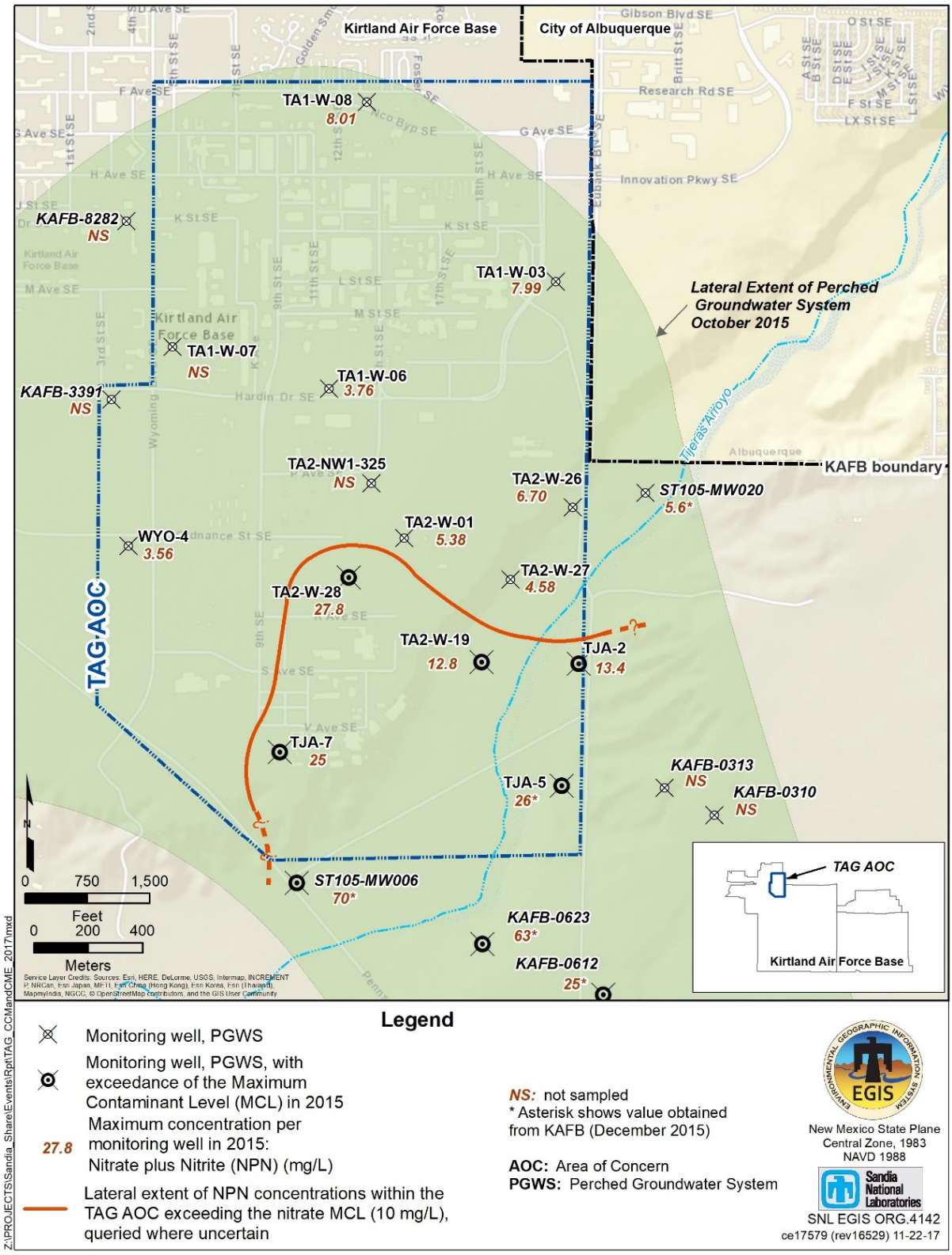


Figure 5-3
Maximum NPN Concentrations in Groundwater Samples Collected in 2015 from Monitoring Wells Screened in the Perched Groundwater System

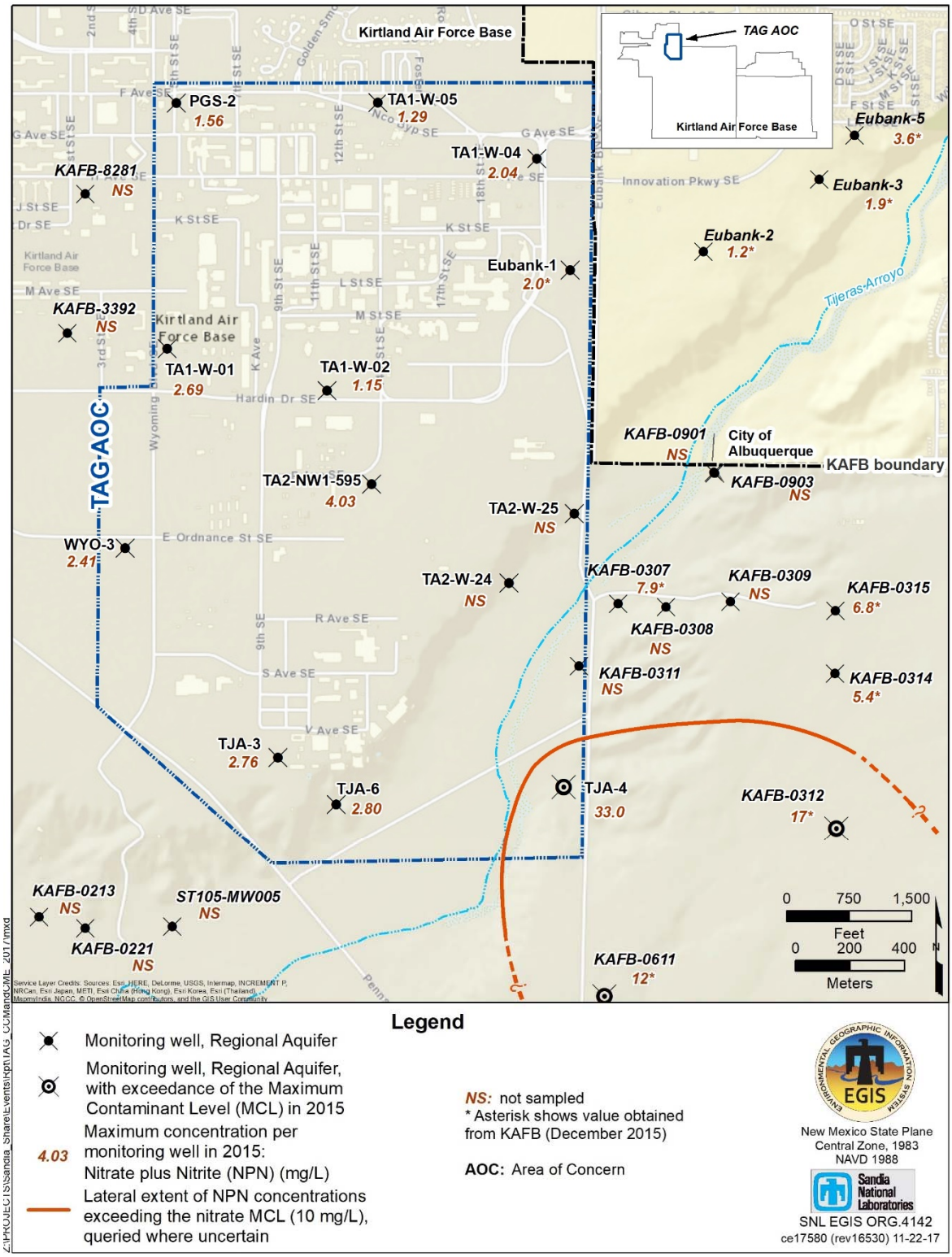


Figure 5-4
Maximum NPN Concentrations in Groundwater Samples Collected in 2015 from Monitoring Wells Screened in the Regional Aquifer

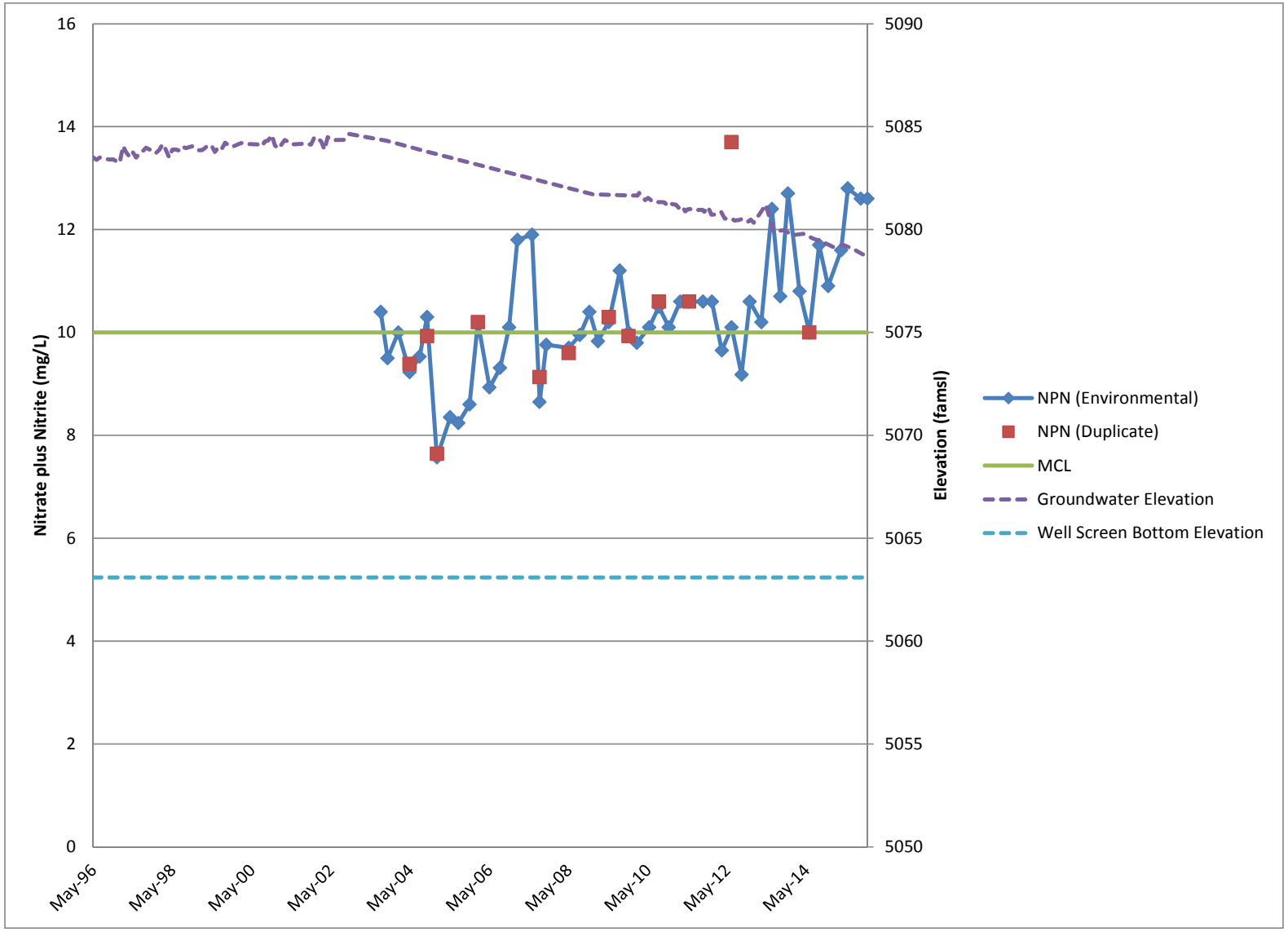


Figure 5–5
Time-Series Plot of NPN Concentrations in Perched Groundwater Samples Collected from Monitoring Well TA2-W-19

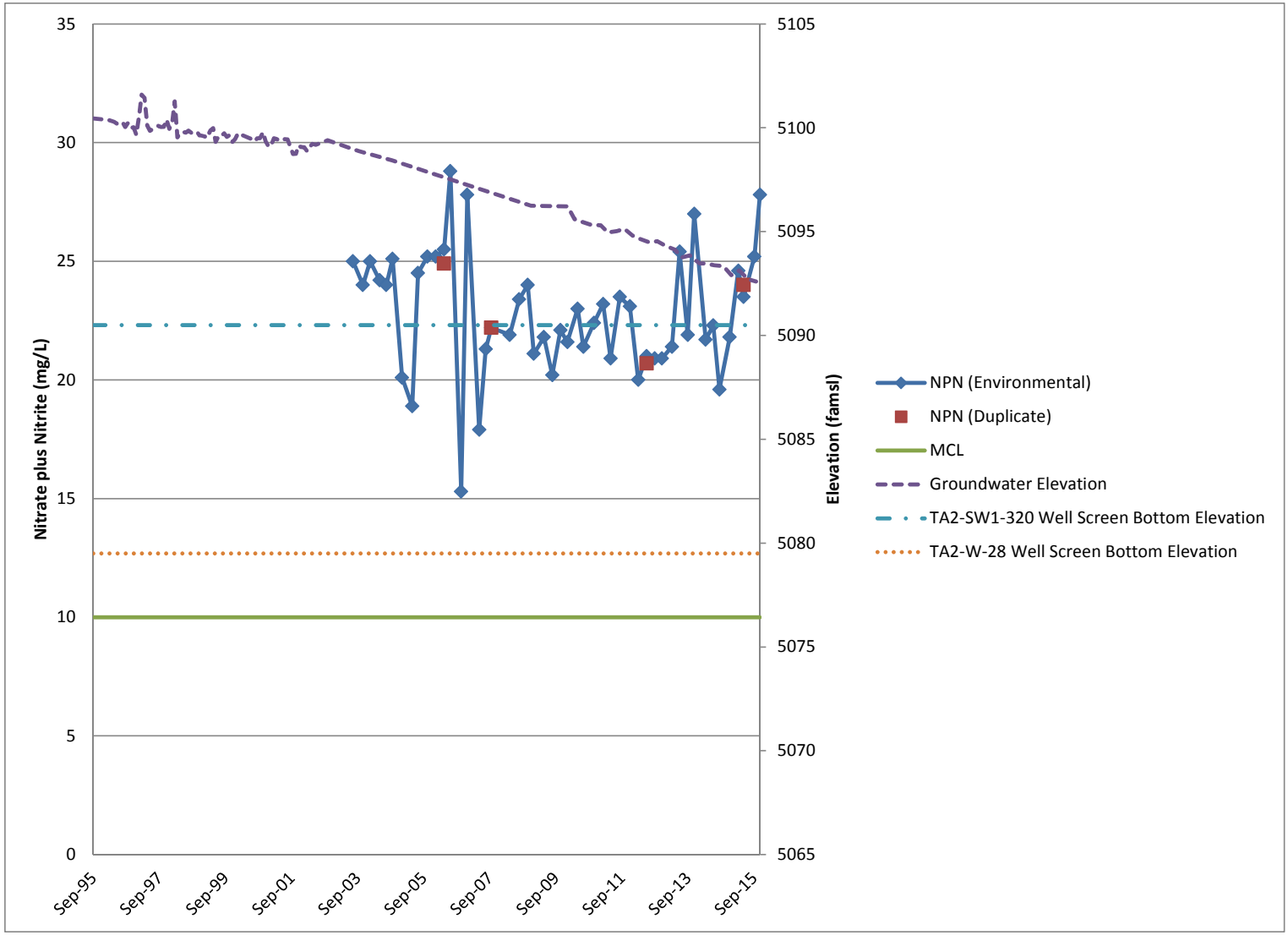


Figure 5–6
Time-Series Plot of NPN Concentrations in Perched Groundwater Samples Collected from Monitoring Wells TA2-SW1-320 and TA2-W-28 (replacement)

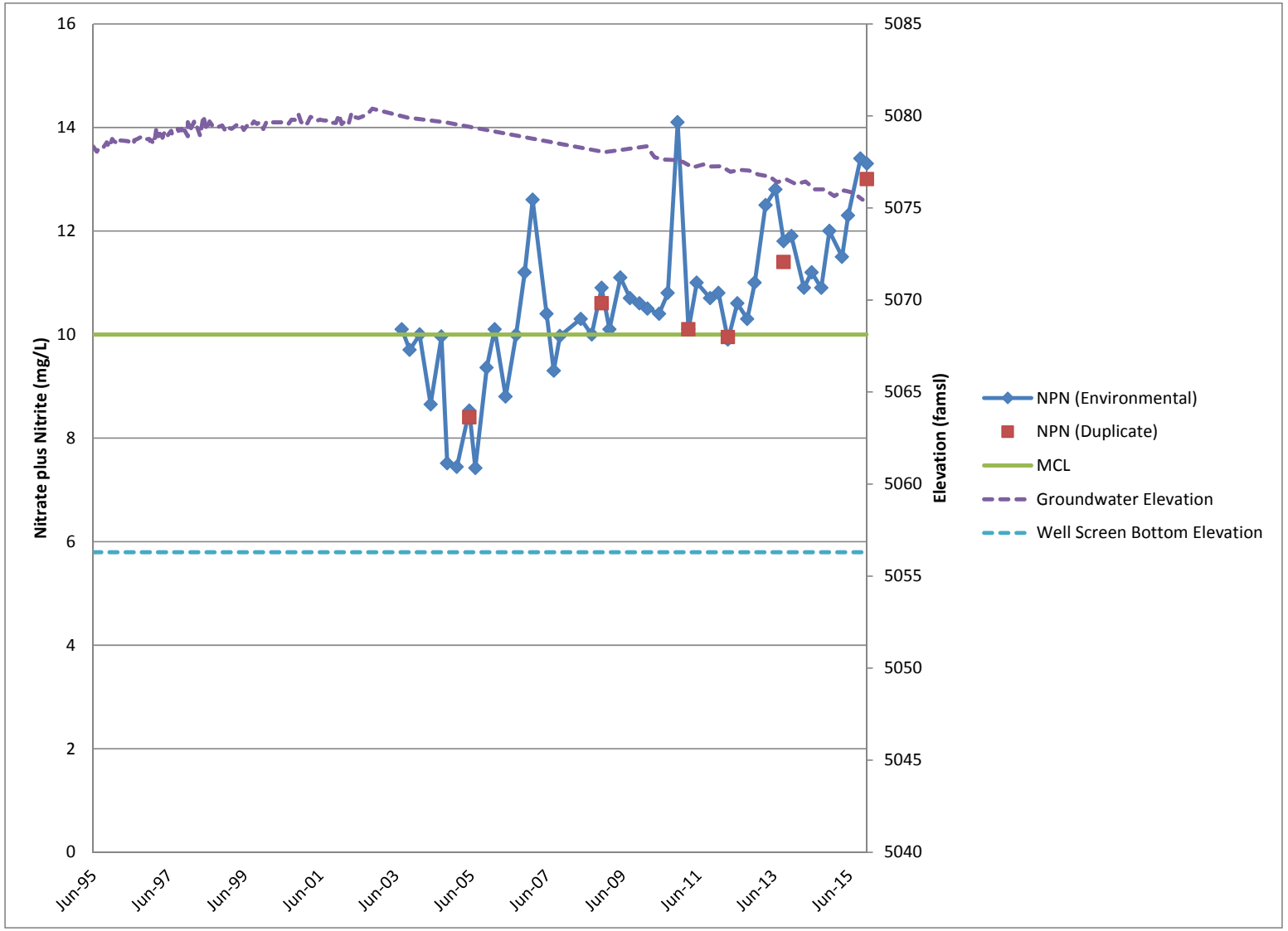


Figure 5–7
Time-Series Plot of NPN Concentrations in Perched Groundwater Samples Collected from Monitoring Well TJA-2

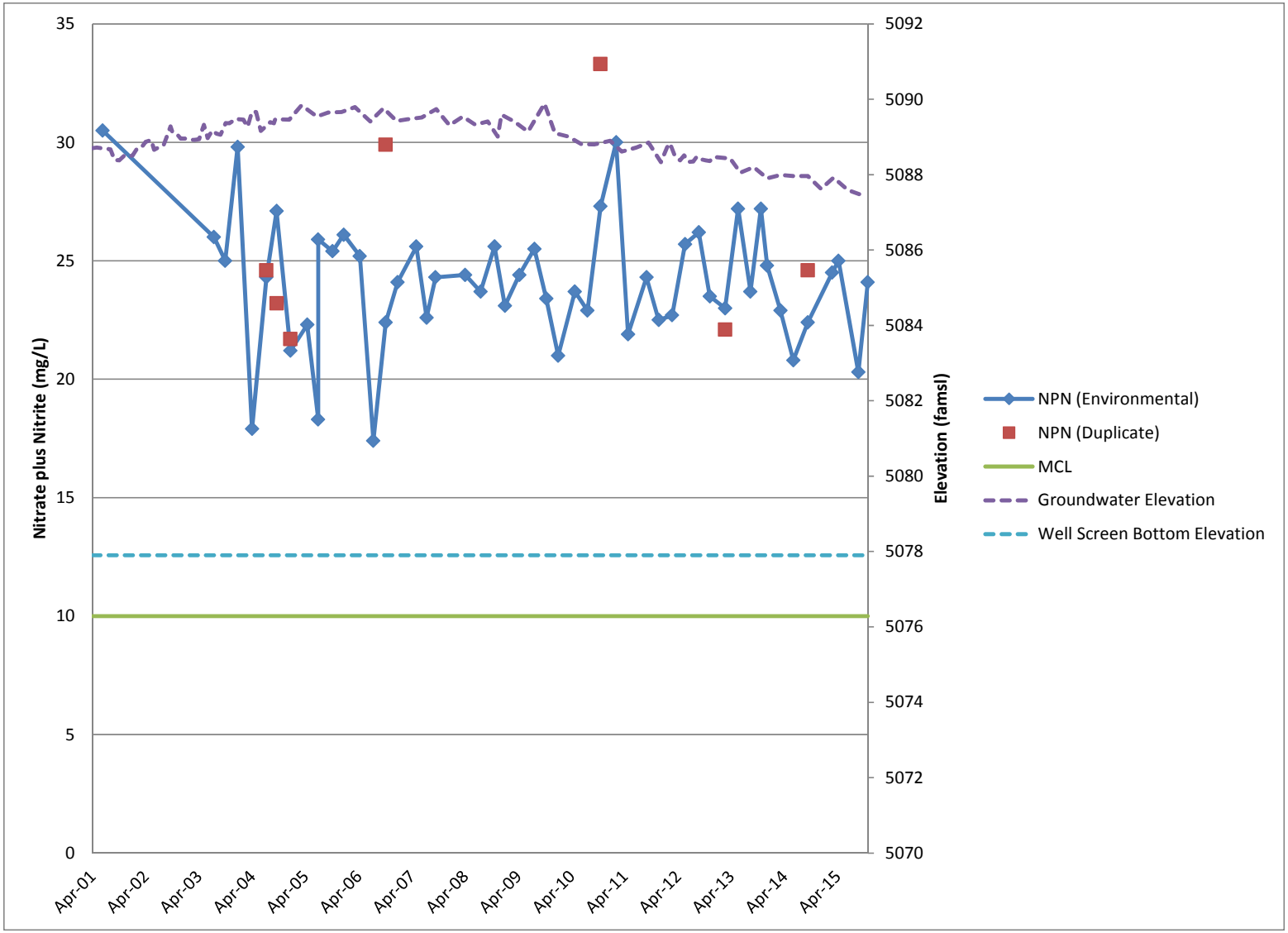


Figure 5–8
Time-Series Plot of NPN Concentrations in Perched Groundwater Samples Collected from Monitoring Well TJA-7

Table 5-2
Evaluation of Trends for NPN Concentrations and Groundwater Elevations for Monitoring Wells in the Perched Groundwater System that Exceed the Nitrate MCL

Monitoring Well	Maximum NPN Concentration in 2015 (mg/L)	Historical Range of NPN concentrations (mg/L)	Trend in NPN	Trend in Groundwater Elevation
TA2-W-19	12.8	7.57 to 12.8	Increasing	Declining
TA2-W-28[a]	27.8	15.1 to 28.8	Stable	Declining
TJA-2	13.4	7.42 to 14.1	Increasing	Declining
TJA-5[b]	26	11 to 28	Increasing	Declining
TJA-7	25.0	17.4 to 30.0	Stable	Declining

Notes:
[a] Includes data for well TA2-SW1-320.
[b] Estimated from data plotted in KAFB (December 2015).
KAFB = Kirtland Air Force Base.
MCL = Maximum contaminant level.
mg/L = Milligrams per liter.
NPN = Nitrate plus nitrite.
TA2-SW = Technical Area-II (Southwest) (monitoring well designation).
TA2-W = Technical Area-II (Well) (monitoring well designation).
TAG = Tijeras Arroyo Groundwater.
TJA = Tijeras Arroyo (monitoring well designation).

Figure 5-9 shows the time-series plot for well TJA-4, which is a merging zone well where nitrate consistently exceeds the MCL. Monitoring well TJA-4 is unique because groundwater elevations are increasing while NPN concentrations are also increasing.

5.4 Trichloroethene (TCE)

Since groundwater monitoring began in 1992, TCE has not been detected above the MCL at any of the TAG AOC monitoring wells that are screened in the Regional Aquifer. TCE has occasionally exceeded the MCL (5 micrograms per liter [µg/L]) at Perched Groundwater System monitoring wells TA2-W-19 and TA2-W-26. The historical maximum TCE concentration for monitoring well TA2-W-19 was 6.23 µg/L, occurring in October 2007, with subsequent samples collected after November 2009 having TCE concentrations below the MCL. The historical maximum TCE concentration for monitoring well TA2-W-26 was 9.6 µg/L, occurring in March 1998. Subsequent samples collected after March 2002 had TCE concentrations below the MCL for well TA2-W-26. These two monitoring wells are located on the Tijeras Arroyo floodplain. The December 2016 CCM/CME Report included the historical TCE concentrations for well WYO-4. Because responsibility for the well is anticipated to be transferred to the KAFB ERP (Section 1.0), the TCE data are not repeated here.

In 2015, no monitoring wells in the TAG AOC had TCE concentrations detected above the MCL in either the Perched Groundwater System or the Regional Aquifer. The maximum TCE concentration in the Perched Groundwater System was 3.87 µg/L at well TJA-2. The maximum TCE concentration in the Regional Aquifer was 1.67 µg/L at well TJA-3.

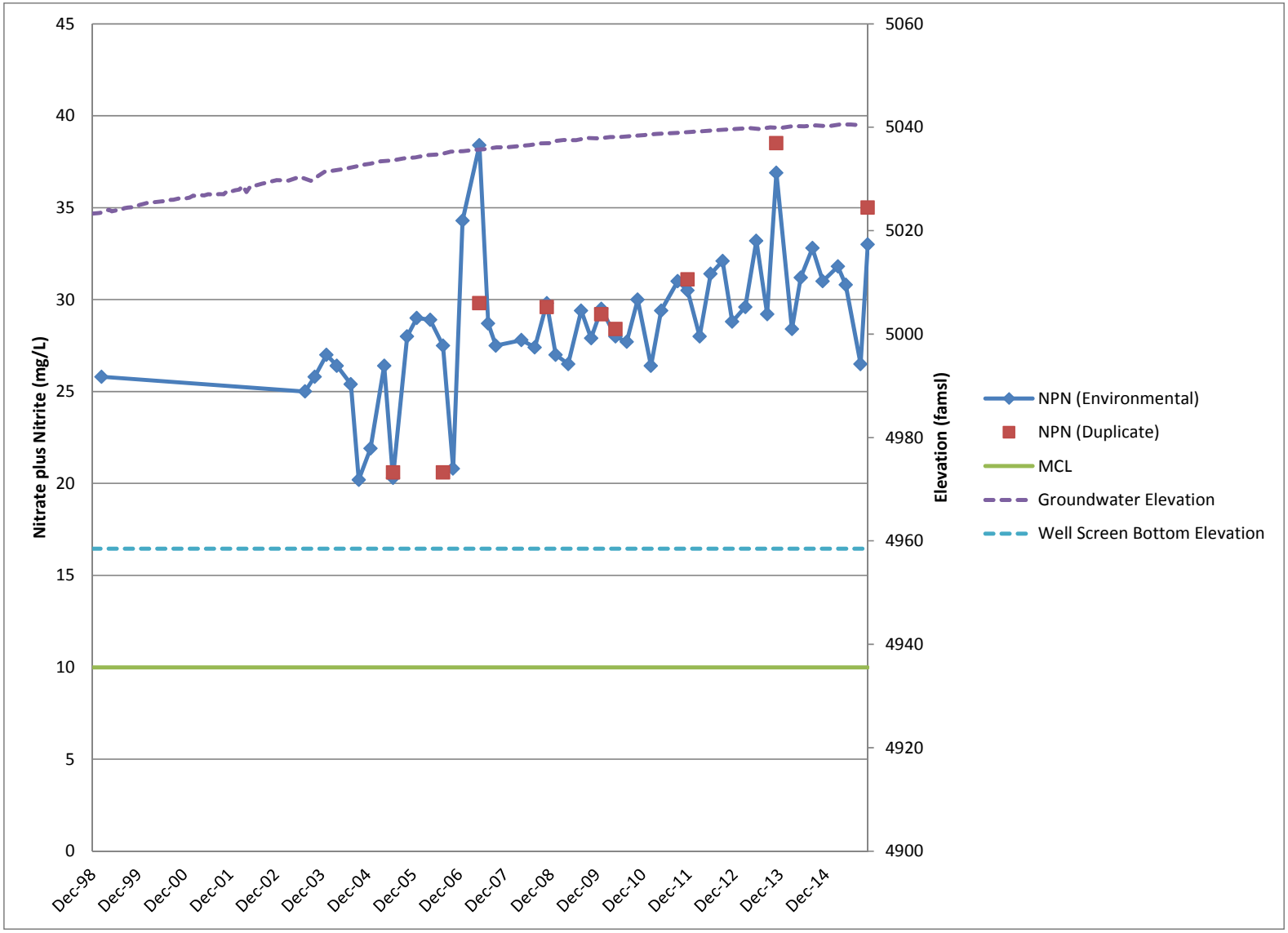


Figure 5–9
Time-Series Plot of NPN Concentrations in Merging-Zone Groundwater Samples Collected from Monitoring Well TJA-4

TCE in groundwater is addressed in the remedial alternative evaluation (Section 7.0) where it affects the nitrate remediation processes such as waste characterization and the treatment of extracted groundwater.

5.5 Other Groundwater Analytes

The Consent Order (NMED April 2004) listed only two COCs (nitrate and TCE) for the TAG AOC. However, TCE is no longer detected in TAG AOC groundwater at concentrations above the MCL. In prior TAG AOC reports and *Annual Groundwater Monitoring Reports,* numerous analytical results have been reported for high explosive compounds, semi-volatile compounds, radionuclides, metals, perchlorate, and volatile organic compounds. Results indicate that no other analytes are potential COCs.

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6.0 CONCEPTUAL SITE MODEL

Groundwater flow and contaminant transport in the TAG vicinity are controlled by stratigraphic, structural, and hydrogeological conditions. The CSM is discussed below and integrates data and interpretations from over 25 years of SNL/NM projects and basin-wide studies conducted by others.

6.1 TAG Conceptual Site Model

In the TAG AOC, groundwater in the Perched Groundwater System is present as shallow as approximately 269 ft bgs, while groundwater in the Regional Aquifer system is encountered at approximately 440 ft bgs. A series of discontinuous, yet overlapping lenses of unsaturated SFG alluvial fan sediments serve as the Perching Horizon beneath the Perched Groundwater System. Across the TAG AOC, the estimated thickness of the Perching Horizon ranges from 4 to 11 ft. The estimated thickness of the Perched Groundwater System ranges from approximately 7 to 20 ft across the northern and central portions of the TAG AOC. In the southeast corner of the TAG AOC, the thickness reaches 40 ft.

The Perched Groundwater System contains both anthropogenic inputs and natural recharge and is recognized as an artificial water-bearing zone. The declining thickness (dewatering) of the Perched Groundwater System is the result of three factors: [1] anthropogenic recharge has been nearly eliminated, [2] perched groundwater is slowly percolating downward through the underlying low conductivity layer, and [3] perched groundwater is slowly migrating to the southeast. Dewatering indicates that the volume of available water in the Perched Groundwater System is decreasing along with a corresponding mass of nitrate.

Figure 6-1 is a visualization of the TAG CSM. The Perched Groundwater System is contained within the SFG alluvial fan facies and covers approximately 4.43 sq. mi. This interpretation of the lateral limit of the Perched Groundwater System is based upon numerous boreholes that were drilled for characterizing the two water-bearing units across the northern portion of KAFB. For example, interpretation of the northern limit of the Perched Groundwater System is based upon core data from the PGS-1 borehole that was cored from 300 to 327 ft bgs; no obvious saturation was observed (Fritts and Van Hart, March 1997). An abrupt edge of the limit of saturation is recognizable along nearly the entire lateral limit except at the southeast corner of the TAG AOC. The southeast edge is gradational because the Perched Groundwater System merges with the Regional Aquifer near Powerline Road and the Tijeras Arroyo Golf Course. This merging zone may result from groundwater migrating downward along the buried West Sandia Fault (Fritts and Van Hart, March 1997). The subsurface expression of this fault roughly parallels Powerline Road, which parallels the eastern boundary of the TAG AOC. The merging zone may also result from groundwater migrating downward through a localized sequence of more permeable sediments.

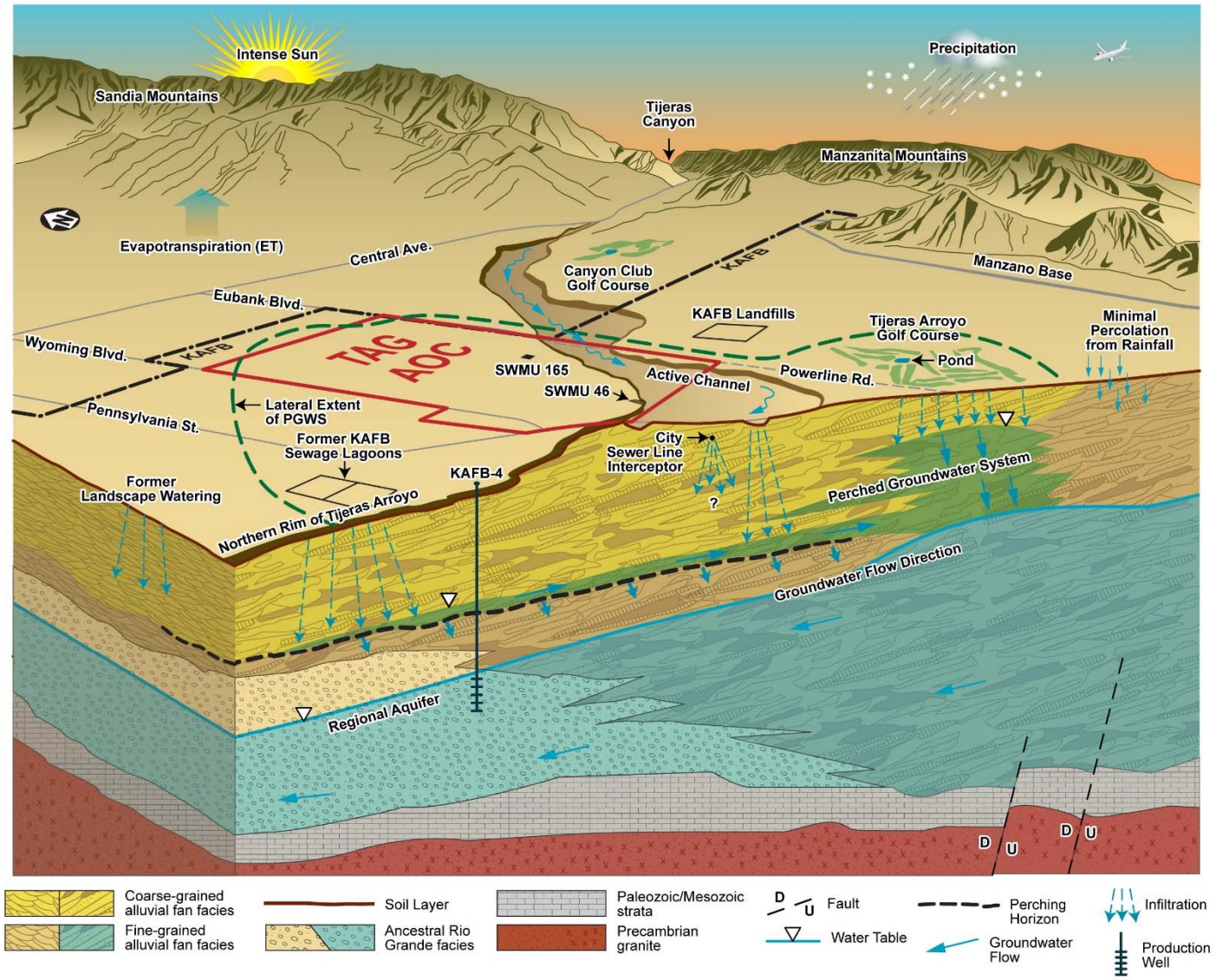


Figure 6-1
Conceptual Site Model for TAG Area, View to Northeast, Not to Scale

In the TAG AOC, the Regional Aquifer is contained within the alluvial fan facies. Near the western edge of TAG AOC, the alluvial fan facies interfingers with the coarser ARG fluvial facies. These two lithofacies in the Regional Aquifer exhibit complex interfingering in a north-south line approximated by Wyoming Boulevard. The alluvial fan facies are typically finer-grained and poorly sorted, exhibit lenticular bedding that is moderately to well-connected, have an east-west depositional fabric, and have low to moderate hydraulic conductivities. In contrast, the ARG fluvial facies is typically coarse-grained and well-sorted, exhibits relatively continuous and well-connected bedding, has moderate to high hydraulic conductivity, and was deposited in north-south–trending, laterally continuous paleochannels that are analogous to the modern Rio Grande. Groundwater in the Perched Groundwater System flows to the southeast and is governed by a combination of stratigraphic bedding dip, interfingering lithofacies, and former anthropogenic recharge sources in the northern portion of KAFB. Bedding dip does not appear to be the sole control of groundwater flow direction in the Perched Groundwater System because the potentiometric-surface contours do not precisely parallel the structure contours. Groundwater in the Regional Aquifer flows in a generally opposite direction to the northwest toward the KAFB, VA, and ABCWUA production wells.

As mentioned above, groundwater in the Perched Groundwater System merges with that of the Regional Aquifer near the southeastern corner of the TAG AOC near Powerline Road and the Tijeras Arroyo Golf Course. Monitoring well TJA-4 is screened in the merging zone and its intermediate groundwater elevation provides evidence that groundwater in the two water-bearing units merge. Merging is also evident as shown by the nearly similar groundwater elevations at well pairs such as KAFB-0613 and KAFB-0614 located at the golf course.

The merging zone may result from groundwater migrating downward along the West Sandia Fault near the eastern boundary of the TAG AOC, or also could result from groundwater migrating downward through a sequence of more permeable sediments. The merging zone could be a combination of both geologic features.

The Perched Groundwater System is restricted to the alluvial fan facies and exhibits the following characteristics in the TAG AOC:

- Unconfined (water table) conditions,
- A depositional pattern typical of a piedmont setting,
- A saturated thickness of approximately 7 to 20 ft across the northern and central portions of the TAG AOC and 40 ft in the southeast corner of the TAG AOC,
- Declining groundwater elevations for over 20 years,
- Groundwater flow direction primarily to the southeast,
- Average lateral gradient of approximately 0.01 ft/ft,
- Not used for potable purposes,
- Limited lateral extent of approximately 4.43 sq. mi. across north-central KAFB,

- Highly variable geochemical signatures between monitoring wells with high chloride, nitrate, and sulfate concentrations,
- Historical recharge by both artificial (leaking water-supply/sewer lines, the golf course, and the former sewage lagoons) and natural sources (Tijeras Arroyo and possibly ancestral Tijeras Creek,
- Ongoing recharge predominantly occurs from natural sources such as Tijeras Arroyo and precipitation,
- Perching Horizon consists of interbedded sequence of low permeability strata,
- Principal hydrogeologic controls consist of: (1) the stratigraphic dip of the Perching Horizon to the southeast; (2) lesser effect of the complex depositional fabric with braided paleochannels trending westward from the mountain flank, and (3) former multiple recharge locations in the northwestern and central parts of the TAG AOC, and
- Approximately 25 percent of the total groundwater loss from the Perched Groundwater System is due to lateral flow, while 75 percent is downward vertical flow through the Perching Horizon.
- Over 200 feet (mapped as averaging 202 feet) of unsaturated sediments are present between the Perched Groundwater System and the Regional Aquifer.
- The Perched Groundwater System discharges into and merges with the Regional Aquifer near the Tijeras Arroyo Golf Course.
- Exept in the merging zone, there is no geochemical evidence that groundwater flowing downward through the Perching Horizon has reached the Regional Aquifer.

The Regional Aquifer is present in both alluvial fan facies and the fluvial facies and exhibits the following characteristics:

- Unconfined to semiconfined conditions,
- Laterally extensive across the Albuquerque Basin,
- Greater than 1,000 ft thick across much of the TAG AOC,
- Groundwater flow direction primarily to the northwest toward production wells,
- Average lateral gradient of approximately 0.01 ft/ft, but steeper east of the TAG AOC in the piedmont terrain, and also steeper to the west of the TAG AOC near production wells,
- Utilized for water supply by KAFB, VA, and ABCWUA,
- Fluctuating groundwater elevations because of seasonal pumping demand,

- Geochemical signatures consistent between well locations with low calcium concentrations, but high bicarbonate/alkalinity concentrations,

- Recharged by natural sources, including the Rio Grande, mountain-front recharge, present-day Tijeras Arroyo, and to some degree the Perched Groundwater System via the merging zone, and

- Principal control upon groundwater flow direction in the Regional Aquifer is topographic effects and the combined drawdown from ABCWUA, KAFB, and VA production wells.

6.2 Nitrate Occurrence in the Environment

As noted earlier, this Revised CCM/CME addresses nitrate in groundwater for the TAG AOC. Nitrate can be naturally derived from geologic deposits. Nitrate in groundwater can be the result of both anthropogenic and natural sources. Potential anthropogenic-nitrate sources include human sewage, nitrate fertilizers, certain HE materials, and industrial waste streams such as nitric-acid solutions. Nitrate also can leach from geologic deposits, especially sedimentary strata (Holloway et al. October 1998; Walvoord et al. November 2003). Animal waste and decomposing plant debris are also potential nitrate sources.

Holloway et al. (2001) coined the term “geologic nitrogen” to refer to nitrogen incorporated into the matrix of rock during diagenesis or through secondary alteration. Potential sources of elevated nitrate concentrations in surface water and groundwater in several states have been attributed to the dissolution of various rock types including sedimentary, igneous, and metamorphic units. As such, bedrock weathering is considered an important part of the terrestrial nitrogen cycle.

Nitrate is highly mobile in soil due to its high solubility in water and weak retention by soil particles (EPA October 2001). The primary mechanism for nitrate transport in the environment is movement of water containing dissolved nitrate through soil. Nitrate does not volatilize and is likely to remain dissolved in water until consumed by plants or other organisms. Nitrate degradation (denitrification) occurs most rapidly where anaerobic conditions are coupled with the presence of denitrifying bacteria and a suitable carbon source (EPA October 2001).

Nitrate occurs primarily in the dissolved phase and does not sorb onto sediments. Therefore, any locally derived nitrate in excess of the background concentration in groundwater was most likely transported by advection through the vadose zone with the septic and/or wastewater discharges. Infiltration of water can follow preferential pathways of saturated or partially saturated flow through the vadose zone to the Perched Groundwater System. Because nitrate does not partition to the soil and is highly soluble, no secondary source of nitrate likely remains within the vadose zone from the wastewater and septic water disposals.

Contaminant transport mechanisms in groundwater include advection, dispersion, and diffusion. Dispersion is a process whereby a solute migrates in directions that are longitudinal and transverse to the advection of groundwater flow. The dispersion process dilutes contaminant concentrations in groundwater. Diffusion is a process whereby a concentration gradient can cause solute to migrate from zones of higher concentration to zones of lower concentration, regardless of groundwater flow direction. A study of denitrification parameters and isotopic

signatures conducted in 2013 indicated that natural denitrification (such as biodegradation) in the Regional Aquifer at the TAG AOC was insignificant (Madrid et al. June 2013).

In general, potential natural attenuation processes capable of reducing nitrate concentrations are biodegradation, dispersion, and dilution (EPA September 1998). The distribution and migration of nitrate compounds in the TAG AOC are most likely controlled by advection and dispersion. Since 1993, all TA-II sanitary waste and wastewater discharges have been eliminated. Discharges at SWMU 46 stopped in 1974. The only potential source of ongoing anthropogenic nitrate is leaking sanitary sewer lines.

6.3 Health Effects Associated with Nitrate

Elevated nitrate levels in drinking water are often caused in many communities due to groundwater contamination from animal waste run-off from dairies and feedlots, excessive use of fertilizers, or seepage of human sewage from septic systems (California Department of Health Services [DHS] February 2000). Microorganisms in soil, water, and sewage can change the nitrate to nitrite. When ingested, nitrite causes hemoglobin in the blood to change to methemoglobin. This condition is known as methemoglobinemia and is a disorder characterized by the blood stream having a decreased ability to bind oxygen. Infants less than 4 months of age are most at risk of adverse health effects from over exposure to nitrates and nitrites through ingestion of formula diluted with nitrate-contaminated water (Agency for Toxic Substances and Disease Registry [ATSDR] December 2015). In addition, the pregnant woman and her fetus might be more sensitive to toxicity from nitrite or nitrates. Decreased oxygen saturation in the blood stream can create cyanosis, which is typically recognized as a bluish tint in skin and fingertips. Healthy children and adults are more tolerant to elevated nitrate and nitrite levels in water. Tainted water can be effectively treated by using distillation or filtration techniques. Boiling is not effective because evaporation increases the nitrate/nitrite concentrations.

6.4 Potential Receptors of Groundwater Contamination

Production wells completed in the Regional Aquifer of the Albuquerque Basin are the only potential exposure points for elevated nitrate in groundwater to reach human receptors. Groundwater modeling demonstrates that elevated NPN concentrations in the Perched Groundwater System will not affect production wells for at least 130 years. Furthermore, the NPN concentrations at the arrival to the production wells are conservatively estimated to be 0.24 mg/L, which is almost two orders of magnitude below the nitrate MCL of 10 mg/L. The production wells are operated by KAFB, VA, and ABCWUA. No production wells are located within the TAG AOC.

Paving, continuous industrial activities, lack of habitat, and fences have reduced the presence of animals in most of the TAG AOC. No wetlands are present. Therefore, there are no significant ecological or biological receptors of concern to the nitrate-impacted groundwater in the TAG AOC.

6.5 Summary of the Conceptual Site Model

The CSM is summarized with these principal findings:

- The focus of the TAG AOC investigation is the Perched Groundwater System, which is a thin, partially natural, dissipating water-bearing unit. This water-bearing unit formed because of historical anthropogenic surface and shallow subsurface discharges that occurred between approximately 1928 and 1992. These discharges may have undergone mixing with naturally occurring residual saturation as the waters percolated through the subsurface.

- Nitrate is the COC for groundwater being addressed within this Revised CCM/CME.

- The elevated nitrate concentrations in the Perched Groundwater System are primarily derived from septic water (sanitary waste).

- Nitrate concentrations in the Perched Groundwater System are expected to decrease as a result of natural groundwater transport mechanisms (advection, dispersion, and diffusion).

- Nitrate concentrations in the Perched Groundwater System are low across the entire TAG AOC, and only exceed the MCL in the southeast corner of the AOC.

- No production wells are screened in the Perched Groundwater System.

- There is no threat to human health and the environment.

- Modeling results show a total transit time of 130 years for NPN concentrations in the TAG AOC to migrate southeast through the Perched Groundwater System, downward to the Regional Aquifer, and then along the nearest capture zones (ABCWUA production wells Ridgecrest 1 and Ridgecrest 2). The model predicted that the NPN concentration would attenuate to 0.24 mg/L, far below the nitrate MCL (10 mg/L), by the time it reached these wells. The modeling flowpath was approximately 5 miles consisting of lateral (mostly southeastward) groundwater migration along the Perched Groundwater System, downward migration via the merging zone, and subsequent lateral (mostly northwestward) migration through the Regional Aquifer. This modeling conservatively used a source term of 44 mg/L NPN, the highest historical detection from TAG AOC monitoring wells.

- Approximately 25 percent of the total groundwater loss from the Perched Groundwater System is due to lateral flow, while 75 percent is downward vertical flow through the Perching Horizon.

- Over 200 feet of unsaturated sediments are present between the Perched Groundwater System and the Regional Aquifer.

- There is no geochemical indication that groundwater flowing downward through the Perching Horizon has reached the Regional Aquifer, except in the merging zone southeast of the TAG AOC.

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7.0 CORRECTIVE MEASURES EVALUATION

The CME process consists of:

- Conducting remedial technology identification and screening (Section 7.1),
- Identifying and describing remedial alternatives (Section 7.2),
- Evaluating the remedial alternatives, including a Sustainability Evaluation (Section 7.3),
- Selecting a preferred remedial alternative (Section 7.4),
- Developing remedial alternative design criteria (Section 7.5), and
- Presenting an outline and schedule for the Corrective Measures Implementation Plan (Section 7.6).

Remedial objectives can consist of medium-specific or area-specific goals for protecting human health and the environment. They address COCs, media of concern, potential exposure pathways, and preliminary cleanup standards. While the Consent Order only specifies contaminant concentrations, remedial objectives for protecting human receptors should also take into account an exposure route, rather than contaminant concentrations alone, because protectiveness may be achieved by controlling or eliminating exposure as well as by reducing contaminant concentrations.

For the TAG AOC, four remedial objectives have been identified:

1. Preventing human ingestion or direct contact with groundwater containing nitrate above the MCL until the artificially created Perched Groundwater System naturally dewaters or nitrate concentrations decrease to below the MCL,
2. Restoring groundwater containing nitrate to concentrations below the MCL,
3. Implementing (or maintaining) land use controls at the TAG AOC, and
4. Preventing further releases of contaminants to the subsurface.

7.1 Remedial Technology Identification and Screening

The technology identification and screening process identifies potential remedial approaches to address nitrate in groundwater at the TAG AOC. Technologies retained after the screening process are developed into remedial alternatives in Section 7.2 and evaluated against the criteria specified in the Consent Order in Section 7.3.

7.1.1 Monitored Natural Attenuation

Monitored natural attenuation relies on natural processes to decrease concentrations of contaminants in soil and groundwater. These processes may include biodegradation, sorption, dispersion, dilution, evaporation, and chemical reactions. The concentrations and extent of contaminants are monitored throughout the duration of the remedy until remedial objectives are met. This technology requires no removal, treatment, or storage of groundwater other than the minor volumes generated during monitoring well sampling.

Monitored natural attenuation is retained as a remedial technology for nitrate in the TAG AOC groundwater and is developed into Remedial Alternative 1 in Section 7.2.

7.1.2 In-Situ Bioremediation

Bioremediation is the use or stimulation of either indigenous or introduced organisms to break down contaminants into less toxic or non-toxic substances. In-situ bioremediation is the application of bioremediation in the subsurface and can be used for remediation of a wide variety of contaminants, both organic and inorganic, under both aerobic and anaerobic conditions. It combines an understanding of biology, geochemistry, hydrogeology, and engineering into a cohesive strategy for the destruction of groundwater contaminants using microbes.

Bioremediation can involve aerobic or anaerobic processes. Anaerobic bioremediation is applicable to nitrate, and involves injecting an electron donor (often ethyl lactate) to create subsurface conditions conducive to nitrate degradation (denitrification) by indigenous microbes. Denitrification results in the conversion of nitrate to nitrite and ultimately to innocuous nitrogen gas.

A Permeable Reactive Barrier (PRB) can be constructed to introduce a bioremediation substrate mixture into the subsurface. This can be implemented either by using a series of closely spaced injection wells or by excavating a trench extending below groundwater and mixing a reactive or nutrient substrate with the trench backfill. Due to the depth of nitrate-contaminated groundwater in the TAG AOC (greater than 300 feet), injection wells would be used in lieu of a trench to deliver a dissolved substrate solution to the saturated zone.

In-situ bioremediation is retained as a remedial technology for nitrate in the TAG AOC groundwater and is developed into Remedial Alternative 2 in Section 7.2.2.

7.1.3 Groundwater Extraction and Treatment

Groundwater can be pumped to the ground surface and treated to remove contaminants. Systems consist of extraction wells to remove contaminated groundwater for ex-situ treatment and a disposal method for the treated water. Disposal of treated water can include reinjection, onsite reuse (irrigation), misting, discharge to a sewer system, or disposal in infiltration trenches or surface water bodies. Disposal using a reinjection well would be the most feasible method for the TAG AOC. The most common ex-situ treatment technology used to remove nitrate from extracted groundwater is sorption onto ion-exchange resin.

Groundwater extraction and treatment is retained as a remedial technology for nitrate in the TAG AOC groundwater and is developed into Remedial Alternative 3 in Section 7.2.3.

7.1.4 Other Remedial Technologies

Other potential remedial technologies (phytoremediation and monolithic confinement using a grout curtain) were reviewed for potential applicability to address nitrate in groundwater in the TAG AOC.

Phytoremediation involves the use of plants to remove contaminants from soil or groundwater. The term is used to describe a number of biochemical interactions that may occur among plants, microbes living on plant roots, and contaminants, and ultimately reduce contaminant concentrations. This technology is screened out because: (1) it is only applicable to relatively shallow contamination, and (2) it is not effective for large, dilute groundwater contaminant plumes.

Monolithic confinement is used in remedial actions to confine groundwater contamination by sealing it from the outside environment or to manipulate the flow of groundwater to avoid contaminant transport through advection. Barriers can be constructed by digging a trench and backfilling it with cement or clay. Although monolithic confinement can slow or prevent contaminant migration, the contaminants in groundwater behind the barrier would not be remediated. This technology is screened out because of the length of barrier that would be required in the TAG AOC (over 14,000 linear feet) and the extreme depth to contaminated groundwater (over 300 ft bgs).

No other newer technologies appropriate to address nitrate in groundwater in the TAG AOC have been identified since submittal of the superseded CME Report (SNL/NM August 2005).

7.2 Identification and Description of Remedial Alternatives

Three remedial alternatives for nitrate in groundwater in the TAG AOC have been identified:

1. Monitored Natural Attenuation,
2. In-Situ Bioremediation, and
3. Groundwater Extraction and Treatment.

The Consent Order states that cost estimates should be presented in Present Value. Present Value assumes the entire predicted cost of the remedy is invested up-front in an interest-bearing account and drawn upon as needed to fund the remediation project. However, Congress allocates environmental project funding for DOE/SNL M&O contractor activities on an individual fiscal year basis. The Total Cost estimate is the sum of the fiscal year funding throughout the anticipated lifecycle of the project, and more accurately represents the actual expense of the remediation to the taxpayers. For projects with long durations, Present Value calculations can significantly underestimate the true project costs. Both Present Value and Total Cost are presented in this Revised CCM/CME Report.

The following sections describe the scope, conceptual design, and estimated costs of each alternative.

7.2.1 Alternative 1: Monitored Natural Attenuation

The objective of the Monitored Natural Attenuation Alternative is to measure the concentration and extent of nitrate and prevent exposure until remedial objectives are met or the Perched Groundwater System naturally dewaters.

Preparatory Activities

The preparatory activities include:

- Obtaining concurrence on the remedy by NMED via a Statement of Basis, and
- Preparing a Corrective Measures Implementation Plan. This would include a schedule for remedy implementation, a Contingency Plan that identifies measures that would be taken if the remedy does not proceed as anticipated, and a Land Use Controls Implementation Plan to define any institutional or engineered controls needed.

Implementation

Monitoring wells completed in the Perched Groundwater System within the TAG AOC would be sampled semiannually for nitrate as NPN until remedial objectives are met, or the Perched Groundwater System has naturally dewatered. Select Regional Aquifer wells would be sampled annually for nitrate as NPN. To reiterate, nitrate is the sole analyte for monitored natural attenuation. Figure 7-1 shows the conceptual monitoring well field and sampling frequency for each well in the TAG AOC during remedy implementation. Table E-2 (Appendix E) shows the anticipated changes to the sampling program as the remedy progresses, taking into account when water levels in the Perched Groundwater System are anticipated to fall below the screen in each well.

Groundwater from each monitoring well would be sampled annually for constituents required under the sanitary sewer discharge permit that is currently used for purge water and equipment decontamination water disposal.

Groundwater elevations would be measured semiannually in monitoring wells completed in the Perched Groundwater System and the underlying Regional Aquifer. Wells where the water level has declined below the bottom of the screened interval would be periodically checked to identify any groundwater rises into the well screen.

Remedy Performance Monitoring, Maintenance, and Closure

Annual remedy performance reviews would be conducted, and would identify any required modifications or optimization measures for the remedy. A review of land use controls would also be incorporated into this process.

The Contingency Plan will address several issues. For example, groundwater wells will be redeveloped and repaired as needed. The need for replacing a monitoring well where the water level has dropped below the bottom of the screen will be determined on a case by case basis, depending on the progress of the remedy, and will take into account the remaining saturated



Figure 7-1
Conceptual Design for Alternative1: Monitored Natural Attenuation

thickness below the well screen, local nitrate concentrations, and the need for water level data. Replacement wells will be screened down to the top of the Perching Horizon. Work Plans will be used for obtaining NMED approval of proposed field tasks. Well-Installation Work Plans will be submitted to NMED within one year of a well having a water level unsuitable for sampling purposes. After remediation is complete and verified, monitoring wells completed in the Perched Groundwater System will be plugged and abandoned. Monitoring wells completed in the Regional Aquifer will be transferred to the DOE Long Term Stewardship program.

Land Use Controls

Land use controls to mitigate potential exposure to contaminated groundwater would be implemented and maintained. Most of these controls are already in place, including maintaining existing SNL/NM site access controls. The Corrective Measures Implementation Plan would include a Land Use Control Implementation Plan that would be amended if site conditions change.

Groundwater from each monitoring well would be sampled annually for constituents required under the sanitary sewer discharge permit, which is currently used for purge water and equipment decontamination water disposal.

Timeframe

The estimated timeframe to achieve remedial objectives for this alternative (or for most of the Perched Groundwater System to naturally dewater) is estimated to be approximately 41 years, assuming remedy implementation in 2018. Groundwater in the immediate vicinity of well TJA-5 and adjacent deeper well TJA-4 in the farthest southeast portion of the TAG AOC may be impacted by recharge and contaminant sources outside of the TAG AOC and is not included in this timeframe estimate.

Cost

The estimated Total Cost of the Monitored Natural Attenuation Alternative (in 2018 dollars) is $7,772,000; the Present Value is $6,789,000. A detailed cost breakdown is presented in Appendix E.

7.2.2 Alternative 2: In-Situ Bioremediation

The objective of Alternative 2 is to reduce nitrate concentrations in all TAG AOC groundwater to below the MCL within 20 years by implementing an in-situ bioremediation remedy. This would be accomplished by injecting a bioremediation substrate solution into multiple closely spaced injection wells throughout the area where nitrate exceeds the MCL, thereby creating a series of PRBs. As nitrate-contaminated groundwater flows through the PRBs, denitrification by indigenous microbes would occur, converting the nitrate to non-toxic nitrogen gas.

Figure 7-2 shows the conceptual design of Alternative 2, and includes the injection wells that would create PRBs, and the performance monitoring well locations. Appendix E provides additional details on the conceptual design.

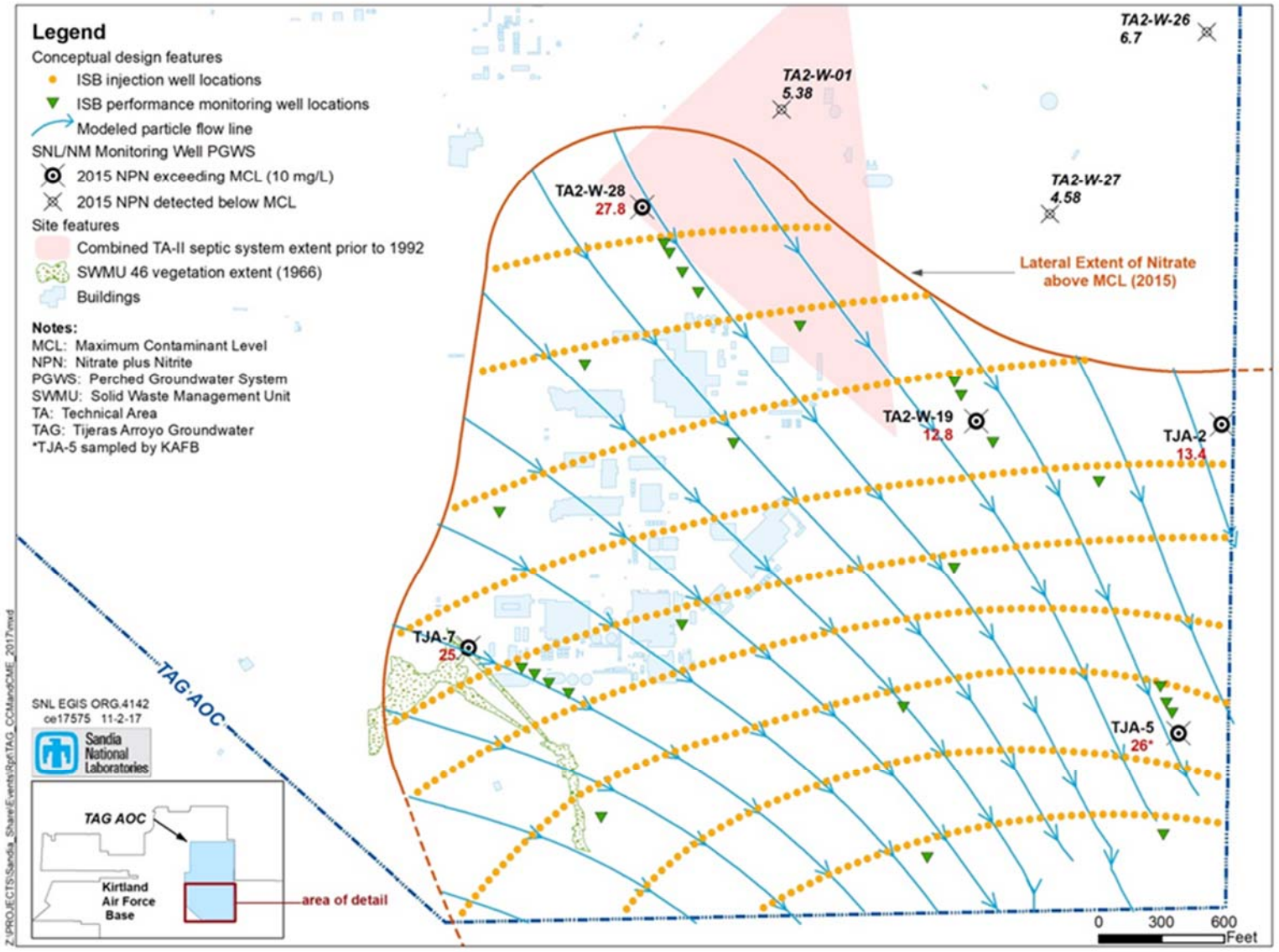


Figure 7-2
Conceptual Design for Remedial Alternative 2: In-Situ Bioremediation

Preparatory Activities

The preparatory activities include:

- Obtaining concurrence on the preferred remedy by NMED via a Statement of Basis,
- Preparing a Corrective Measures Implementation Plan. This would include a schedule for remedy implementation, a Contingency Plan that identifies measures that would be taken if the remedy does not proceed as anticipated, and a Land Use Control Implementation Plan to define any institutional or engineered controls needed, and
- Obtaining a Discharge Permit from NMED to allow bioremediation substrate injection.

Implementation

Nine PRBs would be created by installing 575 injection wells spaced 50 feet apart. Multiple PRBs are needed due to the slow groundwater velocity (24 ft/yr). The length of the PRBs would range from 1,700 to 4,150 feet, each with 33 to 83 injection wells depending on the PRB length.

Each PRB would be oriented perpendicular to the groundwater flow direction, with a spacing of no more than 20 years of groundwater travel time between each PRB. The spacing between each PRB would be 300 to 500 feet, depending on the groundwater flow rate in the area.

Groundwater travel times and flow paths were simulated using the numerical model MODFLOW, with Groundwater Vistas pre/post processing. The model domain includes the TAG AOC, and extends onto KAFB to the east and south. The model was calibrated to 2015 groundwater elevations by the use of constant-head boundary conditions under steady-state conditions. Hydraulic conductivity values were obtained from slug tests, and interpolated across the model domain using a kriging algorithm. The elevations of the top of the Perching Horizon were primarily obtained from geophysical well logs, and interpolated across the model domain using a kriging algorithm. The porosity of the alluvial fan lithofacies was assumed to be 25 percent. Groundwater flow paths and velocities were predicted by inserting virtual particles and conducting MODPATH simulations.

Twenty-five remedy performance monitoring wells would be installed. Fourteen of the wells would be installed between selected PRBs along the groundwater flow path to evaluate the effectiveness of treatment downgradient of the PRBs. The wells would be placed in consideration of groundwater travel time between the PRBs (1-year, 2-year, 5-year, 10-year, and 15-year travel times). Eleven monitoring wells would be installed at strategic locations throughout the nitrate plume for additional remedy performance monitoring. The depth of the monitoring wells would be approximately 300 ft bgs and screened across the full-saturated thickness of the Perched Groundwater System. Figure 7-2 shows locations of the performance monitoring wells. Existing monitoring wells would also be incorporated into the performance-monitoring network.

An average of 20,000 gallons of substrate-amended potable water would be injected into each well. The volume injected into each well would be dependent on the saturated thickness,

hydraulic conductivity, and porosity of the Perched Groundwater System at each location. A 25-ft diameter biological denitrification treatment area would be created around each injection well, providing 50 percent lateral treatment coverage along the length of the PRBs. Figure 7-3 presents a conceptual cross-section showing groundwater flow through a PRB. Figure 7-4 shows a small-scale plan view of the treated areas around injection wells. The average nitrate concentration would be reduced to below the MCL downgradient of each PRB because of the in-situ mixing of treated and untreated groundwater as it moves downgradient.

The injected bioremediation substrate mixture would consist of potable water, an electron donor (ethyl lactate), biological nutrients, buffering agents, and tracers. In addition to ethyl lactate, a complementary electron donor such as vegetable oil may be added to the substrate mixture to create a longer-lasting denitrification zone. The low yield of wells in the TAG AOC makes it impractical to (1) extract, amend, and reinject groundwater in a reasonable timeframe, or (2) create effective recirculation cells. The bioremediation substrate amendments would be mixed with potable water from fire hydrants and injected under a discharge permit issued by NMED.

The injection wells would be re-dosed as necessary with smaller volumes of substrate mixture (500 gallons per well) to maintain denitrifying conditions in the PRBs. For costing purposes, it is assumed re-dosing would be performed every two years for the duration of the remedy, beginning in the third year after the initial injections.

The conceptual locations of the PRBs are designed solely to reduce nitrate concentrations in groundwater to below the MCL within 20 years after active remedy implementation. Adverse and interfering logistics (buildings, infrastructure, steep topography, and other natural features) are not considered.

Remedy Performance Monitoring, Maintenance, and Closure

Perched Groundwater System monitoring wells and selected injection wells would initially be sampled quarterly to confirm treatment and adjust bioremediation substrate dosing parameters, and transitioned to semiannual sampling after two years. Analysis and associated quality control would include NPN, anions (bromide, chloride, fluoride, nitrite, sulfate), dissolved metals (arsenic, calcium, iron, magnesium, manganese, potassium, sodium), orthophosphate as P, and total organic carbon. Electronic logging of water levels and parameter measurements would be implemented in selected monitoring and injection wells. Regional Aquifer wells would be sampled semiannually.

Groundwater from each monitoring well would be sampled annually for constituents required under the sanitary sewer discharge permit that is currently used for purge water and equipment decontamination water disposal.

Quarterly post-remediation verification monitoring would be performed in Perched Groundwater System wells after the cleanup standard is reached to detect any rebound (increase) in nitrate concentrations and restoration of naturally occurring conditions such as decrease in localized metals concentrations. Annual remedy performance reviews would be conducted that would identify any required modifications or optimization measures for the remedy.

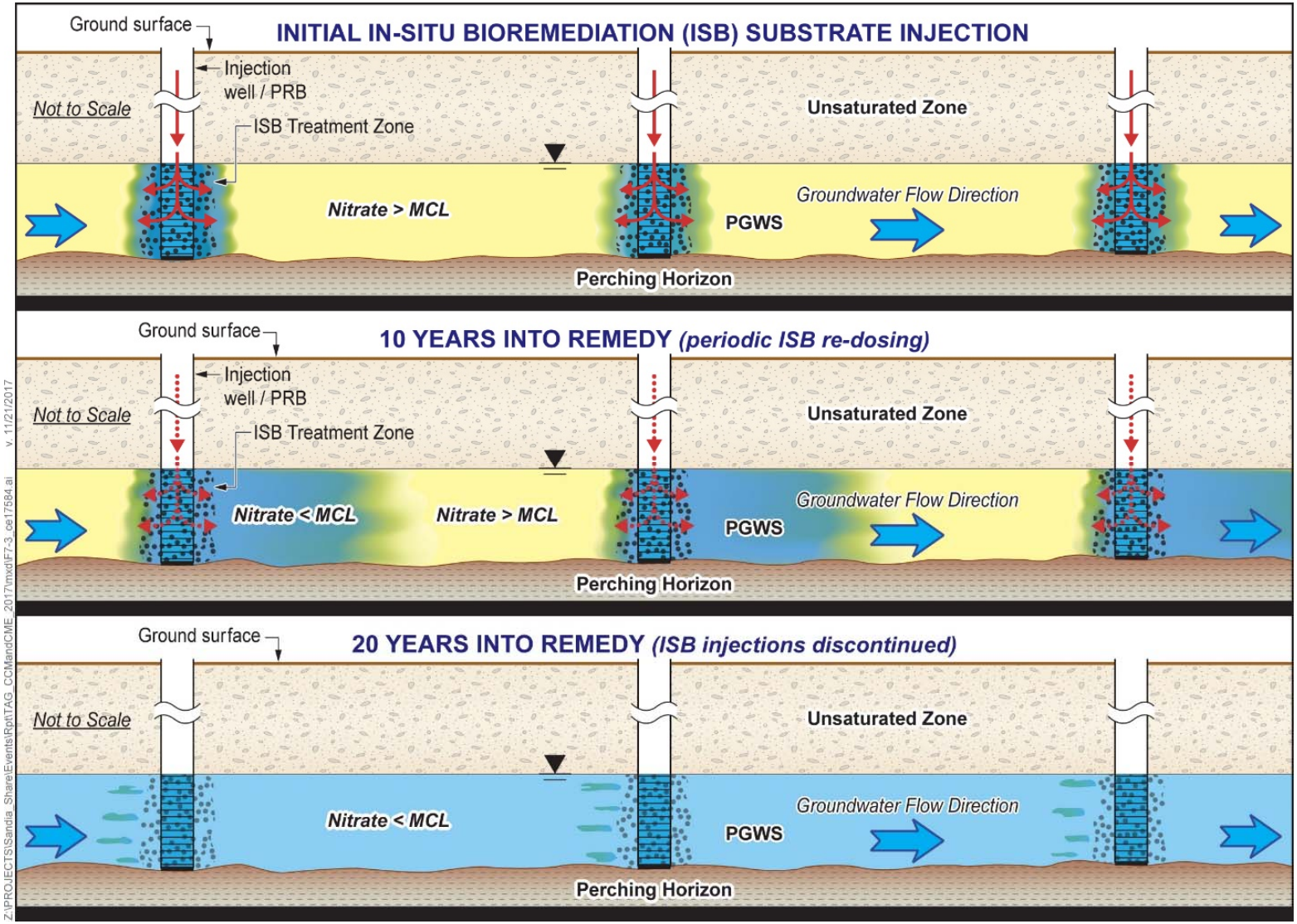


Figure 7-3
Conceptual Cross-Section of In-Situ Bioremediation Treatment Areas

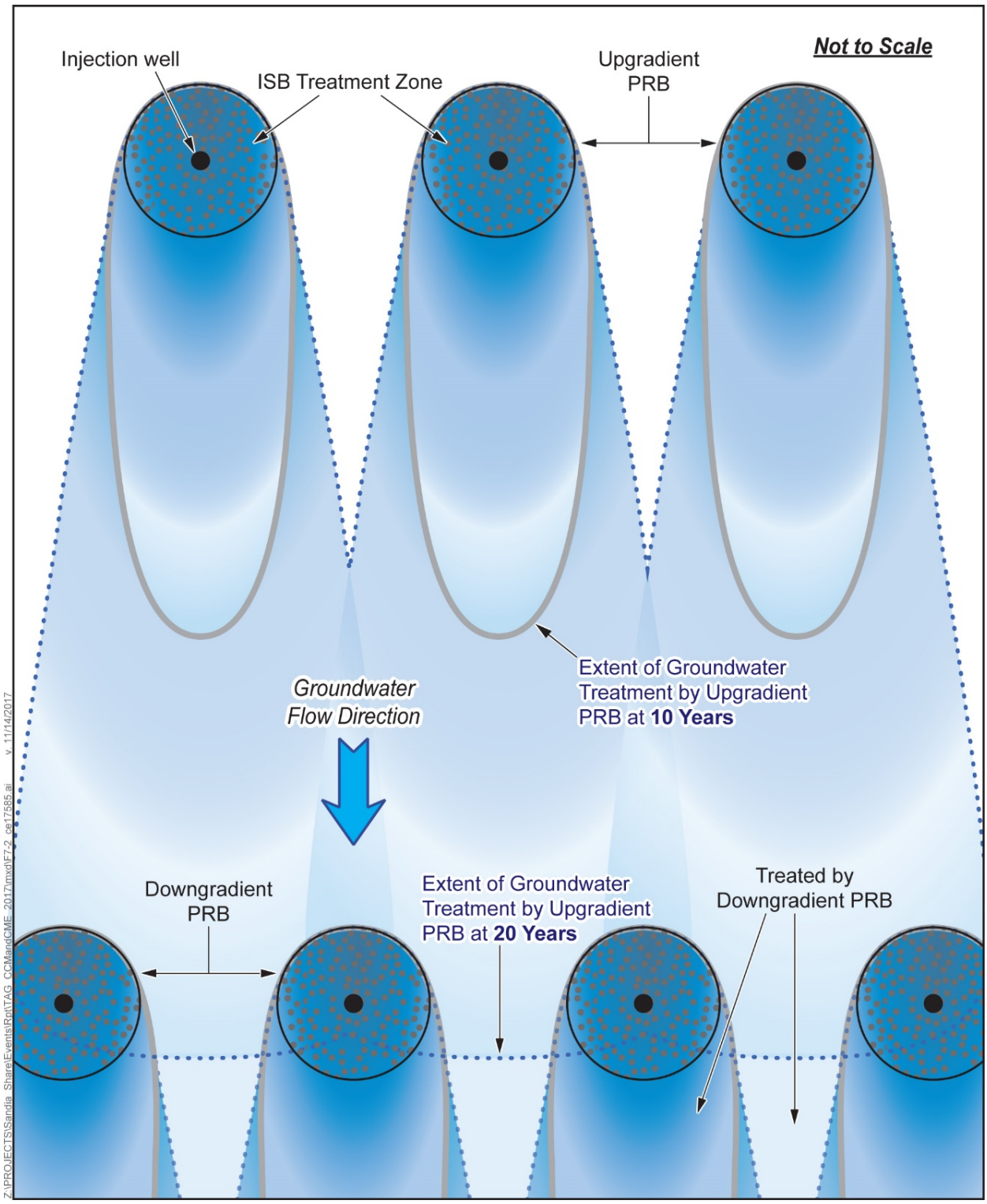


Figure 7-4
Conceptual Plan View of ISB Treatment Areas
Surrounding Injection Wells

The Contingency Plan will address several issues. For example, groundwater wells will be redeveloped and repaired as needed. Replacement wells will be considered. Well Installation Work Plans will be submitted to NMED within one year of a well being unsuitable for injection or sampling purposes. After remediation is complete and verified, wells completed in the Perched Groundwater System will be plugged and abandoned. Monitoring wells completed in the Regional Aquifer will be transferred to the DOE Long Term Stewardship program.

Land Use Controls

Land use controls to mitigate potential exposure to contaminated groundwater would be implemented and maintained. Most of these controls are already in place. This includes maintaining existing SNL/NM site access controls. Land use controls would be reviewed annually and modified if necessary. The Corrective Measures Implementation Plan would include a Land Use Control Implementation Plan that would be amended if site conditions change.

Timeframe

The estimated total timeframe for Alternative 2 is 27 years. This includes:

- 5 years to design the remedy, obtain permits, install injection and monitoring wells, and perform initial bioremediation substrate injections,
- 20 years of performance monitoring, and periodic bioremediation substrate re-dosing, and
- 2 years of quarterly post-remediation verification monitoring after the MCL cleanup standard is reached.

Cost

The estimated Total Cost of the In-Situ Bioremediation Alternative (in 2018 dollars) is $173,266,000; the Present Value is $167,579,000. A detailed cost breakdown is presented in Appendix E.

7.2.3 Alternative 3: Groundwater Extraction and Treatment

The objective of Alternative 3 is to extract all TAG AOC groundwater with a nitrate concentration exceeding the MCL within 20 years. This would be accomplished by installing multiple groundwater extraction wells, a nitrate treatment system, a reinjection well, and associated infrastructure (pipelines).

Figure 7-5 shows the conceptual design of Alternative 3. Appendix E provides additional details on the conceptual design.

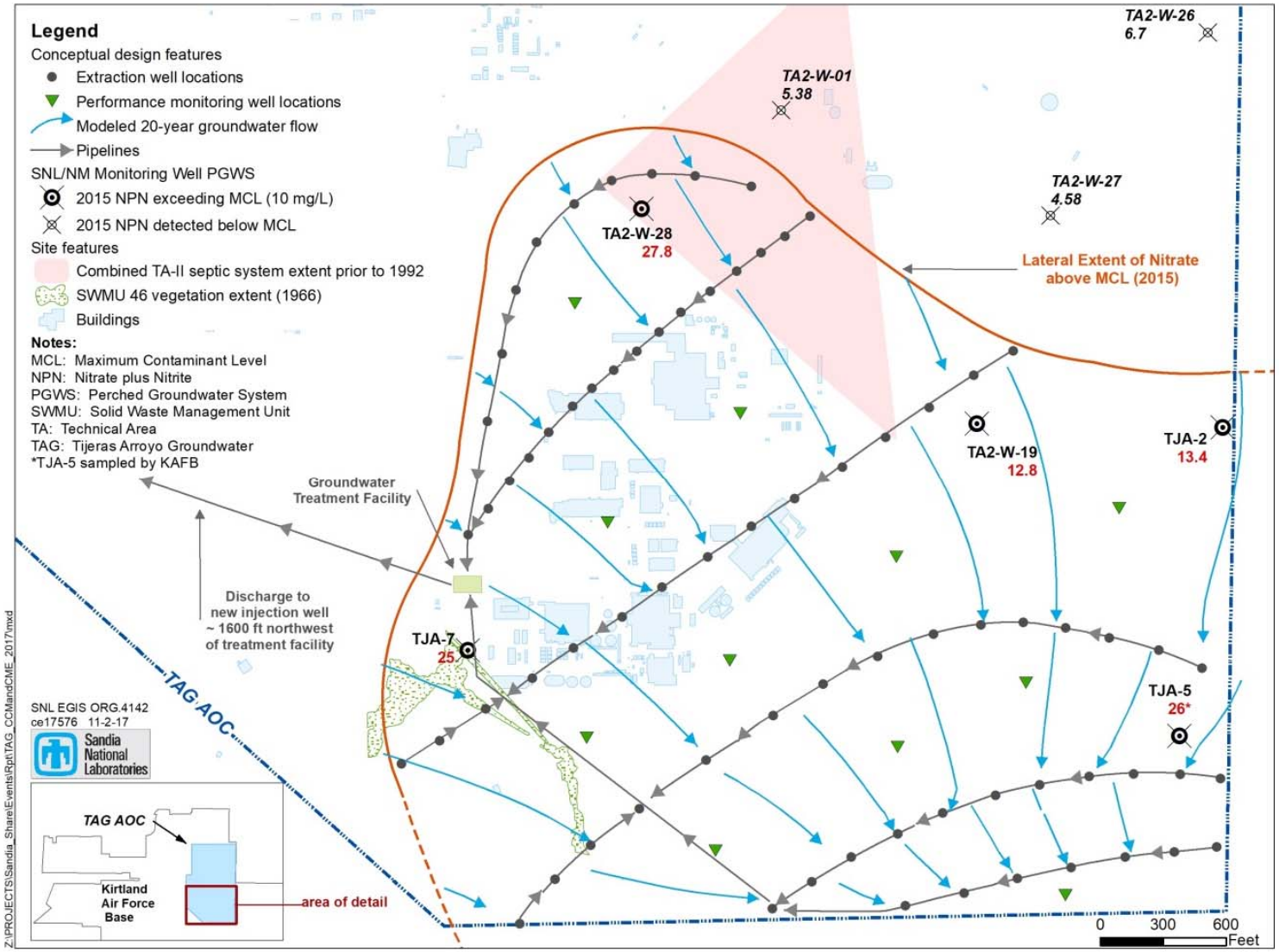


Figure 7-5
Conceptual Design for Alternative 3: Groundwater Extraction and Treatment

Preparatory Activities`

The preparatory activities include:

- Obtaining concurrence on the preferred remedy by NMED via a Statement of Basis.
- Preparing a Corrective Measures Implementation Plan. This would include a schedule for remedy implementation, a Contingency Plan that identifies measures that would be taken if the remedy does not proceed as anticipated, and a Land Use Control Implementation Plan to define any institutional or engineered controls needed.
- Obtaining a permit from NMED to allow discharge of treated water into a reinjection well completed in the Regional Aquifer.

Implementation

A minimum of 73 groundwater extraction wells would be required to capture all groundwater in the TAG AOC with a nitrate concentration exceeding the MCL within a pumping period of 20 years. The extraction wells would be completed approximately 300 ft bgs and screened across the full thickness of the Perched Groundwater System. Figure 7-5 provides the conceptual locations of the extraction wells, and includes a number of lines depicting the 20-year groundwater flow paths into the extraction wells.

Eleven additional monitoring wells would be installed at strategic locations throughout the nitrate plume for additional remedy performance monitoring. The depth of the monitoring wells would be approximately 300 ft bgs and screened across the full-saturated thickness of the Perched Groundwater System. Existing monitoring wells would also be incorporated into the performance-monitoring network.

Groundwater travel times and flow paths were simulated using the numerical model MODFLOW, with Groundwater Vistas pre/post processing. The model domain includes all TAG AOC, and extends onto KAFB to the east and south. The model was calibrated to 2015 groundwater elevations by the use of constant-head boundary conditions under steady-state conditions. Hydraulic conductivity values were obtained from slug tests, and interpolated across the model domain using a kriging algorithm. The elevations of the top of the Perching Horizon were primarily obtained from geophysical well logs, and interpolated across the model domain using a kriging algorithm. The porosity of the alluvial fan lithofacies was assumed to be 25 percent. Groundwater flow paths and velocities were predicted by inserting virtual particles and conducting MODPATH simulations.

The total extraction rate is estimated to be approximately 100 gpm. Individual extraction well yields are estimated to be 0.5 to 2 gpm, and are dependent on lateral variability in hydraulic conductivity and saturated thickness.

Groundwater would be pumped from extraction wells and conveyed to a treatment facility via a network of buried double-contained piping (approximately 3.6 miles in total length) and above-ground transfer tanks. The extracted water would be treated with strong base anion ion-exchange resin to reduce nitrate concentrations to below the 10 mg/L MCL. The treated water would be discharged to a reinjection well completed in the Regional Aquifer. The reinjection well would be located on the west side of Wyoming Boulevard and screened in the

highly transmissive ARG lithofacies of the Regional Aquifer. Figure 7-5 shows the locations of the pipelines, transfer tanks, treatment facility, and reinjection well. Granular activated carbon (GAC) would be used after the ion-exchange resin to remove any VOCs potentially present in the extracted groundwater prior to discharge.

Ion-exchange resin would be regenerated offsite. Spent GAC would be disposed of offsite in accordance with applicable waste disposal requirements.

The conceptual locations of the extraction wells are designed solely to achieve complete removal of all nitrate-contaminated groundwater exceeding the MCL within 20 years after active remedy implementation. Adverse and interfering logistics (buildings, infrastructure, steep topography, and other natural features) are not considered.

Remedy Performance Monitoring, Maintenance, and Closure

Sampling of Perched Groundwater System monitoring wells within the remediation area and selected extraction wells for nitrate as NPN would initially be quarterly, and transitioned to semiannual sampling after two years. Electronic logging of water levels would be implemented in selected monitoring and extraction wells. Regional Aquifer wells would be sampled semiannually.

The groundwater treatment system would be sampled at required points, influent, mid-stream, and effluent of treatment prior to discharge in compliance with the injection well discharge permit. For costing purposes, it is assumed that samples would be collected monthly at these points during system operation and analyzed for NPN, VOCs, total Target Analyte List metals plus uranium, anions (bromide, chloride, fluoride, and sulfate) as well as field measurements for other parameters.

Quarterly post-remediation verification monitoring would be performed in Perched Groundwater System wells after the cleanup standard is reached to detect any rebound (increase) in nitrate concentrations.

Annual remedy performance reviews would be conducted that would identify any required modifications or optimization measures for the remedy.

The Contingency Plan will address several issues. For example, groundwater wells will be redeveloped and repaired as needed. Replacement wells will be considered. Well Installation Work Plans will be submitted to NMED within one year of a well being unsuitable for extraction or sampling purposes. After remediation is complete and verified, wells completed in the Perched Groundwater System will be plugged and abandoned. Monitoring wells completed in the Regional Aquifer will be transferred to the DOE Long Term Stewardship program.

Groundwater from each monitoring well would be sampled annually for constituents required under the sanitary sewer discharge permit that is currently used for purge water and equipment decontamination water disposal.

Land Use Controls

Land use controls to mitigate potential exposure to contaminated groundwater would be implemented and maintained. Most of these controls are already in place. This includes maintaining existing SNL/NM site access controls. Land use controls would be reviewed

annually and modified if necessary. The Corrective Measures Implementation Plan would include a Land Use Control Implementation Plan that would be amended if site conditions change.

Timeframe

The estimated total timeframe for Alternative 3 is 27 years. This includes:

- 5 years to design the remedy, obtain permits, install extraction, reinjection, and monitoring wells, and construct the pipelines and treatment facility,
- 20 years of active groundwater extraction and treatment, and
- 2 years of quarterly post-remediation verification monitoring after the MCL cleanup standard is reached.

Cost

The estimated Total Cost of the Groundwater Extraction and Treatment Alternative (in 2018 dollars) is $61,542,000; the Present Value is $57,822,000. A detailed cost breakdown is presented in Appendix E.

7.3 Evaluation of Remedial Alternatives

This CME Report evaluates the three remedial alternatives using the four threshold criteria and the five balancing evaluation criteria prescribed by Section VII.C.3 of the Consent Order. Table 7-1 summarizes the evaluation.

7.3.1 Evaluation of Alternative 1: Monitored Natural Attenuation

7.3.1.1 Alternative 1 Threshold Criteria

Threshold Criterion 1: *Be Protective of Human Health and the Environment*

The Monitored Natural Attenuation Alternative would be protective of human health and the environment because:

- There is no current or projected use of perched groundwater near the TAG AOC.
- The nearest receptor in the Regional Aquifer is the Ridgecrest Well Field, located approximately 5 miles from the TAG AOC along the groundwater flow path. Contaminant transport modeling estimates that the highest historical nitrate concentration (44 mg/L) would be reduced to 0.24 mg/L, far below the MCL of 10 mg/L, before reaching the production wells. The estimated travel time for nitrate to reach the Ridgecrest production wells is at least 130 years (Section 3.6 and Appendix C).
- There is no potential for formation of hazardous degradation products.
- There are no hazards associated with implementation, operation, and maintenance of the remedy that cannot be easily managed.

Table 7-1
Summary of the Remedial Alternatives Evaluation for the TAG AOC

	Alternative 1: Monitored Natural Attenuation	Alternative 2: In-Situ Bioremediation	Alternative 3: Groundwater Extraction and Treatment
Threshold Criteria			
1. Protective of Human Health and the Environment	Protective. There is no potential for human or ecological receptors to be exposed to nitrate at concentrations of concern.	Protective. There is no potential for human or ecological receptors to be exposed to nitrate at concentrations of concern.	Protective. There is no potential for human or ecological receptors to be exposed to nitrate at concentrations of concern.
2. Attain Media Cleanup Standard	The nitrate MCL cleanup standard would be attained by dispersion, dilution, and advection.	The MCL cleanup standard would be attained by in-situ destruction of nitrate by denitrification.	The MCL cleanup standard would be attained by extracting all nitrate-contaminated groundwater.
3. Control the Source of Releases	The original SNL/NM sources of nitrate contamination (sanitary waste and wastewater discharges) have been eliminated. No discharges have occurred since 1992.	The original SNL/NM sources of nitrate contamination (sanitary waste and wastewater discharges) have been eliminated. No discharges have occurred since 1992.	The original SNL/NM sources of nitrate contamination (sanitary waste and wastewater discharges) have been eliminated. No discharges have occurred since 1992.
4. Comply with Standards for Management of Wastes	The alternative would comply with all standards for the management of wastes.	The alternative would comply with all standards for the management of wastes.	The alternative would comply with all standards for the management of wastes.
Balancing Criteria			
1. Long-Term Reliability and Effectiveness	Groundwater elevations in the Perched Groundwater System have been declining steadily for over 20 years because of ceasing recharge from the infiltration of wastewater discharges. This decline is anticipated to continue. No elevated risks would remain after the Perched Groundwater System has naturally dewatered and no contaminants would be left in place. Land use controls would be maintained during the course of the remedy. A Contingency Plan would be developed identifying measures to be taken if the remedy does not proceed as anticipated.	In-situ bioremediation technology has been demonstrated to effectively create denitrifying conditions in the subsurface. Denitrification is irreversible, because the product is nitrogen gas, which would volatilize from treated groundwater.	Groundwater extraction coupled with ion-exchange resin treatment is a proven, effective technology for the remediation of nitrate-contaminated groundwater.
2. Reduction of Toxicity, Mobility, or Volume	Although monitored natural attenuation would not reduce the toxicity, mobility, or volume of nitrate, there is no risk to human health or the environment, even if no degradation occurred. No hazardous byproducts would be produced during the remedy implementation. The mass of dissolved nitrate in the Perched Groundwater System would decline proportionately to the decrease in groundwater volume.	In-situ bioremediation would destroy nitrate in groundwater, thus reducing toxicity and volume. Mobility of nitrate would not be affected.	Groundwater extraction and treatment would not reduce the toxicity of nitrate because the nitrate would be transferred to ion-exchange resin. The mobility of nitrate would not be reduced. The volume of nitrate in groundwater would be reduced by transferring it onto ion-exchange resin, which would be regenerated offsite.
3. Short-Term Effectiveness	No risks to human health or the environment have been identified for the TAG AOC nitrate plume. There would be no risk of worker exposure to contaminants during remedy implementation that cannot be easily managed. No additional risks would be incurred.	No risks to human health or the environment have been identified for the TAG AOC nitrate plume. There would be no risk of worker exposure to contaminants during remedy implementation that cannot be easily managed. No additional risks would be incurred.	No risks to human health or the environment have been identified for the TAG AOC nitrate plume. There would be no risk of worker exposure to contaminants during remedy implementation that cannot be easily managed. No additional risks would be incurred.
4. Feasibility	Feasible and easily implemented. The monitoring network is in place.	Infeasible. 575 injection wells would be required, and at least 11.5 million gallons of bioremediation substrate-amended potable water would be injected to remediate the nitrate plume. The dense infrastructure (buildings and underground utilities) and disruption to facility operations in the TAG AOC would complicate the logistics necessary for effective implementation of this alternative.	Infeasible. 73 extraction wells and over 3 miles of trenching to bury double-contained pipelines would be required. The total volume of groundwater extracted to remediate the nitrate plume would be over 500 million gallons. The dense infrastructure (buildings and underground utilities) and disruption to facility operations in the TAG AOC would complicate the logistics necessary for effective implementation of this alternative.
5. Cost	Moderate. The total cost would be approximately $7.8M.	Extremely expensive. The total cost would be approximately $173.3M.	Extremely expensive. The total cost would be approximately $61.6M.
Sustainability			
	Lowest greenhouse gas emissions. Lowest emissions from vehicles. Lowest fatality and injury risks.	Highest greenhouse gas emissions. Highest emissions from vehicles. Highest injury risk.	Highest electrical usage. Highest fatality risk.

The Monitored Natural Attenuation Alternative passes Threshold Criterion 1.

Threshold Criterion 2: Attain Media Cleanup Standard or Alternative, Approved Risk-Based Cleanup Goals

The Monitored Natural Attenuation Alternative would achieve remedial objectives for nitrate primarily through dispersion, dilution, and advection. Recharge (past wastewater discharges) has ceased, and the Perched Groundwater System is predicted to dewater naturally in approximately 41 years (from a base year of 2018).

This timeframe is reasonable, considering regulators and facilities should take into a number of factors into account when developing cleanup timeframe(s) for a given facility, where appropriate (EPA 1996):

- Potential risks from exposures to contamination: There is no current or potential for exposure to nitrate at a concentration exceeding the MCL.
- Current and reasonably expected future land and water use(s): The TAG AOC is expected to remain under DOE control for the foreseeable future, and site use is not anticipated to change. There is no current or projected use of groundwater from the Perched Groundwater System (an artificially created groundwater body).
- Type, source(s), and extent of contamination: The SNL/NM sources of nitrate (wastewater discharges) have ceased. The nitrate plume is large in areal extent, thin, and relatively dilute, especially compared to the KAFB nitrate plume to the south that commingles with the TAG AOC nitrate plume.
- Hydrogeologic characteristics: The low hydraulic conductivity typically present in the Perched Groundwater System limits the groundwater flow velocity and makes active technologies (groundwater extraction and treatment or in-situ bioremediation) extremely difficult.
- Reliability of exposure controls: The area is under DOE/NTESS control. Land use controls either are in place or easily implemented to prevent exposure.
- Community preferences: To be determined during stakeholder outreach.
- Financial resources of the facility: DOE/NTESS would request adequate funding from Congress to operate the cleanup until remedial objectives are met.

The Monitored Natural Attenuation Alternative passes Threshold Criterion 2.

Threshold Criterion 3: 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

The original SNL/NM sources of the nitrate (sanitary waste and wastewater discharges) have been eliminated. No discharges have occurred since 1992.

The Monitored Natural Attenuation Alternative passes Threshold Criterion 3.

Threshold Criterion 4: Comply with Standards for Management of Wastes

The Monitored Natural Attenuation Alternative would comply with all applicable state and federal regulations regarding waste management.

The Monitored Natural Attenuation Alternative passes Threshold Criterion 4.

7.3.1.2 Alternative 1 Balancing Criteria

Balancing Criterion 1: Long-Term Reliability and Effectiveness

Groundwater elevations have been declining steadily in the Perched Groundwater System for over 20 years because of the cessation of recharge from the infiltration of wastewater discharges. This is anticipated to continue. No risks would remain after the Perched Groundwater System has naturally dewatered and no contaminants would be left in place. Land use controls would be maintained during the course of the remedy. A Contingency Plan would be developed that identifies measures that would be taken if the remedy does not proceed as anticipated.

Balancing Criterion 2: Reduction of Toxicity, Mobility, or Volume

Although the Monitored Natural Attenuation Alternative would not reduce the toxicity, mobility, or volume of nitrate, there is no risk to human health or the environment, even if no degradation occurred. No hazardous byproducts would be produced during the remedy implementation. The mass of dissolved nitrate in the Perched Groundwater System would decline proportionately to the decrease in groundwater volume.

Balancing Criterion 3: Short-Term Effectiveness

No risks to human health or the environment have been identified for the TAG AOC nitrate plume. There would be no risk of worker exposure to contaminants during remedy implementation (groundwater sampling) that cannot be easily managed as part of the existing SNL/NM monitoring program. No additional risks would be incurred.

Balancing Criterion 4: Feasibility

The Monitored Natural Attenuation Alternative is feasible and readily implementable. The monitoring well network is already in place. No issues have been identified related to remedy installation, operation and maintenance, permitting/approvals, availability of necessary equipment, services, and expertise. The alternative can be implemented quickly and easily.

Balancing Criterion 5: Cost

The estimated Total Cost of the Monitored Natural Attenuation Alternative (in 2018 dollars) is $7,772,000; the Present Value is $6,789,000. A detailed cost breakdown is presented in Appendix E.

7.3.2 Evaluation of Alternative 2: In-Situ Bioremediation

7.3.2.1 Alternative 2 Threshold Criteria

Threshold Criterion 1: *Be Protective of Human Health and the Environment*

The In-Situ Bioremediation Alternative would protective of human health and the environment because:

- There is no current or projected use of perched groundwater near the TAG AOC.
- The nearest receptor in the Regional Aquifer is the Ridgecrest Well Field, located approximately 5 miles from the TAG AOC along the groundwater flow path. Contaminant transport modeling estimates that the highest historical nitrate concentration (44 mg/L) would be reduced to 0.24 mg/L, far below the MCL of 10 mg/L, before reaching the production wells. The estimated travel time for nitrate to reach the Ridgecrest production wells is at least 130 years (Section 3.6 and Appendix C).
- There is no potential for formation of hazardous degradation products.
- There are no hazards associated with implementation, operation, and maintenance of the alternative that cannot be easily managed.

The In-Situ Bioremediation Alternative passes Threshold Criterion 1.

Threshold Criterion 2: Attain Media Cleanup Standard or Alternative, Approved Risk-Based Cleanup Goals

The In-Situ Bioremediation Alternative would achieve remedial objectives for nitrate by microbial destruction (denitrification). The average nitrate concentration in the treatment area would be below the MCL within 20 years of the initial bioremediation substrate injections.

The In-Situ Bioremediation Alternative passes Threshold Criterion 2.

Threshold Criterion 3: 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

The original SNL/NM sources of the nitrate (sanitary waste and wastewater discharges) have been eliminated. No discharges have occurred since 1992.

The In-Situ Bioremediation Alternative passes Threshold Criterion 3.

Threshold Criterion 4: Comply with Standards for Management of Wastes

The In-Situ Bioremediation Alternative would comply with all applicable state and federal regulations regarding waste management.

The In-Situ Bioremediation Alternative passes Threshold Criterion 4.

7.3.2.2 Alternative 2 Balancing Criteria

Balancing Criterion 1: Long-Term Reliability and Effectiveness

In-situ bioremediation technology has been demonstrated to effectively create denitrifying conditions in the subsurface. Denitrification is irreversible, because the product is nitrogen gas, which would volatilize from treated groundwater.

Balancing Criterion 2: Reduction of Toxicity, Mobility, or Volume

In-situ bioremediation would destroy nitrate in groundwater, thus reducing toxicity and volume. Mobility of nitrate would not be affected.

Balancing Criterion 3: Short-Term Effectiveness

No risks to human health or the environment have been identified for the TAG AOC nitrate plume. There would be no risk of worker exposure to contaminants during remedy implementation that cannot be easily managed as part of the existing SNL/NM monitoring program. No additional risks would be incurred.

Balancing Criterion 4: Feasibility

Implementing in-situ bioremediation would be extremely challenging. Factors specific to the TAG AOC include:

- In-situ bioremediation is infeasible for remediating a large, relatively dilute plume (nitrate concentrations barely exceed the MCL) such as is present in the TAG AOC. The nitrate in groundwater is derived from multiple release sources within the AOC and no distinct regions of high nitrate concentrations are present. Nine PRBs would need to be located throughout the extent of the nitrate plume exceeding the MCL. Groundwater in the TAG AOC exhibits aerobic conditions, and 575 injection wells would be needed to deliver and distribute enough bioremediation substrate to create anaerobic conditions throughout the nitrate plume.

- The possible influence of the higher nitrate concentration KAFB plume to the south, which commingles with the TAG AOC nitrate plume, is unknown.

- Subsurface heterogeneities may cause non-uniform distribution of the bioremediation substrate. Denitrification may only occur within the higher permeability sediments in the Perched Groundwater System, significantly increasing the time required achieve cleanup standards or requiring additional injection wells.

- The dense infrastructure (buildings and underground utilities) and topography in the TAG AOC would make installation of a sufficient number of injection wells extremely difficult and expensive.

Balancing Criterion 5: Cost

The estimated Total Cost of the In-Situ Bioremediation Alternative (in 2018 dollars) is $173,266,000; the Present Value is $167,579,000. A detailed cost breakdown is presented in Appendix E.

7.3.3 Evaluation of Alternative 3: Groundwater Extraction and Treatment

7.3.3.1 Alternative 3 Threshold Criteria

Threshold Criterion 1: *Be Protective of Human Health and the Environment*

The Groundwater Extraction and Treatment Alternative would be protective of human health and the environment because:

- There is no current or projected use of perched groundwater near the TAG AOC.

- The nearest receptor in the Regional Aquifer is the Ridgecrest Well Field, located approximately 5 miles from the TAG AOC along the groundwater flow path. Contaminant transport modeling estimates that the highest historical nitrate concentration (44 mg/L) would be reduced to 0.24 mg/L far below the MCL of 10 mg/L, before reaching the production wells. The estimated travel time for nitrate to reach the Ridgecrest production wells is at least 130 years (Section 3.6 and Appendix C).

- There is no potential for formation of hazardous degradation products.

- There are no hazards associated with implementation, operation, and maintenance of the remedy that cannot be easily managed.

The Groundwater Extraction and Treatment Alternative passes Threshold Criterion 1.

Threshold Criterion 2: Attain Media Cleanup Standard or Alternative, Approved Risk-Based Cleanup Goals

The Groundwater Extraction and Treatment Alternative would achieve remedial objectives for nitrate by removing (pumping) all groundwater contaminated by nitrate above the MCL. This

Alternative has been constructed to achieve this objective within 20 years of initiating groundwater extraction.

The Groundwater Extraction and Treatment Alternative passes Threshold Criterion 2.

Threshold Criterion 3: 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

The original SNL/NM sources of the nitrate (sanitary waste and wastewater discharges) have been eliminated. No discharges have occurred since 1992.

The Groundwater Extraction and Treatment Alternative passes Threshold Criterion 3.

Threshold Criterion 4: Comply with Standards for Management of Wastes

The Groundwater Extraction and Treatment Alternative would comply with all applicable state and federal regulations regarding waste management.

The Groundwater Extraction and Treatment Alternative passes Threshold Criterion 4.

7.3.3.2 Alternative 3 Balancing Criteria

Balancing Criterion 1: Long-Term Reliability and Effectiveness

Groundwater extraction is a proven, effective technology for the remediation of nitrate-contaminated groundwater.

Balancing Criterion 2: Reduction of Toxicity, Mobility, or Volume

Groundwater extraction and treatment would not reduce the toxicity of nitrate because the nitrate would be transferred to ion-exchange resin. The mobility of nitrate would not be reduced. The volume of nitrate in groundwater would be reduced by transferring it onto ion-exchange resin, which would require offsite regeneration.

Balancing Criterion 3: Short-Term Effectiveness

No risks to human health or the environment have been identified for the TAG AOC nitrate plume. There would be no risk of worker exposure to contaminants during remedy implementation that cannot be easily managed as part of the existing SNL/NM monitoring program. No additional risks would be incurred.

Balancing Criterion 4: Feasibility

Implementing a groundwater extraction and treatment remedy would be extremely challenging. Factors specific to the TAG AOC include:

- Groundwater extraction is infeasible for remediating a large, relatively dilute plume, such as is present in the TAG AOC. Concentrations barely exceed the MCL. The nitrate in groundwater is derived from multiple release sources within the AOC and no distinct regions of high nitrate concentrations are present. At least 73 extraction wells and over 3.6 miles of double-contained, buried pipeline would be required. Typical groundwater extraction and treatment remedies are effective for remediating high-concentration contaminant source areas, or protecting a nearby sensitive receptor. They have very high capital and operation/maintenance costs.

- The low hydraulic conductivity and thin saturated thickness of the sediments in the Perched Groundwater System would severely limit the yield of extraction wells; sustained pumping may not be possible. The estimated maximum sustainable yield from an individual extraction well at the TAG AOC is 2 gpm or less.

- The dense infrastructure and topography in the TAG AOC would make installation of multiple wells and associated pipelines for extracted and treated water extremely difficult and expensive.

- Extracting groundwater in the TAG AOC could induce nitrate and other contaminants present in the higher-concentration KAFB nitrate plume to the south (downgradient) to migrate northward into the AOC.

- Removing nitrate from extracted groundwater would generate a large quantity of waste (regeneration brine) that would require offsite disposal.

Balancing Criterion 5: Cost

The estimated Total Cost of the Groundwater Extraction and Treatment Alternative (in 2018 dollars) is $61,564,000; the Present Value is $57,844,000. A detailed cost breakdown is presented in Appendix E.

7.3.4 Sustainability Evaluation

As required by DOE Order 436.1 (DOE May 2011) and consistent with U.S. EPA sustainability guidance (EPA April 2008), sustainability metrics were calculated for the three remedial alternatives presented in this CME. Sustainability was modeled using the *SiteWise™ Tool for Green and Sustainable Remediation* (Naval Facilities Engineering Command [NAVFAC] July 2013).

7.3.4.1 Scope of the Alternatives Relevant to Sustainability

Alternative 1: Monitored Natural Attenuation

- Perform groundwater sampling and water level measurements.
- Plug and abandon all Perched Groundwater System monitoring wells after remediation is complete (14 total).
- Estimated remedy duration is 41 years.

Alternative 2: In-Situ Bioremediation

- Perform groundwater sampling and water level measurements.
- Install 575 bioremediation substrate injection wells.
- Install 25 additional performance monitoring wells.
- Initially inject 20,000 gallons of substrate-amended potable water into each injection well.
- Periodically re-dose each injection well with 500 gallons of substrate mixture.
- Plug and abandon all injection and Perched Groundwater System monitoring wells after remediation is complete (614 total).
- Estimated remedy duration is 27 years.

Alternative 3: Groundwater Extraction and Treatment

- Perform groundwater sampling and water level measurements.
- Install 73 groundwater extraction wells.
- Install 11 additional performance monitoring wells.
- Install 3.6 miles of double-contained underground pipelines to convey extracted groundwater to the nitrate treatment facility.
- Install 2,000 feet of underground pipeline to convey treated water to the reinjection well.
- Install one reinjection well for disposal of treated water.
- Construct, operate, and maintain a nitrate treatment facility, including compliance monitoring.

- Off-site regeneration of ion-exchange resin.
- Plug and abandon wells all extraction wells, the reinjection well, and Perched Groundwater System monitoring wells after remediation is complete (99 total).
- Estimated remedy duration is 27 years.

7.3.4.2 Sustainability Evaluation Methodology

The following sustainability metrics were estimated:

- Greenhouse gas emissions, including carbon dioxide, methane, and nitrous oxide. These emissions result from transportation, consumables, and material production,
- Energy usage, primarily from manufacturing, fuels, and electricity,
- Water consumption,
- Nitrogen oxide, sulfur oxide, and particulate matter emissions from transportation, and
- Accident risk (injury and fatality), based on published transportation-related statistics.

7.3.4.3 Results

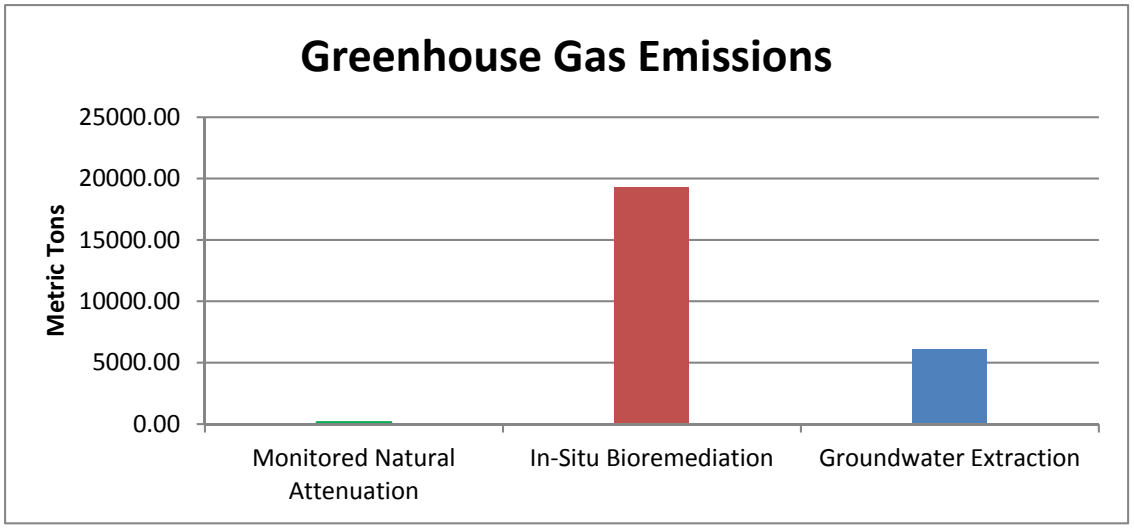
The sustainability evaluation indicates that the Monitored Natural Attenuation Alternative would be the most sustainable (have a far smaller environmental footprint) than either the In-Situ Bioremediation or Groundwater Extraction and Treatment Alternatives. This is primarily because:

- The Monitored Natural Attenuation Alternative would have the lowest greenhouse gas emissions, lowest emissions from vehicles, and lowest accident/fatality risk.
- The In-Situ Bioremediation Alternative would have the highest greenhouse gas emissions, highest emissions from vehicles, and highest injury risk.
- The Groundwater Extraction and Treatment Alternative would have the highest electrical usage due to the operation of extraction pumps and the highest fatality risk due to transportation of ion-exchange resin to an off-site regeneration facility.

Table 7-2 presents the numerical results of the sustainability evaluation for the three remedial alternatives. Figures 7-6 through 7-9 show comparisons of individual sustainability metrics and Figure 7-10 provides a normalized comparison.

Table 7-2
Results of the Sustainability Evaluation for the TAG AOC Remedial Alternatives

Parameter	Alternative 1 Monitored Natural Attenuation	Alternative 2 In-Situ Bioremediation	Alternative 3 Groundwater Extraction and Treatment
Greenhouse gas emissions (metric tons)	148 Major contributor: transportation	19,300 Major contributors: transportation, material production	6,100 Major contributors: transportation, material production
Total energy used (million British Thermal Units [BTUs])	1,034 Major contributor: transportation	5,607,000 Major contributors: transportation, material production	846,000 Major contributors: transportation, material production
Water consumption (gallons)	0	15,000,000 Major contributors: Drilling, injection water	1,000,000 Major contributors: Drilling, trenching
Electricity use (megawatt hours)	0	0	1,961 Major contributor: electric extraction pumps
Total nitrogen oxide emissions (metric tons)	0.3 Major contributor: transportation	117 Major contributors: transportation and drilling	18.5 Major contributors: transportation, drilling, trenching
Total sulfur oxide emissions (metric tons)	0.57 Major contributor: transportation	40 Major contributors: transportation and drilling	7 Major contributors: transportation, drilling, trenching
Total particulate matter emissions (metric tons)	0.11 Major contributor: transportation	15 Major contributors: transportation and drilling	2.3 Major contributors: transportation, drilling, trenching
Injury accident risk	4.43E-02 Major contributor: transportation	8.51E-01 Major contributors: transportation and drilling	9.0E-01 Major contributors: transportation and drilling
Fatality accident risk	3.57E-04 Major contributor: transportation	3.39E-03 Major contributors: transportation and drilling	9.7E-03 Major contributors: transportation and drilling



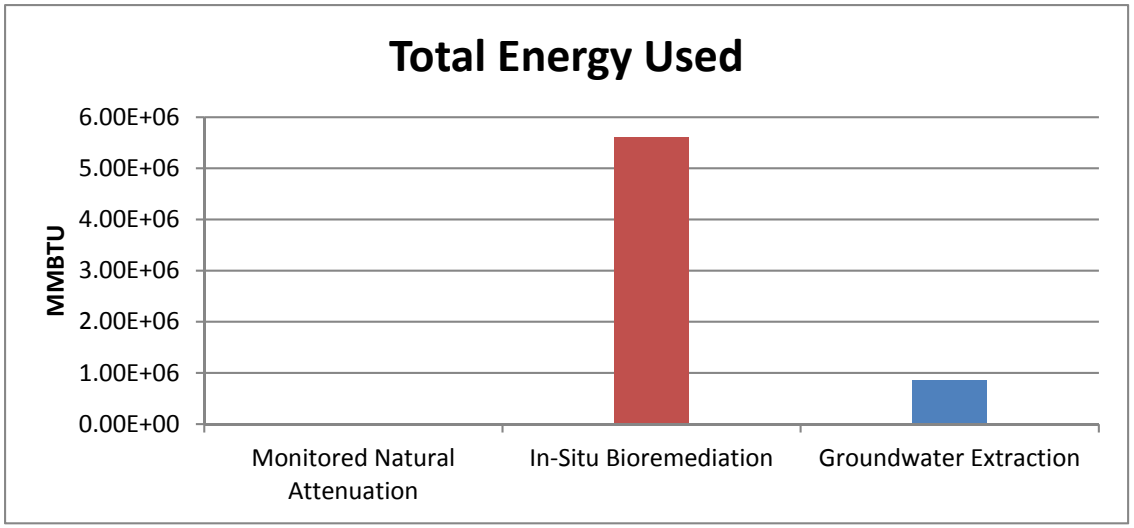
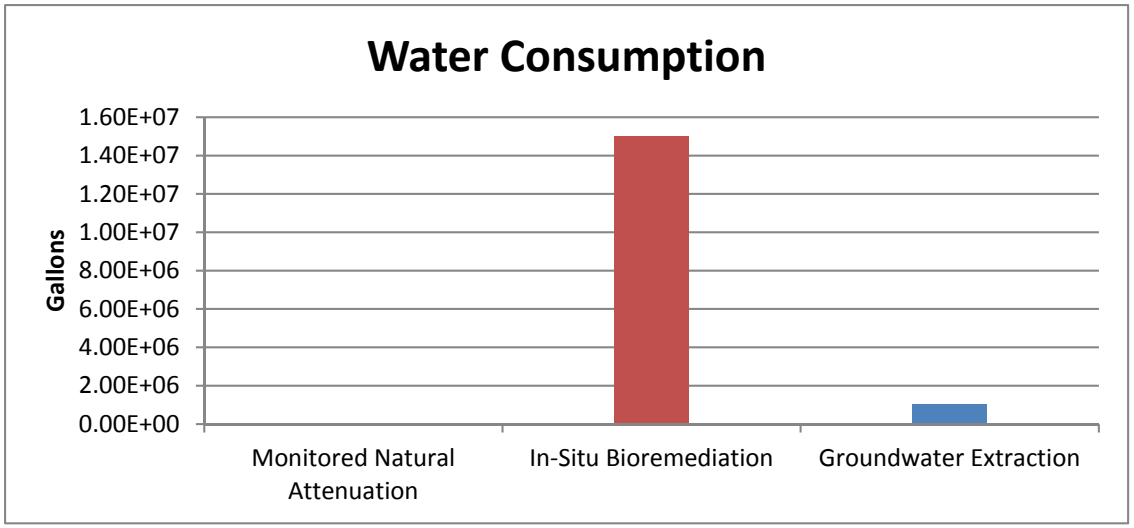


Figure 7-6
Results of the Sustainability Evaluation for the TAG AOC Remedial Alternatives (greenhouse gas and energy use)



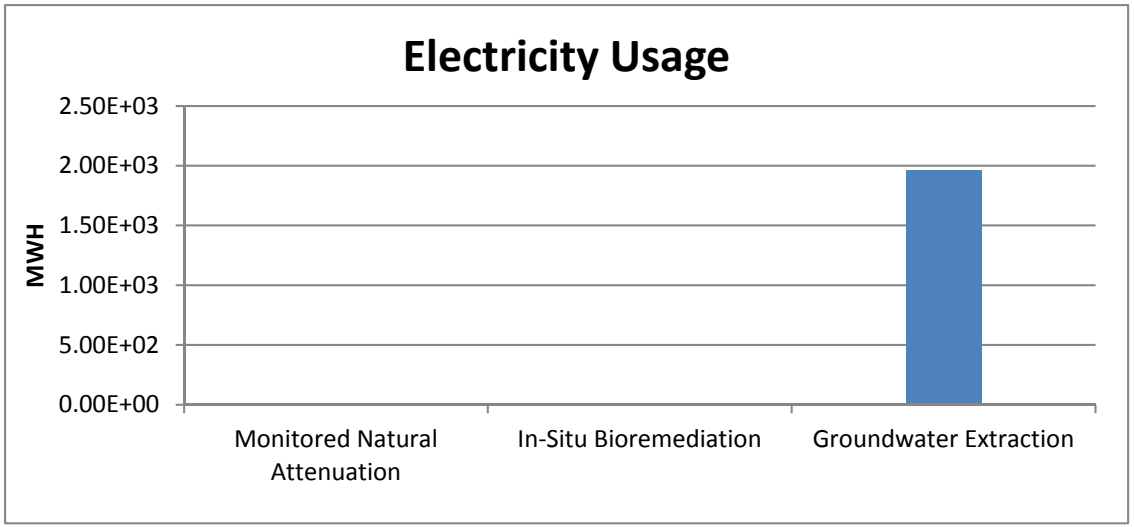


Figure 7-7
Results of the Sustainability Evaluation for the TAG AOC Remedial Alternatives (water consumption and electricity usage)

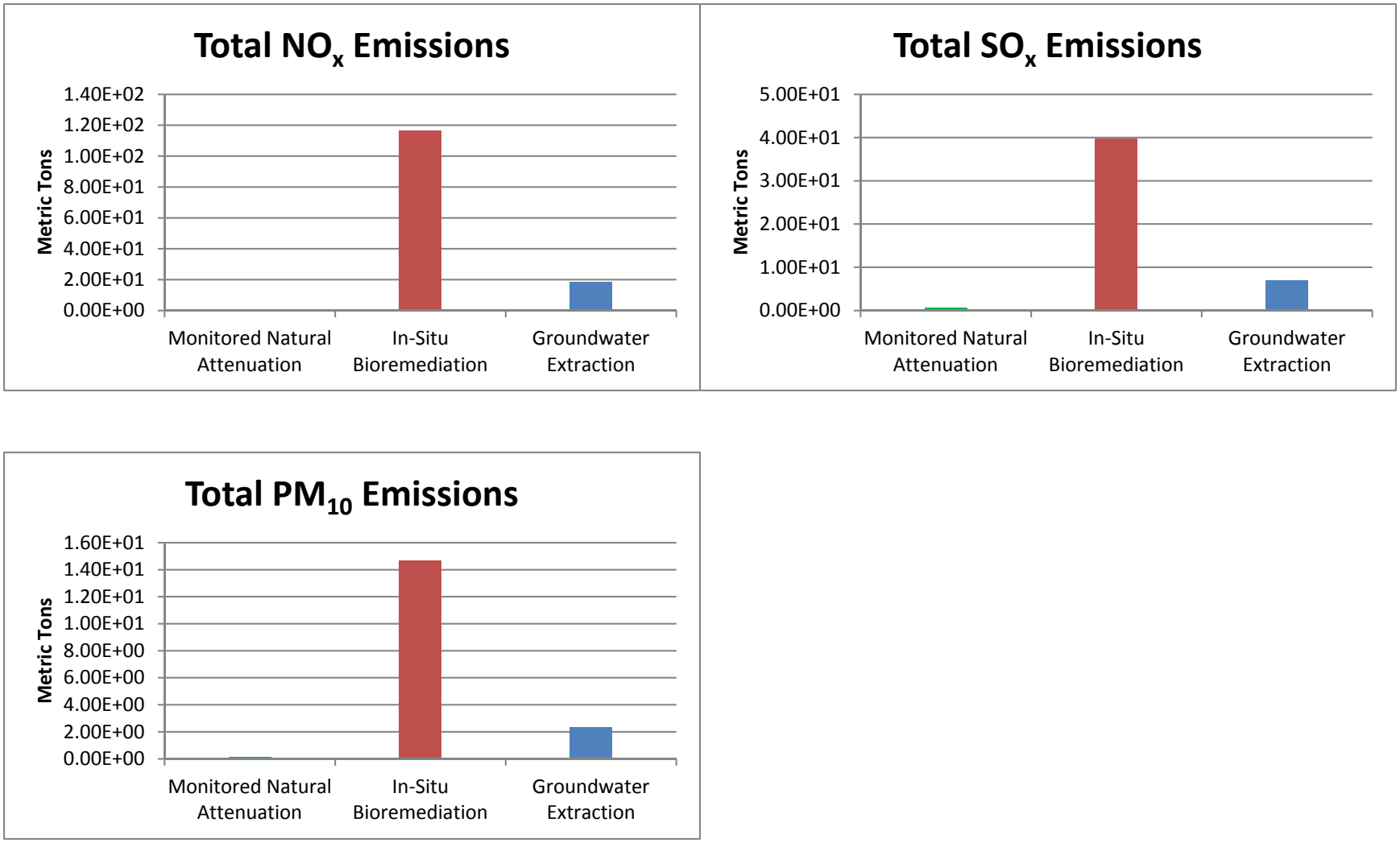
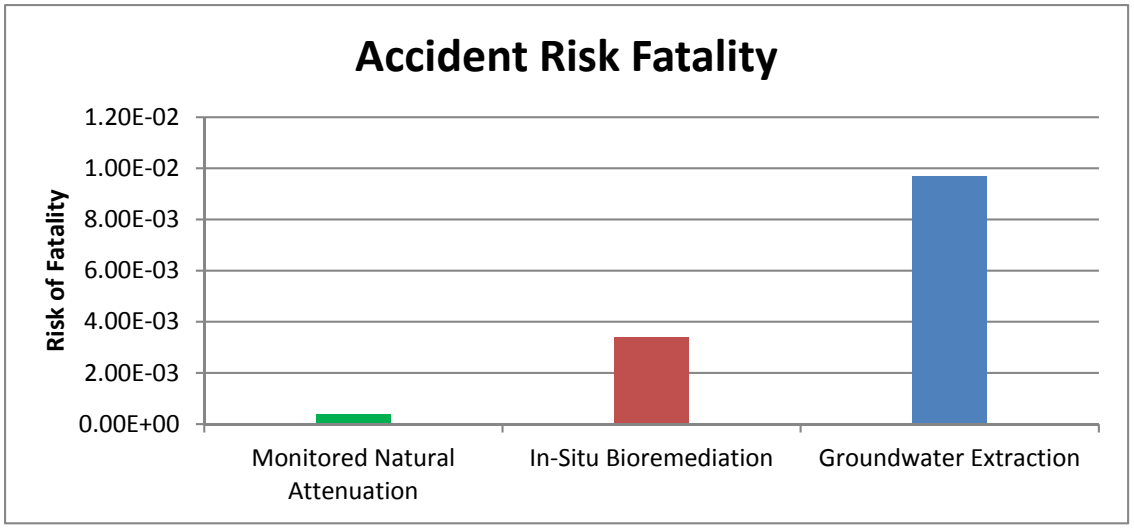


Figure 7-8
Results of the Sustainability Evaluation for the TAG AOC Remedial Alternatives (emissions)



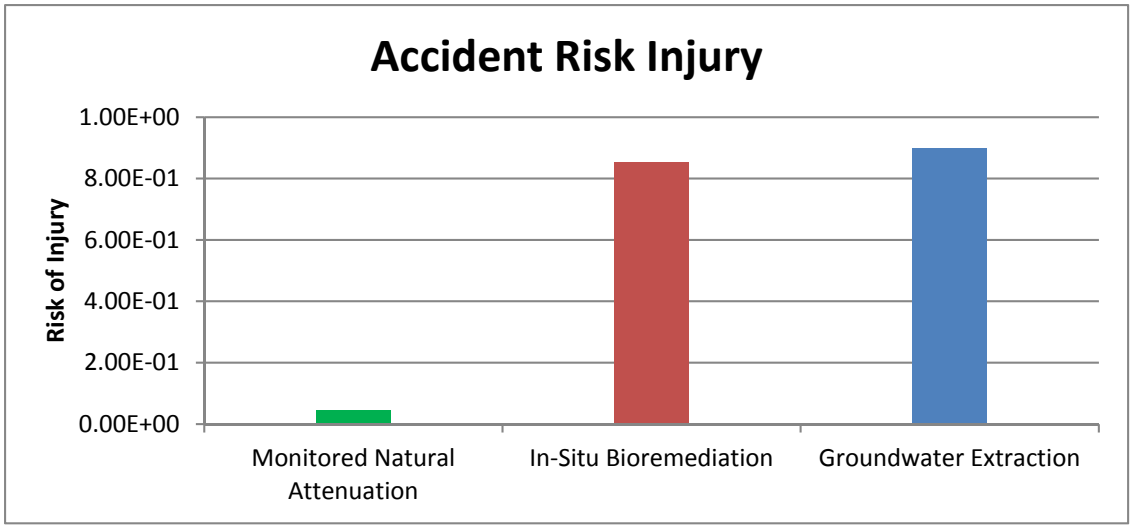


Figure 7-9
Results of the Sustainability Evaluation for the TAG AOC Remedial Alternatives (fatality and injury risk)

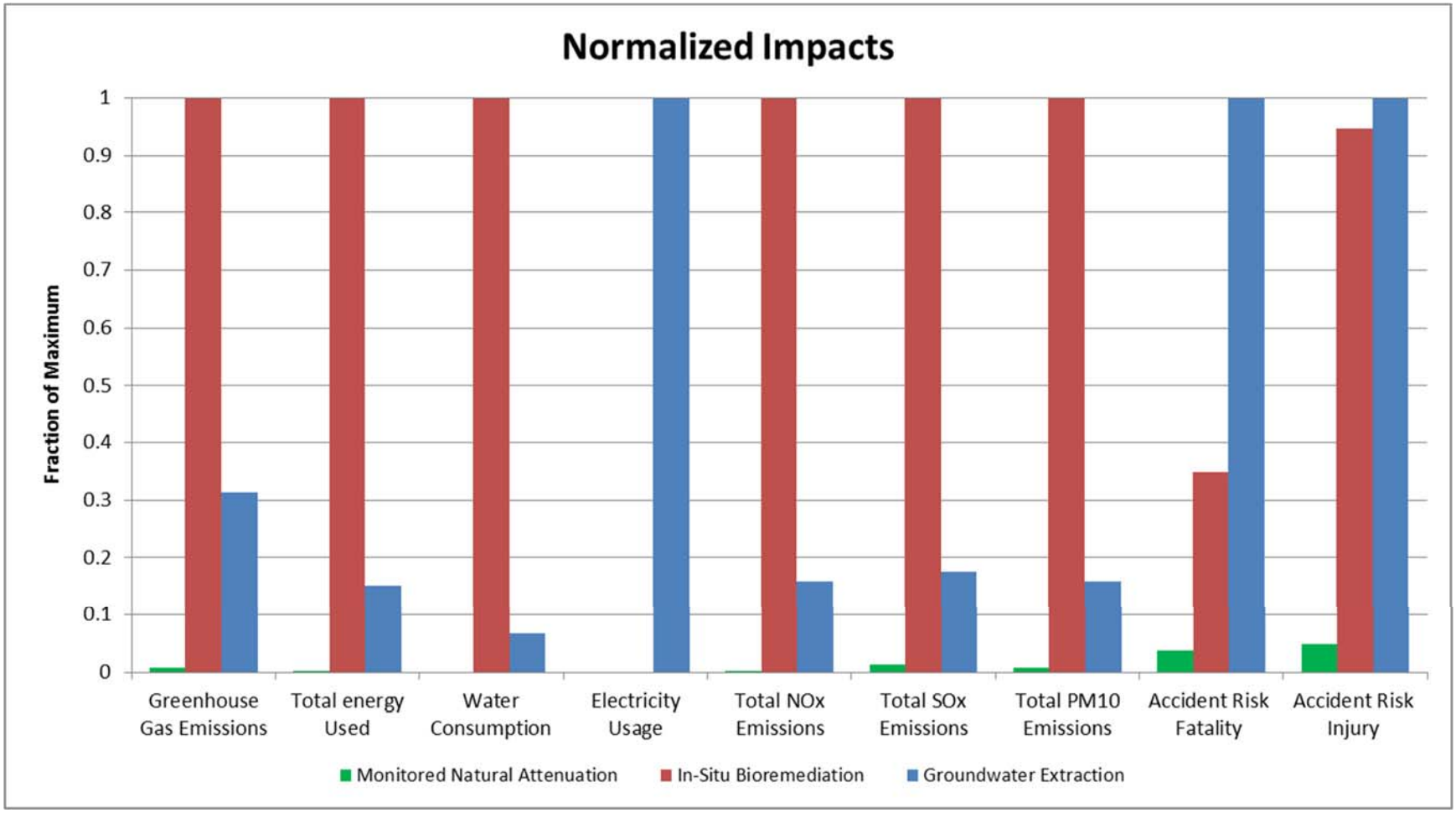


Figure 7-10
Normalized Sustainability Impacts for the TAG AOC Remedial Alternatives

7.4 Preferred Remedy

The Monitored Natural Attenuation Alternative is the preferred remedy for groundwater in the TAG AOC. This alternative meets the threshold criteria, is readily implementable, and is projected to meet the remedial objectives in a reasonable timeframe.

Nitrate concentrations in groundwater are low at this site (barely exceeding the MCL), are inaccessible to onsite receptors, and do not pose a potentially unacceptable risk to offsite receptors. Alternative 1 includes development of a Contingency Plan that would provide mechanisms for changing the remedial approach if the remedy does not proceed as anticipated.

Monitored Natural Attenuation is the preferred remedy for the TAG AOC, because:

There is No Unacceptable Risk to Receptors and / or Foreseeable Groundwater Beneficial Use

- There is no current or anticipated use of groundwater from the Perched Groundwater System near the TAG AOC. The nearest receptor in the Regional Aquifer is the Ridgecrest Well Field located approximately 5 miles from the TAG AOC along the groundwater flow path. Modeling predicts any nitrate reaching the well field would be attenuated by over two orders of magnitude and well below the MCL. Thus, there is no foreseeable risk to human health or threat to beneficial use of groundwater.

- Although Regional Aquifer groundwater flow is toward the west, the primary local flow direction of Perched Groundwater System at the TAG AOC is toward the southeast, away from the Ridgecrest production wells.

- Groundwater is relatively deep, approximately 270 to 340 ft bgs in the Perched Groundwater System. There is no potential for direct human contact or exposure to groundwater contaminants near the TAG AOC.

- Approximately 25 percent of the total groundwater loss from the Perched Groundwater System is due to lateral flow, while 75 percent is downward vertical flow through the Perching Horizon. On average, over 200 feet of unsaturated sediments are present between the Perched Groundwater System and the Regional Aquifer.

- Exept in the merging zone, there is no geochemical evidence that groundwater flowing downward through the Perching Horizon has reached the Regional Aquifer.

There Are No Remaining Active Sources of Contamination Release at the TAG AOC

- The original sources of nitrate from wastewater and sanitary-waste sites are no longer in operation (discharges ceased as of 1992).

- There is no longer a driving force for downward migration of contaminants through the vadose zone to groundwater. There is no indication that residual nitrate in the vadose zone would result in future impacts to groundwater at higher concentrations than are now present.

TAG AOC Contaminant Concentrations Are Relatively Low

- Nitrate concentrations only slightly exceed the MCL. The nitrate plume in the TAG AOC commingles with higher concentrations associated with KAFB and possibly COA operations farther to the south.
- The nitrate plume is dilute with no distinct areas of high concentration.
- Nitrate concentrations in groundwater are variable, but generally stable.

Attenuation is Projected to Occur within a Reasonable Timeframe

- Natural processes are predicted to reduce concentrations to below the MCL in a reasonable timeframe (41 years from 2018), primarily through natural dewatering of the Perched Groundwater System and natural groundwater transport mechanisms (advection, dispersion, and diffusion).
- The estimated duration of the Monitored Natural Attenuation remedy is comparable to the timeframe at other sites nationwide with similar conditions.

Land Use Controls can be Controlled, Maintained, or Implemented

- DOE is expected to retain stewardship of the site for the foreseeable future.
- If land use changes at the TAG AOC, or transfer of the property from DOE control were to occur in the future, the protectiveness of the remedy would be reevaluated.
- Existing or readily implementable land use controls would prevent any exposure to contaminants until remedial objectives are attained. These controls would include site access controls and production well drilling restrictions.

The Remedy is Readily Implementable

- A Monitored Natural Attenuation remedy is easily implemented. The monitoring well network is already in place.
- A Monitored Natural Attenuation remedy would have few detrimental impacts on ongoing programmatic operations in the area.
- A Monitored Natural Attenuation remedy minimizes safety risks to field personnel otherwise present during construction and operation of more active measures.
- In-situ bioremediation or groundwater extraction/treatment remedies would be infeasible at the TAG AOC.

The Remedy is Sustainable

Compared to the In-Situ Bioremediation and Groundwater Extraction and Treatment Alternatives, the Monitored Natural Attenuation Alternative would generate far less greenhouse gases, have lower energy and water use, emit fewer particulates, and have the lowest risk of injuries or fatalities during remedy implementation.

Performance Assurance Measures are Included

- The Monitored Natural Attenuation Alternative would include groundwater monitoring until remedial objectives are achieved.
- A Contingency Plan would include measures to be implemented if the remedy does not proceed as anticipated. The Plan would include topics such as:
  - Groundwater elevations do not continue to decline, or drop much more slowly than predicted, such that the predicted 41-year life cycle is not achievable.
  - Nitrate concentrations unexpectedly increase.
  - Land or groundwater use in the area changes such that there is potential exposure to contaminants, or new land use controls are needed.
  - Groundwater flow direction or velocity change significantly.
  - Additional contamination migrates into the TAG AOC from an upgradient source.
  - Substances that are not currently COCs are detected above MCLs.
  - Regulatory cleanup standards are adjusted (for example, a revision to the nitrate MCL).
  - The public would be kept informed of the progress of the remedy by: (1) annual monitoring and remedial progress reports, and (2) semiannual public meetings.

7.5 Remedial Alternative Design Criteria

Design criteria are used to: (a) measure meaningful progress toward achieving remedial objectives, (b) show that the remedy remains protective to human health and the environment during the lifecycle of the remedy, and (c) verify that the remedy complies with regulatory requirements.

Analysis of performance monitoring data leads to periodic decisions on whether or not the remedy is performing as expected and whether or not the remedy would ultimately achieve the remedial objectives.

Design criteria and actions for the Monitored Natural Attenuation Alternative at the TAG AOC include:

- Measuring and plotting groundwater elevations to verify the Perched Groundwater System is naturally dewatering as anticipated.
- Monitoring nitrate concentrations and distribution to verify that the remedy is performing as anticipated.
- Collecting groundwater-monitoring data using consistent sampling and analytical methods in order to support operational decisions for optimizing the monitoring program, and for regulatory compliance.
- Collecting sufficient data to support operational decisions, changes to field procedures, and revisions to the remedial approach (including implementation of the Contingency Plan, if necessary).
- Implementing (or maintaining) land-use controls to protect human health and the environment during the remediation timeframe.
- Conducting the remedial action in compliance with applicable regulatory requirements.

These criteria (and corresponding actions) would be used in developing the detailed remedial design that would be included in the Corrective Measures Implementation Plan.

7.6 Corrective Measures Implementation Plan

As stated in the Section VII.D.2 of the Consent Order, the Corrective Measures Implementation Plan would outline the design, construction, operation, maintenance, and performance monitoring for the selected remedy, and a schedule for implementation.

7.6.1 Corrective Measures Implementation Plan Outline

The following is a draft outline of the key components of the Corrective Measures Implementation Plan and includes the required elements listed in the Consent Order. Some of the elements stated in the Consent Order (such as results of pilot tests, construction work plans, and engineering design drawings and specifications) are not included in this outline because they are not applicable to the preferred remedy (Monitored Natural Attenuation) for nitrate.

The proposed outline is:

1. **Introduction**

2. **Background Information**

3. **Description of Selected Final Remedy**

   3.1 Remediation System Objectives
   3.2 Cleanup Goals

4. **Remedy Implementation**

   4.1 Implementation Team Qualifications
   4.2 Monitoring Well Network Description and Specifications
   4.3 Operation and Maintenance Plan
   4.3 Waste Management Plan

5. **Remedy Performance Monitoring**

   5.1 Sampling and Analysis Plan
   5.2 Contingency Plan
   5.3 Land Use Control Implementation Plan

6. **Schedule**

   6.1 Implementation Schedule
   6.2 Reporting Schedule

7. **Appendices**

7.6.2 Estimated Schedule for Initiating Corrective Measures Implementation and Associated Deliverables

Table 7-3 presents the estimated Corrective Measures implementation schedule. This schedule includes tasks, documents, and milestones. This CME Report and the Corrective Measures Implementation Plan are identified deliverables and have clearly defined NMED and public review/comment and comment resolution periods as well as the required NMED review and approval step.

Table 7-3
Preliminary Schedule for the TAG AOC Corrective Action

Activity	Start	Finish	Milestone	Comments
Draft CCM/CME Report	3/1/2016	12/2/2016	12/2/2016	-
Final CCM/CME Report	5/18/2017	2/15/2018	-	Dependent on NMED approval
Selected Remedy Fact Sheet	-	-	-	To be determined (TBD)
Statement of Basis	-	-	-	TBD
Corrective Measures Implementation Plan	-	-	-	TBD, within 90 days of final Statement of Basis
Semiannual Water Level Measurements	2017	2059	-	Ongoing
Semiannual Groundwater Sampling (Perched Groundwater System)	2017	2059	-	Ongoing during review/approval of CME Report through the Corrective Measures Implementation Plan
Annual Groundwater Sampling (Regional Aquifer)	2017	2059	-	Ongoing
Annual Progress Reports	2018	2059	-	-
Corrective Measures Implementation Report	-	-	2059	TBD, within 90 days of remedy completion
Plug and abandon monitoring wells	2059	2060	-	Start time is dependent on receiving NMED approval of CAC

Note: Where applicable, dates are subject to regulatory review.
AOC = Area of Concern.
CAC = Corrective Action Complete.
CCM = Current Conceptual Model.
CME = Corrective Measures Evaluation.
NMED = New Mexico Environment Department.
TBD = To be determined.

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8.0 CONCLUSIONS

The primary conclusions of this Revised CCM/CME Report are:

- The focus of the TAG AOC investigation is the Perched Groundwater System, which is a thin, artificially created (partially natural), dissipating water-bearing unit. This perched groundwater zone formed because of historical anthropogenic surface and shallow subsurface discharges between 1928 and 1992. These discharges may have undergone mixing with naturally occurring residual saturation as it percolated through the subsurface.

- Nitrate is a COC for groundwater in the TAG AOC.

- Nitrate concentrations in the Perched Groundwater System are low across the entire TAG AOC, and only exceed the MCL in the southeast corner of the AOC.

- Nitrate concentrations in the Perched Groundwater System are expected to decrease to below the MCL as a result of natural groundwater transport mechanisms (advection, dispersion, and diffusion).

- Approximately 25 percent of the total groundwater loss from the Perched Groundwater System is due to lateral flow, while 75 percent is downward vertical flow through the Perching Horizon. Over 200 feet of unsaturated sediments are present between the Perched Groundwater System and the Regional Aquifer.

- Exept in the merging zone, there is no geochemical evidence that groundwater flowing downward through the Perching Horizon has reached the Regional Aquifer.

- No production wells (receptors) are completed in the Perched Groundwater System.

- There is no threat to human health and the environment.

- Modeling results show a total transit time of 130 years for NPN concentrations in the TAG AOC to migrate southeast through the Perched Groundwater System, downward to the Regional Aquifer, and then to the west and northwest to the nearest production wells. The model-predicted NPN concentration of 0.24 mg/L would be far below the nitrate MCL (10 mg/L) at the nearest production well in the Regional Aquifer. This modeling used the TAG AOC historical maximum nitrate concentration in the Perched Groundwater System.

- Groundwater extraction or in-situ bioremediation technologies are unsuitable for addressing the nitrate plume at the TAG AOC. This is primarily due to:

  - The large areal extent (but dilute nitrate concentrations) within the TAG AOC plume.

  - The absence of high nitrate concentration regions in the plume that could be targeted by active technologies.

  - Low hydraulic conductivity and the thin (and decreasing) thickness of the Perched Groundwater System, that severely restrict extraction rates (for groundwater extraction) or injection rates (for in-situ bioremediation).

  - Groundwater extraction in the TAG AOC could cause higher nitrate concentrations in the KAFB plume that is currently located to the south, to migrate northward into the TAG AOC. As such, this groundwater extraction might reverse the hydraulic gradient.

  - The extremely high capital and operation/maintenance costs associated with in-situ bioremediation and groundwater extraction technologies.

  - Neither in-situ bioremediation nor groundwater extraction would provide any additional protection to human health and the environment. No current or potential future risk is present, even if nitrate concentrations in the TAG AOC do not decrease, because there is no current use of groundwater in the nitrate-impacted area. Any nitrate reaching the offsite production wells would be naturally attenuated to far below the MCL.

- The preferred remedy (Monitored Natural Attenuation of nitrate in groundwater) is protective of human health and the environment, implementable, cost-effective, and compliant with environmental regulations. It is anticipated to achieve remedial objectives in a reasonable period and is the most sustainable of the remedial alternatives.

9.0 REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR), December 2015. *Case Studies in Environmental Medicine Nitrate/Nitrite Toxicity*, course WB2342, U.S. Department of Health and Human Services - Agency for Toxic Substances and Disease Registry, 135 pp.

AquaVISION, July 1999. "Colloidal Borescope Investigation of the Sandia North Site," AquaVISION, Albuquerque, New Mexico. July 21, 1999.

ATSDR, see Agency for Toxic Substances and Disease Registry.

Balleau Groundwater, Inc. (BGW), February 2001. "Preliminary Model of a Perched Zone of Saturation at Sandia National Laboratories, New Mexico," Balleau Groundwater Inc., Albuquerque, New Mexico.

Balleau Groundwater, Inc. (BGW), September 2002. "Model of a Perched Zone of Saturation at Sandia National Laboratories, New Mexico," Balleau Groundwater Inc., Albuquerque, New Mexico, 94 pp.

Bartolino, J.R., and J.C. Cole, 2002. "Groundwater Resources of the Middle Rio Grande Basin," U.S. Geological Survey, Circular 1222.

BGW, see Balleau Groundwater, Inc.

Beller, H.R., Madrid, V.M., Hudson, G.B., McNab, W.W., Carlsen, T., 2004. Biogeochemistry and natural attenuation of nitrate in groundwater at an explosives test facility. Applied Geochemistry 19, pages1483-1494.

Bodine, M.W, and Jones, B.F., 1986. *The Salt Norm: A Quantitative Chemical-mineralogical Characterization of Natural Waters*, U.S. Geological Survey Water – Resources Investigation Report, pp. 130.

Bouwer, H., and R.C. Rice, 1976. "A Slug Test Method for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells," *Water Resources Research*, Vol. 12, No. 3, pp. 423-428.

Brady, P.V. and Domski, P.S., 2001. *Geochemical Analysis of Shallow Aquifer System at Sandia North,* internal report - Sandia National Laboratories, New Mexico, 24 pp.

Brigham Young University (BYU), 2003. "Department of Defense Groundwater Modeling System, Version 4.0," developed by the Environmental Modeling Research Laboratory at Brigham Young University for the U.S. Department of Defense, Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi. http://chl.wes.army.mil/software/gms and http://www.emrl.byu.edu/gms.htm.

BYU, see Brigham Young University.

California Department of Health Services (California DHS), February 2000. *Health Concerns Related to Nitrate and Nitrite in Private Well Water*, California Department of Health Services – Environmental Health Investigations Branch, 4 pp.

California DHS, see California Department of Health Services.

Carlson, C., February 2011. "An Industrial-Sized Mess," *Weekly Alibi,* v.20, no.5, February 3-9, 2011.

CE2 Corporation, September 2016. E-mail "RE: old TAG release sites," from CE2 Corporation, Pleasanton, CA, Sandia National Laboratories, New Mexico, Environmental Operations, Albuquerque, NM, with two attachments "Notes_HistoricalAirfieldImageryAndDocumentation_20160921.docx" and "Fx_ce16548_TAG_CCM_HistoricalFacilitySites_portrait_v03_20161017.pdf."

City of Albuquerque (COA), July 2016. Website http: www.cabq.gov/envservices/ eslandfill.html, Environmental Health Department, Environmental Services Division, City of Albuquerque, New Mexico.

City of Albuquerque (COA), September 2016. E-mail with Excel spreadsheet *All Eubank analytical 2015.xlsx* from Ziegler, K.R. of COA EHD to Copland, J.R., SNL/NM ER, September 23.

COA, see City of Albuquerque.

Collins, S. (Sandia National Laboratories, New Mexico), December 2000. *Memo to: All ER Personnel Re: Project Name Change from the "Sandia North Groundwater Investigation" to the "Tijeras Arroyo Groundwater Investigation,"* Sandia National Laboratories, Albuquerque, New Mexico.

Copland, J.R. and Skelly, M.F., February 2011. Internal memo – *Redevelopment of SNL/NM Monitoring Wells TA2-W-01 and TA2-W-19*, Sandia National Laboratories, Albuquerque, New Mexico.

Daniel B. Stephens & Associates (DBS&A), April 2002. "Landfill Gas Investigation and Characterization Study," prepared for City of Albuquerque by DBS&A, Albuquerque, New Mexico.

DBS&A, see Daniel B. Stephens & Associates.

Dinwiddie, R.S. (New Mexico Environment Department), September 1997. Letter to M.J. Zamorski (U.S. Department of Energy), "Request for Supplemental Information: Background Concentrations Report, SNL/KAFB." September 24, 1997.
DOE, see U.S. Department of Energy.

Earp, D. (City of Albuquerque Environmental Health Department), January 2002. Personal communication with J. Copland (Sandia National Laboratories, New Mexico) Environmental Restoration Project, Operable Unit 1309, ER Logbook ER-050, p. 148, January 9, 2002.
EPA, see U.S. Environmental Protection Agency.

Freeze, R. A. and Cherry, J.A., 1979. *Groundwater*, Prentice-Hall, Englewood Cliffs, New Jersey, 604 pp.

Fritts, J.E., and D. Van Hart, March 1997. "Sandia North Geologic Investigation Project Report," prepared for Sandia National Laboratories Environmental Restoration Project under Contract AS-4959, GRAM, Inc., Albuquerque, New Mexico, 31 March 1997, 28 pp.

Furman, N.S., 1990. Sandia National Laboratories – The Postwar Decade, University of New Mexico Press, Albuquerque, NM, 858 pp.

Galloway, R. (Sandia National Laboratories, New Mexico), 2001a. E-mail to J. Copland (Sandia National Laboratories, New Mexico), *Re: Septic*. December 12, 2001.

Galloway, R. (Sandia National Laboratories, New Mexico), 2001b. E-mail to J. Copland (Sandia National Laboratories, New Mexico), *Re: High Performing Team*. December 13, 2001.

Gould, J., April 1992. *Memo for Record – Subject: Nitrates*, Kirtland Air Force Base – Installation Restoration Program, 3 pp., April 4.

GRAM and Lettis December 1995. *Conceptual Geologic Model of the Sandia National Laboratories and Kirtland Air Force Base,* prepared for Site Wide Hydrogeologic Characterization Project, Sandia National Laboratories, Albuquerque, New Mexico, by GRAM, Inc., Albuquerque NM and William Lettis & Associates, Inc., 2 volumes.

Grauch, V.J.S., and Connell, S.D., 2013. *New perspectives on the geometry of the Albuquerque Basin, Rio Grande rift, New Mexico: Insights from geophysical models of rift-fill thickness,* in Hudson, M.R., and Grauch, V.J.S., eds., New Perspectives on Rio Grande Basins: From Tectonics to Groundwater: Geological Society of America Special Paper 494, p. 427-462.

Harbaugh, A.W., E.R. Banta, M.C. Hill, and M.G. McDonald, 2000. "MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model—User Guide to Modularization Concepts and the Ground-Water Flow Process," Open-File Report 00-92, U.S. Geological Survey, Branch of Information Services, Denver, Colorado or http://water.usgs.gov/software/ground_water.html/.

Hawley, J.W., and C.S. Haase, 1992. "Hydrogeologic Framework of the Northern Albuquerque Basin," Open-File Report 387, New Mexico Bureau of Geology and Mineral Resources, Socorro, New Mexico.

Hawley, J.W., January 2016. "A Tale of Two Mesas: One High, Dry and Windy; the Other, Somewhat Less So — A Curmudgeonly* Geologist's Groundwater / Energy-Resource Perspective on Current Activity and Prospects for the Future Development in the Semiarid Uplands of the Albuquerque – Rio Rancho Metro-Area: East Mesa—Mesa del Sol, and the Southeast Heights Area Impacted by the KAFB Fuel Spill. West Mesa—Santolina, and a Proposed Exploratory Oil Well West of Rio Rancho," PowerPoint presentation at the January 5, 2016 meeting of the New Mexico Chapter of the Air and Waste Management Association, 18 slides.

Holloway, J.M., R.A. Dahlgren, B. Hansen, and W.H. Casey, October 1998. "Contribution of Bedrock Nitrogen to High Nitrate Concentrations in Stream Water," *Nature*, Vol. 395, October 22, 1998, pp. 785–788.

Holloway, J.M., R.A. Dahlgren, and W.H. Casey, 2001. “Nitrogen Release from rock and soil under simulated field conditions,” *Chemical Geology*, Volume 174, Elsevier Science B.V., pages 403-414.

Hsin-Chi, J. Lin, D.R. Richards, C.A. Talbot, Gour-Tsyh Yeh, Jing-Ru Cheng, Hwai-Ping Cheng, and N.L. Jones, 1997. “FEMWATER: A Three-Dimensional Finite Element Computer Model for Simulating Density-Dependent Flow and Transport in Variably Saturated Media,” U.S. Army Corps of Engineers Technical Report CHL-97-12, U.S. Army Corps of Engineers, Vicksburg, Mississippi.

Hvorslev, M.J., 1951. “Time Lag and Soil Permeability in Ground-Water Observations,” Bulletin No. 26, Waterways Experiment Station, U.S. Army Corps of Engineers, Vicksburg, Mississippi.

KAFB, see Kirtland Air Force Base.

Kelley, V.C., 1954. “Tectonic Map of a Part of the Upper Rio Grande Area, New Mexico,” U.S. Geological Survey Oil and Gas Inv. Map, OM-157, U.S. Geological Survey.

Kelson, K.I., C.S. Hitchcock, and J.B.J. Harrison, 1999. *Paleoseismology of the Tijeras Fault Near Golden, New Mexico. Albuquerque Geology,* F.J. Pazzaglia and S. Lucas (eds.)*, New Mexico Geological Society, Fiftieth Annual Field Conference*, New Mexico Geological Society, Socorro, New Mexico, September.

Kendall, C., 1998. “Chapter 16: Tracing Nitrogen Sources and Cycling in Catchments,” in *Isotope Tracers in Catchment Hydrology,* C. Kendall and J.J. McDonnell (eds.), Elsevier Science B.V., Amsterdam, pp. 519–576.

Kirtland Air Force Base (KAFB), 2000a. “KAFB Landfills,” spreadsheet compiled by C. Dewitt, Manager, Installation Restoration Program, Kirtland Air Force Base, Albuquerque, New Mexico.

Kirtland Air Force Base (KAFB), 2000b. “Corrective Action Units on Annual Unit Audit,” spreadsheet compiled by C. Dewitt, Manager, Installation Restoration Program, Kirtland Air Force Base, Albuquerque, New Mexico.

Kirtland Air Force Base (KAFB), December 2004. Memorandum: *Request for a Class 3 Modification under 20.4.1.900 NMAC Incorporating 40 CVF 270.42 (2) to the Hazardous Waste permit for Kirtland AFB (NM9570024423) for 18 SWMUs*, from 377th Civil Engineer Division, KAFB to J. Bearzi, Hazardous Waste Bureau, NMED, 7 December 2004, 67 pp.

Kirtland Air Force Base (KAFB), February 2005. “Summary of Activities at Solid Waste Management Unit WP-26, Sewage Lagoons and Golf Course Main Pond, Kirtland Air Force Base,” prepared by MWH Americas, Inc. for the Installation Restoration Program, Kirtland Air Force Base, Albuquerque, New Mexico.

Kirtland Air Force Base (KAFB), June 2005. “Summary of Activities at Solid Waste Management Unit WP-26, Sewage Lagoons and Golf Course Main Pond, Kirtland Air Force Base,” prepared by MWH Americas, Inc. for the Installation Restoration Program, Kirtland Air Force Base, Albuquerque, New Mexico.

Kirtland Air Force Base (KAFB), August 2005. *Phase 2, Stage 1 Abatement Report for Nitrate-Contaminated Groundwater at Kirtland Air Force Base, New Mexico*, prepared by MWH Americas, Inc. for the Environmental Compliance Program, Kirtland Air Force Base, Albuquerque, New Mexico. 480 pp.

Kirtland Air Force Base (KAFB), July 2009. Letter (no subject line) from Colonel M.S. Duval, Commander KAFB, Headquarters 377th Air Base Wing (AFMC), Department of the Air Force to M.S. Sanchez, Executive Director, Albuquerque Bernalillo County Water Utility Authority, July 16.

Kirtland Air Force Base (KAFB), April 2014. "Draft Investigation Report Nitrate Characterization at KAFB, Albuquerque, NM," prepared by Oneida Total Integrated Enterprises, LLC for the Air Force Civil Engineer Center, 96 pp. plus 10 appendices.

Kirtland Air Force Base (KAFB), February 2015. "Long-Term Groundwater Monitoring Summary Report for Solid Waste Management Unit (SWMU) WP-26 Sewage Lagoons and Golf Course Main Pond," prepared by CAPE Environmental Management Inc., for the Air Force Civil Engineer Center, 140 pp.

Kirtland Air Force Base (KAFB), December 2015. "Draft Fiscal Year 2015 Long-Term Monitoring Report ST-105 Nitrate Contaminated Groundwater," prepared by URS Group, Inc. and FPM Remediations, Inc. for the Air Force Civil Engineer Center.

Kirtland Air Force Base (KAFB), January 2016. "Final Fiscal Year 2015 Long-Term Monitoring Report WP-026 Base Sewage Lagoons and Golf Course Main Pond (SWMU WP-26)," prepared by URS Group, Inc. and FPM Remediations, Inc. for the Air Force Civil Engineer Center.

Lozinsky, R.P., 1994. "Cenozoic Stratigraphy, Sandstone Petrology, and Depositional History of the Albuquerque Basin, Central New Mexico," in *Basins of the Rio Grande Rift: Structure, Stratigraphy, and Tectonic Setting*, Geological Society of America Special Paper 291, pp. 73–81.

Madrid, V.M., Singleton, M.J., Visser, A., and Esser, B.K., June 2013. Summary of isotopic data and preliminary interpretation of denitrification and age-dating for groundwater samples from three sites at Sandia National Laboratories, New Mexico, LLNL-TR-636381, Lawrence Livermore National Laboratory, 19 pp.

McQuillan, D., April 2016. "Groundwater Nitrate Pollution," draft presentation at the New Mexico Environment Department public meeting for groundwater monitoring issues at SNL/NM, April 26. 15 pages.

Moats, W. (New Mexico Environment Department), November 2001. *Personal communication during Tijeras Arroyo Groundwater—High Performing Team meeting*, ER Logbook ER-050, p. 148, entry by J.R. Copland, November 29, 2001.

Moats, W., and L. Winn, January 1995. "Background Ground-Water Quality of the Kirtland Air Force Base Area, Bernalillo County, New Mexico," NMED/DOE/AIP-95/4, AIP/DOE Oversight Program, Hazardous and Radioactive Materials Bureau, New Mexico Environment Department, Santa Fe, New Mexico.

Montgomery Watson, August 2000. “Stage 1 Abatement Plan for Nitrate-Impacted Groundwater at WP-26, Sewage Lagoons, and Golf Course Pond (WP-26); and City of Albuquerque Sanitary Sewer Line Break,” prepared for Environmental Compliance Program, Kirtland Air Force Base, Albuquerque, New Mexico.

Montgomery, Watson, Harza (MWH) Americas, Inc., July 2003. “Stage 1 Abatement Report for Nitrate-Impacted Groundwater at Kirtland Air Force Base, New Mexico,” prepared for Environmental Compliance Program, Kirtland Air Force Base, Albuquerque, New Mexico.

MWH, see Montgomery, Watson, Harza.

Naval Facilities Engineering Command (NAVFAC) Engineering and Expeditionary Warfare Center, July 2013. *SiteWise™ Tool for Green and Sustainable Remediation - Version 3*, U.S. NAVFAC Engineering and Expeditionary Warfare Center.

Nelson, T.L., June 1997. “Past and Present Solid Waste Landfills in Bernalillo County, New Mexico,” Water Resource Administration—Professional Paper, University of New Mexico School of Public Administration, Albuquerque, New Mexico. June 25, 1997.

New Mexico Environment Department (NMED), September 2003. Letter from J. Kieling (New Mexico Environment Department) to K. Boardman (Sandia Site Office, U.S. Department of Energy), “Tijeras Arroyo Groundwater Investigation Work Plan, June 2003, Sandia National Laboratories, NM5890110518-1, HWB-SNL-03-006.” September 3, 2003.

New Mexico Environment Department (NMED), April 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, Santa Fe, New Mexico. April 29, 2004.

New Mexico Environment Department (NMED), October 2004. “Approved with Modifications: Corrective Measures Evaluation Work Plan for Tijeras Arroyo Groundwater, July 2004,” October 22, 2004.

New Mexico Environment Department (NMED), August 2008. *Notice of Disapproval: Tijeras Arroyo Groundwater Investigation Report, November 2005, Sandia National Laboratories EPA ID# NM5890110518, SNL-05-028*, New Mexico Environment Department, Santa Fe, New Mexico.

New Mexico Environment Department (NMED), April 2009. “RE: Perchlorate Contamination in Groundwater, Sandia National Laboratories, EPA ID#NM5890110518,” New Mexico Environment Department, Santa Fe, New Mexico, April 30, 2009.

New Mexico Environment Department (NMED), August 2009. “Notice of Disapproval: Response to the Notice of Disapproval for the Tijeras Arroyo Groundwater Investigation Report, February 2009, Sandia National Laboratories EPA ID# NM5890110518, SNL-05-028,” New Mexico Environment Department, Santa Fe, New Mexico, August 12, 2009.

New Mexico Environment Department (NMED), February 2010. “Notice of Approval: Tijeras Arroyo Groundwater Investigation Report, November 2005, Sandia National Laboratories EPA ID# NM5890110518, SNL-05-028,” New Mexico Environment Department, Santa Fe, New Mexico, February 22, 2010.

New Mexico Environment Department (NMED) July 2010, *Hazardous Waste Treatment Facility Operating Permit EPA ID No. NM9570024423, issued to the United States Air Force for the Open Detonation Unit located at Kirtland Air Force Base, Bernalillo County, New Mexico*, New Mexico Environment Department, Santa Fe, New Mexico, 184 pp.

New Mexico Environment Department (NMED), January 2015. *Resource Conservation and Recovery Act Facility Operating Permit – EPA ID No. NM5890110518* issued to the U.S. Department of Energy/Sandia Corporation for the Sandia National Laboratories Hazardous and Mixed Waste Treatment and Storage Units and Post-Closure Care of the Corrective Action Management Unit.

New Mexico Environment Department (NMED), April 2016. *Summary of Agreements and Proposed Milestones Pursuant to the Meeting of July 20, 2015, March 30, 2016, EPA ID#NM5890110518, HWB-SNL-16-MISC,* April 14, 2016.

New Mexico Environment Department (NMED), May 2017. *"*Disapproval: Tijeras Arroyo Groundwater Current Conceptual Model and Corrective Measures Evaluation Report December 2016, Sandia National Laboratory [sic] EPA ID#NM5890110518, HWB-SNL-16-020,*"* May 18.

New Mexico Environment Department (NMED), August 2017. *"*Approval: Annual Groundwater Monitoring Report, Calendar Year 2016, June 2017. Sandia National Laboratory [sic] EPA ID#NM5890110518, HWB-SNL-17-010*",* August 24.

New Mexico Environment Department (NMED), October 2017. *"*Approval: Request for Extension for Submittal of Revised Current Conceptual Model and Corrective Measures Evaluation Report, Sandia National Laboratory [sic] EPA ID#NM5890110518, HWB-SNL-16-020,*"* October 13.

New Mexico Office of the State Engineer (NMOSE), September 2017. *ABCWUA Monthly Water Production Report for 2016* spreadsheet sent via e-mail from D.H. Rappuhn (NMOSE Hydrology Bureau) to J.R. Copland (Sandia National Laboratories/ New Mexico Environmental Restoration Operations), September 7.

Pazzaglia, F.J., L.A. Woodward, S.G. Lucas, O.J. Anderson, K.W. Wegmann, and J.W. Estep, September 1999. "Phanerozoic Geologic Evolution of the Albuquerque Area," in *New Mexico Geological Society 50th Annual Field Conference, Albuquerque Geology*, pp. 97–114.

Pollock, D.W., 1994. "User's Guide for MODPATH/MODPATH-PLOT, Version 3: A Particle Tracking Post-Processing Package for MODFLOW, the U.S. Geological Survey Finite-Difference Ground-Water Flow Model," Open-File Report 94-464, U.S. Geological Survey.

Powell, R.I. and McKean, S.E., 2014. "Estimated 2012 Groundwater Potentiometric Surface and Drawdown from Predevelopment to 2012 in the Santa Fe Group Aquifer System in the Albuquerque metropolitan Area, Central New Mexico," U.S. Geological Survey Scientific Investigations Map 3301, 1 sheet.

Reiter, M., March 1998. "Hydrogeothermal Studies on the Southern Part of Sandia National Laboratories/Kirtland Air Force Base—Data Regarding Ground-Water Flow Across the Boundary of an Intermontane Basin," draft prepared for a Geological Society of America Special Paper.

Sanders, M.R. and Skelly, M.F, February 2010. Internal memo – *February 2010 Redevelopment of SNL/NM Monitoring Wells MRN-3D and TA1-W-03*, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories, New Mexico (SNL/NM), August 1994. *Technical Area II RCRA Facility Investigation Work Plan*, Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories, New Mexico (SNL/NM), 1995. "Site-Wide Hydrogeologic Characterization Project 1995 Hydrology Testing Laboratory Results for Projects: I-25 Persons Section, TA2-NW1-595, MRN-2, CWL-BW4, CWL-MW2B, CWL-MW4, and CWL-MW5, Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico, 106 pp.

Sandia National Laboratories, New Mexico (SNL/NM), March 1995. *Site-Wide Hydrogeologic Characterization Project, Calendar Year 1994 Annual Report*, Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories, New Mexico (SNL/NM), March 1996a. *Sandia North Groundwater Investigation Plan*, Sandia National Laboratories Environmental Restoration Project for U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico.

Sandia National Laboratories, New Mexico (SNL/NM), March 1996b. "Tijeras Arroyo Infiltration Experiment," Sandia National Laboratories, New Mexico, Albuquerque, New Mexico.

Sandia National Laboratories, New Mexico (SNL/NM), February 1998. "Revised Conceptual Geologic Model of the Sandia National Laboratories and Kirtland Air Force Base," prepared for Site Wide Hydrogeologic Characterization Project, Sandia National Laboratories, Albuquerque, New Mexico, by GRAM, Inc., Albuquerque NM and William Lettis & Associates, Inc., 2 volumes.

Sandia National Laboratories, New Mexico (SNL/NM), March 1998. *Sandia North Groundwater Investigation, Annual Report, Fiscal Year 1997*, Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories, New Mexico (SNL/NM), February 2001. "Groundwater Modeling Report – Appendix D" in *Environmental Restoration Project Long-Term Monitoring Strategy for Groundwater*, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories, New Mexico (SNL/NM), November 2002. *Tijeras Arroyo Groundwater Continuing Investigation Report,* Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico, 448 pp.

Sandia National Laboratories, New Mexico (SNL/NM), June 2003. *Tijeras Arroyo Groundwater Investigation Work Plan (Final Version)*, Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico.

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

Sandia National Laboratories/New Mexico (SNL/NM), November 2004. *Corrective Measures Evaluation Work Plan, Tijeras Arroyo Groundwater*, SAND2004-3247P, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories, New Mexico (SNL/NM), December 2004. *Corrective Measures Evaluation Work Plan, Tijeras Arroyo Groundwater, Revision 0)*, Report SAND2004-6111. Environmental Restoration Project, U.S. Department of Energy, Albuquerque Operations Office, Sandia National Laboratories, New Mexico.

Sandia National Laboratories, New Mexico (SNL/NM), August 2005. *Corrective Measures Evaluation Report for Tijeras Arroyo Groundwater*, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories, New Mexico (SNL/NM), November 2005. *Tijeras Arroyo Groundwater Investigation Report*, Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico, 548 pp.

Sandia National Laboratories, New Mexico (SNL/NM), February 2009. "Response to NMED's Notice of Disapproval: Tijeras Arroyo Groundwater Investigation Report, November 2005 Dated August 2008," Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico, February 26, 2009.

Sandia National Laboratories, New Mexico (SNL/NM), January 2010. "Response to NMED's Notice of Disapproval: Tijeras Arroyo Groundwater Investigation Report, November 2005 Dated February 2009," Environmental Restoration Operations, Sandia National Laboratories, Albuquerque, New Mexico, January 19, 2010.

Sandia National Laboratories, New Mexico (SNL/NM), April 2015. *Installation of Groundwater Monitoring Wells CYN-MW14A, CYN-MW15, and TA2-W-28 and the Decommissioning of Groundwater Monitoring Well TA2-SW1-320,* Sandia National Laboratories, New Mexico Environmental Restoration Operations and Long-Term Stewardship, Albuquerque, New Mexico.

Sandia National Laboratories, New Mexico (SNL/NM), September 2015. *Current Conceptual Model for Technical Area V Groundwater Area of Concern at Sandia National Laboratories, New Mexico*, Environmental Restoration Operations, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories, New Mexico (SNL/NM), June 2017. *Annual Groundwater Monitoring Report, Calendar Year 2016*, Long-Term Stewardship Consolidated Groundwater Monitoring Program, Long-Term Stewardship and Environmental Restoration Operations, Sandia National Laboratories, Albuquerque, New Mexico, SAND2017-5876R, 583 pp.

Skelly, M., S. Griffith, R. Lynch, and G. Quintana, May 2004. "Technical Memorandum—Field Report on the Slug Tests at Tijeras Arroyo Groundwater Investigation Wells," prepared for U.S. Department of Energy, Albuquerque Operations Office by Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico.

Smith, G.A., and A.J. Kuhle, February 1998. "Hydrostratigraphic Implications of New Geologic Mapping in the Santo Domingo Basin, New Mexico," in *New Mexico Geology*, Vol. 20, No. 1.

SNL/NM, see Sandia National Laboratories, New Mexico.

Spearing, D.R., 1974. “Alluvial fan Deposits: Summary Sheets of Sedimentary Deposits,” sheet 1. Geological Society of America, January 1, 1974.

Stone, B.D., J.C. Cole, and D.A. Sawyer, February 2000. “Regional Stratigraphic Framework for an Integrated Three-Dimensional Geologic Model of the Rio Grande Rift,” in *U.S. Geological Survey, Middle Rio Grande Basin Study—Proceedings of the Fourth Annual Workshop*, *Albuquerque, New Mexico*, February 15-16, 2000, Open File Report 00-488. U.S. Geological Survey, Albuquerque, New Mexico.

Thorn, C.R., D.P. McAda, and J.M. Kernodle, 1993. “Geohydrologic Framework and Hydrologic Conditions in the Albuquerque Basin, Central New Mexico,” Water-Resources Investigations Report 93-4149, U.S. Geological Survey, prepared in cooperation with Water Utility Division, City of Albuquerque, Public Works Department, Albuquerque, New Mexico.

Tiedeman, C., M. Kernodle, and D. McAda, 1998. “Application of Nonlinear-Regression Methods to a Ground-Water Flow Model of the Albuquerque Basin, New Mexico,” U.S. Geological Survey Water-Resources Investigations Report 98-4172, U.S. Geological Survey, Menlo Park, California.

USACE, see U.S, Army Corps of Engineers.

U.S. Army Corps of Engineers (USACE), 1979. *Special Flood Hazard Information: Tijeras Arroyo and Arroyo del Coyote, Kirtland AFB, New Mexico*, U.S. Army Corps of Engineers, Albuquerque District, Albuquerque, New Mexico.

U.S. Department of Energy (DOE), September 1987. “Comprehensive Environmental Assessment and Response Program (CEARP), Phase I: Installation Assessment, Sandia National Laboratories,” Albuquerque Operations Office, U.S. Department of Energy, Albuquerque, New Mexico.

U.S. Department of Energy (DOE), October 1999. “Final Site-Wide Environmental Impact Statement, Sandia National Laboratories, Albuquerque, New Mexico,” DOE/EIS-0281, Albuquerque Operations Office, U.S. Department of Energy, Albuquerque, New Mexico.

U.S. Department of Energy (DOE), May 2011. *DOE Order 436.1: Departmental Sustainability*.

U.S. Department of Energy (DOE), March 2016. “Summary of Agreements and Proposed Milestones Pursuant to the Meeting of July 20, 2015,” DOE/NNSA Sandia Field Office, Albuquerque, New Mexico, 30 March 2016.

U.S. Department of Energy (DOE), September 2017. “Request for Extension for Submittal of the Revised Tijeras Arroyo Groundwater Current Conceptual Model and Corrective Measures Evaluation Report in Response to the NMED Disapproval Letter dated May 18, 2017*”,* September 25.

U.S. Environmental Protection Agency (EPA), November 1986. “Test Methods for Evaluating Solid Waste,” 3rd ed., Update 3, SW 846, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA), May 1994. “RCRA Corrective Action Plan (Final),” OSWER 9902.3-2A, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington D.C.

U.S. Environmental Protection Agency (EPA), 1996. “Advance Notice of Proposed Rulemaking (61 FR 19432, May 1).” Available at http://www.epa.gov/docs/fedrgstr/EPA-WASTE/1996/May/Day-01/pr-547.pdf.

U.S. Environmental Protection Agency (EPA), September 1998. “Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water,” U. S. Environmental Protection Agency, Office of Research and Development, Washington D. C.

U.S. Environmental Protection Agency (EPA), January 1999. “Compendium of Methods for Determination of Toxic Organic Compounds in Ambient Air,” 2nd ed., EPA/625/R-96/010b, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA), April 1999. “Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites,” OSWER Directive 9200.4-17P.

U.S. Environmental Protection Agency (EPA), July 2000. “A Guide to Developing and Documenting Cost Estimates During the Feasibility Study,” EPA 540-R-00-002. OSWER 9355.0-75.

U.S. Environmental Protection Agency (EPA), October 2001. “Technical Drinking Water and Health Contaminant Specific Fact Sheet – Nitrate/Nitrite,” wysiwyg://8/http://epa.gov/OGWDW/dwh/t-ioc/nitrates.html, Office of Water, U.S. Environmental Protection Agency, Washington, D.C. October 23, 2001.

U.S. Environmental Protection Agency (EPA), April 2008. *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites*. EPA 542-R-08-002.

U.S. Geologic Survey (USGS), May 1990. *Water Fact Sheet – Largest Rivers in the United States*, Open-File Report 87-242, revised May 1990.

USGS, see U.S. Geologic Survey.

Van Hart, D., June 2003. “Geologic Investigation: An Update of Subsurface Geology on Kirtland Air Force Base, New Mexico,” SAND2003-1869, Sandia National Laboratories, Albuquerque, New Mexico.146 pp.

Van Hart, D., June 2001. “Shallow Groundwater System Investigation: Tijeras Arroyo and Vicinity,” Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico.

Van Hart, D., D.A. Hyndman, and S.S. Brandwein, October 1999. “Analysis of the USGS Isleta/Kirtland Air Force Base Aeromagnetic Survey for Application to SNL/KAFB Area Geologic Structure,” prepared for the Sandia National Laboratories, New Mexico Groundwater Protection Program, Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico. October 15, 1999.

Vukovic, M. and Soro, A., 1992. Determination of Hydraulic Conductivity of Porous Media from Grain-Size Composition," Water Resources Publications, Littleton, Colorado, 83 pp.

Walvoord, M.A., F.M. Phillips, D.A. Stonestrom, R.D. Evans, P.C. Hartsough, B.D. Newman, and R.G. Striegl, November 2003. "A Reservoir of Nitrate Beneath Desert Soils," *Science,* Vol. 302. November 7, 2003.

Wolford, R., September 1996. "Hydrologic Evaluation of a Perched Aquifer Near TA-II Tijeras Arroyo: Estimating Aquifer Parameters, Water Travel Times, and Possible Sources of Recharge in the Perched Zone. Site-Wide Hydrogeologic Characterization Project, Environmental Restoration Program, SNL/NM," GRAM, Inc., Albuquerque, New Mexico.

Zheng, C., and P.P. Wang, 1999. "MT3DMS, A Modular Three-Dimensional Multi-Species Transport Model," Strategic Environmental Research and Development Program (SERDP), U.S. Army Corps of Engineers.

APPENDIX A
Tijeras Arroyo Groundwater Investigation Historical Timeline

Appendix A
Tijeras Arroyo Groundwater Investigation Historical Timeline

Year	Event	Reference
1928	Land-use development began in 1928 when the public Albuquerque Airport was built. Renamed Oxnard Field in 1929, the airport was used until late 1939 when the vicinity of Oxnard Field was purchased by the federal government for use as an Army Air Depot Training Station, later to be known as Sandia Base.	www.airfields-freeman.com; CE2 Corporation September 2016
1939	In 1939, public airline service was moved approximately four miles to the west of Oxnard Field where the Albuquerque Municipal Airport was built. Using the municipal set of runways, the Albuquerque Army Air Base began operations in 1941.	www.econtent.enm.edu
1945	"Z Division" of the Manhattan Engineers District, an extension of the original Los Alamos Laboratory, was established at Sandia Base in the area that would become known as TA-I.	Furman, 1990
1946	After World War II, the old Oxnard Field runways and an extensive grid of taxiways were used for parking aircraft. Starting in 1946, the War Assets Administration managed the sale or dismantlement of approximately 2,250 surplus military aircraft.	www.militarymediainc.com
1947	Wastewater and septic water discharges begin at TA-II. (All cease during 1992.)	SNL/NM November 2005
1948	Wastewater and possibly septic water discharges begin at SWMU 46. (All cease during 1974.)	SNL/NM November 2005
1949	The independent Sandia Laboratory was established. Existing buildings in TA-I were remodeled. New buildings in TA-I and TA-II were constructed.	Furman 1990
1977	Construction of TA-IV began in 1977.	SNL/NM June 2016
1987	The Comprehensive Environmental Assessment and Response Program was established to evaluate specific release sites at SNL/NM.	DOE September 1987
1989	The ER Project begins conducting site investigations.	
1992–1993	SNL/NM began to investigate groundwater at TA-II. The shallow Perched Groundwater System was discovered with the installation of wells TA2-SW1-320, TA2-NW1-325, and TA2-NW1-595. The presence of the Regional Aquifer was previously known.	SNL/NM March 1995a
1994	First detection of TCE in groundwater samples.	SNL/NM March 1996a
1995	First detection of TCE above the EPA MCL of 5 µg/L in TAG groundwater samples.	SNL/NM March 1996b
1996	Sandia North Groundwater Investigation Plan submitted to the NMED.	SNL/NM March 1996a
1996	Shallow (perched) Water-Bearing Zone Hydrologic Evaluation prepared.	Wolford September 1996
1996	Pressure transducer program initiated for select monitoring wells.	SNL/NM March 1998
1997	Sandia North Geological Investigation Project Report submitted.	Fritts and Van Hart March 1997
1997	Downhole geophysical surveying (electromagnetic induction, neutron, and natural gamma) completed on 21 SNL/NM and KAFB monitoring wells.	SNL/NM March 1998
1999	Colloidal borescope investigation performed on 18 Perched Groundwater System monitoring wells.	AquaVISION July 1999
1999	Analysis of the USGS aeromagnetic survey performed to revise the interpretation of the SNL/NM and KAFB area geologic structure.	Van Hart et al. October 1999
2000	At NMED direction, the TAG High Performing Team held its first meeting in Albuquerque, NM.	SNL/NM June 2003
2000	Project name changed from the Sandia North to the Tijeras Arroyo Groundwater Investigation.	Collins December 2000
2001	Geologic model of the Perched Groundwater System updated.	Van Hart June 2001
2002	Complete the calibration of the three-dimensional modeling of the TAG vicinity using finite element numerical code (FEM-WATER).	Balleau Groundwater Inc., September 2002
2002	TAG Continuing Investigation Report submitted to the NMED.	SNL/NM November 2002
2003	Subsurface geology at KAFB, including the TAG area, updated.	Van Hart June 2003
2003	TAG Investigation Work Plan submitted to the NMED.	SNL/NM June 2003

Refer to footnotes at end of table.

Appendix A (Continued)
Tijeras Arroyo Groundwater Investigation Historical Timeline

Year	Event	Reference
2003	TAG Investigation Work Plan approved by the NMED.	NMED September 2003
2004	The Compliance Order on Consent (the Consent Order) identified TAG as an area with groundwater contamination requiring a CME.	NMED April 2004
2004	TAG CME Work Plan submitted to the NMED.	SNL/NM July 2004
2004	TAG CME Work Plan approved by the NMED.	NMED October 2004
2005	TAG CME Report submitted to NMED.	SNL/NM August 2005
2005	TAG Investigation Report (analogous to a CCM) submitted to the NMED.	SNL/NM November 2005
2008	NMED issues Notice of Disapproval on November 2005 TAG Investigation Report.	NMED August 2008
2009	DOE and the SNL M&O contractor submit Response to NMED's August 2008 Notice of Disapproval (NOD) for the November 2005 TAG Investigation Report.	SNL/NM February 2009
2009	NMED issues Second Notice of Disapproval on November 2005 TAG Investigation Report.	NMED August 2009
2010	DOE and the SNL M&O contractor submit Response to NMED's August 2009 Second NOD for the November 2005 TAG Investigation Report.	SNL/NM January 2010
2010	NMED issues Notice of Approval for the November 2005 TAG Investigation Report.	NMED February 2010
2015	Meeting held between personnel from SNL/NM, DOE/NNSA, and NMED for discussing the schedule (milestones) for report submittals for TAG, TA-V, and the Burn Site.	DOE March 2016
2016	NMED milestones letter stipulates that an "Updated CCM and CME Report" for the TAG AOC be submitted in December 2016.	NMED April 2016
2016	Submittal of the December 2016 CCM and CME Report to NMED.	SNL/NM December 2016
2017	NMED issues Disapproval letter for the 2016 CCM and CME Report. NMED requests submittal of a revised report by November 30, 2017.	NMED May 2017
2017	Meeting held between personnel from SNL/NM, DOE/NNSA, and NMED to discuss disapproval-letter issues.	none
2017	DOE/NNSA requests a time extension for submittal of the Revised CCM and CME Report.	DOE/NNSA September 2017
2017	NMED approves the time-extension request. Submittal date set for February 15, 2018.	NMED October 2017
2017-2018	Preparation of Revised CCM/CME Report.	

Notes:
µg/L = Microgram(s) per liter.
AOC = Area of Concern.
BGW = Balleau Groundwater, Inc.
CME = Corrective Measures Evaluation.
Consent Order = Compliance Order on Consent.
CY = Calendar Year.
DOE = U.S. Department of Energy.
EPA = U.S. Environmental Protection Agency.
FY = Fiscal Year.
HWB = Hazardous Waste Bureau.
IT = IT Corporation.
KAFB = Kirtland Air Force Base.
MCL = Maximum Contaminant Level.
NMED = New Mexico Environment Department.
NOD = Notice of Disapproval.
NNSA = National Nuclear Security Administration.

SNL = Sandia National Laboratories.
SNL/NM = Sandia National Laboratories, New Mexico.
SWMU = Solid Waste Management Unit.
TA = Technical Area.
TAG = Tijeras Arroyo Groundwater.
TCE = Trichloroethene.
USGS = U.S. Geological Survey.

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APPENDIX B
Construction Details for Monitoring, Production, and Remediation Wells near the TAG AOC

Appendix B
Construction Details for Monitoring, Production, and Remediation Wells in the Vicinity of the TAG AOC

Well	Type	Measuring Point (feet amsl)	Ground Surface (feet amsl)	Top of Screen (feet bgs)	Bottom of Screen (feet bgs)	Top of Screen (feet amsl)	Bottom of Screen (feet amsl)	Casing Total Depth (feet bgs)	Casing, Inner Diameter (inches)	Casing Material	Lithology of Screened Interval	Installation Date	P&A Date, If Applicable
Monitoring Wells in the TAG AOC													
PGS-1	MW	5407.41	5407.9	503.0	513.0	4904.9	4894.9	538.0	5.0	SS	Regional Aquifer	09-Aug-1994	Apr-1998
PGS-2	MW	5408.29	5408.9	535.0[a]	645.0[a]	4872.9	4842.9	655.0	5.0	SS	Regional Aquifer	22-Sep-1995	
TA1-W-01	MW	5403.82	5401.8	575.0	595.0	4826.8	4806.8	600.0	4.8	PVC	Regional Aquifer	22-Mar-1997	
TA1-W-02	MW	5416.62	5416.9	540.0	560.0	4876.9	4856.9	565.6	5.0	PVC	Regional Aquifer	27-Feb-1998	
TA1-W-03	MW	5457.03	5454.9	337.0	357.0	5117.9	5097.9	362.6	5.0	PVC	Perched Groundwater System	27-Jan-1998	
TA1-W-04	MW	5460.98	5458.3	576.0	596.0	4882.3	4862.3	601.7	5.0	PVC	Regional Aquifer	06-Oct-1998	
TA1-W-05	MW	5433.84	5434.2	597.5	617.5	4836.7	4816.7	623.2	5.0	PVC	Regional Aquifer	16-Nov-1998	
TA1-W-06	MW	5417.10	5417.4	300.0	320.0	5117.4	5097.4	325.6	5.0	PVC	Perched Groundwater System	27-Feb-1998	
TA1-W-07	MW	5404.92	5402.8	268.6	288.6	5134.2	5114.2	289.1	5.0	PVC	Perched Groundwater System	13-Aug-1998	
TA1-W-08	MW	5434.19	5434.7	302.0	322.0	5132.7	5112.7	327.0	4.5	PVC	Perched Groundwater System	03-Aug-2001	
TA2-NW1-325	MW	5421.94	5420.0	295.0	325.0	5125.0	5095.0	330.3	4.8	PVC	Perched Groundwater System	01-Apr-1993	
TA2-NW1-595	MW	5421.26	5420.0	535.0[b]	595.0[b]	4885.0	4865.0	598.0	4.8	PVC	Regional Aquifer	27-Jul-1993	
TA2-SW1-320	MW	5411.85	5410.1	299.6	319.6	5110.5	5090.5	324.6	3.8	PVC	Perched Groundwater System	30-Nov-1992	12-Dec-2014
TA2-W-01	MW	5419.99	5417.4	312.0	332.0	5105.4	5085.4	332.0	4.8	PVC	Perched Groundwater System	27-Jun-1994	
TA2-W-19	MW	5351.21	5349.0	265.9	285.9	5083.1	5063.1	285.9	4.8	PVC	Perched Groundwater System	09-Nov-1995	
TA2-W-24	MW	5363.66	5361.8	465.0	485.0	4896.8	4876.8	490.6	5.0	PVC	Regional Aquifer	09-Feb-1998	
TA2-W-25	MW	5374.86	5372.5	492.0	512.0	4880.5	4860.5	517.8	4.8	PVC	Regional Aquifer	01-Apr-1997	
TA2-W-26	MW	5375.77	5373.8	276.0	296.0	5097.8	5077.8	301.6	5.0	PVC	Perched Groundwater System	19-Jan-1998	
TA2-W-27	MW	5362.85	5360.8	275.0	295.0	5085.8	5065.8	300.6	5.0	PVC	Perched Groundwater System	09-Feb-1998	
TA2-W-28	MW	5412.41	5410.0	310.5	330.5	5099.5	5079.5	335.45	4.8	PVC	Perched Groundwater System	05-Dec-2014	
TJA-1	MW	5353.20?	5351.3	275.0	295.0	5076.3	5056.3	305.0	4.8	PVC	Perched Groundwater System	25-Jun-1994	9-Jul-1994
TJA-2	MW	5353.20	5351.3	275.0	295.0	5076.3	5056.3	305.0	3.8	PVC	Perched Groundwater System	12-Jul-1994	
TJA-3	MW	5390.56	5387.8	496.0	516.0	4891.8	4871.8	521.7	5.0	PVC	Regional Aquifer	31-Aug-1998	
TJA-4	MW	5341.16	5338.5	360.0	380.0	4978.5	4958.5	385.7	5.0	PVC	Regional Aquifer – Merging Zone	04-Aug-1998	
TJA-5	MW	5341.33	5338.5	267.0	287.0	5071.5	5051.5	292.7	5.0	PVC	Perched Groundwater System	7-Aug-1998	
TJA-6	MW	5343.16	5340.6	454.9	474.9	4885.7	4865.7	480.7	5.0	PVC	Regional Aquifer	04-Feb-2001	
TJA-7	MW	5391.27	5388.4	290.5	310.5	5097.9	5077.9	316.3	5.0	PVC	Perched Groundwater System	07-Mar-2001	
WYO-1	MW	5392.50	5390.4	510.0	560.0	4880.4	4830.4	570.0	4.3	PVC	Regional Aquifer	27-Aug-1995	23-Jul-2001
WYO-2	MW	5392.50	5390.4	265.0	285.0	5125.4	5105.4	295.0	2.0	PVC	Perched Groundwater System	27-Aug-1995	23-Jul-2001
WYO-3	MW	5392.09	5390.0	520.0	540.0	4870.0	4850.0	545.0	4.5	PVC	Regional Aquifer	31-Jul-2001	
WYO-4	MW	5392.57	5390.2	275.0	295.0	5115.2	5095.2	300.0	4.5	PVC	Perched Groundwater System	22-Jul-2001	
EUBANK-1	MW	5460.02	5458.1	550.0	610.0	4908.1	4848.1	615.0	4.0	SS	Regional Aquifer	16-Jul-1988	
Monitoring Wells in the Vicinity of the TAG AOC													
EUBANK-2	MW	5474.39	5472.4	552.0	592.0	4920.4	4880.4	597.0	4.0	PVC	Regional Aquifer	15-Nov-1996	
EUBANK-3	MW	5498.73	5496.7	590.0	650.0	4906.7	4846.7	655.0	4.0	PVC	Regional Aquifer	15-Nov-1996	
EUBANK-5	MW	5507.40	5505.4	605.0	665.0	4900.4	4850.4	670.0	4.0	PVC	Regional Aquifer	15-Nov-1996	
KAFB-0213	MW	5281.50	5297.3	378.0	428.0	4919.3	4869.3	438.0	5.0	PVC	Regional Aquifer	10-Jan-1984	
KAFB-0219	MW	5263.69	5262.7	396.0	426.0	4866.7	4836.7	428.5	4.0	PVC	Regional Aquifer	08-Jun-2006	
KAFB-0220	MW	5265.10	5262.5	424.0	454.0	4838.5	4808.5	456.0	4.0	SS/PVC	Regional Aquifer	15-Jul-2006	
KAFB-0221	MW	5274.36	5271.5	410.5	440.5	4863.9	4833.9	455.0	4.0	PVC	Regional Aquifer	unk	
KAFB-0307	MW	5364.53	5362.7	405.0	450.0	4957.7	4912.7	460.0	3.8	PVC	Regional Aquifer	04-Aug-1991	
KAFB-0308	MW	5381.65	5380.7	463.0	488.0	4917.7	4892.7	498.0	3.8	PVC	Regional Aquifer	31-Jul-1991	
KAFB-0309	MW	5411.80	5410.7	501.6	526.6	4909.1	4884.1	536.6	4.0	PVC/SS	Regional Aquifer	7-Jul-1992	
KAFB-0310	MW	5416.48	5413.2	400.0	445.0	5013.2	4968.2	455.0	3.8	PVC	Perched Groundwater System	27-Aug-1991	
KAFB-0311	MW	5353.29	5351.7	433.0	458.0	4918.7	4893.7	468.0	3.8	PVC	Regional Aquifer	24-Jul-1992	
KAFB-0312	MW	5432.17	5430.2	503.0	528.0	4927.2	4902.2	533.0	4.5	PVC	Regional Aquifer	26-Aug-1998	
KAFB-0313	MW	5418.98	5416.9	348.0	368.0	5068.9	5048.9	373.0	4.5	PVC	Perched Groundwater System	13-Aug-1998	
KAFB-0314	MW	5455.75	5453.9	428.0	448.0	5025.9	5005.9	453.0	4.5	PVC	Regional Aquifer	30-Sep-1998	
KAFB-0315	MW	5466.11	5464.1	447.0	472.0	5017.1	4992.1	477.0	4.5	PVC	Regional Aquifer	08-Sep-2000	
KAFB-0504	MW	5357.87	5356.9	470.0	490.0	4886.9	4866.9	500.0	4.0	PVC/SS	Regional Aquifer	21-Jan-1990	
KAFB-0505	MW	5362.81	5360.8	495.4	520.5	4865.4	4840.3	521.3	4.5	PVC	Regional Aquifer	22-Jul-1999	

Refer to footnotes at end of table.

Appendix B (Continued)
Construction Details for Monitoring, Production, and Remediation Wells in the Vicinity of the TAG AOC

Well	Type	Measuring Point (feet amsl)	Ground Surface (feet amsl)	Top of Screen (feet bgs)	Bottom of Screen (feet bgs)	Top of Screen (feet amsl)	Bottom of Screen (feet amsl)	Casing Total Depth (feet bgs)	Casing, Inner Diameter (inches)	Casing Material	Lithology of Screened Interval	Installation Date	P&A Date, If Applicable
Monitoring Wells in the Vicinity of the TAG AOC (Continued)													
KAFB-0506	MW	5363.47	5361.0	200.0	220.0	5161.0	5141.0	220.0	4.5	PVC	Perched Groundwater System	31-Aug-1998	
KAFB-0507R	MW	5358.21	5355.7	492.0	512.0	4863.7	4843.7	517.0	4.0	PVC	Regional Aquifer	3-Apr-2013	
KAFB-0508	MW	5351.88	5349.7	481.0	506.0	4868.7	4843.7	507.0	3.5	PVC	Regional Aquifer	02-May-2001	
KAFB-0510	MW	5367.10	5364.7	511.0	536.0	4853.7	4828.7	537.0	3.5	PVC	Regional Aquifer	17-May-2001	
KAFB-0512R	MW	5302.73	5300.2	430.0	450.0	4870.2	4850.2	455.0	4.0	PVC	Regional Aquifer	4-Apr-2013	
KAFB-0516	MW	5205.64	5203.4	322.0	357.0	4881.4	4856.4	360.45	4.0	PVC	Regional Aquifer	30-Jan-2002	
KAFB-0517	MW	5197.10	5194.6	325.0	350.0	4869.6	4844.6	352.0	4.0	PVC	Regional Aquifer	08-Nov-2002	
KAFB-0522	MW	5267.48	5265.7	405.0	430.0	4860.7	4835.7	432.5	4.0	PVC	Regional Aquifer	23-Jun-2004	
KAFB-0523	MW	5352.62	5350.5	600.0	625.0	4750.5	4725.5	627.0	4.0	PVC	Regional Aquifer	unk	
KAFB-0525	MW	5229.75	5227.9	371.0	396.0	4856.9	4831.9	398.0	4.0	PVC	Regional Aquifer	19-Nov-2006	
KAFB-0608	MW	5361.17	5359.9	307.0	327.0	5052.9	5032.9	338.0	4.0	PVC	Perched Groundwater System	28-Mar-1990	
KAFB-0611	MW	5386.09	5383.5	498.0	508.0	4885.5	4875.5	513.0	4.0	PVC	Regional Aquifer	13-Nov-2002	
KAFB-0612	MW	5385.45	5383.5	290.0	315.0	5093.5	5068.5	317.0	4.0	PVC	Perched Groundwater System	21-Nov-2002	
KAFB-0613	MW	5390.78	5391.3	420.0	450.0	4971.3	4941.3	452.0	4.0	PVC	Regional Aquifer	08-Dec-2002	
KAFB-0614	MW	5390.89	5391.4	360.0	370.0	5031.4	5021.4	372.0	4.0	PVC	Perched Groundwater System	12-Dec-2002	
KAFB-0616	MW	5481.07	5478.7	472.0	497.0	5006.7	4981.7	499.0	4.0	PVC	Regional Aquifer	24-Nov-2002	
KAFB-0617	MW	5505.78	5503.3	565.0	590.0	4938.3	4913.3	592.0	4.0	PVC	Regional Aquifer	18-May-2004	
KAFB-0618	MW	5410.05	5408.2	535.0	560.0	4873.2	4848.2	562.0	4.0	PVC	Regional Aquifer	15-Jun-2004	
KAFB-0619	MW	5410.78	5409.0	389.0	404.0	5020.0	5005.0	406.0	4.0	PVC	Perched Groundwater System	04-Jun-2004	
KAFB-0620	MW	5334.64	5332.0	447.0	472.0	4885.0	4860.0	474.5	4.0	PVC	Regional Aquifer	18-Jun-2004	
KAFB-0621	MW	5569.89	5568.0	624.0	649.0	4944.0	4919.0	650.0	4.0	PVC	Regional Aquifer	17-Jun-2004	
KAFB-0623	MW	5328.94	5327.0	265.0	290.0	5062.0	5037.0	292.5	4.0	PVC	Perched Groundwater System	29-Jun-2004	
KAFB-0625	MW	5392.90	5390.2	470.0	495.0	4920.2	4895.2	497.5	4.0	unk	Regional Aquifer	unk	
KAFB-0901	MW	5390.07	5389.8	465.0	527.0	4924.8	4862.8	537.0	4.0	PVC	Regional Aquifer	15-Mar-1990	
KAFB-0903	MW	5391.63	5389.4	225.0	250.0	5164.4	5139.4	251.0	4.0	PVC	Regional Aquifer	3-Apr-2002	
KAFB-0904	MW	5379.50	5377.0**	343.0	368.0	5034.0	5009.0	368.0	4.0	PVC	Regional Aquifer	2002	
KAFB-2622	MW	5358.14	5356.5	195.0	215.0	5161.5	5141.5	217.0	4.0	PVC	Perched Groundwater System	02-Dec-2004	
KAFB-2623	MW	5367.48	5365.3	199.8	219.8	5165.5	5145.5	221.8	4.0	PVC	Perched Groundwater System	30-Dec-2004	
KAFB-2624	MW	5362.27	5359.6	195.0	215.0	5164.6	5144.6	217.0	4.0	PVC	Perched Groundwater System	unk	
KAFB-2625	MW	5359.26	5356.8**	185.0	205.0	5171.8	5151.8	207.0	4.0	PVC	Perched Groundwater System	unk	
KAFB-2626	MW	5357.51	5355.1**	185.0	205.0	5170.0	5150.0	208.0	4.0	PVC	Perched Groundwater System	unk	
KAFB-2627	MW	5367.47	5365.5	195.0	215.0	5172.5	5152.5	217.5	4.0	PVC	Perched Groundwater System	unk	
KAFB-2628	MW	5369.64	5367.1**	506.0	530.0	4861.1	4837.1	535.0	5.0	PVC	Regional Aquifer	unk	
KAFB-2629	MW	5361.53	5359.0**	499.5	519.5	4859.5	4839.5	523.5	5.0	PVC	Regional Aquifer	unk	
KAFB-3391	MW	5396.60	5394.1	262.3	282.3	5131.8	5111.8	284.3	4.0	PVC	Perched Groundwater System	1-Aug-1998	
KAFB-3392	MW	5394.51	5393.4	536.0	561.0	4857.4	4832.4	562.0	4.0	PVC	Regional Aquifer	08-Oct-1999	
KAFB-8281	MW	5401.03	5401.7	544.0	569.0	4857.7	4832.7	570.0	4.0	PVC	Regional Aquifer	27-Oct-1999	
KAFB-8282	MW	5402.92	5403.4	262.0	287.0	5141.4	5116.4	288.0	4.0	PVC	Perched Groundwater System	unk	
ST105-MW004	MW	5234.61	5232.2*	365.0	385.0	4867.2	4847.2	390.0	4.0	PVC	Regional Aquifer	20-Feb-2013	
ST105-MW005	MW	5287.57	5285.2*	273.0	293.0	5012.2	4992.2	298.0	4.0	PVC	Perched Groundwater System	27-May-2103	
ST105-MW006	MW	5313.26	5310.9*	228.0	248.0	5082.9	5062.9	253.0	4.0	PVC	Perched Groundwater System	2-Feb-2013	
ST105-MW007	MW	5311.18	5308.8*	290.0	310.0	5018.8	4998.8	315.0	4.0	PVC	Perched Groundwater System	24-Feb-2013	
ST105-MW008	MW	5358.94	5356.7*	461.0	476.0	4895.7	4880.7	481.0	4.0	PVC	Perched Groundwater System	20-Feb-2013	
ST105-MW009	MW	5519.71	5517.7*	480.0	500.0	5037.7	5017.7	505.0	4.0	PVC	Regional Aquifer	7-Nov-2013	
ST105-MW010	MW	5334.70	5332.4*	436.5	456.5	4895.9	4875.9	461.5	4.0	PVC	Regional Aquifer	1-Jun-2013	
ST105-MW011	MW	5422.66	5420.2*	456.8	476.8	4963.4	4943.4	482.3	4.0	PVC	Regional Aquifer	9-Apr-2013	
ST105-MW012	MW	5419.90	5417.5*	376.0	396.0	5041.5	5021.5	401.0	4.0	PVC	Perched Groundwater System	17-Apr-2013	
ST105-MW013	MW	5447.27	5444.8*	433.6	453.6	5011.2	4991.2	453.6	4.0	PVC	Regional Aquifer	16-Apr-2013	
ST105-MW015	MW	5623.95	5621.5*	687.0	707.0	4934.5	4914.5	712.0	4.0	PVC	Regional Aquifer	7-May-2013	

Refer to footnotes at end of table.

Appendix B (Continued)
Construction Details for Monitoring, Production, and Remediation Wells in the Vicinity of the TAG AOC

Well	Type	Measuring Point (feet amsl)	Ground Surface (feet amsl)	Top of Screen (feet bgs)	Bottom of Screen (feet bgs)	Top of Screen (feet amsl)	Bottom of Screen (feet amsl)	Casing Total Depth (feet bgs)	Casing, Inner Diameter (inches)	Casing Material	Lithology of Screened Interval	Installation Date	P&A Date, If Applicable
Monitoring Wells in the Vicinity of the TAG AOC (Continued)													
ST105-MW017	MW	5621.97	5616.2*	702.0	722.0	4914.2	4894.2	727.0	4.0	PVC	Regional Aquifer	14-Jun-2013	
ST105-MW018	MW	5221.68	5219.0*	349.2	369.2	4869.8	4849.8	374.6	4.0	PVC	Regional Aquifer	9-Mar-2013	
ST105-MW019	MW	5217.94	5215.4*	345.0	365.0	4870.4	4850.4	370.0	4.0	PVC	Regional Aquifer	6-Mar-2013	
ST105-MW020	MW	5383.72	5381.6*	281.0	301.0	5100.6	5080.6	306.0	4.0	PVC	Perched Groundwater System	24-Apr-2013	
ST105-MW021	MW	5390.90	5388.7*	322.0	342.0	5066.7	5046.7	347.0	4.0	PVC	Perched Groundwater System	5-Apr-2013	
ST105-MW023	MW	5275.86	5273.5*	406.0	426.0	4867.5	4847.5	431.0	4.0	PVC	Regional Aquifer	28-Oct-2013	
ST105-MW024	MW	5595.67	5593.4	442.0	462.0	5151.4	5131.4	467.0	4.0	PVC	Regional Aquifer	12-Nov-2013	
Production and Remediation Wells in the Vicinity of the TAG AOC													
KAFB-1	Pd	unk	5386.5	550	1199	4836.5	4187.5	1199	12.0	S	Regional Aquifer	1-Aug-1949	
KAFB-2	Pd	5327.06	5327.1	494	1000	4833.1	4327.1	1000	12.0	S	Regional Aquifer	Jan-1951	
KAFB-3	Pd	unk	5356.9	452	900	4904.9	4456.9	920	14.0	S	Regional Aquifer	1-Oct-1949	
KAFB-4	Pd	unk	5360.2	494	1000	4866.2	4360.2	1000	14.0	S	Regional Aquifer	01-Dec-1949	
KAFB-5	Pd	unk	5439.0	504	1004	4935.0	4435.0	1004	14.0	S	Regional Aquifer	1-Jul-1952	1983?
KAFB-6	Pd	unk	5423.5	504	1002	4919.5	4421.5	1006	14.0	S	Regional Aquifer	1-Jul-1952	1985
KAFB-7	Rem	unk	5350.4	448	976	4902.4	4374.4	976	16.0	S	Regional Aquifer	1-Feb-1955	
KAFB-8	Pd	5372.00	5372.0	440	975	4932.0	4397.0	1000	14.0	S	Regional Aquifer	1-Feb-1955	2000
KAFB-9	Pd	5501.19	5501.2	unk	unk	unk	4851.2?	650	10.0	S	Regional Aquifer	1-Oct-1949	1970
KAFB-10	Pd	5418.65	5418.7	495	970	4923.7	4448.7	970	12.75	S	Regional Aquifer	27-May-1959	Apr-1996
KAFB-11	Pd	5470.67	5481.0	670	1327	4811	4154	1327	16.0	S	Regional Aquifer	10-Apr-1972	
KAFB-12	Pd	5322.87	5324.2	446	1032	4878.2	4292.2	1032	16.0	S	Regional Aquifer	1-Oct-1952	Before 2002
KAFB-13	Pd	5305.67	5307.0	413	953	4894.0	4354.0	977	14.0	S	Regional Aquifer	1-Mar-1956	
KAFB-14	Pd	unk	5324.2	380	620	4944.2	4704.2	930	16.0	S	Regional Aquifer	1-Jan-1969	
KAFB-15	Pd	unk	5335.0	697	993	4638	4342	1600	30.0	S	Regional Aquifer	unk	
KAFB-16	Pd	unk	5370.0	697	993	4673.0	4377.0	1600	30.0	S	Regional Aquifer	2000?	
KAFB-20	Pd	unk	5393.4	710	1180	4683.4	4213.4	1250	20.0	S	Regional Aquifer	2010?	
KAFB-PG-1598	Rem	5369.90	5368.4	290	440	5078.4	4928.4	455	12.0	SS	Perched Groundwater System	14-Oct-1998	
KAFB-0602	Rem	5365.47	5364.2	437	457	4927.2	4907.2	467	4.0	PVC/SS	Perched Groundwater System	20-Mar-1990	
KAFB-0609	Rem	5365.87	5364.7	316	336	5048.7	5028.7	345	4.0	PVC/SS	Perched Groundwater System	31-Mar-1990	22-Jun-2014
KAFB-0610	Rem	5359.47	5357.3	333	353	5024.3	5004.3	363	4.0	PVC/SS	Perched Groundwater System	04-Apr-1990	
Ridgecrest 1	Pd	unk	5444.7	636	1260	4808.7	4184.7	1260	16.0	S	Regional Aquifer	13-Jan-1964	
Ridgecrest 2	Pd	unk	5418.7	730	1500	4688.7	3918.7	1543	16.0	S	Regional Aquifer	1-Jan-1977	
Ridgecrest 3	Pd	unk	5387.7	621	1436	4766.7	3951.7	1449	16.0	S	Regional Aquifer	01-May-1974	
Ridgecrest 4	Pd	unk	5346.7	573	1413	4773.7	3933.7	1450	unk	S	Regional Aquifer	01-Mar-1974	
Ridgecrest 5	Pd	unk	5356.7	650	1450	4706.7	3906.7	1450	20.0	S	Regional Aquifer	8-Dec-1990	
VA-2	Pd	unk	5344.0?	590	990	4754	4354	1010	14.0	S	Regional Aquifer	18-Apr-1997	

Refer to footnotes at end of table.

Construction Details for Monitoring, Production, and Remediation Wells in the Vicinity of the TAG AOC

Notes:
Measuring Point is the top of well casing elevation used for calculating groundwater elevations.
Elevations are relative to the North American Vertical Datum of 1988 (NAVD 88), New Mexico State Plane Coordinate System, Central Zone. Elevation data from other government agencies were converted as necessary using a conversion (re-projection) of +2.671 ft.
Well KAFB-PG-1598 is also known as the Golf Course Main Pond well. Some KAFB documents also use the identifier RG-1598-S-4 or RG-1589-S-4.
*Indicates elevation of concrete pad.
**Only the Measuring Point was known. Ground surface calculated using an assumed stickup of 2.5 ft.
[a] Well PGS-2 has three screens: 535 to 565 ft bgs, 585 to 595 ft bgs, and 625 to 645 ft bgs. Groundwater samples are collected from the upper screen. No packer is installed.
[b] Well TA2-NW1-595 has two screens: 535 to 555 ft bgs, and 585 to 595 ft bgs. Groundwater samples are collected from the upper screen. No packer is installed.

amsl	= Elevation above mean sea level.
bgs	= Below ground surface.
KAFB	= Kirtland Air Force Base.
MW	= Monitoring Well.
P&A	= Plugged and abandoned (decommissioned).
Pd	= Production (water supply) for potable purposes.
PGS	= Parade Ground South.
PVC	= Polyvinyl chloride.
PVC/SS	= Composition of blank well casing is PVC and composition of well screen is stainless steel.
Rem	= Remediation (groundwater extraction or treated-water injection) for KAFB nitrate abatement program.
S	= Steel (carbon steel).
SFG	= Santa Fe Group.
SS	= Stainless steel.
S/SS	= Composition of blank well casing is carbon steel and composition of well screen is stainless steel.
SNL/NM	= Sandia National Laboratories/New Mexico.
TA1-W	= Technical Area I (Well).
TA2-NW	= Technical Area II (Northwest).
TA2-SW	= Technical Area II (Southwest).
TA2-W	= Technical Area II (Well).
TAV	= Technical Area V.
TJA	= Tijeras Arroyo.
unk	= Unknown information, not available.
VA	= Veterans Administration.
WYO	= Wyoming.

APPENDIX C
Groundwater Elevations Measured in 2015 at Monitoring Wells near the TAG AOC

Appendix C
Groundwater Elevations Measured in 2015 at Monitoring Wells in the Vicinity of the TAG AOC

Well ID	M.P. (ft amsl) NAVD 88	Depth to Water (ft btoc)	Groundwater Elevation (ft amsl)	Date Measured	Data Source	Well Owner	Screened Unit	Comment
PGS-2	5408.29	542.03	4866.26	7-Oct-15	SNL/NM	SNL/NM	Regional Aquifer	
TA1-W-01	5403.82	538.71	4865.11	6-Oct-15	SNL/NM	SNL/NM	Regional Aquifer	
TA1-W-02	5416.62	522.54	4894.08	7-Oct-15	SNL/NM	SNL/NM	Regional Aquifer	
TA1-W-03	5457.03	353.07	5103.96	6-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
TA1-W-04	5460.98	569.33	4891.65	6-Oct-15	SNL/NM	SNL/NM	Regional Aquifer	
TA1-W-05	5433.84	564.78	4869.06	7-Oct-15	SNL/NM	SNL/NM	Regional Aquifer	
TA1-W-06	5417.10	308.09	5109.01	7-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
TA1-W-07	5404.92	286.24	5118.68	6-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
TA1-W-08	5434.19	311.35	5122.84	7-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
TA2-NW1-325	5421.94	318.84	5103.10	6-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
TA2-NW1-595	5421.26	522.33	4898.93	6-Oct-15	SNL/NM	SNL/NM	Regional Aquifer	
TA2-W-01	5419.99	328.85	5091.14	6-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
TA2-W-19	5351.21	272.42	5078.79	6-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
TA2-W-24	5363.66	442.38	4921.28	6-Oct-15	SNL/NM	SNL/NM	Regional Aquifer	
TA2-W-25	5374.86	468.73	4906.13	6-Oct-15	SNL/NM	SNL/NM	Regional Aquifer	
TA2-W-26	5375.77	287.92	5087.85	6-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
TA2-W-27	5362.85	280.62	5082.23	6-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
TA2-W-28	5412.41	319.81	5092.60	6-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
TJA-2	5353.20	277.75	5075.45	6-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
TJA-3	5390.56	499.23	4891.33	7-Oct-15	SNL/NM	SNL/NM	Regional Aquifer	
TJA-4	5341.16	300.78	5040.38	6-Oct-15	SNL/NM	SNL/NM	Regional Aquifer	Merging Zone
TJA-5	5341.33	270.09	5071.24	6-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
TJA-6	5343.16	451.44	4891.72	6-Oct-15	SNL/NM	SNL/NM	Regional Aquifer	
TJA-7	5391.27	303.80	5087.47	7-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
WYO-3	5392.09	526.82	4865.27	7-Oct-15	SNL/NM	SNL/NM	Regional Aquifer	
WYO-4	5392.57	293.54	5099.03	7-Oct-15	SNL/NM	SNL/NM	Perched Groundwater System	
Non Sandia Wells								
Eubank-1	5460.02	548.92	4911.10	6-Oct-15	SNL/NM	COA EHD	Regional Aquifer	
Eubank-2	5474.39	576.74	4897.65	5-Oct-15	COA EHD	COA EHD	Regional Aquifer	
Eubank-3	5498.73	604.77	4893.96	5-Oct-15	COA EHD	COA EHD	Regional Aquifer	
Eubank-5	5507.40	613.62	4893.78	5-Oct-15	COA EHD	COA EHD	Regional Aquifer	
KAFB-0213	5281.50	415.19	4866.31	12-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0219	5263.69	396.43	4867.26	8-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0220	5265.10	398.14	4866.96	8-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0221	5274.36	407.44	4866.92	12-Oct-15	KAFB	KAFB	Regional Aquifer	

Appendix C (Continued)
Groundwater Elevations Measured in 2015 at Monitoring Wells in the Vicinity of the TAG AOC

Well ID	M.P. (ft amsl) NAVD 88	Depth to Water (ft btoc)	Groundwater Elevation (ft amsl)	Date Measured	Data Source	Well Owner	Screened Unit	Comment
KAFB-0307	5364.53	426.96	4937.57	7-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0308	5381.65	446.12	4935.53	7-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0309	5411.80	480.03	4931.77	7-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0310	5416.48	352.99	5063.49	7-Oct-15	KAFB	KAFB	Perched Groundwater System	
KAFB-0311	5353.29	n.m.	n.m.	n.m.	KAFB	KAFB	Regional Aquifer	
KAFB-0312	5432.17	417.35	5014.82	7-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0313	5418.98	350.05	5068.93	7-Oct-15	KAFB	KAFB	Perched Groundwater System	
KAFB-0314	5455.75	416.24	5039.51	7-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0315	5466.11	438.21	5027.90	12-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0504	5357.87	491.83	4866.04	9-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0505	5362.81	498.48	4864.33	9-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0506	5363.47	209.02	5154.45	9-Oct-15	KAFB	KAFB	Perched Groundwater System	
KAFB-0507R	5358.21	493.64	4864.57	9-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0508	5351.88	488.43	4863.45	6-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0510	5367.10	504.16	4862.94	6-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0512R	5302.73	437.31	4865.42	9-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0516	5205.64	340.12	4865.52	6-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0517	5197.10	329.11	4867.99	6-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0522	5267.48	404.00	4863.48	9-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0523	5352.62	480.19	4872.43	6-Oct-15	KAFB	KAFB	Regional Aquifer	n.c.
KAFB-0525	5229.75	363.06	4866.69	8-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0608	5361.17	293.89	5067.28	12-Oct-15	KAFB	KAFB	Perched Groundwater System	n.c.
KAFB-0611	5386.09	462.74	4923.35	12-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0612	5385.45	293.23	5092.22	12-Oct-15	KAFB	KAFB	Perched Groundwater System	
KAFB-0613	5390.78	353.57	5037.21	8-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0614	5390.89	331.77	5059.12	8-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0616	5481.07	442.88	5038.19	12-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0617	5505.78	558.15	4947.63	12-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0618	5410.05	484.15	4925.90	8-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0619	5410.78	385.74	5025.04	8-Oct-15	KAFB	KAFB	Perched Groundwater System	
KAFB-0620	5334.64	442.79	4891.85	12-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0621	5569.89	626.00	4943.89	12-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0623	5328.94	258.94	5070.00	12-Oct-15	KAFB	KAFB	Perched Groundwater System	
KAFB-0625	5392.90	472.09	4920.81	9-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-0901	5390.07	470.20	4919.87	7-Oct-15	KAFB	KAFB	Regional Aquifer	

Appendix C (Continued)
Groundwater Elevations Measured in 2015 at Monitoring Wells in the Vicinity of the TAG AOC

Well ID	M.P. (ft amsl) NAVD 88	Depth to Water (ft btoc)	Groundwater Elevation (ft amsl)	Date Measured	Data Source	Well Owner	Screened Unit	Comment
KAFB-0903	5391.63	237.54	5154.09	7-Oct-15	KAFB	KAFB	Regional Aquifer	n.c.
KAFB-0904	5379.50	351.77	5027.73	12-Oct-15	KAFB	KAFB	Regional Aquifer	n.c.
KAFB-2622	5358.14	202.42	5155.72	9-Oct-15	KAFB	KAFB	Perched Groundwater System	
KAFB-2623	5367.48	222.22	5145.26	9-Oct-15	KAFB	KAFB	Perched Groundwater System	
KAFB-2624	5362.27	217.57	5144.70	9-Oct-15	KAFB	KAFB	Perched Groundwater System	
KAFB-2625	5359.26	197.23	5162.03	9-Oct-15	KAFB	KAFB	Perched Groundwater System	
KAFB-2626	5357.51	207.20	5150.31	9-Oct-15	KAFB	KAFB	Perched Groundwater System	
KAFB-2627	5367.47	217.67	5149.80	9-Oct-15	KAFB	KAFB	Perched Groundwater System	
KAFB-2628	5369.64	504.60	4865.04	9-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-2629	5361.53	497.49	4864.04	9-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-3391	5396.60	275.60	5121.00	9-Oct-15	KAFB	KAFB	Perched Groundwater System	
KAFB-3392	5394.51	531.64	4862.87	9-Oct-15	KAFB	KAFB	Regional Aquifer	
KAFB-8281	5401.03	n.m.	n.m.	n.m.	KAFB	KAFB	Regional Aquifer	
KAFB-8282	5402.92	n.m.	n.m.	n.m.	KAFB	KAFB	Perched Groundwater System	
ST105-MW004	5234.61	367.88	4866.73	8-Oct-15	KAFB	KAFB	Regional Aquifer	
ST105-MW005	5287.57	297.20	4990.37	12-Oct-15	KAFB	KAFB	Regional Aquifer	n.c.
ST105-MW006	5313.26	236.00	5077.26	7-Oct-15	KAFB	KAFB	Perched Groundwater System	
ST105-MW007	5311.18	317.59	4993.59	12-Oct-15	KAFB	KAFB	Regional Aquifer	n.c.
ST105-MW008	5358.94	481.99	4876.95	9-Oct-15	KAFB	KAFB	Regional Aquifer	
ST105-MW009	5519.71	484.66	5035.05	12-Oct-15	KAFB	KAFB	Regional Aquifer	
ST105-MW010	5334.70	444.97	4889.73	9-Oct-15	KAFB	KAFB	Regional Aquifer	
ST105-MW011	5422.66	483.92	4938.74	8-Oct-15	KAFB	KAFB	Regional Aquifer	
ST105-MW012	5419.90	384.09	5035.81	8-Oct-15	KAFB	KAFB	Perched Groundwater System	
ST105-MW013	5447.27	437.00	5010.27	8-Oct-15	KAFB	KAFB	Regional Aquifer	
ST105-MW015	5623.95	689.97	4933.98	12-Oct-15	KAFB	KAFB	Regional Aquifer	
ST105-MW017	5621.97	707.60	4914.37	12-Oct-15	KAFB	KAFB	Regional Aquifer	
ST105-MW018	5221.68	354.80	4866.88	6-Oct-15	KAFB	KAFB	Regional Aquifer	
ST105-MW019	5217.94	351.30	4866.64	6-Oct-15	KAFB	KAFB	Regional Aquifer	
ST105-MW020	5383.72	295.82	5087.90	7-Oct-15	KAFB	KAFB	Perched Groundwater System	

Appendix C (Concluded)
Groundwater Elevations Measured in 2015 at Monitoring Wells in the Vicinity of the TAG AOC

Well ID	M.P. (ft amsl) NAVD 88	Depth to Water (ft btoc)	Groundwater Elevation (ft amsl)	Date Measured	Data Source	Well Owner	Screened Unit	Comment
ST105-MW021	5390.90	331.03	5059.87	12-Oct-15	KAFB	KAFB	Perched Groundwater System	
ST105-MW023	5275.86	410.14	4865.72	9-Oct-15	KAFB	KAFB	Regional Aquifer	
ST105-MW024	5595.67	336.83	5258.84	12-Oct-15	KAFB	KAFB	Regional Aquifer - Sandia Granite	

COA EHD = City of Albuquerque Environmental Health Department.
ft amsl = Feet above mean sea level.
ft btoc = Feet below top of casing.
KAFB = Kirtland Air Force Base.
m.p. = Measurement point, typically the top of the well casing.
NAVD = North American Vertical Datum of 1988.
n.c. = Not contoured (anomalous water level that does not correspond to either water-bearing zone).
n.m. = Not measured.
SNL/NM = Sandia National Laboratories, New Mexico.

APPENDIX D
***Evaluation of Contaminant Transport* (SNL/NM August 2005)**

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

Prepared by
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National Nuclear Security Administration under Contract DE-AC04-94AL85000.

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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

EXECUTIVE SUMMARY 2

ACRONYMS AND ABBREVIATIONS 5

1.0 INTRODUCTION 6

1.1 Purpose and Scope 6

2.0 CONCEPTUAL MODEL 8

2.1 Perched System 8

2.2 Regional Aquifer 10

2.2.1 Large-Scale Geologic Features 11
2.2.2 Hydrostratigraphic Framework 12
2.2.3 Regional Recharge 12
2.2.4 Regional Discharge 12
2.2.5 Regional Groundwater Flow 12
2.2.6 Hydrostratigraphic Units 14
2.2.7 Groundwater Flow in Alluvial Fan Lithofacies 14

2.3 Distribution of Groundwater Contaminants 14

2.3.1 Implications of Contaminant Distribution to Numerical Modeling 17

3.0 MODELING APPROACH 18

3.1 Estimate of Flow from the Perched Groundwater System 22

3.1.1 Estimate of Perched Groundwater System Discharge 24
3.1.2 Estimate of Transport Time 25

3.2 Alluvial Fan Model Section 26

3.3 Ancestral Rio Grande Model Section 28

4.0 RESULTS AND INTERPRETATIONS 32

4.1 Simulation of Solute Transport to Production Wells 32

4.2 Interpretations of Modeling Relative to Observed Concentrations 33

5.0 CONCLUSIONS 35

6.0 REFERENCES 36

FIGURES

1-1. Illustration of the staged process of data gathering activities and production of subsequent reports. 7

2-1. Potentiometric surface map for the perched system in the TAG Area of Responsibility, March 2002 (SNL/NM 2004a)..... 9

2-2. Configuration of the regional groundwater surface in the Albuquerque Basin, 1994-1995. 13

2-3. Subregional potentiometric surface elevation contour map for basin fill deposits, 2000. 15

2-4. Potentiometric surface map for the regional aquifer in the TAG area, March 2002. 16

3-1. Regional potentiometric surface map and location of simulated regions. 19

3-2. Local potentiometric surface map and location of simulated regions. 20

3-3. Perched system illustration. 23

3-4. Comparison of simulated and observed potentiometric head along the alluvial fan model section. 28

3-5. Comparison of simulated and observed potentiometric head along the ARG model section 29

3-6. Illustration of solute flux simulation from the alluvial fan model section into the ARG model section. 31

4-1. Plot of solute arrival at the ARG/ alluvial fan model section interface and at the Ridgecrest well field. 32

TABLES

2-1. Summary of perched system properties. 10

2-2. Summary of regional aquifer properties. 11

3-1. Summary information and input parameters..... 22

3-2. Estimate of contaminant travel time in the perched system. 26

4-1. Interpretations of solute transport simulation relative to nitrate contamination. 34

4-2. Interpretations of solute transport simulation relative to TCE contamination. 34

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

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 the locations of potential 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.

Remediation responsibility within the historical TAG area has been assigned to 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 CME Work Plan (SNL/NM 2004a) identifies the specific area within the overall TAG 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 TAG 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.

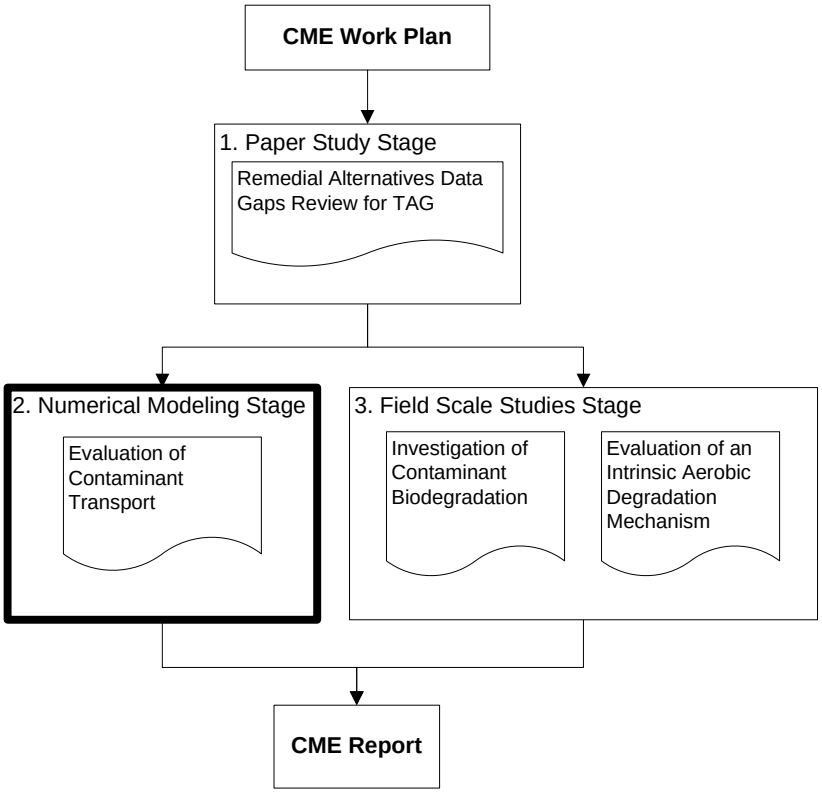


Figure 1-1. Illustration of the staged process of data gathering activities and production of subsequent reports.

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 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 migrates from the perched system into the underlying regional aquifer southeast of Tijeras Arroyo. 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. These pumping centers are a potential pathway for contaminants to reach human receptors.

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 System

The perched system is present beneath the Tijeras Arroyo 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. Groundwater in the perched system is thought to merge with the regional aquifer southeast of Tijeras Arroyo where alluvial-fan sediments may be more coarse-grained. 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).

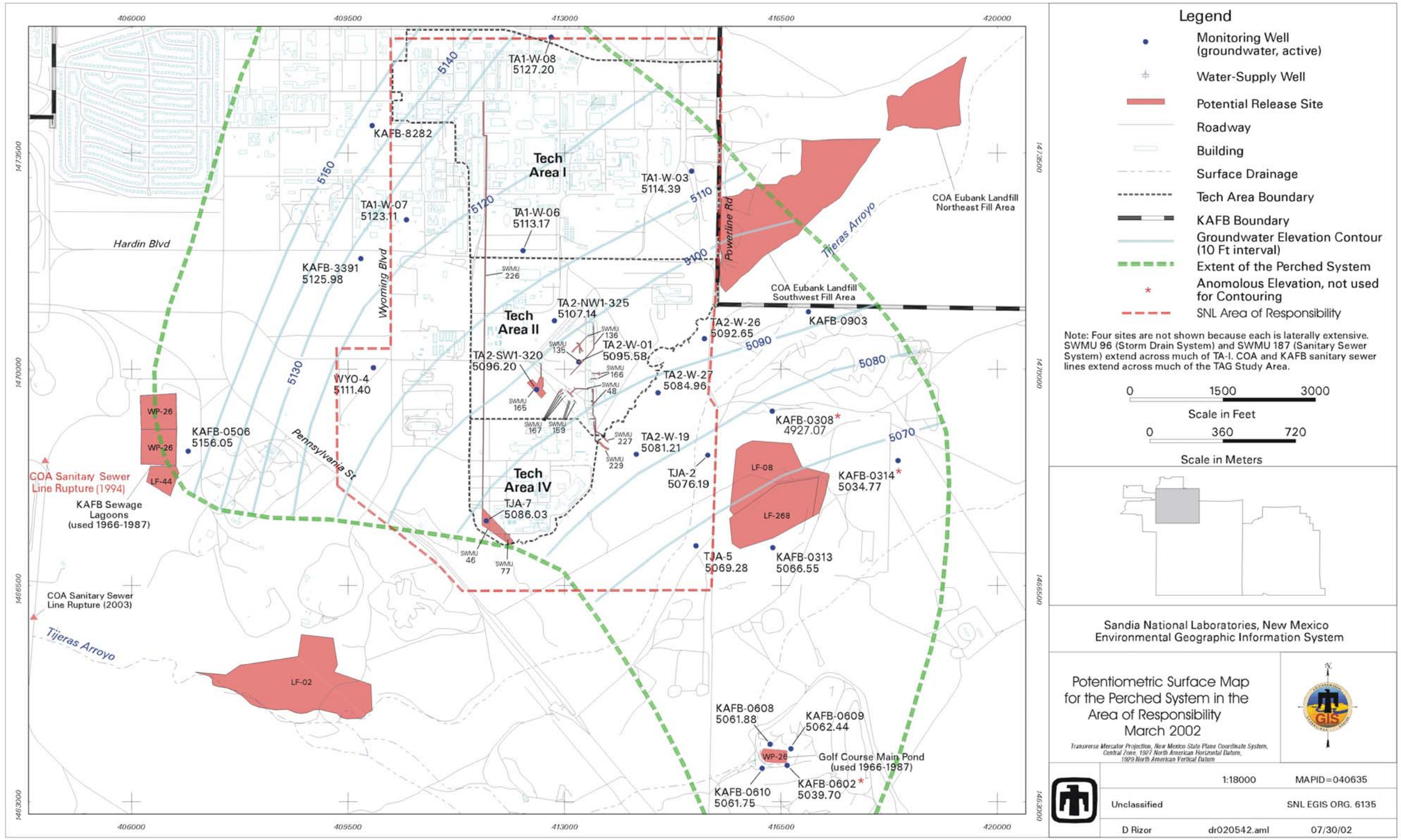


Figure 2-1. Potentiometric surface map for the perched system in the TAG Area of Responsibility, March 2002 (SNL/NM 2004a).

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 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 Paleozic 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 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.

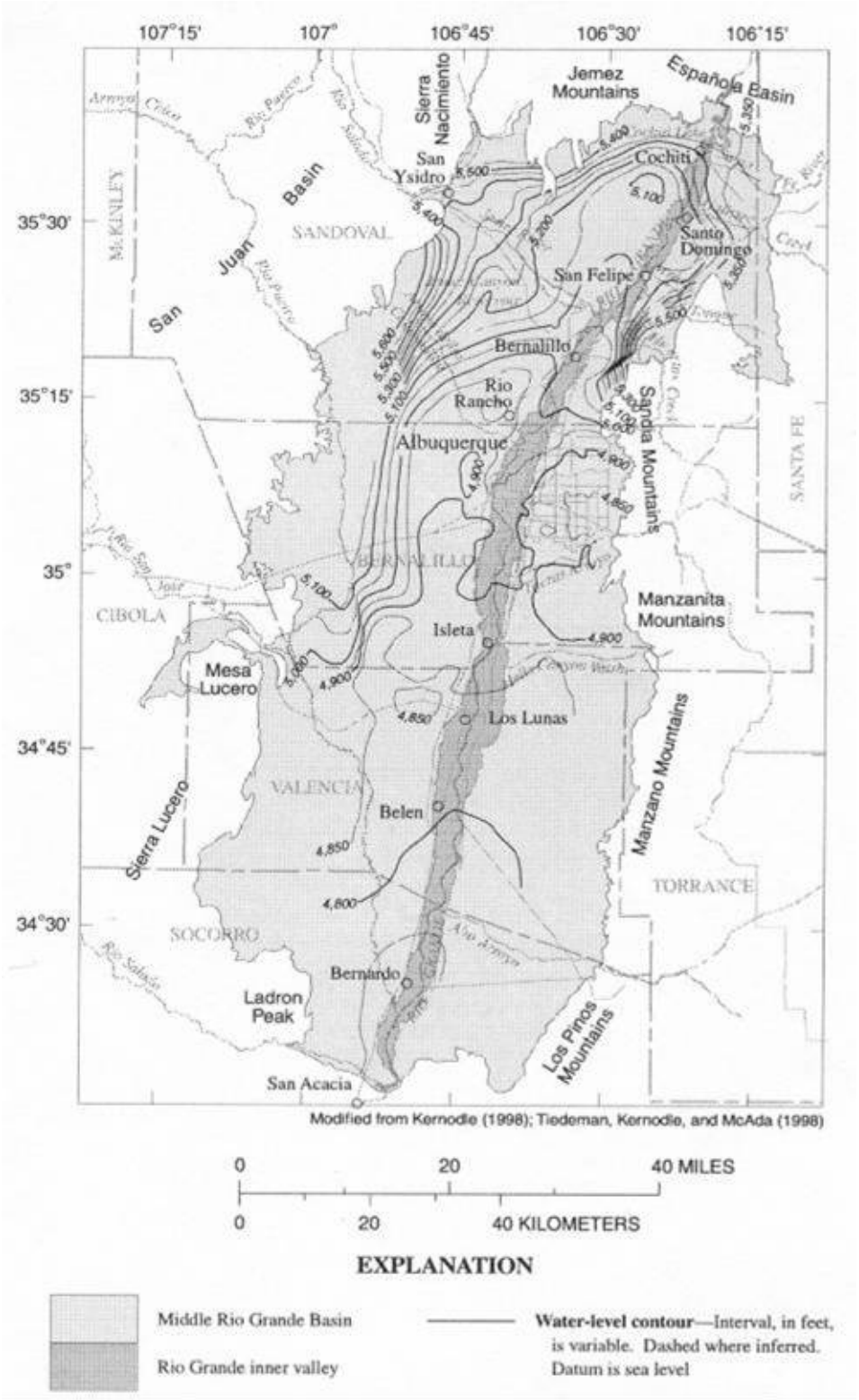
2.2.4 Regional Discharge

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 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 area probably reflect recharge of the regional aquifer from the perched system, Tijeras Arroyo, the golf course, and the mountain front.



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 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

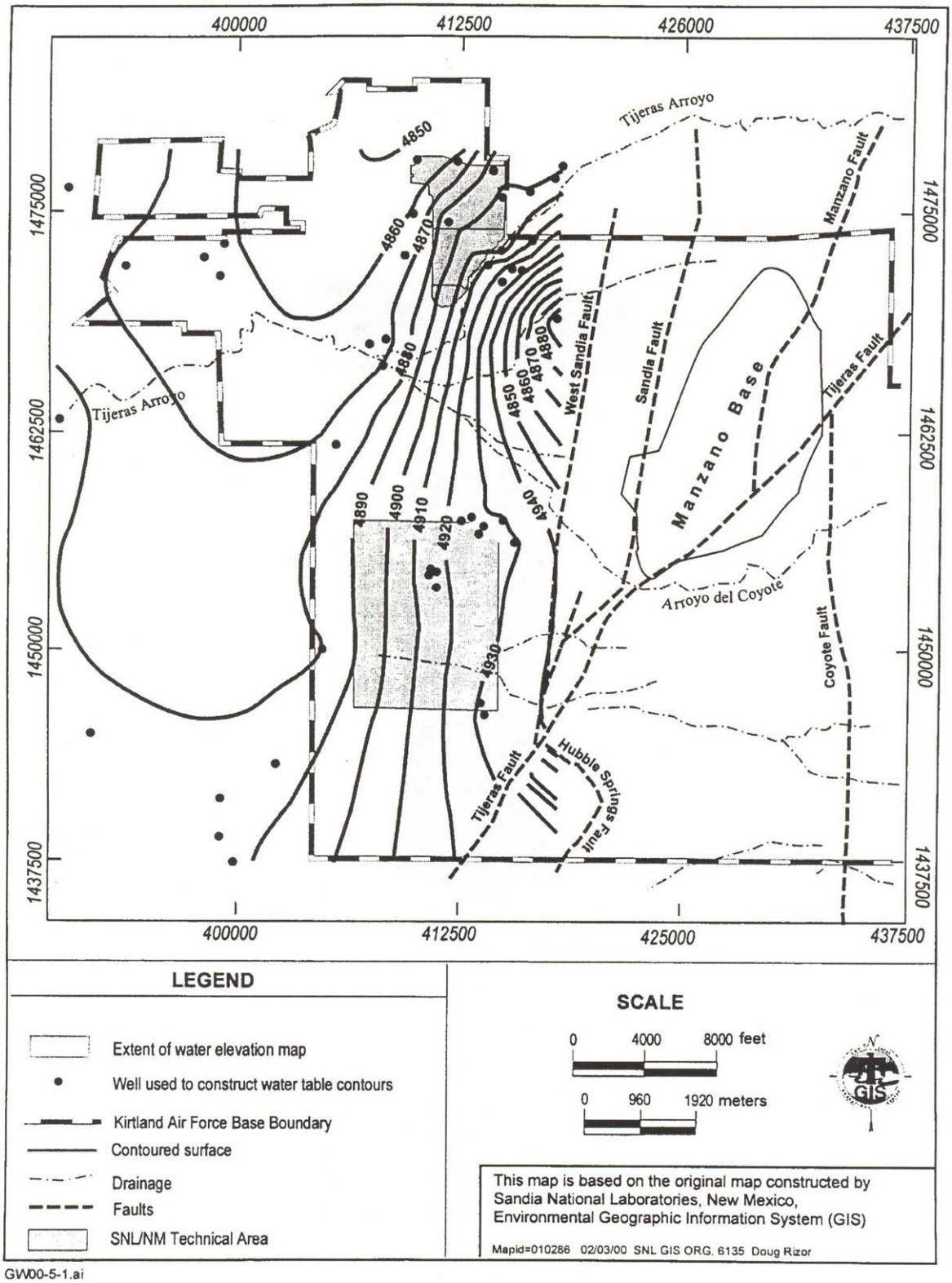
The aquifer in the alluvial fan lithofacies consists of fine-grained, layered, clay-rich sediments of the alluvial fan lithofacies of the Santa Fe Group. These sediments interfinger with the highly permeable sediments of the ARG to the west. The horizontal hydraulic conductivity of the alluvial fan lithofacies 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 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.

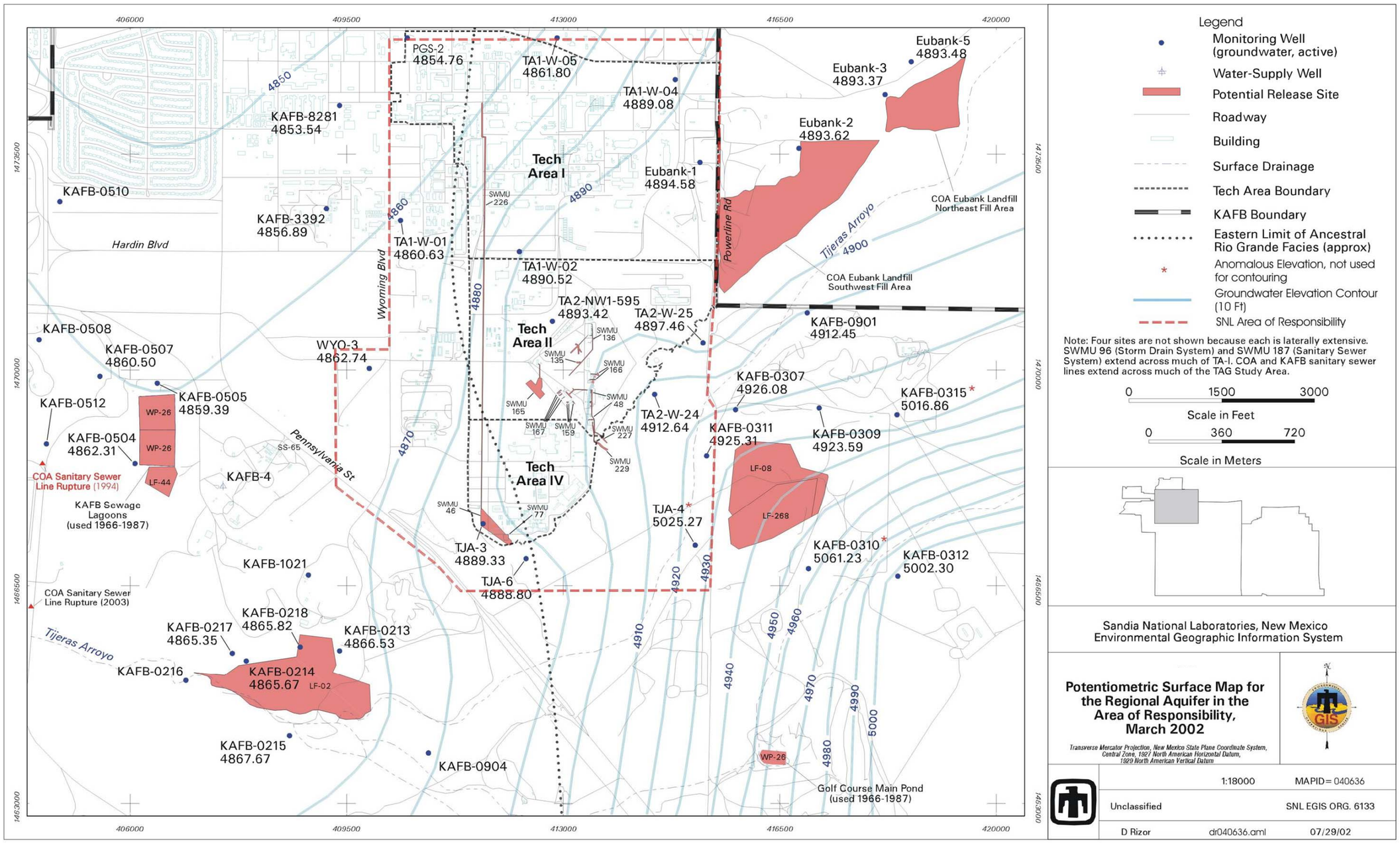
2.3 Distribution of Groundwater Contaminants

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.



From SNL/NM 2000

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



Legend

- Monitoring Well (groundwater, active)
- Water-Supply Well
- Potential Release Site
- Roadway
- Building
- Surface Drainage
- Tech Area Boundary
- KAFB Boundary
- Eastern Limit of Ancestral Rio Grande Facies (approx)
- Anomalous Elevation, not used for contouring
- Groundwater Elevation Contour (10 Ft)
- SNL Area of Responsibility

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.

0 1500 3000

Scale in Feet

0 360 720

Scale in Meters

Sandia National Laboratories, New Mexico
Environmental Geographic Information System

Potentiometric Surface Map for the Regional Aquifer in the Area of Responsibility, March 2002

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

	1:18000	MAPID= 040636
Unclassified		SNL EGIS ORG. 6133
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Figure 2-4. Potentiometric surface map for the regional aquifer in the TAG area, March 2002.

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.

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. Perched Groundwater System Estimate of Flow. 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. Alluvial Fan Model Section. 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. ARG Model Section. 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).

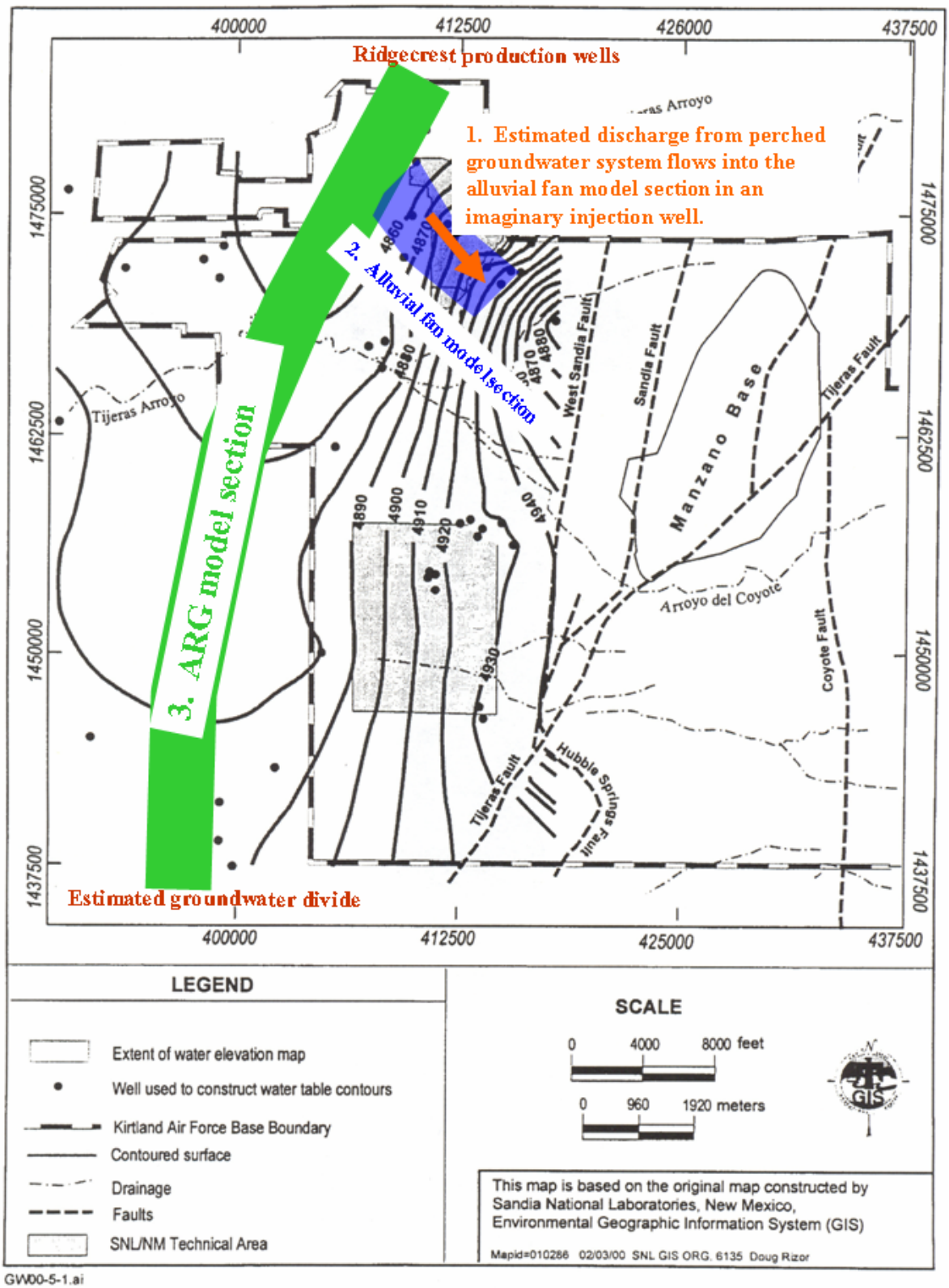


Figure 3-1. Regional potentiometric surface map and location of simulated regions.

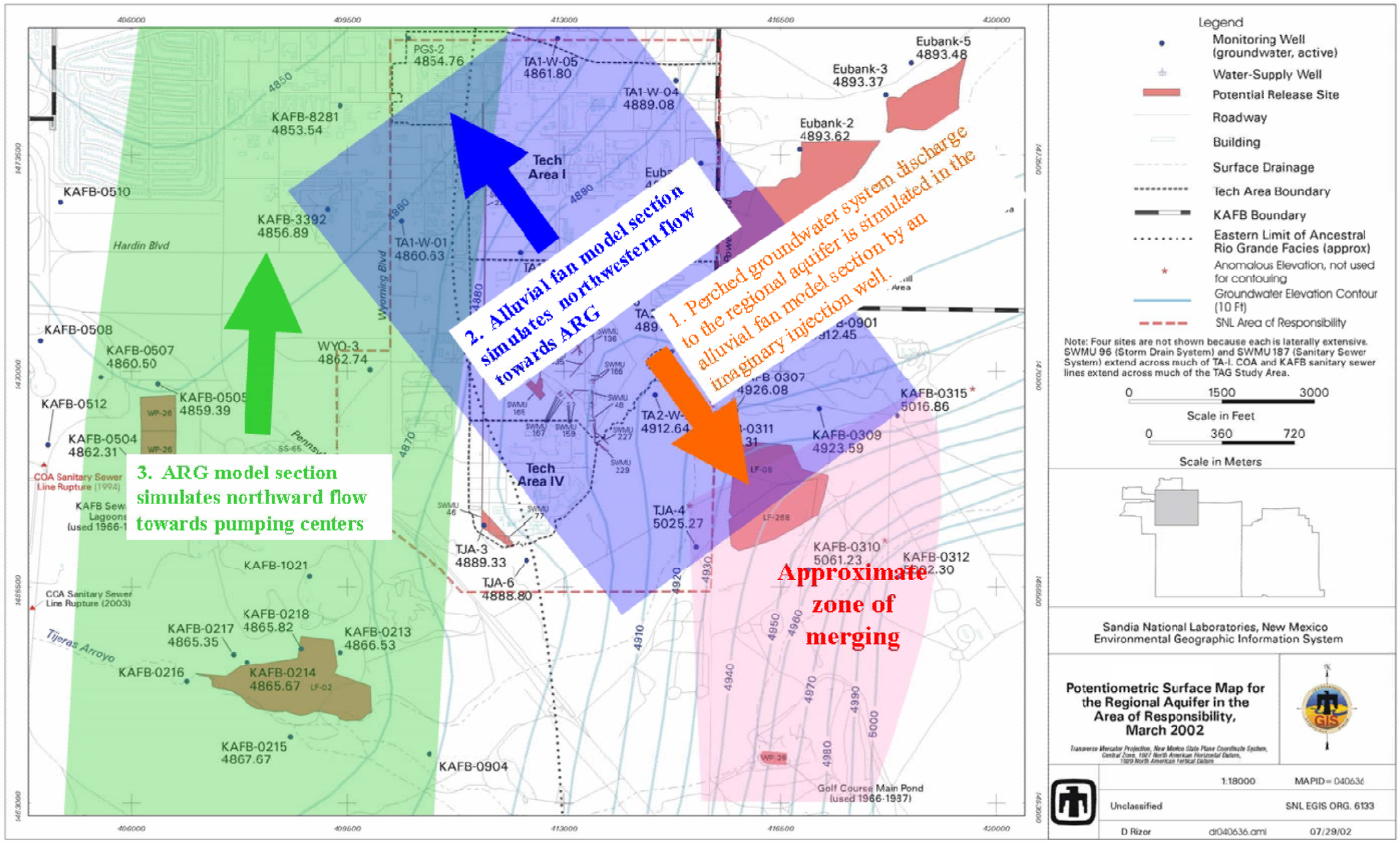


Figure 3-2. Local potentiometric surface map and location of simulated regions.

- 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).

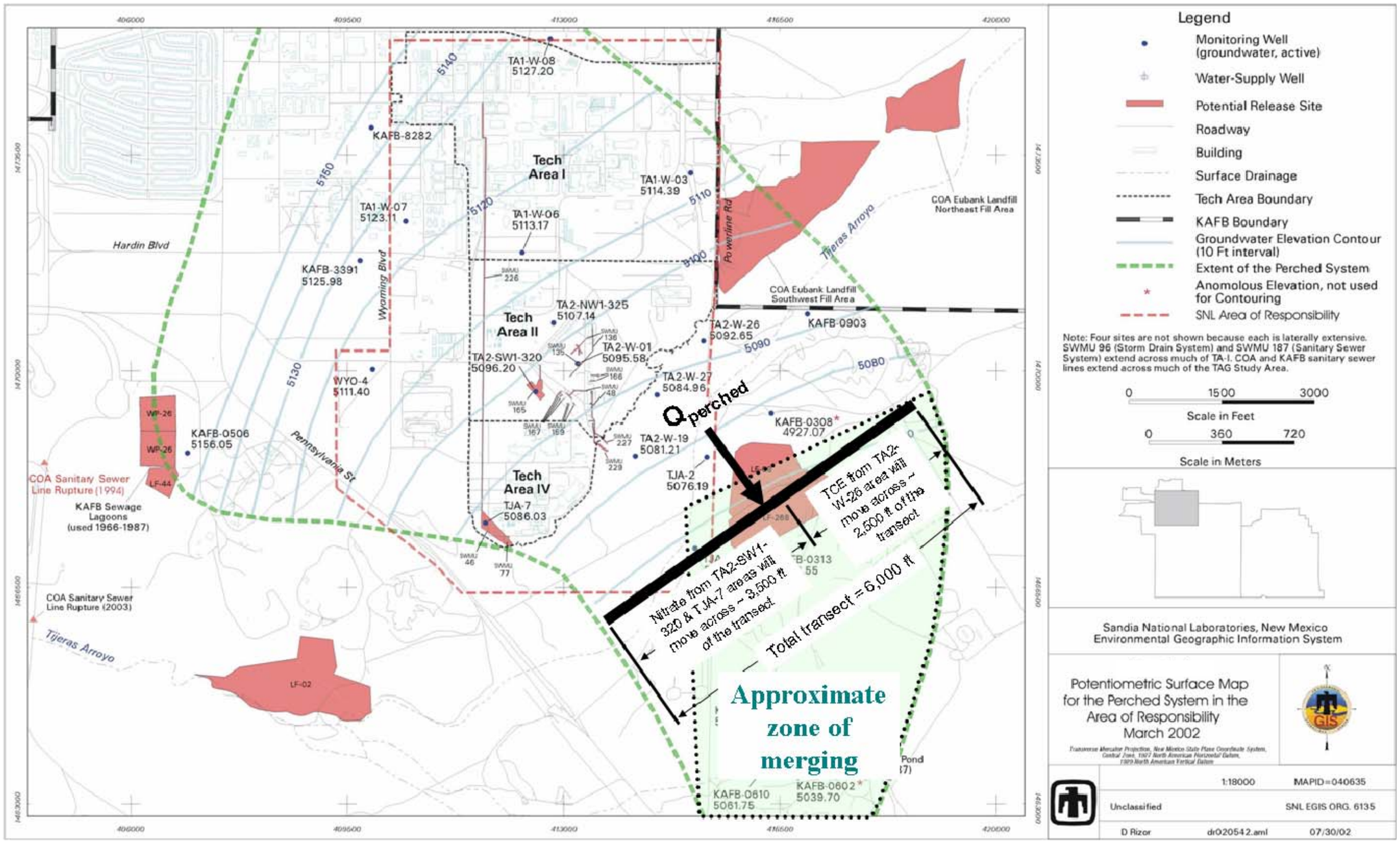


Figure 3-3. Perched system illustration.

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 60 years for TCE and 70 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 (TCE)	0.05	0.002	2,200	3,800
TA2-SW1-320 area (nitrate)	0.05	0.002	3,500	6,000
TA2-W26 area (nitrate)	0.05	0.002	2,700	4,600
TJA-7 area (TCE)	3.1	0.10	2,200	60
TA2-SW1-320 area (nitrate)	3.1	0.10	3,500	96
TA2-W26 area (nitrate)	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.

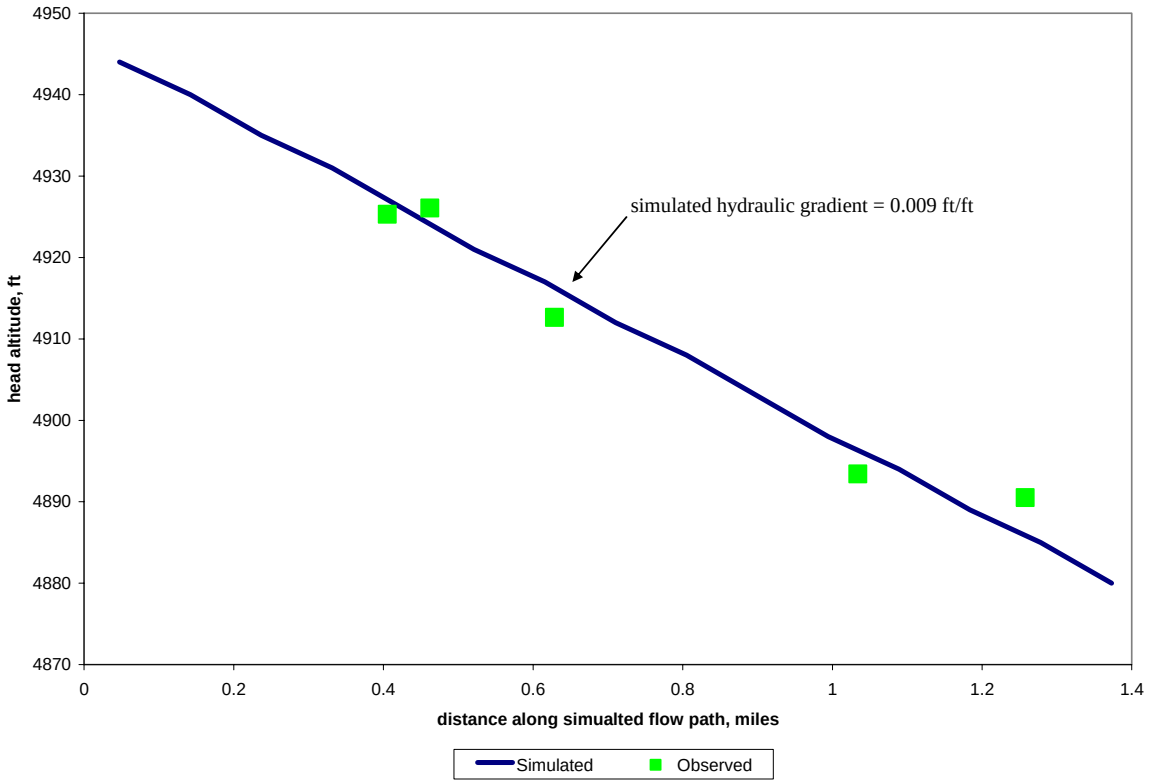


Figure 3-4. Comparison of simulated and observed potentiometric head along the alluvial fan model section.

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.

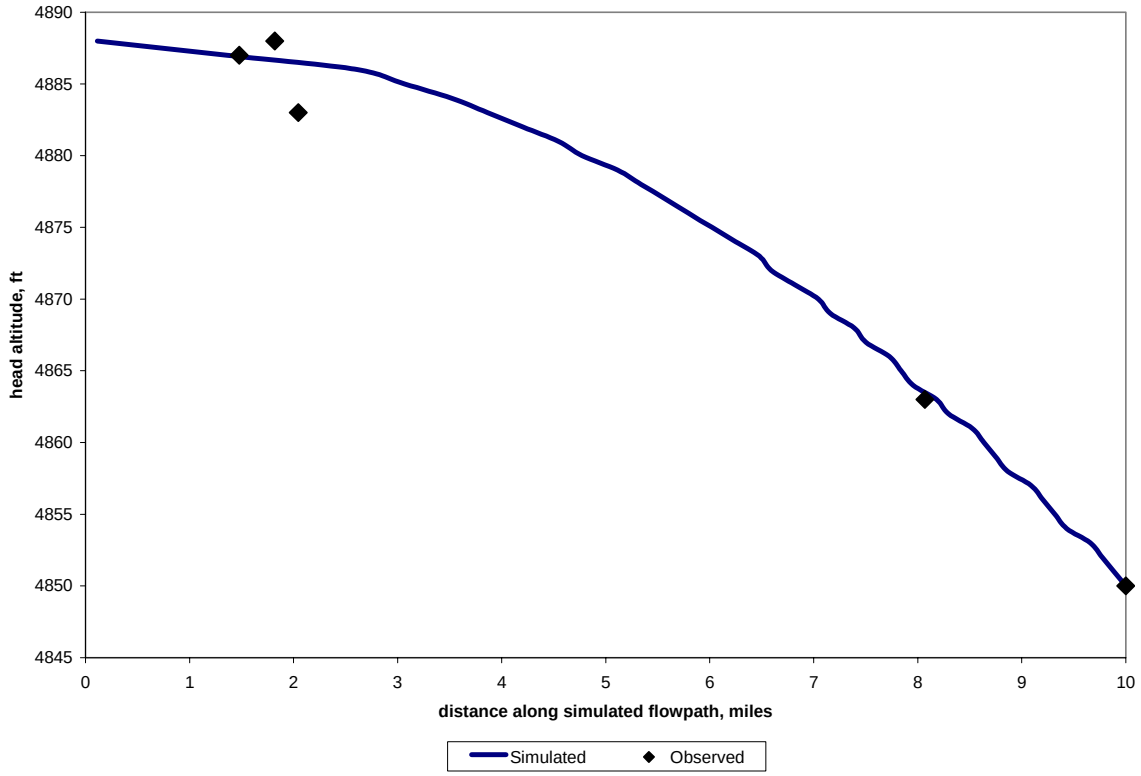


Figure 3-5. Comparison of simulated and observed potentiometric head along the ARG model section

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.

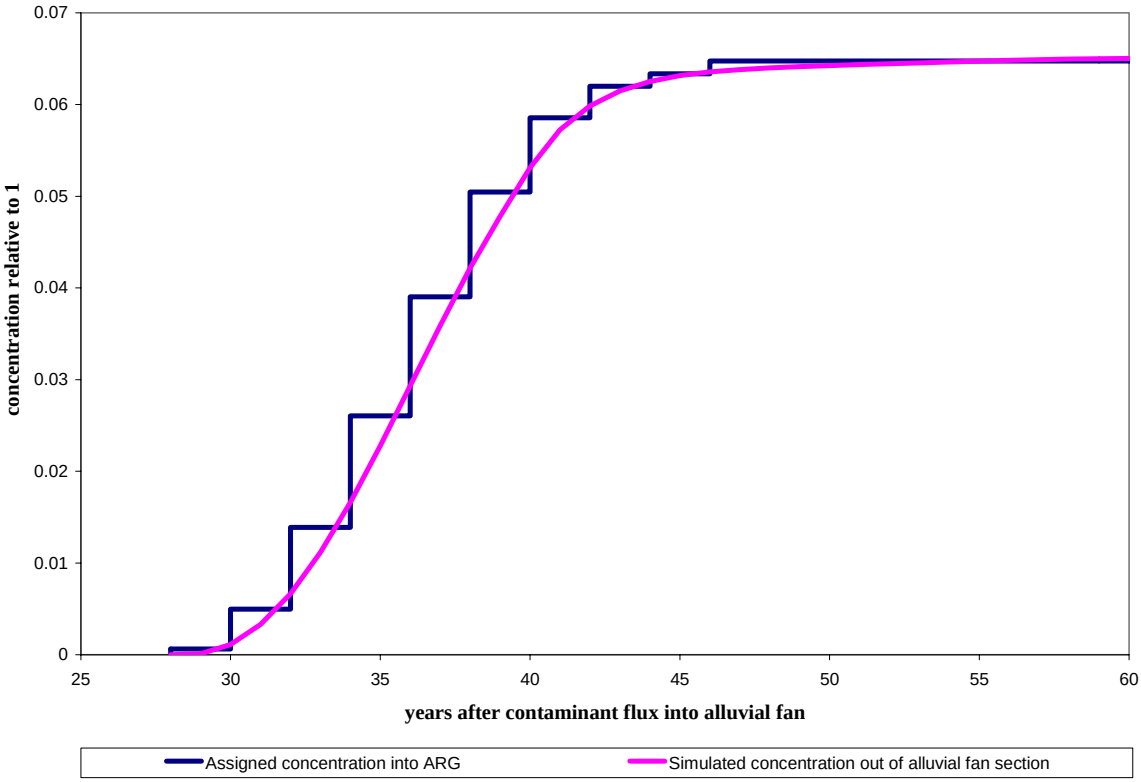


Figure 3-6. Illustration of solute flux simulation from the alluvial fan model section into the ARG model section.

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.

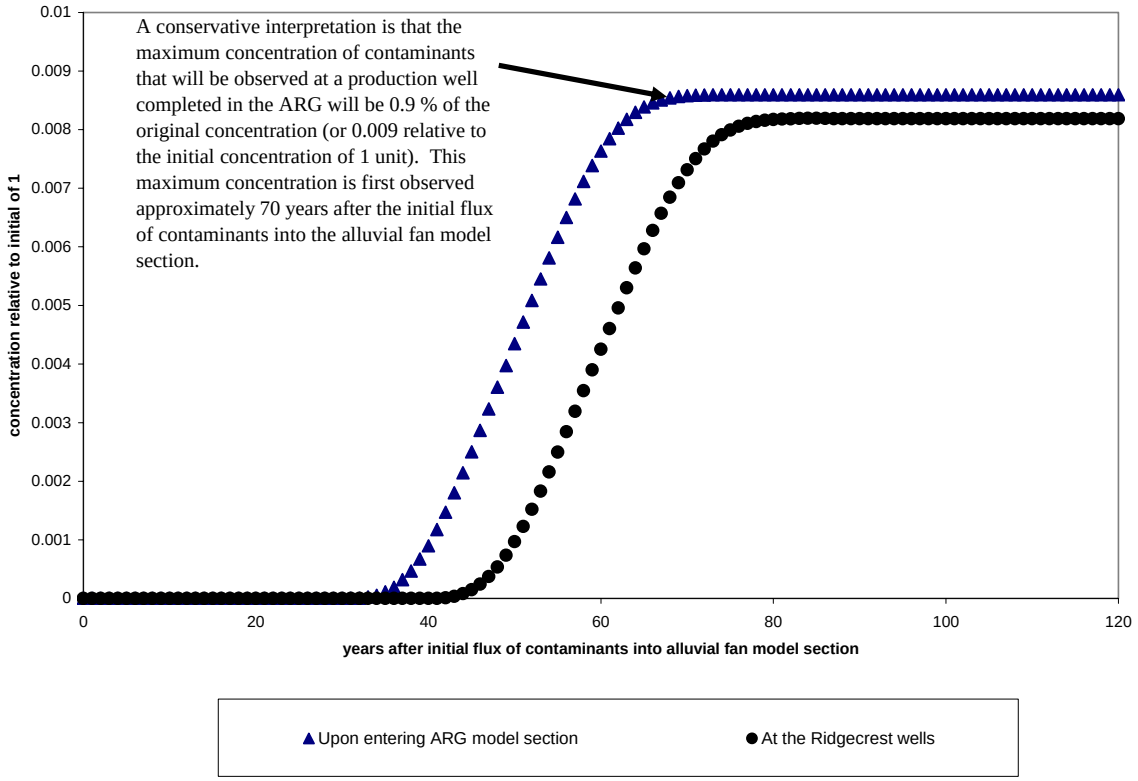


Figure 4-1. Plot of solute arrival at the ARG/ alluvial fan model section interface and at the Ridgecrest well field.

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 was 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. For comparison, the MCLs for these compounds are 10 mg/L (as nitrogen) for nitrate and 5 μg/L for TCE.

Travel time estimates are also shown on Tables 4-1 and 4-2 for each contaminant. The estimates are the estimated time of arrival 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	140

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	130

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

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 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.

6.0 REFERENCES

Balleau Groundwater, Inc. 2002, "Model of a Perched Zone of Saturation at Sandia National Laboratories, New Mexico," Prepared for Sandia National Laboratories, September 2002.

Bartolino, J.R., and J.C. Cole, 2002, "Groundwater Resources of the Middle Rio Grande Basin," U.S. Geological Survey, Circular 1222, http://water.usgs.gov/pubs/circ/2002/circ1222/.

Bexfield, L.M., and Anderholm, S.K., 2000, "Predevelopment water-level map of the Santa Fe Group aquifer system in the Middle Rio Grande Basin between Cochiti Lake and San Acacia, New Mexico," U.S. Geological Survey Water-Resources Investigations Report 00-4249, 1 map sheet with text, scale approximately 1:400,000.

Bexfield, L.M., and D.P. McAda, 2003, "Simulated effects of ground-water management scenarios on the Santa Fe Group Aquifer System, Middle Rio Grande Basin, New Mexico, 2001-40," U.S. Geological Survey Water-Resources Investigations Report 03-4040, 39 p.

BYU, 2003, Department of Defense Groundwater Modeling System, Version 4.0, developed by the Environmental Modeling Research Laboratory at Brigham Young University for the U.S. Department of Defense, Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi. See http://chl.wes.army.mil/software/gms and http://www.emrl.byu.edu/gms.htm.

City of Albuquerque, 2003, "Water Quality Report 2003," Available online at: http://www.cabq.gov/waterquality/results/pdf/2003_CABQ_Water_Quality_Report.pdf.

Harbaugh, A.W., E.R. Banta, M.C. Hill, and M.G. McDonald, 2000, MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model—User guide to modularization concepts and the ground-water flow process, Open-File Report 00-92, U.S. Geological Survey, Branch of Information Services, Box 25286, Denver, CO 80225-0425 or http://water.usgs.gov/software/ground_water.html/.

MWH Americas, Inc., 2003, "Stage I Abatement Report for Nitrate-Impacted Groundwater at Kirtland Air Force Base, New Mexico," Environmental Compliance Program, Kirtland Air Force Base, Albuquerque, New Mexico, July 2003.

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.

SNL/NM, 1998, *Sandia North Groundwater Investigation Plan, Annual Report, Fiscal Year 1997*, Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico, March 1998.

SNL/NM, 2001a, *1999 Annual Site Environmental Report Sandia National Laboratories Albuquerque, New Mexico*, Sandia Report SAND2000-2228, Sandia National Laboratories / New Mexico, February 2001.

SNL/NM, 2001b, “SNL/NM Environmental Restoration Project Long-Term Monitoring Strategy for Groundwater,” Environmental Restoration Project, U.S. Department of Energy, Albuquerque Operations Office, Sandia National Laboratories/New Mexico, February 2001.

SNL/NM, 2002, *Tijeras Arroyo Groundwater Continuing Investigation Report*, Sandia National Laboratories Environmental Restoration Project for U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico, November 2002.

SNL/NM, 2004a, *Corrective Measures Evaluation Work Plan Tijeras Arroyo Groundwater*, SAND2004-3247P, November 2004, Sandia National Laboratories/New Mexico.

SNL/NM 2004b, *Current Conceptual Model of Groundwater Flow and Contaminant Transport at Sandia National Laboratories/New Mexico Technical Area V*, Sandia Report SAND2004-1470, April 2004.

SNL/NM 2004c, Technical Memorandum – Field Report, Slug Tests at Tijeras Arroyo Groundwater Investigation Wells, SNL/NM Environmental Restoration Project.

SNL/NM 2005a, Monitored Natural Attenuation Field Studies, Investigation of Anaerobic Contaminant Biodegradation in Tijeras Arroyo Groundwater, *in press.*

SNL/NM, 2005b, “Remedial Alternatives Data Gaps Review for Tijeras Arroyo Groundwater,” Sandia National Laboratories/New Mexico, *in press*.

Zheng, C., and P.P. Wang, 1999, “MT3DMS, A Modular Three-Dimensional Multi-species Transport Model”, U.S. Army Corps of Engineers, Strategic Environmental Research and Development Program (SERDP).

APPENDIX E
Cost Estimate and Design Assumptions for the Remedial Alternatives

Appendix E
Cost Estimate and Design Assumptions for the Remedial Alternatives

Section 7 of this document describes cost estimates prepared to support evaluation of the three remedial alternatives. The estimates and the assumptions made are presented in this appendix. The cost estimates and associated backup worksheets are included at the end of this appendix. The assumptions discussed here are based on the conceptual scope of the alternatives presented in Sections 7.2.1 (Alternative 1: Monitored Natural Attenuation), 7.2.2 (Alternative 2: In-Situ Bioremediation), and 7.2.3 (Alternative 3: Groundwater Extraction and Treatment).

These costs may be subject to:

- Changes in regulatory requirements,
- Variations in specific assumptions such as timing and duration of alternative implementation and associated effectiveness of the remedy,
- Changes in dollar value at the time of implementation,
- Changes in the assumed discount rate used in present-value calculations,
- Uncertainties associated with the hydrogeologic characteristics, subsurface heterogeneities, estimated rate that the Perched Groundwater System will naturally dewater, and extent of contaminant distribution, and
- Impact from potential offsite sources of contamination.

The estimated cost accuracy is -30 percent to +50 percent.

Costing Assumptions

The timeframe for all three alternatives assumes a Base Year of 2018 also referred to as Year 1. Elements of corrective actions that occur after the Base Year reference a year after Year 1 (Year 2 through Year 41.)

Costs are presented in three categories:

1. Capital Costs

   This includes costs for preparing planning documents, obtaining permits, design, equipment and materials procurement, remediation and performance monitoring component installation, and initial deployment of remedial measures.

   Alternative 1 has no capital costs other than planning documents and this work is assumed to be done in parallel with monitoring currently ongoing at the TAG AOC.

   Alternatives 2 and 3 capital costs include installation of an extensive network of wells and either large-scale initial bioremediation substrate injections (Alternative 2) or installation of groundwater, extraction, conveyance, and treatment infrastructure (Alternative 3). Installation of these elements would be

conducted during the first five years of their respective remedy timeframes, but for simplicity, related costs are assumed to be incurred in Year 1.

Sampling of currently existing monitoring wells would be conducted in parallel with these activities during Years 1 through 5.

2. Annual Operation and Maintenance, Monitoring, and Reporting

   This includes costs for water level measurements, groundwater sample collection, analysis, and validation for plume and corrective action performance monitoring and investigation-derived waste (IDW) profiling, IDW disposal, data processing and reporting, and an allowance for routine wellhead maintenance. Annual Remedy Performance Reports are also included.

   Under Alternative 2, cost for routine maintenance of dedicated downhole multi-parameter measurement equipment is also included. Equipment deployment is assumed to be in Year 5 with maintenance starting in Year 6. Starting in Year 8, annual bioremediation substrate re-dosing of 50 percent of the injection wells is included in annual costs assuming work crews would be working year-round to re-dose each injection well biennially. Costs for redeveloping 45 of the injection well and performance monitoring wells are incorporated into the annual costs for Years 11 through 17, assuming approximately 50 percent of injection wells needing redevelopment during the overall timeframe.

   Alternative 3 also includes cost items for operation and maintenance of the groundwater extraction and treatment system including electricity, ion-exchange resin regeneration and granular activated carbon (GAC) replacement and associated waste byproduct disposal. Costs also include discharge compliance sampling and performance reporting.

   These annual costs are subdivided into selected time period intervals over the corrective action timeframes corresponding to projected changes in sampling frequency, the number of wells being sampled, and significant stages of corrective action implementation such as the initial injection of bioremediation substrate for Alternative 2, or the start and stop of groundwater extraction for Alternative 3.

3. Periodic Costs

   This category includes costs assumed to be incurred one or more times after initial implementation but not less frequently than annually during the corrective action timeframe. Costs for a Corrective Measures Implementation Report, well decommissioning (plugging and abandonment), and Alternative 3 extraction and treatment system component removal, are included in Year 41. Costs include Remedy Performance Review Reports, review and updates to the Institutional Control Plan, and an allowance for as-needed well redevelopment to address potential biofouling and/or silting of monitoring well screens (redevelopment costs under Alternative 2 are included in Annual Costs for Years 11-17).

General Assumptions

Several costing assumptions are applicable across the three costing categories. These include:

- Cost estimates for each alternative are based on the outlined conceptual scope of work for the projected timeline from a base year of 2018. Estimates are anticipated to be within the range of -30 percent to +50 percent.

- Labor rates used for cost estimating tasks to be performed by onsite contractors are based on anticipated fully burdened costs for FY2018. These rates are obtained from current Resource Loaded Baseline FY17 to FY28. Standard Labor Rates are based on the mid-point of each salary band then increased to recover overtime, allowances, and fringe benefits. The Total Burdened Labor Rate is the Standard Labor Rate (with fringe) increased by a multiplier for the recovery of Division Support, Program Management, Corporate Taxes, New Mexico Site Support, Strategic Partnership Projects Office Support, General & Administrative, and Research & Development.

- Contractors will perform laboratory analyses, third-party validation, and well development. Analytical costs per analysis were obtained from the Sample Management Office (SMO) for unit pricing, effective in 2017 and are valid for Base Year 2018. Validation costs are estimated per SMO because actual costs are formula based and affected by laboratory quality control data, batching, project-specific requirements, and other variable factors. Well development cost estimates are informed based on recently performed work at SNL/NM.

- Costs for documents (for example, plans and reports) include three preparation steps to allow for applicable review: Draft, Draft Final, and Final. Draft Final and Final labor are assigned costs of 50 percent and 25 percent of the Draft, respectively, except for technical editor/production costs that are assumed to be equal for each preparation step.

  Some documents have several components, each of which are prepared separately, but are summed in the cost estimate to simplify cost presentation.

- Costs include a contingency allowance of 10 percent to the base cost followed by a 5 percent allowance for project management.

- Present value costs were calculated using the real discount rate of 0.70 percent for federal facilities based on the 2017 Discount Rates for Office of Management and Budget (OMB) Circular A-94 (OMB December 2016) for projects with a timeframe of 30 years or more. U.S. Environmental Protection Agency (EPA) guidance indicates that the same discount rate should be used for all evaluated alternatives based on the alternative with the longest timeframe (Alternative 1 timeframe is 41 years).

Implementation Plan Preparation

The scope for implementation plan preparation includes the following for all three alternatives:

- Prepare Corrective Measure Implementation Plan (CMIP) including a Management Plan, a Community Relations Plan, a Sampling and Analysis Plan, and a Corrective Measures Permitting Plan, and a Land Use Controls Implementation Plan.
- Prepare a Corrective Measure Design to be appended to the CMIP. Includes Operation and Maintenance Plan, Progress Reporting and Implementation Schedule, and a Health and Safety Plan.
- Prepare a Contingency Plan to be submitted with the CMIP.
- Alternatives 2 and 3 include preparing Design Plans and Specifications.
- Alternative 3 includes preparing a Construction Quality Assurance Plan.

Annual Monitoring and Reporting

Tables E-1, E-2, and E-3 below summarize the number of groundwater monitoring wells to be sampled throughout the timeframe for Alternatives 1, 2, and 3, respectively. As described in the CCM, declining groundwater elevations in the Perched Groundwater System indicate that the lateral extent of perched zone saturation is decreasing as it dewaters. Tables E-4, E-5, and E-6 provide well-specific, detailed sampling schedule using the monitoring well network that is currently in place and, as applicable additional wells installed depending on the alternative scope. The schedules incorporate projected times when groundwater elevations in individual Perched Groundwater System monitoring wells are anticipated to drop below the bottom of the well screen (go dry); therefore, taken off of the sampling schedule. Depth to water measurements would be conducted in all wells including ones that have gone dry to verify that groundwater elevations have not risen into the screen. The overall monitoring period for Alternative 1 is based on an estimated timeframe of 41 years, when all Perched Groundwater System monitoring wells are projected to go dry with the exception of well TJA-5, which is located in the merging zone and does not exhibit significant water level decline. The overall monitoring period for Alternatives 2 and 3 is 27 years including 5 years of monitoring while remedial action infrastructure is put in place and proactive remediation is initiated followed by 20 years of either in-situ bioremediation or groundwater extraction and treatment and a final 2 years of post-remediation confirmation monitoring.

The sampling schedule and associated cost estimate for annual monitoring reporting is divided into periods of time based on when individual wells go dry and at the 10-year interval when the Perched Groundwater System monitoring frequency is reduced from a semiannual to annual frequency, matching that of Regional Aquifer monitoring.

Table E-1
Alternative 1: Number of Sampled Wells per Time Period

Period (Years from 2018)	Number of Sampled Wells		Sampling Frequency
	PGWS	Regional Aquifer	
1 – 3	12	9	Semiannual - PGWS Annual - Regional Aquifer
4 – 7	10	9	
8 – 10	9	9	
11 – 17	8	9	
18 – 23	7	9	
24 – 26	6	9	
27 – 28	4	9	
29 – 32	3	9	
33 – 41	2	9	

PGWS = Perched Groundwater System.

Table E-2
Alternative 2: Number of Sampled Wells per Time Period

Period (Years from 2018)	Number of Sampled Wells		Sampling Frequency
	PGWS	Regional Aquifer	
1 – 3	12	9	Semiannual - PGWS Annual - Regional Aquifer
4 – 5	10	9	Semiannual – PGWS Annual - Regional Aquifer
6[a] – 7	65[b]	9	Quarterly – PGWS (60) Semiannual – PGWS (5) Annual - Regional Aquifer
8 – 10	64[b]	9	Semiannual - PGWS Annual - Regional Aquifer
11 – 17	63[b]	9	
18 – 23	62[b]	9	
24 – 25	61[b]	9	
26[c]	61[b]	9	Quarterly – PGWS Annual - Regional Aquifer
27[c]	59[b]	9	Quarterly – PGWS Annual - Regional Aquifer

[a] Assumes all 575 ISB injection wells and 25 new performance monitoring wells are installed and ISB injections have been completed at the end of Year 5.
[b] Includes 30 injection wells (approximately 5% of total injection wells per sampling event).
[c] Assumes remedial objectives were met in Year 25. Confirmation sampling conducted in Years 26 and 27.
PGWS = Perched Groundwater System.
ISB = in-situ bioremediation.

Table E-3
Alternative 3: Number of Sampled Wells per Time Period

Period (Years from 2018)	Number of Sampled Wells		Sampling Frequency
	PGWS	Regional Aquifer	
1 – 3	12	9	Semiannual - PGWS Annual - Regional Aquifer
4 – 5	10	9	Semiannual – PGWS Annual - Regional Aquifer
6[a] – 7	94[b]	9	Quarterly – PGWS (16) Quarterly – PGWS extraction wells (73) – from sampling ports Semiannual – PGWS (5) Annual - Regional Aquifer
8 – 10	93[b]	9	Semiannual - PGWS Annual - Regional Aquifer
11 – 17	92[b]	9	
18 – 23	91[b]	9	
24 – 25	90[b]	9	
26[c]	90[b]	9	Quarterly – PGWS Annual - Regional Aquifer
27[c]	88[b]	9	Quarterly – PGWS Annual - Regional Aquifer

[a] Assumes all 73 extraction wells and 11 new performance monitoring wells are installed and extraction is initiated at the end of Year 5.
[b] Includes collection of samples from 73 extraction wells taken from sampling ports.
[c] Assumes remedial objectives were met in Year 25. Confirmation sampling conducted in Years 26 and 27.
PGWS = Perched Groundwater System.
ISB = in-situ bioremediation.

These time intervals are summarized below and the groundwater sampling frequencies for each alternative are shown in more detail in Tables E-4, E-5, and E-6 below.

Select wells that are not needed to delineate the extent of nitrate above the MCL in groundwater are planned for water level measurement only and are not scheduled for groundwater sampling. Sampling is discontinued from wells indicated as “dry” when the water level is projected to drop below the bottom of the screened interval, but water level measurements would continue in those wells and sampling would resume as applicable if the water level rose sufficiently.

Well	Comments	Maximum NPN Concentration CY2015 (mg/L)	Screened Interval (ft bgs)	Water Level Change (ft/yr)	Estimated Year Water Level Drops Below Well Screen	Number of Years Until Water Level Drops Below Well Screen (from CY 2018)	Years 1 - 3 (CY 2018 - 2020)	Years 4 - 7 (CY 2021 - 2024)	Years 8 - 10 (CY 2025 - 2027)	Years 11 - 17 (CY 2028 - 2034)	Years 18 - 23 (CY 2035 - 2040)	Years 24 - 26 (CY 2041 - 2043)	Years 27 - 28 (CY 2044 - 2045)	Years 29 - 32 (CY 2046 - 2050)	Years 33 - 41 (CY 2051-2059)	CY 2060+
							3	4	3	7	6	3	2	4	9	Post-closure
Perched Groundwater System																
TA1-W-03	Upgradient Background	7.99	337.0 – 357.0	-1.17	2020	3	SA	dry	dry	dry	dry	dry	dry	dry	dry	P & A
TA1-W-06	Upgradient Background	3.76	300.0 – 320.0	-0.44	2041	24	SA	SA	SA	SA	SA	dry	dry	dry	dry	P & A
TA1-W-07	Upgradient Background	3.2 (2002)	268.6 – 288.6	-0.15	2044	**WL only** (26 yrs until dry)	WL	WL	WL	WL	WL	WL	dry	dry	dry	P & A
TA1-W-08	Upgradient Background	8.01	302.0 – 322.0	-0.52	2035	18	SA	SA	SA	SA	dry	dry	dry	dry	dry	P & A
TA2-NW1-325	Upgradient Background	3.9 (2002)	295.0 – 325.0	-0.53	2030	**WL only** (12 yrs until dry)	WL	WL	WL	WL dry Yr 13	dry	dry	dry	dry	dry	P & A
TA2-W-01	Crossgradient Sentinel	5.38	312.0 – 332.0	-0.7	2025	8	SA	SA	dry	dry	dry	dry	dry	dry	dry	P & A
TA2-W-19	Performance Monitoring Well	**12.8**	265.9 – 285.9	-0.5	2046	29	SA	SA	SA	SA	SA	SA	SA	dry	dry	P & A
TA2-W-26	Crossgradient Sentinel	6.7	276.0 – 296.0	-0.75	2028	11	SA	SA	SA	dry	dry	dry	dry	dry	dry	P & A
TA2-W-27	Crossgradient Sentinel	4.58	275.0 – 295.0	-0.56	2044	27	SA	SA	SA	SA	SA	SA	dry	dry	dry	P & A
TA2-W-28	Performance Monitoring Well	**27.8**	310.5 – 330.5	-0.55	2044	27	SA	SA	SA	SA	SA	SA	dry	dry	dry	P & A
TJA-2	Performance Monitoring Well	**13.4**	275.0 – 295.0	-0.43	2059	42	SA	SA	SA	SA	SA	SA	SA	SA	SA	P & A
TJA-5	Performance Monitoring Well	**26** (per KAFB)	267.0 – 287.0	-0.02	NA	NA	SA	SA	SA	SA	SA	SA	SA	SA	SA	P & A
TJA-7	Performance Monitoring Well	**25.0**	290.5 – 310.5	-0.27	2051	33	SA	SA	SA	SA	SA	SA	SA	SA	dry	P & A
WYO-4	Upgradient Background	3.56	275.0 – 295.0	-0.68	2021	4	WL	dry	dry	dry	dry	dry	dry	dry	dry	P & A
Regional Aquifer																
Eubank-1	City-owned well	2.0 (per COA)	550.0 – 610.0	0.59	NA	NA	A	A	A	A	A	A	A	A	A	COA
PGS-2	Multiple screens	1.56	535.0 – 565.0 585.0 - 595.0 625.0 - 645.0	2.65	NA	NA	WL	WL	WL	WL	WL	WL	WL	WL	WL	LTS
TA1-W-01		2.69	575.0 – 595.0	1.25	NA	NA	WL	WL	WL	WL	WL	WL	WL	WL	WL	LTS
TA1-W-02		1.15	540.0 – 560.0	0.6	NA	NA	A	A	A	A	A	A	A	A	A	LTS
TA1-W-04		2.04	576.0 – 596.0	0.59	NA	NA	WL	WL	WL	WL	WL	WL	WL	WL	WL	LTS
TA1-W-05		1.29	597.5 – 617.5	2.24	NA	NA	WL	WL	WL	WL	WL	WL	WL	WL	WL	LTS
TA2-NW1-595	Multiple screens	4.03	535.0 – 555.0 585.0 - 595.0	0.66	NA	NA	A	A	A	A	A	A	A	A	A	LTS
TJA-3		2.76	496.0 – 516.0	-0.04	NA	NA	A	A	A	A	A	A	A	A	A	LTS
TJA-4	Merging Zone	**33.0**	360.0 – 380.0	0.41	NA	NA	A	A	A	A	A	A	A	A	A	LTS
TJA-6		2.80	454.9 – 474.6	-0.07	NA	NA	A	A	A	A	A	A	A	A	A	LTS
WYO-3		2.41	520.0 – 540.0	1.08	NA	NA	A	A	A	A	A	A	A	A	A	LTS
TA2-W-24		2.8 (2002)	465.0 – 485.0	0.41	NA	NA	A	A	A	A	A	A	A	A	A	LTS
TA2-W-25		2.1 (2002)	492.0 – 512.0	0.69	NA	NA	A	A	A	A	A	A	A	A	A	LTS
					Total samples during period	**877**	**93**	**116**	**81**	**175**	**138**	**63**	**34**	**60**	**117**	**0**

Notes

Concentration values in **bold** exceed the 10 mg/L Maximum Contaminant Level for nitrate
A = annual sampling frequency
COA = City of Albuquerque
ft bgs = feet below ground surface
ft/yr = feet per year
KAFB = Kirtland Air Force Base
LTS = well to be transferred into the Long-Term Stewardship program as part of sitewide monitoring
mg/L = milligrams per liter
NA = not applicable
P & A = plugged and abandoned
SA = semiannual sampling frequency
WL = water level measurement only (not sampled)

Table E-4. Alternative 1: Monitored Natural Attenuation – Groundwater Sampling Frequency

Well	Comments	Maximum NPN Concentration CY2015 (mg/L)	Screened Interval (ft bgs)	Water Level Change (ft/yr)	Estimated Year Water Level Drops Below Well Screen	Number of Years Until Water Level Drops Below Well Screen (from CY 2018)	Pre-injection	Initial Injection by Year 5	Remedy Performance					Confirmation		Post-closure
							Years 1 - 3 (CY 2018 - 2020)	Years 4 - 5 (CY 2021 - 2022)	Years 6 - 7 (CY 2023 - 2024)	Years 8 - 10 (CY 2025 - 2027)	Years 11 - 17 (CY 2028 - 2034)	Years 18 - 23 (CY 2035 - 2040)	Years 24 - 25 (CY 2041 - 2042)	Year 26 (CY 2043)	Year 27 (CY 2044)	CY 2045+
							3	2	2	3	7	6	2	1	1	
Perched Groundwater System																
TA1-W-03	Upgradient Background	7.99	337.0 – 357.0	-1.17	2020	3	SA	dry	dry	dry	dry	dry	dry	dry	dry	P & A
TA1-W-06	Upgradient Background	3.76	300.0 – 320.0	-0.44	2041	24	SA	SA	SA	SA	SA	SA	dry	dry	dry	P & A
TA1-W-07	Upgradient Background	3.2 (2002)	268.6 – 288.6	-0.15	2044	**WL only** (26 yrs until dry)	WL	WL	WL	WL	WL	WL	WL	WL	dry	P & A
TA1-W-08	Upgradient Background	8.01	302.0 – 322.0	-0.52	2035	18	SA	SA	SA	SA	SA	dry	dry	dry	dry	P & A
TA2-NW1-325	Upgradient Background	3.9 (2002)	295.0 – 325.0	-0.53	2030	**WL only** (12 yrs until dry)	WL	WL	WL	WL	WL dry Yr 13	dry	dry	dry	dry	P & A
TA2-W-01	Crossgradient Sentinel	5.38	312.0 – 332.0	-0.7	2025	8	SA	SA	SA	dry	dry	dry	dry	dry	dry	P & A
TA2-W-19	ISB Performance Monitoring Well	**12.8**	265.9 – 285.9	-0.5	2046	29	SA	SA	Q	SA	SA	SA	SA	Q	Q	P & A
TA2-W-26	Crossgradient Sentinel	6.7	276.0 – 296.0	-0.75	2028	11	SA	SA	SA	SA	dry	dry	dry	dry	dry	P & A
TA2-W-27	Crossgradient Sentinel	4.58	275.0 – 295.0	-0.56	2044	27	SA	SA	SA	SA	SA	SA	SA	Q	dry	P & A
TA2-W-28	ISB Performance Monitoring Well	**27.8**	310.5 – 330.5	-0.55	2044	27	SA	SA	Q	SA	SA	SA	SA	Q	dry	P & A
TJA-2	ISB Performance Monitoring Well	**13.4**	275.0 – 295.0	-0.43	2059	42	SA	SA	Q	SA	SA	SA	SA	Q	Q	P & A
TJA-5	ISB Performance Monitoring Well	**26** (per KAFB)	267.0 – 287.0	-0.02	NA	NA	SA	SA	Q	SA	SA	SA	SA	Q	Q	P & A
TJA-7	ISB Performance Monitoring Well	**25.0**	290.5 – 310.5	-0.27	2051	33	SA	SA	Q	SA	SA	SA	SA	Q	Q	P & A
WYO-4	Upgradient Background	3.56	275.0 – 295.0	-0.68	2021	4	WL	dry	dry	dry	dry	dry	dry	dry	dry	P & A
25 New Monitoring Wells	ISB Performance Monitoring Wells (installed before CY2023)	**Anticipated 10 - 20**	Average 280 - 300	NA	NA	NA	NA	NA	Q	SA	SA	SA	SA	Q	Q	P & A
575 Injection Wells	5% of ISB Injection Wells (installed before CY2023)	**Anticipated 10 - 20**	Average 280 - 300	NA	NA	NA	NA	NA	Q	SA	SA	SA	SA	Q	Q	P & A all 575 injection wells
Regional Aquifer																
Eubank-1	City-owned well	2.0 (per COA)	550.0 – 610.0	0.59	NA	NA	A	A	A	A	A	A	A	A	A	COA
PGS-2	Multiple screens	1.56	535.0 – 565.0 585.0 - 595.0 625.0 - 645.0	2.65	NA	NA	WL	WL	WL	WL	WL	WL	WL	WL	WL	LTS
TA1-W-01		2.69	575.0 – 595.0	1.25	NA	NA	WL	WL	WL	WL	WL	WL	WL	WL	WL	LTS
TA1-W-02		1.15	540.0 – 560.0	0.6	NA	NA	A	A	A	A	A	A	A	A	A	LTS
TA1-W-04		2.04	576.0 – 596.0	0.59	NA	NA	WL	WL	WL	WL	WL	WL	WL	WL	WL	LTS
TA1-W-05		1.29	597.5 – 617.5	2.24	NA	NA	WL	WL	WL	WL	WL	WL	WL	WL	WL	LTS
TA2-NW1-595	Multiple screens	4.03	535.0 – 555.0 585.0 - 595.0	0.66	NA	NA	A	A	A	A	A	A	A	A	A	LTS
TJA-3		2.76	496.0 – 516.0	-0.04	NA	NA	A	A	A	A	A	A	A	A	A	LTS
TJA-4	Merging Zone	**33.0**	360.0 – 380.0	0.41	NA	NA	A	A	A	A	A	A	A	A	A	LTS
TJA-6		2.80	454.9 – 474.6	-0.07	NA	NA	A	A	A	A	A	A	A	A	A	LTS
WYO-3		2.41	520.0 – 540.0	1.08	NA	NA	A	A	A	A	A	A	A	A	A	LTS
TA2-W-24		2.8 (2002)	465.0 – 485.0	0.41	NA	NA	A	A	A	A	A	A	A	A	A	LTS
TA2-W-25		2.1 (2002)	492.0 – 512.0	0.69	NA	NA	A	A	A	A	A	A	A	A	A	LTS
						Total samples during period	**3,583**	93	58	518	411	945	798	262	253	245	

Notes

Concentration values in **bold** exceed the 10 mg/L Maximum Contaminant Level for nitrate
A = annual sampling frequency
COA = City of Albuquerque
ft bgs = feet below ground surface
ft/yr = feet per year
KAFB = Kirtland Air Force Base
LTS = well to be transferred into the Long-Term Stewardship program as part of sitewide monitoring
mg/L = milligrams per liter
NA = not applicable
P & A = plugged and abandoned
Q = quarterly sampling frequency
SA = semiannual sampling frequency
WL = water level measurement only (not sampled)

Table E-5. Alternative 2: In-Situ Bioremediation – Groundwater Sampling Frequency

Well	Comments	Maximum NPN Concentration CY2015 (mg/L)	Screened Interval (ft bgs)	Water Level Change (ft/yr)	Estimated Year Water Level Drops Below Well Screen	Number of Years Until Water Level Drops Below Well Screen (from CY 2018)	Pre-extraction	Start extraction by Year 5	Remedy Performance					Confirmation		Post-closure
							Years 1 - 3 (CY 2018 - 2020)	Years 4 - 5 (CY 2021 - 2022)	Years 6 - 7 (CY 2023 - 2024)	Years 8 - 10 (CY 2025 - 2027)	Years 11 - 17 (CY 2028 - 2034)	Years 18 - 23 (CY 2035 - 2040)	Years 24 - 25 (CY 2041 - 2042)	Year 26 (CY 2043)	Year 27 (CY 2044)	CY 2045+
							3	2	2	3	7	6	2	1	1	
Perched Groundwater System																
TA1-W-03	Upgradient Background	7.99	337.0 – 357.0	-1.17	2020	3	SA	dry	dry	dry	dry	dry	dry	dry	dry	**P & A**
TA1-W-06	Upgradient Background	3.76	300.0 – 320.0	-0.44	2041	24	SA	SA	SA	SA	SA	SA	dry	dry	dry	**P & A**
TA1-W-07	Upgradient Background	3.2 (2002)	268.6 – 288.6	-0.15	2044	WL only (26 yrs until dry)	WL	WL	WL	WL	WL	WL	WL	WL	dry	**P & A**
TA1-W-08	Upgradient Background	8.01	302.0 – 322.0	-0.52	2035	18	SA	SA	SA	SA	SA	dry	dry	dry	dry	**P & A**
TA2-NW1-325	Upgradient Background	3.9 (2002)	295.0 – 325.0	-0.53	2030	WL only (12 yrs until dry)	WL	WL	WL	WL	WL dry Yr 13	dry	dry	dry	dry	**P & A**
TA2-W-01	Crossgradient Sentinel	5.38	312.0 – 332.0	-0.7	2025	8	SA	SA	SA	dry	dry	dry	dry	dry	dry	**P & A**
TA2-W-19	ISB Performance Monitoring Well	**12.8**	265.9 – 285.9	-0.5	2046	29	SA	SA	Q	SA	SA	SA	SA	Q	Q	**P & A**
TA2-W-26	Crossgradient Sentinel	6.7	276.0 – 296.0	-0.75	2028	11	SA	SA	SA	SA	dry	dry	dry	dry	dry	**P & A**
TA2-W-27	Crossgradient Sentinel	4.58	275.0 – 295.0	-0.56	2044	27	SA	SA	SA	SA	SA	SA	SA	Q	dry	**P & A**
TA2-W-28	ISB Performance Monitoring Well	**27.8**	310.5 – 330.5	-0.55	2044	27	SA	SA	Q	SA	SA	SA	SA	Q	dry	**P & A**
TJA-2	ISB Performance Monitoring Well	**13.4**	275.0 – 295.0	-0.43	2059	42	SA	SA	Q	SA	SA	SA	SA	Q	Q	**P & A**
TJA-5	ISB Performance Monitoring Well	**26** (per KAFB)	267.0 – 287.0	-0.02	NA	NA	SA	SA	Q	SA	SA	SA	SA	Q	Q	**P & A**
TJA-7	ISB Performance Monitoring Well	**25.0**	290.5 – 310.5	-0.27	2051	33	SA	SA	Q	SA	SA	SA	SA	Q	Q	**P & A**
WYO-4	Upgradient Background	3.56	275.0 – 295.0	-0.68	2021	4	WL	dry	dry	dry	dry	dry	dry	dry	dry	**P & A**
11 New Monitoring Wells	GWE&T Performance Monitoring Wells (installed before CY2023)	**Anticipated 10 - 20**	Average 280 - 300	NA	NA	NA	NA	NA	Q	SA	SA	SA	SA	Q	Q	**P & A**
73 Extraction Wells	Samples collected from inline port during pumping (installed before CY2023)	**Anticipated 10 - 20**	Average 280 - 300	NA	NA	NA	NA	NA	Q	QA	QA	QA	QA	Not sampled	Not sampled	**P & A all 73 extraction wells**
Regional Aquifer																
Eubank-1	City-owned well	2.0 (per COA)	550.0 – 610.0	0.59	NA	NA	A	A	A	A	A	A	A	A	A	**COA**
PGS-2	Multiple screens	1.56	535.0 – 565.0 585.0 - 595.0 625.0 - 645.0	2.65	NA	NA	WL	WL	WL	WL	WL	WL	WL	WL	WL	**LTS**
TA1-W-01		2.69	575.0 – 595.0	1.25	NA	NA	WL	WL	WL	WL	WL	WL	WL	WL	WL	**LTS**
TA1-W-02		1.15	540.0 – 560.0	0.6	NA	NA	A	A	A	A	A	A	A	A	A	**LTS**
TA1-W-04		2.04	576.0 – 596.0	0.59	NA	NA	WL	WL	WL	WL	WL	WL	WL	WL	WL	**LTS**
TA1-W-05		1.29	597.5 – 617.5	2.24	NA	NA	WL	WL	WL	WL	WL	WL	WL	WL	WL	**LTS**
TA2-NW1-595	Multiple screens	4.03	535.0 – 555.0 585.0 - 595.0	0.66	NA	NA	A	A	A	A	A	A	A	A	A	**LTS**
TJA-3		2.76	496.0 – 516.0	-0.04	NA	NA	A	A	A	A	A	A	A	A	A	**LTS**
TJA-4	Merging Zone	**33.0**	360.0 – 380.0	0.41	NA	NA	A	A	A	A	A	A	A	A	A	**LTS**
TJA-6		2.80	454.9 – 474.6	-0.07	NA	NA	A	A	A	A	A	A	A	A	A	**LTS**
WYO-3		2.41	520.0 – 540.0	1.08	NA	NA	A	A	A	A	A	A	A	A	A	**LTS**
TA2-W-24		2.8 (2002)	465.0 – 485.0	0.41	NA	NA	A	A	A	A	A	A	A	A	A	**LTS**
TA2-W-25		2.1 (2002)	492.0 – 512.0	0.69	NA	NA	A	A	A	A	A	A	A	A	A	**LTS**
						Total samples during period	**7,151**	**93**	**58**	**766**	**1023**	**2373**	**2022**	**670**	**77**	**69**	

Notes

Concentration values in **bold** exceed the 10 mg/L Maximum Contaminant Level for nitrate
A = annual sampling frequency
COA = City of Albuquerque
ft bgs = feet below ground surface
ft/yr = feet per year
KAFB = Kirtland Air Force Base
LTS = well to be transferred into the Long-Term Stewardship program as part of sitewide monitoring
mg/L = milligrams per liter
NA = not applicable
P & A = plugged and abandoned
Q = quarterly sampling frequency
SA = semiannual sampling frequency
WL = water level measurement only (not sampled)

Table E-6. Alternative 3: Groundwater Extraction and Treatment – Groundwater Sampling Frequency

Annual monitoring and reporting costs for all three alternatives also include:

- Laboratory analysis for nitrate and third-party validation,
- Analytical data handling and verification,
- An allowance for wellhead maintenance,
- Annual IDW profiling analysis of purge water and decontamination water to meet Albuquerque Bernalillo County Water Utility Authority discharge permit requirement before disposal to the sanitary sewer,
- Labor for transport and disposal of purge water and decontamination water to the onsite permitted sanitary sewer discharge point, and
- Preparation of an annual progress report to include potentiometric surface contour maps, nitrate isoconcentration contour maps, hydrographs, nitrate concentration trend graphs, and an evaluation of remedy performance. This may be incorporated into the TAG section of DOE and the SNL M&O contractor *Annual Groundwater Monitoring Reports*.

Alternative 2 annual monitoring and reporting costs include:

- Laboratory analysis for anions (bromide, chloride, fluoride, nitrite, and sulfate), dissolved metals (arsenic, calcium, iron, magnesium, manganese, potassium, and sodium), orthophosphate as P, and total organic carbon with associated third-party validation, and
- Additional data handling and verification.

Years 6 - 25:

- Logged data retrieval from downhole multi-parameter sondes installed as dedicated monitoring equipment in select wells),
- Maintenance and as-needed replacement of dedicated monitoring equipment, and
- Re-dosing of in-situ bioremediation (ISB) substrate (targeting each injection well biennially).

Alternative 3 annual monitoring and reporting costs include:

Years 6 - 25:

- Electricity for operating extraction well, transfer tank pumps, and the treatment system components,
- Sample collection from extraction well sampling ports to monitor local remedy performance and optimize extraction configuration,

- Sample collection from treatment system sampling ports to ensure optimal and compliance operation,
- Additional data handling and verification,
- Ion exchange resin replacement and offsite regeneration servicing,
- An allowance for 5 percent new resin replacement during each year of operation, and
- An allowance for as-needed replacement of tubing used for conveying extracted groundwater from the extraction wells to the treatment system. Assumes 100 percent replacement over the 20-year extraction timeframe (applied annually as 5 percent replacement each year).

Periodic Costs

Periodic costs are broken into either 5-year or 10-year intervals for convenience of cost estimation with final closure-related costs in the final year. They include:

- Redeveloping wells that become biofouled or silted up hindering collection of representative groundwater samples. The cost estimates for Alternative 1 assumes that 50 percent of wells being sampled at any one-time interval would require redevelopment in Years 10, 20, and 30. For Alternative 3, 50 percent of wells being sampled would be redeveloped in Year 15 (this assumes most wells are installed by Year 5). Extraction wells are assumed not to required redevelopment. Costs for redeveloping monitoring wells and injection wells in Alternative 2 are included in the Annual cost sections because this would be a more continuous activity due to the large number of wells.
- Decommissioning all TAG AOC monitoring, injection, and extraction wells screened in the Perched Groundwater System after completion of the remedy and any associated confirmation monitoring. For costing purposes, well plugging and abandonment is placed in the final year after the final sampling event (Year 41 for Alternative 1, Year 27 for Alternatives 2 and 3). The actual schedule of well decommissioning would be dependent on receiving final Corrective Action Complete approval from NMED and other site logistical factors.

Total Cost and Present Value Analysis

Total costs are summarized both in 2018 dollars (Total Cost) and by applying Present Value analysis. Per EPA guidance (EPA July 2000), “Present value analysis is a method to evaluate expenditures, either capital or O&M, which occur over different time periods. This standard methodology allows for cost comparisons of different remedial alternatives based on a single cost figure for each alternative. This single number, referred to as the present value, is the amount needed to be set aside at the initial point in time (base year) to assure that funds will be available in the future as they are needed, assuming certain economic conditions.”

Present value costs were calculated using the real discount rate of 0.7 percent for federal facilities based on the 2017 Discount Rates for Office of Management and Budget Circular A-94 (OMB December 2016) for projects with a timeframe of 30 years or more. EPA guidance indicates that the same discount rate should be used for all evaluated alternatives based on the alternative with the longest timeframe (EPA July 2000). A remedy that is less costly, but does not sacrifice protection of health and the environment, shall be preferred.

The Consent Order states that cost estimates be presented in Present Value. Present Value assumes the entire predicted cost of the remedy is invested up-front in an interest-bearing account and drawn upon as needed to fund the remediation project. However, Congress allocates environmental project funding on an individual fiscal year basis. The Total Cost estimate is the sum of the fiscal year funding throughout the anticipated lifecycle of the project, and more accurately represents the actual expense of the cleanup to the taxpayers. For projects with long durations, Present Value calculations can significantly underestimate the true project costs. Both Present Value and Total Cost are presented in this Corrective Measures Evaluation.

References

Office of Management and Budget (OMB), December 2016. “Memorandum for the Heads of Departments and Agencies M-17-10, 2017 Discount Rates for OMB Circular A-94.” Executive Office of the President, Office of Management and Budget, Washington, D.C., December 12.

U.S. Environmental Protection Agency (EPA), July 2000. “A Guide to Developing and Documenting Cost Estimates During the Feasibility Study,” EPA 540-R-00-002. OSWER 9355.0-75.

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LIST OF COST ESTIMATES

- Summary of Remedial Alternative Total Costs
- Cost Estimate: TAG AOC Alternative 1: Monitored Natural Attenuation of Nitrate
- Cost Estimate: TAG AOC Alternative 2: In-Situ Bioremediation
- Cost Estimate: TAG AOC Alternative 3: Groundwater Extraction and Treatment
- Cost Worksheets
  - Corrective Measures Implementation Plan (Alternative 1, Alternatives 2 and 3 are 50% more than this cost)
  - Corrective Measures Design (Alternative 1)
  - Corrective Measure Design (Alternative 2)
  - Corrective Measure Design (Alternative 3)
  - Contingency Plan (Alternatives 1, 2, and 3)
  - NMED Discharge Permit (Alternatives 2 and 3)
  - NEPA Evaluation (Alternatives 2 and 3)
  - Groundwater well installation (Alternatives 2 and 3)
  - Groundwater well development (Alternatives 1, 2, and 3) (also applies to redevelopment)
  - Well installation and testing report (Alternatives 1, 2, and 3)
  - Potable water transportation (Alternative 2)
  - Substrate initial injection (Alternative 2)
  - Install dedicated monitoring equipment and initiate logging (Alternative 2)
  - Install groundwater extraction and conveyance system (Alternative 3)
  - Ion exchange and carbon polish groundwater treatment system (Alternative 3)
  - Discharge injection line (Alternative 3)
  - Depth to water measurements (Alternatives 1, 2, and 3)
  - Groundwater well sampling (Alternatives 1, 2, and 3)
  - Groundwater laboratory analysis and validation (Alternatives 1 and 3)
  - Groundwater laboratory analysis and validation (Alternative 2)
  - Analytical data handling and verification (Alternatives 1, 2, and 3)
  - IDW analysis (Alternatives 1, 2, and 3)
  - IDW transport and disposal – water (Alternatives 1, 2, and 3)
  - Annual Remedy Performance Review (Alternatives 1, 2, and 3)
  - Logged data retrieval (Alternative 2)

  - ISB substrate re-dosing injection (Alternative 2)
  - Sampling port sample collection (Alternative 3)
  - Treatment system discharge compliance analysis (Alternative 3)
  - Discharge compliance report (Alternative 3)
  - Corrective Measures Implementation Report (Alternatives 1, 2, and 3)
  - Groundwater well plugging and abandonment (Alternatives 1) (Alternatives 2 and 3 are twice this cost)
  - Dismantle groundwater conveyance and treatment system (Alternative 3)
- Input factors
  - Fully Burdened Labor Rates
  - Present Value Discount Factors
  - Escalation Factors to Base Year

SUMMARY OF REMEDIAL ALTERNATIVE TOTAL COSTS

Site: Tijeras Arroyo Groundwater Area of Concern

Location: Sandia National Laboratories/New Mexico

Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)

Base Year: 2018

Revision Date: January 31, 2018

	TAG AOC Alternative 1: Monitored Natural Attenuation	**TAG AOC Alternative 2: In-situ Bioremediation**	**TAG AOC Alternative 3: Groundwater Extraction and Treatment**
Total Project Duration (Years)	**41**	**27**	**27**
Cost Breakdown - before Present Value calculation			
Total Capital Cost (Only Implementation Plan Costs for Alternative 1)	$334,105	$125,123,627	$26,284,575
Total Cumulative Operation, Maintenance, Monitoring and Reporting Cost	$6,755,060	$36,546,779	$32,553,798
Total Periodic Cost	$683,075	$11,595,748	$2,703,285
Total Cost of Alternative before Present Value Calculation	**$7,772,240**	**$173,266,155**	**$61,541,658**
Total Present Value of Alternative	**$6,789,200**	**$167,579,239**	**$57,822,225**

COST ESTIMATE
TAG AOC Alternative 1:
Monitored Natural Attenuation

Description: Alternative 1 consists of applying monitored natural attenuation (MNA) throughout the plume of elevated nitrate. Monitoring will be continued until either nitrate concentrations have dropped below the MCL of 10 mg/L or the water level in all Perched Groundwater System (PGWS) monitoring wells within the AOC has dropped below the screened interval (except TJA-5). Institutional controls will be maintained until monitoring is completed and site closure is approved by regulatory agencies.
Anticipated timeframe for this alternative is 41 years from the base year of 2018. All TAG AOC monitoring wells to be plugged and abandoned after Corrective Action Complete status is approved by NMED.
Cost estimate basis includes:

- Preparing a Corrective Measures Implementation Plan (CMIP) and associated documents.
- Groundwater monitoring for 41 years (from 2018).
  - Semiannual water level measurements (and tagging dry wells) in all AOC wells for the duration of the remedy.
  - Semiannual sampling of PGWS wells within the AOC for the duration of the remedy unless the water level drops below the screened interval.
  - Annual sampling of select Regional Aquifer wells within the AOC for the duration of remedy.
- Institutional controls for duration of the remedy until site closure.
- Annual progress reporting.
- As-needed well redevelopment and wellhead maintenance.
- Preparitng a Corrective Measures Implementation Report with request for Corrective Action Complete approval.
- Decommissioning of (plug and abandon) all TAG AOC PGWS monitoring wells (14 wells).

Site: Tijeras Arroyo Groundwater Area of Concern

Location: Sandia National Laboratories/New Mexico

Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)

Base Year: 2018

Revision Date: January 31, 2018

CAPTIAL COST (IMPLEMENTATION PLAN PREPARATION)

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Planning and Design Documents					
Corrective Measures Implementation Plan	1	EA	$176,068	$176,068	Includes Management Plan, Community Relations Plan, Sampling and Analysis Plan, Corrective Measures Permitting Plan, and Land Use Controls Implementation Plan.
Corrective Measures Design	1	EA	$48,257	$48,257	Submitted with CMIP. Includes O&M plan, Waste Management Plan, Progress Reporting and Implementation Schedule, and Health and Safety Plan. No Design Plans/Specifications/associated construction schedule or Construction Quality Assurance Plan, are necessary for this Alternative.
Contingency Plan	1	EA	$64,944	$64,944	Submitted with CMIP.
SUBTOTAL				**$289,268**	
Contingency	10%			**$28,927**	
SUBTOTAL				**$318,195**	
Project Management	5%			**$15,910**	
TOTAL CAPITAL COST				**$334,105**	

ANNUAL MONITORING & REPORTING COST (Years 1-3)					Dry PGWS Wells: none
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$2,139	$4,279	Semiannual DTW measurements from 27 wells. Includes data entry and QC.
Groundwater well sampling	22	WELLS	$2,152	$47,349	Semiannual sampling for 11 PGWS wells (22). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling for 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	31	SAMPLES	$32	$1,004	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENTS	$4,225	$8,449	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 16 sampling locations/event.
SUBTOTAL				**$80,452**	
Site Maintenance					
Wellhead maintenance	27	WELLS	$25	$675	General maintenance of well heads/vaults. Assume $25/well/year. 27 wells.
SUBTOTAL				**$675**	
IDW Disposal - Publically Owned Treatment Works (POTW)					
IDW laboratory analysis	20	WELLS	$1,122	$22,446	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from the 11 PGWS wells and the 9 Regional Aquifer wells (20). Performed annually in conjunction with one semiannual well sampling event.
IDW transport & disposal - water	2	EVENTS	$3,782	$7,564	Semiannual discharge to POTW. Up to 20 drums/event.
SUBTOTAL				**$30,010**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$58,735	$58,735	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report.
SUBTOTAL				**$58,735**	
SUBTOTAL Performance Monitoring				**$169,871**	
Contingency	10%			**$16,987**	
SUBTOTAL				**$186,859**	
Project Management	5%			**$9,343**	
TOTAL ANNUAL MONITORING & REPORTING (Years 1-3)				**$196,202**	

ANNUAL MONITORING & REPORTING COST (Years 4-7)					Dry PGWS Wells: TA1-W-03 and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$2,139	$4,279	Semiannual DTW measurements from 27 wells. Includes data entry and QC.
Groundwater well sampling	20	WELLS	$2,152	$43,045	Semiannual sampling of 10 PGWS wells (20). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	29	SAMPLES	$32	$940	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENTS	$3,961	$7,921	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 15 sampling locations/event.
SUBTOTAL				**$75,555**	
Site Maintenance					
Wellhead maintenance	27	WELLS	$25	$675	General maintenance of well heads/vaults. Assume $25/well/year. 27 wells (includes dry wells).
SUBTOTAL				**$675**	
IDW Disposal - POTW					
IDW laboratory analysis	19	WELLS	$1,122	$21,324	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from the 10 PGWS wells and the 9 Regional Aquifer wells (19). Performed annually in conjunction with one semiannual well sampling event.
IDW transport & disposal - water	2	EVENT	$3,782	$7,564	Semiannual discharge to POTW. Up to 20 drums/event.
SUBTOTAL				**$28,887**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$58,735	$58,735	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report.
SUBTOTAL				**$58,735**	
SUBTOTAL Performance Monitoring				**$163,852**	
Contingency	10%			**$16,385**	
SUBTOTAL				**$180,237**	
Project Management	5%			**$9,012**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 4-7)				**$189,249**	

ANNUAL MONITORING & REPORTING COST (Years 8-10)					Dry PGWS Wells: TA1-W-03, TA2-W-01, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$2,139	$4,279	Semiannual DTW measurements from 27 wells. Includes data entry and QC.
Groundwater well sampling	18	WELLS	$2,152	$38,740	Semiannual sampling of 9 PGWS wells (18). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	27	SAMPLES	$32	$875	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENTS	$3,697	$7,393	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 14 sampling locations/event.
SUBTOTAL				**$70,657**	
Site Maintenance					
Wellhead maintenance	27	WELLS	$25	$675	General maintenance of well heads/vaults. Assume $25/well/year. 27 wells (includes dry wells).
SUBTOTAL				**$675**	
IDW Disposal - POTW					
IDW laboratory analysis	18	WELLS	$1,122	$20,201	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from the 9 PGWS wells and the 9 Regional Aquifer wells (18). Performed annually in conjunction with one semiannual well sampling event.
IDW transport & disposal - water	2	EVENT	$3,782	$7,564	Semiannual discharge to POTW. Up to 20 drums/event.
SUBTOTAL				**$27,765**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$58,735	$58,735	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report.
SUBTOTAL				**$58,735**	
SUBTOTAL Performance Monitoring				**$157,832**	
Contingency	10%			**$15,783**	
SUBTOTAL				**$173,615**	
Project Management	5%			**$8,681**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 8-10)				**$182,296**	

ANNUAL MONITORING & REPORTING COST (Years 11-17)					Dry PGWS Wells: TA1-W-03, TA2-W-01, TA2-W-26, and WYO-4 (water level only well TA2-NW1-325 dry in year 14)
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$2,139	$4,279	Semiannual DTW measurements from 27 wells. Includes data entry and QC.
Groundwater well sampling	16	WELLS	$2,152	$34,436	Semiannual sampling of 8 PGWS wells (16). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	25	SAMPLES	$32	$810	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENT	$3,433	$6,865	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 13 sampling locations per event.
SUBTOTAL				**$65,760**	
Site Maintenance					
Wellhead maintenance	27	WELLS	$25	$675	General maintenance of well heads/vaults. Assume $25/well/year. 27 wells (includes dry wells).
SUBTOTAL				**$675**	
IDW Disposal - POTW					
IDW laboratory analysis	17	WELLS	$1,122	$19,079	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from the 8 PGWS wells and the 9 Regional Aquifer wells (17). Performed annually in conjunction with one semiannual well sampling event.
IDW transport & disposal - water	2	EVENT	$3,782	$7,564	Semiannual discharge to POTW. Up to 20 drums/event.
SUBTOTAL				**$26,643**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$58,735	$58,735	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report.
SUBTOTAL				**$58,735**	
SUBTOTAL Performance Monitoring				**$151,812**	
Contingency	10%			**$15,181**	
SUBTOTAL				**$166,994**	
Project Management	5%			**$8,350**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 11-17)				**$175,343**	

ANNUAL MONITORING & REPORTING COST (Years 18-23)					Dry PGWS Wells: TA1-W-03, TA1-W-08, TA2-NW1-325 (water level only well), TA2-W-01, TA2-W-26, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$2,139	$4,279	Semiannual DTW measurements from 27 wells. Includes data entry and QC.
Groundwater well sampling	14	WELLS	$2,152	$30,131	Semiannual sampling of 7 PGWS wells (14). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	23	SAMPLES	$32	$745	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENT	$3,169	$6,337	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 12 sampling locations per event.
SUBTOTAL				**$60,862**	
Site Maintenance					
Wellhead maintenance	27	WELLS	$25	$675	General maintenance of well heads/vaults. Assume $25/well/year. 27 wells (includes dry wells).
SUBTOTAL				**$675**	
IDW Disposal - POTW					
IDW laboratory analysis	16	WELLS	$1,122	$17,957	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from the 7 PGWS wells and the 9 Regional Aquifer wells (16). Performed annually in conjunction with one semiannual well sampling event.
IDW transport & disposal - water	2	EVENT	$3,782	$7,564	Semiannual discharge to POTW. Up to 20 drums/event.
SUBTOTAL				**$25,520**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$58,735	$58,735	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report.
SUBTOTAL				**$58,735**	
SUBTOTAL Performance Monitoring				**$145,793**	
Contingency	10%			**$14,579**	
SUBTOTAL				**$160,372**	
Project Management	5%			**$8,019**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 18-23)				**$168,391**	

ANNUAL MONITORING & REPORTING COST (Years 24-26)					Dry PGWS Wells: TA1-W-03, TA1-W-06, TA1-W-08, TA2-NW1-325 (water level only well), TA2-W-01, TA2-W-26, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$2,139	$4,279	Semiannual DTW measurements from 27 wells. Includes data entry and QC.
Groundwater well sampling	12	WELLS	$2,152	$25,827	Semiannual sampling of 6 PGWS wells (12). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	21	SAMPLES	$32	$680	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENT	$3,169	$6,337	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 11 sampling locations per event.
SUBTOTAL				**$56,493**	
Site Maintenance					
Wellhead maintenance	27	WELLS	$25	$675	General maintenance of well heads/vaults. Assume $25/well/year. 27 wells (includes dry wells).
SUBTOTAL				**$675**	
IDW Disposal - POTW					
IDW laboratory analysis	15	WELLS	$1,122	$16,835	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from the 6 PGWS wells and the 9 Regional Aquifer wells (15). Performed annually in conjunction with one semiannual well sampling event.
IDW transport & disposal - water	2	EVENT	$3,782	$7,564	Semiannual discharge to POTW. Up to 20 drums/event.
SUBTOTAL				**$24,398**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$58,735	$58,735	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report.
SUBTOTAL				**$58,735**	
SUBTOTAL Performance Monitoring				**$140,301**	
Contingency	10%			**$14,030**	
SUBTOTAL				**$154,331**	
Project Management	5%			**$7,717**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 24-26)				**$162,048**	

ANNUAL MONITORING & REPORTING COST (Years 27-28)					Dry PGWS Wells: TA1-W-03, TA1-W-06, TA1-W-07, TA1-W-08, TA2-NW1-325 (water level only well), TA2-W-01, TA2-W-26, TA2-W-27, TA2-W-28, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$2,139	$4,279	Semiannual DTW measurements from 27 wells. Includes data entry and QC.
Groundwater well sampling	8	WELLS	$2,152	$17,218	Semiannual sampling of 4 PGWS wells (8). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	17	SAMPLES	$32	$551	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENT	$2,376	$4,753	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 9 sampling locations per event.
SUBTOTAL				**$46,170**	
Site Maintenance					
Wellhead maintenance	27	WELLS	$25	$675	General maintenance of well heads/vaults. Assume $25/well/year. 27 wells (includes dry wells).
SUBTOTAL				**$675**	
IDW Disposal - POTW					
IDW laboratory analysis	13	WELLS	$1,122	$14,590	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from the 4 PGWS wells and the 9 Regional Aquifer wells (13). Performed annually in conjunction with one semiannual well sampling event.
IDW transport & disposal - water	2	EVENT	$3,782	$7,564	Semiannual discharge to POTW. Up to 20 drums/event.
SUBTOTAL				**$22,153**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$58,735	$58,735	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report.
SUBTOTAL				**$58,735**	
SUBTOTAL Performance Monitoring				**$127,734**	
Contingency	10%			**$12,773**	
SUBTOTAL				**$140,507**	
Project Management	5%			**$7,025**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 27-28)				**$147,533**	

ANNUAL MONITORING & REPORTING COST (Years 29-32)					Dry PGWS Wells: TA1-W-03, TA1-W-06, TA1-W-07, TA1-W-08, TA2-NW1-325 (water level only well), TA2-W-01, TA2-W-19, TA2-W-26, TA2-W-27, TA2-W-28, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$2,139	$4,279	Semiannual DTW measurements from 27 wells. Includes data entry and QC.
Groundwater well sampling	6	WELLS	$2,152	$12,913	Semiannual sampling of 3 PGWS wells (6). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	15	SAMPLES	$32	$486	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENT	$2,112	$4,225	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 8 sampling locations per event.
SUBTOTAL				**$41,273**	
Site Maintenance					
Wellhead maintenance	27	WELLS	$25	$675	General maintenance of well heads/vaults. Assume $25/well/year. 27 wells (includes dry wells).
SUBTOTAL				**$675**	
IDW Disposal - POTW					
IDW laboratory analysis	12	WELLS	$1,122	$13,468	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from the 3 PGWS wells and the 9 Regional Aquifer wells (12). Performed annually in conjunction with one semiannual well sampling event.
IDW transport & disposal - water	2	EVENT	$3,782	$7,564	Semiannual discharge to POTW. Up to 20 drums/event.
SUBTOTAL				**$21,031**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$58,735	$58,735	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report.
SUBTOTAL				**$58,735**	
SUBTOTAL Performance Monitoring				**$121,714**	
Contingency	10%			**$12,171**	
SUBTOTAL				**$133,886**	
Project Management	5%			**$6,694**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 29-32)				**$140,580**	

ANNUAL MONITORING & REPORTING COST (Years 33-41)					Dry PGWS Wells: TJA-7, TA1-W-03, TA1-W-06, TA1-W-07, TA1-W-08, TA2-NW1-325 (water level only well), TA2-W-01, TA2-W-19, TA2-W-26, TA2-W-27, TA2-W-28, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$2,139	$4,279	Semiannual DTW measurements from 27 wells. Includes data entry and QC.
Groundwater well sampling	4	WELLS	$2,152	$8,609	Semiannual sampling of 2 PGWS wells (4). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	13	SAMPLES	$32	$421	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENT	$1,848	$3,697	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 7 sampling locations per event.
SUBTOTAL				**$36,376**	
Site Maintenance					
Wellhead maintenance	27	WELLS	$25	$675	General maintenance of well heads/vaults. Assume $25/well/year. 27 wells (includes dry wells).
SUBTOTAL				**$675**	
IDW Disposal - POTW					
IDW laboratory analysis	11	WELLS	$1,122	$12,345	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from the 2 PGWS wells and the 9 Regional Aquifer wells (11). Performed annually in conjunction with one semiannual well sampling event.
IDW transport & disposal - water	2	EVENT	$3,782	$7,564	Semiannual discharge to POTW. Up to 20 drums/event.
SUBTOTAL				**$19,909**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$58,735	$58,735	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report.
SUBTOTAL				**$58,735**	
SUBTOTAL Performance Monitoring				**$115,694**	
Contingency	10%			**$11,569**	
SUBTOTAL				**$127,264**	
Project Management	5%			**$6,363**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 33-41)				**$133,627**	

PERIODIC COSTS

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Groundwater well development	10	9	EA	$9,490	$85,409	Nine (half of actively sampled) wells.
SUBTOTAL (Y10)					**$85,409**	
Project Management		5%			$4,270	
TOTAL (Y10)					**$89,679**	
Groundwater well development	20	8	EA	$9,490	$75,919	Eight (half of actively sampled) wells.
SUBTOTAL (Y20)					**$75,919**	
Project Management		5%			$3,796	
TOTAL (Y20)					**$79,715**	
Groundwater well development	30	6	WELL	$9,490	$56,939	Six (half of actively sampled) wells.
SUBTOTAL (Y30)					**$56,939**	
Project Management		5%			$2,847	
TOTAL (Y30)					**$59,786**	
Groundwater well development	40	6	WELL	$9,490	$56,939	Six (half of actively sampled) wells.
SUBTOTAL (Y40)					**$56,939**	
Project Management		5%			$2,847	
TOTAL (Y40)					**$59,786**	
Corrective Measures Implementation Report	41	1	EA	$131,944	$131,944	Will include request for Certificate of Completion from NMED.
Plugging and abandonment	41+	14	EA	$17,385	$243,397	Plug and abandon all TAG PWGS monitoring wells. Regional Aquifer monitoring wells trasnsferred to Long-Term Stewardship program. City-owned well Eubank #1 remains in place. Assigned to year 41 for costing purposes. Actual schedule is dependent on receiving Corrective Action Complete approval from NMED and site logistics.
SUBTOTAL (Y41+)					**$375,341**	
Project Management		5%			$18,767	
TOTAL (Y41+)					**$394,108**	

PRESENT VALUE ANALYSIS

COST TYPE	YEARS	TOTAL COST PER YEAR	TOTAL COST	DISCOUNT FACTOR (0.7%)	PRESENT VALUE	NOTES
Implementation Plan Preparation Cost	0	$334,105	$334,105	1.000	$334,105	Occurs during Base Year
Annual Monitoring & Reporting Cost (Years 1-3)	3	$196,202	$588,605	2.958	$580,459	Year 1 = Base Year.
Annual Monitoring & Reporting Cost (Years 4-7)	4	$189,249	$756,995	3.850	$728,525	Present value costs were calculated using the real discount rate of 0.7% for federal facilities based on the 2017 Discount Rates for Office of Management and Budget Circular A-94 for projects with a timeframe of 30 years or more. EPA guidance indicates that the same discount rate should be used for all evaluated alternatives based on the alternative with the longest timeframe (Alternative 1 timeframe is 41 years).
Annual Monitoring & Reporting Cost (Years 8-10)	3	$182,296	$546,888	2.817	$513,618	
Annual Monitoring & Reporting Cost (Years 11-17)	7	$175,343	$1,227,404	6.349	$1,113,313	
Annual Monitoring & Reporting Cost (Years 18-23)	6	$168,391	$1,010,344	5.201	$875,782	
Annual Monitoring & Reporting Cost (Years 24-26)	3	$162,048	$486,144	2.520	$408,352	
Annual Monitoring & Reporting Cost (Years 27-28)	2	$186,859	$373,717	1.651	$308,486	
Annual Monitoring & Reporting Cost (Years 29-32)	4	$140,580	$562,319	3.234	$454,566	
Annual Monitoring & Reporting Cost (Years 33-41)	9	$133,627	$1,202,644	6.954	$929,217	
Periodic Cost (Year 10)	1	$89,679	$89,679	0.933	$83,637	
Periodic Cost (Year 20)	1	$79,715	$79,715	0.870	$69,335	
Periodic Cost (Year 30)	1	$59,786	$59,786	0.811	$48,497	
Periodic Cost (Year 40)	1	$59,786	$59,786	0.757	$45,230	
Periodic Cost (Year 41+)	1	$394,108	$394,108	0.751	$296,079	
			$7,772,240		**$6,789,200**	Subtotal and Total values may reflect minor incremental discrepancies due to rounding of initial unit cost amounts in referenced cost worksheets.
TOTAL PRESENT VALUE OF ALTERNATIVE					**$6,789,200**	

COST ESTIMATE
TAG AOC Alternative 2:
In-situ Bioremediation

Description: Alternative 2 consists of applying in-situ bioremediation (ISB) via a series of permeable reactive barriers (PRBs) oriented perpendicular to the local groundwater flow direction to reduce nitrate concentrations to below the Maximum Contaminant Level (MCL) of 10 mg/L within the Perched Groundwater System (PGWS) Area of Concern (AOC). Spacing between PRBs is approximately between 300 and 500 feet to treat groundwater within a 20-year period. Each PRB consists of a row of injection wells screened vertically through the PGWS saturated zone and laterally spaced approximately 50 ft apart. Between approximately 9,000 to 27,000 gallons of potable water mixed with electron donor substrate and associated nutrients and buffer will be gravity-injected at each injection well to create localized anaerobic and low redox conditions needed to facilitate denitrification of groundwater flowing through the area. The injected volume targets approximately 50% treatment coverage along the length of each PRB. Net nitrate concentration reduction throughout the plume relies in part on downgradient mixing to result in concentrations dropping from an average of 20 mg/L to below the MCL. Additional substrate mixture injection will be conducted as needed to maintain denitrifying conditions. Monitoring will continue until either nitrate concentrations in all PGWS AOC wells have dropped below the MCL for eight consecutive quarters or water levels have declined below the well screen interval. Land use controls will be maintained until monitoring is completed and site closure is approved by regulatory agencies.
The remedy timeline for this alternative depends on the groundwater advection rate. Anticipated timeframe for this alternative is 27 years from the base year of 2018 assuming 5 years to design, permit, and install wells and to inject the initial substrate mixture volumes plus 20 years for groundwater to migrate the distance from one PRB to another and 2 more years for confirmation monitoring. All TAG AOC injection and monitoring wells in the PGWS will be plugged and abandoned after Corrective Action Complete status is approved by New Mexico Environment Department (NMED). Regional Aquifer monitoring wells will be transferred to the sitewide Long-Term Stewardship program.
Alternative 2 assumes 9 PRBs ranging in length from approximately 1,700 ft with 33 injection wells to 4,150 ft with 83 injection wells. A total of 575 injection wells and 25 performance monitoring wells would be installed within 5 years. ISB injection would commence incrementally as injection wells were completed. For costing purposes, injections are assumed to happen at the same time in all injection wells and 20-year performance period begins in Year 6.

Cost estimate basis includes:

- Preparing a Corrective Measures Implementation Plan (CMIP) and associated documents.
- Obtaining a Discharge Permit from the New Mexico Environment Department.
- Installing, developing, testing, and surveying 575 injection wells; average depth 300 ft bgs along 9 PRBs.
- Installing, developing, testing, and surveying 25 performance monitoring wells; average depth 300 ft bgs.
- Conducting initial substrate mixture injections averaging 20,000 gallons per injection well.
- Groundwater monitoring for 27 years (5 years during wells installation, 20 years during implementation of ISB, 2 years post-remediation confirmation monitoring).
    - Semiannual manual water level measurements in the PGWS and Regional Aquifer monitoirng wells for the duration of the remedy.
    - Electrically logging water level measurements and water quality parameters in 30 injection wells (~5%) for the duration of the remedy.
    - Quarterly sampling of the 30 PGWS monitoirng wells within the ISB treatment area for first 2 years of the remedy followed by semiannual sampling for remainder of the remedy.
    - Semiannual sampling of 5 PGWS monitoring wells upgradient of the ISB treatment area for the duration of remedy.
    - Annual sampling of the 9 Regional Aquifer monitoirng for the duration of the remedy.
- Administering land use controls for duration of remediation until site closure.
- Annual Remedy Performance Reviews.
- As-needed ISB substrate redosing. Assumes injection wells are redosed biennially (50% of wells each year) with 500 gallons of substrate mixture between 3rd and 18th year after initial injection.
- As-needed well redevelopment and wellhead maintenance.
- A Corrective Measures Implementation Report with request for Corrective Action Complete approval.
- Decommissioning (plug and abandon) all TAG AOC injection (575) and AOC PGWS monitoring wells (39).

Site: Tijeras Arroyo Groundwater Area of Concern

Location: Sandia National Laboratories/New Mexico

Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)

Base Year: 2018

Revision Date: January 31, 2018

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Planning and Design Documents					
Corrective Measures Implementation Plan	1	EA	$264,102	$264,102	Includes Management Plan, Community Relations Plan, Sampling and Analysis Plan, Corrective Measures Permitting Plan, and Land Use Control Implementation Plan. 50% more than Alternative 1.
Corrective Measures Design	1	EA	$127,314	$127,314	Submitted with CMIP. Includes preparation of Design Plans and Specifications, Operation and Maintenance Plan, Waste Management Plan, Progress reporting and implementation schedule, Health and Safety Plan. A Construction Quality Assurance Plan is not necessary for Alternative 2.
Contingency Plan	1	EA	$64,944	$64,944	Submitted with CMIP. Same as Alternative 1.
NMED Discharge Permit	1	EA	$71,829	$71,829	Includes application preparation, submittal, and fees for NMED Discharge Permit to allow ISB injection.
NEPA Evaluation	1	EA	$17,549	$17,549	Prepare, submit, and review National Environmental Protection Act (NEPA) check list. Internally reviewed by DOE.
SUBTOTAL Planning and Design Documents				**$545,738**	
ISB Injection Well and Monitoring Well Installation					
Injection well installation	575	WELLS	$145,121	$83,444,673	ISB injection wells installed to an average depth of 300 ft bgs. Continuous core for bottom 30 ft. Includes geophysics and surveying.
Performance monitoring well installation	25	WELLS	$145,121	$3,628,029	Performance monitoring wells installed to an average depth of 300 ft bgs. Continuous core for bottom 30 ft. Includes geophysics and surveying.
Groundwater well development	600	WELLS	$9,490	$5,693,920	Well is surged and bailed, then pumped to obtain parameter stabilization. Includes setup and decontamination, containerization of investigation-derived waste (IDW).
Initial sampling of new wells	600	WELLS	$2,152	$1,291,344	Initial sampling of 575 injection well and 25 new performance monitoring wells.
Groundwater laboratory analysis and validation	600	WELLS	$32	$19,440	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	1	EVENT	$158,425	$158,425	Upload EDD and related analytical data into database, review analytical reports/perform verification. 600 sampling locations/event.
IDW laboratory analysis	600	WELLS	$1,122	$673,380	New wells. Includes analyses required by IDW Discharge Permit.
Well Installation and Testing Report	4	REPORT	$532,392	$2,129,569	Four annual reports with 150 wells/report.
SUBTOTAL ISB Injection Well and Monitoring Well Installation				**$97,038,780**	

Dedicated Monitoring Equipment					
Downhole mulitparameter sonde	35	EA	$11,000	$385,000	In-Situ "AquaTroll 600" or functional equivalent including cabling and sensors for water level, optical DO, pH and ORP, turbidity, conductivity and temperature. Installed permanently in 30 injection wells (spaced ~1,000 ft apart) + 5 as spares used during other sonde maintenance, for spot measurements in other wells, and for groundwater sampling parameter stabilization measurements.
Laptop computer	2	EA	$2,500	$5,000	Used to download and process electronically logged data.
Handheld monitors	2	EA	$5,000	$10,000	Manufacturer to match multiparameter sonde.
SUBTOTAL Dedicated Monitoring Equipment				**$400,000**	
Initial ISB substrate mixture injection					
Potable water transportation	575	WELLS	$6,671	$3,835,940	Transport potable water from source fire hydrant to injection well locations for subsequent substrate mixing prior to injection. 3 crews with two, 4,000-gal water trucks per crew. Assumes 8,000 gallons/day delivered, 2 wells fully injected per week/crew (6 wells/week total).
Mixing and injection equipment	3	EA	$5,000	$15,000	Utility trailer with mounted mixing tank (<250 gal.), injection hose (<350 ft) and reel, hose decon equipment.
Substrate initial injection	575	WELLS	$10,963	$6,303,955	Gravity-inject into each well an average of 20,000 gallons of potable water mixed with 0.5 % ethyl lactate (5 gal/1,000 gal water) and supplemental nutrients, buffer, and non-reactive tracer.
Install dedicated monitoring equipment and initiate logging	60	WELLS	$3,212	$192,732	Calibrate, test, and install dedicated multiparameter sondes and initiate monitoring.
SUBTOTAL Initial ISB substrate mixture injection				**$10,347,627**	
SUBTOTAL				**$108,332,145**	
Contingency	10%			**$10,833,214**	
SUBTOTAL				**$119,165,359**	
Project Management	5%			**$5,958,268**	
TOTAL CAPITAL COST				**$125,123,627**	

ANNUAL MONITORING & REPORTING COST (Years 1-3)					Dry PGWS Wells: none
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$2,139	$4,279	Semiannual manual DTW measurements from monitoring 27 wells. Includes data entry and QC.
Groundwater well sampling	22	WELLS	$2,152	$47,349	Semiannual sampling for 11 PGWS wells (22). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling for 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	31	SAMPLES	$32	$1,004	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENTS	$4,225	$8,449	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 16 sampling locations/event.
SUBTOTAL Performance Monitoring				**$80,452**	
Site Maintenance					
Wellhead maintenance	27	WELLS	$25	$675	General maintenance of well heads/vaults. Assume $25/well/year. 27 wells.
SUBTOTAL Site Maintenance				**$675**	
IDW Disposal - Publically Owned Treatment Works (POTW)					
IDW laboratory analysis	20	WELLS	$1,122	$22,446	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from each of 20 wells. Performed annually in conjunction with one semiannual well sampling event.
IDW transport & disposal - water	2	EVENTS	$3,782	$7,564	Semiannual discharge to POTW. Up to 20 drums/event.
SUBTOTAL IDW Disposal - POTW				**$30,010**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$58,735	$58,735	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report.
SUBTOTAL Reporting				**$58,735**	
SUBTOTAL				**$169,871**	
Contingency	10%			**$16,987**	
SUBTOTAL				**$186,859**	
Project Management	5%			**$9,343**	
TOTAL ANNUAL MONITORING & REPORTING (Years 1-3)				**$196,202**	

ANNUAL MONITORING & REPORTING COST (Years 4-5)					Dry PGWS Wells: TA1-W-03 and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$2,139	$4,279	Semiannual manual DTW measurements from 27 monitoring wells (includes checking dry wells). Includes data entry and QC.
Groundwater well sampling	20	WELLS	$2,152	$43,045	Semiannual sampling of 10 PGWS wells (20). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory lab analysis and validation	29	SAMPLES	$569	$16,506	Analysis and associated QC for NPN, anions (bromide, chloride, fluoride, nitrite, sulfate), dissolved metals (arsenic, calcium, iron, magnesium, manganese, potassium, sodium), orthophosphate as P, total organic carbon. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENTS	$3,961	$7,921	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 15 sampling locations/event.
SUBTOTAL Performance Monitoring				**$91,121**	
Site Maintenance					
Wellhead maintenance	27	WELLS	$25	$675	General maintenance of well heads/vaults. Assume $25/well/year. 27 wells (includes dry wells).
SUBTOTAL Site Maintenance				**$675**	
IDW Disposal - POTW					
IDW laboratory analysis	19	WELLS	$1,122	$21,324	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from each of 19 wells. Performed annually in
IDW transport & disposal - water	2	EVENT	$3,782	$7,564	Semiannual discharge to POTW. Up to 20 drums/event.
SUBTOTAL IDW Disposal - POTW				**$28,887**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$58,735	$58,735	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report.
SUBTOTAL Reporting				**$58,735**	
SUBTOTAL				**$179,418**	
Contingency	10%			**$17,942**	
SUBTOTAL				**$197,360**	
Project Management	5%			**$9,868**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 4-5)				**$207,228**	

ANNUAL MONITORING & REPORTING COST (Years 6-7) **Dry PGWS Wells: TA1-W-03 and WYO-4**
ISB injection initiated

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$4,120	$8,241	Semiannual manual DTW measurements from 52 monitoring wells (includes checking dry wells). Includes data entry and QC.
Logged Data Retrieval	4	EVENTS	$6,787	$27,148	Quarterly download of data from mulitparameter sondes in 30 injection wells.
Groundwater well sampling	120	WELLS	$2,152	$258,269	Quarterly sampling of 30 PGWS monitoring wells (120) located within the ISB treatment area. Includes routine equipment
Groundwater well sampling	120	WELLS	$2,152	$258,269	Quarterly sampling of 30 PGWS injection wells (120). Includes routine equipment maintenance.
Groundwater well sampling	10	WELLS	$2,152	$21,522	Semiannual sampling of 5 PGWS monitoring wells (10) upgradient of the ISB treatment area. Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory lab analysis and validation	259	SAMPLES	$569	$147,412	Analysis and associated QC for NPN, anions (bromide, chloride, fluoride, nitrite, sulfate), dissolved metals (arsenic, calcium, iron, magnesium, manganese, potassium, sodium), orthophosphate as P, total organic carbon. 100% Level IV third-party validation.
Analytical data handling and verification	4	EVENTS	$17,163	$68,651	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 65 sampling locations/event.
SUBTOTAL Performance Monitoring				**$808,882**	
Site Maintenance					
Dedicated monitoring equipment maintenance and replacement	1	LS	$20,000	$20,000	General maintenance of multiparameter sondes/sensors and associated laptops and handheld monitors. Assumes 5% of capital expenditure for this equipment per year.
Wellhead maintenance	627	WELLS	$25	$15,675	General maintenance of well heads/vaults. Assume $25/well/year. 52 monitoring wells and 575 injection wells (includes dry wells).
SUBTOTAL Site Maintenance				**$35,675**	
IDW Disposal - POTW					
IDW laboratory analysis	74	WELLS	$1,122	$83,050	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from each of 74 wells. Performed annually in conjunction with one well sampling event.
IDW transport & disposal - water	4	EVENT	$13,993	$55,970	Quarterly discharge to POTW. Up to 74 drums/event.
SUBTOTAL IDW Disposal - POTW				**$139,020**	

Reporting					
Annual Remedy Performance Review	1	REPORT	$176,205	$176,205	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report. 3 × Alternative 1 cost.
SUBTOTAL Reporting				**$176,205**	
SUBTOTAL				**$1,159,782**	
Contingency	10%			**$115,978**	
SUBTOTAL				**$1,275,760**	
Project Management	5%			**$63,788**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 6-7)				**$1,339,548**	

ANNUAL MONITORING & REPORTING COST (Years 8-10)					Dry PGWS Wells: TA1-W-03, TA2-W-01, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$4,120	$8,241	Semiannual manual DTW measurements from 52 monitoring wells (includes checking dry wells). Includes data entry and QC.
Logged Data Retrieval	4	EVENTS	$6,787	$27,148	Quarterly download of data from mulitparameter sondes in 30 injection wells.
Groundwater well sampling	68	WELLS	$2,152	$146,352	Semiannual sampling of 34 PGWS monitoring wells (68) throughout the AOC. Includes routine equipment maintenance.
Groundwater well sampling	60	WELLS	$2,152	$129,134	Semiannual sampling of 30 PGWS injection wells (60). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory lab analysis and validation	137	SAMPLES	$569	$77,975	Analysis and associated QC for NPN, anions (bromide, chloride, fluoride, nitrite, sulfate), dissolved metals (arsenic, calcium, iron, magnesium, manganese, potassium, sodium), orthophosphate as P, total organic carbon. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENTS	$18,219	$36,438	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 69 sampling locations/event.
SUBTOTAL Performance Monitoring				**$444,658**	
Site Maintenance					
ISB substrate redosing injection	288	WELLS	$2,147	$618,305	Inject ~500 gallons of potable water/substrate mixture into 50% of the injection wells (288 wells).
Dedicated monitoring equipment maintenance and replacement	1	LS	$20,000	$20,000	General maintenance of multiparameter sondes/sensors and associated laptops and handheld monitors. Assumes 5% of capital expenditure for this equipment per year.
Wellhead maintenance	627	WELLS	$25	$15,675	General maintenance of well heads/vaults. Assume $25/well/year. 52 monitoring wells and 575 injection wells (includes dry wells).
SUBTOTAL Site Maintenance				**$653,980**	
IDW Disposal - POTW					
IDW laboratory analysis	73	WELLS	$1,122	$81,928	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from each of 73 wells. Performed annually in conjunction with one well sampling event.
IDW transport & disposal - water	2	EVENT	$13,803	$27,607	Semiannual discharge to POTW. Up to 73 drums/event.
SUBTOTAL IDW Disposal - POTW				**$109,535**	

Reporting					
Annual Remedy Performance Review	1	REPORT	$176,205	$176,205	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report. 3 × Alternative 1 cost.
SUBTOTAL Reporting				**$176,205**	
SUBTOTAL				**$1,384,377**	
Contingency	10%			**$138,438**	
SUBTOTAL				**$1,522,815**	
Project Management	5%			**$76,141**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 8-10)				**$1,598,956**	

ANNUAL MONITORING & REPORTING COST (Years 11-17)					Dry PGWS Wells: TA1-W-03, TA2-W-01, TA2-W-26, and WYO-4 (water level only well TA2-NW1-325 dry in year 14)
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$4,120	$8,241	Semiannual manual DTW measurements from 52 monitoring wells (includes checking dry wells). Includes data entry and QC.
Logged Data Retrieval	4	EVENTS	$6,787	$27,148	Quarterly download of data from mulitparameter sondes in 30 injection wells.
Groundwater well sampling	66	WELLS	$2,152	$142,048	Semiannual sampling of 33 PGWS monitoring wells (66) throughout the AOC. Includes routine equipment maintenance.
Groundwater well sampling	60	WELLS	$2,152	$129,134	Semiannual sampling of 30 PGWS injection wells (60). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory lab analysis and validation	135	SAMPLES	$569	$76,837	Analysis and associated QC for NPN, anions (bromide, chloride, fluoride, nitrite, sulfate), dissolved metals (arsenic, calcium, iron, magnesium, manganese, potassium, sodium), orthophosphate as P, total organic carbon. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENT	$17,955	$35,910	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 68 sampling locations/event.
SUBTOTAL Performance Monitoring				**$438,687**	
Site Maintenance					
ISB substrate redosing injection	288	WELLS	$2,147	$618,305	Inject ~500 gallons of potable water/substrate mixture into 50% of the injection wells (288 wells).
Dedicated monitoring equipment maintenance and replacement	1	LS	$20,000	$20,000	General maintenance of multiparameter sondes/sensors and associated laptops and handheld monitors. Assumes 5% of capital expenditure for this equipment per year.
Wellhead maintenance	627	WELLS	$25	$15,675	General maintenance of well heads/vaults. Assume $25/well/year. 52 monitoring wells and 575 injection wells (includes dry wells).
Groundwater well development	45	WELLS	$9,490	$427,044	Assume 50% of injection wells and actively sampled monitoring wells require redevelopment once during remedy lifetime. Assume 45 well/year redeveloped between years 11-17.
SUBTOTAL Site Maintenance				**$1,081,024**	
IDW Disposal - POTW					
IDW laboratory analysis	72	WELLS	$1,122	$80,806	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from each of 72 wells. Performed annually in conjunction with one well sampling event.
IDW transport & disposal - water	2	EVENT	$13,614	$27,229	Semiannual discharge to POTW. Up to 72 drums/event.
SUBTOTAL IDW Disposal - POTW				**$108,034**	

Reporting					
Annual Remedy Performance Review	1	REPORT	$176,205	$176,205	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report. 3 × Alternative 1 cost.
SUBTOTAL Reporting				**$176,205**	
SUBTOTAL				**$1,803,950**	
Contingency	10%			**$180,395**	
SUBTOTAL				**$1,984,345**	
Project Management	5%			**$99,217**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 11-17)				**$2,083,562**	

ANNUAL MONITORING & REPORTING COST (Years 18-23)					Dry PGWS Wells: TA1-W-03, TA1-W-08, TA2-NW1-325 (water level only well), TA2-W-01, TA2-W-26, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$4,120	$8,241	Semiannual manual DTW measurements from 52 monitoring wells (includes checking dry wells). Includes data entry and QC.
Logged Data Retrieval	4	EVENTS	$6,787	$27,148	Quarterly download of data from mulitparameter sondes in 30 injection wells.
Groundwater well sampling	64	WELLS	$2,152	$137,743	Semiannual sampling of 32 PGWS monitoring wells (64) throughout the AOC. Includes routine equipment maintenance.
Groundwater well sampling	60	WELLS	$2,152	$129,134	Semiannual sampling of 30 PGWS injection wells (60). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory lab analysis and validation	133	SAMPLES	$569	$75,698	Analysis and associated QC for NPN, anions (bromide, chloride, fluoride, nitrite, sulfate), dissolved metals (arsenic, calcium, iron, magnesium, manganese, potassium, sodium), orthophosphate as P, total organic carbon. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENT	$17,691	$35,382	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 67 sampling locations/event.
SUBTOTAL Performance Monitoring				**$432,716**	
Site Maintenance					
ISB substrate redosing injection	288	WELLS	$2,147	$618,305	Inject ~500 gallons of potable water/substrate mixture into 50% of the injection wells (288 wells).
Dedicated monitoring equipment maintenance and replacement	1	LS	$20,000	$20,000	General maintenance of multiparameter sondes/sensors and associated laptops and handheld monitors. Assumes 5% of capital expenditure for this equipment per year.
Wellhead maintenance	627	WELLS	$25	$15,675	General maintenance of well heads/vaults. Assume $25/well/year. 52 monitoring wells and 575 injection wells (includes dry wells).
SUBTOTAL Site Maintenance				**$653,980**	
IDW Disposal - POTW					
IDW laboratory analysis	71	WELLS	$1,122	$79,683	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from each of 71 wells. Performed annually in conjunction with one well sampling event.
IDW transport & disposal - water	2	EVENT	$13,425	$26,850	Semiannual discharge to POTW. Up to 71 drums/event.
SUBTOTAL IDW Disposal - POTW				**$106,534**	

Reporting					
Annual Remedy Performance Review	1	REPORT	$176,205	$176,205	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report. 3 × Alternative 1 cost.
SUBTOTAL Reporting				**$176,205**	
SUBTOTAL				**$1,369,435**	
Contingency	10%			**$136,943**	
SUBTOTAL				**$1,506,378**	
Project Management	5%			**$75,319**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 18-23)				**$1,581,697**	

ANNUAL MONITORING & REPORTING COST (Years 24-25)					Dry PGWS Wells: TA1-W-03, TA1-W-06, TA1-W-08, TA2-NW1-325 (water level only well), TA2-W-01, TA2-W-26, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$4,120	$8,241	Semiannual manual DTW measurements from 52 monitoring wells (includes checking dry wells). Includes data entry and QC.
Logged Data Retrieval	4	EVENTS	$6,787	$27,148	Quarterly download of data from mulitparameter sondes in 30 injection wells.
Groundwater well sampling	62	WELLS	$2,152	$133,439	Semiannual sampling of 31 PGWS monitoring wells (62) throughout the AOC. Includes routine equipment maintenance.
Groundwater well sampling	60	WELLS	$2,152	$129,134	Semiannual sampling of 30 PGWS injection wells (60). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory lab analysis and validation	131	SAMPLES	$569	$74,560	Analysis and associated QC for NPN, anions (bromide, chloride, fluoride, nitrite, sulfate), dissolved metals (arsenic, calcium, iron, magnesium, manganese, potassium, sodium), orthophosphate as P, total organic carbon. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENT	$17,427	$34,854	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 66 sampling locations/event.
SUBTOTAL Performance Monitoring				**$426,745**	
Site Maintenance					
Dedicated monitoring equipment maintenance and replacement	1	LS	$20,000	$20,000	General maintenance of multiparameter sondes/sensors and associated laptops and handheld monitors. Assumes 5% of capital expenditure for this equipment per year.
Wellhead maintenance	627	WELLS	$25	$15,675	General maintenance of well heads/vaults. Assume $25/well/year. 52 monitoring wells and 575 injection wells (includes dry wells).
SUBTOTAL Site Maintenance				**$35,675**	
IDW Disposal - POTW					
IDW laboratory analysis	70	WELLS	$1,122	$78,561	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from each of 70 wells. Performed annually in conjunction with one well sampling event.
IDW transport & disposal - water	2	EVENT	$13,236	$26,472	Semiannual discharge to POTW. Up to 70 drums/event.
SUBTOTAL IDW Disposal - POTW				**$105,033**	

Reporting					
Annual Remedy Performance Review	1	REPORT	$176,205	$176,205	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report. 3 × Alternative 1 cost.
SUBTOTAL Reporting				**$176,205**	
SUBTOTAL				**$743,658**	
Contingency	10%			**$74,366**	
SUBTOTAL				**$818,024**	
Project Management	5%			**$40,901**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 24-25)				**$858,925**	

ANNUAL MONITORING & REPORTING COST (Year 26) Confirmation Sampling					Dry PGWS Wells: TA1-W-03, TA1-W-06, TA1-W-07, TA1-W-08, TA2-NW1-325 (water level only well), TA2-W-01, TA2-W-26, TA2-W-27, TA2-W-28, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$4,120	$8,241	Semiannual manual DTW measurements from 52 monitoring wells (includes checking dry wells). Includes data entry and QC.
Groundwater well sampling	124	WELLS	$2,152	$266,878	Quarterly sampling of 31 PGWS monitoring wells (124) throughout the AOC. Includes routine equipment maintenance.
Groundwater well sampling	120	WELLS	$2,152	$258,269	Quarterly sampling of 30 PGWS injection wells (120). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory lab analysis and validation	253	SAMPLES	$569	$143,997	Analysis and associated QC for NPN, anions (bromide, chloride, fluoride, nitrite, sulfate), dissolved metals (arsenic, calcium, iron, magnesium, manganese, potassium, sodium), orthophosphate as P, total organic carbon. 100% Level IV third-party validation.
Analytical data handling and verification	4	EVENT	$16,635	$66,539	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 63 sampling locations/event.
SUBTOTAL Performance Monitoring				**$763,293**	
Site Maintenance					
Wellhead maintenance	627	WELLS	$25	$15,675	General maintenance of well heads/vaults. Assume $25/well/year. 52 monitoring wells (includes dry wells).
SUBTOTAL Site Maintenance				**$15,675**	
IDW Disposal - POTW					
IDW laboratory analysis	70	WELLS	$1,122	$78,561	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from each of 70 wells. Performed annually in conjunction with one well sampling event.
IDW transport & disposal - water	4	EVENT	$13,236	$52,945	Quarterly discharge to POTW. Up to 70 drums/event.
SUBTOTAL IDW Disposal - POTW				**$131,506**	

Reporting					
Annual Remedy Performance Review	1	REPORT	$176,205	$176,205	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report. 3 × Alternative 1 cost.
SUBTOTAL Reporting				**$176,205**	
SUBTOTAL				**$1,086,679**	
Contingency	10%			**$108,668**	
SUBTOTAL				**$1,195,347**	
Project Management	5%			**$59,767**	
TOTAL ANNUAL MONITORING & REPORTING COST (Year 26)				**$1,255,114**	

ANNUAL MONITORING & REPORTING COST (Year 27) Confirmation Sampling					Dry PGWS Wells: TA1-W-03, TA1-W-06, TA1-W-07, TA1-W-08, TA2-NW1-325 (water level only well), TA2-W-01, TA2-W-19, TA2-W-26, TA2-W-27, TA2-W-28, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$4,120	$8,241	Semiannual manual DTW measurements from 52 monitoring wells (includes checking dry wells). Includes data entry and QC.
Groundwater well sampling	116	WELLS	$2,152	$249,660	Quarterly sampling of 29 PGWS monitoring wells (116) throughout the AOC. Includes routine equipment maintenance.
Groundwater well sampling	120	WELLS	$2,152	$258,269	Quarterly sampling of 30 PGWS injection wells (120). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory lab analysis and validation	245	SAMPLES	$569	$139,444	Analysis and associated QC for NPN, anions (bromide, chloride, fluoride, nitrite, sulfate), dissolved metals (arsenic, calcium, iron, magnesium, manganese, potassium, sodium), orthophosphate as P, total organic carbon. 100% Level IV third-party validation.
Analytical data handling and verification	4	EVENT	$16,107	$64,426	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 61 sampling locations/event.
SUBTOTAL Performance Monitoring				**$739,410**	
Site Maintenance					
Wellhead maintenance	627	WELLS	$25	$15,675	General maintenance of well heads/vaults. Assume $25/well/year. 52 monitoring wells (includes dry wells).
SUBTOTAL Site Maintenance				**$15,675**	
IDW Disposal - POTW					
IDW laboratory analysis	68	WELLS	$1,122	$76,316	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from each of 68 wells. Performed annually in conjunction with one well sampling event.
IDW transport & disposal - water	4	EVENT	$12,858	$51,432	Quarterly discharge to POTW. Up to 68 drums/event.
SUBTOTAL IDW Disposal - POTW				**$127,748**	
Reporting					
Annual Remedy Performance Review	0	REPORT		$0	Replaced by Corrective Measures Implementation Report under Periodic Costs for Year 27.
SUBTOTAL Reporting				**$0**	
SUBTOTAL				**$882,833**	
Contingency	10%			**$88,283**	
SUBTOTAL				**$971,116**	
Project Management	5%			**$48,556**	
TOTAL ANNUAL MONITORING & REPORTING COST (Year 27)				**$1,019,672**	

PERIODIC COSTS

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Replacement sensors for multiparameter sonde	15	35	LOT	$3,000	$105,000	pH and ORP, optical DO, conductivity and temperature, turbidity
SUBTOTAL (Y15)					**$105,000**	
Project Management		5%			$5,250	
TOTAL (Y15)					**$110,250**	
Corrective Measures Implementation Report	27	1	EA	$263,889	$263,889	Will include request for Certificate of Completion from NMED. Replaces Year 27 Annual Remedy Performance Report. 2 × cost of Alternative 1 CMIP.
Plugging and abandonment	27+	614	EA	$17,385	$10,674,681	Plug and abandon all TAG PWGS monitoring wells (39) and all injection wells (575). Regional Aquifer monitoring wells (9) trasnsferred to Long-Term Stewardship program. City-owned well Eubank #1 remains in place. Assigned to year 27 for costing purposes. Actual schedule is dependent on receiving Corrective Action Complete approval from NMED and site logistics.
SUBTOTAL (Y27+)					**$10,938,570**	
Project Management		5%			$546,928	
TOTAL (Y27+)					**$11,485,498**	

PRESENT VALUE ANALYSIS

COST TYPE	YEARS	TOTAL COST PER YEAR	TOTAL COST	DISCOUNT FACTOR (0.7%)	PRESENT VALUE	NOTES
Capital Costs	0	$125,123,627	$125,123,627	1.000	$125,123,627	Base Year: 2018
Annual Monitoring & Reporting Cost (Years 1-3)	3	$196,202	$588,605	2.958	$580,459	Present value costs were calculated using the real discount rate of 0.7% for federal facilities based on the 2017 Discount Rates for Office of Management and Budget Circular A-94 for projects with a timeframe of 30 years or more. EPA guidance indicates that the same discount rate should be used for all evaluated alternatives based on the alternative with the longest timeframe (Alternative 1 timeframe is 41 years).
Annual Monitoring & Reporting Cost (Years 4-5)	2	$207,228	$414,455	1.938	$401,650	
Annual Monitoring & Reporting Cost (Years 6-7)	2	$1,339,548	$2,679,096	1.911	$2,560,350	
Annual Monitoring & Reporting Cost (Years 8-10)	3	$1,598,956	$4,796,868	2.817	$4,505,049	
Annual Monitoring & Reporting Cost (Years 11-17)	7	$2,083,562	$14,584,936	6.349	$13,229,219	
Annual Monitoring & Reporting Cost (Years 18-23)	6	$1,581,697	$9,490,182	5.201	$8,226,237	
Annual Monitoring & Reporting Cost (Years 24-25)	2	$858,925	$1,717,851	1.686	$1,447,992	
Annual Monitoring & Reporting Cost (Year 26)	1	$1,255,114	$1,255,114	0.834	$1,046,928	
Annual Monitoring & Reporting Cost (Year 27)	1	$1,019,672	$1,019,672	0.828	$844,627	
Periodic Cost (Year 15)	1	$110,250	$110,250	0.901	$99,297	
Periodic Cost (Year 27+)	1	$11,485,498	$11,485,498	0.828	$9,513,802	
			$173,266,155		**$167,579,239**	Subtotal and Total values may reflect minor incremental discrepancies due to rounding of initial unit cost amounts in referenced cost worksheets.
TOTAL PRESENT VALUE OF ALTERNATIVE					**$167,579,239**	

COST ESTIMATE
TAG AOC Alternative 3:
Groundwater Extraction and Treatment

Description: Alternative 3 consists of implementing groundwater extraction and treatment (GWE&T) to remove, treat, and discharge groundwater from the Perched Groundwater System (PGWS) Area of Concern (AOC) where nitrate concentrations exceed the Maximum Contaminant Level (MCL) of 10 mg/L. A network of groundwater extraction wells would be installed along six transects across the MCL plume spaced to reduce concentrations througout the AOC to below the MCL within 20 years. Additional PGWS monitoring wells would be installed to enhance the monitoring network. Extracted groundwater would be pumped through an onsite treatment facility consisting of particulate filtering followed by strong-base anion ion exchange resin and finally granular activated carbon (GAC) for potential VOC removal. Treated groundwater would be discharged to a newly installed deep injection well screened in the Regional Aquifer. Estimated total system flow rate is 100 gallons per minute (gpm) with an average per well yield under 1.5 gpm. Ion-exchange resin would be regenerated offiste and used to replace saturated resin throughout the remedy operiation. Treated groundwater would be reinjected into a injection well screened in the Regional Aquifer up to a depth of 1,000 feet.
Anticipated timeframe for this alternative is 27 years from the Base Year of 2018 assuming 5 years to design, permit, and install wells, groundwater conveyance piping, and the treatement system, plus 20 years of groundwater extraction and treatment followed by 2 more years for confirmation monitoring. All TAG AOC extraction and PGWS monitoring wells would be plugged and abandoned and the treatment system would be decommissioned after Corrective Action Complete status is approved by the New Mexico Environment Department (NMED). Regional Aquifer monitoring wells would be transferred to the sitewide Long-Term Stewardship program.

Cost estimate basis includes:

- Preparing a Corrective Measures Implementation Plan (CMIP) and associated documents.
- Obtaining a discharge permit from the NMED.
- Installing, developing, testing, and surveying 73 groundwater extraction wells; average depth 300 ft bgs along 6 transects.
- Installing, developing, testing, and surveying 11 performance monitoring wells; average depth 300 ft bgs.
- Installing a buried groundwater conveyance system consisting of tubing enlosed in secondary containment piping pumped to the treatment system via aboveground transfer tanks.
- Installing a groundwater treatment system (particulate filtration, ion exchange, and GAC).
- Groundwater extraction and treatment for 20 years (years 6 through 25) including system maintenance, monthly discharge permit compliance monitoring, and reporting.
- Offiste regeneration of spent ion-exchange resin as needed throughout treatment system operation. Periodic replacement and offiste disposal of GAC.
- Groundwater monitoring for 27 years (5 years during well and system installation, 20 years during groundwater extraction and treatement, and 2 years of post-remediation confirmation monitoring).
  - Semiannual manual water level measurements in the PGWS and Regional Aquifer monitoirng wells for the duration of the remedy.
  - Quarterly sampling of the 73 groundwater extraction wells for the duration of the remedy (via wellhead sampling ports).
  - Quarterly sampling of 16 PGWS monitoring wells within the MCL plume for the first two years of system operation then reduced to semiannual sampling for the remaining 18 years of extraction followed by two years of quarterly confirmation sampling.
  - Semiannual sampling of 5 PGWS monitoring wells upgradient of the ISB treatment area for the duration of remedy.
  - Annual sampling of the 9 Regional Aquifer monitoirng for the duration of the remedy.
- Administering institutional controls for duration of remediation until site closure.
- Annual Remedy Performance Reviews.
- As-needed well redevelopment and wellhead maintenance.
- A Corrective Measures Implementation Report with request for Corrective Action Complete approval.
- Decommissioning (plug and abandon) all TAG AOC extraction wells (73), AOC PGWS monitoring wells (25), and the onsite injection well (1).
- Decommissioning the extraction and treatment system (buried secondary containment and electical wire conduit capped and abandoned in place).

Site: Tijeras Arroyo Groundwater Area of Concern

Location: Sandia National Laboratories/New Mexico

Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)

Base Year: 2018

Revision Date: January 31, 2018

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Planning and Design Documents					
Corrective Measures Implementation Plan	1	EA	$264,102	$264,102	Includes Management Plan, Community Relations Plan, Sampling and Analysis Plan, Corrective Measures Permitting Plan, and Land Use Control Implementation Plan. 50% more than Alternative 1.
Corrective Measures Design	1	EA	$351,881	$351,881	Submitted with CMIP. Includes preparation of Design Plans and Specifications, Construction Quality Assurance Plan, Operation and Maintenance Plan, Waste Management Plan, Progress reporting and implementation schedule, and a Health and Safety Plan.
Contingency Plan	1	EA	$64,944	$64,944	Submitted with CMIP. Same as Alternative 1.
NMED Discharge Permit	1	EA	$71,829	$71,829	Includes application preparation, submittal, and fees for NMED Discharge Permit to allow re-injection of treated water. Same cost as Alternative 2.
NEPA Evaluation	1	EA	$17,549	$17,549	Prepare, submit, and review National Environmental Protection Act (NEPA) check list. Internally reviewed by DOE. Same cost as Alternative 2.
SUBTOTAL Planning and Design Documents				**$770,305**	
Groundwater Extraction Well and Monitoring Well Installation					
Extraction well installation	73	WELLS	$145,121	$10,593,845	Groundwater extraction wells installed to an average depth of 300 ft bgs. Continuous core for bottom 30 ft. Includes geophysics and surveying.
Performance monitoring well installation	11	WELLS	$145,121	$1,596,333	Performance monitoring wells installed to an average depth of 300 ft bgs. Continuous core for bottom 30 ft. Includes geophysics and surveying.
Groundwater well development	84	WELLS	$9,490	$797,149	Well is surged and bailed, then pumped to obtain parameter stabilization. Includes setup and decontamination, containerization of investigation-derived waste (IDW).
Initial sampling of new wells	84	WELLS	$2,152	$180,788	Initial sampling of 73 extraction wells and 11 new performance monitoring wells.
Groundwater laboratory analysis and validation	84	WELLS	$32	$2,722	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	1	EVENT	$22,180	$22,180	Upload EDD and related analytical data into database, review analytical reports/perform verification. 84 sampling locations/event.
IDW laboratory analysis	84	WELLS	$1,122	$94,273	New wells. Includes analyses required by IDW Discharge Permit.
Well Installation and Testing Report	2	REPORT	$149,070	$298,140	Two annual reports with average of 42 wells/report.
SUBTOTAL Extraction and Monitoring Well Installation				**$13,585,429**	

Groundwater Extraction and Treatment System

Install groundwater extraction and conveyance system					
Extraction pump assemblies	73	WELLS	$3,660	$267,180	Submersible pump, downhole piping, controls, and wellhead fittings.
Trenching, backfill, compaction, repaving	1	LS	$895,658	$895,658	2 ft wide, ≤ 8 ft deep (piping not included), piping top ≥ 3 ft deep, 19,000 ft of trench, 4,500 ft within paved areas.
Primary conveyance tubing	1	LS	$229,615	$229,615	Includes materials and installation for 107,190 LF of 1/2-in tubing for wellheads to transfer tanks, and 6,050 LF of 2-in tubing from transfer tanks to the treatment system.
Secondary containment pipe	1	LS	$467,734	$467,734	Includes materials and installation for 41,110 LF of 2-in Sched 40 PVC pipe and couplings from wellheads to transfer tanks and from transfer tanks to the treatement system.
Electrical wiring , conduit, and control panels	1	LS	$549,755	$549,755	Includes material an installation for 47,110 LF of 2-in PVC conduit and 149,560 LF of electrical wire to power the submersible pumps, the transfer pumps and associated level controls.
Concreate vault pull boxes	95	EA	$1,550	$147,250	32-in square by 24-in deep traffic-rated vault plus connection fittings for piping and conduit. Includes labor to set into existing trench prior to paving. Placed every 200 ft of trenching.
Transfer tanks and pumps	5	EA	$45,000	$225,000	12,500 gallon, HDPE, double-wall. Includes hi/lo switch and transfer pump. Staged to collect water from mulitple extraction wells prior to combined transfer to the treatment system.
Cement pads for transfer tanks	1,125	SF	$12	$13,500	Five pads, each 15 ft × 15 ft, 6-in thick, portland cement pad. Install pad ($9/SF) plus site grading/prep ($3/SF).
SUBTOTAL Extraction and conveyance system				**$2,795,693**	

Install groundwater treatment system, discharge line, and onsite injection well					
Cement pad for treatment system	800	SF	$12	$9,600	20 ft × 40 ft, 6-in thick, portland cement pad. Intall pad ($9/SF) plus site grading/prep ($3/SF)
Treatment system building	800	SF	$150	$120,000	20 ft × 40 ft, enclosed building with electricity, cooling and heating, used to house the treatment system components.
Transfer tank, hi/lo switches, transfer pump	1	EA	$2,200	$2,200	500 gal poly tank
Ion exchange and carbon polish groundwater treatment system	1	LS	$1,048,797	$1,048,797	Ion-exchange system consists of: 24 vessels (8 plumbed in series: 4 lead and 4 lag) with 8 spare onsite and 8 "float" being in transit to/from the regeneration facility. Each canister has a 60 cu ft resin capacity. Cost includes piping, controls, strong base anion IX resin, carbon, nitrate analyzer, and associated fittings. Includes installation labor onsite.
Electric control panel	1	EA	$10,000	$10,000	Master system control panel linking the transect-specific control panels with the operating treatment system.
Discharge injection well	1,000	FT	$516	$516,000	Located ~2,000 ft south of monitoring well WYO-4 and 1,600 ft west of TA-IV boundary (inside west end of AOC). Total depth up to ~ 1,000 ft. 24-in borehole with 12-in diameter casing. Screened in Regional Aquifer. Includes development, geophyscial surveying, hydraulic testing. wellhead completion, level controls, and other required instrumentation. $430/ft + 20% for site logistics.
Discharge line	1	LS	$234,699	$234,699	Approximately 2,000 LF of trenching, installation of 6-in Sched 80 PVC, backfill, compaction, and minor paving. Assumes traversing large paved drainage ditch along west side of TA-IV.
SUBTOTAL Treatment system and discharge connection				**$1,941,297**	
SUBTOTAL Groundwater Extraction and Treatement System				**$18,322,419**	
SUBTOTAL Groundwater Extraction and Treatement System + operational overhead	1.20			**$21,986,903**	
SUBTOTAL CAPITAL COSTS				**$22,757,208**	
Contingency	10%			**$2,275,721**	
SUBTOTAL				**$25,032,928**	
Project Management	5%			**$1,251,646**	
TOTAL CAPITAL COST				**$26,284,575**	

ANNUAL MONITORING & REPORTING COST (Years 1-3)					Dry PGWS Wells: none
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$2,139	$4,279	Semiannual manual DTW measurements from monitoring 27 wells. Includes data entry and QC.
Groundwater well sampling	22	WELLS	$2,152	$47,349	Semiannual sampling for 11 PGWS wells (22). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling for 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	31	SAMPLES	$32	$1,004	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENTS	$4,225	$8,449	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 16 sampling locations/event.
SUBTOTAL Performance Monitoring				**$80,452**	
Site Maintenance					
Wellhead maintenance	27	WELLS	$25	$675	General maintenance of well heads/vaults. Assume $25/well/year. 27 wells.
SUBTOTAL Site Maintenance				**$675**	
IDW Disposal - Publically Owned Treatment Works (POTW)					
IDW laboratory analysis	20	WELLS	$1,122	$22,446	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from each of 20 wells. Performed annually in conjunction with one semiannual well sampling event.
IDW transport & disposal - water	2	EVENTS	$3,782	$7,564	Semiannual discharge to POTW. Up to 20 drums/event.
SUBTOTAL IDW Disposal				**$30,010**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$58,735	$58,735	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report.
SUBTOTAL Reporting				**$58,735**	
SUBTOTAL				**$169,871**	
Contingency	10%			**$16,987**	
SUBTOTAL				**$186,859**	
Project Management	5%			**$9,343**	
TOTAL ANNUAL MONITORING & REPORTING (Years 1-3)				**$196,202**	

ANNUAL MONITORING & REPORTING COST (Years 4-5)					Dry PGWS Wells: TA1-W-03 and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$2,139	$4,279	Semiannual manual DTW measurements from 27 monitroing wells (includes checking dry wells). Includes data entry and QC.
Groundwater well sampling	20	WELLS	$2,152	$43,045	Semiannual sampling of 10 PGWS wells (20). Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	29	SAMPLES	$32	$940	NPN analysis and associated QC. 100% Level IV third-party validation.
Analytical data handling and verification	2	EVENTS	$3,961	$7,921	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 15 sampling locations/event.
SUBTOTAL Performance Monitoring				**$75,555**	
Site Operation and Maintenance					
Wellhead maintenance	27	WELLS	$25	$675	General maintenance of well heads/vaults. Assume $25/well/year. 27 wells (includes dry wells).
SUBTOTAL Site O&M				**$675**	
IDW Disposal					
IDW laboratory analysis	19	WELLS	$1,122	$21,324	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from each of 19 wells. Performed annually in conjunction with one well sampling event.
IDW transport & disposal - water	2	EVENTS	$3,593	$7,185	Semiannual discharge to POTW. Up to 19 drums/event.
SUBTOTAL IDW Disposal				**$28,509**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$58,735	$58,735	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. May be included within the Annual Groundwater Monitoring Report.
SUBTOTAL Reporting				**$58,735**	
SUBTOTAL				**$163,474**	
Contingency	10%			**$16,347**	
SUBTOTAL				**$179,821**	
Project Management	5%			**$8,991**	
TOTAL ANNUAL MONITORING & REPORTING COST (Years 4-5)				**$188,812**	

ANNUAL OPERATION & MAINTENANCE, MONITORING, & REPORTING COST (Years 6-7) Grounwater extraction & treatment initiated					Dry PGWS Wells: TA1-W-03 and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$3,011	$6,022	Semiannual manual DTW measurements from 38 monitoring wells (includes checking dry wells). Includes data entry and QC.
Sampling port sample collection	292	PORTS	$177	$51,763	Quarterly sampling of 73 PGWS extraction wells (292) from inline sampling ports.
Groundwater well sampling	64	WELLS	$2,152	$137,743	Quarterly sampling of 16 PGWS monitoring wells (64) located within the ISB treatment area. Includes routine equipment maintenance.
Groundwater well sampling	10	WELLS	$2,152	$21,522	Semiannual sampling of 5 PGWS monitoring wells (10) upgradient of the ISB treatment area. Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	375	SAMPLES	$32	$12,150	Analysis and associated QC for NPN. 100% Level IV third-party validation.
Analytical data handling and verification	4	EVENTS	$25,348	$101,392	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 96 sampling locations/event.
SUBTOTAL Performance Monitoring				**$349,963**	
Site O&M					
Electricty	1,981,000	KWH	$0.06	$118,860	73 submersible pumps and 6 transfer pumps cycling 50% time $0.06 kWh (industrial rate).
Sampling port sample collection	60	PORTS	$177	$10,636	Monthly sampling of treatment system influent, 3 midpoint locations (2 IX, 1 GAC), and effluent to injection well (60 samples) from inline sampling ports. Includes recording totalizing flow meter readings and basic system inspection.
Treatment system discharge compliance laboratory lab analysis	60	SAMPLES	$753	$45,166	Cost for treatment system NMED discharge permit compliance analyses.
Analytical data handling and verification	12	EVENTS	$1,320	$15,843	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 5 sampling locations/event.
Particulate filter replacement	48	EA	$10	$480	Replace particulate filters bimonthly (2 parallel canisters: 2 × 12).
Strong base anion ion-exchange resin offiste regeneration	36	EVENTS	$17,000	$612,000	Offiste transportation and regeneration of eight, 60-cu ft canisters/event. 36 trips/year (approximately every 10 days).
Resin loss/replacement	72	CU FT	$146	$10,512	5% resin loss per year. 5% of 1,440 total cu ft = 72 cu ft.
Primary conveyance tubing - replacement	0.05	LS	$229,615	$11,481	Assume 5% of primary conveyance tubing replaced each year.
Wellhead maintenance	113	WELL	$25	$2,825	General maintenance of well heads/vaults. Assume $25/well/year. 38 monitoring wells and 75 extraction wells (includes dry wells).
SUBTOTAL Site O&M				**$827,802**	

IDW Disposal					
IDW laboratory analysis	Not applicable				Purge water from monitoring well sampling to be disposed of via the onsite treatment system. Analytical costs included in treatment system monitoring.
IDW transport & disposal - water	4	EVENTS	$5,673	$22,691	Quarterly discharge to injection well via onsite treatment system. Up to 30 drums/event.
SUBTOTAL IDW Disposal				**$22,691**	
Reporting					
Discharge compliance report	4	REPORTS	$12,052	$48,209	Quarterly discharge compliance reporting to NMED. Includes total volume discharged, flow rates, sytem influent, midpoint, and discharge point analytical results, and summarized narrative of operational maintenance.
Annual Remedy Performance Review	1	REPORT	$176,205	$176,205	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report. 3 × Alternative 1 cost.
SUBTOTAL Reporting				**$224,414**	
SUBTOTAL				**$1,424,869**	
Contingency	10%			**$142,487**	
SUBTOTAL				**$1,567,356**	
Project Management	5%			**$78,368**	
TOTAL ANNUAL O&M, MONITORING, & REPORTING COST (Years 6-7)				**$1,645,724**	

ANNUAL OPERATION & MAINTENANCE, MONITORING, & REPORTING COST (Years 8-10) **Dry PGWS Wells: TA1-W-03, TA2-W-01, and WYO-4**
Grounwater extraction & treatment initiated

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$3,011	$6,022	Semiannual manual DTW measurements from 38 monitoring wells (includes checking dry wells). Includes data entry and QC.
Sampling port sample collection	292	PORTS	$177	$51,763	Quarterly sampling of 73 PGWS extraction wells (292) from inline sampling ports.
Groundwater well sampling	40	WELLS	$2,152	$86,090	Semiannual sampling of 20 PGWS monitoring wells (40) throughout the AOC. Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	341	SAMPLES	$32	$11,048	Analysis and associated QC for NPN. 100% Level IV third-party validation.
Analytical data handling and verification	4	EVENTS	$22,972	$91,887	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 87 sampling locations/event.
SUBTOTAL Performance Monitoring				**$266,180**	
Site O&M					
Electricty	1,981,000	KWH	$0.06	$118,860	73 submersible pumps and 6 transfer pumps cycling 50% time $0.06 kWh (industrial rate).
Sampling port sample collection	60	PORTS	$177	$10,636	Monthly sampling of treatment system influent, 3 midpoint locations (2 IX, 1 GAC), and effluent to injection well (60 samples) from inline sampling ports. Includes recording totalizing flow meter readings and basic system inspection.
Treatment system discharge compliance laboratory lab analysis	60	SAMPLES	$753	$45,166	Cost for treatment system discharge permit analyses.
Analytical data handling and verification	12	EVENTS	$1,320	$15,843	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 5 sampling locations/event.
Particulate filter replacement	48	EA	$10	$480	Replace particulate filters bimonthly (2 parallel canisters: 2 × 12).
Strong base anion ion-exchange resin offiste regeneration	36	EVENTS	$17,000	$612,000	Offiste transportation and regeneration of eight, 60-cu ft canisters/event. 36 trips/year (approximately every 10 days).
Resin loss/replacement	72	CU FT	$146	$10,512	5% resin loss per year. 5% of 1,440 total cu ft = 72 cu ft.
Primary conveyance tubing - replacement	0.05	LS	$229,615	$11,481	Assume 5% of primary conveyance tubing replaced each year.
Wellhead maintenance	113	WELL	$25	$2,825	General maintenance of well heads/vaults. Assume $25/well/year. 38 monitoring wells and 75 extraction wells (includes dry wells).
SUBTOTAL Site O&M				**$827,802**	

IDW Disposal					
IDW laboratory analysis	Not applicable				Purge water from monitoring well sampling to be disposed of via the onsite treatment system. Analytical costs included in treatment system monitoring.
IDW transport & disposal - water	2	EVENT	$5,484	$10,967	Semiannual discharge to through treatment system. Up to 29 drums/event.
SUBTOTAL IDW Disposal				**$10,967**	
Reporting					
Discharge compliance report	4	REPORTS	$12,052	$48,209	Quarterly discharge compliance reporting to NMED. Includes total volume discharged, flow rates, sytem influent, midpoint, and discharge point analytical results, and summarized narrative of operational maintenance.
Annual Remedy Performance Review	1	REPORT	$176,205	$176,205	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report. 3 × Alternative 1 cost.
SUBTOTAL Reporting				**$224,414**	
SUBTOTAL				**$1,329,363**	
Contingency	10%			**$132,936**	
SUBTOTAL				**$1,462,299**	
Project Management	5%			**$73,115**	
TOTAL ANNUAL O&M, MONITORING, & REPORTING COST (Years 8-10)				**$1,535,414**	

ANNUAL OPERATION & MAINTENANCE, MONITORING & REPORTING COST (Years 11-17) Groundwater extraction & treatment operational					Dry PGWS Wells: TA1-W-03, TA2-W-01, TA2-W-26, and WYO-4 (water level only well TA2-NW1-325 dry in year 14)
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$3,011	$6,022	Semiannual manual DTW measurements from 38 monitoring wells (includes checking dry wells). Includes data entry and QC.
Sampling port sample collection	292	PORTS	$177	$51,763	Quarterly sampling of 73 PGWS extraction wells (292) from inline sampling ports.
Groundwater well sampling	38	WELLS	$2,152	$81,785	Semiannual sampling of 19 PGWS monitoring wells (38) throughout the AOC. Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	339	SAMPLES	$32	$10,984	Analysis and associated QC for NPN. 100% Level IV third-party validation.
Analytical data handling and verification	4	EVENTS	$22,972	$91,887	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 87 sampling locations/event.
SUBTOTAL Performance Monitoring				**$261,810**	
Site O&M					
Electricty	1,981,000	KWH	$0.06	$118,860	73 submersible pumps and 6 transfer pumps cycling 50% time $0.06 kwh (industrial rate).
Sampling port sample collection	60	PORTS	$177	$10,636	Monthly sampling of treatment system influent, 3 midpoint locations (2 IX, 1 GAC), and effluent to injection well (60 samples) from inline sampling ports. Includes recording totalizing flow meter readings and basic system inspection.
Treatment system discharge compliance laboratory lab analysis	60	SAMPLES	$753	$45,166	Cost for treatment system discharge permit analyses.
Analytical data handling and verification	12	EVENTS	$1,320	$15,843	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 5 sampling locations/event.
Particulate filter replacement	48	EA	$10	$480	Replace particulate filters bimonthly (2 parallel canisters: 2 × 12).
Strong base anion ion-exchange resin offiste regeneration	36	EVENTS	$17,000	$612,000	Offiste transportation and regeneration of eight, 60-cu ft canisters/event. 36 trips/year (approximately every 10 days).
Resin loss/replacement	72	CU FT	$146	$10,512	5% resin loss per year. 5% of 1,440 total cu ft = 72 cu ft.
Primary conveyance tubing - replacement	0.05	LS	$229,615	$11,481	Assume 5% of primary conveyance tubing replaced each year.
Wellhead maintenance	113	WELL	$25	$2,825	General maintenance of well heads/vaults. Assume $25/well/year. 38 monitoring wells and 75 extraction wells (includes dry wells).
SUBTOTAL Site O&M				**$827,802**	

IDW Disposal					
IDW laboratory analysis	Not applicable				Purge water from monitoring well sampling to be disposed of via the onsite treatment system. Analytical costs included in treatment system monitoring.
IDW transport & disposal - water	2	EVENTS	$5,294	$10,589	Semiannual discharge to through treatment system. Up to 28 drums/event.
SUBTOTAL IDW Disposal				**$10,589**	
Reporting					
Discharge compliance report	4	REPORTS	$12,052	$48,209	Quarterly discharge compliance reporting to NMED. Includes total volume discharged, flow rates, sytem influent, midpoint, and discharge point analytical results, and summarized narrative of operational maintenance.
Annual Remedy Performance Review	1	REPORT	$176,205	$176,205	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report. 3 × Alternative 1 cost.
SUBTOTAL Reporting				**$224,414**	
SUBTOTAL				**$1,324,615**	
Contingency	10%			**$132,462**	
SUBTOTAL				**$1,457,077**	
Project Management	5%			**$72,854**	
TOTAL ANNUAL O&M, MONITORING, & REPORTING COST (Years 11-17)				**$1,529,931**	

ANNUAL OPERATION & MAINTENANCE, MONITORING, & REPORTING COST (Years 18-23) Groundwater extraction & treatment operational					Dry PGWS Wells: TA1-W-03, TA1-W-08, TA2-NW1-325, TA2-W-01, TA2-W-26, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$3,011	$6,022	Semiannual manual DTW measurements from 38 monitoring wells (includes checking dry wells). Includes data entry and QC.
Sampling port sample collection	292	PORTS	$177	$51,763	Quarterly sampling of 73 PGWS extraction wells (292) from inline sampling ports.
Groundwater well sampling	36	WELLS	$2,152	$77,481	Semiannual sampling of 18 PGWS monitoring wells (36) throughout the AOC. Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	337	SAMPLES	$32	$10,919	Analysis and associated QC for NPN. 100% Level IV third-party validation.
Analytical data handling and verification	4	EVENTS	$22,708	$90,830	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 86 sampling locations/event.
SUBTOTAL Performance Monitoring				**$256,385**	
Site O&M					
Electricty	1,981,000	KWH	$0.06	$118,860	73 submersible pumps and 6 transfer pumps cycling 50% time $0.06 kwh (industrial rate).
Sampling port sample collection	60	PORTS	$177	$10,636	Monthly sampling of treatment system influent, 3 midpoint locations (2 IX, 1 GAC), and effluent to injection well (60 samples) from inline sampling ports. Includes recording totalizing flow meter readings and basic system inspection.
Treatment system discharge compliance laboratory lab analysis	60	SAMPLES	$753	$45,166	Cost for treatment system discharge permit analyses.
Analytical data handling and verification	12	EVENTS	$1,320	$15,843	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 5 sampling locations/event.
Particulate filter replacement	48	EA	$10	$480	Replace particulate filters bimonthly (2 parallel canisters: 2 × 12).
Strong base anion ion-exchange resin offiste regeneration	36	EVENTS	$17,000	$612,000	Offiste transportation and regeneration of eight, 60-cu ft canisters/event. 36 trips/year (approximately every 10 days).
Resin loss/replacement	72	CU FT	$146	$10,512	5% resin loss per year. 5% of 1,440 total cu ft = 72 cu ft.
Primary conveyance tubing - replacement	0.05	LS	$229,615	$11,481	Assume 5% of primary conveyance tubing replaced each year.
Wellhead maintenance	113	WELL	$25	$2,825	General maintenance of well heads/vaults. Assume $25/well/year. 38 monitoring wells and 75 extraction wells (includes dry wells).
SUBTOTAL Site O&M				**$827,802**	

IDW Disposal					
IDW laboratory analysis	Not applicable				Purge water from monitoring well sampling to be disposed of via the onsite treatment system. Analytical costs included in treatment system monitoring.
IDW transport & disposal - water	2	EVENTS	$5,105	$10,211	Semiannual discharge to through treatment system. Up to 27 drums/event.
SUBTOTAL IDW Disposal				**$10,211**	
Reporting					
Discharge compliance report	4	REPORTS	$12,052	$48,209	Quarterly discharge compliance reporting to NMED. Includes total volume discharged, flow rates, sytem influent, midpoint, and discharge point analytical results, and summarized narrative of operational maintenance.
Annual Remedy Performance Review	1	REPORT	$176,205	$176,205	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report. 3 × Alternative 1 cost.
SUBTOTAL Reporting				**$224,414**	
SUBTOTAL				**$1,318,812**	
Contingency	10%			**$131,881**	
SUBTOTAL				**$1,450,693**	
Project Management	5%			**$72,535**	
TOTAL ANNUAL O&M, MONITORING, & REPORTING COST (Years 18-23)				**$1,523,227**	

ANNUAL OPERATION & MAINTENANCE, MONITORING, & REPORTING COST (Years 24-25) Groundwater extraction & treatment operational. Discontinued in Year 25.					Dry PGWS Wells: TA1-W-03, TA1-W-06, TA1-W-08, TA2-NW1-325, TA2-W-01, TA2-W-26, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$3,011	$6,022	Semiannual manual DTW measurements from 38 monitoring wells (includes checking dry wells). Includes data entry and QC.
Sampling port sample collection	292	PORTS	$177	$51,763	Quarterly sampling of 73 PGWS extraction wells (292) from inline sampling ports.
Groundwater well sampling	34	WELLS	$2,152	$73,176	Semiannual sampling of 17 PGWS monitoring wells (34) throughout the AOC. Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	335	SAMPLES	$32	$10,854	Analysis and associated QC for NPN. 100% Level IV third-party validation.
Analytical data handling and verification	4	EVENTS	$22,708	$90,830	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 86 sampling locations/event.
SUBTOTAL Performance Monitoring				**$252,016**	
Site O&M					
Electricty	1,981,000	KWH	$0.06	$118,860	73 submersible pumps and 6 transfer pumps cycling 50% time $0.06 kwh (industrial rate).
Sampling port sample collection	60	PORTS	$177	$10,636	Monthly sampling of treatment system influent, 3 midpoint locations (2 IX, 1 GAC), and effluent to injection well (60 samples) from inline sampling ports. Includes recording totalizing flow meter readings and basic system inspection.
Treatment system discharge compliance laboratory lab analysis	60	SAMPLES	$753	$45,166	Cost for treatment system discharge permit analyses.
Analytical data handling and verification	12	EVENTS	$1,320	$15,843	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 5 sampling locations/event.
Particulate filter replacement	48	EA	$10	$480	Replace particulate filters bimonthly (2 parallel canisters: 2 × 12).
Strong base anion ion-exchange resin offiste regeneration	36	EVENTS	$17,000	$612,000	Offiste transportation and regeneration of eight, 60-cu ft canisters/event. 36 trips/year (approximately every 10 days).
Resin loss/replacement	72	CU FT	$146	$10,512	5% resin loss per year. 5% of 1,440 total cu ft = 72 cu ft.
Primary conveyance tubing - replacement	0.05	LS	$229,615	$11,481	Assume 5% of primary conveyance tubing replaced each year.
Wellhead maintenance	113	WELL	$25	$2,825	General maintenance of well heads/vaults. Assume $25/well/year. 38 monitoring wells and 75 extraction wells (includes dry wells).
SUBTOTAL Site O&M				**$827,802**	

IDW Disposal					
IDW laboratory analysis	Not applicable				Purge water from monitoring well sampling to be disposed of via the onsite treatment system. Analytical costs included in treatment system monitoring.
IDW transport & disposal - water	2	EVENTS	$4,916	$9,833	Semiannual discharge to through treatment system. Up to 26 drums/event.
SUBTOTAL IDW Disposal				**$9,833**	
Reporting					
Discharge compliance report	4	REPORTS	$12,052	$48,209	Quarterly discharge compliance reporting to NMED. Includes total volume discharged, flow rates, sytem influent, midpoint, and discharge point analytical results, and summarized narrative of operational maintenance.
Annual Remedy Performance Review	1	REPORT	$176,205	$176,205	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report. 3 × Alternative 1 cost.
SUBTOTAL Reporting				**$224,414**	
SUBTOTAL				**$1,314,064**	
Contingency	10%			**$131,406**	
SUBTOTAL				**$1,445,471**	
Project Management	5%			**$72,274**	
TOTAL ANNUAL O&M, MONITORING, & REPORTING COST (Years 24-25)				**$1,517,744**	

ANNUAL MONITORING & REPORTING COST (Year 26) Confirmation Sampling					Dry PGWS Wells: TA1-W-03, TA1-W-06, TA1-W-07, TA1-W-08, TA2-NW1-325, TA2-W-01, TA2-W-26, TA2-W-27, TA2-W-28, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$3,011	$6,022	Semiannual manual DTW measurements from 38 monitoring wells (includes checking dry wells). Includes data entry and QC.
Groundwater well sampling	68	WELLS	$2,152	$146,352	Quarterly sampling of 17 PGWS monitoring wells (68) throughout the AOC. Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	77	SAMPLES	$32	$2,495	Analysis and associated QC for NPN. 100% Level IV third-party validation.
Analytical data handling and verification	4	EVENT	$5,017	$20,067	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 19 sampling locations/event.
SUBTOTAL Performance Monitoring				**$194,306**	
Site Maintenance					
Wellhead maintenance	113	WELLS	$25	$2,825	General maintenance of well heads/vaults. Assume $25/well/year. 38 monitoring wells and 75 injection wells (includes dry wells).
SUBTOTAL Site Maintenance				**$2,825**	
IDW Disposal					
IDW laboratory analysis	40	WELLS	$1,122	$44,892	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from each of 40 wells. Performed annually in conjunction with one well sampling event.
IDW transport & disposal - water	4	EVENTS	$7,564	$30,254	Quarterly discharge to POTW. Up to 40 drums/event.
SUBTOTAL IDW Disposal				**$75,146**	
Reporting					
Annual Remedy Performance Review	1	REPORT	$176,205	$176,205	Includes four semiannual potentiometric surface maps (two PGWS and two Regional Aquifer), three isoconcentration maps (two semiannual PGWS and on annual Regional Aquifer), updates to concentration trend graphs and hydrographs. Evaluation of remedy effectiveness. Incorporates a review of land use controls. May be included within the Annual Groundwater Monitoring Report. 3 × Alternative 1 cost.
SUBTOTAL Reporting				**$176,205**	
SUBTOTAL				**$448,482**	
Contingency	10%			**$44,848**	
SUBTOTAL				**$493,331**	
Project Management	5%			**$24,667**	
TOTAL ANNUAL MONITORING & REPORTING COST (Year 26)				**$517,997**	

ANNUAL MONITORING & REPORTING COST (Year 27) Confirmation Sampling					Dry PGWS Wells: TA1-W-03, TA1-W-06, TA1-W-07, TA1-W-08, TA2-NW1-325, TA2-W-01, TA2-W-19, TA2-W-26, TA2-W-27, TA2-W-28, and WYO-4
DESCRIPTION	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	
Performance Monitoring					
Depth-to-water measurements	2	EVENTS	$3,011	$6,022	Semiannual manual DTW measurements from 38 monitoring wells (includes checking dry wells). Includes data entry and QC.
Groundwater well sampling	60	WELLS	$2,152	$129,134	Quarterly sampling of 15 PGWS monitoring wells (60) throughout the AOC. Includes routine equipment maintenance.
Groundwater well sampling	9	WELLS	$2,152	$19,370	Annual sampling of 9 Regional Aquifer wells. Includes routine equipment maintenance.
Groundwater laboratory analysis and validation	69	SAMPLES	$32	$2,236	Analysis and associated QC for NPN. 100% Level IV third-party validation.
Analytical data handling and verification	4	EVENT	$4,489	$17,955	Upload EDD and related analytical data into database, review analytical reports/perform verification. Average 17 sampling locations/event.
SUBTOTAL Performance Monitoring				**$174,717**	
Site Maintenance					
Wellhead maintenance	113	WELLS	$25	$2,825	General maintenance of well heads/vaults. Assume $25/well/year. 38 monitoring wells and 75 injection wells (includes dry wells).
SUBTOTAL Site Maintenance				**$2,825**	
IDW Disposal					
IDW laboratory analysis	38	WELLS	$1,122	$42,647	Cost for POTW-required analyses and 100% Level IV third-party validation. Samples from each of 38 wells. Performed annually in conjunction with one well sampling event.
IDW transport & disposal - water	4	EVENTS	$7,185	$28,741	Quarterly discharge to POTW. Up to 38 drums/event.
SUBTOTAL IDW Disposal				**$71,389**	
Reporting					
Annual Remedy Performance Review	0	REPORT		$0	Replaced by Corrective Measures Implementation Report under Periodic Costs for Year 27.
SUBTOTAL Reporting				**$0**	
SUBTOTAL				**$248,931**	
Contingency	10%			**$24,893**	
SUBTOTAL				**$273,824**	
Project Management	5%			**$13,691**	
TOTAL ANNUAL MONITORING & REPORTING COST (Year 27)				**$287,515**	

PERIODIC COSTS

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Replace granular activated carbon	10	4,000	LBS	$5	$20,000	Consumption due to VOC concentrations nominal. Cost based on potential biofouling over time. Assumes one-time full replacement of carbon in two, 2000-lb canisters.
SUBTOTAL (Y10)					**$20,000**	
Project Management		5%			$1,000	
TOTAL (Y10)					**$21,000**	
Groundwater well development	15	15	WELLS	$9,490	$142,348	50% of the actively sampled monitoring wells. Extraction wells assumed to not need redevelopment.
Replace granular activated carbon	15	4,000	LBS	$5	$20,000	Consumption due to VOC concentrations nominal. Cost based on potential biofouling over time. Assumes one-time full replacement of carbon in two, 2000-lb canisters.
SUBTOTAL (Y15)					**$162,348**	
Project Management		5%			$8,117	
TOTAL (Y15)					**$170,465**	
Replace granular activated carbon	20	4,000	LBS	$5	$20,000	Consumption due to VOC concentrations nominal. Cost based on potential biofouling over time. Assumes one-time full replacement of carbon in two, 2000-lb canisters.
SUBTOTAL (Y20)					**$20,000**	
Project Management		5%			$1,000	
TOTAL (Y20)					**$21,000**	

Corrective Measures Implementation Report	27	1	WELLS	$263,889	$263,889	Will include request for Certificate of Completion from NMED. Replaces Year 27 Annual Remedy Performance Report. 2 × cost of Alternative 1 CMIP.
Dismantle groundwater conveyance and treatment system	27+	1	LS	$317,617	$317,617	Tubing and wiring removed. Pull-box vaults, transfer tanks and pads, removed. Buried conduits capped and abandoned in place. Final spent resin and GAC disposed of. Treatment system components removed and building demolished.
Plugging and abandonment	27+	98	WELLS	$17,385	$1,703,776	Plug and abandon all TAG PWGS monitoring wells (25) and all extraction wells (73). Regional Aquifer monitoring wells (9) trasnsferred to Long-Term Stewardship program. City-owned well Eubank #1 remains in place. Assigned to year 27 for costing purposes. Actual schedule is dependent on receiving Corrective Action Complete approval from NMED and site logistics.
Plug and abandon injection well	27+	1	WELLS	$86,927	$86,927	Plug and abandon the discharge injection well. Assigned to year 27 for costing purposes. Actual schedule is dependent on receiving Corrective Action Complete approval from NMED and site logistics. Assume 5 × cost of monitoring well P&A due to triple depth and more than double the diameter.
SUBTOTAL (Y27+)					**$2,372,209**	
Project Management		5%			$118,610	
TOTAL (Y27+)					**$2,490,820**	

PRESENT VALUE ANALYSIS

COST TYPE	YEARS	TOTAL COST PER YEAR	TOTAL COST	DISCOUNT FACTOR (0.7%)	PRESENT VALUE	NOTES
Capital Costs	0	$26,284,575	$26,284,575	1.000	$26,284,575	Base Year: 2018
Annual Monitoring & Reporting Cost (Years 1-3)	3	$196,202	$588,605	2.958	$580,459	Present value costs were calculated using the real discount rate of 0.7% for federal facilities based on the 2017 Discount Rates for Office of Management and Budget Circular A-94 for projects with a timeframe of 30 years or more. EPA guidance indicates that the same discount rate should be used for all evaluated alternatives based on the alternative with the longest timeframe (Alternative 1 timeframe is 41 years).
Annual Monitoring & Reporting Cost (Years 4-5)	2	$188,812	$377,624	1.938	$365,957	
Annual Monitoring & Reporting Cost (Years 6-7)	2	$1,645,724	$3,291,448	1.911	$3,145,561	
Annual Monitoring & Reporting Cost (Years 8-10)	3	$1,535,414	$4,606,242	2.817	$4,326,020	
Annual Monitoring & Reporting Cost (Years 11-17)	7	$1,529,931	$10,709,514	6.349	$9,714,030	
Annual Monitoring & Reporting Cost (Years 18-23)	6	$1,523,227	$9,139,364	5.201	$7,922,143	
Annual Monitoring & Reporting Cost (Years 24-25)	2	$1,517,744	$3,035,488	1.686	$2,558,640	
Annual Monitoring & Reporting Cost (Year 26)	1	$517,997	$517,997	0.834	$432,077	
Annual Monitoring & Reporting Cost (Year 27)	1	$287,515	$287,515	0.828	$238,158	
Periodic Cost (Year 10)	1	$21,000	$21,000	0.933	$19,585	
Periodic Cost (Year 15)	1	$170,465	$170,465	0.901	$153,530	
Periodic Cost (Year 20)	1	$21,000	$21,000	0.870	$18,265	
Periodic Cost (Year 27+)	1	$2,490,820	$2,490,820	0.828	$2,063,225	
			$61,541,658		**$57,822,225**	Subtotal and Total values may reflect minor incremental discrepancies due to rounding of initial unit cost amounts in referenced cost worksheets.
TOTAL PRESENT VALUE OF ALTERNATIVE					**$57,822,225**	

COST WORKSHEET

Corrective Measures Implementation Plan **Alternative 1**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Prepare Corrective Measure Implementation Plan. Includes Management Plan, Community Relations Plan, Sampling and Analysis Plan, Corrective Measures Permitting Plan, Land Use Controls Implementation Plan, based on MNA Alternative. Alternatives 2 and 3 apply a 50% increase in cost.

Cost Analysis:

General assumption: Draft Final and Final labor = 50% and 25% of Draft, respectively, except for technical editor/production costs which are assumed to be equal.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Management Plan							
Prepare Draft							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	8	HR	$290.38			$2,323	
Sr. Geologist/Engineer/Scientist	32	HR	$216.10			$6,915	
Staff Geologist/Engineer/Scientist	0	HR	$159.82			$0	
Technician	0	HR	$118.18			$0	
Graphics	16	HR	$84.41			$1,351	
Technical Editor/Production	12	HR	$123.81			$1,486	
Production Supplies/Distribution costs	1	LS			$1,000	$1,000	
Prepare Draft Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	4	HR	$290.38			$1,162	
Sr. Geologist/Engineer/Scientist	16	HR	$216.10			$3,458	
Staff Geologist/Engineer/Scientist	0	HR	$159.82			$0	
Technician	0	HR	$118.18			$0	
Graphics	8	HR	$84.41			$675	
Technical Editor/Production	12	HR	$123.81			$1,486	
Production Supplies/Distribution costs	1	LS			$1,000	$1,000	
Prepare Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	2	HR	$290.38			$581	
Sr. Geologist/Engineer/Scientist	8	HR	$216.10			$1,729	
Staff Geologist/Engineer/Scientist	0	HR	$159.82			$0	
Technician	0	HR	$118.18			$0	
Graphics	4	HR	$84.41			$338	
Technical Editor/Production	12	HR	$123.81			$1,486	
Production Supplies/Distribution costs	1	LS			$1,000	$1,000	
SUBTOTAL						**$25,988**	

Community Relations Plan

Prepare Draft						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	8	HR	$290.38		$2,323	
Sr. Geologist/Engineer/Scientist	40	HR	$216.10		$8,644	
Staff Geologist/Engineer/Scientist	8	HR	$159.82		$1,279	
Technician	0	HR	$118.18		$0	
Graphics	16	HR	$84.41		$1,351	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Draft Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	4	HR	$290.38		$1,162	
Sr. Geologist/Engineer/Scientist	20	HR	$216.10		$4,322	
Staff Geologist/Engineer/Scientist	4	HR	$159.82		$639	
Technician	0	HR	$118.18		$0	
Graphics	8	HR	$84.41		$675	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	2	HR	$290.38		$581	
Sr. Geologist/Engineer/Scientist	10	HR	$216.10		$2,161	
Staff Geologist/Engineer/Scientist	2	HR	$159.82		$320	
Technician	0	HR	$118.18		$0	
Graphics	4	HR	$84.41		$338	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
SUBTOTAL					**$31,250**	

Sampling and Analysis Plan

Prepare Draft						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	16	HR	$290.38		$4,646	
Sr. Geologist/Engineer/Scientist	60	HR	$216.10		$12,966	
Staff Geologist/Engineer/Scientist	80	HR	$159.82		$12,786	
Technician	8	HR	$118.18		$945	
Graphics	32	HR	$84.41		$2,701	
Technical Editor/Production	24	HR	$123.81		$2,971	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Draft Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	8	HR	$290.38		$2,323	
Sr. Geologist/Engineer/Scientist	30	HR	$216.10		$6,483	
Staff Geologist/Engineer/Scientist	40	HR	$159.82		$6,393	
Technician	4	HR	$118.18		$473	
Graphics	16	HR	$84.41		$1,351	
Technical Editor/Production	24	HR	$123.81		$2,971	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	4	HR	$290.38		$1,162	
Sr. Geologist/Engineer/Scientist	15	HR	$216.10		$3,242	
Staff Geologist/Engineer/Scientist	20	HR	$159.82		$3,196	
Technician	2	HR	$118.18		$236	
Graphics	8	HR	$84.41		$675	
Technical Editor/Production	24	HR	$123.81		$2,971	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
SUBTOTAL					**$71,492**	

Corrective Measures Permitting Plan

Prepare Draft						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	4	HR	$290.38		$1,162	
Sr. Geologist/Engineer/Scientist	16	HR	$216.10		$3,458	
Staff Geologist/Engineer/Scientist	0	HR	$159.82		$0	
Technician	0	HR	$118.18		$0	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	8	HR	$123.81		$990	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Draft Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	2	HR	$290.38		$581	
Sr. Geologist/Engineer/Scientist	8	HR	$216.10		$1,729	
Staff Geologist/Engineer/Scientist	0	HR	$159.82		$0	
Technician	0	HR	$118.18		$0	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	8	HR	$123.81		$990	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	1	HR	$290.38		$290	
Sr. Geologist/Engineer/Scientist	4	HR	$216.10		$864	
Staff Geologist/Engineer/Scientist	0	HR	$159.82		$0	
Technician	0	HR	$118.18		$0	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	8	HR	$123.81		$990	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
SUBTOTAL					**$14,055**	

Land Use Controls Implementation Plan — **Integrate existing LUCIP elements and update them as necessary.**

Prepare Draft						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	12	HR	$290.38		$3,485	
Sr. Geologist/Engineer/Scientist	40	HR	$216.10		$8,644	
Staff Geologist/Engineer/Scientist	8	HR	$159.82		$1,279	
Technician	0	HR	$118.18		$0	
Graphics	16	HR	$84.41		$1,351	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Draft Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	6	HR	$290.38		$1,742	
Sr. Geologist/Engineer/Scientist	20	HR	$216.10		$4,322	
Staff Geologist/Engineer/Scientist	4	HR	$159.82		$639	
Technician	0	HR	$118.18		$0	
Graphics	8	HR	$84.41		$675	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	3	HR	$290.38		$871	
Sr. Geologist/Engineer/Scientist	10	HR	$216.10		$2,161	
Staff Geologist/Engineer/Scientist	2	HR	$159.82		$320	
Technician	0	HR	$118.18		$0	
Graphics	4	HR	$84.41		$338	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
SUBTOTAL					**$33,283**	

CMIP TOTAL COST **$176,068**

Source of Cost Data:
Based on estimated level of effort for onsite contractor staff to produce report.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	No field work. Not Applicable.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Pricing based on onsite contractor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Corrective Measures Design **Alternative 1**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Prepare Corrective Measure Design: Append to CMIP. Includes O&M plan, Waste Management Plan, Progress reporting and implementation schedule, and Health and Safety Plan. No Design Plans/Specifications/associated construction schedule or Construction Quality Assurance Plan, are necessary for Alternative 1.

Cost Analysis:

General assumption: Draft Final and Final labor = 50% and 25% of Draft, respectively, except for technical editor/production costs which are assumed to be equal.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Operation and Maintenance Plan							**Well maintenance plan and groundwater sampling procedures.**
Prepare Draft							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	2	HR	$290.38			$581	
Sr. Geologist/Engineer/Scientist	12	HR	$216.10			$2,593	
Staff Geologist/Engineer/Scientist	16	HR	$159.82			$2,557	
Technician	12	HR	$118.18			$1,418	
Graphics	0	HR	$84.41			$0	
Technical Editor/Production	8	HR	$123.81			$990	
Production Supplies/Distribution costs	1	LS			$500	$500	
Prepare Draft Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	1	HR	$290.38			$290	
Sr. Geologist/Engineer/Scientist	6	HR	$216.10			$1,297	
Staff Geologist/Engineer/Scientist	8	HR	$159.82			$1,279	
Technician	6	HR	$118.18			$709	
Graphics	0	HR	$84.41			$0	
Technical Editor/Production	8	HR	$123.81			$990	
Production Supplies/Distribution costs	1	LS			$500	$500	
Prepare Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	0.5	HR	$290.38			$145	
Sr. Geologist/Engineer/Scientist	3	HR	$216.10			$648	
Staff Geologist/Engineer/Scientist	4	HR	$159.82			$639	
Technician	3	HR	$118.18			$355	
Graphics	0	HR	$84.41			$0	
Technical Editor/Production	8	HR	$123.81			$990	
Production Supplies/Distribution costs	1	LS			$500	$500	
SUBTOTALOperation and Maintenance Plan						**$16,983**	

Waste Management Plan						**No new Waste Management Plan necessary for this Alternative (use existing).**
Progress reporting and implementation schedule						
Project Manager	4	HR	$290.38		$1,162	
Sr. Geologist/Engineer/Scientist	16	HR	$216.10		$3,458	
Staff Geologist/Engineer/Scientist	0	HR	$159.82		$0	
Technician	4	HR	$118.18		$473	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	4	HR	$123.81		$495	
Production Supplies/Distribution costs	1	LS		$500	$500	
SUBTOTAL Schedule					**$6,087**	
Construction Quality Assurance Plan						**Not required for this Alternative.**
Health and Safety Plan						**Integrate existing HASP elements and update them as necessary.**
Prepare Draft						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	8	HR	$290.38		$2,323	
Sr. Geologist/Engineer/Scientist	12	HR	$216.10		$2,593	
Staff Geologist/Engineer/Scientist	24	HR	$159.82		$3,836	
Technician	16	HR	$118.18		$1,891	
Graphics	4	HR	$84.41		$338	
Technical Editor/Production	8	HR	$123.81		$990	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Draft Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	4	HR	$290.38		$1,162	
Sr. Geologist/Engineer/Scientist	6	HR	$216.10		$1,297	
Staff Geologist/Engineer/Scientist	12	HR	$159.82		$1,918	
Technician	8	HR	$118.18		$945	
Graphics	2	HR	$84.41		$169	
Technical Editor/Production	8	HR	$123.81		$990	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	

Prepare Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	2	HR	$290.38		$581	
Sr. Geologist/Engineer/Scientist	3	HR	$216.10		$648	
Staff Geologist/Engineer/Scientist	6	HR	$159.82		$959	
Technician	4	HR	$118.18		$473	
Graphics	1	HR	$84.41		$84	
Technical Editor/Production	8	HR	$123.81		$990	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
SUBTOTAL Health and Safety Plan					**$25,187**	
CORRECTIVE MEASURE DESIGN TOTAL COST					**$48,257**	

Source of Cost Data:
Based on estimated level of effort for onsite contractor staff to produce report.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	No field work. Not Applicable.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Pricing based on onsite contractor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Corrective Measures Design **Alternative 2**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Prepare Corrective Measure Design: Append to CMIP. Includes preparation of Design Plans and Specifications, Operation and Maintenance Plan, Waste Management Plan, Progress reporting and implementation schedule, Health and Safety Plan. A Construction Quality Assurance Plan is not necessary for Alternative 2.

Cost Analysis:

General assumption: Draft Final and Final labor = 50% and 25% of Draft, respectively, except for technical editor/production costs which are assumed to be equal.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Design Plans and Specifications							**Mixing equipment specification and substrate mixing/injection procedures.**
Prepare Draft							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	8	HR	$290.38			$2,323	
Sr. Geologist/Engineer/Scientist	24	HR	$216.10			$5,186	
Staff Geologist/Engineer/Scientist	48	HR	$159.82			$7,671	
Technician	8	HR	$118.18			$945	
Graphics	16	HR	$84.41			$1,351	
Technical Editor/Production	8	HR	$123.81			$990	
Production Supplies/Distribution costs	1	LS			$1,000	$1,000	
Prepare Draft Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	4	HR	$290.38			$1,162	
Sr. Geologist/Engineer/Scientist	12	HR	$216.10			$2,593	
Staff Geologist/Engineer/Scientist	24	HR	$159.82			$3,836	
Technician	4	HR	$118.18			$473	
Graphics	8	HR	$84.41			$675	
Technical Editor/Production	8	HR	$123.81			$990	
Production Supplies/Distribution costs	1	LS			$1,000	$1,000	
Prepare Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	2	HR	$290.38			$581	
Sr. Geologist/Engineer/Scientist	6	HR	$216.10			$1,297	
Staff Geologist/Engineer/Scientist	12	HR	$159.82			$1,918	
Technician	2	HR	$118.18			$236	
Graphics	4	HR	$84.41			$338	
Technical Editor/Production	8	HR	$123.81			$990	
Production Supplies/Distribution costs	1	LS			$1,000	$1,000	
SUBTOTAL Design Plans and Specifications						**$36,556**	

Construction Quality Assurance Plan						**Not necessary for this Alternative.**
Operation and Maintenance Plan						**Well maintenance plan, groundwater sampling and multiparameter monitoring procedures.**
Prepare Draft						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	6	HR	$290.38		$1,742	
Sr. Geologist/Engineer/Scientist	24	HR	$216.10		$5,186	
Staff Geologist/Engineer/Scientist	40	HR	$159.82		$6,393	
Technician	12	HR	$118.18		$1,418	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$500	$500	
Prepare Draft Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	3	HR	$290.38		$871	
Sr. Geologist/Engineer/Scientist	12	HR	$216.10		$2,593	
Staff Geologist/Engineer/Scientist	20	HR	$159.82		$3,196	
Technician	6	HR	$118.18		$709	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$500	$500	
Prepare Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	2	HR	$290.38		$436	
Sr. Geologist/Engineer/Scientist	6	HR	$216.10		$1,297	
Staff Geologist/Engineer/Scientist	10	HR	$159.82		$1,598	
Technician	3	HR	$118.18		$355	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$500	$500	
SUBTOTAL Operation and Maintenance Plan					**$31,752**	
Waste Management Plan						**Review cycle costs incorporated into O&M Plan review.**
Project Manager	2	HR	$290.38		$581	
Sr. Geologist/Engineer/Scientist	16	HR	$216.10		$3,458	
Staff Geologist/Engineer/Scientist	32	HR	$159.82		$5,114	
Technician	4	HR	$118.18		$473	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	4	HR	$123.81		$495	
Production Supplies/Distribution costs	1	LS		$500	$500	
SUBTOTAL Waste Management Plan					**$10,621**	

Progress reporting and implementation schedule						**Review cycle costs incorporated into O&M Plan review.**
Project Manager	8	HR	$290.38		$2,323	
Sr. Geologist/Engineer/Scientist	40	HR	$216.10		$8,644	
Staff Geologist/Engineer/Scientist	8	HR	$159.82		$1,279	
Technician	8	HR	$118.18		$945	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	4	HR	$123.81		$495	
Production Supplies/Distribution costs	1	LS		$500	$500	
SUBTOTAL Progress reporting and implementation schedule					**$14,186**	
Health and Safety Plan						**Integrate existing HASP elements and update them as necessary.**
Prepare Draft						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	8	HR	$290.38		$2,323	
Sr. Geologist/Engineer/Scientist	24	HR	$216.10		$5,186	
Staff Geologist/Engineer/Scientist	40	HR	$159.82		$6,393	
Technician	16	HR	$118.18		$1,891	
Graphics	4	HR	$84.41		$338	
Technical Editor/Production	8	HR	$123.81		$990	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Draft Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	4	HR	$290.38		$1,162	
Sr. Geologist/Engineer/Scientist	12	HR	$216.10		$2,593	
Staff Geologist/Engineer/Scientist	20	HR	$159.82		$3,196	
Technician	8	HR	$118.18		$945	
Graphics	2	HR	$84.41		$169	
Technical Editor/Production	8	HR	$123.81		$990	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	2	HR	$290.38		$581	
Sr. Geologist/Engineer/Scientist	6	HR	$216.10		$1,297	
Staff Geologist/Engineer/Scientist	10	HR	$159.82		$1,598	
Technician	4	HR	$118.18		$473	
Graphics	1	HR	$84.41		$84	
Technical Editor/Production	8	HR	$123.81		$990	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
SUBTOTAL Health and Safety Plan					**$34,200**	
CORRECTIVE MEASURE DESIGN TOTAL COST					**$127,314**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	No field work. Not Applicable.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Pricing based on onsite contractor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Corrective Measures Design **Alternative 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Prepare Corrective Measure Design: Append to CMIP. Includes preparation of Design Plans and Specifications, Construction Quality Assurance Plan, Operation and Maintenance Plan, Waste Management Plan, Progress reporting and implementation schedule, and a Health and Safety Plan.

Cost Analysis:

General assumption: Draft Final and Final labor = 50% and 25% of Draft, respectively, except for technical editor/production costs which are assumed to be equal.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Design Plans and Specifications							**Mixing equipment specification and substrate mixing/injection procedures.**
Prepare Draft							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	40	HR	$290.38			$11,615	
Sr. Geologist/Engineer/Scientist	160	HR	$216.10			$34,576	
Staff Geologist/Engineer/Scientist	240	HR	$159.82			$38,357	
Technician	80	HR	$118.18			$9,454	
Graphics	80	HR	$84.41			$6,753	
Technical Editor/Production	40	HR	$123.81			$4,952	
Production Supplies/Distribution costs	1	LS			$3,000	$3,000	
Prepare Draft Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	20	HR	$290.38			$5,808	
Sr. Geologist/Engineer/Scientist	80	HR	$216.10			$17,288	
Staff Geologist/Engineer/Scientist	120	HR	$159.82			$19,178	
Technician	40	HR	$118.18			$4,727	
Graphics	40	HR	$84.41			$3,376	
Technical Editor/Production	40	HR	$123.81			$4,952	
Production Supplies/Distribution costs	1	LS			$3,000	$3,000	
Prepare Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	10	HR	$290.38			$2,904	
Sr. Geologist/Engineer/Scientist	40	HR	$216.10			$8,644	
Staff Geologist/Engineer/Scientist	60	HR	$159.82			$9,589	
Technician	20	HR	$118.18			$2,364	
Graphics	20	HR	$84.41			$1,688	
Technical Editor/Production	40	HR	$123.81			$4,952	
Production Supplies/Distribution costs	1	LS			$3,000	$3,000	
SUBTOTAL Design Plans and Specifications						**$200,179**	

Construction Quality Assurance Plan

Prepare Draft						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	8	HR	$290.38		$2,323	
Sr. Geologist/Engineer/Scientist	40	HR	$216.10		$8,644	
Staff Geologist/Engineer/Scientist	60	HR	$159.82		$9,589	
Technician	8	HR	$118.18		$945	
Graphics	16	HR	$84.41		$1,351	
Technical Editor/Production	16	HR	$123.81		$1,981	
Production Supplies/Distribution costs	1	LS		$2,000	$2,000	
Prepare Draft Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	4	HR	$290.38		$1,162	
Sr. Geologist/Engineer/Scientist	20	HR	$216.10		$4,322	
Staff Geologist/Engineer/Scientist	30	HR	$159.82		$4,795	
Technician	4	HR	$118.18		$473	
Graphics	8	HR	$84.41		$675	
Technical Editor/Production	16	HR	$123.81		$1,981	
Production Supplies/Distribution costs	1	LS		$2,000	$2,000	
Prepare Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	2	HR	$290.38		$581	
Sr. Geologist/Engineer/Scientist	10	HR	$216.10		$2,161	
Staff Geologist/Engineer/Scientist	15	HR	$159.82		$2,397	
Technician	2	HR	$118.18		$236	
Graphics	4	HR	$84.41		$338	
Technical Editor/Production	16	HR	$123.81		$1,981	
Production Supplies/Distribution costs	1	LS		$2,000	$2,000	
SUBTOTAL Construction Quality Assurance Plan					**$51,934**	

Operation and Maintenance Plan						**Well maintenance plan, groundwater sampling and multiparameter monitoring procedures.**
Prepare Draft						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	6	HR	$290.38		$1,742	
Sr. Geologist/Engineer/Scientist	18	HR	$216.10		$3,890	
Staff Geologist/Engineer/Scientist	24	HR	$159.82		$3,836	
Technician	12	HR	$118.18		$1,418	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$500	$500	
Prepare Draft Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	3	HR	$290.38		$871	
Sr. Geologist/Engineer/Scientist	9	HR	$216.10		$1,945	
Staff Geologist/Engineer/Scientist	12	HR	$159.82		$1,918	
Technician	6	HR	$118.18		$709	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$500	$500	
Prepare Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	2	HR	$290.38		$436	
Sr. Geologist/Engineer/Scientist	5	HR	$216.10		$972	
Staff Geologist/Engineer/Scientist	6	HR	$159.82		$959	
Technician	3	HR	$118.18		$355	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$500	$500	
SUBTOTAL Operation and Maintenance Plan					**$25,008**	
Waste Management Plan						**Review cycle costs incorporated into O&M Plan review.**
Project Manager	2	HR	$290.38		$581	
Sr. Geologist/Engineer/Scientist	16	HR	$216.10		$3,458	
Staff Geologist/Engineer/Scientist	32	HR	$159.82		$5,114	
Technician	4	HR	$118.18		$473	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	4	HR	$123.81		$495	
Production Supplies/Distribution costs	1	LS		$500	$500	
SUBTOTAL Waste Management Plan					**$10,621**	

Progress reporting and implementation schedule						**Review cycle costs incorporated into O&M Plan review.**
Project Manager	8	HR	$290.38		$2,323	
Sr. Geologist/Engineer/Scientist	40	HR	$216.10		$8,644	
Staff Geologist/Engineer/Scientist	8	HR	$159.82		$1,279	
Technician	8	HR	$118.18		$945	
Graphics	0	HR	$84.41		$0	
Technical Editor/Production	4	HR	$123.81		$495	
Production Supplies/Distribution costs	1	LS		$500	$500	
SUBTOTAL Progress reporting and implementation schedule					**$14,186**	
Health and Safety Plan						**Integrate existing HASP elements and update them as necessary.**
Prepare Draft						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	12	HR	$290.38		$3,485	
Sr. Geologist/Engineer/Scientist	40	HR	$216.10		$8,644	
Staff Geologist/Engineer/Scientist	60	HR	$159.82		$9,589	
Technician	16	HR	$118.18		$1,891	
Graphics	8	HR	$84.41		$675	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Draft Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	6	HR	$290.38		$1,742	
Sr. Geologist/Engineer/Scientist	20	HR	$216.10		$4,322	
Staff Geologist/Engineer/Scientist	30	HR	$159.82		$4,795	
Technician	8	HR	$118.18		$945	
Graphics	4	HR	$84.41		$338	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
Prepare Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	3	HR	$290.38		$871	
Sr. Geologist/Engineer/Scientist	10	HR	$216.10		$2,161	
Staff Geologist/Engineer/Scientist	15	HR	$159.82		$2,397	
Technician	4	HR	$118.18		$473	
Graphics	2	HR	$84.41		$169	
Technical Editor/Production	12	HR	$123.81		$1,486	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
SUBTOTAL Health and Safety Plan					**$49,954**	
CORRECTIVE MEASURE DESIGN TOTAL COST					**$351,881**	

Source of Cost Data:

Based on estimated level of estimate for onsite contractor staff to produce report.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	No field work. Not Applicable.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Pricing based on onsite contractor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Contingency Plan **Alternatives 1, 2, and 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Prepare Contingency Plan to be submitted along with Corrective Measures Implementation Plan.

Cost Analysis:

General assumption: Draft Final and Final labor = 50% and 25% of Draft, respectively, except for technical editor/production costs which are assumed to be equal.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	24	HR	$290.38			$6,969	
Sr. Geologist/Engineer/Scientist	80	HR	$216.10			$17,288	
Staff Geologist/Engineer/Scientist	40	HR	$159.82			$6,393	
Technician		HR	$118.18			$0	
Graphics	16	HR	$84.41			$1,351	
Technical Editor/Production	16	HR	$123.81			$1,981	
Production Supplies/Distribution costs	1	LS			$1,000	$1,000	
Prepare Draft Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	12	HR	$290.38			$3,485	
Sr. Geologist/Engineer/Scientist	40	HR	$216.10			$8,644	
Staff Geologist/Engineer/Scientist	20	HR	$159.82			$3,196	
Technician	0	HR	$118.18			$0	
Graphics	8	HR	$84.41			$675	
Technical Editor/Production	16	HR	$123.81			$1,981	
Production Supplies/Distribution costs	1	LS			$1,000	$1,000	
Prepare Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	6	HR	$290.38			$1,742	
Sr. Geologist/Engineer/Scientist	20	HR	$216.10			$4,322	
Staff Geologist/Engineer/Scientist	10	HR	$159.82			$1,598	
Technician	0	HR	$118.18			$0	
Graphics	4	HR	$84.41			$338	
Technical Editor/Production	16	HR	$123.81			$1,981	
Production Supplies/Distribution costs	1	LS			$1,000	$1,000	
TOTAL COST						**$64,944**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	No field work. Not Applicable.
[ ]	Escalation to Base Year	Not applicable
[√]	Area Cost Factor	Pricing based on onsite contractor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

NMED Discharge Permit **Alternatives 2 and 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Prepare and submit a discharge permit application to the New Mexico Environment Department (NMED) for discharge (i.e., injection) of substrate mixture for in-situ bioremediation. Includes costs for responding to NMED comments.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare NMED Discharge Permit Application							Assumes Notice of Intent is bypassed. Includes internal draft for review and submittal to regulatory agencies.
Project Manager	20	HR	$290.38			$5,808	
Sr. Geologist/Engineer/Scientist	80	HR	$216.10			$17,288	
Staff Geologist/Engineer/Scientist	160	HR	$159.82			$25,571	
Technician	0	HR	$118.18			$0	
Graphics	60	HR	$84.41			$5,065	
Technical Editor/Production	40	HR	$123.81			$4,952	
Permit application fees	1	LS			$4,000	$4,000	Filing and permit fees paid to NMED.
Production Supplies/Distribution costs	1	LS			$2,000	$2,000	
Public Notification							Publish notices in local newspapers. Includes internal draft for review and submittal to regulatory agencies.
Project Manager	2	HR	$290.38			$581	
Sr. Geologist/Engineer/Scientist	12	HR	$216.10			$2,593	
Staff Geologist/Engineer/Scientist	0	HR	$159.82			$0	
Technician	0	HR	$118.18			$0	
Graphics	0	HR	$84.41			$0	
Technical Editor/Production	24	HR	$123.81			$2,971	
Newspaper placement costs	1	LS			$1,000	$1,000	
TOTAL COST						**$71,829**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	No field work. Not Applicable.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Pricing based on onsite contractor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

NEPA Evaluation **Alternatives 2 and 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Prepare, submit, and review National Environmental Protection Act (NEPA) checklist. Internally reviewed by DOE.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare NEPA Checklist							Assumes Notice of Intent is bypassed. Includes internal draft for review and submittal to regulatory agencies.
Project Manager	4	HR	$290.38			$1,162	
Sr. Geologist/Engineer/Scientist	40	HR	$216.10			$8,644	
Staff Geologist/Engineer/Scientist	40	HR	$159.82			$6,393	
Technician	0	HR	$118.18			$0	
Graphics	16	HR	$84.41			$1,351	
Technical Editor/Production	0	HR	$123.81			$0	
TOTAL COST						**$17,549**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	No field work. Not Applicable.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Pricing based on onsite contractor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Groundwater well installation **Alternatives 2 and 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Install groundwater monitoring, extraction, or injection well to total depth of 300 feet with 20 feet of 0.020-inch factory-slotted screen. Installation uses a combination of Air-Rotary Casing-Hammer (ARCH) and Air-Rotary drilling methods, continuous core collection for bottom 30 feet, installation of nominal 5-inch diameter flush-threaded Schedule 80 PVC blank and screen with filter pack and grout seal. Includes setup and decontamination, containerization of investigation-derived water (IDW), and wellhead completion (stovepipe with hinged lid, concrete pad, 3 steel bollards). Includes geophysical logging and location/elevation surveying. Well development is not included (see separate Cost Worksheet for Well Development). Health and safety protection is Level D.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Subcontractor costs							
Drill rig mobilization/demobilization	1.00	LS				$2,153	Between wells onsite. Assume done in conjunction with multiple well installations and initial site move/demob waived.
Borehole drilling	300	LF		$108.66		$32,598	ARCH rig
Well installation	300	LF		$71.64		$21,493	ARCH rig
Standby	30	HR	$390.46			$11,714	Video logging assistance and grout setup time
Wellhead completion	1	LS				$1,870	Well pad and bollards/installation
Decon	1	LS				$2,153	
Geophysical logging	1	LS				$1,198	Gamma Ray/Neutron, Induction/Conductivity. Assumes mulitple wells logged in one mobilizaiton.
Surveying	1	LS				$597	Based on prorated cost for surveying horizontal coordinates and vertical elevations for four wells under one mobilization.
Subtotal onsite contractor costs						$73,775	
Subtotal subcontractor costs + operational overhead	1.20					**$88,530**	Multiplier applied to "outside" contractors.
Contractor labor costs							
Sr. Geologist/Engineer/Scientist	48	HR	$216.10			$10,373	Drilling and facilities/safety logistical coordination
Sr. Geologist/Engineer/Scientist	144	HR	$216.10			$31,118	Onsite drilling, well installation, logging, and well development oversight.
Sr. Geologist/Engineer/Scientist	48	HR	$216.10			$10,373	Post field work documentation/logs/field notes, etc.
Technician	16	HR	$118.18			$1,891	One day hydraulic testing and associated coordination and data submittal.
Technician	24	HR	$118.18			$2,836	Onsite handling/disposal of IDW soil based on prior site profiling. Onsite handling/disposal of IDW water sitewide POTW permit.
Subtotal contractor labor costs						**$56,591**	
TOTAL COST						**$145,121**	

Source of Cost Data:

Well installation costs based on applicable sections of Boart Longyear quotation for installation of MW-13 (7/3/2012) plus 6 years of 3% annual escalation. Geophysics costs prorated based on averaging vendor invoice (Jet West Geophysical Services #15375) in 2010 for logging four wells approx. 550 ft deep (prorated cost at 310/550) plus 8 years of 3% annual escalation.

Surveyor cost based on prorated cost in 2012 plus 6 years of 3% annual escalation.

Operational overhead multiplier of 1.20 applied to outside contractor cost line items based on funding under Environmental Management (EM).

Cost Adjustment Checklist:

	FACTOR	NOTES
√	H&S Productivity (labor & equip only)	Quotation is for Level D.
√	Escalation to Base Year	For contractor.
√	Area Cost Factor	Quotation is from local vendor.
√	Subcontractor Overhead and Profit	Included in quotation.
√	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Groundwater well development **Alternatives 1, 2, and 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Develop groundwater monitoring, injection, or extraction well (average 310 feet deep). Well is surged and bailed, then pumped to obtain parameter stabilization. Includes setup and decontamination, containerization of investigation-derived waste (IDW). Health and safety protection is Level D.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Subcontractor costs							
Well Development	12	HR	$437.05			$5,245	Performed by drilling company using pump truck rig.
Subtotal contractor costs						$5,245	
Subtotal subcontractor costs + operational overhead	1.20					**$6,293**	Multiplier applied to outside contractors.
Contractor labor costs							
Staff Geologist/Engineer/Scientist	20	HR	$159.82			$3,196	Subcontractor coordination, oversight, and documentation.
Subtotal contractor labor costs						**$3,196**	
TOTAL COST						**$9,490**	

Source of Cost Data:

Hourly drilling company rate for well development based on applicable section of Boart Longyear quotation for installation of MW-13 (7/3/2012) plus 6 years of 3% annual escalation.
Level of effort based on site-specific past experience.
Operational overhead multiplier of 1.20 applied to subcontractor cost line items.

Cost Adjustment Checklist:

	FACTOR	NOTES
√	H&S Productivity (labor & equip only)	Quotation is for Level D.
√	Escalation to Base Year	For contractor.
√	Area Cost Factor	Quotation is from local vendor.
√	Subcontractor Overhead and Profit	Included in quotation.
√	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Well Installation and Testing Report **Alternatives 2 and 3**

Site: Tijeras Arroyo Groundwater Area of Concern
Location: Sandia National Laboratories/New Mexico
Phase: Corrective Measure Evaluation (-30% to +50%)
Base Year: 2018

Prepared by: Tom Berry, CE2
Date: January 31, 2018

Work Statement:

Report of well installations conducted during prior year. Includes tabulated information on new well installation and associated baseline hydraulic testing results and narrative on well installation methods. Laboratory analytical results reported under separate annual remedy reporting. **Costs shown are per well,** but assume level of effort based efficiencies gained by combining multiple wells into one report. Example: 30 wells = 30 × Total Cost. Use a multiplier of 10 for quantities of wells from 1-10.

General assumption: Draft Final and Final labor = 50% and 25% of Draft, respectively, except for technical editor/production costs which are assumed to be equal.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	0.25	HR	$290.38			$73	
Sr. Geologist/Engineer/Scientist	1	HR	$216.10			$216	
Staff Geologist/Engineer/Scientist	8	HR	$159.82			$1,279	
Technician	0	HR	$118.18			$0	
Graphics	4	HR	$84.41			$338	
Technical Editor/Production	0.5	HR	$123.81			$62	
Production Supplies/Distribution costs	1	LS			$10	$10	
Prepare Draft Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	0.125	HR	$290.38			$36	
Sr. Geologist/Engineer/Scientist	0.5	HR	$216.10			$108	
Staff Geologist/Engineer/Scientist	4	HR	$159.82			$639	
Technician	0	HR	$118.18			$0	
Graphics	2	HR	$84.41			$169	
Technical Editor/Production	0.5	HR	$123.81			$62	
Production Supplies/Distribution costs	1	LS			$10	$10	
Prepare Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	0.0625	HR	$290.38			$18	
Sr. Geologist/Engineer/Scientist	0.25	HR	$216.10			$54	
Staff Geologist/Engineer/Scientist	2.0	HR	$159.82			$320	
Technician	0	HR	$118.18			$0	
Graphics	1	HR	$84.41			$84	
Technical Editor/Production	0.5	HR	$123.81			$62	
Production Supplies/Distribution costs	1	LS			$10	$10	
TOTAL COST (per well)						**$3,549**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

Cost Adjustment Checklist:

	FACTOR	NOTES
☑	H&S Productivity (labor & equip only)	No field work. Not Applicable
☐	Escalation to Base Year	Not applicable
☑	Area Cost Factor	Quotation is from local vendor.
☐	Subcontractor Overhead and Profit	Not applicable
☑	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Potable water transportation **Alternative 2**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Transport potable water from source fire hydrant to injection well locations for subsequent substrate mixing prior to injection.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Equipment/supply costs							
Water truck rental	2	EA		$750		$1,500	Two 4,000-gallon water trucks full time to transport potable water to injection well locations for subsequent on-location mixing and injection through trailer-mounted unit. Rate assumes truck rental at $6,000/month/truck and one-half week/well).
Diesel fuel	40	GAL			$3.00	$120	5 mpg. 2 trucks, 20 miles/day ea, 40 gal/week total.
Subtotal equipment/supply costs						$1,620	
Subtotal equipment/supply costs + operational overhead	1.20					**$1,944**	
Contractor labor costs							
Technician	40	HR	$118.18			$4,727	One technician per water truck to fill up potable water and deliver it to the injection site. 2 wells per week = 20 hrs/driver/well, 2 drivers.
Subtotal contractor labor costs						**$4,727**	
TOTAL COST						**$6,671**	

Source of Cost Data:

Rental vendor online catalogues (2017). Assume applicabale to Base Year 2018.
Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases (funding from either EM or LTS).

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	Quotation is for Level D.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Quotation is from local vendor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Substrate initial injection **Alternative 2**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Gravity inject an average of 20,000 gallons of potable water mixed with ISB substrate and associated buffer and nutrients into one injection well to create a treatment area around the injection well approximately 25 feet in diameter (assumes average saturated thickness of 20 feet). Potable water to be transported to location in a water truck (cost under separate worksheet). Substrate and components to be mixed above ground in a mobile trailer unit or functional equivalent and then gravity fed into the injection well. Monitoring water levels in nearest surrounding monitoring wells under static (pre-pumping) conditions, during and after injection. Dose mixed and injected at approximately 20 gpm (two working days).

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Equipment/supply costs							
Ethyl lactate	100	GAL			$26.22	$2,622	Assumes average of 5 gal/1,000 gallon of injected water (0.5% solution).
Food grade nutrient additive and buffer	10	LBS			$3.00	$30	Assumes 10% by weight of ethyl lactate.
Misc. consumable supplies	1	LS			$50	$50	PPE, plastic sheeting around wellhead, decon supplies, misc. replacement fittings for mixing trailer/injeciton hose assembly.
Subtotal equipment/supply costs						$2,702	
Subtotal equipment/supply costs + operational overhead	1.20					**$3,242**	
Contractor labor costs							
Sr. Geologist/Engineer/Scientist	10	HR	$216.10			$2,161	Test design and protocol development QC. Coordinate access/logistics issues. Review daily paperwork submitted by field team. Assumes 20 hrs/week, 2 wells/per week = 10 hrs/well.
Staff Geologist/Engineer/Scientist	20	HR	$159.82			$3,196	Field lead for injection operation. Assume full time (40 hrs) per week, two wells/week = 20 hrs/well.
Technician	20	HR	$118.18			$2,364	Operator for mixing trailer and injection (assisted by staff geologist). Additional assistance provided by truck drivers (included in potable water transport time). Assume full time (40 hrs) per week, two wells/week = 20 hrs/well.
Subtotal contractor labor costs						**$7,721**	
TOTAL COST						**$10,963**	

Source of Cost Data:

Substrate components based on BGI quotation for TA-V Treatability Study (April 2017).
Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases (funding from either EM or LTS).

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	Quotation is for Level D.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Quotation is from local vendor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Install dedicated monitoring equipment and initiate logging **Alternative 2**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Deploy dedicated multiparameter sonde to a selected injection or performance monitoring well. Includes receiving and inspecting the multiparameter sonde, associated sensors, cabling, and wellhead fittings. Sonde sensors calibrated and checked, the sonde lowered to prescribed depth and suspended by wellhead fittings. Logging initiated and inital data recorded. Staff return within a day or so to verify integrity of deployment and confirm data is being logged properly.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Contractor labor costs							
Sr. Geologist/Engineer/Scientist	2	HR	$216.10			$432	Coordinate access/logistics issues. Review initial calibration and data results submitted by field team. Assumes 2 per well.
Staff Geologist/Engineer/Scientist	10	HR	$159.82			$1,598	Field lead. 1 full day (8 hrs) per sonde installation + 2 hrs to confirm proper operation on subsequent day (in conjunction with checking other sonde deployments).
Technician	10	HR	$118.18			$1,182	One full day (8 hrs) to assist staff geologist in calibrating and installing sonde into well + 2 hrs to receive equipment and prep it for field deployment.
Subtotal contractor labor costs						**$3,212**	
TOTAL COST						**$3,212**	

Source of Cost Data:
Estimated level of effort for contractor staff.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	Quotation is for Level D.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Quotation is from local vendor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Install groundwater extraction and conveyance system **Alternative 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Install equipment and materials to extract and transfer groundwater from extraction wells through transfer tanks and to the treatment system. Includes submersible pumps, primary and secondary containment, electrical wiring and conduit and level controls, and trenching, backfilling, compacting, and repaving.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	NOTES
Extract pump assemblies								
Extraction wellhead fittings	1	EA			$250.00	$250	$250	Fittings, sampling port, pressure guage, and totalizing flow meter.
Extraction pumps	1	EA			$700.00	$700	$700	Electric submersible pump (up to 5 gpm), downhole wiring, fittings, riser pipe/tubing, and safety cable.
Downhole pipe, wire, fittings	300	FT			$1.50	$ 1.50	$450	
Safety cable	300	FT			$0.75	$ 0.75	$225	Stainless steel (7 × 19 strand)
Extraction pump controller	1	EA			$700.00	$700	$700	Pump controller and high/low level switching.
Hi/Lo level sensor and cabling	1	EA			$450.00	$450	$450	
Hi/Lo level sensor controller	1	EA			$275.00	$275	$275	
Subtotal extraction pump assemblies							**$3,050**	
Subtotal subcontractor costs + operational overhead	1.20						**$3,660**	Multiplier applied to "outside" contractors.
Trenching, backfill, compaction, and paving								
Pavement sawcutting	9,000	LF				$2.55	$22,969	4,500 LF of trenching in paved areas × two sides of trench = 9,000 LF. Sawcut A/C pavement < 6-in thick.
Remove existing pavement	333	SY				$9.63	$3,210	4,500 LF × 2 FL = 333 SY.
Trenching, backfilling, compaction	19,000	LF				$37.61	$714,567	2 ft wide, ≤ 8 ft deep (piping not included).
Trench paving	333	SY				$16.93	$5,636	4,500 LF X 2 ft wide = 333 SY. Surface prep, emulsified asphalt prime coat, 2-in thick asphalt concrete. Remaining 14,500 LF of trenching is in unpaved non-traffic areas not requiring pavement removal/replacement.
Subtotal trenching, backfill, compaction, and paving							**$746,382**	
Subtotal subcontractor costs + operational overhead	1.20						**$895,658**	Multiplier applied to "outside" contractors.

Primary conveyance tubing						
Primary groundwater conveyance tubing (wells to transfer tanks)	107,190	LF		$0.67	$71,817	1/2-in ID PVC tubing with polyester braiding. Individual lines for each of the 9 extraction wells. Connector fittings included.
Primary groundwater conveyance tubing (transfer tanks to treatment system)	6,050	LF		$5.01	$30,311	2-in ID PVC tubing with polyester braiding. Individual lines for each transfer tank to the treatment system.
Install primary conveyance tubing and connect at wellheads	113,240	LF	$0.79		$89,218	Assumes tubing is pulled through secondary containment piping in 200 ft sections (between pull boxes). Wells to transfer tanks are bundled in three 200 ft lengths of tubing each (total of 600 LF). Two technicians, two hours each/600 LF of tubing.
Subtotal primary conveyance tubing					**$191,346**	
Subtotal subcontractor costs + operational overhead	1.20				**$229,615**	Multiplier applied to "outside" contractors.
Secondary containment pipe						
Secondary containment pipe (wells to transfer tanks)	41,060	LF		$3.10	$127,286	4-in ID Sched 40 PVC pipe. 3-4 tubing lines per piping run.
Secondary containment couplings (wells to transfer tanks)	4,517	EA		$4.06	$18,337	4-in ID Sched 40 PVC pipe, slip couplings. 1 coupling / 10 ft of piping + 10%
Secondary containment pipe (transfer tanks to treatment system)	6,050	LF		$3.10	$18,755	4-in ID Sched 40 PVC pipe. 3-4 tubing lines per piping run.
Secondary containment couplings (transfer tanks to treatment system)	666	EA		$4.06	$2,702	4-in ID Sched 40 PVC pipe, slip couplings. 1 coupling / 10 ft of piping + 10%
Install secondary containment pipe	47,110	LF	$4.73		$222,698	Assumes two technicians can install 50 ft of piping (five, 10-ft sections) per hour.
Subtotal secondary containment pipe					**$389,779**	
Subtotal subontractor costs + operational overhead	1.20				**$467,734**	Multiplier applied to "outside" contractors.

Electrical conduit, wiring, and control panels for extraction and transfer pumps

Electrical wire conduit (to wellheads)	41,060	LF		$0.72		$29,563	2-in ID Sched 40 PVC pipe, integral belled couplings, intalled parallet to secondary containment piping. Each conduit contains power lines for three pumps and associated level controls.
Electrical wire conduit (to transfer tanks)	6,050	LF		$0.72		$4,356	2-in ID Sched 40 PVC pipe, integral belled couplings, intalled parallel to secondary containment piping. Each conduit contains power lines or one transfer pump and associated level controls.
Install electrical conduit	47,110	LF	$4.73			$222,830	2-in ID PVC pipe installed in 10-ft sections with cemented bell couplings. Assumes two technicians can install 50 ft of conduit (five, 10-ft sections) per hour.
Electrical wire (to wellheads)	143,510	LF		$0.30		$43,053	2-wire, sheethed Romex (or functional equivalent). Miscellaneous connectors are nominal cost. Total equals primary tubing length plus distance from nearest electrical drop/control panel.
Install electrical wiring and connect at wellheads	143,510	LF	$0.79			$113,373	Assumes wiring is pulled through electrical conduit in 200 ft sections (between pull boxes) containing three bundled 200 ft lengths of wire (total of 600 LF). Two technicians, two hours each/600 LF of wire.
Electrical wire (to transfer tank pumps)	6,050	LF		$0.30		$1,815	2-wire, sheethed Romex (or functional equivalent). Miscellaneous connectors are nominal cost. Total equals primary tubing length plus distance from nearest electrical drop/control panel.
Install electrical wiring and connect at wellheads	6,050	LF	$1.18			$7,139	Assumes wiring is pulled through electrical conduit in 200 ft sections (between pull boxes) containing one wire. Two technicians, one hour each/200 LF of wire.
Electrical control panel	6	EA		$6,000	$6,000	$36,000	Master pump control panel for each transect (A through F). Includes controls for transfer tank pumps. Includes $1,000 ea for installation labor.
Subtotal electrical conduit, wiring, and control panels for extraction and transfer pumps						**$458,129**	
Subtotal subontractor costs + operational overhead	1.20					**$549,755**	Multiplier applied to "outside" contractors.

Source of Cost Data:
Contractor trenching, paving, sewer connection costs: Based on COA City Engineer's Estimated Unit Prices for Contract Items (2009) - escalated 9 yrs to 2018.
Various product vendor online catalogues (2017). Cost escalation assumed to be negligible.
Operational overhead multiplier of 1.20 applied to outside contractor cost line items based on funding under Enivironmental Management (EM).

Cost Adjustment Checklist:	FACTOR	NOTES
√	H&S Productivity (labor & equip only)	Quotation is for Level D.
√	Escalation to Base Year	As applicable.
√	Area Cost Factor	Pricing from local/national vendor.
√	Subcontractor Overhead and Profit	
	Prime Contractor Overhead and Profit	Applied on summary sheet.

COST WORKSHEET

Ion exchange and carbon polish groundwater treatment system **Alternative 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Purchase and install the groundwater treatment system including particulate filtration, nitrate treatment with ion exchange resin, and final polish for organic compounds with granular activated carbon (GAC). Assumes total influent 100 gpm total flow rate at 20 mg/L nitrate as N with treated flow of 68 gpm and bypass flow of 32 gpm. Blended effluent flow of 100 gpm at 8 mg/L nitrate as N.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	NOTES
Equipment/supply costs								
Ion exchange resin canisters	24	EA			$18,500		$444,000	Ion-exchange system consists of: 24 vessels (8 plumbed in series: 4 lead and 4 lag) with 8 spare onsite and 8 "float" being in transit to/from the regeneration facility. Each canister has a 60 cu ft resin capacity.
Ion exchage resin	1,440	CU FT			$146		$210,240	Strong base anion (SBA) resin. 60 cu ft/canister.
Additional system equipment/materials	1	LS			$87,500		$87,500	Particulate prefilters, hose and connectors, nitrate analyzer and other controls, freight.
GAC canisters	2	EA			$4,000		$8,000	Two, 2,000-lb canisters.
Subtotal equipment/supply costs							$749,740	
Subtotal equipment/supply costs + operational overhead	1.20						**$899,688**	
Contractor labor costs								
Sr. Geologist/Engineer/Scientist	340	HR	$216.10				$73,474	Coordination, oversight, and documentation. 20 hrs/week × 4 weeks during construction + 13 weeks during start up/optimization.
Technician	640	HR	$118.18				$75,635	System installation (two full-time technicians for three weeks = 120 hrs), testing and optimization (two techincians 50% time for 13 weeks = 520 hrs).
Subtotal contractor labor costs							**$149,109**	
TOTAL COST							**$1,048,797**	

Source of Cost Data:

Ion exchange system costs based on Evoqua Water Technologies email estimate (11/12/2017). Facility installation and onsite contractor level of effort based on professional judgment.
Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases based on funding under Enivironmental Management (EM).

Cost Adjustment Checklist:

	FACTOR	NOTES
√	H&S Productivity (labor & equip only)	Quotation is for Level D.
	Escalation to Base Year	Not applicable.
√	Area Cost Factor	Quotation is from local vendor.
√	Subcontractor Overhead and Profit	Included in quotation.
√	Prime Contractor Overhead and Profit	Applied on summary sheet.

COST WORKSHEET

Discharge injection line **Alternative 3**

Site: Tijeras Arroyo Groundwater Area of Concern
Location: Sandia National Laboratories/New Mexico
Phase: Corrective Measure Evaluation (-30% to +50%)
Base Year: 2018

Prepared by: Tom Berry, CE2
Date: January 31, 2018

Work Statement:

Lay underground discharge pipe from treatment system to injection well.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	NOTES
Trenching, backfill, compaction, and paving								
Pavement sawcutting	1	LS				$500	$500	Crosses Wyoming Blvd and adjacent bike/pedestrian path.
Remove existing pavement	1	LS				$1,000	$1,000	
Trenching, backfilling, compaction	2,000	LF				$37.61	$75,218	2 ft wide, ≤ 8 ft deep (piping not included).
Repave road and bike path	1	LS				$1,000	$1,000	
Discharge pipe	2,000	LF			$ 13.84		$27,680	6-in ID Sched 80 PVC pipe.
Discharge pipe coupling	220	EA			$ 27.23		$5,991	6-in ID Sched 90 PVC pipe, slip couplings. 1 coupling / 10 ft of piping + 10%
Install discharge pipe	2,000	LF	$4.73				$9,460	Assumes two technicians can install 50 ft of piping (five, 10-ft sections) per hour.
Subtotal subcontractor costs							$120,848	
Subtotal subcontractor costs + operational overhead	1.20						**$145,018**	Multiplier applied to "outside" contractors.
Contractor labor costs								
Sr. Geologist/Engineer/Scientist	240	HR	$216.10				$51,864	Coordination, oversight, and documentation. 20 hrs/week during installation for 8 weeks + 80 hrs for prep.
Technician	320	HR	$118.18				$37,818	Onsite for discharge pipe installation. 40 hrs/week for 8 weeks.
Subtotal contractor labor costs							**$89,682**	
TOTAL COST							**$234,699**	

Source of Cost Data:

Contractor trenching, paving, sewer connection costs: Based on COA City Engineer's Estimated Unit Prices for Contract Items (2009) - escalated 9 yrs to 2018.
Various product vendor online catalogues (2017). Cost escalation assumed to be negligible.
Operational overhead multiplier of 1.20 applied to outside contractor cost line items based on funding under Enivironmental Management (EM).

Cost Adjustment Checklist:

	FACTOR	NOTES
√	H&S Productivity (labor & equip only)	Quotation is for Level D.
√	Escalation to Base Year	
√	Area Cost Factor	Quotation is from local vendor.
√	Subcontractor Overhead and Profit	Included in quotation.
√	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Depth-to-water measurements **Atlernatives 1, 2, and 3**

Site: Tijeras Arroyo Groundwater Area of Concern
Location: Sandia National Laboratories/New Mexico
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Prepared by: Tom Berry, CE2
Date: January 31, 2018

Work Statement:

Depth-to-water measurement from 1-10 groundwater monitoring, extraction, or injection wells. Includes submittal of field data, QC, and database entry. Health and safety protection is Level D. For events with more than 10 wells being sampled, linear scaling is used (e.g. 25 wells = 25/10 × total cost).

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Technician	4.00	HR	$118.18			$473	DTW measurement in 10 wells including transportation to/from TAG AOC from main office.
Staff Geologist/Engineer/Scientist	2.00	HR	$159.82			$320	Database entry and review.
TOTAL COST						**$792**	

Source of Cost Data:

Based on 2017 typical level of effort, using onsite contractor staff.

Cost Adjustment Checklist:

	FACTOR	NOTES
√	H&S Productivity (labor & equip only)	Quotation is for Level D.
	Escalation to Base Year	Not applicable.
√	Area Cost Factor	Pricing based on onsite contractor.
	Subcontractor Overhead and Profit	Not applicable.
√	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Groundwater well sampling **Alternatives 1, 2, and 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Groundwater sample collection and analysis from one groundwater monitoring well. Assumes well is sampled using portable pumps. Health and safety protection is Level D.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Technician	2	HR	$118.18			$236	Mobilization/Demobilization: load/unload equipment & supplies, drive to/from site.
Technician	12	HR	$118.18			$1,418	Groundwater sample collection 6 hrs/technician/well * 2 technicians. Sample collection, using portable pump system. Includes equipment decontamination. Includes sample handling and coordinating delivery to analytical lab(s).
Technician	2	HR	$118.18			$236	Sampling equipment calibration/maintenance.
Sampling equipment repair/replacement and consumables	1	EA		~~$500~~	$25	$25	Per well allowance for replacement parts, tubing, calibration supplies and other consumables.
Technician	2	HR	$118.18			$236	Decontaminate equipment and file documentation. 2 technicians for 1 hr each.
TOTAL COST						**$2,152**	

Source of Cost Data:

Based on current (2017) typical level of effort, using onsite contractor staff.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	Quotation is for Level D.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Pricing based on onsite contractor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Groundwater laboratory analysis and validation **Alternatives 1 and 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Analytical costs for one suite of groundwater sample analysis, and independent third party validation from one groundwater monitoring well for purposes of monitoring COC (Nitrate).

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Off-site services costs							
Lab analysis - NPN as nitrogen	1.2	EA			$15.00	$18	Standard turn around time: EPA Method 353.2.
Level IV validation	1.2	EA			$7.50	$9	Third-party validation. 100% of all analyses.
Subtotal off-site services costs before escalation						$27	
Escalation from quotation to Base Year	1.00						
Subtotal off-site services costs with escalation						$27	
Subtotal equipment/supply costs + operational overhead	1.20					**$32**	
TOTAL COST						**$32**	

Source of Cost Data:

Analytical costs per analysis based on typical unit pricing in effect in 2017 and are valid estmates for Base Year 2018. The validation costs are estimated as actual costs are formula based and affected by laboratory quality control data, batching, project specific requirements, etc. Quantity of 1.2 used to account for approximately 20% cost of applicable QC sample analyses (equipment and trip blanks, MS/DS, duplicates, etc.). Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases (funding from either EM or LTS).

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	Not applicable.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Quotation is from local vendor.
[√]	Subcontractor Overhead and Profit	Included in quotation.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Groundwater laboratory lab analysis and validation **Alternative 2**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Analytical costs for one suite of groundwater sample analysis, and independent third party validation from one groundwater monitoring well for purposes of monitoring COC (Nitrate), bioremediation performance parameters, and discharge permit monitoring requirements.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Off-site services costs							
Lab analysis - NPN as nitrogen	1.2	EA			15.00	$18	Standard turn around time: EPA Method 353.2.
Level IV validation	1.2	EA			7.50	$9	Third-party validation. 100% of all analyses.
Lab analysis - Anions (Bromide, Chloride, Fluoride, Nitrite, Sulfate)	1.2	EA			95.00	$114	Standard TAT: SW846-9056
Level IV validation	1.2	EA			47.50	$57	Third-party validation. 100% of all analyses.
Lab analysis - Dissolved metals (aresenic,calcium, iron, magnesium, manganese, potassium, sodium)	1.2	EA			115.50	$139	Standard TAT: SW846-3005/6020
Level IV validation	1.2	EA			57.75	$69	Third-party validation. 100% of all analyses.
Lab analysis - Orthophosphate (as P)	1.2	EA			19.00	$23	Standard TAT: EPA 300.0
Level IV validation	1.2	EA			9.50	$11	Third-party validation. 100% of all analyses.
Lab analysis - Total organic carbon	1.2	EA			19.00	$23	Standard TAT: SW846-9060
Level IV validation	1.2	EA			9.50	$11	Third-party validation. 100% of all analyses.
Subtotal off-site services costs before escalation						$474	
Escalation from quotation to Base Year	1.00						
Subtotal off-site services costs with escalation						$474	
Subtotal equipment/supply costs + operational overhead	1.20					**$569**	
TOTAL COST						**$569**	

Source of Cost Data:

Analytical costs per analysis based on typical unit pricing in effect in 2017 and are valid estmates for Base Year 2018. The validation costs are estimated as actual costs are formula based and affected by laboratory quality control data, batching, project specific requirements, etc. Quantity of 1.2 used to account for approximately 20% cost of applicable QC sample analyses (equipment and trip blanks, MS/DS, duplicates, etc.). Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases (funding from either EM or LTS).

Cost Adjustment Checklist:

	FACTOR	NOTES
☑	H&S Productivity (labor & equip only)	Not applicable.
☐	Escalation to Base Year	Not applicable.
☑	Area Cost Factor	Quotation is from local vendor.
☑	Subcontractor Overhead and Profit	Included in quotation.
☑	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Analytical data handling and verification **Alternatives 1, 2, and 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Receive and verify laboratory Electronic Data Deliverables (EDDs) and hard copy analytical report prior to third-party validation. Upload validated data to database.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Project Manager	1	HR	290.38			$290	
Sr. Geologist/Engineer/Scientist	2	HR	216.10			$432	
Staff Geologist/Engineer/Scientist	12	HR	159.82			$1,918	
Technician	0	HR	118.18			$0	
Graphics	0	HR	84.41			$0	
Technical Editor/Production	0	HR	123.81			$0	
TOTAL COST						**$2,640**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report for 10 wells. Prorate this value for events with different numbers of wells being sampled (e.g. 25 wells = 25/10 X Total Cost).

Cost Adjustment Checklist:

	FACTOR	NOTES
√	H&S Productivity (labor & equip only)	No field work. Not Applicable.
	Escalation to Base Year	Not applicable.
√	Area Cost Factor	Pricing based on onsite contractor.
	Subcontractor Overhead and Profit	Not applicable.
√	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

IDW laboratory analysis **Alternatives 1, 2, and 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Analytical costs for one suite of groundwater sample analyses from one groundwater monitoring well to ensure compliance with requirements for discharge of purge water to the POTW: Unfiltered Target Analyte List metals plus uranium, anions (bromide and fluoride plus chloride and sulfate), gamma spec, gross alpha/beta, isotopic uranium, tritium, anions, bicarbonate/carbonates, cations. Third-partly validation is not required for IDW characterization.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Off-site services costs							
Lab analysis - VOCs	1	EA			120.00	$120	Standard TAT: SW846-8260B
Level IV validation - VOCs	1	EA			60.00	$60	Third-party validation. 100% of all analyses
Lab analysis - Unfiltered TAL Metals plus Uranium	1	EA			189.00	$189	Standard TAT: SW846-6010/6020/7470
Level IV validation - TAL Metals incl. Uranium	1	EA			94.50	$95	Third-party validation. 100% of all analyses
Lab analysis - Gamma spec (short list)	1	EA			88.00	$88	Standard TAT: EPA Method 901.0
Level IV validation - Gamma spec (short list)	1	EA			44.00	$44	Third-party validation. 100% of all analyses
Lab analysis - Gross Alpha/Beta	1	EA			64.00	$64	Standard TAT: EPA 900.0
Level IV validation - Gross Alpha/Beta	1	EA			32.00	$32	Third-party validation. 100% of all analyses
Lab analysis - Tritium	1	EA			52.00	$52	Standard TAT: EPA Method 906.0
Level IV validation - Tritium	1	EA			26.00	$26	Third-party validation. 100% of all analyses
Lab analysis - Alkalinity	1	EA			34.50	$35	Standard TAT: SM2320B
Level IV validation - Alkalinity	1	EA			17.25	$17	Third-party validation. 100% of all analyses
Lab analysis - Anions (Bromide, Chloride, Fluoride, Sulfate)	1	EA			76.00	$76	Standard TAT: SW846-9056
Level IV validation - Anions (Bromide, Chloride, Fluoride, Sulfate)	1	EA			38.00	$38	Third-party validation. 100% of all analyses
Subtotal off-site services costs						$935	
Escalation from quotation to Base Year	1.00						
Subtotal off-site services costs with escalation						$935	
Subtotal equipment/supply costs + operational overhead	1.20					$1,122	
TOTAL COST						**$1,122**	

Source of Cost Data:

Analytical costs per analysis based on typical unit pricing in effect in 2017 and are valid estmates for Base Year 2018. The validation costs are estimated as actual costs are formula based and affected by laboratory quality control data, batching, project specific requirements, etc. Quantity of 1.2 used to account for approximately 20% cost of applicable QC sample analyses (equipment and trip blanks, MS/DS, duplicates, etc.). Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases (funding from either EM or LTS).

Cost Adjustment Checklist:

	FACTOR	NOTES
☑	H&S Productivity (labor & equip only)	Not applicable.
☐	Escalation to Base Year	No applicable.
☑	Area Cost Factor	Quotation is from local vendor.
☑	Subcontractor Overhead and Profit	Included in quotation.
☑	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

IDW transport & disposal - water **Alternatives 1, 2, and 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Disposal of up to 20 55-gallon drums of waste water from well sampling or well redevelopment. Assumes water is transported to sanitary sewer access point at SNL and disposed under current POTW discharge permit. Health and safety protection is Level D.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Technician	16	HR	$118.18			$1,891	Two technicians for 8 hours each to pick up and transport drums approximately 8 miles to POTW discharge point. Includes completing related documentation.
TOTAL COST						**$1,891**	

Source of Cost Data:

Based on current onsite contractor staff typical level of effort for similar onsite operations.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	Quotation is for Level D.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Pricing based on onsite contractor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Annual Remedy Performance Review **Alternative 1**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Annual Remedy Performance Review: 1) description of work completed during the reporting period, 2) summary of all problems, potential problems, or delays encountered during the reporting period, 3) description of actions taken to eliminate or mitigate problems, potential problems, or delays, 4) discussion of work projected for next reporting period, including sampling, 5) copies of results from monitoring, including sampling/analysis, and other data generated during the reporting period, and 6) copies of waste disposal records generated during the reporting period. Includes potentiometric surface contour maps and isoconcentration maps for both the PGWS and Regional Aquifer. Triple the cost for Alternatives 2 and 3 to incorporate reporting of additional monitoirng results, ISB injection activities and parameter monitoring, GWE&T volumes and system operation & maintenance, and discharge compliance results.

Cost Analysis:

General assumption: Draft Final and Final labor = 50% and 25% of Draft, respectively, except for technical editor/production costs which are assumed to be equal.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	12	HR	$290.38			$3,485	
Sr. Geologist/Engineer/Scientist	32	HR	$216.10			$6,915	Prepare text and review of figures, graphs, and appendices.
Staff Geologist/Engineer/Scientist	80	HR	$159.82			$12,786	Draft figures. Update water level and concentration trend graphs.
Technician	16	HR	$118.18			$1,891	Assemble field data form appendices and files.
Graphics	40	HR	$84.41			$3,376	Up to ten figures at four hours each.
Technical Editor/Production	16	HR	$123.81			$1,981	
Production Supplies/Distribution costs	1	LS			$1,000	$1,000	
Prepare Draft Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	6	HR	$290.38			$1,742	
Sr. Geologist/Engineer/Scientist	16	HR	$216.10			$3,458	
Staff Geologist/Engineer/Scientist	40	HR	$159.82			$6,393	
Technician	8	HR	$118.18			$945	
Graphics	20	HR	$84.41			$1,688	
Technical Editor/Production	16	HR	$123.81			$1,981	
Production Supplies/Distribution costs	1	LS			$1,000	$1,000	

Prepare Final						Includes internal draft for review and submittal to regulatory agencies.
Project Manager	3	HR	$290.38		$871	
Sr. Geologist/Engineer/Scientist	8	HR	$216.10		$1,729	
Staff Geologist/Engineer/Scientist	20	HR	$159.82		$3,196	
Technician	4	HR	$118.18		$473	
Graphics	10	HR	$84.41		$844	
Technical Editor/Production	16	HR	$123.81		$1,981	
Production Supplies/Distribution costs	1	LS		$1,000	$1,000	
TOTAL COST					**$58,735**	

Source of Cost Data:

Based on estimated level of estimate for onsite contractor staff to produce report.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	No field work. Not Applicable.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Pricing based on onsite contractor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Logged Data Retrieval **Alternative 2**

Site: Tijeras Arroyo Groundwater Area of Concern
Location: Sandia National Laboratories/New Mexico
Phase: Corrective Measure Evaluation (-30% to +50%)
Base Year: 2018

Prepared by: Tom Berry, CE2
Date: January 31, 2018

Work Statement:

Download logged data from multiparameter sonde onto handheld device and transferred to main laptop for processing or downloaded directly to laptop. Cost estimate per well. Assumes travel to/from site will be combined with data retrieval from 8 wells per day and is negligible per well.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Contractor labor costs							
Sr. Geologist/Engineer/Scientist	0.5	HR	$216.10			$108	Review of downloaded data.
Technician	1	HR	$118.18			$118	Assumes 8 wells data downloaded per day
Subtotal contractor labor costs						**$226**	
TOTAL COST						**$226**	

Source of Cost Data:
Estimated level of effort.

Cost Adjustment Checklist:

	FACTOR	NOTES
√	H&S Productivity (labor & equip only)	Quotation is for Level D.
	Escalation to Base Year	Not applicable
√	Area Cost Factor	Quotation is from local vendor.
	Subcontractor Overhead and Profit	Not applicable
√	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

ISB substrate redosing injection **Alternative 2**

Site: Tijeras Arroyo Groundwater Area of Concern
Location: Sandia National Laboratories/New Mexico
Phase: Corrective Measure Evaluation (-30% to +50%)
Base Year: 2018

Prepared by: Tom Berry, CE2
Date: January 31, 2018

Work Statement:

Inject ~500 gallons of substrate mixture (ethyl lactate, nutrients & buffer, mixed with potable water) into one injection well. Assumes 2 days to perform redosing one injection well. Potable water collected from central site location and transported to well in small tank trailer.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Equipment/supply costs							
Ethyl lactate	0.5	GAL			$26.22	$13.11	Assume average NPN concentration treated is 20 mg/L. Ethyl lactate concentration of 1%.
Food grade nutrient additive and buffer	0.05	LBS			$3.00	$0.15	Assumes 10% by weight of ethyl lactate.
Misc. consumeable supplies	1	LOT			$20.00	$20.00	Disposable gloves/PPE, cleaning supplies, couplings/hose parts replacement, truck fuel.
Subtotal equipment/supply costs						$33.26	
Subtotal equipment/supply costs + operational overhead	1.20					**$39.91**	
Contractor labor costs							
Sr. Geologist/Engineer/Scientist	1	HR	$216.10			$216.10	Coordination, oversight, and documentation (assumes work performed as an ongoing task from muliple tasks)
Technician	16	HR	$118.18			$1,890.88	Fill mixing trailer with ~ 500 gallons of potable water, transport to well location, mix in substrate components, gravity inject mixture into the injection well, and retrieve injection hose. Two technicians, 1 day/well.
Subtotal contractor labor costs						**$2,107**	
TOTAL COST						**$2,147**	

Source of Cost Data:

Ethyl lactate costs based on 2017 vendor quotation for ethyl lactate and associated nutrients and buffer.
Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases (funding from either EM or LTS).

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	Quotation is for Level D.
[ ]	Escalation to Base Year	Not applicable
[√]	Area Cost Factor	Quotation is from local vendor.
[ ]	Subcontractor Overhead and Profit	Not applicable
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Sampling port sample collection **Alternative 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Groundwater sample collection from one sampling port (at wellhead, or as part of a treatment system). Assumes sample collection while extraction and treatment system is operating. Health and safety protection is Level D.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Technician	1.5	HR	$118.18			$177	Access wellhead or treatment system, check and record water flow rate from totalizing flow meter, fill sample bottles from sampling port and submit related paperwork. Assumes sampling is conducted in conjuntion with other tasks so travel to/from site and associated mobilzation time is not included here.
TOTAL COST						**$177**	

Source of Cost Data:

Based on estimated level of effort, using onsite contractor staff.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	Quotation is for Level D.
[ ]	Escalation to Base Year	No applicable.
[√]	Area Cost Factor	Pricing based on onsite contractor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Treatment system discharge compliance laboratory lab analysis **Alternative 3**

Site: Tijeras Arroyo Groundwater Area of Concern
Location: Sandia National Laboratories/New Mexico
Phase: Corrective Measure Evaluation (-30% to +50%)
Base Year: 2018

Prepared by: Tom Berry, CE2
Date: January 31, 2018

Work Statement:

Analytical costs for one suite of groundwater sample analysis from one treatment system sampling port for purposes of reporting NMED discharge permit complance for reinjection into the Regional Aquifer. Third-party validation is not required.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Off-site services costs							
Lab analysis - NPN as nitrogen	1.2	EA			15.00	$18	Standard turn around time: EPA Method 353.2.
Level IV validation - NPN as nitrogen	1.2	EA			7.50	$9	Third-party validation. 100% of all analyses.
Lab analysis - VOCs	1	EA			120.00	$120	Standard TAT: SW846-8260B
Level IV validation - VOCs	1	EA			60.00	$60	Third-party validation. 100% of all analyses
Lab analysis - Unfiltered TAL Metals plus Uranium	1	EA			189.00	$189	Standard TAT: SW846-6010/6020/7470
Level IV validation - Unfiltered TAL Metals incl. Uranium	1	EA			94.50	$95	Third-party validation. 100% of all analyses
Lab analysis - Anions (Bromide, Chloride, Fluoride, Sulfate)	1.2	EA			76.00	$91	Standard TAT: SW846-9056
Level IV validation - Anions (Bromide, Chloride, Flouride, Sulfate)	1.2	EA			38.00	$46	Third-party validation. 100% of all analyses.
Subtotal off-site services costs before escalation						$627	
Escalation from quotation to Base Year	1.00						
Subtotal off-site services costs with escalation						627	
Subtotal equipment/supply costs + operational overhead	1.20					**$753**	
TOTAL COST						**$753**	

Source of Cost Data:

Analytical costs per analysis based on typical unit pricing in effect in 2017 and are valid estmates for Base Year 2018. The validation costs are estimated as actual costs are formula based and affected by laboratory quality control data, batching, project specific requirements, etc. Quantity of 1.2 used to account for approximately 20% cost of applicable QC sample analyses (equipment and trip blanks, MS/DS, duplicates, etc.). Operational overhead multiplier of 1.20 applied to off-site services/equipment/supply purchases (funding from either EM or LTS).

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	Not applicable.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Quotation is from local vendor.
[√]	Subcontractor Overhead and Profit	Included in quotation.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Discharge compliance report **Alternative 3**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Quarterly discharge compliance reporting to NMED. Includes total volume discharged, flow rates, sytem influent, midpoint, and discharge point analytical results, and summarized narrative of operational maintenance. Draft and Draft Final not necessary

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Discharge compliance report							
Prepare Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	8	HR	$290.38			$2,323	
Sr. Geologist/Engineer/Scientist	16	HR	$216.10			$3,458	
Staff Geologist/Engineer/Scientist	24	HR	$159.82			$3,836	
Technician	8	HR	$118.18			$945	
Graphics	0	HR	$84.41			$0	
Technical Editor/Production	8	HR	$123.81			$990	
Production Supplies/Distribution costs	1	LS			$500	$500	
TOTAL COST						**$12,052**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	No field work. Not Applicable.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Pricing based on onsite contractor.
[ ]	Subcontractor Overhead and Profit	Not applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Corrective Measures Implementation Report **Alternatives 1**

Site: Tijeras Arroyo Groundwater Area of Concern **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Prepare Corrective Measure Implementation Report: Includes 1) summary of work completed, 2) signed statement by PE (if appropriate) that remedy has been completed to the full satisfaction of the CMIP, 3) as-built drawings, 4) copies of monitoring results and other data not previously presented in progress reports, 5) waste disposal records not previously submitted in progress reports, 6) certification statement. Also includes a request for Certificate of Completion from NMED and associated supporting information. Alternatves 2 and 3 are estimated at 2 times this cost.

Cost Analysis:

General assumption: Draft Final and Final labor = 50% and 25% of Draft, respectively, except for technical editor/production costs which are assumed to be equal.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	TOTAL	NOTES
Prepare Draft							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	40	HR	$290.38			$11,615	
Sr. Geologist/Engineer/Scientist	120	HR	$216.10			$25,932	
Staff Geologist/Engineer/Scientist	120	HR	$159.82			$19,178	
Technician	0	HR	$118.18			$0	
Graphics	80	HR	$84.41			$6,753	
Technical Editor/Production	40	HR	$123.81			$4,952	
Production Supplies/Distribution costs	1	LS			$2,000	$2,000	
Prepare Draft Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	20	HR	$290.38			$5,808	
Sr. Geologist/Engineer/Scientist	60	HR	$216.10			$12,966	
Staff Geologist/Engineer/Scientist	60	HR	$159.82			$9,589	
Technician	0	HR	$118.18			$0	
Graphics	40	HR	$84.41			$3,376	
Technical Editor/Production	40	HR	$123.81			$4,952	
Production Supplies/Distribution costs	1	LS			$2,000	$2,000	
Prepare Final							Includes internal draft for review and submittal to regulatory agencies.
Project Manager	10	HR	$290.38			$2,904	
Sr. Geologist/Engineer/Scientist	30	HR	$216.10			$6,483	
Staff Geologist/Engineer/Scientist	30	HR	$159.82			$4,795	
Technician	0	HR	$118.18			$0	
Graphics	20	HR	$84.41			$1,688	
Technical Editor/Production	40	HR	$123.81			$4,952	
Production Supplies/Distribution costs	1	LS			$2,000	$2,000	
TOTAL COST						**$131,944**	

Source of Cost Data:

Based on estimated level of effort for onsite contractor staff to produce report.

Cost Adjustment Checklist:

	FACTOR	NOTES
[√]	H&S Productivity (labor & equip only)	No field work. Not Applicable.
[ ]	Escalation to Base Year	Not applicable.
[√]	Area Cost Factor	Pricing based on onsite contractor.
[ ]	Subcontractor Overhead and Profit	No applicable.
[√]	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Plugging and abandonment **Alternatives 1, 2, and 3**

Site: Tijeras Arroya Groundwater **Prepared by:** Tom Berry, CE2
Location: Sandia National Laboratories/New Mexico **Date:** January 31, 2018
Phase: Corrective Measures Evaluation (Cost estimate range -30% to +50%)
Base Year: 2018

Work Statement:

Plug and abandon (P&A) up to 5-in diameter PVC monitoring, injection, or extraction well. Remove wellhead completion. Health and safety protection is Level D.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	NOTES
Subcontractor costs								
Mob/Demob	1	EA				$2,153	$2,153	Between wells onsite. Assume done in conjunction with other well P&A and initial mobe/demobe is waived.
Well pad demolition	1	EA				$757	$757	Demolish well pad and bollards.
Grout well to ground surface	300	FT				$17	$5,015	Approximate average depth of TAG wells.
Concrete monument	1	EA				$448	$448	Placed at location of abandoned well.
Subtotal contractor costs							$8,373	
Subtotal subcontractor costs + operational overhead	1.20						**$10,047**	Multiplier applied to outside contractors.
Contractor labor costs								
Staff Geologist/Engineer/Scientist	40	HR	159.82			$6,393	$6,393	Contractor coordination, 3 days onsite oversight, and follow up documentation.
Technician	8	HR	118.18			$945	$945	Onsite handling/disposal of IDW water under site-wide POTW permit.
Subtotal contractor labor costs							$7,338	
TOTAL COST							**$17,385**	

Source of Cost Data:

Hourly drilling company rate for well decommissioning based on applicable sections of Boart Longyear quotation for installation of MW-13 (7/3/2012) plus 6 years of 3% annual escalation.
Level of effort based on site-specific past experience.
Operational overhead multiplier of 1.20 applied to outside contractor cost line items based on funding under Long-Term Stewardship (LTS).

Cost Adjustment Checklist:

	FACTOR	NOTES
√	H&S Productivity (labor & equip only)	Quotation is for Level D.
√	Escalation to Base Year	For contractor.
√	Area Cost Factor	Quotation is from local vendor.
√	Subcontractor Overhead and Profit	Included in quotation.
√	Prime Contractor Overhead and Profit	Included in unit pricing.

COST WORKSHEET

Dismantle groundwater conveyance and treatment system **Alternative 3**

Site: Tijeras Arroyo Groundwater Area of Concern
Location: Sandia National Laboratories/New Mexico
Phase: Corrective Measure Evaluation (-30% to +50%)
Base Year: 2018

Prepared by: Tom Berry, CE2
Date: January 31, 2018

Work Statement:

- Remove and dispose of all extraction pumps and controls.
- Pull out and dispose of all buried electrical wiring and water conveyance tubing out of the PVC conduit and secondary containment.
- Cap and abandon in place all buried conduit and secondary containment piping (not filling them with grout or digging them up).
- Remove and dispose of all pull box vaults – they are spaced every 200 feet. Backfill, compact, and pave as necessary to match.
- Remove and dispose of five large (12,000-gal) transfer tanks and their cement pads that are spaced through the extraction well field.
- Remove and dispose of all treatment system equipment.
- Demo 20 ft × 40 ft treatment system building and its cement pad.

Cost Analysis:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	NOTES
Subontractor costs								
Remove extraction pump, downhole piping and wiring, level controls, and wellhead fixtures.	292	HRS	$75				$21,900	Two man crew, 4 hrs ea (total 8) per well at @ $75/hr. Wellhead vault removal included in well P&A. 29 PGWS monitoring wells and 73 extraction wells.
Remove buried pirmary conveyance tubing and electrical wiring	304	HRS	$75				$22,800	Pull tubing and wiring out from secondary containment and conduit via pull boxes. Two-man crew, materials within 1,000 ft of trenching per day. 19,000 ft of trenching = 19 days × 2 technicians × 8 hrs each per day.
Pull box removal, cap ends of conduit and secondary containment pipe	95	EA				$700	$66,500	Two laborers @ $75/hr. 4 hrs per box. + $100 equipment rental.
Remove transfer tanks, transfer pumps, and controls	5	EA				$2,000	$10,000	
Dispose of remaining ion exchange resin	1,440	CF					$0	Remaining onsite resin taken by resin servicing vendor during last three servicing trips (covered under annual O&M)
Dispose of remaining GAC	4,000	LBS				$5	$20,000	Two 2,000-lb GAC canisters
Remove treatment equipment from building	1	LS				$8,500	$8,500	1 week: 1 laborer at $75/hr. Equipment operator at $125/hr. 40 hrs each. Equipment rental: $500.

Demolish treatment system building	1	LS		$13,000	$13,000	1 week: 2 laborers at $75/hr. Equipment operator at $125/hr. 40 hrs each. Equipment rental: $2,000.
Break out and remove cement pads	3,000	SF		$8	$24,000	Approx 3,000 sq ft: Five 15 ft × 15 ft pads for transfer tanks, one 20 ft X 40 ft pad for the treatent system, and four 16 ft X 16 ft pads for regen waste storage.
Materials hauling and disposal fees	1	LS		$10,000	$10,000	Used equipment, tubing, building materials. Hauled to Albuquerque landfill. Approximately 130 tons disposal fees plus hauling costs.
Subtotal contractor costs					$196,700	
Subtotal subcontractor costs + operational overhead	1.20				**$236,040**	Multiplier applied to "outside" contractors.
Contractor labor costs						
Sr. Geologist/Engineer/Scientist	200	HR	216.10	$216	$43,220	Coordination, oversight, and documentation. 20 hrs/week during demo. 6 weeks for demo. 80 hrs for prep.
Staff Geologist/Engineer/Scientist	240	HR	159.82	$160	$38,357	On-site supervision for 6 weeks (40 hrs/week).
Subtotal contractor labor costs					**$81,577**	
TOTAL COST					**$317,617**	

Source of Cost Data:

Professional judgment and online vendor research.

Operational overhead multiplier of 1.20 applied to outside contractor cost line items based on funding under Long-Term Stewardship (LTS).

Cost Adjustment Checklist:

	FACTOR	NOTES
√	H&S Productivity (labor & equip only)	Quotation is for Level D.
	Escalation to Base Year	Not applicable.
√	Area Cost Factor	Quotation is from local vendor.
√	Subcontractor Overhead and Profit	Included in quotation.
√	Prime Contractor Overhead and Profit	Included in unit pricing.

Fully Burdened Labor Rates				
Annual escalation (%)	3.0%	**Used for Cost Estimate**		
LABOR CATEGORY		**Base Year (2018) Rate ($/hr) [1]**	**Base Year (2019) Rate ($/hr) [1]**	**Base Year (2020) Rate ($/hr) [1]**
Project Manager		**$290.38**	$299.09	$308.06
Sr. Geologist/Engineer/Scientist		**$216.10**	$222.58	$229.26
Staff Geologist/Engineer/Scientist		**$159.82**	$164.61	$169.55
Technician		**$118.18**	$121.73	$125.38
Graphics		**$84.41**	$86.94	$89.55
Technical Editor/Production		**$123.81**	$127.52	$131.35

Notes:

1 = Labor hourly rates based on anticipated fully burdened cost for onsite contractor cost according to projected Baseline FY17 to FY28.

Present Value Discount Factors		
30+ YR PROJECT		
		Discount Rate (%)
Year	Factor	0.70%
1	0.993	0.70%
2	0.986	0.70%
3	0.979	0.70%
4	0.972	0.70%
5	0.966	0.70%
6	0.959	0.70%
7	0.952	0.70%
8	0.946	0.70%
9	0.939	0.70%
10	0.933	0.70%
11	0.926	0.70%
12	0.920	0.70%
13	0.913	0.70%
14	0.907	0.70%
15	0.901	0.70%
16	0.894	0.70%
17	0.888	0.70%
18	0.882	0.70%
19	0.876	0.70%
20	0.870	0.70%
21	0.864	0.70%
22	0.858	0.70%
23	0.852	0.70%
24	0.846	0.70%
25	0.840	0.70%
26	0.834	0.70%
27	0.828	0.70%
28	0.823	0.70%
29	0.817	0.70%
30	0.811	0.70%
31	0.806	0.70%
32	0.800	0.70%
33	0.794	0.70%
34	0.789	0.70%
35	0.783	0.70%
36	0.778	0.70%
37	0.773	0.70%
38	0.767	0.70%
39	0.762	0.70%
40	0.757	0.70%
41	0.751	0.70%

Present value costs were calculated using the real discount rate of 0.70% for federal facilities based on the 2017 Discount Rates for Office of Management and Budget Circular A-94 for projects with a timeframe of 30 years or more. EPA guidance indicates that the same discount rate should be used for all evaluated alternatives based on the alternative with the longest timeframe (Alternative 1 timeframe is 41 years).

Escalation Factors to Base Year	
Annual escalation rate	3.0%
Years from quotation to Base Year	Cumulative escalation rate multiplier
	1.03
1	1.03
2	1.06
3	1.09
4	1.13
5	1.16
6	1.19
7	1.23
8	1.27
9	1.30
10	1.34

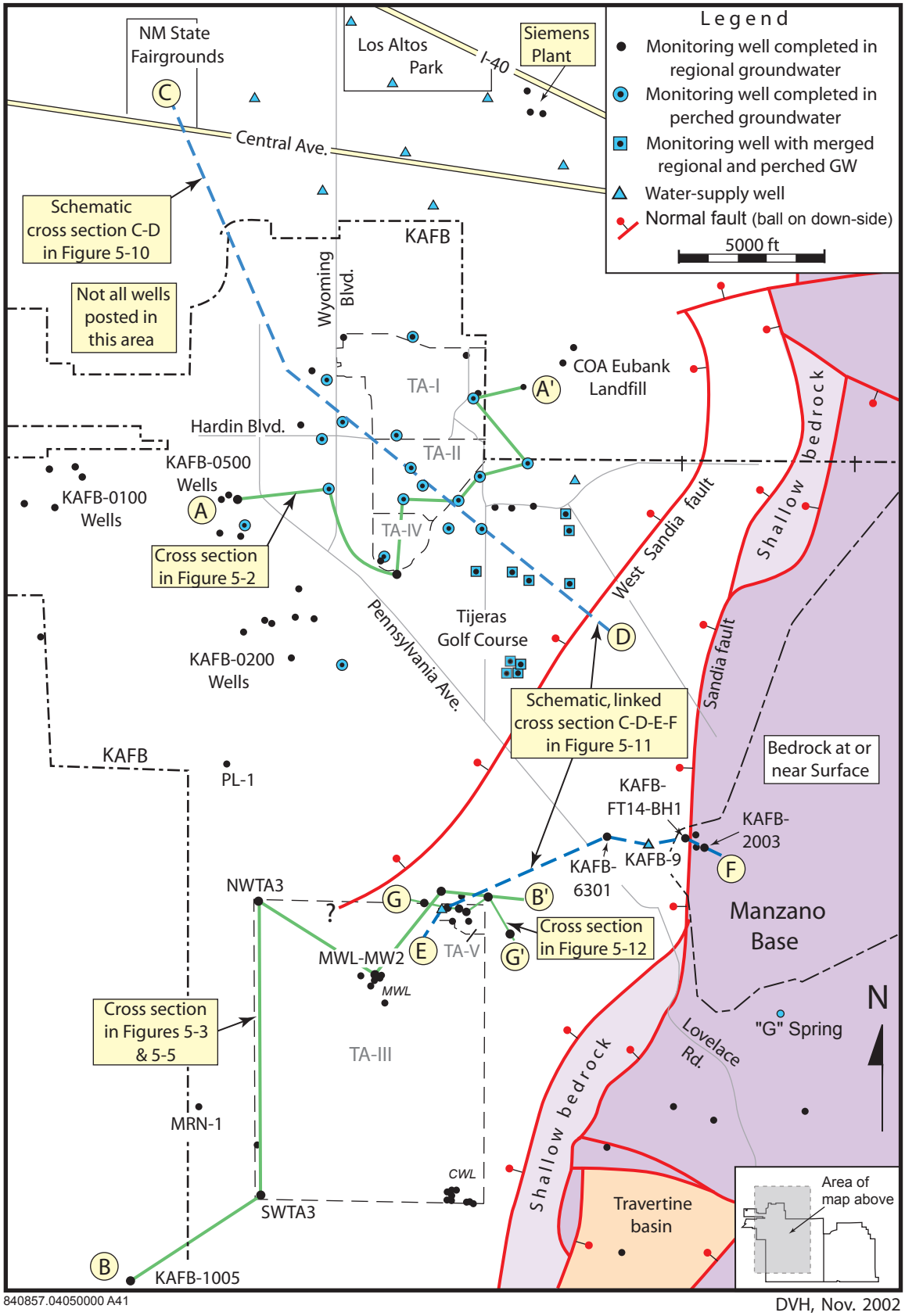
ATTACHMENT 1
Stratigraphic Cross-Sections for the TAG AOC

Attachment 1
Stratigraphic Cross-Sections for the TAG AOC

Item	Reference
Index Map - 2002	Van Hart (June 2003)
Section A – A' - 2002	Van Hart (June 2003)
Index Map - 2001	Van Hart (June 2001)
Section A – A'	Van Hart (June 2001)
Section B - B'	Van Hart (June 2001)
Section C – C'	Van Hart (June 2001)
Section C' - C''	Van Hart (June 2001)
Section D - D'	Van Hart (June 2001)
Section E – E'	Van Hart (June 2001)

Van Hart, D., June 2003. "Geologic Investigation: An Update of Subsurface Geology on Kirtland Air Force Base, New Mexico," SAND2003-1869, Sandia National Laboratories, Albuquerque, New Mexico.146 pp.

Van Hart, D., June 2001. "Shallow Groundwater System Investigation: Tijeras Arroyo and Vicinity," Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico.



840857.04050000 A41

DVH, Nov. 2002

Figure 5-1 Cross Section Location Map, Western Portion of Kirtland Air Force Base (KAFB)

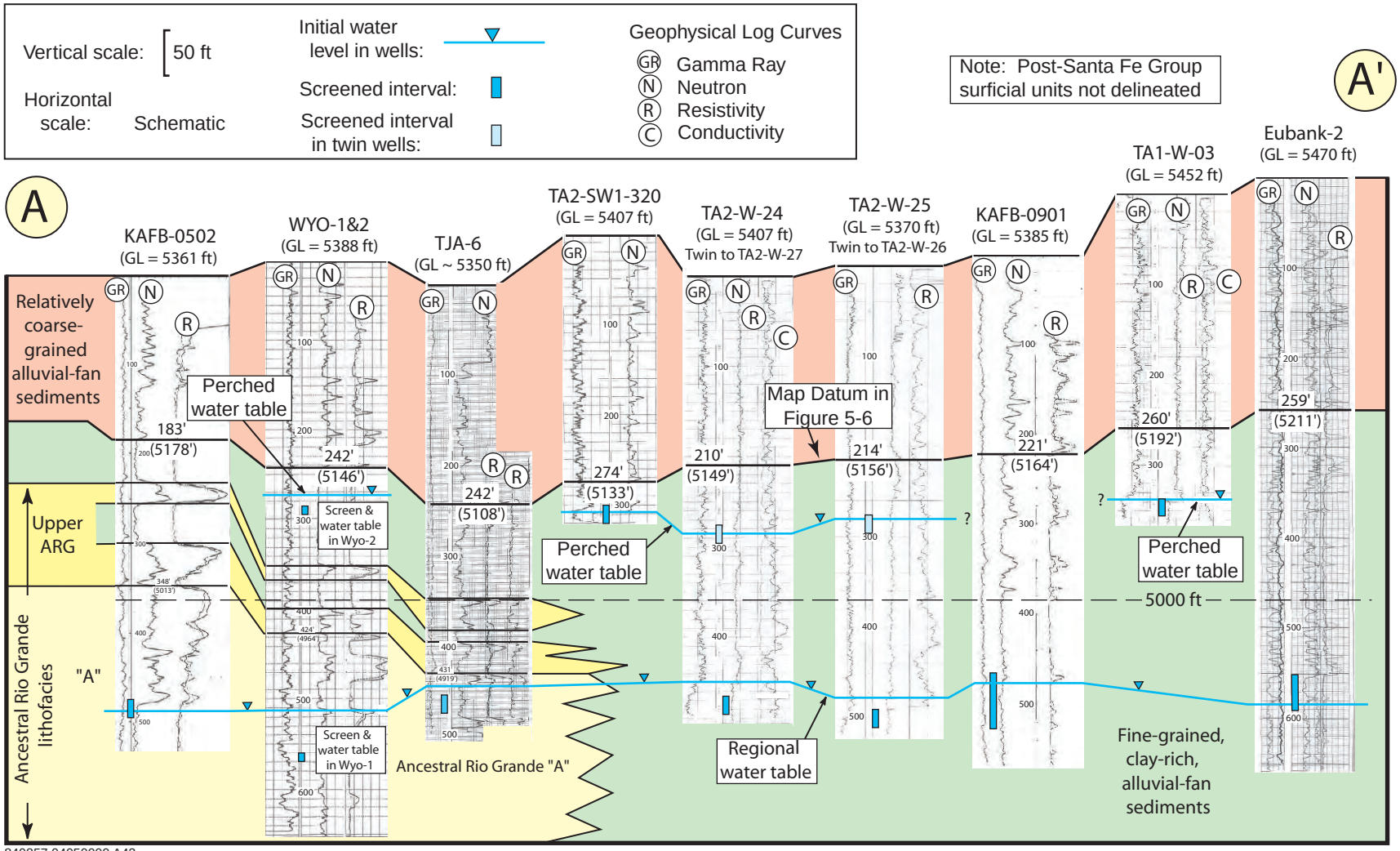


Figure 5-2 Geophysical-Log Correlation Section A-A' , Tijeras Arroyo Groundwater (TAG) Area
(Location in Figure 5-1)

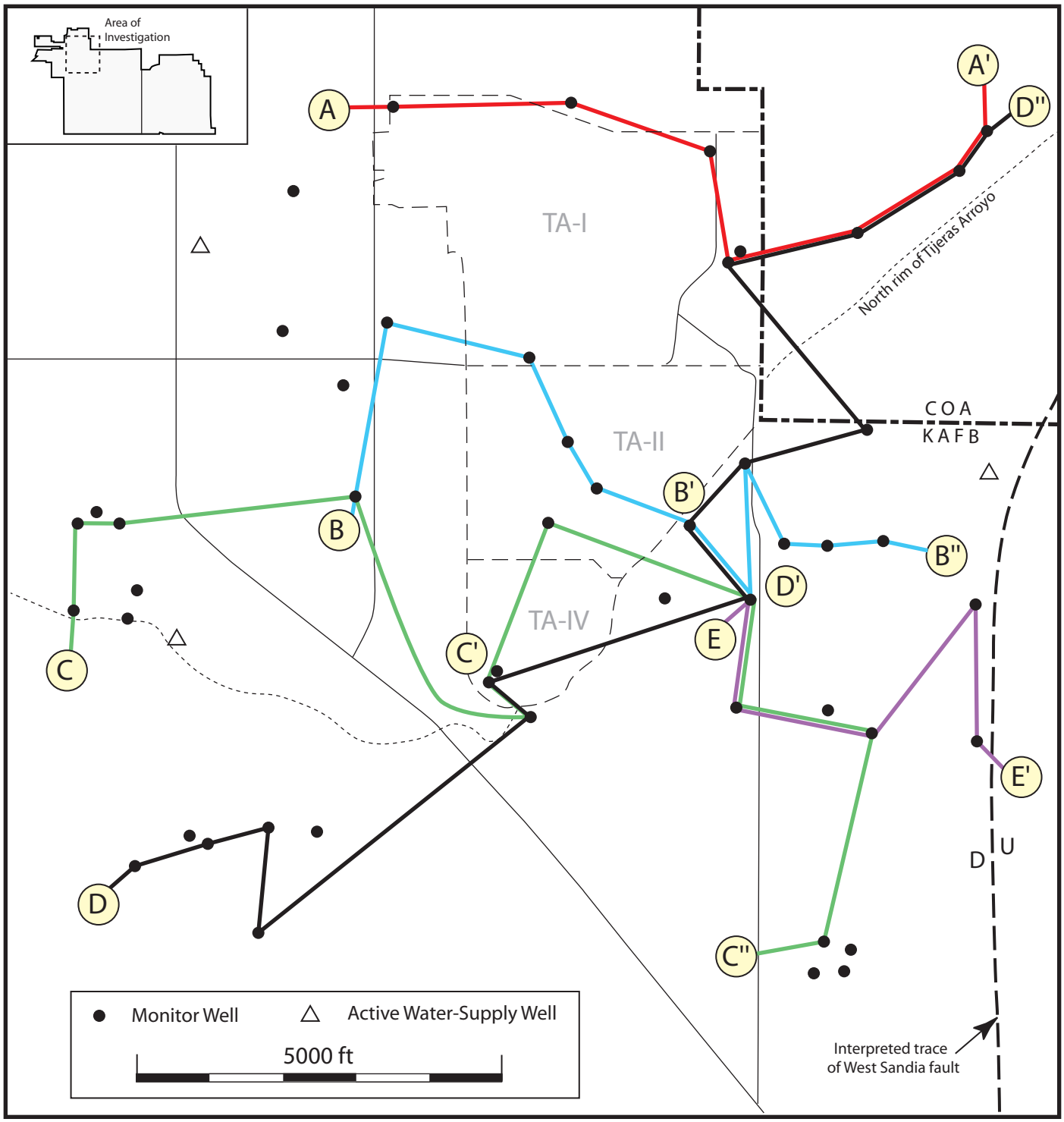
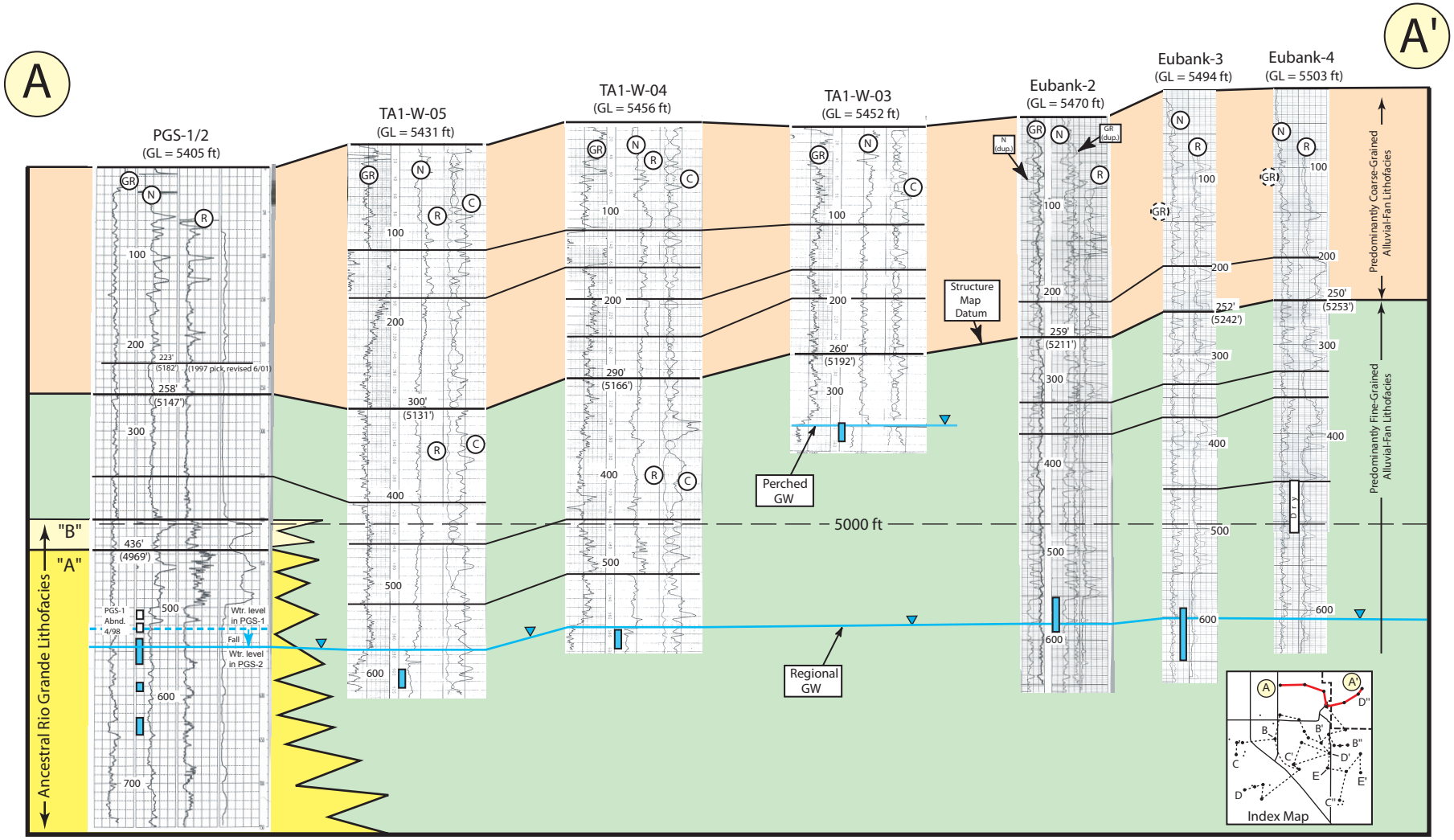


Figure 2. Cross Section Index Map, Tijeras Arroyo Area



Geophysical-Log Correlation Section
A-A'
Tijeras Arroyo Area

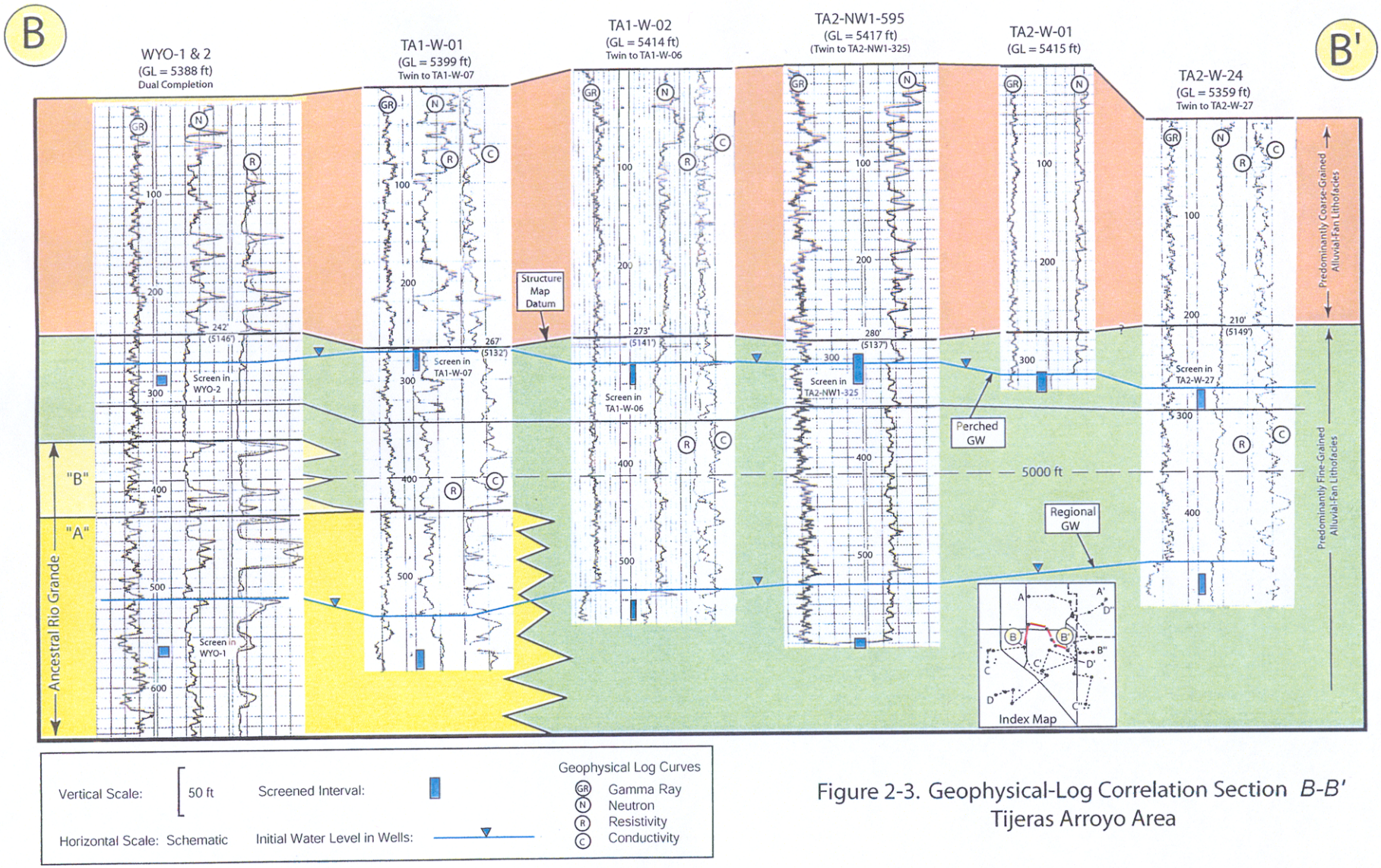
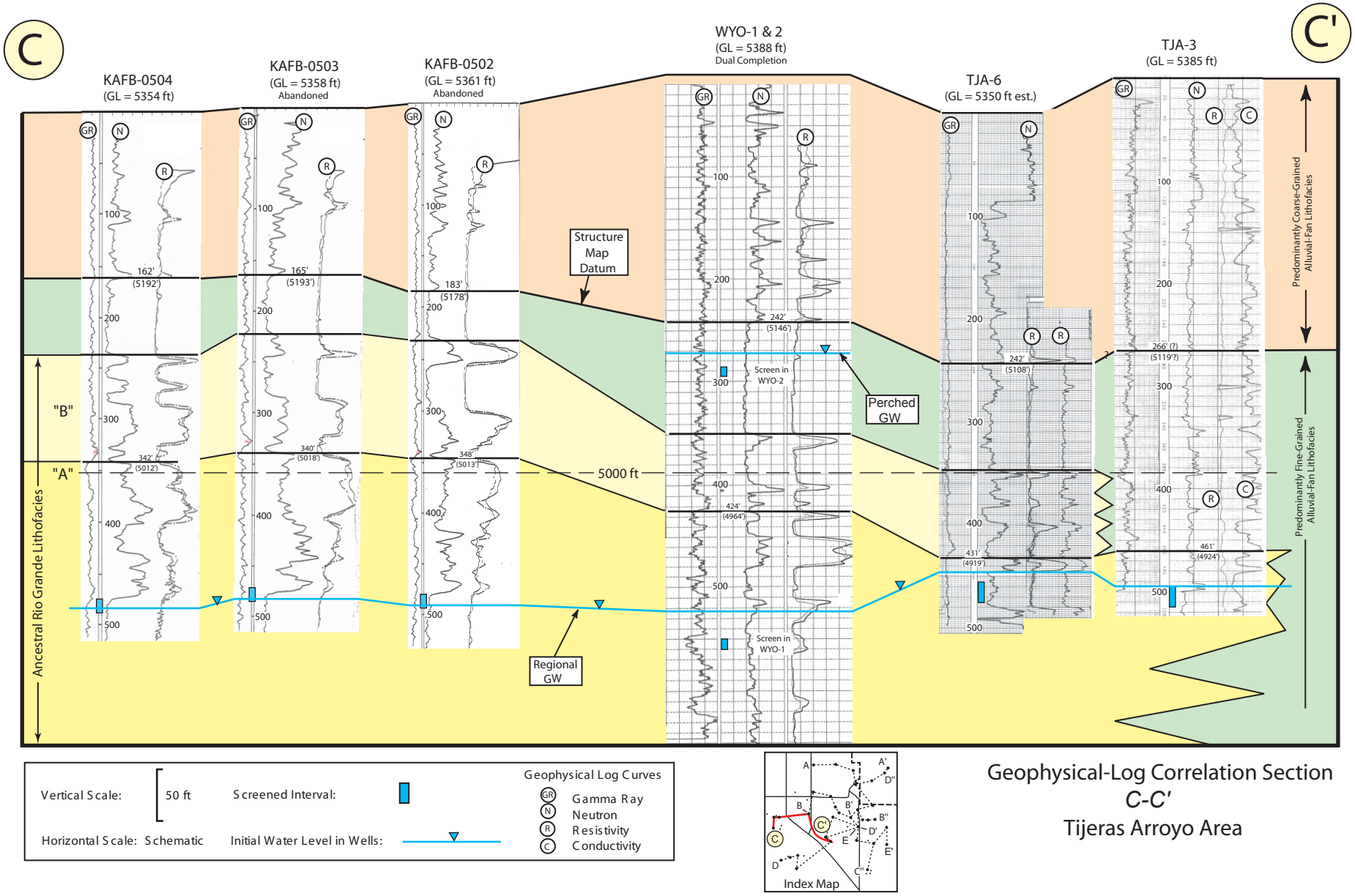


Figure 2-3. Geophysical-Log Correlation Section *B-B'* Tijeras Arroyo Area



Geophysical-Log Correlation Section
C-C'
Tijeras Arroyo Area

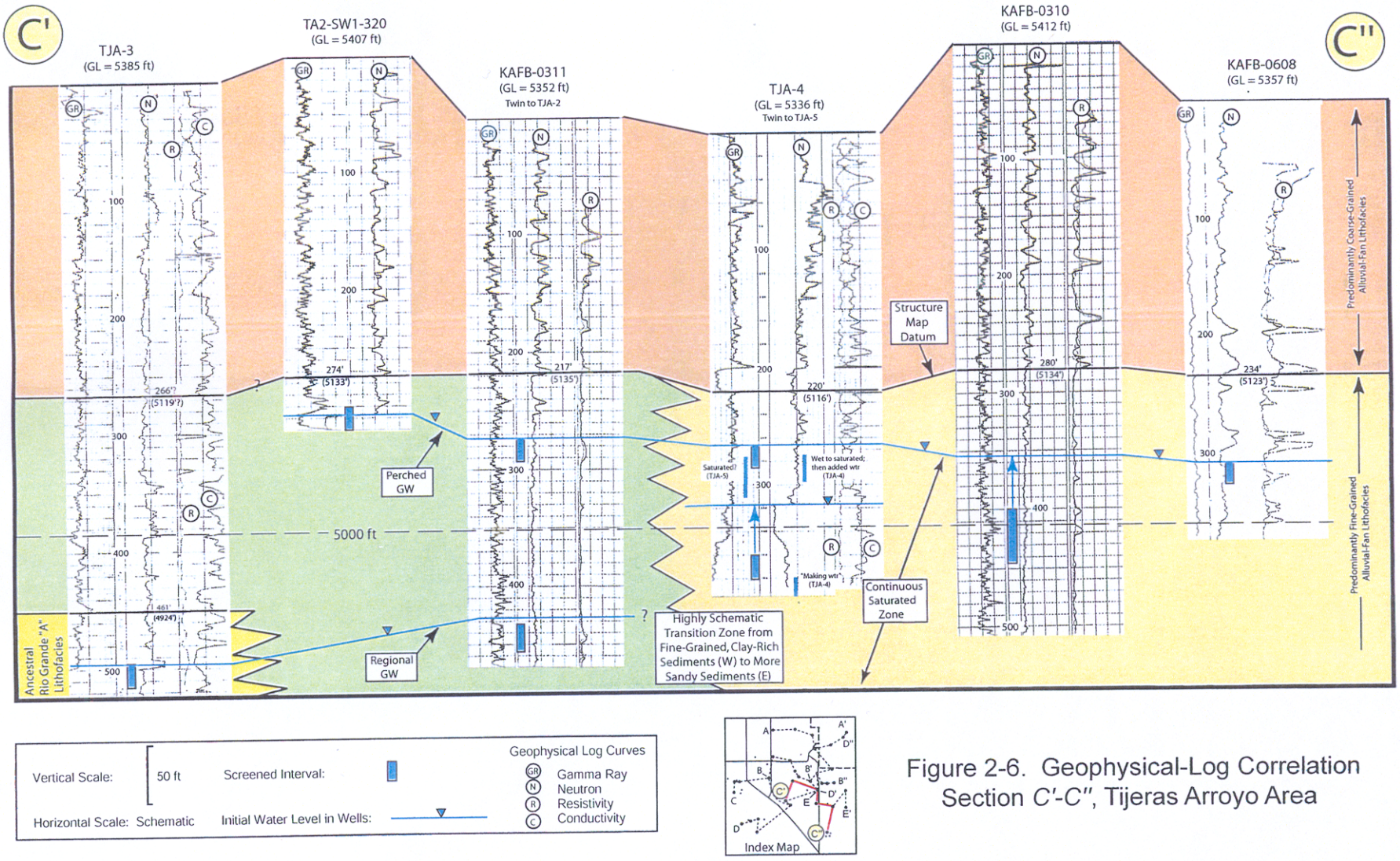


Figure 2-6. Geophysical-Log Correlation Section *C'-C''*, Tijeras Arroyo Area

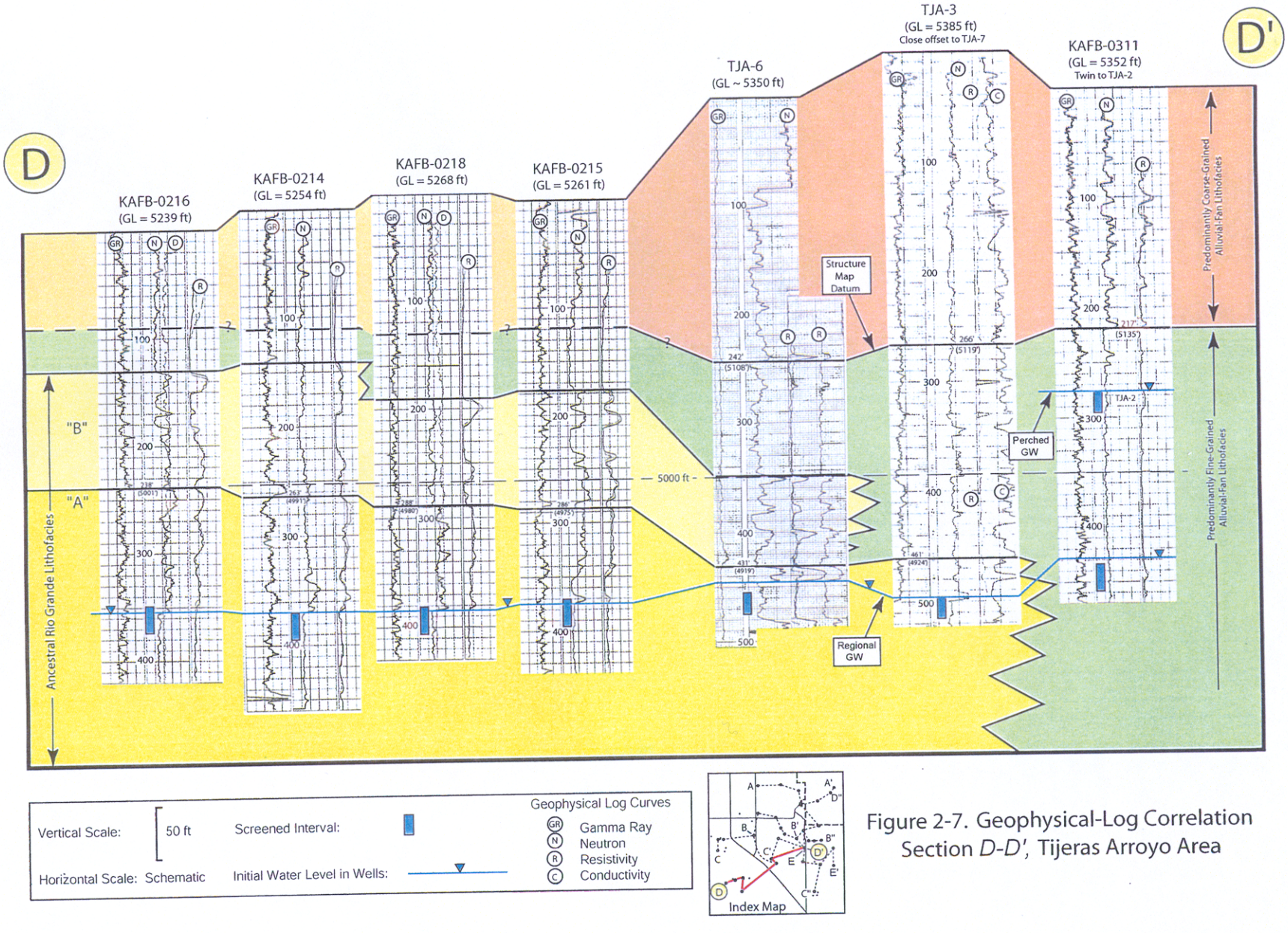
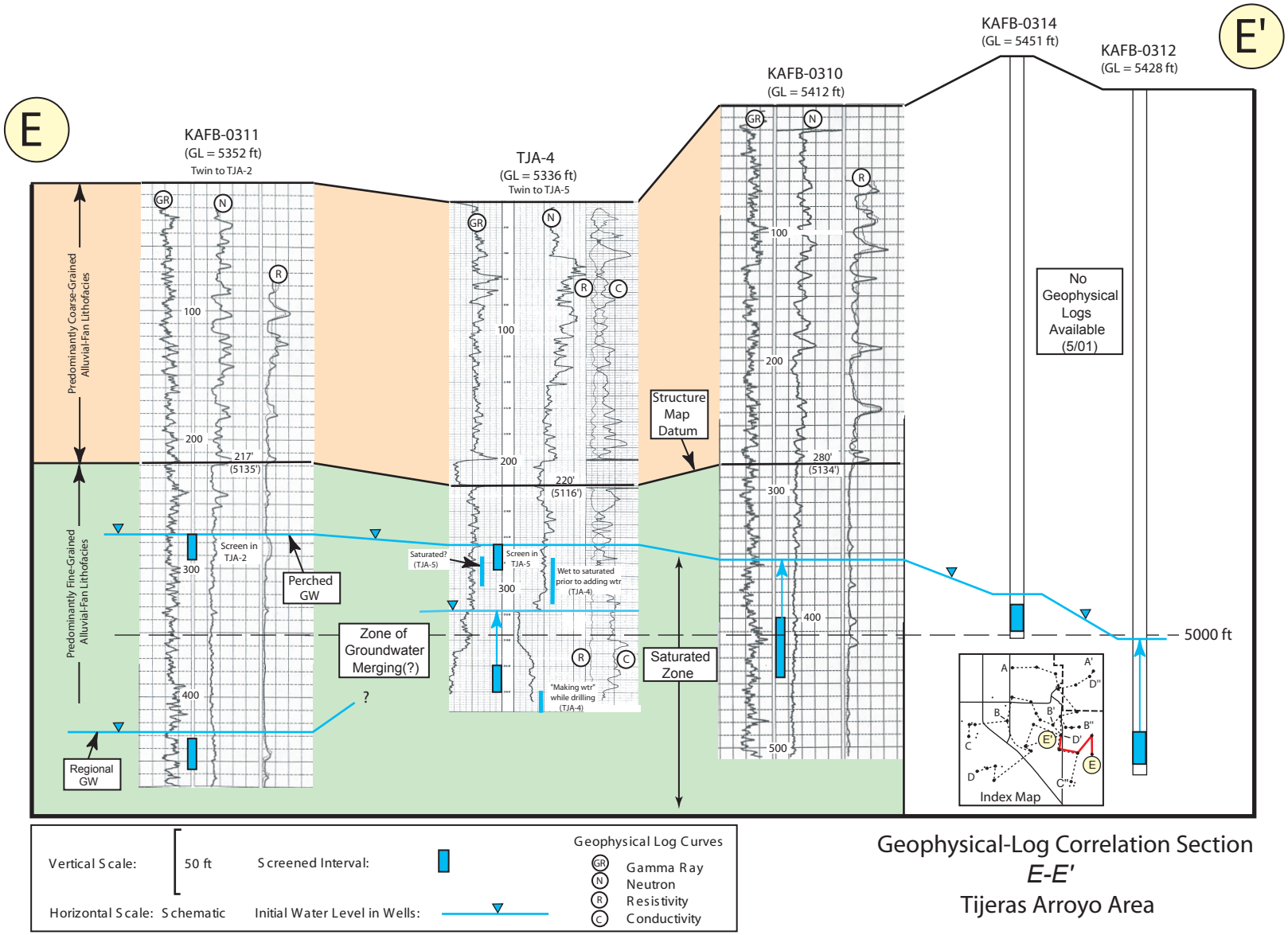


Figure 2-7. Geophysical-Log Correlation Section *D-D'*, Tijeras Arroyo Area



Geophysical-Log Correlation Section
E-E'
Tijeras Arroyo Area

ATTACHMENT 2
Index of Downhole Geophysical Logging Conducted near the TAG AOC

Attachment 2
Index of Downhole Geophysical Logging Conducted near the TAG AOC

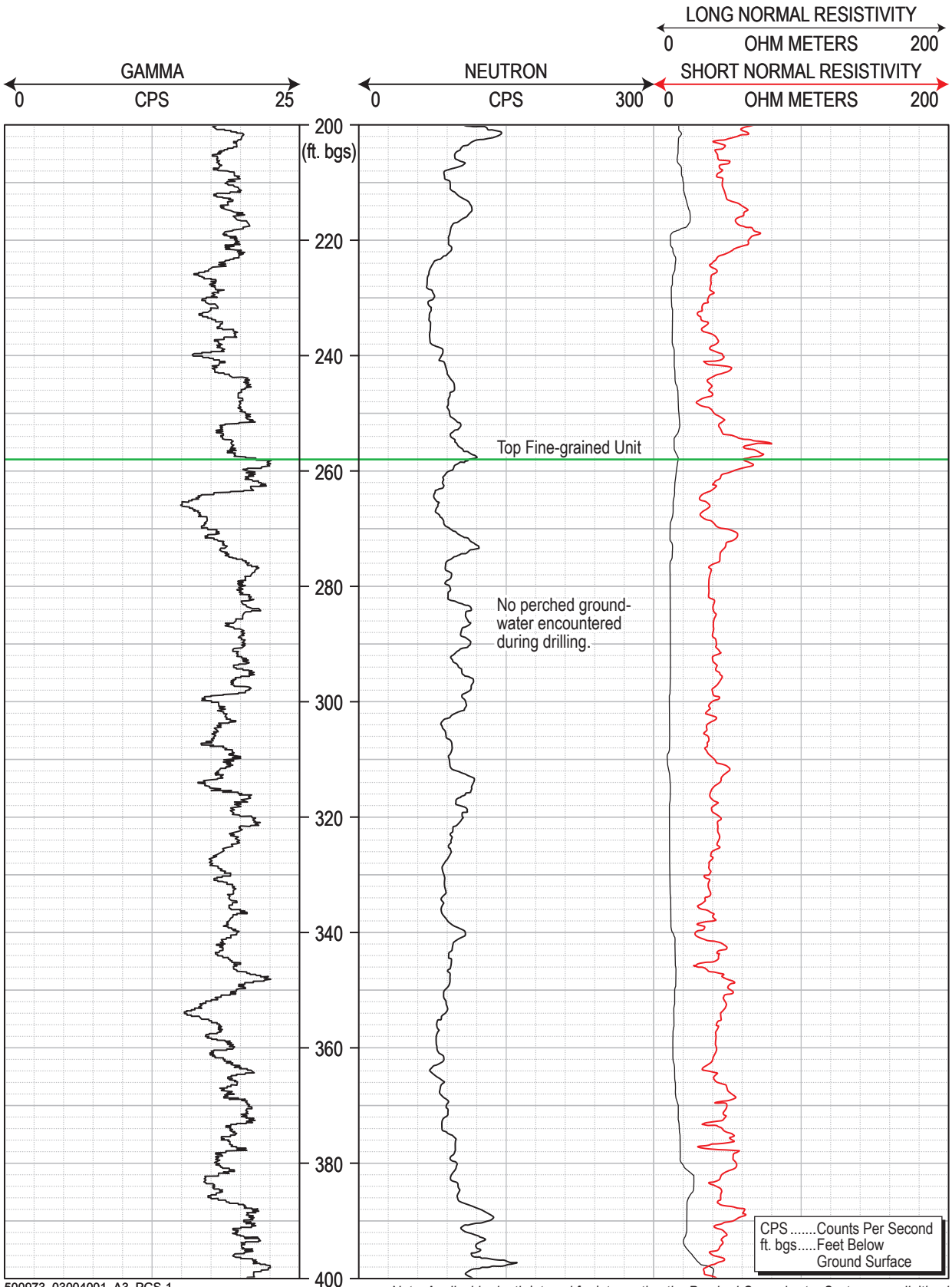
Well ID	Date of Geophysical Logging	Logging Conditions	Geophysical Company	Applicable Geophysical Log for Well Pair
PGS-1	5 Aug 1994	MFB	USGS	PGS-1
PGS-2	Not logged	n.a.	n.a.	See PGS-1
TA1-W-01	4 Aug 1997	PVC casing	COLOG	TA1-W-01
TA1-W-02	29 Apr 1999	PVC casing	COLOG	TA1-W-02
TA1-W-03	29 Apr 1999	PVC casing	COLOG	TA1-W-03
TA1-W-04	28 Apr 1999	PVC casing	COLOG	TA1-W-04
TA1-W-05	29 Apr 1999	PVC casing	COLOG	TA1-W-05
TA1-W-06	29 Apr 1999	PVC casing	COLOG	See TA1-W-02
TA1-W-07	Not logged	n.a.	n.a.	See TA1-W-01
TA1-W-08	Not logged	n.a.	n.a.	See TA1-W-05
TA2-NW1-325	Not logged	n.a.	n.a.	See TA2-NW1-595
TA2-NW1-595	26 June 1993	MFB	USGS	TA2-NW1-595
TA2-SW1-320	14 Sep 1994	PVC casing	USGS	TA2-SW1-320
TA2-W-01	14 Sep 1994	PVC casing	COLOG	TA2-W-01
TA2-W-19	12 Oct 2017	PVC casing	JWGS	TA2-W-19
TA2-W-24	28 Apr 1999	PVC casing	COLOG	TA2-W-24
TA2-W-25	11 Aug 1997	PVC casing	COLOG	TA2-W-25
TA2-W-26	Not logged	n.a.	n.a.	See TA2-W-25
TA2-W-27	28 Apr 1999	PVC casing	COLOG	See TA2-W-24
TA2-W-28	12 Oct 2017	PVC casing	JWGS	TA2-W-28
TJA-1	Not logged	n.a.	n.a.	See TJA-2
TJA-2	12 Aug 1997	PVC casing	COLOG	TJA-2 and KAFB-0311
TJA-3	27 Apr 1999	PVC casing	COLOG	TJA-3
TJA-4	28 Apr 1999	PVC casing	COLOG	TJA-4
TJA-5	Not logged	n.a.	n.a.	See TJA-4
TJA-6	31 Jan 2001	MFB	SGS	TJA-6
TJA-7	Not logged	n.a.	n.a.	See TJA-3
WYO-1	12 Aug 1997	MFB	COLOG	WYO-1
WYO-2	Not logged	n.a.	n.a.	See WYO-1
WYO-3	Not logged	n.a.	n.a.	See WYO-1
WYO-4	Not logged	n.a.	n.a.	See WYO-1
Eubank-1	July 1998	MFB	USGS	Eubank-1
KAFB-0213	6 Aug 1997	PVC casing	COLOG	KAFB-0213
KAFB-0311	24 July 1992	MFB	USGS	KAFB-0311
KAFB-0611	5 Feb 2003	PVC casing	Century Geophysics	KAFB-0612

Green shading indicates that well is screened in the Perched Groundwater System.
Monitoring wells WYO-1 and WYO-2 comprised a well cluster completed in the same borehole.
Well PGS-2 is the replacement well for well PGS-1. Located 29 feet apart.
Well TA2-W-28 is the replacement well for TA2-SW1-320. Located 24 ft apart.
Well TJA-1 is the replacement well for well TJA-2. Located 25 ft apart.
At wells WYO-1 and KAFB-0213, the second phase of geophysical logging was run through the PVC casings and used for interpretative purposes. The primary logging was conducted in the open (mud filled) boreholes.
COLOG = COLOG, Inc.
JWGS = Jet West Geophysical Services.
MFB = Mud filled borehole.
n.a. = Not applicable.
PVC = Polyvinyl chloride.
SGS = Southwest Geophysical Services.
USGS = United States Geological Survey – Water Sciences Division.

ATTACHMENT 3
Geophysical Logs for the TAG AOC

PGS-1
(REPLACED BY WELL PGS-2)

Geophysical Logging Date: 5 August 1994
Logging Company: USGS
Logging Conditions: Mud filled borehole
Ground Elevation, ft amsl NAVD 88: 5407.9

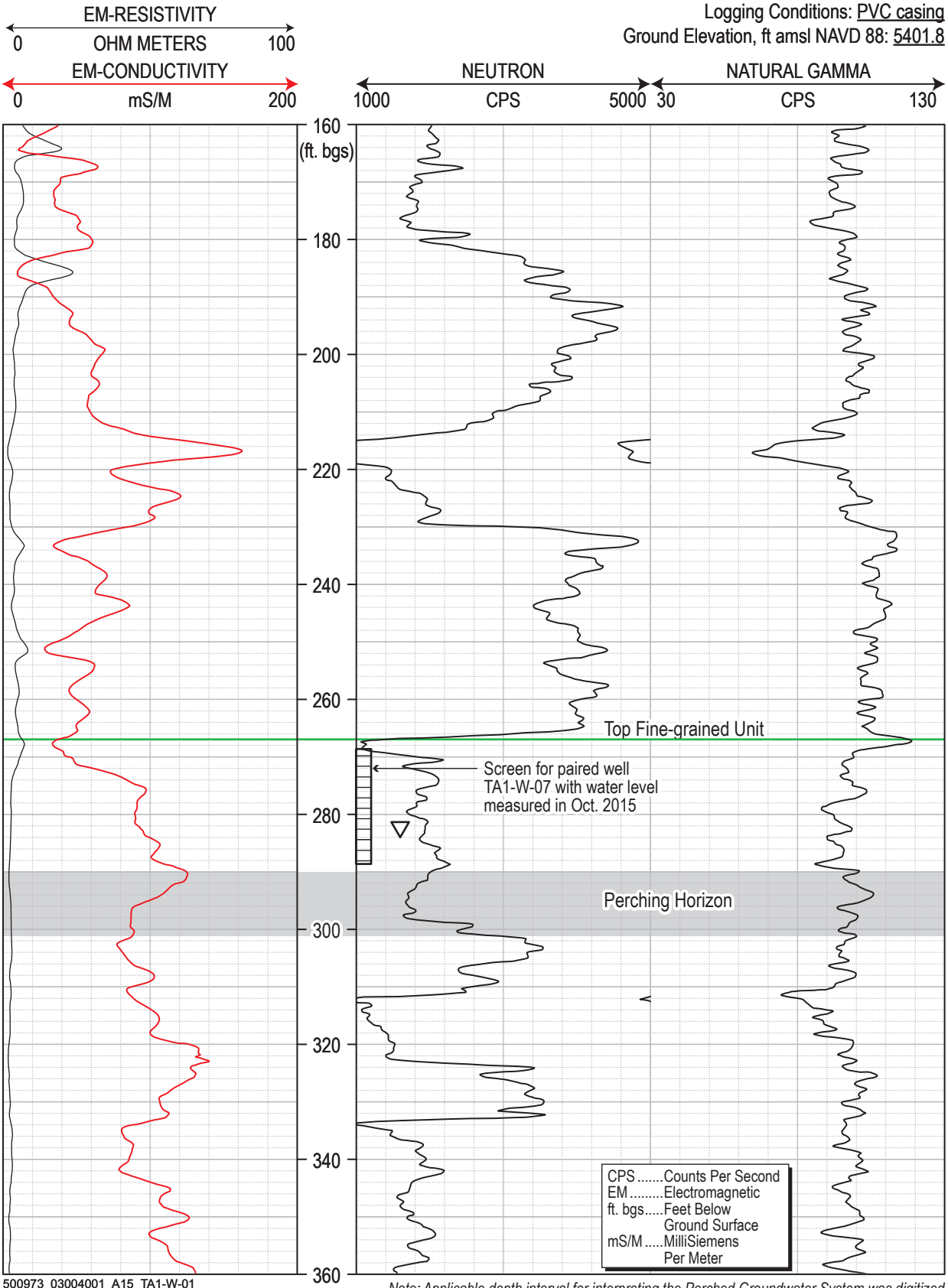


500973_03004001_A3_PGS-1

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original U.S. Geological Survey (USGS) hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

TA1-W-01
(WELL PAIR TA1-W-07)

Geophysical Logging Date: 4 August 1997
Logging Company: COLOG, Inc.
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5401.8

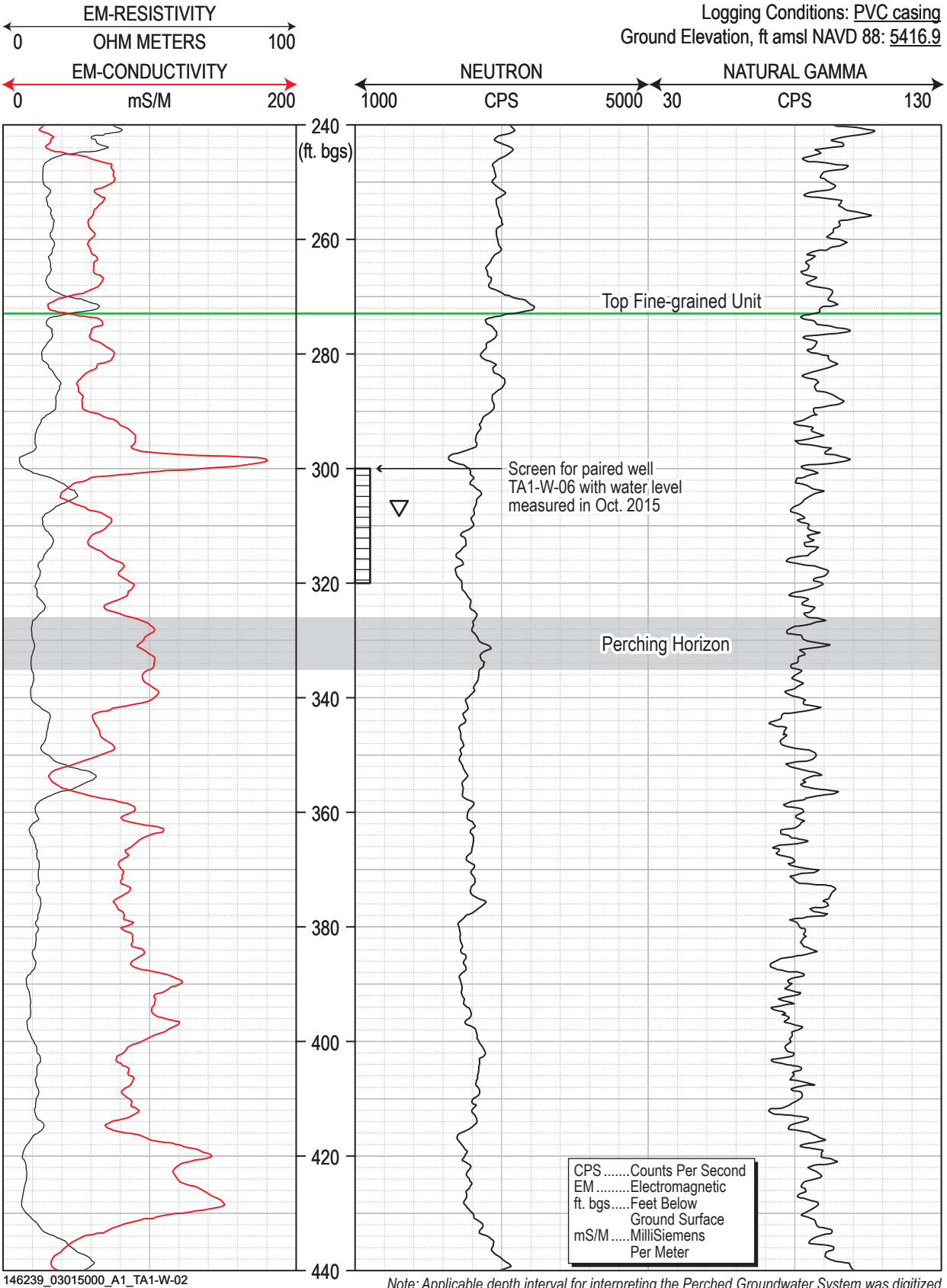


500973_03004001_A15_TA1-W-01

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

TA1-W-02
(WELL PAIR TA1-W-06)

Geophysical Logging Date: 29 April 1999
Logging Company: COLOG, Inc.
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5416.9

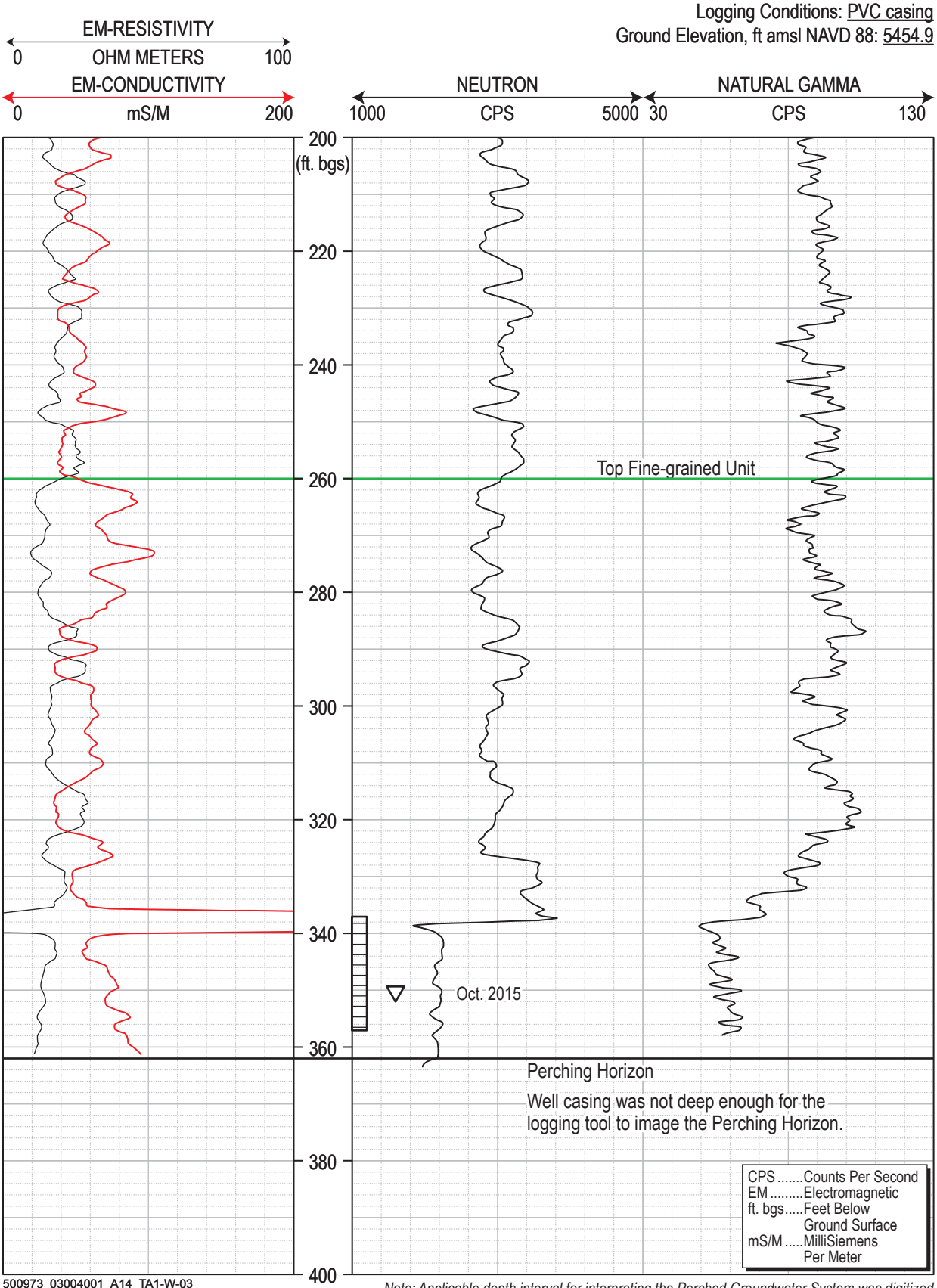


146239_03015000_A1_TA1-W-02

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

TA1-W-03

Geophysical Logging Date: 29 April 1999
Logging Company: COLOG, Inc.
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5454.9

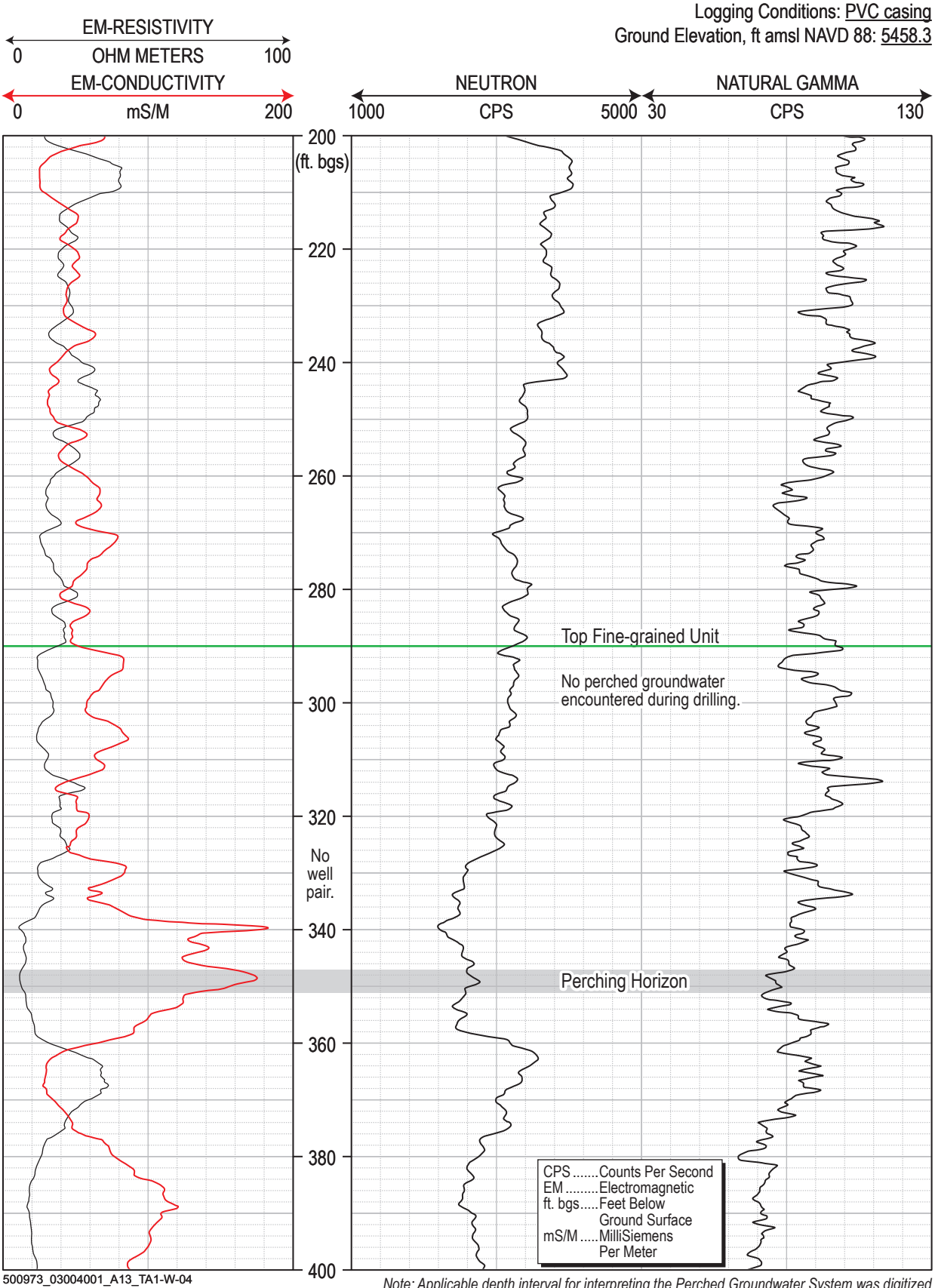


500973_03004001_A14_TA1-W-03

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

TA1-W-04

Geophysical Logging Date: 28 April 1999
Logging Company: COLOG, Inc.
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5458.3

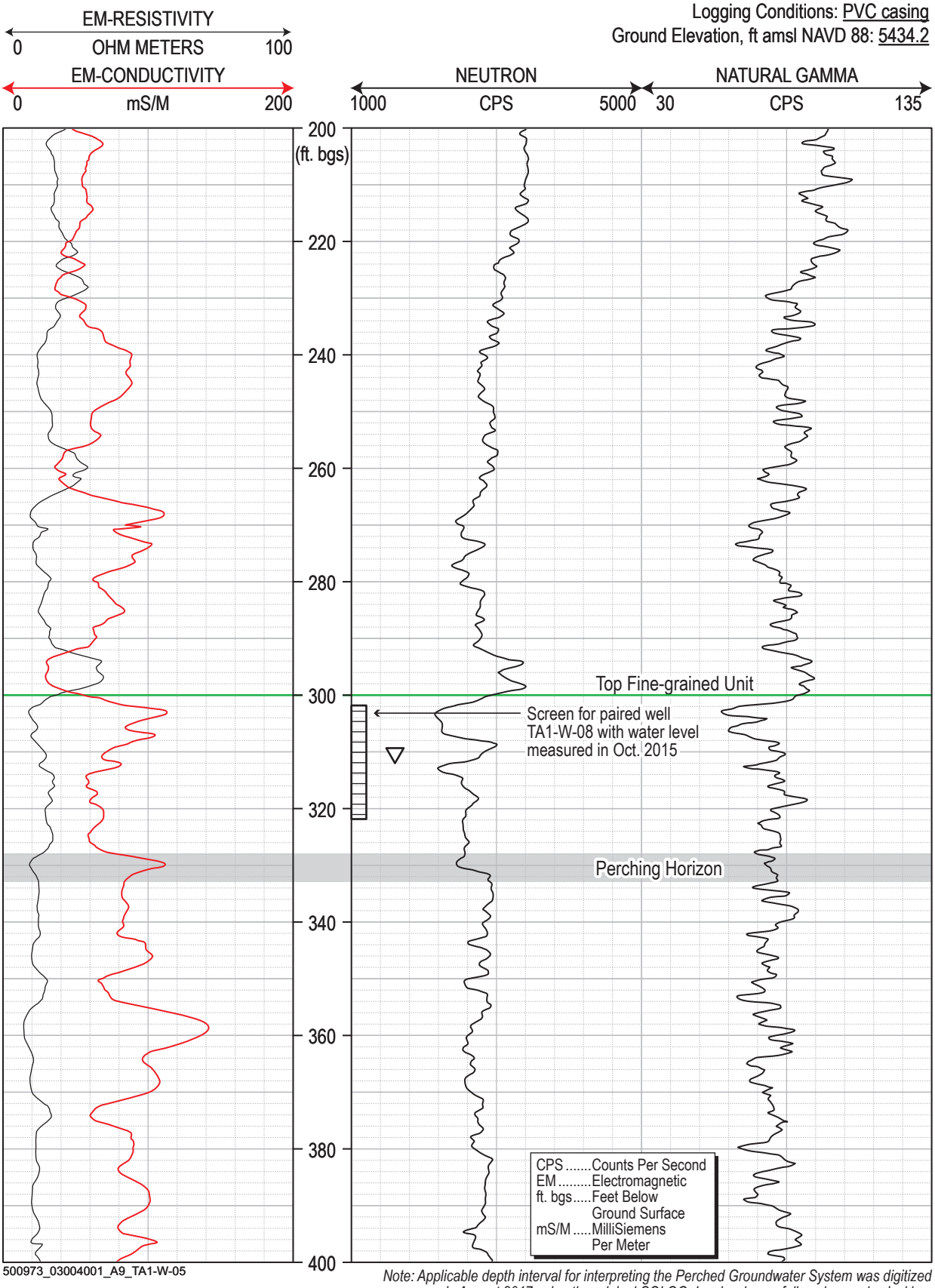


500973_03004001_A13_TA1-W-04

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

TA1-W-05
(WELL PAIR TA1-W-08)

Geophysical Logging Date: 29 April 1999
Logging Company: COLOG, Inc.
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5434.2

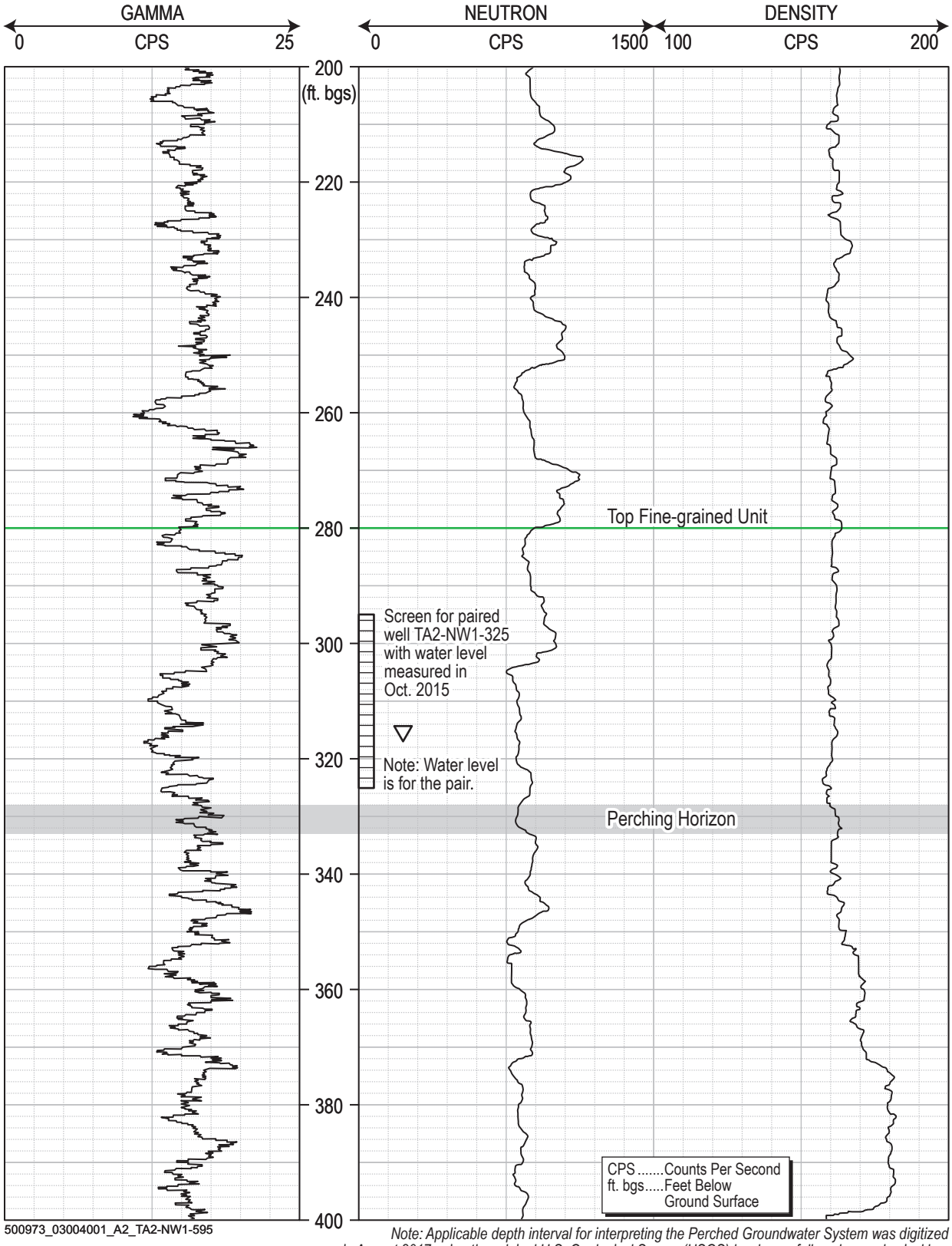


500973_03004001_A9_TA1-W-05

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003).

TA2-NW1-595
(WELL PAIR TA2-NW1-325)

Geophysical Logging Date: 15 June 1993
Logging Company: USGS
Logging Conditions: Mud filled borehole
Ground Elevation, ft amsl NAVD 88: 5420

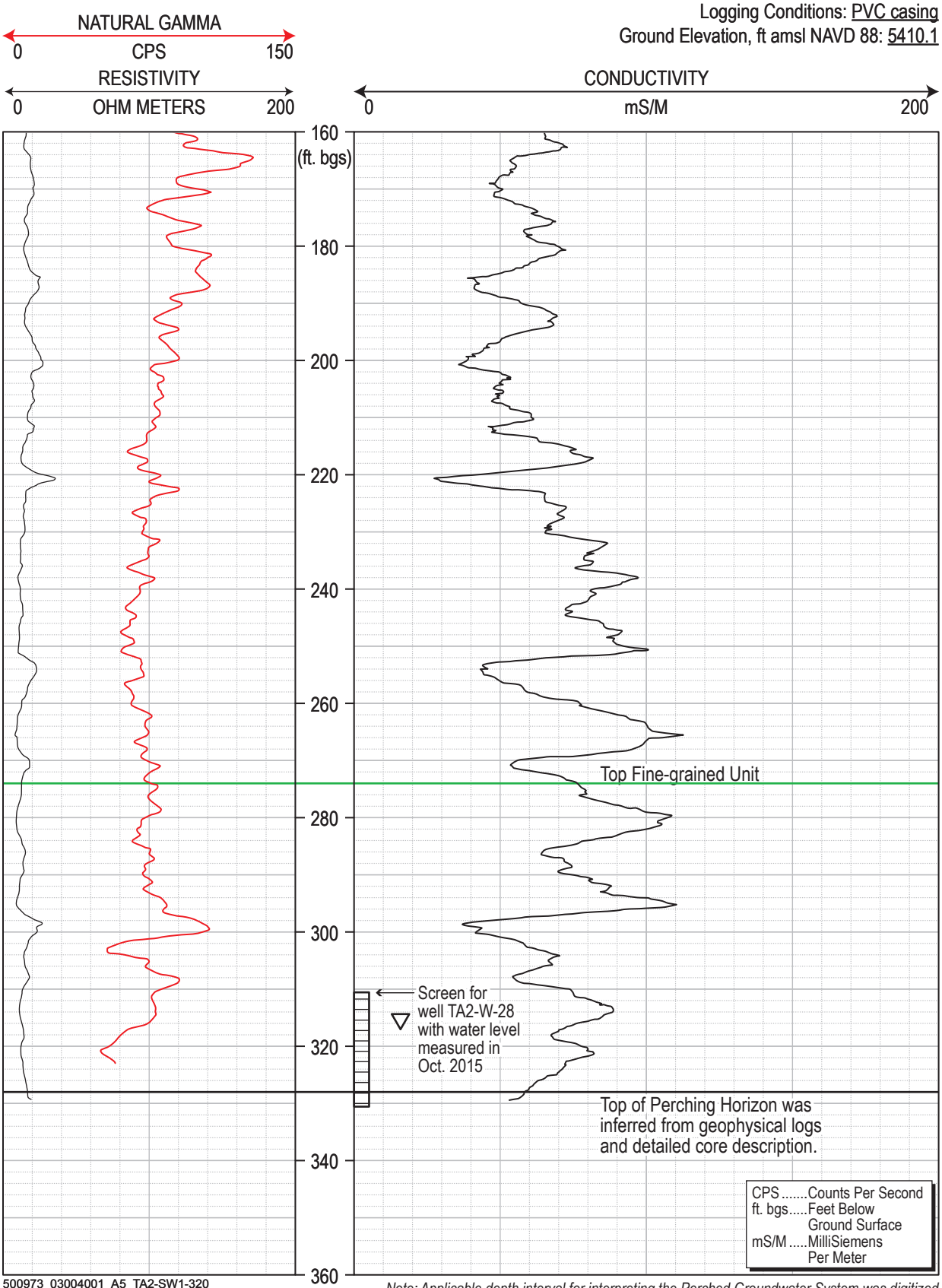


500973_03004001_A2_TA2-NW1-595

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original U.S. Geological Survey (USGS) hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

TA2-SW1-320
(REPLACED BY WELL TA2-W-28)

Geophysical Logging Date: 14 September 1994
Logging Company: COLOG, Inc.
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5410.1

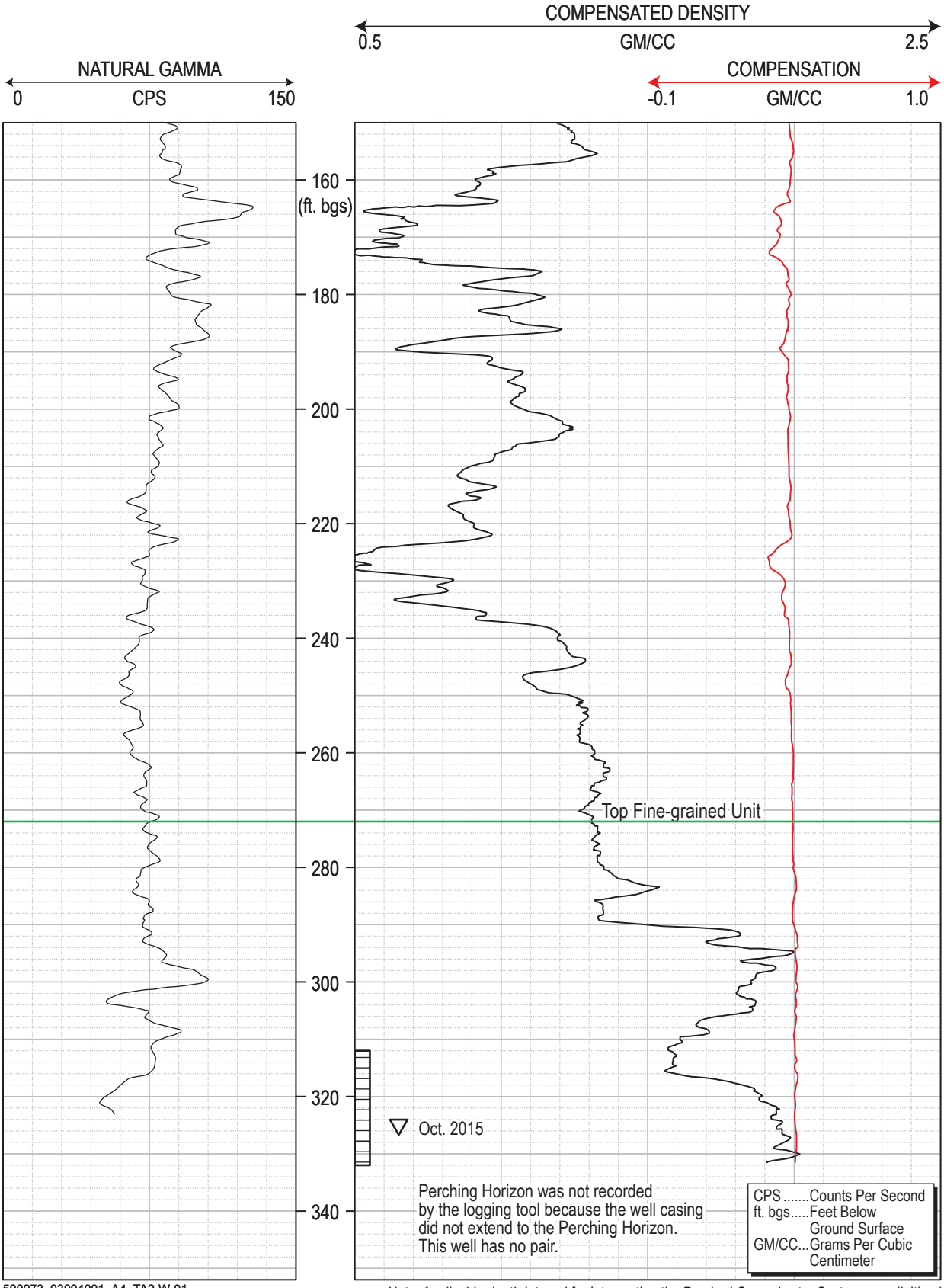


500973_03004001_A5_TA2-SW1-320

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

TA2-W-01

Geophysical Logging Date: 14 September 94
Logging Company: COLOG, Inc.
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5417.4

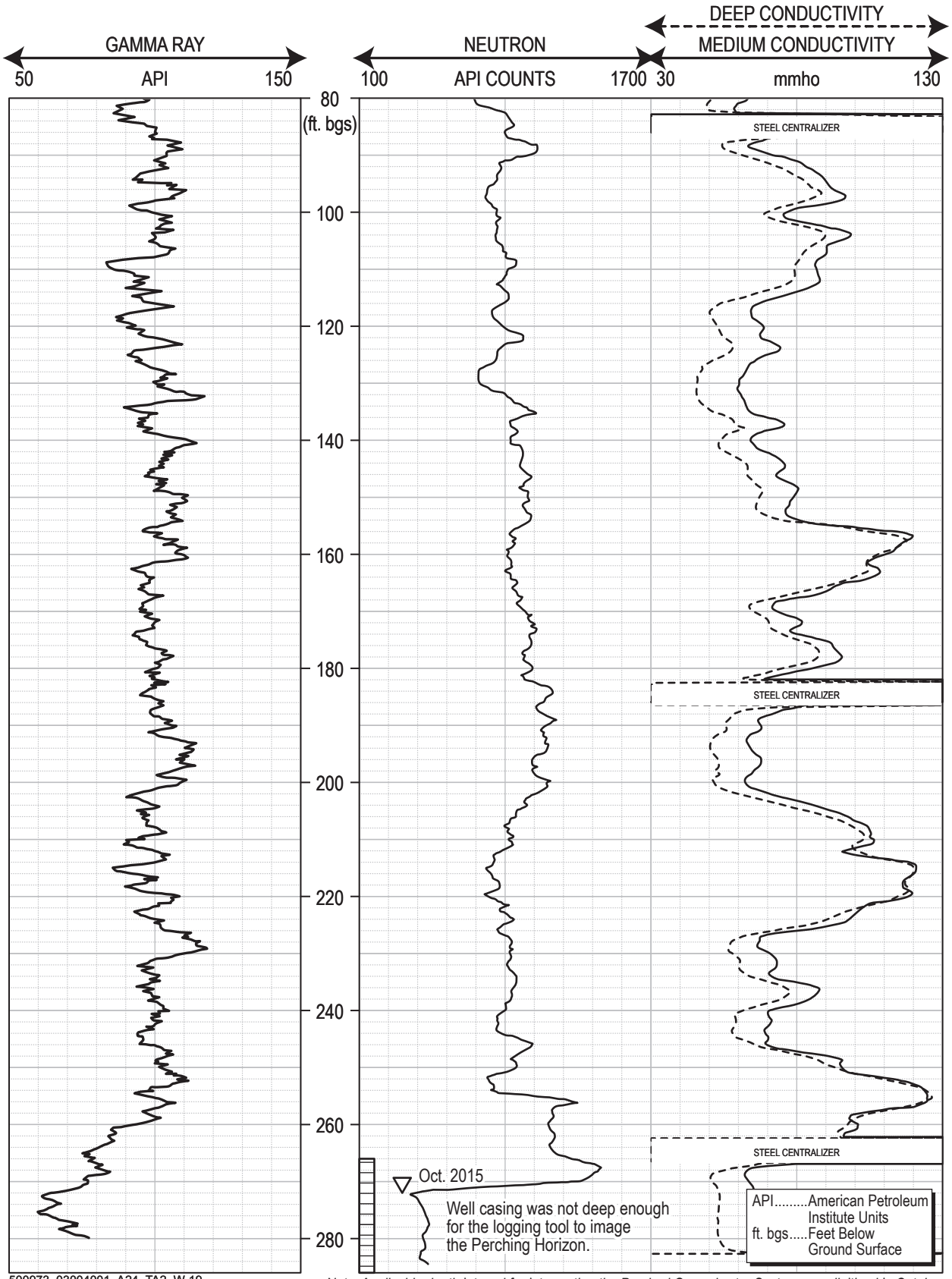


500973_03004001_A4_TA2-W-01

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003).

TA2-W-19

Geophysical Logging Date: 12 Oct 2017
Logging Company: Jet West Geophysical Services
Logging Conditions: PVC Casing
Ground Elevation, ft amsl NAVD 88: 5349.0

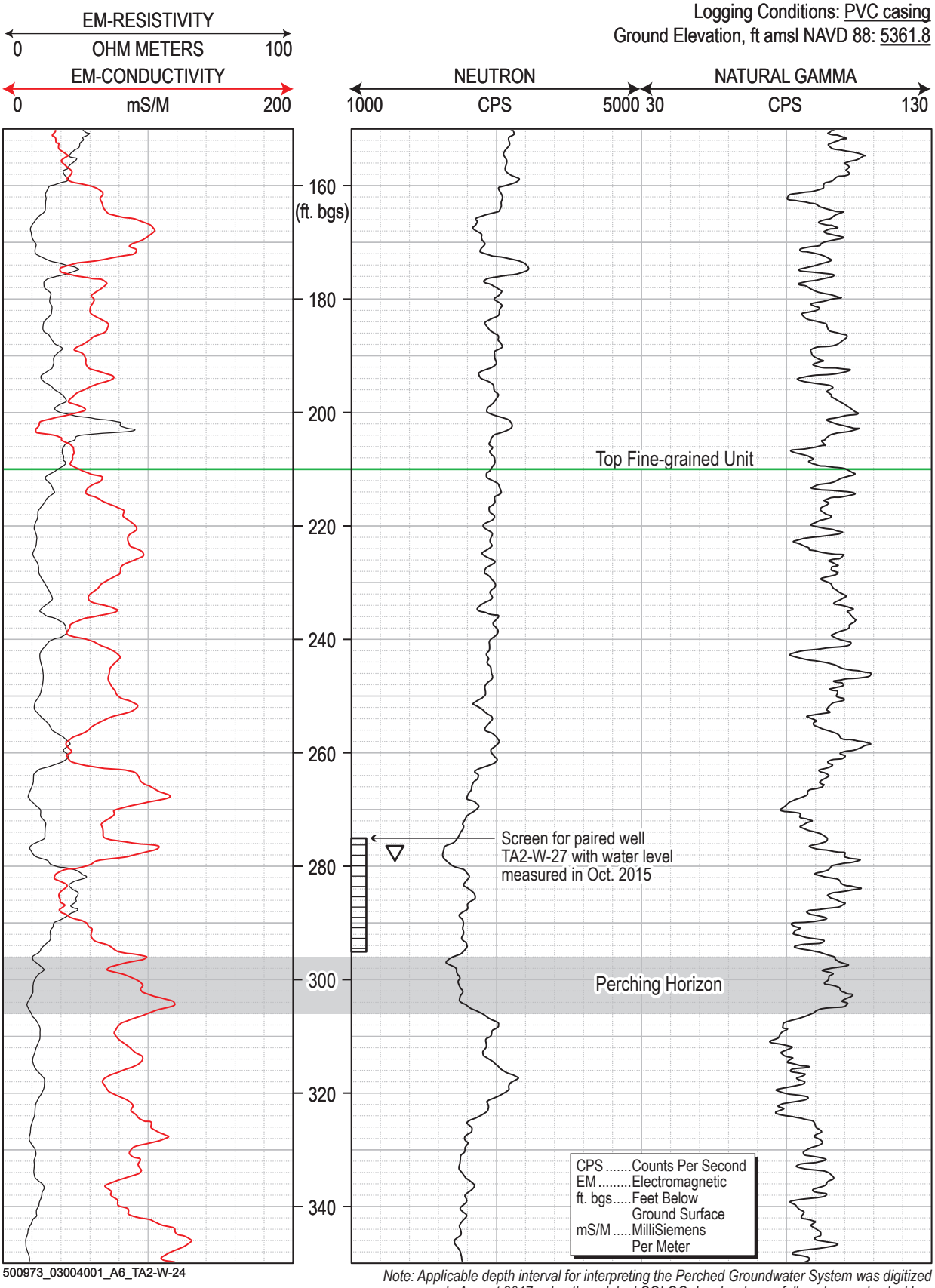


500973_03004001_A24_TA2_W-19

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in October 2017 from the geophysical log provided in the Downhole Geophysical Logging Report by Jet West, LLC. No geophysical log was available for this well when Van Hart (June 2001 and 2003) was prepared.

TA2-W-24
(WELL PAIR TA2-W-27)

Geophysical Logging Date: 28 April 1999
Logging Company: COLOG, Inc.
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5361.8

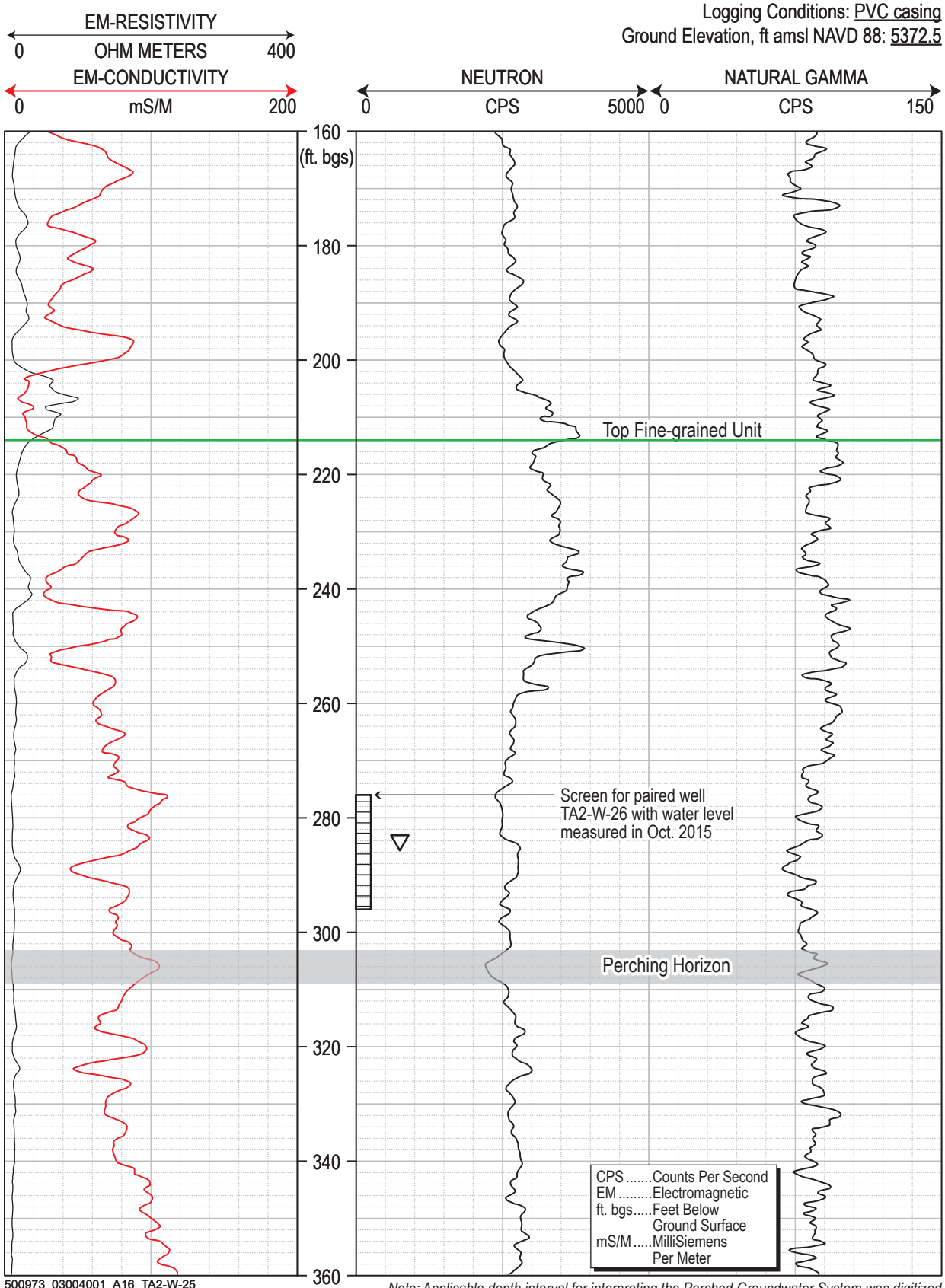


500973_03004001_A6_TA2-W-24

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

TA2-W-25
(WELL PAIR TA2-W-26)

Geophysical Logging Date: 11 August 1997
Logging Company: COLOG, Inc.
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5372.5

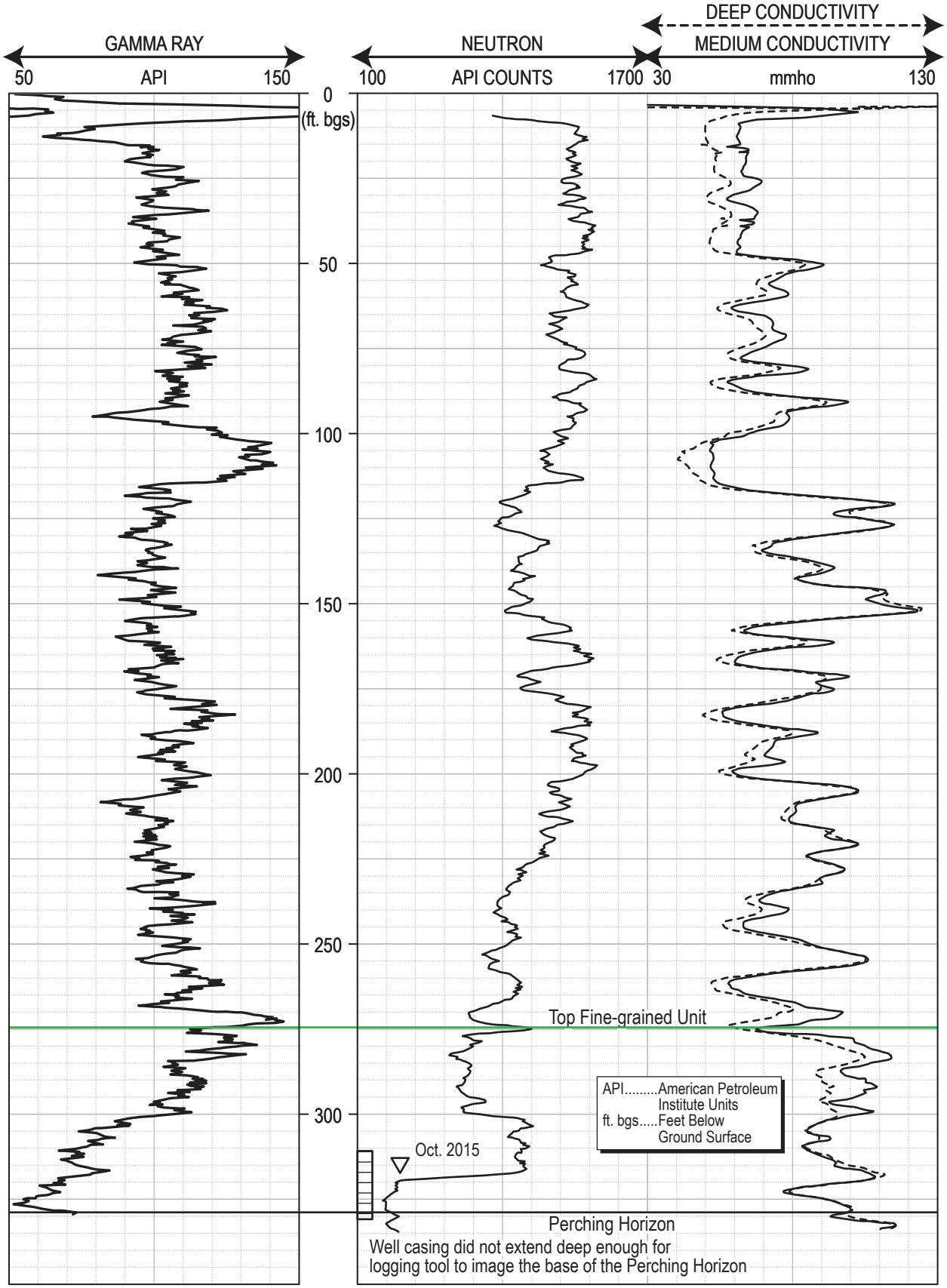


500973_03004001_A16_TA2-W-25

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

TA2-W-28
(REPLACEMENT WELL FOR TA2-SW1-320)

Geophysical Logging Date: 12 Oct 2017
Logging Company: Jet West Geophysical Services
Logging Conditions: PVC Casing
Ground Elevation, ft amsl NAVD 88: 5410.0

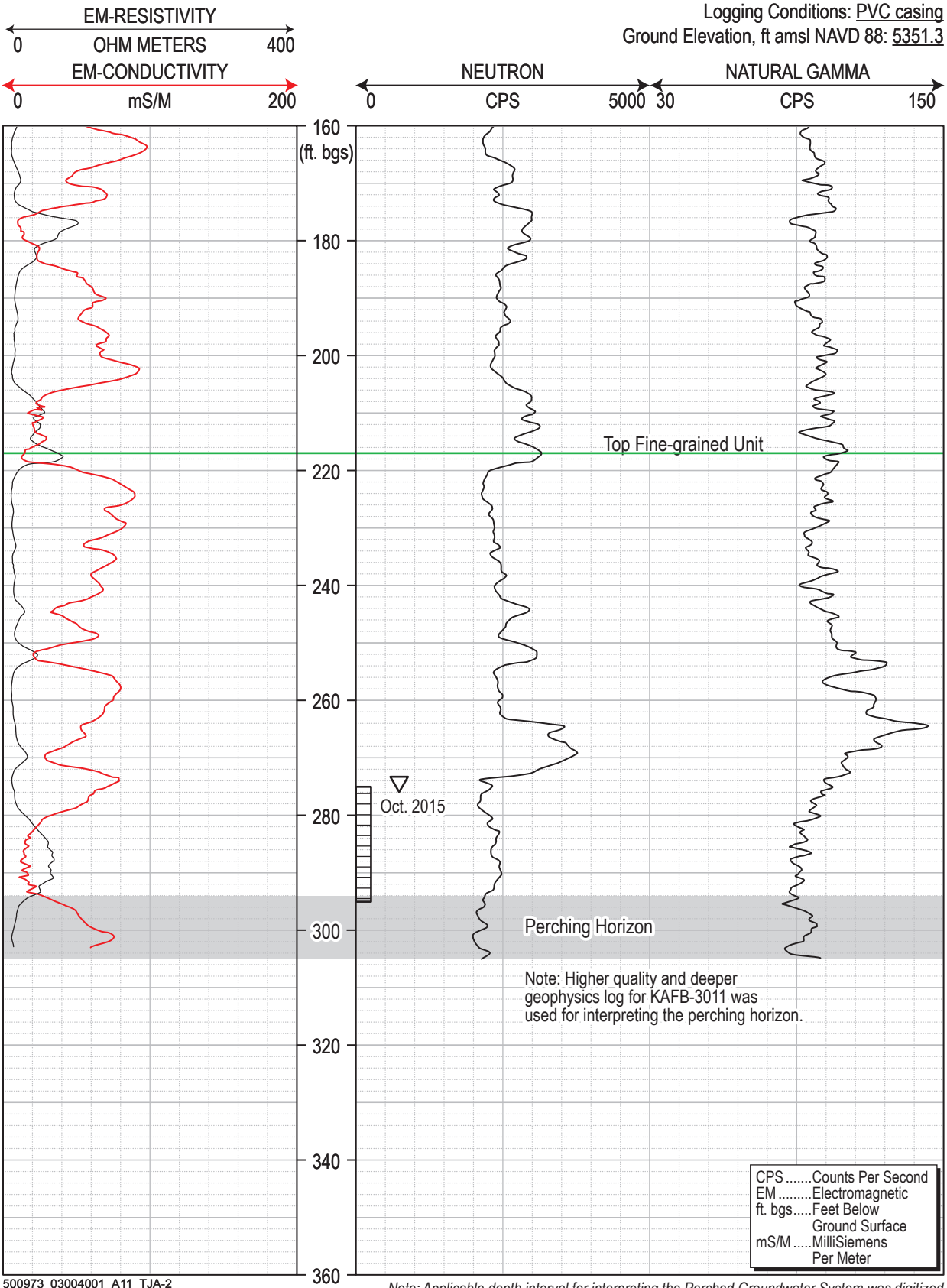


500973_03004001_A25_TA2_W-28

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in October 2017 from the geophysical log provided in the Downhole Geophysical Logging Report by Jet West, LLC. Top fine-grained unit interpreted by Van Hart (June 2001 and 2003) for Well TA2-SW1-320. The Perching Horizon was interpreted using the higher resolution original logs.

TJA-2
(REPLACEMENT WELL FOR TJA-1, WELL PAIR KAFB-0311)

Geophysical Logging Date: 12 August 1997
Logging Company: COLOG, Inc.
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5351.3

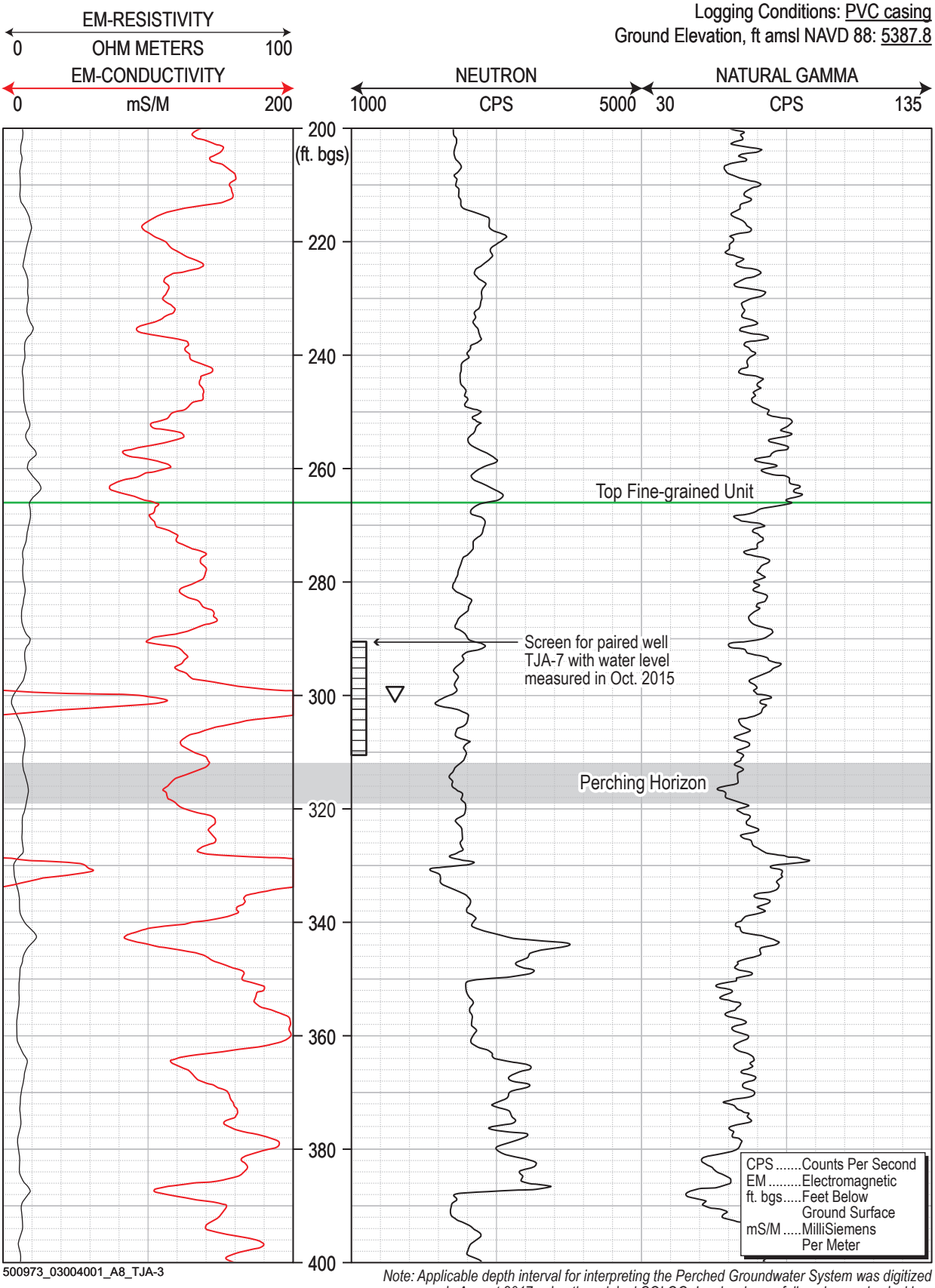


500973_03004001_A11_TJA-2

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log.
Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003).
The Perching Horizon was interpreted using the higher resolution original logs.

TJA-3
(WELL PAIR TJA-7)

Geophysical Logging Date: 27 April 1999
Logging Company: COLOG, Inc.
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5387.8

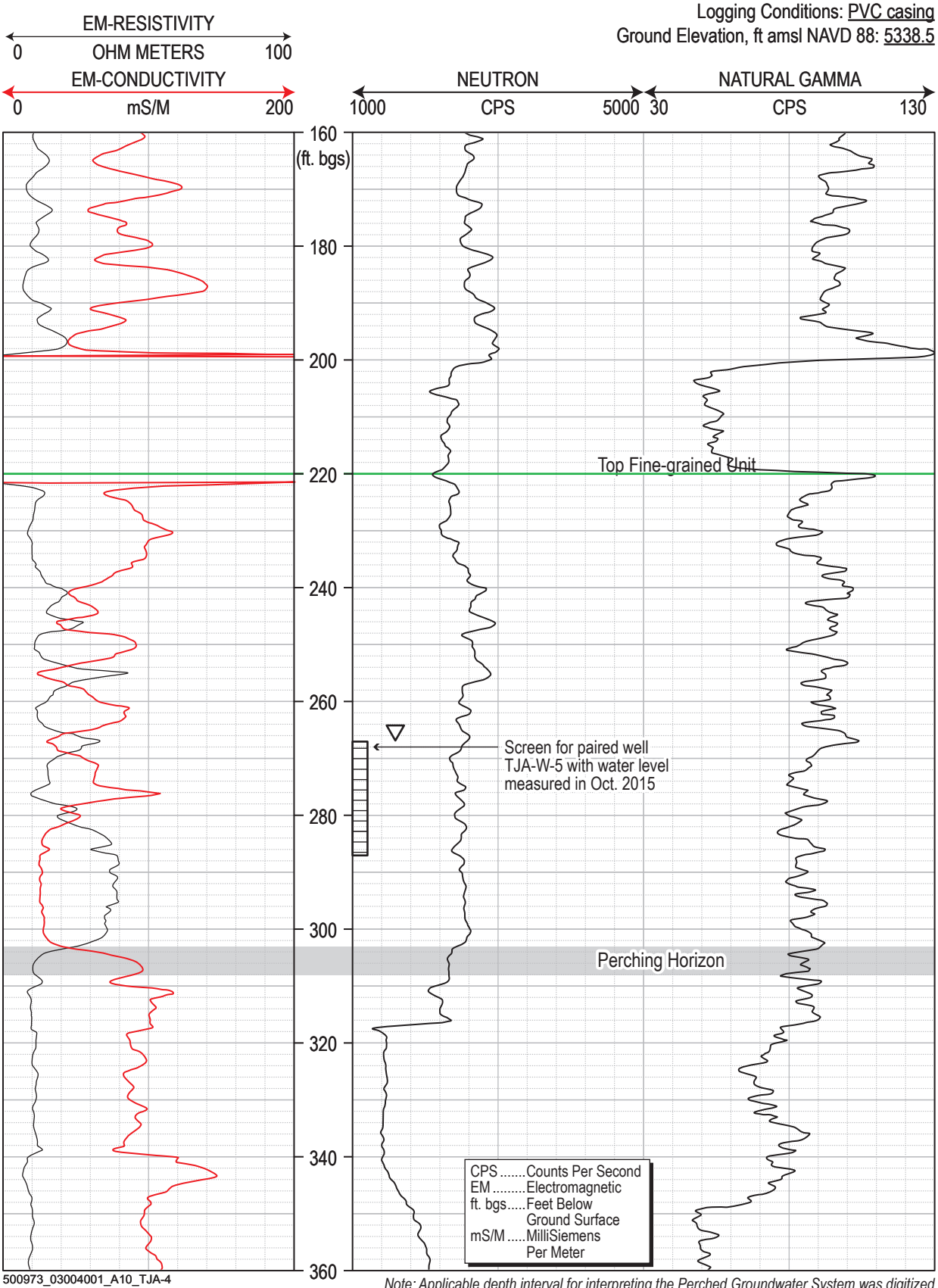


500973_03004001_A8_TJA-3

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

TJA-4
(WELL PAIR TJA-5)

Geophysical Logging Date: 28 April 1999
Logging Company: COLOG, Inc.
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5338.5

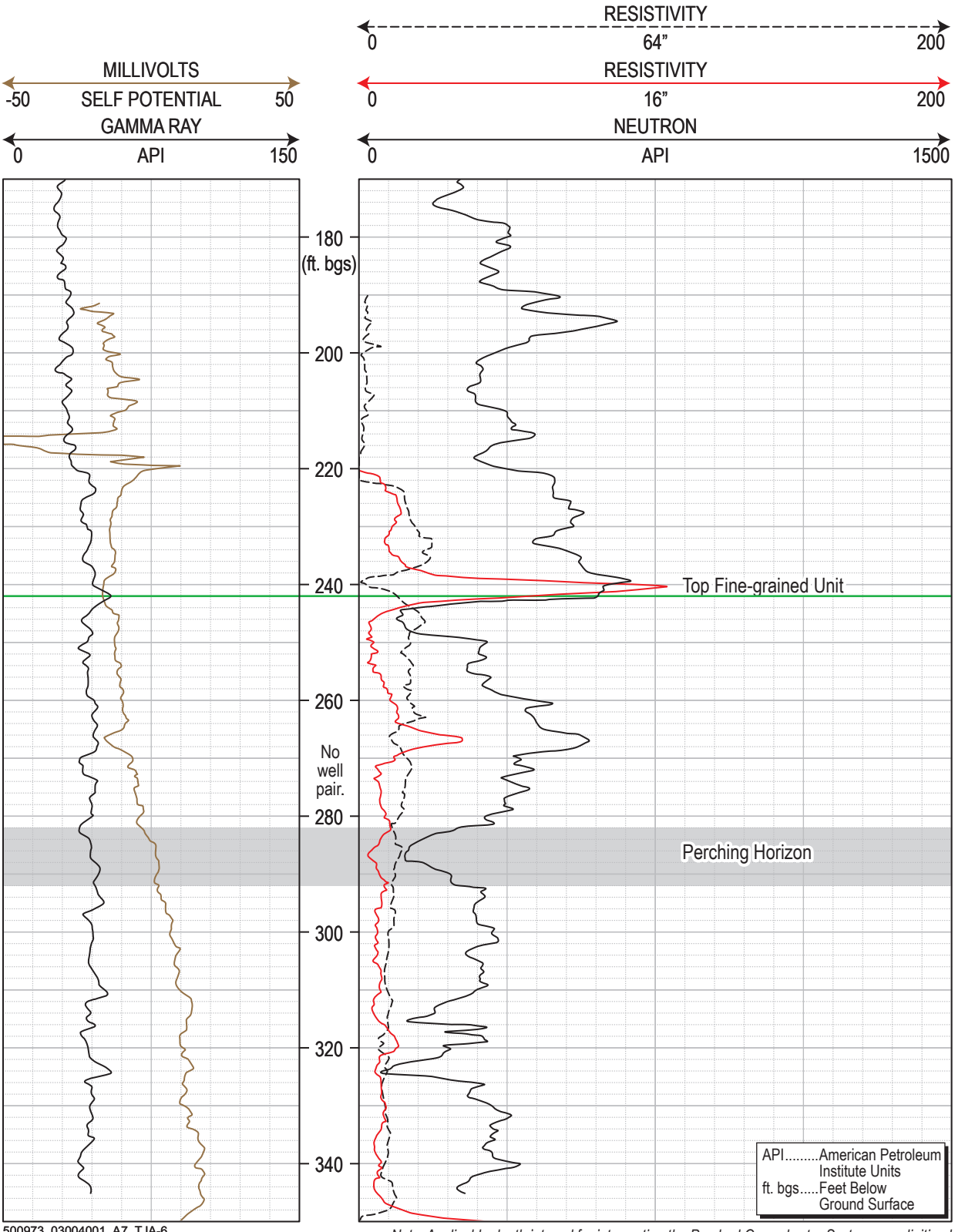


500973_03004001_A10_TJA-4

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

TJA-6

Geophysical Logging Date: 31 January 2001
Logging Company: Southwest Geophysical Services, Inc.
Logging Conditions: Mud filled borehole
Ground Elevation, ft amsl NAVD 88: 5340.6

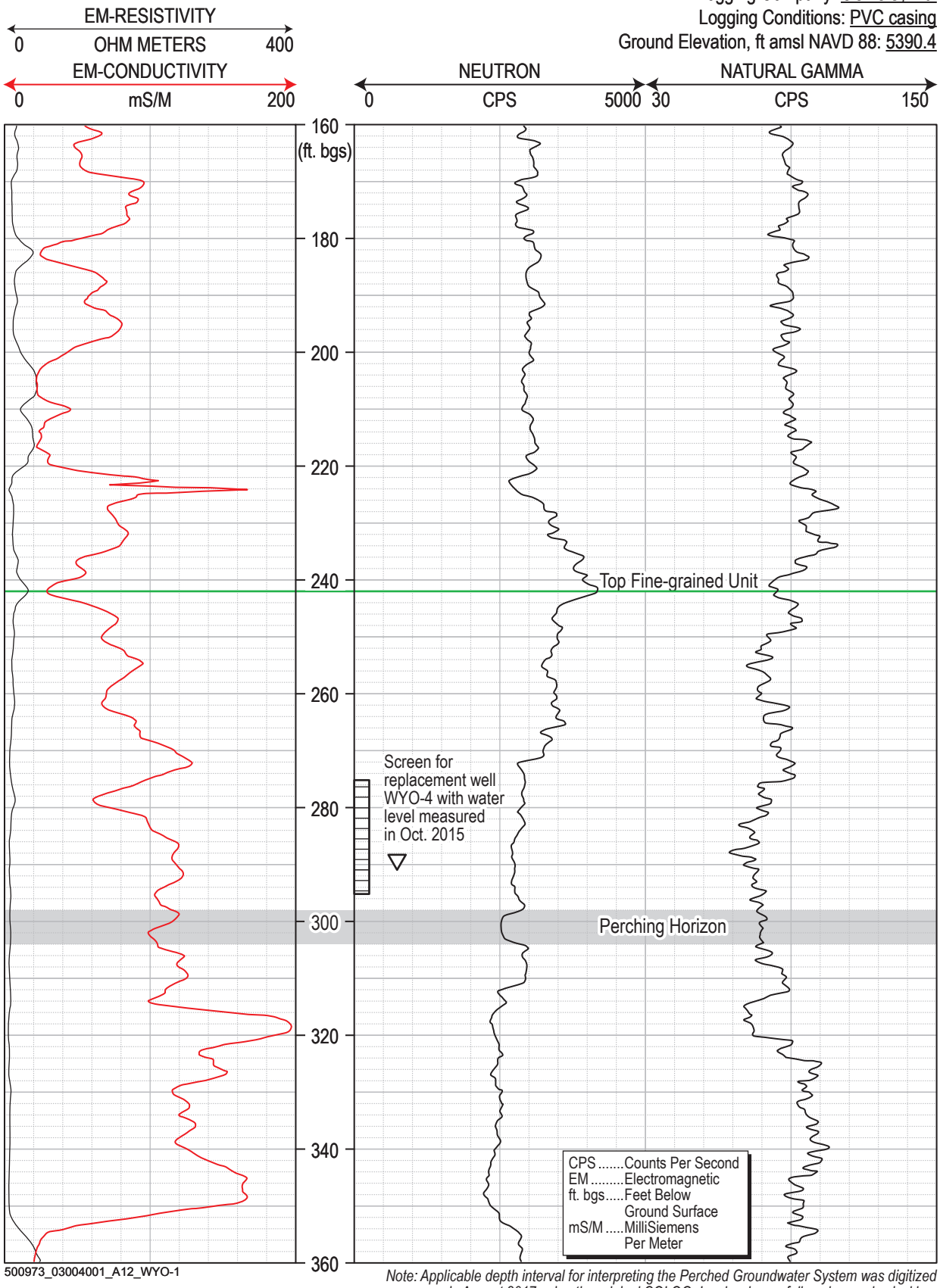


500973_03004001_A7_TJA-6

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original Southwest Geophysical Services, Inc. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

WYO-1
(WELL CLUSTER WITH WYO-2.
REPLACEMENT WELLS ARE WYO-3 AND WYO-4)

Geophysical Logging Date: 12 August 1997
Logging Company: COLOG, Inc.
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5390.4

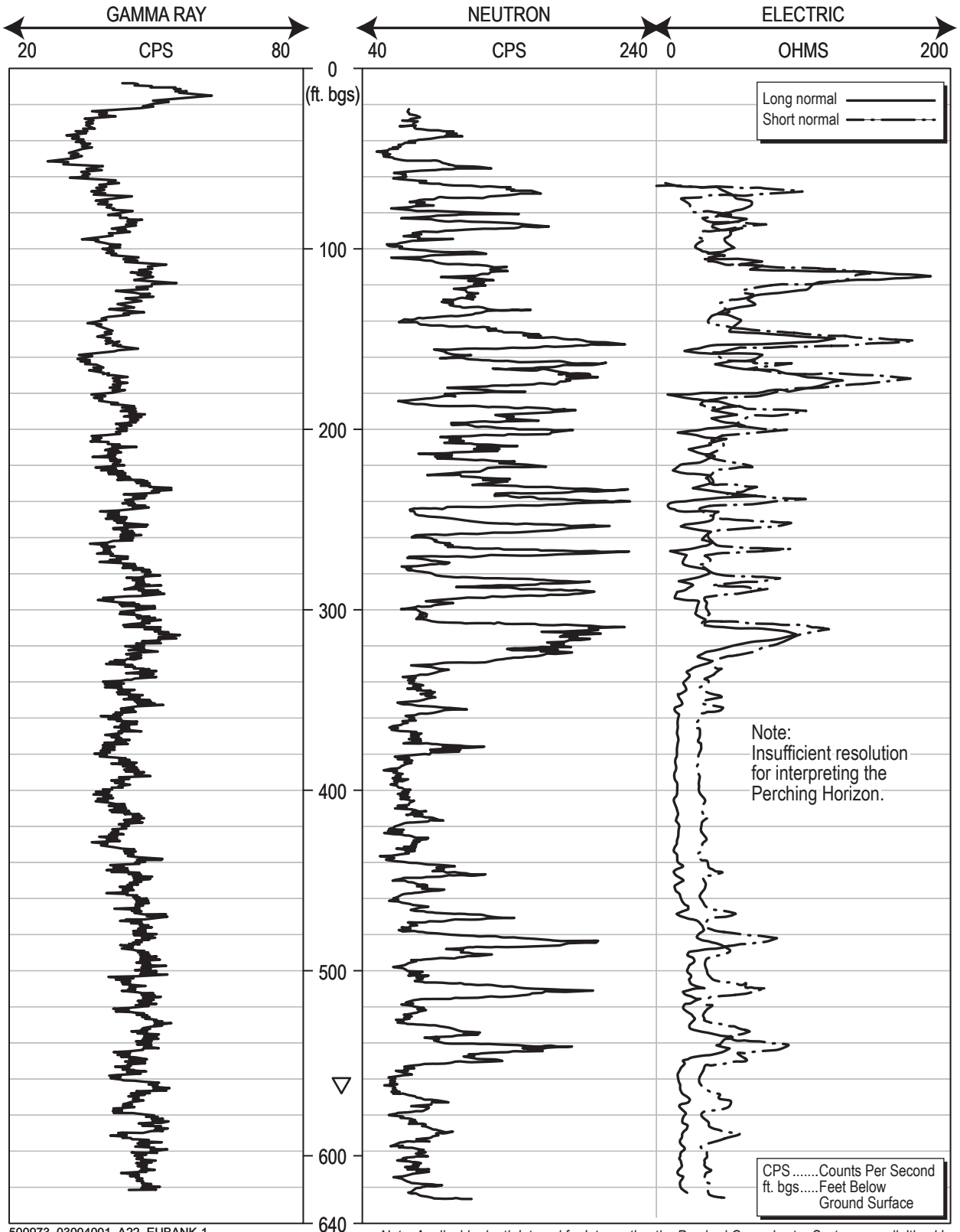


500973_03004001_A12_WYO-1

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

EUBANK-1

Geophysical Logging Date: July 1998
Logging Company: USGS
Logging Conditions: Mud filled borehole
Ground Elevation, ft amsl NAVD 88: 5458.1

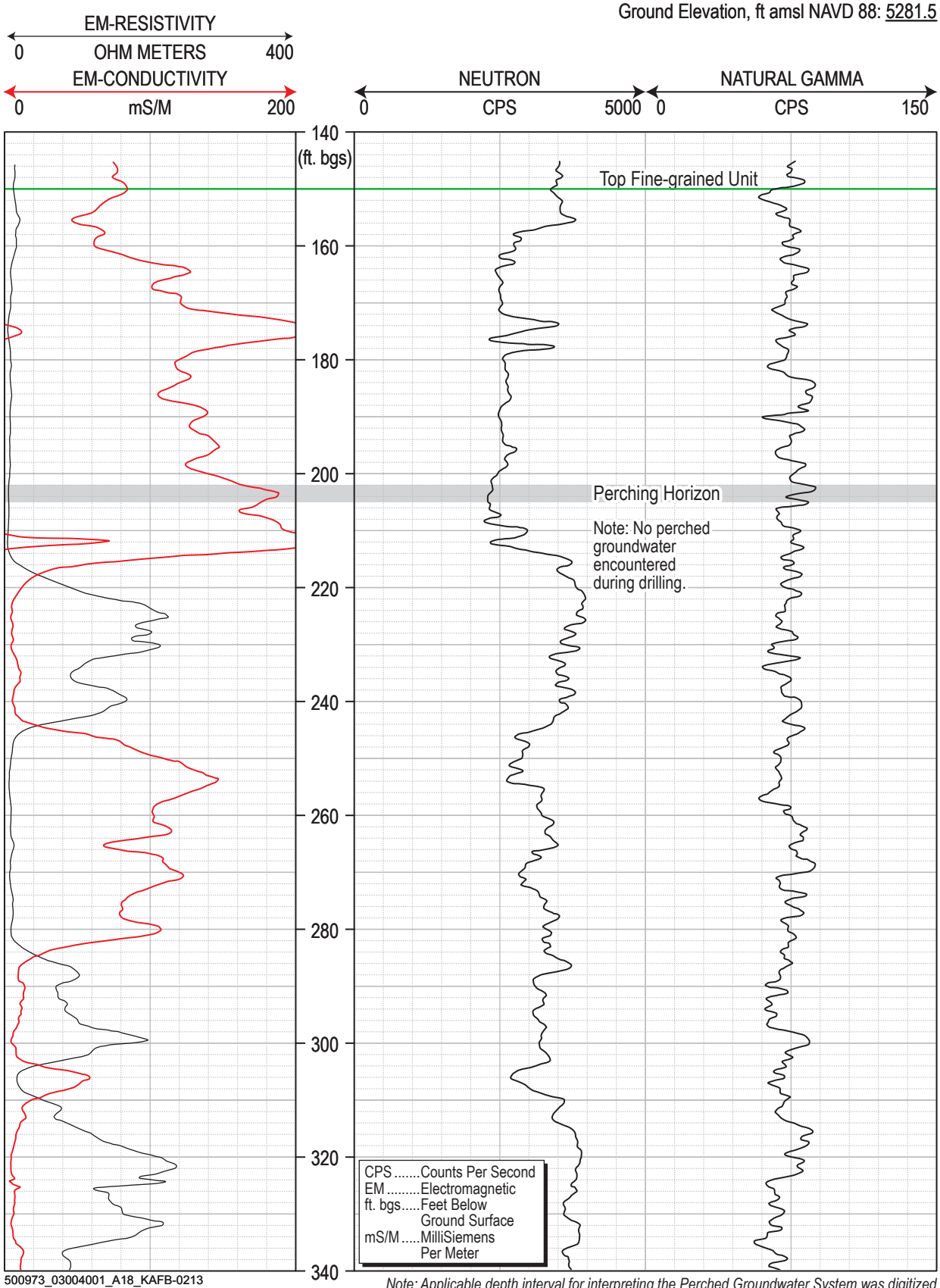


500973_03004001_A22_EUBANK-1

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in October 2017 using a USGS hard copy geophysical log.

KAFB-0213

Geophysical Logging Date: 6 August 1997
Logging Company: COLOG, Inc.
Logging Conditions: PVC Casing
Ground Elevation, ft amsl NAVD 88: 5281.5

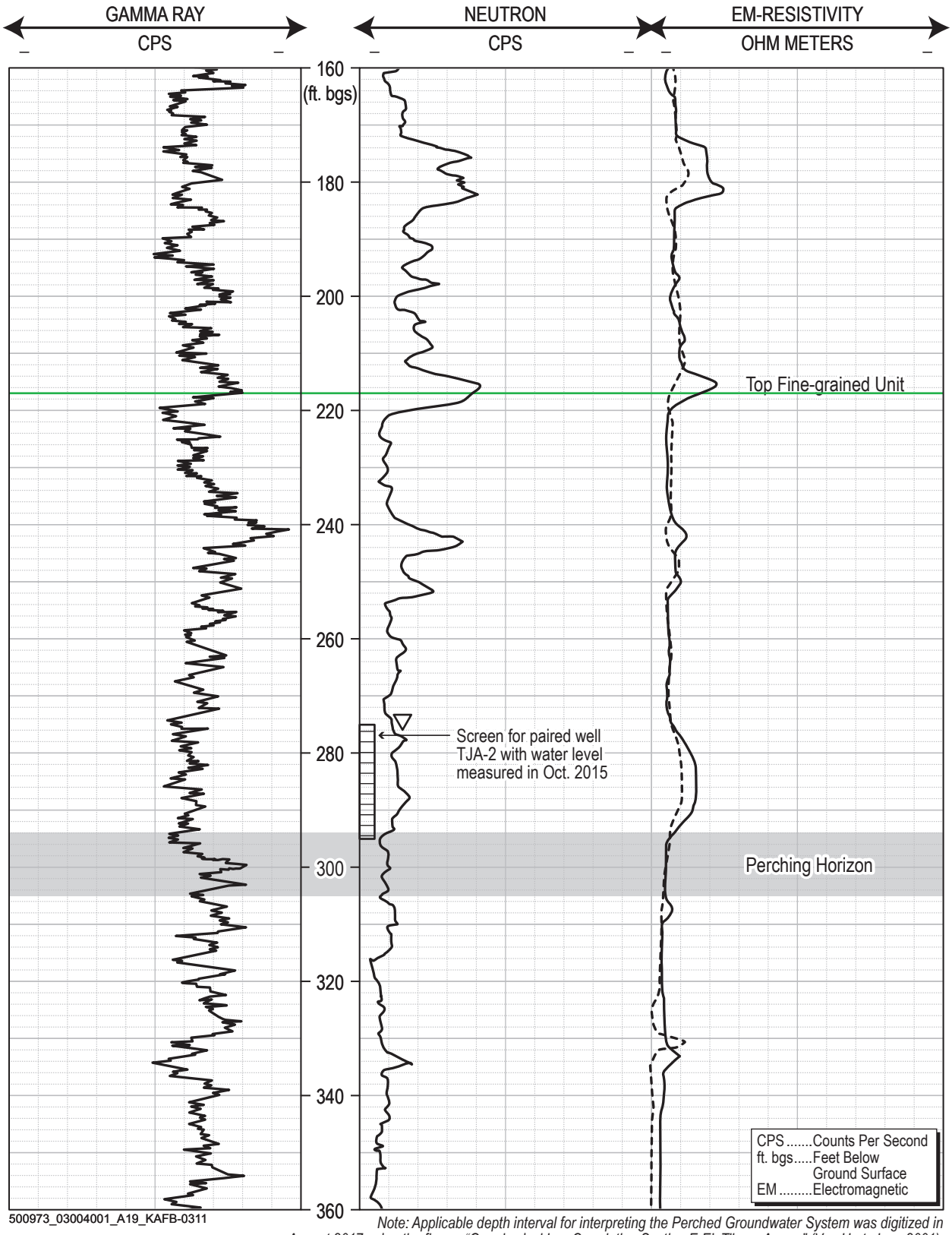


500973_03004001_A18_KAFB-0213

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original COLOG, Inc. hard copy full-scale geophysical log.
Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003).
The Perching Horizon was interpreted using the higher resolution original logs.

KAFB-0311
(WELL PAIR TJA-2)

Geophysical Logging Date: 24 July 1992
Logging Company: USGS
Logging Conditions: Mud filled borehole
Ground Elevation, ft amsl NAVD 88: 5351.7

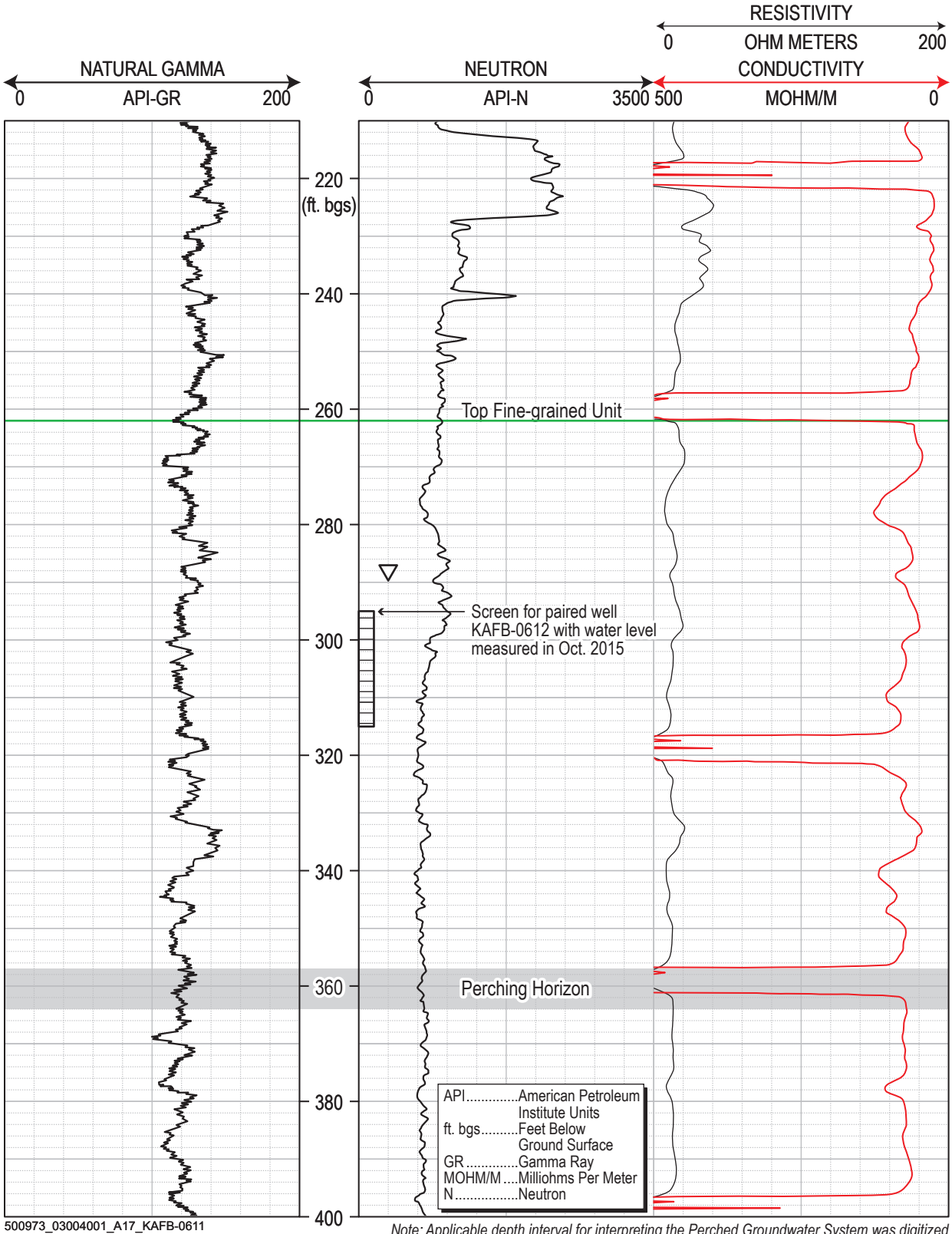


500973_03004001_A19_KAFB-0311

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the figure, "Geophysical Log Correlation Section E-E', Tijeras Arroyo" (Von Hart, June 2001). Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). Geophysical logging units not available. The Perching Horizon was interpreted using the higher resolution original logs.

KAFB-0611
(WELL PAIR KAFB-0612)

Geophysical Logging Date: 5 February 2003
Logging Company: Century Geophysics
Logging Conditions: PVC casing
Ground Elevation, ft amsl NAVD 88: 5383.5



500973_03004001_A17_KAFB-0611

Note: Applicable depth interval for interpreting the Perched Groundwater System was digitized in August 2017 using the original Century Geophysical Corp. hard copy full-scale geophysical log. Top Fine-grained Unit interpreted by Van Hart (June 2001 and June 2003). The Perching Horizon was interpreted using the higher resolution original logs.

ATTACHMENT 4
Index of Borehole Lithologic Logs for Monitoring Wells Installed in the TAG AOC

Attachment 4
Index of Borehole Lithologic Logs for Monitoring Wells Installed in the TAG AOC

Well ID	Drilling Method	Dates of Drilling Operations*	Core Barrel Intervals (ft bgs)	Split Spoon Intervals (ft bgs)
PGS-1	MR	Jul 21 to Aug 5, 1994	10 to 27, 320 to 327	10 to 27.3
PGS-2	MR	Sep 9 to 12, 1995	None	None
TA1-W-01	ARCH	Mar 6 to 17, 1997	None	40 to 41.5, 140 to 141.5, and 260 to 261.5
TA1-W-02	ARCH	Feb 11 to 17, 1998	None	80 to 81, 200 to 201, and 320 to 321
TA1-W-03	ARCH	Jan 19 to 21, 1998	None	None
TA1-W-04	ARCH	Sep 8 to Oct 6, 1998	None	51 to 52, 91 to 92, 152 to 153, and 252 to 253
TA1-W-05	ARCH	Oct 8 to 11, 1998	None	60 to 61, 160 to 165, and 257 to 260
TA1-W-06	ARCH	Feb 24 to 25, 1998	None	None
TA1-W-07	ARCH	Aug 11 to 13, 1998	None	None
TA1-W-08	ARCH	Aug 1 to 3, 2001	None	None
TA2-NW1-325	ARCH&S	Mar 7 to 22, 1993	0 to 330	None
TA2-NW1-595	ARCH&S	May 17 to Jun 25, 1993	325 to 650	None
TA2-SW1-320	ARCH&S	Nov 2 to 19, 1992	0 to 330	None
TA2-W-01	ARCH&S	Mar 9 to Jun 22, 1994	0 to 151	200 to 202, 260 to 262, and 297 to 299
TA2-W-19	ARCH	Nov 7 to 9, 1995	None	None
TA2-W-24	ARCH	Jan 27 to 30, 1998	None	60 to 61, 160 to 161, and 260 to 261
TA2-W-25	ARCH	Mar 24 to 27, 1997	None	40 to 42, 160 to 162, and 290 to 292
TA2-W-26	ARCH	Jan 12 to 14, 1998	None	None
TA2-W-27	ARCH	Feb 4 to 6, 1998	None	None
TA2-W-28	ARCH	Nov 20 to Dec 5, 2014	None	None
TJA-1	MR	Jun 8 to 21, 1994	220 to 295	None
TJA-2	MR	Jul 9 to 11, 1994	285 to 290	None
TJA-3	ARCH	Aug 14 to 26, 1998	None	37 to 39, 99 to 101, 137 to 139, 314 to 316, and 512 to 514
TJA-4	ARCH	Jul 28 to 31, 1998	None	57 to 58.5, 157 to 158.5, 259 to 261, and 399 to 401
TJA-5	ARCH	Aug 5 to 7, 1998	None	None
TJA-6	ARCH&MR	Jan 16 to 30, 2001	None	45.5 to 47, 95.5 to 97, 145.5 to 147, 195.5 to 197, and 245.5 to 247
TJA-7	ARCH	Mar 2 to 7, 2001	None	45 to 47, 95 to 97, 145 to 147, 195 to 197, 245 to 247, and 295 to 297
WYO-1	MR	Aug 15 to 27, 1995	None	None for well cluster**
WYO-2	MR	Aug 15 to 27, 1995	n.a.	None for well cluster**

Refer to footnotes at end of table.

Attachment 4 (Concluded)
Index of Borehole Lithologic Logs for Monitoring Wells Installed in the TAG AOC

Well ID	Drilling Method	Dates of Drilling Operations*	Core Barrel Intervals (ft bgs)	Split Spoon Intervals (ft bgs)
WYO-3	ARCH	Jul 24 to 31, 2001	None	None for replacement well**
WYO-4	ARCH	Jul 21 to 23, 2001	None	None for replacement well**
Eubank-1	MR	Jul 11 to 15, 1998	None	None

Note:
Lithologic logs were compiled by J.R. Copland using the original hand-written field logs. Minor editing was done.
Green shading indicates that well is screened in the Perched Groundwater System.
Depending on location, the core barrel was 5- or 10-ft long.
*Dates of drilling operations include borehole drilling and construction of well casing; does not include well development (bailing, surging, or pumping of well casing).
**Monitoring wells WYO-1 and WYO-2 comprised a well cluster. In August 1995, the two wells were installed in the same borehole. In July 2001, the wells were plugged and abandoned because the annular seal between the two well screens was not effective. Two replacement wells (WYO-3 and WYO-4) were subsequently installed in individual boreholes.
Well PGS-2 is the replacement well for well PGS-1. Located 29 ft apart.
Well TA2-W-28 is the replacement well for well TA2-SW1-320. Located 24 ft apart.
Well TJA-1 is the replacement well for well TJA-2. Located 25 ft apart.
ARCH = Air rotary casing hammer (with temporary drive casing).
ARCH&S = Air rotary casing hammer and sonic (both with temporary drive casing).
ft bgs = Feet below ground surface.
MR = Mud rotary (no drive casing).
SS = Split spoon, 18 or 24 inches long.

ATTACHMENT 5
Lithologic Logs for the TAG AOC

Lithologic log for borehole at monitoring well Eubank-1

Drilling company	Rodgers and Company
Dates of drilling	July 11 to 15, 1998
Drilling method	Mud Rotary
Total depth of borehole, ft	630
Ground elevation, ft amsl NAVD 88	5458.1
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Screen, ft bgs	550.0 to 610.0
Date developed	July 16, 1998
Initial water level, ft bgs	552.0
Rig Geologist	Doug Earp, City of Albuquerque - Environmental Health Department

Depth, ft bgs	Description
0-5	Silty, sandy, gravel; poorly- to moderately-sorted. Silt (25 percent), light brown (7.5YR 6/4). Sand (25 percent), medium- to very coarse grained, subangular, mainly clear and white quartz, lesser amounts of black quartzite and white feldspar, and minor biotite. Pebbles and granules (50 percent) to 10 mm, subangular, mainly quartz and dark metamorphic rock fragments with lesser amounts of granite. Violently effervescent to HCl, discontinuous carbonate coatings on most grains.
5-10	Sandy, gravelly silt; poorly- to moderately-sorted. Silt (40 percent), pink (7.5YR 8/4). Sand (30 percent), medium- grained, subangular, mainly clear and white quartz with lesser amounts of white feldspar. Granules (30 percent) to 4 mm, subangular, mainly white quartz and dark quartzite. Violently effervescent to HCl, hard carbonate masses and continuous carbonate grain coatings.
10-20	Silty, sandy, gravel; poorly- to moderately-sorted. Silt (30 percent), pink (7.5YR 7/4). Sand (25 percent), fine- to medium-grained, subangular, mainly clear and white quartz with minor biotite. Pebbles and granules (45 percent) to 6 mm, subangular, mainly white quartzite and granite with minor dark quartzite. Violently effervescent to HCl, hard carbonate masses and discontinuous carbonate grain coatings.
20-30	Gravelly sand; poorly- to moderately-sorted. Silt (5 percent), light brown (7.5YR 6/4). Sand (60 percent), medium- to coarse grained, subangular, mainly clear quartz and dark· quartzite, lesser amounts of granite, and minor biotite. Pebbles and granules (35 percent) to 8 mm, subangular, mainly dark metamorphic rock fragments white quartz with lesser amounts of granite. Strongly effervescent to HCl.
30-35	Silty, sandy gravel; poorly-sorted. Silt (20 percent), light brown (7.5YR 6/4). Sand (30 percent), medium-to very coarse-grained, subangular, mainly clear and white quartz, lesser amounts of white feldspar, and minor biotite. Pebbles and granules (50 percent) to 8 mm, subangular, mainly dark metamorphic rock fragments and quartz. Violently effervescent to HCl.
35-50	Gravelly sand; moderately-sorted. Silt (5 percent) light brown (7.5YR 6/4). Sand (65 percent), medium- to coarse-grained, subangular, mainly clear quartz and white feldspar with minor pink feldspar, biotite, and limestone. Granules (30 percent) to 4 mm, subangular, mainly white quartz and granite, lesser amounts of rose, clear, and dark quartz, and minor dark metamorphic rock fragments. Strongly effervescent to HCl.
50-60	Sandy gravel; poorly- to moderately-sorted. Silt (5 percent), light brown (7.5YR 6/4). Sand (40 percent), medium- to very coarse-grained, subangular, mainly white quartz and quartzite, lesser amounts of pink and white feldspar, and minor dark quartzite and biotite. Pebble and granules (55 percent) to 8 mm, subangular, mainly dark metamorphic rock fragments with lesser amounts of granite and white quartz. Slightly effervescent to HCl.

Depth, ft bgs	Description
60-70	Silty, sandy gravel; poorly-sorted. Silt (15 percent), brown (7.5YR 5/4). Sand (30 percent), fine-to coarse-grained, subangular to subrounded, mainly clear and white quartz and quartzite, lesser amounts of dark metamorphic rock fragments, and minor biotite. Pebbles and granules (55 percent) to greater than 10 mm, subrounded, mainly dark metamorphic rock fragments and white quartz with lesser amounts of clear quartz and granite. Strongly effervescent to HCl.
70-80	Sandy gravel; poorly-sorted. Silt (5 percent), brown (7.5YR 5/4). Sand (25 percent), coarse- to very coarse- grained, subangular, mainly clear and white quartz with minor biotite, pink feldspar, and rose quartz. Pebbles and granules (70 percent) to 10 mm, subangular, mainly white quartz, white feldspar, and dark metamorphic rock fragments with lesser amounts of granite. Strongly effervescent to HCl.
80-90	Gravelly sand; moderately-sorted. Silt (5 percent), brown (7.5 YR 5/4). Sand (60 percent), medium-to very coarse-grained, subangular, mainly white quartzite and feldspar, lesser amount of clear quartz, and minor dark metamorphic rocks fragments, biotite, and pink feldspar. Granules (40 percent) to 4 mm, subangular, mainly white quartz, white feldspar, and dark metamorphic rock fragments with lesser amounts of granite. Strongly effervescent to HCl.
90-100	Silty, sandy gravel; poorly-sorted. Silt (20 percent), light brown (7.5YR 6/4). Sand (30 percent), coarse-to very coarse-grained, subangular, mainly clear quartz and white feldspar with minor biotite and dark metamorphic rock fragments. Pebbles and granules (50 percent) to 6 mm, subangular, mainly white feldspar and quartz with lesser amounts of dark metamorphic rock fragments. Violently effervescent to HCl.
100-115	Gravelly sand; poorly- to moderately-sorted. Silt (5 percent), light brown (7.5 YR 6/4). Sand (60 percent), medium-to very coarse-grained, subangular, mainly clear quartz with minor biotite, pink feldspar and white feldspar. Granules (35 percent) to 3 mm with few pebbles to 6 mm, subangular, mainly clear and dark quartz and white feldspar with lesser amounts of dark metamorphic rock fragments and granite. Strongly effervescent to HCl.
115-120	Sandy gravel; poorly-sorted. Sand (25 percent), coarse- to very coarse- grained, angular, mainly clear and white quartz, lesser amounts of white feldspar, and minor biotite, dark metamorphic rock fragments, pink feldspar and rose quartz. Pebbles and granules (60 percent) to 6 mm, angular, mainly white quartz and feldspar with lesser amounts of granite and dark metamorphic rock fragments. Slightly effervescent to HCl.
120-130	Gravelly sand, moderately-sorted. Sand (65 percent), very coarse-grained, subangular, mainly clear quartz with lesser amounts of biotite, dark metamorphic rocks fragments, and pink feldspar. Granules (35 percent) to 4 mm, subangular, mainly clear and dark quartz, white feldspar, and gray limestone with minor dark metamorphic rock fragments and granite. Slightly effervescent to HCl.
130-135	Silty gravelly sand; poorly-sorted. Silt (25 percent), light brown (7.5YR 6/4). Sand (45 percent), fine- to very coarse-grained, subangular, mainly clear quartz, lesser amounts of white feldspar and dark metamorphic rock fragments, and minor biotite. Granules (30 percent) to 4 mm, subangular, mainly white feldspar and dark metamorphic rock fragments with lesser amounts of granite and limestone. Strongly effervescent to HCl.
135-140	Silty, sandy gravel; poorly-sorted. Silt (25 percent), pink (7.5YR 7/4). Sand (30 percent), fine- to coarse-grained, subangular, mainly clear quartz and white feldspar with minor biotite. Pebbles and granules (45 percent) to 10 mm, subangular, mainly dark metamorphic rock fragments and white feldspar with lesser amounts of dark quartz. Strongly effervescent to HCl.
140-150	Silty gravelly sand; poorly-sorted. Silt (15 percent), light brown (7.5YR 5/4). Sand (50 percent), medium- to very coarse-grained, subangular, mainly clear quartz and white feldspar with lesser amounts of dark metamorphic rock fragments. Pebbles and granules (35 percent) to 6 mm, subangular, mainly dark metamorphic rock fragments and white feldspar with lesser amounts of granite and dark quartz. Strongly effervescent to HCl.
150-155	Gravelly sand; poorly- to moderately-sorted. Silt (5 percent), brown (7.5YR 5/4). Sand (65 percent), coarse- to very coarse, angular, mainly clear and white quartz, lesser amounts of white

Depth, ft bgs	Description
	feldspar and minor biotite and magnetite. Granules (30 percent) to 3 mm, angular, mainly dark metamorphic rock fragments with lesser amounts quartz, white feldspar, and granite. Slightly effervescent to HCl.
155-160	Silty sandy gravel; poorly-sorted. Silt (15 percent), light brown (7.5YR 6/4). Sand (35 percent), medium- to very coarse-grained, subangular, mainly clear and white quartz with lesser amounts of white feldspar. Pebbles and granules (50 percent) to 10 mm, subangular, mainly dark metamorphic rock fragments, white and clear quartz, and white feldspar with lesser amounts of granite. Strongly effervescent to HCl.
160-165	Gravelly sand; moderately-sorted. Sand (70 percent), coarse- to very coarse grained, subangular, mainly clear quartz with lesser amounts of white feldspar and dark quartz. Granules (30 percent) to 3 mm, subangular, mainly clear and white quartz and quartzite with lesser amounts of granite and metamorphic rock fragments. Slightly effervescent to HCl.
165-180	Sandy gravel; poorly-sorted. Silt (5 percent), pink (7.5YR 7/4). Sand (40 percent), coarse- to very coarse-grained, angular, mainly clear quartz, lesser amounts of white feldspar, and minor biotite. Pebbles and granules (55 percent) to 6 mm, angular, mainly white quartz and feldspar, lesser amounts of granite, and minor dark metamorphic rock fragments and rose quartz. Strongly effervescent to HCl.
180-195	Sandy gravel; poorly-sorted. Sand (30 percent), medium- to very coarse-grained, subangular, mainly clear quartz with minor white feldspar and biotite. Pebbles and granules (70 percent) to 10 mm, subangular, mainly dark metamorphic rock fragments and granite. Strongly effervescent to HCl.
195-200	Silty gravelly sand; poorly-sorted. Silt (10 percent), pink (7.5YR 7/4). Sand (55 percent), fine- to very coarse-grained, subangular, mainly clear and white quartz with minor biotite, dark metamorphic rock fragments, and white feldspar. Pebbles and granules (35 percent) to 10 mm, subangular, mainly white quartz and granite with minor dark metamorphic rock fragments. Strongly effervescent to HCl.
200-205	Gravelly sand; moderately-sorted. Silt (5 percent), pink (7.5YR 6/4). Sand (80 percent), coarse- to very coarse-grained, subangular, mainly clear quartz with minor biotite. Granules (15 percent) to 4 mm, subangular, mainly clear, white, and dark quartz and granite with lesser amounts of dark metamorphic rock fragments. Strongly effervescent to HCl.
205-220	Silty, sandy, gravel; poorly-sorted. Silt (20 percent), light brown (7.5YR 6/4). Sand (30 percent), medium- to very coarse-grained, subangular, mainly clear quartz with minor biotite, dark metamorphic rock fragments, and white feldspar. Pebbles and granules (50 percent) to 3 mm, subangular, mainly dark metamorphic rock fragments and granite with minor limestone. Violently effervescent to HCl, hard masses of carbonate and continuous carbonate grain coatings.
220-230	Silty gravelly sand; poorly- to moderately sorted. Silt (25 percent), light brown (7.5YR 6/4). Sand (40 percent), coarse- to very coarse-grained, subangular to subrounded, mainly clear and white quartz with minor biotite and dark metamorphic rock fragments. Pebbles and granules (35 percent) to 6 mm, subrounded, mainly granite and dark metamorphic rock fragments with minor limestone. Strongly effervescent to HCl.
230-240	Gravelly sand; poorly- to moderately sorted. Sand (60 percent), fine- and coarse- to very coarse-grained, subangular, mainly clear and dark quartz, lesser amount of white feldspar, and minor dark metamorphic rock fragments and pink feldspar. Granules (40 percent) to 4 mm, subangular, mainly clear and white quartz with lesser amounts of dark metamorphic rock fragments and granite. Strongly effervescent to HCl.
240-245	Silty gravelly sand; poorly-sorted. Silt (10 percent), light brown (7.5YR 6/4). Sand (60 percent), medium- to very coarse-grained, subangular, mainly clear and white quartz with minor biotite and dark metamorphic rock fragments. Pebbles and granules (30 percent) to 6 mm, subangular, mainly granite with lesser amounts of dark metamorphic rock fragments and clear, white and dark quartz. Strongly effervescent to HCl.

Depth, ft bgs	Description
245-255	Gravelly sand; moderately-sorted. Sand (70 percent), medium- to coarse-grained, subangular, mainly clear quartz with lesser amounts of white feldspar, biotite, and granite. Granules (30 percent) to 4 mm, subangular, mainly clear and white quartz with lesser amounts of granite and dark metamorphic rock fragments. Slightly effervescent to HCl.
255-265	Silty, sandy, gravel; poorly-sorted. Silt (20 percent), light brown (7.5YR 6/4). Sand (30 percent), fine- to very coarse-grained, angular to subangular, mainly clear quartz with lesser amounts of dark metamorphic rock fragments, and white feldspar. Pebbles and granules (50 percent) to 6 mm, subangular, mainly white feldspar, quartz and granite with minor dark metamorphic rock fragments. Strongly effervescent to HCl.
265-280	Silty, sandy gravel; poorly-sorted. Silt (10 percent), light brown (7.5YR 6/4). Sand (30 percent), medium to very coarse-grained, angular, mainly clear quartz with minor biotite. Pebbles and granules (60 percent) to 10 mm, angular, mainly clear quartz and granite with minor dark metamorphic rock fragments and limestone. Strongly effervescent to HCl.
280-310	Gravely sand; moderately-sorted. Sand (60 percent), fine- and coarse- to very coarse-grained, subangular to subrounded, mainly clear and white quartz with minor white feldspar and biotite. Granules (40 percent) to 3 mm, subrounded, mainly clear and white quartz with lesser amounts of granite, dark quartz and dark metamorphic rock fragments. Strongly effervescent to HCl.
310-315	Sandy gravel; poorly sorted. Silt (5 percent), pinkish gray (7.5YR 7/3). Sand (35 percent), medium- to very coarse-grained, subangular, mainly clear quartz with lesser amounts of dark metamorphic rock fragments, biotite and muscovite. Pebbles and granules (60 percent) to 6 mm, subangular, mainly white quartz with lesser amounts of granite and dark metamorphic rock fragments. Strongly effervescent to HCl.
315-320	Sand and gravel; moderately-sorted. Silt (5 percent), pinkish gray (7.5YR 7.3). Sand (45 percent), medium- to very coarse-grained, subangular to subrounded, mainly clear and white quartz with minor white and pink feldspar, rose quartz, and biotite. Granules (50 percent) to 4 mm, subrounded, mainly dark quartz and granite with minor dark metamorphic rock fragments. Strongly effervescent to HCl.
320-325	Sandy gravel; poorly- to moderately-sorted. Sand (30 percent), fine- and coarse- to very coarse-grained, angular to subangular, mainly clear quartz, lesser amounts of white feldspar, and minor biotite. Pebbles and granules (70 percent) to 8 mm, subangular, mainly granite with lesser amounts of dark quartz and dark metamorphic rock fragments. Strongly effervescent to HCl.
325-330	Silty, sandy gravel; poorly-sorted. Silt (15 percent), pale brown (10YR 6/3). Sand (30 percent), fine- to medium- and very coarse-grained, subangular, mainly clear and white quartz with minor biotite. Pebbles and granules (55 percent) to 10 mm, subangular, mainly dark metamorphic rock fragments with lesser amounts of granite and dark quartz. Violently effervescent to HCl.
330-355	Gravelly sand; moderately-sorted. Silt (5 percent), brown (7.5YR 5/4). Sand (60 percent), medium- to coarse-grained, subangular to subrounded, mainly clear quartz, lesser amounts of white feldspar, and minor biotite. Pebbles and granules (35 percent) to 6 mm, subrounded, mainly granite with lesser amounts of dark metamorphic rock fragments and white quartz. Slightly effervescent to HCl.
355-365	Silty sand and gravel; poorly-sorted. Silt (15 percent), light brown (7.5YR 6/4). Sand (40 percent), medium- to very coarse-grained, subangular to subrounded, mainly clear quartz and white feldspar with minor dark quartz and biotite. Granules (45 percent) to 3 mm with few pebbles to 6 mm, subrounded, mainly granite with lesser amounts of clear and white quartz and dark metamorphic rock fragments. Strongly effervescent to HCl.
365-405	Clayey, sandy gravel; poorly sorted. Clay and silt (30 percent), light brown (7.5YR 6/5). Sand (25 percent), coarse-to very coarse-grained, subangular, mainly clear and dark quartz, lesser amounts of white feldspar, and minor biotite. Pebbles and granule (45 percent) to 6 mm with few to 12 mm, subangular, mainly granite with lesser amounts of dark metamorphic rock fragments. Violently effervescent to HCl.

Depth, ft bgs	Description
405-420	Clayey, gravelly sand; poorly- to moderately-sorted. Clay and silt (20 percent), light brown (7.5YR 6/4). Sand (50 percent), medium- to very coarse-grained, subangular, mainly clear quartz, lesser amounts of white feldspar and minor pink feldspar and biotite. Granules (30 percent) to 4 mm, subangular, mainly granite with lesser amounts of dark metamorphic rock fragments. Strongly effervescent to HCl.
420-440	Silty, sandy gravel; poorly sorted. Silt (30 percent). Light brown (7.5YR 6/4). Sand (20 percent), medium- to coarse-grained, subangular to subrounded, mainly clear quartz, lesser amounts of white quartz and feldspar, and minor biotite. Pebbles and granules (50 percent) to 6 mm, subrounded, mainly granite with lesser amounts of dark quartz. Violently effervescent to HCl.
440-465	Silty, sandy gravel; poorly- to moderately sorted. Silt (30 percent), light brown (7.5YR 6/4). Sand (30 percent), fine- to coarse-grained, subangular to subrounded, mainly clear quartz, lesser amounts of white quartz and feldspar, and minor biotite and pink feldspar. Granules (40 percent) to 4 mm, subrounded, mainly granite with lesser amounts of clear quartz. Violently effervescent to HCl.
465-470	Silty, gravelly sand; poorly- to moderately sorted. Silt (10 percent), light brown (7.5YR 6/4). Sand (60 percent), fine- to medium-grained, subangular to subrounded, mainly clear and white quartz, with minor white and pink feldspar, and biotite. Granules (30 percent) to 4 mm with few pebbles to 6 mm, subrounded, mainly granite with lesser amounts of clear quartz. Strongly effervescent to HCl.
470-475	Silty, sandy gravel; poorly-sorted. Silt (20 percent), light brown (7.5YR 6/4). Sand (30 percent), medium- to coarse-grained, subangular, mainly clear and white quartz with minor white and pink feldspar and biotite. Pebbles and granules (50 percent) to 5 mm with few to 8 mm subangular, mainly granite. Strongly effervescent to HCl.
475-490	Gravelly sand; moderately-sorted. Sand (70 percent), medium-to very coarse-grained, subangular to subrounded, mainly clear quartz with minor biotite and white and pink feldspar. Granules (30 percent) to 3 mm, subrounded, mainly granite with minor dark quartz and dark metamorphic rock fragments. Strongly effervescent to HCl.
490-500	Silty gravelly sand; poorly-sorted. Silt (10 percent), light brown (7.5YR 6/4). Sand (55 percent), fine- to medium and very coarse grained, subangular to subrounded, mainly clear quartz, lesser amounts of white feldspar, and minor biotite and magnetite. Granules (35 percent) to 4 mm with few pebbles to 6 mm, subrounded, mainly granite with lesser amounts of clear and dark quartz. Strongly effervescent to HCl.
500-515	Gravelly sand; poorly-sorted. Sand (60 percent), fine- and coarse- to very coarse-grained, subangular, mainly clear quartz, lesser amounts of white feldspar, and minor biotite. Granules (40 percent) to 4 mm, subangular, mainly granite with lesser amounts of clear quartz and dark metamorphic rock fragments. Strongly effervescent to HCL.
515-520	Silty, gravelly sand; poorly-sorted. Silt (10 percent), light brown (7.5YR 6/4). Sand (55 percent), fine- and coarse- to very coarse-grained, subangular, mainly clear quartz, lesser amounts of white feldspar and dark quartz, and minor biotite. Pebbles and granules (35 percent) to 6 mm with few to 12 mm, subangular, mainly granite with minor clear quartz and limestone. Strongly effervescent to HCl.
520-535	Gravelly sand; poorly- to moderately-sorted. Silt (5 percent), light brown (7.5YR 6/4). Sand (60 percent), medium- to very coarse-grained, subangular to subrounded, mainly clear quartz, lesser amounts of white feldspar, and minor biotite. Granules (35 percent) to 4 mm, subrounded, mainly granite with lesser amounts of dark metamorphic rock fragments and dark quartz. Strongly effervescent to HCL.
535-545	Silty, gravelly sand; poorly- to moderately-sorted. Silt (10 percent), pinkish gray (7.5YR 6/2). Sand (60 percent), fine- to coarse-grained, subangular, mainly clear and white quartz, lesser amounts of white feldspar and minor magnetite and pink feldspar. Pebbles and granules (30 percent) to 5 mm, subangular, mainly granite with lesser amounts of limestone and dark metamorphic rock fragments. Strongly effervescent to HCl.

Depth, ft bgs	Description
545-565	Gravelly sand; moderately-sorted. Silt (5 percent), light brown (7.5YR 6/4). Sand (65 percent), medium- to very coarse-grained, angular, mainly clear quartz with lesser amounts of white feldspar. Granules (30 percent) to 4 mm with few pebbles to 8 mm, angular, mainly granite with minor limestone. Strongly effervescent to HCL.
565-570	Silty, gravelly sand; moderately-sorted. Silt (10 percent), pinkish gray (7.5YR 6/2). Sand (65 percent), medium- to coarse-grained, subangular, mainly clear quartz and white feldspar with minor biotite. Granules (35 percent) to 4 mm, subangular, mainly granite with lesser amounts of dark metamorphic rock fragments and quartz. Strongly effervescent to HCl.
570-580	Silty, sand and gravel; poorly-sorted. Silt (10 percent), light brown (7.5YR 6/4). Sand (40 percent), coarse- to very coarse-grained, subangular, mainly white feldspar and clear quartz with minor biotite. Pebbles and granules (50 percent) to 6 mm, subangular, mainly granite with lesser amounts of dark metamorphic rock fragments. Violently effervescent to HCl.
580-590	Gravelly sand; moderately-sorted. Sand (65 percent), medium- to very coarse-grained, angular, mainly white feldspar and clear quartz with minor biotite. Granules (35 percent) to 4 mm, angular, mainly granite with minor dark metamorphic rock fragments. Strongly effervescent to HCl.
590-610	Silty, sandy gravel; poorly-sorted. Silt (10 percent), light brown (7.5YR 6/4). Sand (35 percent), coarse- to very coarse-grained, subangular to subrounded, mainly clear quartz, lesser amounts of white feldspar and minor biotite. Pebbles and granules (65 percent) to 6 mm, subrounded, mainly granite with lesser amounts of dark metamorphic rock fragments and limestone. Strongly effervescent to HCl.
610-625	Gravelly sand; moderately-sorted. Sand (70 percent), medium- to very coarse-grained, subangular to subrounded, mainly clear quartz, lesser amounts of white feldspar and minor biotite. Granules (30 percent) to 4 mm, subrounded, mainly granite with lesser amounts of clear quartz and limestone. Strongly effervescent to HCl.
625-630	Silty, sandy gravel; poorly-sorted. Silt (15 percent), light brown (7.5YR 6/4). Sand (30 percent), fine- to coarse-grained, subangular, mainly clear quartz, lesser amounts of white feldspar and minor pink feldspar, biotite, and magnetite. Pebbles and granules (55 percent) to 6 mm with few to 12 mm, subangular, mainly granite with lesser amounts of dark metamorphic rock fragments and limestone. Violently effervescent to HCl.
630	Borehole Total Depth

The Unified Soil Classification System symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well PGS-1

Drilling company	USGS Water Sciences Division
Dates of drilling	July 21 - August 5, 1994
Drilling method	Mud Rotary, cuttings logged, also with split-spoon cores from 10 to 27.3 ft, and 300 to 326.7 ft
Total depth of borehole, ft	750
Ground elevation, ft amsl NAVD 88	5407.9
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Screen, ft bgs	518.0 to 528.0
Date well developed	October 12, 1994
Initial water level, ft bgs	524
Rig Geologist	Joe Fritts

Three descriptions:

- Cuttings description by rig geologist.
- Core description (300 to 326.7 ft).
- Composite Description from USGS combined geophysics/lithologic log.

Depth, ft bgs	Description	USCS Group
0 - 2	Silty sand, trace fine gravel, fine to coarse sand, 10YR 5/3, brown, dry, probably fill sand and gravel, subangular to angular.	SM
2 - 5	Silty clay, trace fine sand, moist 10YR 3/3, dark brown.	CL
5 - 7	Sandy silt, fine to medium sand, 10YR 4/3, brown, moist.	ML
7 - 10	Clay, trace silt, trace fine sand, 10YR 4/3, brown, moist.	CL
10 - 13	Gravelly sand, fine to coarse sand, fine gravel, 10YR 4/4, dark yellow-brown, moist.	SP
13 - 14	Sandy silt, fine sand, 10YR 4/3, brown, slightly moist.	ML
14 - 21	Gravelly sand, medium to coarse sand, gravel to 3-inch diameter, 10YR 4/3, brown, moist, subangular sand and gravel.	SP
21 - 22	Silt, trace fine sand, trace clay, 10YR 5/3, brown, slightly moist.	ML
22 - 23	Sand, fine to medium, slightly moist.	SP
23 - 27.3	Sandy silt, fine to medium sand, 10YR 5/3, brown, slightly moist. Stopped augering at 27.3 feet.	ML
27.3 - 33	Begin mud rotary drilling. Gravely sand, fine to coarse sand, fine gravel, subrounded to subangular sand and gravel.	SW
33 - 58.7	Sandy gravel, fine gravel, fine to coarse sand, subrounded sand and gravel.	GP
58.7 - 70	Gravelly sand, some silt, medium to coarse sand, fine gravel, some silt; difficult to interpret in drilling mud. Driller reports easier drilling. Subrounded to subangular sand and gravel.	SP
70 - 90	Silty sand, trace gravel, medium to coarse sand, fine gravel, subrounded sand and gravel.	SM
90- 103	Clay, fine gravel in sample; but drills like mostly clay. Subrounded to subrounded gravel.	CL
103 - 107	Gravel, fine angular.	GP
107 - 118	Silty sand, some clay, fine sand. Subrounded to subangular sand.	SM
118 - 136	Sandy silt, some clay, fine to coarse sand, subrounded.	ML
136 - 150	Silty sand, some fine gravel, medium to coarse sand. Rounded to subrounded sand, subrounded gravel.	SP

Depth, ft bgs	Description	USCS Group
150 - 154	Silty sand, some fine gravel, medium to coarse sand, subrounded to subangular sand, subangular gravel.	SM
154 - 158	Clay reported by driller.	CL
158 - 195	Silty sand, some fine gravel, medium to coarse sand. Subrounded to subangular sand, subrounded gravel. Transition.	SP and SM
195 - 212	Gravelly sand, some silt, medium to coarse sand, fine gravel. Subrounded to subangular sand and gravel.	SP
212 - 216	Clayey sand, some silt, medium to coarse sand.	SC
216 - 225	Sandy gravel, fine gravel, medium to coarse sand. Subrounded to subangular sand and gravel.	GP
225 - 241	Silty clay or clayey silt, trace coarse sand, fine gravel, subrounded to subangular sand and gravel.	CL
241 - 243	Clay – reported by driller.	CL
243 - 250	Sandy silt, fine to medium sand, subrounded sand.	ML
250 - 264	Sandy silt, fine to medium sand, subrounded sand.	ML
264 - 286	Silty sand, trace fine gravel, medium to coarse sand, subangular to subrounded sand and gravel.	SM
286 - 298	Clayey silt, trace fine sand.	ML
298 - 310.4	Sandy silt, very fine sand, moist to wet at 306.5 ft assuming core loss was from bottom. Other: 302.65 to 302.75 ft sand stringer. Fine to coarse subangular; 306.8 to 306.9 ft, sandy fine, moist to wet.	ML
310.4 - 312.4	Sandy silt. 5% well graded gravel, fine to coarse sand, some medium, subrounded to subangular sand, angular gravel.	ML
312.4 - 314	Sandy silt with 5% well graded gravel, fine to coarse sand, subrounded to subangular sand, angular gravel, dry.	ML
314 - 315.75	Sandy silt, largely fine sand, some medium to coarse, subrounded sand, moist. Less than 1% gravel, up to 0.7-inch diameter.	ML
315.75- 323.4	Sandy silt, less than 5% well graded gravel, fine to coarse sand, subrounded to subangular sand and gravel, moist.	ML
323.4 - 327	Sandy silt, fine sand, moist.	ML
327 - 350	Silty clay with less than 10% fine sand.	CL
350 - 360	Sandy silt with less than 10% clay. Sand is well graded, subangular.	ML
360 - 366	Silty clay, little return.	CL
366 - 394	Sandy silt, 15% clay, fine to medium sand, subangular.	ML
394 - 424	Sandy silt, well graded sand, subangular.	ML
424 - 435	Silty sand, 10% fine gravel, subrounded to subangular, gravel and sand.	SM
435 - 440	Clayey silt, 20% fine sand.	ML
440 - 454	Silty gravel, some sand, subangular sand and gravel, fine gravel, well graded sand.	GM
454 - 473	Silty sand, 10% gravel, subrounded to rounded sand, subangular gravel, fine gravel, well graded sand.	SM
473 - 484	Gravelly sand, some silt, fine gravel, well graded sand, subangular to subrounded gravel, subrounded sand.	SW
484 - 494	Sandy gravel, some silt, fine gravel, medium to coarse sand, subrounded to subangular gravel, subrounded sand.	GP
494 - 515	Sandy gravel, fine gravel, medium to coarse sand, subangular gravel, subrounded sand.	GP
515 - 535	Silty sand, some gravel, well graded mostly fine-grained sand, subangular sand and gravel.	SM
535 - 554	Sandy silt, some clay, well graded, subangular sand.	ML

Depth, ft bgs	Description	USCS Group
554 - 572	Clayey silt, trace sand.	ML
572 - 580	Sandy silt, trace clay, fine to medium sand, subangular to subrounded.	ML
580 - 605	Silty clay.	CL
605 - 634	Sandy silt, some clay, fine sand.	ML
634 - 644	Silt, some clay and fine sand.	ML
644 - 664	Sandy silt, well graded sand, subangular.	ML
664 - 684	Clay silt, 15% fine to medium subangular sand.	ML
684 - 704	Sandy silt, some clay, fine grained, subangular sand.	ML
704 - 713	Sandy silt, fine grained, subangular sand.	ML
713 - 730	Few drilling returns. Clay reported by driller. Sandy clay with some silt.	CL
730 - 750	Sandy clay or possibly clayey sand. Some silt.	CL
750	Borehole Total Depth.	

USCS = Unified Soil Classification System

Depth, ft bgs	Core Description extracted from rig geologist log
300.0 - 302.65	Sandy silt, very fine sand.
302.65 - 302.75	Sand stringer. Fine to coarse subangular; moist to wet at 306.5 ft assuming core loss was from bottom of interval.
302.75 - 306.8	Sandy silt, very fine sand.
306.8 - 306.9	Sandy fine, moist to wet.
306.9 - 310.4	Sandy silt, very fine sand.
310.4 - 312.4	Sandy silt. 5% well graded gravel, fine to coarse sand, some medium, subrounded to subangular sand, angular gravel.
312.4 – 314.0	Sandy silt with 5% well graded gravel, fine to coarse sand, subrounded to subangular sand, angular gravel, dry.
314.0 - 315.75	Sandy silt, largely fine sand, some medium to coarse, subrounded sand, moist. Less than 1% gravel, up to 0.7-inch diameter.
315.75 - 323.4	Sandy silt, less than 5% well graded gravel, fine to coarse sand, subrounded to subangular sand and gravel, moist.
323.4 – 326.7	Sandy silt, fine sand, moist.

Depth, ft bgs	Composite Description from USGS combined geophysics/lithologic log	USCS Group
0 - 10	Silt, sandy. Brown, fine- to medium–grained sand, minor clay, moist.	ML
10 - 20	Sand, gravelly. Dark–yellowish brown, fine- to coarse-grained sand, gravel to 3 inches, moist.	SW
20 - 30	Silt, sandy. Brown, minor clay, slightly moist.	ML
30 - 55	Gravel, sandy. Dark yellowish brown, fine gravel, fine- to coarse-grained sand, moist.	GP
55 - 65	Sand, gravelly. Medium- to coarse-grained sand, subrounded to subangular, fine gravel, minor silt.	SP
65 - 90	Sand, silty. Medium- to coarse-grained sand, sub-rounded, trace gravel.	SM
90 - 100	Clay. Minor subrounded gravel.	CL
100 - 105	Gravel. Fine, angular.	GP
105 - 155	Sand, silty. Fine- to medium-grained sand, subrounded to subangular, minor gravel.	SM
155 - 160	Clay. Reported by driller.	CL
160 - 195	Sand, silty. Medium- to coarse-grained sand, subrounded to subangular, minor gravel.	SM
195 - 210	Sand, gravelly. Medium- to coarse-grained sand, subrounded to subangular, minor silt (SP).	SP
210 - 215	Sand, clayey. Medium- to coarse-grained sand, minor silt.	SC
215 - 225	Gravel, sandy. Fine gravel, medium-to coarse-grained sand, both subrounded to subangular.	GP
225 - 240	Clay, silty. Minor coarse sand, minor gravel.	CL
240 - 255	Sand, silty.	ML
255 - 275	Sand, silty. Medium- to coarse-grained, subangular to subrounded minor gravel.	SM
275 - 325	Sand, silty. Sand very fine- to coarse-grained, minor gravel, moist to wet depending on grain size.	ML
325 - 350	Clay, silty. Minor fine-grained sand.	CL
350 - 420	Silt, sandy. Well graded, subangular sand, minor clay.	ML
420 - 465	Sand, silty. Well graded, subangular sand, minor clay and gravel.	SM
465 - 515	Gravel, sandy. Well graded, subangular to subrounded gravel, subrounded sand, minor silt.	SW
515 - 535	Sand, silty. Well graded, minor gravel.	SM
535 - 580	Silt, clayey. Well graded, subangular sand.	ML
580 - 605	Clay, silty.	CL
605 - 705	Silt, clayey and sandy. Fine-grained sand, well graded.	ML
705 - 750	Clay, sandy. Minor silt.	CL
750	Borehole Total Depth.	

Lithologic log for borehole at monitoring well PGS-2

Drilling Company	USGS Water Sciences Division
Dates of Drilling	September 9 – 12, 1995
Drilling Method	Mud Rotary, cuttings logged, no cores
Total depth of borehole, ft	660
Ground Elevation, ft amsl NAVD 88	5407.9
Completion zone	Regional Aquifer, in in Santa Fe Group sediments
Screens (3), ft bgs	535.0 to 565.0, 585.0 to 595.0, and 625.0 to 645.0
Date well developed	September 22, 1995
Initial water level, ft bgs	546.30
Rig Geologist	See log for PGS-1 (which is located 29 ft to the south)

Depth, ft bgs	Description from driller's notes
0-3	Over-burden fill.
3-30	Sandy silt, silty sand.
30-45	Sandy gravel, gravelly sand with some larger material.
45-49	Cobbles at 45 to 46 ft, sandy gravel.
49-54	Sandy gravel with silty sand layers.
54-55	Cobbles.
55-59	Sandy gravel, silty sand layers.
59-61	Cobbles.
61-64	Caliche concretions possibly, cobbles.
64-68	Sandy gravel, silty sand.
68-76	Sandy silt, tighter, possibly silty sand.
76-91	Clayey silt, tight with some silty sand from 85 to 87 ft.
91-96	Softer silty sand, sandy silt.
96-102	Clayey silt, silty clay.
102-109	Sandy gravel with cobbles.
109-136	Clayey silt with possibly some gravels.
136-144	Softer sandier silt with possibly some clayey silt layers.
144-147	Clayey silt, silty clay.
147-149	Softer sandier silt with clayey silt layers.
149-158	Silty sand, sand, sandy silt with some gravels.
158-184	Clayey silt, silty clay with some gravels (entire borehole so far trends silty).
184-217	Sandier silt with some gravels, possibly caliche concretions, silty sands.
217-235	Clayey silt with some sandy layers, tighter.
235-250	Softer sandier silt, silty sand, with some clayey layers.
250-264	Harder sandy silt, silty sand, possible cementation. Few larger cobbles.
264-307	Softer sandy silt, silty sand with some clays and gravels.
307-311	Harder, possibly caliche concretions.
311-313	Softer silty sand, sandy silt with some clays and gravels.
313-314	Harder, caliche concretions or possibly cemented cobbles/gravels.
314-317	Softer sandy silt, silty sand with some gravels.
317-322	Clayey silt, silty clay with some sandy layers.
322-334	Harder, caliche concretions or possibly cemented sandy gravel.
334-343	Softer silty sand, sandy silt.
343-347	Clayey silt, silty clay, tighter.
347-353	Harder concretion or possibly cemented sandy gravels.

Depth, ft bgs	Description from driller's notes
353-358	Clayey silt with some gravels, harder silty clay.
358-376	Softer sandy silt, silty sand, with some gravel or cementation zones.
376-395	Harder clayey silt, silty clay with some sands, sandy gravels.
395-414	Sandier silt with some gravelly sections or possibly cementation. Tight.
414-415	Cobble or cementation/caliche.
415-416	Silty sand with some gravelly zones and sandy silt.
416-418	Sandy gravel, gravelly sand with some cobbles.
418-430	Sandy silt, silty sand, softer than above but still tight.
430-434	Clayey silt, silty clay with some sandy gravel zones.
434-478	Sandier sandy silt, silty sand, some larger cobbles or concretions.
478-480	Softer silty sand, sandy silt.
480-481	Clayey silt, silty clay, tighter.
481-484	Back to sandy gravel, sand with some concretions or cementation.
484-500	Very tough drilling, cobbles or cemented gravels.
500-519	Sandier silt, silty sand, softer.
519-532	Clayey silt, silty clay with some sandy silt lenses.
532-537	Sandier silt, silty sand, softer.
537-538	Clayey silt, silty clay with some sandier layers.
538-545	Dense clay, tight, drill bit is dull because of caliche/cobbles above.
545-547	Caliche harder, possible cementation.
547-555	Sandier silt or less clayey silt, some caliche or cementation.
555-559	Clayey silt, clay.
559-578	Siltier clay, silty sand, softer, with some caliche/cemented layers. Change bit at 578 ft.
578-595	Softer, sandier silt/silty sand with possibly some cemented/caliche layers.
595-597	Silty sand, hard layers are possibly caliche.
597-604	Sandier, less silty/silty sand, sandy silt with some hard layers.
604-605	Softer clayey silt/silty clay, tight.
605-616	Silty sand/sandier with some hard sections, still silty.
616-623	Tighter silty clay/clayey silt, then clay, tight.
623-624	Siltier clay/clayey silt, softer.
624-627	Clay, tight.
627-650	Sandier/sandy silt/silty sand, softer with some larger grained or cementation, fairly tough drilling.
660	Borehole total depth.

The Unified Soil Classification System symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TA1-W-01

Drilling company	Water Development Corporation
Dates of drilling	March 6 – 17, 1997
Drilling method	ARCH, cuttings logged, also split spoon cores from 40.0 to 41.5 ft, 140.0 to 141.5 ft, and 260.0 to 261.5 ft
Total depth of borehole, ft	613
Ground elevation, ft amsl NAVD 88	5401.8
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Screen, ft bgs	575.0 to 595.0
Date well developed	March 22, 1997
Initial water level, ft bgs	539.57
Rig Geologist	Mike Skelly

Depth, ft bgs	Description	USCS Group
0-4	Silty sand, moderate yellowish brown (10YR 5/4), loose, dry, 60% sand, 35% silt, 5% fine gravel.	SM
4-8	Silty sand as above, grayish orange (10YR 7/4) to pale yellowish brown (10YR 6/2).	SM
8-40	Silty sand as above, moderate brown (5YR 4/4) to dark yellowish brown (10YR 4/2), some (10%) fine gravel at 20 ft up to 1 inch in diameter, dry to slightly moist. Gravel layers at approximately 32 ft and 36 ft.	SM
40	Sandy gravel, pale yellowish brown (10YR 6/2) to moderate yellowish brown (10YR 5/4), dry to slightly moist, trace silt, gravel to 2 inches in diameter. Gravel composed of limestone predominantly.	SG
44	Silty sand as above, thin clay layers approximately 50 ft, occasional gravel and cobbles.	n.r.
60	Silty sand, as above, some clay layers/gravel layers.	n.r.
74	Silt, some fine sand, grayish orange (10YR 7/4) to light brown (5YR 6/4), well sorted - poorly graded, dry to slightly damp, possible aeolian sands and silts.	n.r.
90	Silty sand, as above; pale yellowish brown (10YR 6/2), some gravel, poorly sorted, well graded, dry	n.r.
114	Silty gravel and sand, light brown (5YR 5/6), gravel to 2 ft, dry.	SM/SP
140	Silty sand, as above at 114 ft, but with no gravel, dry, some coarse gravel in sampler appears to be slough.	n.r.
160	Silty and gravelly sand, as above, dry, gravel to 1 inches in diameter.	n.r.
168 - 174	Sand and gravel, as above, dry.	n.r.
174	Silty sand, as above.	n.r.
196	Some gravel layers with gravel to 1 inch in diameter.	n.r.
200	Silty sand as above.	n.r.
220	Silty sand, moderate yellowish brown (10YR 5/4), slightly moist, some sand.	n.r.
223	Gravel layer.	n.r.
224	Clay, very moist	n.r.
240	Gravels possibly.	n.r.
260	At approximately 260 ft (based on cuttings only) – silty and sandy clay (balling up), trace to some fine gravel, clayey sand layers, coarse sand, throughout especially at approximately 272 ft, moist.	n.r.
280	Silty and sandy clay/clayey silt, as above, moist to slightly wet. After standing by for 1.5 hours, blew out some fairly wet mud from drill string.	n.r.

Depth, ft bgs	Description	USCS Group
300	Silty and sand clay / clayey silt, as above, moist.	n.r.
320	Silty and sandy clay, as above, moist.	n.r.
340	Silty sand, as above, light brown (5YR 6/4) to pale brown (5YR 5/2), some clay and fine gravel, dry.	n.r.
360	Start injecting water. Silty sand and clay, no gravel.	n.r.
380	Silt / sand / clay, no gravel, cuttings are balling up.	n.r.
400	Silt / sand / clay, no gravel, some coarse sand.	n.r.
420	Silt / sand / clay, trace of gravel, slight color change to pale yellowish brown (10YR 6/2) to dusty yellow (5YR 6/4), more olive and less red.	n.r.
440	Silt and sand, less clay than above.	n.r.
445 to 448	Coarse sand, well sorted - poorly graded, only a few feet thick.	n.r.
448	Silt and sand, as above.	n.r.
457	Sand and gravel, gravel to 1-inch diameter, mostly pea-sized.	n.r.
470	Drilled without injecting water for approximately 10 ft, cuttings came up damp but not producing groundwater.	n.r.
480	Sand and pea gravel, as above, gravel consists mostly of pink granite, some metamorphics with a trace of limestone.	n.r.
500	Sand and gravel, as above, some clay and silt balls brought up with cuttings, gravel up to 2 inches in diameter consisting of volcanic material and pink granite.	n.r.
520	Silty sand, as above.	n.r.
540	Silty sand, as above, moist to possibly wet.	n.r.
557	At approximately 557 ft (driller's comment) hard drilling, then hit sands and gravels.	n.r.
560	Silty sand, as above, some pea gravel, moist to possibly wet.	n.r.
577	At approximately 577 ft hard drilling (possibly cemented gravel), not making much water below 577 ft.	n.r.
580	Coarse sand and gravel, moist.	n.r.
597	Firmer drilling at approximately 597 ft.	n.r.
607	Based on driller comment and cuttings, encounter clay layer at approximately 607 ft.	n.r.
613	Borehole total depth, confirmed with geophysical log footage meter.	

n.r. = not recorded. The Unified Soil Classification System (USCS) symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TA1-W-02

Drilling company	Water Development Corporation
Dates of drilling	February 11 – 17, 1998
Drilling method	ARCH, cuttings logged, also split spoon cores from 80 to 81 ft, 200 to 201 ft, 320 to 321 ft
Total depth of borehole, ft	578
Ground elevation, ft amsl NAVD 88	5416.9
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Screen, ft bgs	540.0 to 560.0
Date well developed	February 27, 1998
Initial water level, ft bgs	528.40
Rig Geologist	Mike Skelly and Mike Sanders

Depth, ft bgs	Description	USCS Group
0-0.25	Asphalt pavement; no subgrade materials.	n.r.
0.25-32	Silty sand, grayish red (10R 4/2) to moderate brown (5YR 4/4); some coarse sand; trace of fine and coarse gravel (composed of granite, greenstone, and limestone clasts) to 2-inch diameter; dry to slightly damp; some thin layers (few inches) of clay rich or gravel rich from 25 to 32 ft; dry.	SM
32-35	Fine sand; grayish orange (10YR 7/4); possibly aeolian; trace of coarse sand and fine gravel; dry.	SP
35-43	Coarse sand and gravel; pale yellowish brown (10YR 6/2); up to 3-inch diameter, gravel lithology as above plus quartzite; dry.	SP/GP
43-60	Fine sand (as above at 32 ft) except color is light brown (5YR 5/6); dry.	SP
60-63	Sand and gravel (as above at 35 ft); dry.	SP/GP
63-88	Silty sand (as above at 25 ft); (same coarse sand/fine gravel); damp (added); thin zones of clay to 88 ft. Started misting at 65 ft to control dust (in parking lot).	SM
88-94	Silty sandy clay; light brown (5YR 5/6); trace of gravel; damp (added).	SC/CL
94-114	Silty sand (as above at 63 ft); damp (added), thin layers of clay rich and gravel rich.	SM
114-117	Sand and gravel (as above at 60 ft); dry to damp (added).	SP/GP
117-123	Silty sand (as above at 94 ft); damp (added).	SM
123-132	Sand and gravel (as above); damp (added). Adding water to bring up cuttings and keep dust down.	SP/GP
132-137	Silty sand (as above) thin (less than 0.5 ft) clay layers; some gravel; damp (added).	SM
137-142	Sand and gravel (as above).	SP/GP
142-180	Fine sand (as above at 43 ft); thin (less than 0.5 ft) layers of silty sand and coarse sand fine gravel; damp (added). Increasing gravel at 178 ft; still mostly fine/medium sand; damp (added)	SP/GP
180-188	Fine/medium sand; as above 184 ft; coarse sand and gravel as above; damp (added).	SP/GP
188-215	Silty sand (as above); thin sand and gravel layers (less than 0.5 ft); damp (apparently natural, not added) at approximately 195 ft. [Split spoon had silty sandy clay and gravel). Thin (less than 0.5 ft) gravel layers (coarse gravel to 3 inches diameter).	SM
215-240	Fine sand (as above) occasional gravel; dry to slightly damp; moderate yellowish brown (10YR 5/4). Some thin (0.5 ft) layers of silty sand/gravel.	SP

Depth, ft bgs	Description	USCS Group
240-248	Sand and gravel (as above); damp (added) Adding water to bring up cuttings/keep down dust. Stopped at 242 ft.	SP
248-250	Coarse gravel (to 2 inches) damp (natural).	SP
250-260	Fine sand/silty sand (as above); some gravel, dry to damp. Add water 265 ft.	SP
260-283	Fine sand, very well sorted (aeolian?); dry to damp (added). Thin gravelly clay/sand layers at approximately 275 ft.	n.r.
283-288	Silty sand and clay; dry to damp. Added water from 280 to 285 ft.	n.r.
288-300	Fine sand/silty sand; damp to slightly moist. Based on driller comments 'close to making water' because cuttings are burping up the casing.	n.r.
300-303	Silty sand (as above); very damp to moist.	SM
303-307	Sand and gravel (as above); very damp to moist.	SP/GP
307-317	Silty sandy clay, very damp.	CL
317-320	Silty sand/fine sand, very damp to moist.	SM
320-345	Silty sandy clay; very dense/firm. Start injecting water, from 320 to 578 ft.	CL
345-388	Silty clay with less than 20% very fine- to very coarse sand and very fine pea gravel; angular to subangular, mainly quartzite, granite, greenstone and gneissic fragments.	SC/SM
388-414	Clay and silty clay with 5 to 10% very fine- very coarse sand. Perhaps some fine gravel ground up by drill bit. Angular to subangular gravel mainly quartzite, granite, gneiss, and some greenstone clasts. Water injection continues (from 320 to 578 ft).	CL
414-420	Sandy and clayey silt. Very fine coarse sand, 20%, as above (345 to 388 ft).	SC
420-434	Clay and silty clay like 388 to 414 ft. Water injection continues (added from 320 to total depth at 578 ft).	CL
434-455	Gravel, sand, silt mixture. Less than 30% fine gravel and very fine to very coarse sand, angular to subangular. Mainly granite and gneissic fragments with minor quartzite and greenstone.	GM
455-488	Like 434-455 ft except up to 50% fine gravel and very fine to very coarse sand	GM
488-493	Clay and silt with less than 10% very fine to coarse sand. Water injection continues.	CL
493-525	Interbedded gravelly silty sands and silty/clayey sands. Gravel and coarse sand. Angular to subrounded, mainly Precambrian clasts. Interval drilled relatively quickly.	SP/SM
525-536	Silty and clayey sand.	SM
536-573	Gravel, sand, and silt mixture with occasional clay-rich zones. Gravel less than 0.5 inches in diameter, subangular to subrounded, Precambrian clasts.	CM
573-578	Like 536 to 573 ft, except larger (less than 1-inch diameter) gravel and pebbles composed of granite, gneissic, quartzite, and greenstone clasts.	GM
578	Borehole Total Depth.	

n.r. = not recorded. The Unified Soil Classification System (USCS) symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TA1-W-03

Drilling company	Water Development Corporation
Dates of drilling	January 19 – 21, 1998
Drilling method	ARCH, cuttings logged, no cores
Total depth of borehole, ft	363
Ground elevation, ft amsl NAVD 88	5454.9
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	337.0 to 357.0
Date well developed	January 27, 1998
Initial water level, ft bgs	337.74
Rig Geologist	Mike Skelly

Depth, ft bgs	Description	USCS Group
0	Silty sand, light brown to yellowish brown, very fine to medium sand, dry.	SP
15	Silty sand, moderate brown to dark brown, very fine and poorly sorted, moist, minor amounts of gravel (limestone) up to 3 inches diameter.	SM
30	Sand, light to moderate brown, poorly sorted, fine to coarse sand, moist.	SP
40	Sand, as above, more gravel, clasts to 4 inches diameter.	SP
48	Sand, as above, sand grading to gravel, light brown, dry.	GP
50-52	Sandy, light to medium brown, very fine to coarse sand, minor silt and gravel, poorly sorted, dry.	SP
63	Sand, as above, more gravel clast up to 2 inches diameter.	SP
65	Sand, light brown, medium to coarse sand, dry, some gravel	SP
79	Silty sand, medium-dark brown, very fine to medium sand, moist.	SM
80	Gravel lens, clasts are 3 to 4 inches in diameter.	n.r.
90	Sand, as above, slightly moist.	SM
95	Silty sand, medium brown, very fine to coarse sand, poorly sorted, slightly moist.	SM
100	Clay, brown (10YR 4/4), moist.	CL
110	Sand, light to medium brown (10YR 4/2), fine to coarse sand, poorly sorted, dry, minor gravel, subrounded.	SP
117	Gravel lens with sand, as above.	SP
135	Gravel lens.	SP
140	Sand, as above, moderate brown (5YR 4/4), very fine to coarse sand, angular to subrounded, poorly sorted, moist, minor small gravel to silty sand.	ML/SM
150	Sandy silt to silty sand, moderate brown (5YR 4/4), very fine sand to coarse sand, subrounded, moist, slight plasticity.	n.r.
162	Sand, moderate to yellowish brown, very fine to coarse sand, angular to subrounded, moist gravel lens, minor clay.	SP
172	Gravel lens, minor clay.	SP
180	Sand, as above.	SP
185	Sand, as above.	SP
195	Sand, as above.	SP
205-210	Coarse sand and gravel.	n.r.
210	Sand, as above.	n.r.
220	Sand with silt, dark yellowish brown (10YR 4/2), very fine sand, well sorted, moist, some gravel.	SP
230	Sand, moderate yellowish brown (10YR 5/4), very fine to some coarse sand, dry to moist.	SW

Depth, ft bgs	Description	USCS Group
242	Gravel lens.	n.r.
245	Coarse sand, fine gravel lens.	n.r.
250	Sand with gravel, moderate brown to yellowish brown sand, very fine to coarse, poorly sorted, gravel fine, dry.	SP
260	Sand, moderate brown (5YR 4/4) to moderate yellowish brown (10YR 5/4) very fine to coarse sand, well graded, slightly moist.	SW
280	Sand, as above.	SP
290	Sand, as above, poorly sorted.	n.r.
300	Minor gravel.	SP
305	Silty sand, dark yellowish brown (10YR 4/2), very fine sand to small amount of coarse sand, moist, very minor amount of gravel.	SM
310	Sand grading coarser.	n.r.
315	Sand, moderate yellowish brown (10YR 5/4), fine to coarse sand, slightly moist, minor fine gravel.	SP
318	Gravel lens, fine to coarse, subrounded to rounded, limestone gravel.	n.r.
320	Sand, moderate yellowish brown (10YR 5/4), very fine to fine sand, moist, well graded.	n.r.
338	Sand, dark yellowish brown (10YR 4/2), fine to coarse sand, some fine gravel, moist.	n.r.
363	Borehole total depth.	

n.r. = not recorded. The Unified Soil Classification System (USCS) symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TA1-W-04

Drilling company	Water Development Corporation
Dates of drilling	September 8 to October 6, 1998
Drilling method	ARCH, cuttings logged, also split spoon cores from 51-52 ft, 91-92 ft, 152-153 ft, and 252-253 ft
Total depth of borehole, ft	630
Ground elevation, ft amsl NAVD 88	5458.3
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Screen, ft bgs	576.0 to 596.0
Date well developed	October 6, 1998
Initial water level, ft bgs	572.00
Rig Geologist	Mike Skelly, Mike Sanders, and John Copland

Depth, ft bgs	Description	USCS Group
0-3	Sand and gravel, pale yellowish brown (10YR 6/2), fine to medium sand, gravel to 2 inches diameter, dry.	n.r.
3-8	Silty sand and gravel, moderate brown (5YR 4/4), trace clay, some gravel (to 1-inch diameter), dry to slightly damp.	n.r.
8-10	Fine sand, moderate brown, well sorted, poorly graded, slightly damp.	n.r.
10-17	Sand and gravel, mostly coarse sand and fine gravel, some coarse gravel to 3-inches diameter, dry.	n.r.
17-31	Fine sand, moderate brown, some fine gravel, some silt, slightly damp.	n.r.
31-36	Sand and gravel, mostly coarse sand/fine gravel, dry.	n.r.
36-54	Fine sand, some silt and fine gravel, color change (reddish tint) at approximately 43 ft, dry to slightly damp.	n.r.
54-68	Coarse sand and gravel (to 3 plus inches diameter), dry.	n.r.
68-73	Fine sand, some gravel (to 1-inch diameter), dry to slightly damp.	n.r.
73-79	Sand and gravel (to 2 inches diameter approximately), dry to damp.	n.r.
79-91	Fine sand, trace of silt and gravel (to 1-inch diameter), dry to damp	n.r.
91-110	Sandy silt, moderate brown (5YR 4/4), somewhat dusty out of cyclone	SM
110-117	Gravel (sand and silt mixture), 30% silt moderate yellow brown (10YR 5/4) 50% very fine to very coarse sand, 20% fine gravel less than 0.25 inches diameter, mainly Precambrian granite and gneiss, with minor limestone, very coarse gravel less than 2.5-inches diameter at 116 ft (thin lens), limestone and Precambrian rock types.	CM
117-137	Silty sand and sandy silt, like 79 to 110 ft, minor (< 20%) coarse sand at 125 ft.	SM
137-150	Gravelly sandy silt, silt is moderately brown (5YR 4/4), less than 20% fine to coarse sand and occasionally very coarse gravel fragments less than 3 inches in diameter, limestone and Precambrian greenstone, granite and gneiss.	CM
150-185	Gravel (sand and silt mixture), 20% silt to very fine sand, 40% medium coarse sand, 40% fine to coarse gravel less than 1.5-inches diameter, fragments are limestone and Precambrian lithologies	GM
185-202	Silt, very fine sand, moderately brown (5 YR 4/4) like 79 to 110 ft, slightly damp.	
202-206	Gravel (sand/silt mixture), like 150 to 85 ft, gravel less than 1-inch diameter.	GM
206-235	Silt (sandy silt) moderately brown (5 YR 4/4), like 79 to 110 ft.	GM
235-255	Sand (50%) and gravel (40%) with minor (less than 10%) silt. Gravel subrounded-subangular, limestone and Precambrian fragments less than 1-inch in diameter.	GM
255-270	Silty sand (sandy silt) like 201 to 235 ft, increasing clay content 264 to 270 ft (less than 10%?)	SM

Depth, ft bgs	Description	USCS Group
270-289	Sand (50%) gravel (40%) and minor (less than 10%) silt, like 235 to 255 ft, dusty out of cyclone.	GM
289-297	Clayey sandy silt, like 255 to 270 ft, somewhat damp.	SM
297-304	Coarse sand (50%), gravel (40%), with minor silt (10%), like 270 to 289 ft.	GM
304-309	Gravelly silt, gravel fragments to 1-inch diameter, slightly damp out of cyclone.	SP
309-313	Silt (sand) fine gravel mixture, slightly damp.	n.r.
313-317	Sand and gravel, mostly (more than 50%) gravel to 2-inches in diameter, various lithologies but predominantly granite, dry to slightly damp.	n.r.
317-319	Sand and gravel mostly coarse sand, damp.	n.r.
319-322	Fine sand, some gravel, damp to very damp.	n.r.
322-324	Caliche, cemented sand and gravel, dry.	n.r.
324-330	Fine sand, some gravel, very damp.	n.r.
330-337	Alternating layers of silty sand and clayey silty sand with some gravel, very damp.	n.r.
337-357	Interbedded silty sand with clayey silty sands, some gravel in a few layers, damp to very damp.	n.r.
357-360	Silty sand, no gravel, damp to very damp.	n.r.
360-371	Silty sand and gravel, damp to very damp.	n.r.
371-377	Fine sand, thin approximately 0.5 ft gravel layer at approximately 376 ft, damp to very damp.	n.r.
377-380	Fine sand, damp to very damp. Cuttings stopped returning after 2 to 4 ft.	n.r.
380-383	Silty sandy clay.	n.r.
383-389	Sand or gravel interbedded with silty sand.	n.r.
389-396	Silty sandy clay with some interbedded gravels especially at approximately 396 ft.	n.r.
396-416	Interbedded silty sand with sand and gravel, trace of sandy clay in thin (less than 6 inches diameter) layers, gravel to 1.5-inches diameter, last few feet mostly silty sand.	n.r.
416-418	Sand and gravel.	n.r.
418-421	Silty sandy clay.	n.r.
421-423	Sand and gravel.	n.r.
423-436	Interbedded silty sandy clay (usually thin less than 6 inches diameter) with silty sand and sandy gravel, possibly marking water.	n.r.
436-439	Sand and gravel, little to no fines, making less than 1 gallon per minute (gpm) of ground water.	n.r.
439-451	Possibly silty sand with thin sandy gravel.	n.r.
451-456	Interbedded silty sand with silty to sandy clay. Increasing clay with depth. Not making much water.	n.r.
456-457	Sandy gravel.	n.r.
457-458	Clayey sand.	n.r.
458-470	Clay, brown.	n.r.
470-473	Coarse sand, silty.	n.r.
473-475	Medium sand to coarse sand, silty.	n.r.
475-476	Gravelly sand, silty (little water).	n.r.
476-480	Interbedded medium sand and clayey sand, silty.	n.r.
480-485	Medium to gravelly sand with silt.	n.r.
485-487	Coarse to gravelly sand, silty.	n.r.
487-490	Silty sand interbedded with clay sand.	n.r.
490-492	Clay streak, brown.	n.r.
492-504	Fine to coarse sand, silty.	n.r.
504-508	Interbedded medium sand and clayey sand.	n.r.

Depth, ft bgs	Description	USCS Group
508-511	Coarse sand, 10% gravel, no silt.	n.r.
511-512	Gravelly sand, silty.	n.r.
512-513	Fine to coarse sand, silty.	n.r.
513-516	Clayey sand to fine sand, interbedded.	n.r.
516-521	Medium to coarse sand, silty.	n.r.
521-526	Interbedded medium to coarse sand with clayey sand.	n.r.
526-532	Coarse to gravelly sand, silty.	n.r.
532-536	Fine to gravelly sand, silty.	n.r.
536-540	Medium to coarse sand, silty.	n.r.
540-544	Fine to coarse sand, silty.	n.r.
544-550	Interbedded clayey fine sand with fine/medium sand, silty.	n.r.
550-556	Clayey sand, fine to medium, makes no water.	n.r.
556-565	Interbedded clay with fine to coarse sand, silt, no water.	n.r.
565-570	Clay, brown, no water.	n.r.
570-575	Interbedded clay with fine to coarse sand, silty, no water.	n.r.
576	Clay, brown.	n.r.
577-579	Interbedded clay with medium-coarse sand, silty.	n.r.
579-581	Fine to coarse sand, silty.	n.r.
581-586	Medium to gravely sand, silty, no water.	n.r.
586-591	Fine to medium sand, silty.	n.r.
591-594	Medium to gravelly sand, silty	n.r.
594-597	Medium to coarse sand, silty.	n.r.
597-600	Medium to coarse with occasional clay, no water.	n.r.
600-605	Fine to coarse sand, silty.	n.r.
605-606	Interbedded clay with fine sand.	n.r.
606-610	Fine to medium sand, silty.	n.r.
610-612	Medium to coarse sand, silty.	n.r.
612-613	Clay interbedded with medium sand.	n.r.
613-615	Medium to coarse sand, silty.	n.r.
615-619	Medium to gravelly sand, silty.	n.r.
619-620	Coarse to gravelly sand, silty.	n.r.
620-626	Medium to coarse sand, silty.	n.r.
626-628	Fine to medium sand, silty.	n.r.
628-630	Medium to gravelly sand, silty. Borehole may be making a little water but difficult to know due to 1800 CFM (cubic feet per minute) of air being injected down the drill pipe.	n.r.
630	Borehole Total Depth.	

n.r. = not recorded. The Unified Soil Classification System (USCS) symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TA1-W-05

Drilling company	Water Development Corporation
Dates of drilling	October 8 – 11, 1998
Drilling method	ARCH, cuttings logged, also split spoon cores from 60 to 61 ft, 160 to 165 ft, and 257 to 260 ft
Total depth of borehole, ft	625
Ground elevation, ft amsl NAVD 88	5434.2
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Screen, ft bgs	597.5 to 617.5
Date well developed	November 16, 1998
Initial water level, ft bgs	575.62
Rig Geologist	John Copland and Mike Sanders

Depth, ft bgs	Description
0-18	Silty sand to gravelly sand, dry, no pavement in parking lot.
18-28	Silty sand to gravelly sand, damp, occasional fragments of cobbles.
28-42	Silty sand to gravelly sand, damp.
42-58	Silty sand, damp, brown.
58-78	Silty sand, damp, brown, with occasional cobble fragments.
78-98	Silty sand, brown, damp, with occasional gravel.
98-118	Fine to medium sand, silty, damp, brown.
118-138	Fine to medium sand, silty, damp, brown, with occasional gravel.
138-150	Silty sand, fine to medium, damp, brown.
150-160	Fine to coarse sand, damp, silty, brown.
160-162	Fine to coarse sand, silty, damp, with gravel 20%.
162-170	Interbedded sand and gravel as above with clay streaks as 30% of 3 ft of split-spoon interval, damp.
170-180	Fine to coarse sand, silty, damp, brown.
180-188	Fine to medium sand, silty, damp, brown.
188-200	Fine to coarse sand, silty, damp, brown.
200-201	Coarse to gravelly sand, silty.
201-239	Mixture of silt (30%), fine to coarse sand (60%), and fine gravel (10%), damp, moderate brown, 5YR 4/4. Abundant gravel (greater than 50%) of 0.25- to 1.5-inch diameter from 225 to 226 ft.
239-248	Clayey and sandy silt, moderate brown, 5YR 4/4, damp, very minor (less than 5%) fine gravel.
248-257	Silty (20%), fine to coarse sand (50%), fine to coarse gravel less than 1-inch diameter (30%), limestone and Precambrian igneous and metamorphic fragments, damp.
257-270	Silt and fine sand, moderate brown, 5YR 4/4, damp, gravel fragments to 1.5-inch diameter from 257 to 258 ft.
270-317	Silt (20%), fine to coarse sand (50%), fine to medium gravel (30%). Less than 10% clayey silt at 275 ft.
317-325	Clean medium and coarse sand and fine-medium gravel, mainly igneous and metamorphic fragments, possible perched aquifer.
325-347	Mixture of silt 50%, sand 30%, and gravel 20%.
347-365	Clay (20%), silt (40%), fine to coarse sand (30%), and gravel at 0.5-inch diameter (10%)
365-382	Silty sand (60%) and fine to coarse gravel (40%), fragments of medium brown sandstone to 1.5-inch diameter, drills similar to well-indurated sandstone.
382-392	Clay and silty clay, slow drilling.
392-401	Silt (30%), fine to coarse sand (50%), fine to medium gravel to 0.5-inch diameter, mainly Precambrian igneous and metamorphic fragments, minor limestone.

Depth, ft bgs	Description
401-408	Coarse sand and fine gravel (clean from 401 to 403 ft), then with less than 20% silt to 408 ft.
408-411	Sandy silty clay, slow drilling.
411-460	Silty and gravelly sand, mainly (70%) fine to coarse sand, almost all Precambrian igneous and metamorphic fragments with very minor limestone.
455	Interbeds of 90% brown clay and 10% coarse sand.
460	0.125 to 0.5-inch diameter pebbles of brown rock, possibly tuff.
460-515	Silt, sandy, very fine gravel mixture, ratios variable throughout interval without injecting water but increasingly sparse return of cuttings.
515-599	Very sparse sporadic returns. Unreliable indicator of lithology. Water injected from 538 ft to TD. Lithologies appear to be mainly silts, clayey silts and variable amounts of fine to coarse sand (generally less than 20%), no apparent water producing sand or gravel zones. Thick sequence of relatively fine material could act as confining layer.
599-618	Fine to coarse sand (less than 70%) and fine to medium gravel less than 1-inch diameter (30% to 50%), fairly clean, minor silt fraction (less than 10%?). Appears to be making water. Fining downwards in general.
618-622	Sandy silt, silty sand. Little- no coarse sand, or gravel, fining downward.
622-625	Silty clay and clayey silt. Slow drilling (tough material).
625	Borehole Total Depth.

The Unified Soil Classification System symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TA1-W-06

Drilling company	Water Development Corporation
Dates of drilling	February 24 – 25, 1998
Drilling method	ARCH, cuttings logged, no cores
Total depth of borehole, ft	330
Ground elevation, ft amsl NAVD 88	5417.4
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	300.0 to 320.0
Date well developed	February 27, 1998
Initial water level, ft bgs	299.75
Rig Geologist	Mike Skelly

Depth, ft bgs	Description
0	Asphalt pavement.
0.3	Silty sand, pale yellowish brown (10YR 6/2).
9	Sand and gravel, gravel up to 2-inches diameter consisting of granite, greenstone, and limestone.
13	Silty sand, moderate brown (5YR 4/4), some coarse sand and fine gravel, mostly fine sand. Thin (less than 1 ft) gravel layers at approximately 22 and 25 ft.
28	Sand and gravel, as above.
42	Silty sand, as above, more clay rich at 44 to 46 ft.
46	Sand and gravel, as above.
62	Silty sand, as above, some fine gravel throughout.
102	Sand and gravel, as above.
115	Silty sandy clay, some fine gravel, grades to silty clayey sand with depth.
120	Silty sand, as above, moist with thin gravel layers (gravel up to 3 inches in diameter), in 1- to 2- ft thick beds, especially at approximately 135 ft and 138 ft.
140	Silty sand, as above, clay-rich at approximately 153 ft, similar thin gravel layers throughout.
164	Sand and gravel, as above, fine sand from 176 ft to 178 ft with some coarse gravel.
180	Silty sand, some gravel layers.
200	Silty sand, as above.
228	Sand and gravel as above.
235	Fine sand and silty sand, as above.
248	Sand and gravel, as above.
253	Silty and clayey sand, damp, varying amounts of gravel to 1-inch diameter, and some silty and sandy clays in thin (less than 0.5 ft) layers.
287	Sand and gravel, as above, damp to moist.
293	Silty and clayey sand, some gravel, damp to moist.
300	Silty and clayey sand, some sandy gravel layers throughout, damp to moist.
317	Sandy clay, moist.
322	According to driller, feels like sand and gravel at 322 to 325 ft.
325	Silt and clay.
330	Borehole total depth.

The Unified Soil Classification System symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TA1-W-07

Drilling company	Water Development Corporation
Dates of drilling	August 11 – 13, 1998
Drilling method	ARCH, cuttings logged, no cores
Total depth of borehole, ft	290
Ground elevation, ft amsl NAVD 88	5402.8
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	268.6 to 286.6
Date well developed	December 3, 1998
Initial water level, ft bgs	274.00
Rig Geologist	Mike Skelly

Depth, ft bgs	Description
0-5	Silty sand with some fine gravel, moderate yellow brown, 10YR 5/4, dry.
5-20	Sand and silty sand, some gravel (to 2-inches diameter) in thin (less than 1 ft) layers, dry.
20-32	Silty sand and gravel as above, dry to damp.
32-35	Sand and gravel as above, damp.
35-40	Fine sand, moderate brown, 5YR 4/4, well sorted, damp.
40-43	Fine sand as above, damp.
43-56	Silty sand and gravel, predominately gravel layers at 45 ft to 48 ft underlain by silty sandy clay, gravels were dry, fines were dry.
56-58	Fine sand, as above.
58-60	Silty sand and gravel.
60-75	Silty sand and gravel, as above, gravel layers up to 2 ft-thick, dry to damp, varying amounts of fines.
75-80	Fine sand, as above, with some (trace) gravel, damp.
80-82	Fine sand, as above, damp.
82-100	Silty sand and gravel with gravels up to 2-ft thick starting at approximately 90 ft, dry to damp.
100-103	Fine sand, as above, some gravel, damp.
103-112	Sand and gravel (gravel to 3-inches diameter), dry.
112-120	Interbedded fine sand and clayey silty sand, damp.
120-140	Interbedded fine sand and silty sand, damp, thin (less than 1 ft) gravel layers, some gravels to 1-inch diameter, dry.
140-160	Interbedded fine sand and silty sand, damp. Notable gravel at 148 to 150 ft, dry, some thin (less than 0.5 ft). Occasional clay-rich layers, especially towards bottom, damp.
160-180	Interbedded fine sand and silty sand, damp, less gravel than above, less in thickness (less than 0.5 ft) silty to sandy clay layers.
180-188	Interbedded fine sand and silty sand, damp.
188-193	Sand and gravel, dry.
193-200	Fine sand, silty sand, damp.
200-220	Fine sand, silty sand, as above, damp to very damp, more clay rich at approximately 216 ft.
220-240	Fine and silty sand, as above, damp to very damp, thin (less than 6 inches) gravel layers at approximately 221 ft, underlain by silty sandy clay with increasing clay with depth, damp to very damp. At 240 ft, back to mostly fine sand, damp but not wet.
240	No cuttings returned for 9 to 10 ft, load came up mostly silty and sandy clay, damp.
250-260	Sand and gravel, occasional thin layers of finer grained (to silty clay), damp even in gravels.
260-272	Sand and gravel, increasingly finer grained near bottom, very damp to possibly wet.
272-280	Silty sand, silty sandy clay, little to no gravel, very damp.
280-290	Silty sandy clay, minor gravel, wet.

Depth, ft bgs	Description
290	Borehole Total Depth.

The Unified Soil Classification System symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TA1-W-08

Drilling company	Water Development Corporation
Dates of drilling	August 1 – 3, 2001
Drilling method	ARCH, cuttings logged, no cores
Total depth of borehole, ft	335
Ground elevation, ft amsl NAVD 88	5434.7
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	302.0 to 322.0
Date well developed	October 10, 2001
Initial water level, ft bgs	306.70
Rig Geologist	Robert (Bob) Cooper

Depth, ft bgs	Description	USCS Group
5	Slightly sandy silt, less than 5% medium sand, pale brown, 10YR 8/3.	ML
10	As above.	ML
15	Sandy silt, 10-20% medium sand, pale brown, 10YR 8/3.	ML
20	Silty gravelly sand, well graded, medium to very coarse sand with more than 40% fine pebble gravel, pale brown, subangular, 10YR 8/3.	SM
25	Sandy gravel, 10-20% medium to coarse sand, fine to medium pebble gravel, mostly 0.25- to 0.75-inch diameter gravel, subangular.	GM
30	Sandy silt, 10-20% medium sand, pale brown 10YR 8/3.	ML
35	As above. Sandy silt, 10-20% medium sand, pale brown 10YR 8/3.	ML
40	As above.	ML
45	As above.	ML
50	Silty sand, moderately graded, medium to coarse sand with 20-30% silt, pale brown, 10YR 8/3.	SM
55	Slightly clayey silt, very low plasticity, light brown 7.5YR 6/4.	ML
60	As above.	ML
65	Gravelly sand, well graded, medium to coarse grained, with 20% gravel 0.25- to 0.5-inch diameter subangular, trace silt.	SW
70	Sandy gravel, fine to medium pebble gravel mostly 0.5- to 1-inch diameter containing 30% fine to coarse sand (well graded), subangular, very moist to wet.	GW
75	Sandy silt, less than 10% medium sand, pale brown, 10YR 8/3.	ML
80	Silty sand, well graded, fine to very coarse, subangular.	SM
85	Slightly sandy silt, less than10% medium sand, pale brown, 10YR 5/3.	ML
90	As above.	ML
95	As above.	ML
100	Clayey silt, very low plasticity, light brown 7.5YR 6/6.	ML
105	As above, slightly less clay.	ML
110	As above, less clay.	ML
115	As above.	ML
120	Clayey silt, medium brown, 7.5YR 5/4.	ML
125	Sandy silt, 20-30% medium to coarse sand, light brown 7.5YR 6/6.	ML
130	As above with 10-20% sand.	ML
135	Silty sand, well graded, medium to very coarse sand, mostly coarse sand.	SM
140	Sandy silt, 10% medium sand, light brown, 7.5YR 6/6.	ML
145	As above.	ML
150	Sandy silt, 5 to 10% medium sand, medium brown, 7.5YR 5/4.	ML

Depth, ft bgs	Description	USCS Group
155	Slightly silty sand, well graded, medium to very coarse grained, mostly coarse, pale brown, 10YR 8/3.	SM
160	Sandy silt, 10-20% medium sand, medium brown, 7.5YR 5/4.	ML
165	Sandy silt, 10-20% medium sand, medium brown, 7.5YR 5/4.	ML
170	Slightly silty sand, well graded, medium to very coarse, mostly coarse.	SW
175	Slightly sandy silt, less than 5% medium sand, medium brown, 7.5YR 5/4.	ML
180	Slightly sandy silt, less than 5% medium sand, medium brown, 7.5YR 5/4.	ML
185	Slightly sandy silt, less than 5% medium sand, medium brown, 7.5YR 5/4.	ML
190	Slightly sandy silt, less than 5% medium sand, medium brown, 7.5YR 5/4.	ML
195	Slightly sandy silt, less than 5% medium sand, medium brown, 7.5YR 5/4.	ML
200	Slightly sandy silt, less than 5% medium sand, medium brown, 7.5YR 5/4.	ML
205	Sandy silt, 20-30% medium sand, light brown, 7.5YR 6/6.	ML
210	Slightly sandy silt, less than 10% sand, light brown, 7.5YR 6/6.	ML
215	Slightly sandy silt, less than 10% sand, light brown, 7.5YR 6/6.	ML
220	Very silty sand, well graded, medium to coarse grained, subangular, light brown, 7.5YR 6/6.	SM
225	Sandy silt, 20-30% coarse to very coarse sand, light brown, 7.5YR 6/6.	ML
230	Gravelly sand, well graded medium to coarse sand with 20% fine pebble gravel, subangular, pale brown, 10YR 8/3.	SW
235	Sandy gravelly silt, 30-40% sand and gravel, medium to coarse sand and very fine pebble gravel, subangular, light brown, 7.5YR 6/6.	ML
240	Slightly sandy silt, less than 10% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
245	Slightly sandy silt, less than 10% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
250	Slightly sandy silt, less than 10% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
255	Slightly sandy silt, less than 10% medium to coarse sand, pale brown, 10YR 8/3.	ML
260	Slightly sandy silt, less than 10% medium to coarse sand, pale brown, 10YR 8/3.	ML
265	Silty sand, well graded, fine to coarse grained with trace fine pebble gravel, subangular, pale brown, 10YR 8/3.	SM
270	Slightly silty, gravelly sand, well graded, fine to coarse sand with 10-20% fine pebble gravel, subangular, pale brown, 10YR 8/3.	SW
275	Slightly sandy silt, medium sand with trace fine pebble gravel, light brown, 7.5YR 6/6.	ML
280	Slightly sandy silt, medium sand with trace fine pebble gravel, light brown, 7.5YR 6/6.	ML
285	Slightly sandy silt, medium sand with trace fine pebble gravel, light brown, 7.5YR 6/6.	ML
290	Slightly sandy silt, medium sand with trace fine pebble gravel, light brown, 7.5YR 6/6.	ML
295	Slightly silty sand, well graded fine to coarse grained, subangular, pale brown 10YR 8/3.	SW
300	Slightly silty sand, well graded fine to coarse grained, subangular, pale brown 10YR 8/3.	SW
305	Slightly sandy silt, less than 10% medium sand, light brown 7.5YR 6/6.	ML
310	Very silty gravelly sand, well graded, fine to coarse sand with 30-40% fine to medium pebble gravel, subangular, pale brown, 10YR 8/3, wet.	SM
315	Very silty gravelly sand, well graded, fine to coarse sand with 30-40% fine to medium pebble gravel, subangular, pale brown, 10YR 8/3, makes water.	SM

Depth, ft bgs	Description	USCS Group
320	Slightly silty sand, moderately graded, coarse to very coarse grained, subangular, pale brown, 10YR 8/3.	SW-SP
325	Slightly silty sand, moderately graded, coarse to very coarse grained, subangular, pale brown, 10YR 8/3.	SW-SP
330	Slightly silty sand, moderately graded, coarse to very coarse grained, subangular, pale brown, 10YR 8/3.	SW-SP
335	Sandy clayey silt, medium sand, very low plasticity, wet, medium brown 7.5YR 5/4.	ML
335	Borehole Total Depth.	

USCS = Unified Soil Classification System.

Lithologic Log for borehole at monitoring well TA2-NW1-325

Drilling company	USGS Water Sciences Division
Dates of drilling	March 7 – 22, 1993
Drilling method	Sonicore with Drive Casing. Continuously cored from ground surface to 330 ft bgs
Ground elevation, ft amsl NAVD 88	5420.0
Total depth of borehole, ft	330
Screen, ft bgs	295.0 to 325.0
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Date well developed	April 1, 1993
Initial water level, ft bgs	306.54
Rig Geologist	C. Abeyta and J. Szalona of the USGS.

Three descriptions:

- Composite Description from USGS combined geophysics/lithologic log.
- USGS 17-page description for TA2-NW1-325 borehole (0 to 330 ft).
- Fritts and Van Hart (March 1997) 2-page description (297 to 470 ft) for TA2-NW1-595 borehole.

Depth, ft bgs	Composite Description from USGS combined geophysics/lithologic log
0-15	Sand, silty. Moderate yellowish brown, very fine- to fine-grained, minor pebbles, caliche.
15-42	Silt, sandy. Moderate yellowish brown, very fine- to fine-grained, minor pebbles.
42-71	Sand, silty. Pale yellowish brown, very fine- to fine-grained sand, increased clay content below 60 ft, minor pebbles, cobbles.
71-95	Sand, pebbly and silty. Moderate yellowish brown, very fine- to very coarse-sand, subangular, granite, quartzite, and granite clasts.
95-120	Sand. Moderate to light brown, very fine- to fine-grained sand, minor silt and pebbles, moderately well sorted.
120-128	Silt, sandy. Moderate brown, very fine- to fine-grained sand, minor gravel.
128-162	Sand, silty. Light brown, very fine- to fine-grained sand, minor clay.
162-191	Sand, silty and clayey. Moderate to yellowish brown, very fine- to fine-grained sand, pebbly interbeds.
191-204	Sand, silty. Moderate yellowish brown, very fine- to fine-grained.
204-220	Sand, silty and clayey. Moderate yellowish brown, very fine- to fine-grained sand.
220-255	Sand, silty. Moderate yellowish brown, very fine- to fine-grained sand, limestone, quartzite, and granite clasts in interbeds, moderately sorted.
255-272	Sand, silty and clayey. Moderate yellowish brown, very fine- to fine-grained sand.
272-280	Sand, silty. Moderate yellowish brown, very fine- to fine-grained sand, well sorted.
280-313	Sand, silty. Moderate yellowish brown, very fine- to fine-grained sand, clay, caliche, trace pebbles.
313-325	Sand, silty and clayey. Moderate yellowish brown, very fine- to fine-grained sand, subangular to angular.
325-370	Sand, silty. Light brown, very fine- to fine-grained sand, pebbly below 334 ft, subangular to angular, feldspar, granite, and quartz clasts.
370-382	Clay, silty. Light brown, less than 10 percent sand, very fine- to medium-grained sand.
382-394	Silt, pebbly and sandy. Light brown, very fine- to fine-grained sand.
394-447	Sand, silty. Moderate yellowish brown, very fine- to fine-grained, angular and subangular.
447-460	Silty, clayey and sandy. Light brown, very fine- to fine-grained sand, trace pebbles.

Depth, ft bgs	Composite Description from USGS combined geophysics/lithologic log
460-510	Sand, silty. Moderate yellowish brown, very fine- to fine-grained sand with pebble interbeds, angular to subangular, feldspar, quartz, granite, and limestone clasts.
510-540	Silt, clayey and sandy. Moderate yellowish brown, very fine- to fine-grained sand, pebbly interbeds, angular to subangular, granite and limestone clasts.
540-562	Sand, pebbly. Moderate yellowish brown, very fine-to very coarse-grained sand, silty sand and silty clay interbeds, limestone, granite, quartz, and feldspar clasts.
562-576	Clay, silty and sandy. Moderate brown, very fine- to medium-grained sand, pebbles.
576-595	Sand, clayey and silty. Moderate yellowish brown, very fine- to medium-grained sand, pebbly interbeds, granite, feldspar, and quartzite clasts.

The Unified Soil Classification System symbol was not recorded on the original lithologic log or field notes.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG

Tech Area 2 -- TA2/NW1/~~320~~ 325

Ground Elevation: 5418 feet (Estimated) Drilling Method/Fluids: Sonic/Dry or
Logged by: U.S. Geological Survey (Abeyta, Szalona) driven where noted
Drilling began: 07MAR93 Drilling completed: 22MAR93 Total Depth: 330 feet
Color Chart: Goddard, E.N., and others, 1991, Rock color chart: Geological Society of America, Boulder, Colo.

0'-3' (1.3' recovered, driven) **Silty sand with pebbles and minor clay;** sand - fine to medium grained with approximately 3% coarse to very coarse grains, pebbles approximately 3% and ≤ 35 mm, clay approximately 3%, subangular, poorly sorted; sand - quartz, minor feldspar, mica, pebbles - granite, quartzite, graywacke; Grayish Orange 10YR7/4, clay - Dark Yellowish Brown 10YR4/2; roots abundant; loose to moderately compacted (probably compacted during drilling), caliche present as blebs, moderate to strong reaction with HCl; moist, clay - very moist.

3'-6' (2.5' plus recovered, driven) Upper 0.7' - **Silty sand with clay;** sand - very fine to fine grained, clay approximately 10%, subangular, moderately well sorted; sand - predominately quartz, minor feldspar and mica; Dark Yellowish Brown 10YR4/2 to Moderate Brown 5YR3/4; roots abundant; moderately compacted, moderate reaction with HCl; moist. Middle 0.8' - **Silty sand with pebbles and caliche;** sand - predominately very fine to fine grained, approximately 5% medium to very coarse grains, pebbles approximately 4% and ≤ 35 mm, subangular, poorly sorted; sand - quartz, minor feldspar, pebbles - quartzite, graywacke; Grayish Orange 10YR7/4; loose, caliche as matrix and as nodules ≤ 2 mm, strong reaction with HCl; slightly moist; gradational basal contact. Lower 1' - **Silty sandy caliche;** sand - very fine to fine grained with < 1% medium to very coarse grains, pebbles < 0.5% and ≤ 50 mm, coarser grains - subangular, moderately well sorted; sand - quartz, minor feldspar, pebbles - quartz; Very Pale Orange 10YR8/2; strongly compacted, caliche as matrix, strong reaction with HCl; very slightly moist to dry.

6'-9' (2' plus recovered, driven) **Silty sandy caliche;** sand - very fine to fine grained with < 1% medium to very coarse grains, < 1% pebbles ≤ 50 mm, coarser grains - subangular, moderately well sorted; sand - quartz, minor feldspar, pebbles - quartz, graywacke; Grayish Orange 10YR7/4; strongly compacted, caliche as matrix and blebs, strong reaction with HCl; dry.

9'-12' (2.8' recovered, driven) Upper 1.8' - **Silty sand with caliche, pebbles and cobble;** sand - very fine to very coarse grained, pebbles approximately 3% and ≤ 20 mm, 1 cobble > 63 mm (fractured by drilling), subangular to subrounded, very poorly sorted; sand - quartz, feldspar, limestone, pebbles - quartzite, limestone, graywacke, sandstone, cobble - quartzite/metagranite; finer matrix - Moderate Yellowish Brown 10YR5/4; loose, strong reaction with HCl; very slightly moist to dry; gradational basal contact. Lower 1' - **Sandy silt with caliche;** sand - very fine to fine grained with 1% medium to very coarse grains, well sorted; sand - quartz, feldspar, mica; Grayish Orange 10YR7/4; moderately compacted, caliche as matrix/cement, strong reaction with HCl; dry.

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LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/320 325

12'-14' (2' recovered) **Silty sand with pebbles and cobbles;** sand - predominately very fine to fine grained with approximately 5% medium to very coarse grains, pebbles approximately 5% and ≤ 50 mm, cobbles < 1% and > 65 mm (fractured during drilling); sand - quartz, feldspar, mica, pebbles - quartzite, limestone, cobbles - quartzite, quartz sandstone; Moderate Yellowish Brown 10YR5/4; pebble/cobble content decreases towards bottom; loose, moderate to strong reaction with HCl; very slightly moist to dry.

14'-27' (7.8' recovered) Upper 1' - **Silty sand with pebbles and cobbles;** sand - predominately very fine to fine grained with approximately 5% medium to very coarse grains, pebbles ≤ 3% and ≤ 50 mm, cobbles < 1% and < 80 mm, subangular, larger clasts - subangular to subrounded, very poorly sorted; sand - quartz, feldspar, mica, pebbles - quartzite, minor limestone, cobbles - quartzite; Moderate Yellowish Brown 10YR5/4; loose, moderate reaction with HCl; very slightly moist; abrupt basal contact. Middle 4' - **Sandy silt;** sand - very fine to fine grained, well sorted; Moderate Yellowish Brown 10YR5/4; moderately compacted, moderate reaction with HCl; slightly moist; gradational basal contact. Lower 2.8' - **Pebbly silty sand;** sand - very fine to very coarse grained, pebbles ≤ 15% and ≤ 50 mm, predominately ≤ 20 mm, subangular, larger clasts - subrounded, poorly sorted; sand - quartz, feldspar, mica, pebbles - quartzite, limestone, minor granite; Moderate Yellowish Brown 10YR5/4; loose, slight to moderate reaction with HCl; very slightly moist.

27'-35' (5.1' recovered) Upper 3.1' - **Sandy silt with pebbles and cobbles;** sand - predominately very fine to fine grained with approximately 5% medium to very coarse grains, pebbles < 2% and ≤ 60 mm, cobbles < 0.5% and ≤ 90 mm, sand - subangular, pebbles and cobbles - subangular to subrounded, moderately sorted; sand - quartz, minor feldspar, pebbles - quartzite, limestone, cobbles - quartzite; Moderate Yellowish Brown 10YR5/4; loose/powdery, slight reaction with HCl; dry; abrupt basal contact. Middle 1.7' - **Pebbly sand;** sand - very fine to very coarse grained, pebbles approximately 20% and ≤ 45 mm, subangular, larger clasts - subrounded, poorly sorted; sand - quartz, feldspar, mica, pebbles - quartzite, sandstone, minor granite; Moderate Yellowish Brown 10YR5/4; loose, no to very weak reaction with HCl; slightly moist; abrupt basal contact. Lower 0.3' - **Sandy clayey silt;** sand - approximately 20% and very fine to fine grained, clay - approximately 20%, well sorted; Moderate Yellowish Brown 10YR5/4; strongly compacted, moderate reaction with HCl; very slightly moist.

35'-45' (10.5' recovered) Upper 4.7' - **Sandy silt with pebbles;** sand - very fine to fine grained with < 2% medium to very coarse grains, pebbles approximately 2% and ≤ 60 mm, predominately < 10 mm, subangular, larger pebbles - subrounded to rounded, moderately sorted; coarser sand - quartz, pebbles - quartzite; Moderate Yellowish Brown 10YR5/4, Pale Yellowish Brown 10YR6/2 towards bottom; sand size becomes coarser (approximately 15% medium to very coarse grains) towards bottom; loose/powdery, weak to strong reaction with HCl; dry; abrupt basal contact

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/320 325

(color change). Next 1.7' - **Sandy silt with minor clay;** sand - very fine to fine grained, clay < 4%, well sorted; sand - quartz, feldspar, mica; Light Brown 5YR5/6; clay in matrix and as blebs; slightly compacted, moderate reaction with HCl; slightly moist; gradational basal contact. Next 3.4' - **Pebbly sand;** sand - very fine to very coarse grained, pebbles approximately 20% and ≤ 48 mm, sand - subangular, pebbles - subangular to subrounded, poorly sorted; sand - quartz, feldspar, mica, sandstone, limestone, pebbles - quartzite, minor sandstone, granite; Pale Yellowish Brown 10YR6/2; loose, moderate reaction with HCl; dry; gradational basal contact. Lower 0.7' - **Silty sand;** sand - very fine to fine grained with < 2% medium to very coarse grains, well sorted; sand - quartz, feldspar, mica; Moderate Yellowish Brown 10YR5/4; clay present as blebs in minor zones; moderately compacted, moderate reaction with HCl; slightly moist.

45'-50' (6.4' recovered) Upper 2.4' - **Silty sand with pebbles and cobble;** sand - very fine to fine grained, pebbles < 5% and ≤ 50 mm, one cobble > 90 mm, sand - subangular, pebbles - subangular to subrounded, cobble - rounded, very poorly sorted; sand - quartz, feldspar, mica, pebbles - quartzite, granite, sandstone, greenstone, cobble - quartzite/metaquartzite; Moderate Yellowish Brown 10YR5/4; loose to slightly compacted, moderate reaction with HCl; slightly moist; abrupt basal contact (especially in color). Middle 2.1' - **Sandy silt with pebbles;** sand - very fine to very coarse grained, pebbles approximately 5% and ≤ 32 mm, sand - subangular, pebbles - subangular to subrounded, poorly sorted; sand - quartz, feldspar, mica, pebbles - quartzite, granite, greenstone; Pale Yellowish Brown 10YR6/2; coarse sand and pebble content increase significantly towards bottom of section, pebbles to approximately 10%; loose/powdery, moderate to strong reaction with HCl; dry; abrupt basal contact. Lower 1.9' - **Clayey silty sand;** sand - very fine to fine grained, well sorted; Moderate Yellowish Brown 10YR5/4 to Moderate Brown 5YR4/4; clay in matrix and as blebs; moderately compacted, slight reaction with HCl; moist.

50'-53' (1.4' recovered, driven split spoon) **Silty sand with cobble;** sand - predominately very fine to fine grained with < 2% medium to very coarse grains, cobble > 63 mm (fractured during drilling), sand - subangular, well sorted; sand - quartz, feldspar, mica, cobble - quartzite; Moderate Yellowish Brown 10YR5/4; loose; moderate reaction with HCl; slightly moist.

53'-55' (2' recovered, driven) Upper 1.4' - **Silty sand with pebbles and cobble;** sand - predominately very fine to fine grained with approximately 8% medium to very coarse grains, pebbles approximately 5% and ≤ 20 mm, cobble > 63 mm (fractured during drilling), sand - subangular, pebbles - subangular to subrounded, poorly sorted; sand - quartz, feldspar, mica, pebbles - limestone, quartzite, cobble - cherty limestone; Pale Yellowish Brown 10YR6/2; loose, strong reaction with HCl; dry; abrupt basal contact. Lower 0.6' - **Clayey sand;** sand - very fine to fine grained, well sorted, clay approximately 20%; Moderate Brown 5YR4/4; slightly compacted, moderate reaction with HCl; moist.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/320 325

55'-64' (7.6' recovered) Upper 1.5' - **Silty sand with pebbles;** sand - predominately very fine to fine grained with approximately 8% medium to very coarse grains, pebbles approximately 3% and ≤ 55 mm, subangular, poorly sorted; sand - quartz, feldspar, limestone, pebbles - quartzite, limestone; Moderate Yellowish Brown 10YR5/4; loose to slightly compacted, moderate reaction with HCl; slightly moist; gradational basal contact. Next 2.5' - **Sandy silt with pebbles;** sand - very fine to very coarse grained, pebbles approximately 3% and ≤ 20 mm, predominately 4-8 mm, sand - subangular, pebbles - subangular to subrounded, very poorly sorted; sand - quartz, feldspar, pebbles - quartzite; Pale Yellowish Brown 10YR6/2; becomes sandier towards bottom; loose/ powdery, moderate to strong reaction with HCl; very slightly moist to dry; gradational basal contact. Next 1.5' - **Sandy clayey silt;** sand approximately 20% and very fine to fine grained, clay 10 to 40%, moderately well sorted; sand - quartz, minor feldspar; Moderate Yellowish Brown 10YR5/4 to Dark Yellowish Brown 10YR4/2 where clay is more abundant; contains approximately 4% medium to very coarse grains towards bottom and sand content increases to approximately 30%; strongly compacted to loosely compacted towards bottom, no to weak reaction with HCl; moist; gradational basal contact. Next 0.7' - **Sandy silt;** sand - very fine to very coarse grained, subangular, poorly sorted; Pale Yellowish Brown 10YR6/2; loose/powdery, moderate reaction with HCl; dry; gradational basal contact. Lower 1.4' - **Silty clayey sand;** sand - very fine to fine grained with < 5% medium to very coarse grains, clay approximately 25%, sand - subangular, poorly to moderately well sorted; sand - quartz, feldspar; clay content increases towards bottom; moderately compacted, moderate reaction with HCl; moist.

64'-67' (2.4' recovered, driven) Upper 1' - **Silty clayey sand;** sand - very fine to fine grained with < 5% medium to very coarse grains, clay approximately 25%, subangular, poorly to moderately well sorted; sand - quartz, feldspar; clay content increases towards bottom; moderately compacted, moderate reaction with HCl; moist. Middle 0.5' - **Sandy silt with pebbles;** sand approximately 30% and very fine to fine grained with approximately 8% medium to very coarse grains, pebbles < 2% and ≤ 25 mm, sand - subangular, pebbles - subangular to subrounded, poorly sorted, sand - quartz, feldspar, pebbles - quartzite, limestone; Pale Yellowish Brown 10YR6/2; loose/powdery, moderate reaction with HCl; dry; abrupt basal contact. Lower 0.9' - **Clayey sand;** sand - very fine to fine grained with < 3% medium to very coarse grains, clay approximately 35%, sand - subangular, moderately well sorted; sand - quartz, feldspar; Dark Yellowish Brown 10YR4/2 to Moderate Brown 5YR3/4; loosely to moderately compacted, slight to moderate reaction with HCl; moist.

67'-72' (5' recovered, driven) Upper 4.4' - **Clayey sand;** sand - predominately very fine to fine grained with < 3% medium to very coarse grains, pebbles < 1% and ≤ 20 mm in some zones, subangular, moderately well sorted to poorly sorted where pebbles and coarse sand predominate, well sorted in lower 2.1' of section; sand - quartz, feldspar, pebbles - quartzite, minor granite; Moderate Brown 5YR4/4; strongly to moderate compacted, slight to moderate reaction with HCl;

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/320 325

moist; abrupt basal contact. Lower 0.6' - **Pebbly sand with clayey sandy silt zone;** sand - very fine to very coarse grained, very fine grained in clayey zone, pebbles 25% and ≤ 20 mm, predominately ≤ 6 mm, sand - angular to subangular, pebbles - subangular, poorly sorted; larger sand sizes - quartz, feldspar, pebbles - quartz, feldspar, quartzite; Light Brown 5YR5/6; clayey sandy silt zone is 0.2' thick; loose, moderately compacted where clayey, strong reaction with HCl; moist, very moist where clayey.

72'-82' (9.5' plus recovered) **Pebbly sand with silt, clay, and caliche;** sand - very fine to very coarse grained, pebbles 25% and ≤ 40 mm, predominately ≤ 5 mm, sand - subangular, pebbles - subangular, poorly sorted; sand - quartz, feldspar, pebbles - quartzite, granite, greenstone; Light Brown 5YR6/4; loose, minor to moderate caliche as matrix, strong reaction with HCl; slightly to moderately moist.

82'-85' (2.7' recovered, driven) **Pebbly sand with silt, clay, and caliche;** sand - very fine to very coarse grained, pebbles 25% and ≤ 40 mm, predominately (50%) ≤ 5 mm, sand - subangular, pebbles - subangular, poorly sorted; sand - quartz, feldspar, pebbles - quartzite, granite, greenstone; Light Brown 5YR6/4; loose, minor to moderate caliche as matrix, strong reaction with HCl; slightly to moderately moist.

85'-95' (7.1' recovered) Upper 3.9' - **Pebbly sand with silt and minor clay;** sand - very fine to very coarse grained or very fine to medium grained in a few lenses, pebbles 25% and ≤ 20 mm, predominately ≤ 6 mm, sand - angular to subangular, pebbles - angular to subrounded, poorly sorted; Moderate Yellowish Brown 10YR5/4; scattered 10-80 mm lenses of clayey, silty sand with or without pebbles; loose, with lenses moderately compacted, strong reaction with HCl; moderately to very moist; abrupt basal contact. Next 0.7' - **Silty sand with minor clay;** sand - very fine to fine grained, well sorted; sand - arkosic; Moderate Brown 5YR4/4; strongly compacted, strong reaction with HCl when dry; saturated; abrupt basal contact. Next 0.7' - **Pebbly silty sand with minor clay;** sand - very fine to fine grained, pebbles 18% and ≤ 50 mm, pebbles - angular to subrounded, poorly sorted; pebbles - weathered greenstone, quartzite, granite; Moderate Yellowish Brown 10YR5/4; loose, strong reaction with HCl; moderately to very moist; abrupt basal contact. Lower 1.8' - **Silty pebbly sand with cobble;** sand approximately 50% and very fine to very coarse grained, pebbles approximately 30% and ≤ 50 mm, cobble > 63 mm (fractured during drilling), sand - angular to subangular, pebbles - subangular to subrounded, very poorly sorted; sand - 90% quartz, minor feldspar, mica abundant, pebbles - metaquartzite, greenstone, metasandstone, quartz sandstone, cobble - metaquartzite/granite; upper 1.3' (fine matrix) - Light Olive Gray 5Y5/2, lower 0.5' (fine matrix) - Grayish Orange Pink 10R8/2; loose, silt is powdery, no reaction with HCl.

95'-99' (5' plus recovered, driven) Upper 3.6' - **Sand with silt, pebbles and cobbles;** sand - approximately 80% and predominately medium to very coarse grained with less very fine to fine

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/320 325

grains, pebbles < 3% and ≤ 6 mm, cobbles < 1% and > 63 mm, sand - angular to subangular, pebbles - subangular, cobbles - fractured during drilling, cobbles present only on top of section where top 0.5' is very poorly sorted, lower 2.6' - moderately well sorted; sand - arkosic with abundant quartz, pebbles - quartzite, quartz sandstone, metaquartzite, granite, cobbles - metaquartzite; fine matrix - Moderate Brown 5YR4/4; moderately compacted to loose (due to drilling), no reaction with HCl; moist; abrupt basal contact. Lower 1.4' - **Sandy clay;** sand approximately 20% and predominately very fine to fine grained with < 3% medium to very coarse grains; sand - quartz, feldspar, mica; Moderate Brown 5YR4/4; firmly compacted, some FeO_2 staining (Grayish Black N2), no reaction with HCl; moist.

99'-110' (8' recovered) Upper 4' - **Sandy clay with pebbles and cobbles and Clayey sand with pebbles;** sand 40-60% and very fine to fine grained with < 3% medium to very coarse grains, pebbles ≤ 4% and ≤ 20 mm, cobbles < 1% and ≤ 90 mm, sand - subangular, pebbles - subangular to rounded, cobbles - subrounded to rounded, moderately well sorted; coarser sand - quartz, feldspar, mica, pebbles - quartzite, limestone, cobbles - quartzite, sandstone; Moderate Brown 5YR4/4; pebbles and cobbles more abundant in upper 2 feet; moderately to strongly compacted, no reaction with HCl; moist; gradational basal contact. Lower 4' - **Sand with pebbles and silt;** sand - very fine to very coarse grained, pebbles approximately 10% and ≤ 45 mm, predominately 4-6 mm, subangular, very poorly sorted; sand - arkosic with abundant quartz, pebbles - quartzite, granite; Pale Yellowish Brown 10YR6/2 to Moderate Yellowish Brown 10YR5/4; clayey 0.4' zone 0.4' from bottom of section; loose to moderately compacted, no reaction with HCl; moist.

110'-120' (8.9' recovered) Upper 4.2' - **Silty sand with pebbles grading to Pebbly silt with sand and clay grading to Sandy silt with pebbles;** sand - very fine to very coarse grained in upper section, otherwise very fine to fine grained, pebbles ≤ 63 mm and 35% in upper and central section to < 1% in lower section, pebbles - subangular; sand - arkosic, pebbles - quartzite, sandstone, greenstone, granite; Light Brown 5YR5/6; moderately to strongly compacted, moderate to strong reaction with HCl; very moist; fairly abrupt basal contact. Lower 4.7'- **Sand with pebbles, cobbles and minor silt;** sand - very fine to very coarse grained, pebbles 10% and ≤ 40 mm, predominately ≤ 15 mm, cobbles 4% and ≤ 130 mm, cobbles in central section, sand - angular to rounded, pebbles - angular to subangular, cobbles - angular to subangular, poorly sorted; sand - arkosic with abundant quartz, rounded sand grains - clear quartz, pebbles and cobbles - sandstone, quartzite, very minor greenstone and chert; Moderate Yellowish Brown 10YR5/4; loose to moderately compacted, no reaction with HCl; moist.

120'-130' (10.1' recovered) Upper 2.0' - **Sandy silt with pebbles, minor clay and cobble;** sand - very fine to fine grained, pebbles 5% and ≤ 60 mm, one 90 mm cobble, pebbles - subangular, cobble - subangular; sand - arkosic with abundant quartz in lower section, pebbles - limestone, cobble - greenstone; Moderate Brown 5YR4/4; moderately to strongly compacted, no reaction with

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/320 325

HCl; moist; fairly abrupt basal contact. Middle 5.4' -**Sandy silt with clay grading to Clayey silt with sand;** sand - very fine to medium grained in upper section, grading to very fine grained in lower section; sand - arkosic; Moderate Brown 5YR4/4; moderately to firmly compacted, no reaction with HCl; moist to very moist; abrupt basal contact. Lower 2.7' - **Pebbly sand;** sand - very fine to very coarse grained, pebbles 20% and ≤ 10 mm, predominately (70%) ≤ 5 mm, sand - angular to subangular, rounded in central section, poorly sorted; sand - arkosic with abundant quartz in central section, pebbles - feldspar, quartz, quartzite; Moderate Yellowish Brown 10YR5/4; loose, no reaction with HCl; moist.

130'-140' (9.9' plus recovered) Upper 5.8' - **Silty sand with clay;** sand - very fine to fine grained with minor coarse grains; sand - arkosic; Light Brown 5YR5/6; central zone of clayey silt; moderately compacted, moderate reaction with HCl; very moist; gradational basal contact. Lower 4.1' - **Pebbly silty sand grading to Silty sand with pebbles and minor clay;** sand - very fine to very coarse grained, pebbles 20% in upper section to 5% in lower section and ≤ 25 mm, predominately ≤ 8 mm, larger pebbles in upper section, sand - subangular to rounded, pebbles - subangular; sand - arkosic with minor quartz enriched zones, pebbles - limestone, greenstone, feldspar; Light Brown 5YR6/4; loose, strong reaction with HCl; moist.

140'-150' (10.1' recovered) Upper 4.6' - **Silty sand with clay;** sand - very fine to fine grained grading to very fine to medium grained with 5% coarse to very coarse grains, sand - subangular to rounded; sand - arkosic with abundant rounded quartz; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; moist; fairly abrupt basal contact. Next 0.5' - **Pebbly sand with silt;** sand - very fine to very coarse grained, pebbles 25% and ≤ 30 mm, predominately (70%) ≤ 8 mm, sand - subangular to rounded, pebbles - angular to subangular, poorly sorted; sand - arkosic with abundant quartz, pebbles - greenstone, quartzite, feldspar; Light Brown 5YR6/4; loose, strong reaction with HCl; moist; abrupt basal contact. Next 0.8' - **Silty sand with clay;** sand - very fine to fine grained grading to very fine to medium grained with 5% coarse to very coarse grains, sand - subangular to rounded; sand - arkosic with rounded quartz; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; moist; abrupt basal contact. Next 2.4' - **Pebbly sand with silt**; sand - very fine to very coarse grained, pebbles 25% and < 30 mm, predominately (70%) ≤ 8 mm, sand - subangular to rounded, pebbles - angular to subangular, poorly sorted; sand - arkosic with abundant quartz, pebbles - greenstone, quartzite, feldspar; Light Brown 5YR6/4; loose, strong reaction with HCl; moist; abrupt basal contact. Lower 1.8' - **Silty sand with clay;** sand - very fine to fine grained grading to very fine to medium grained with 5% coarse to very coarse grains, sand - subangular to rounded; sand - arkosic with rounded quartz; Light Brown 5YR5/6; Pebbly sand (similar to previous 1.8' section) in 0.3' zone near bottom of section; moderately compacted, strong reaction with HCl; moist.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/~~320~~ 325

150'-156' (5' recovered, driven) Upper 1.1' - **Silty sand with pebbles and minor clay;** sand - very fine to fine grained; sand - arkosic; Moderate Brown 5YR4/4; moderately to strongly compacted, strong reaction with HCl; moist. Middle 3' - **Sand with silt and minor clay;** sand - very fine to coarse grained, sand - angular to rounded; sand - arkosic with abundant rounded quartz; Moderate Yellowish Brown 10YR5/4; loose, strong reaction with HCl; very moist; abrupt basal contact. Lower 0.9'- **Silty sand;** sand - very fine to medium grained; sand - arkosic; Light Brown 5YR5/6; minor zones of Sandy silt, sand - very fine to fine grained; moderately compacted, strong reaction with HCl; very moist.

156'-160' (5' recovered, driven) **Silty sand with minor sandy silt;** sand - very fine to medium grained; sand - arkosic; Light Brown 5YR5/6; minor zones of Sandy silt, sand - very fine to fine grained; moderately compacted, strong reaction with HCl; very moist.

160'-168' (7.3' plus recovered) Upper 2.9' - **Pebbly silty sand;** sand - very fine to fine grained with approximately 5% medium to very coarse grains, pebbles $\leq$ 15% and $\leq$ 60 mm, sand - subangular, pebbles - subangular to subrounded, very poorly sorted; sand - quartz, minor feldspar, pebbles - quartzite, granite, limestone; Pale Yellowish Brown 10YR6/2; coarse sand content and pebble size increase towards bottom of section; moderately compacted/cemented, loose and powdery in some zones (probably due to drilling), $CaCO_3$ abundant in matrix and as cement, strong reaction with HCl; dry to very slightly moist; gradational basal contact. Middle 2.8' - **Silty clay;** sand < 5% and very fine to fine grained; Moderate Brown 5YR4/4; sand content decreases toward bottom of section; moderately to strongly compacted, weak reaction with HCl at top to no reaction at bottom of section; moist; abrupt basal contact. Lower 1.6' - **Pebbly silty sand;** sand - very fine to very coarse grained, pebbles $\leq$ 15% and $\leq$ 55 mm, predominately $\leq$ 8 mm, sand - angular to subangular, pebbles - subangular to rounded, poorly sorted; finer matrix - Moderate Yellowish Brown 10YR5/4 to Pale Yellowish Brown 10YR6/2 towards bottom; silt content increases significantly towards bottom; some $CaCO_3$ cement, loose/powdery towards bottom, weak reaction with HCl at top of section, strong reaction towards bottom; slightly moist.

168'-174' (5' plus recovered) Upper 2.8' - **Silty clay with sand;** silt abundant, sand < 3% and very fine to fine grained with < 1% medium to very coarse grains, fairly well sorted; Moderate Brown 5YR4/4; mostly strongly compacted, some loose (probably due to drilling), 1.5-inch diameter hollow center in a zone of compacted core (assume due to moisture conveying to center of core with sand grains being pushed out during extraction of core), slight to moderate reaction with HCl; slightly moist to moist; contact disturbed. Lower 2.2' - **Silty sand with clay and pebbles;** (sample disturbed during extraction from core barrel, therefore described as cuttings) sand - very fine to very coarse grained, predominately very fine to fine grained, pebbles $\leq$ 3% and $\leq$ 60 mm (fractured during drilling) predominately $\leq$ 10 mm, sand - subangular, pebbles - subangular to subrounded; sand - arkosic, pebbles - limestone, cherty fossiliferous limestone, very minor granite; Moderate

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/~~320~~ 325

Brown 5YR4/4 to Moderate Yellowish Brown 10YR5/4; moderately compacted chunks to loose, weak to moderate reaction with HCl; very slightly to slightly moist.

174'-183' (8.7' recovered) **Clayey silty sand;** sand - predominately very fine to fine grained with < 2% medium to very coarse grains, pebbles < 0.5% and ≤ 8 mm, moderately well sorted; sand - arkosic; Pale Yellowish Brown 10YR6/2 at top 2.3' to Moderate Brown 5YR4/4 towards bottom; pebble content and sand size increases towards bottom of section, decomposing sand/pebbles in upper 2.3'; strongly to moderately compacted/cemented, $CaCO_3$ present as cement and blebs, moderate to strong reaction with HCl; upper 0.2' - saturated (possible slough from previous interval?) next 0.4' - very moist to saturated, lower 8.1' - very slightly moist to slightly moist.

183'-188' (5' recovered, driven) **Clayey silty sand with pebbles;** sand - approximately 50% and predominately very fine to fine grained, < 4% medium to very coarse grains, pebbles < 2% and ≤ 24 mm, subangular, poorly sorted; sand - arkosic, pebbles - limestone, granite, sandstone, fossiliferous limestone; Dark Yellowish Brown 10YR4/2 at top with zones of Moderate Brown 5YR4/4 and blebs of Dark Yellowish Brown 10YR4/2, blebs of Moderate Brown 5YR4/4 towards bottom; pebble and sand content decreases towards bottom, decomposing sand and pebble material in core; moderately compacted, moderate reaction with HCl; moist, upper 0.05' - very moist.

188'-196' (10' recovered) Upper 3.9' - **Sandy clayey silt with pebbles;** sand ≤ 15% and predominately very fine grained, < 3% fine to very coarse grains, pebbles < 2% and ≤ 42 mm, predominately ≤ 4 mm, sand - subangular, pebbles - subangular to subrounded, moderately sorted; sand - quartz, feldspar, mica, pebbles - cherty limestone, quartzite; Moderate Brown 5YR4/4 to Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted/cemented, $CaCO_3$ cement, strong reaction with HCl; moist; gradational basal contact. Lower 6.1' - **Pebbly silty sand;** sand - very fine to very coarse grained, pebbles ≤ 15% and ≤ 28 mm, predominately ≤ 4 mm, sand - subangular, pebbles - subangular to subrounded, very poorly sorted; sand - arkosic, pebbles - quartzite, granite, limestone; Moderate Yellowish Brown 10YR5/4 to Pale Yellowish Brown 10YR6/2; becomes siltier towards bottom, 2-inch clayey zone 9.5-11.5 inches from bottom of section; mostly loose with some zones cemented with $CaCO_3$, no to moderate reaction with HCl; slightly moist.

196'-201' (4.7' recovered, driven) Upper 2.3' - **Silty sand with clay;** sand - approximately 65% and very fine to fine grained, very well sorted; sand - arkosic; Moderate Brown 5YR4/4; clean sand; moderately compacted, soft, clay in matrix and as blebs, slight reaction with HCl; moist; gradational basal contact. Middle 0.5 - **Clay with sand;** sand ≤ 10% and very fine to fine grained, well sorted; Moderate Brown 5YR4/4; strongly compacted, no to very slight reaction with HCl; moist; gradational basal contact. Lower 1.9' - **Silty sand with clay;** sand - approximately 65% and very fine to fine grained with < 5% medium grains, pebbles 0.5% and ≤ 5 mm, subangular, well

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/~~320~~ 325

sorted; sand - arkosic, pebbles - quartzite; Moderate Yellowish Brown 10YR5/4 to Moderate Brown 5YR4/4; sand content increases towards bottom; moderately compacted, soft, weak to moderate reaction with HCl; moist.

201'-205' (3.9' plus recovered, driven) Upper 2.5' - **Silty sand with clay;** sand - approximately 65% and very fine to fine grained with < 5% medium grains, pebbles < 0.5% and ≤ 5 mm, subangular, well sorted; sand - arkosic, pebbles - quartzite; Moderate Yellowish Brown 10YR5/4 to Moderate Brown 5YR4/4; clay content increases towards bottom; moderately compacted, soft, weak to moderate reaction with HCl; moist; gradational basal contact. Lower 1.4' - **Sandy silty clay;** sand - approximately 30% and very fine to fine grained; Moderate Brown 5YR4/4; sand/clay interbedded in approximately 5 mm intervals; moderately compacted, very weak to no reaction with HCl; moist.

205'-216' (10.9' plus recovered) Upper 4' - **Clayey silty sand;** sand - very fine to fine grained with < 5% medium to very coarse grains, pebbles < 0.5% and ≤ 6 mm, subangular, moderately well sorted; sand - arkosic, pebbles - quartzite, granite, limestone; Moderate Yellowish Brown 10YR5/4; $CaCO_3$ abundant in zones in matrix and as blebs; moderately compacted to strongly compacted/cemented, $CaCO_3$ cement, moderate to strong reaction with HCl; slightly moist at top to dry towards middle to moist towards bottom of section; gradational basal contact. Next 2.7' - **Silty clay with sand;** sand ≤ 12% and very fine to fine grained; Moderate Brown 5YR3/4; moderately to strongly compacted, slight reaction with HCl; moist; gradational basal contact. Next 1.8' - **Silty clayey sand;** sand - approximately 60% and very fine to fine grained with approximately 10% medium to very coarse grains, pebbles < 0.5% and ≤ 32 mm, sand - subangular, pebbles - subangular to rounded, moderately to poorly sorted; sand - arkosic, pebbles - granite, quartzite, cherty limestone; Moderate Yellowish Brown 10YR5/4; loose to moderately compacted/ cemented, $CaCO_3$ cement, strong reaction with HCl; slightly moist; gradational basal contact. Lower 2.4' - **Silty sandy clay;** sand - approximately 20% and very fine to fine grained with approximately 4% medium to very coarse grains, pebbles < 0.5% and ≤ 16 mm, sand - subangular, pebbles - subangular to subrounded, moderately sorted; sand - arkosic, pebbles - quartzite, limestone, granite; Moderate Brown 5YR4/4; silty sandy zone from 1.2' to 1.5' from bottom of section; moderately to strongly compacted, no to moderate reaction with HCl; moist.

216'-223' (7' plus recovered) Upper 3.4' - **Clayey silty sand;** sand - approximately 60% and very fine to fine grained with approximately 10% medium to very coarse grains, moderately to poorly sorted; sand - arkosic; Moderate Yellowish Brown 10YR5/4 to Moderate Brown 5YR3/4 where clay is more abundant; clay zone from 1.9' to 2.4' from top of section, becomes sandier with pebbles < 5% and ≤ 20 mm below clay zone; loose to moderately compacted, strongly compacted in clay zone, moderate reaction with HCl; slightly moist, moist in clay zone; (basal contact blown out). Lower 3.6' - **Silty sand with pebbles**; sand - very fine to fine grained with approximately

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/~~320~~ 325

15% medium to very coarse grains, pebbles 1 to 8% and ≤ 20 mm, predominately ≤ 4 mm, sand - subangular, smaller pebbles - subangular, larger pebbles - subrounded, poorly sorted; sand - arkosic with abundant quartz, pebbles - granite, limestone, quartzite; Pale Yellowish Brown 10YR6/2, Moderate Yellowish Brown 10YR5/4 where sandier; loose (probably due to drilling), zones of strongly $CaCO_3$ cemented silt and sand, strong reaction with HCl; dry to very slightly moist.

223'-233' (10.9' recovered) Upper 1.2' - **Sandy silt;** sand - approximately 20% and very fine to fine grained with < 3% medium to very coarse grains, pebbles < 0.5% and ≤ 50 mm, sand - subangular, pebbles - subrounded, moderately well sorted; sand - quartz, minor feldspar, pebbles - cherty limestone; Pale Yellowish Brown 10YR6/2; loose/powdery, strong reaction with HCl; dry; abrupt basal contact. Middle 8.2' - **Clayey silty sand;** sand - very fine to fine grained with ≤ 8% medium to very coarse grains, clay ≤ 20%, angular to subangular, moderately well sorted; sand - arkosic; Moderate Brown 5YR4/4 to Moderate Yellowish Brown 10YR5/4 towards bottom; clay content decreases to < 8% towards bottom; strongly to moderately compacted, $CaCO_3$ in matrix and as cement and increases towards bottom, strong reaction with HCl; moist; gradational basal contact. Lower 1.5' - **Pebbly silty sand;** sand - very fine to fine grained with approximately 18% medium to very coarse grains, pebbles approximately 25% decreasing to < 15% in lower 0.6', angular to subangular, very poorly sorted; sand - arkosic, pebbles - quartzite, granite, limestone; Dark Yellowish Orange 10YR6/6 to Moderate Yellowish Brown 10YR5/4 at top, Moderate Yellowish Brown 10YR5/4 at bottom; loose, moderately to strongly compacted/cemented towards bottom, $CaCO_3$ cement, moderate to strong reaction with HCl; slightly to moderately moist.

233'-244' (11.4' plus recovered) Upper 2.2' - **Silty sand with clay nodules;** sand - very fine to fine grained with approximately 5% medium to very coarse grains, clay nodules ≤ 3-inch diameter containing approximately 5% medium to very-coarse grained sand, sand - angular to subangular, moderately well sorted; sand - arkosic; Moderate Yellowish Brown 10YR5/4, clay nodules - Moderate Brown 5YR4/4; loose to moderately compacted/cemented, $CaCO_3$ cement, strong reaction with HCl, clay nodules have slight to no reaction with HCl; slightly moist to moist; gradational basal contact. Next 4.5' - **Sandy silty clay;** sand - very fine to fine grained with < 3% medium to very coarse grains, sand approximately 10% at top to 40% towards bottom; sand - arkosic; Moderate Brown 5YR3/4 at top, Moderate Brown 5YR4/4 to Light Brown 5YR5/6 towards bottom; moderately to strongly compacted, no reaction with HCl; moist; gradational basal contact. Next 2.7' - **Clayey silty sand;** sand - very fine to fine grained with < 2% medium to very coarse grains, subangular to angular, well sorted; Moderate Yellowish Brown 10YR5/4; moderately compacted, moderately to strongly compacted/cemented towards bottom, $CaCO_3$ cement, slight reaction with HCl to strong reaction towards bottom; moist; gradational basal contact. Lower 1.9' - **Pebbly silty sand;** sand - very fine to very coarse grained, pebbles ≤ 15% and ≤ 40 mm (fractured by drilling), subangular, very poorly sorted; sand - arkosic, pebbles - cherty

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/~~320~~ 325

limestone, granite, quartzite; Moderate Yellowish Brown 10YR5/4 to Pale Yellowish Brown 10YR6/2; loose with zones of $CaCO_3$ cemented sand, strong reaction with HCl; dry to very slightly moist.

244'-250' (3.3' recovered) Upper 1.8' - **Silty sand**; sand - very fine to fine grained with < 15% medium to coarse grains, $CaCO_3$ cemented silty sand nodules with very fine to very coarse grained sand, subangular to angular, moderately sorted; sand - arkosic; Moderate Yellowish Brown 10YR5/4; loose with some moderately compacted zones, nodules very strongly cemented, moderate to strong reaction with HCl; slightly moist; gradational basal contact. Lower 1.5' - **Clayey silty sand;** sand - very fine to fine grained, well sorted; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, slight to moderate reaction with HCl; moist.

250'-257' (1.8' plus recovered, bottom 4' dropped back into hole) Upper 1.1' - **Pebbly sand;** sand - very fine to very coarse grained, pebbles ≤ 15% and ≤ 27 mm, sand - angular to subangular, pebbles - subangular to subrounded, very poorly sorted; sand - arkosic, mica abundant, pebbles - quartzite, limestone, greenstone, granite; Moderate Yellowish Brown 10YR5/4; loose, with clasts of weakly cemented sand, $CaCO_3$ cement, moderate to strong reaction with HCl; moist; gradational basal contact. Lower 0.7' - **Pebbly silty sand;** sand - very fine to fine grained with approximately 15% medium to very coarse grains, pebbles ≤ 15% and ≤ 30 mm, sand - angular to subangular, pebbles - subangular to subrounded, poorly sorted; sand - arkosic, pebbles - quartzite, cherty limestone, granite; Grayish Orange 10YR7/4 to Pale Yellowish Brown 10YR6/2; loose with weakly cemented clasts, $CaCO_3$ cement, strong reaction with HCl; slightly moist.

257'-266' (15' plus recovered) Upper 5.5' - **Silty sand with pebbles;** sand - very fine to fine grained with < 3% medium to very coarse grains, pebbles < 3% and ≤ 15 mm, sand - angular to subangular, pebbles - subangular to subrounded, moderately well sorted; sand - arkosic, pebbles - granite, quartzite, limestone; Moderate Yellowish Brown 10YR5/4; minor clay increasing towards bottom of section; loose to strongly compacted, strong reaction with HCl; slightly moist; gradational basal contact. Lower 9.5' - **Clayey silty sand;** sand - very fine to fine grained with < 3% medium to very coarse grains, angular to subangular, moderately well sorted; sand - arkosic, pebbles - granite, quartzite; Moderate Brown 5YR4/4 at top to Light Brown 5YR5/6 at middle, Moderate Yellowish Brown 10YR5/4 where siltier and Moderate Brown 5YR4/4 towards bottom; sandy silt zone from 4.3' to 4.9' from bottom of section; moderately to strongly compacted, $CaCO_3$ as blebs and veins in lower 2.5', moderate to strong reaction with HCl; moist.

266'-275' (9.5' plus recovered) Upper 7.5 - **Clayey silty sand;** sand - very fine to fine grained with approximately 5% medium to very coarse grains, pebbles < 0.5% and ≤ 8 mm, angular to subangular, moderately sorted; sand - arkosic, pebbles - granite, quartzite; Moderate Yellowish Brown 10YR5/4 to Dark Yellowish Brown 10YR4/2; moderately to strongly compacted, some

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/~~320~~ 325

$CaCO_3$ cementing, moderate to strong reaction with HCl; moist; gradational basal contact. Middle 0.6' - **Sand;** sand - very fine to medium grained, pebbles < 0.5% and ≤ 4 mm, subangular, well sorted; sand - arkosic with abundant quartz, pebbles - quartzite; Moderate Yellowish Brown 10YR5/4; loose to slightly compacted/cemented, $CaCO_3$ cement, strong reaction with HCl; slightly moist to moist; abrupt basal contact. Lower 1.4' - **Sandy silt with pebbles;** sand - approximately 45% and very fine to very coarse grained, pebbles < 3% and ≤ 18 mm; subangular to angular, poorly sorted; sand - arkosic with abundant quartz, pebbles - limestone, quartzite, granite; Very Pale Orange 10YR8/2 to Pale Yellowish Brown 10YR6/2; loose/powdery to strongly cemented, $CaCO_3$ cement (probably broken up during drilling, driller reported very hard drilling), moderate to strong reaction with HCl; dry.

275'-276.5' (1.9' plus recovered) Upper 0.7' - **Sandy silt with pebbles;** sand - approximately 45% and very fine to very coarse grained, pebbles ≤ 8% and ≤ 15 mm, sand - angular to subangular, pebbles - angular to rounded, very poorly sorted; sand - arkosic with abundant quartz, pebbles - limestone, quartzite, granite; Very Pale Orange 10YR8/2 to Pale Yellowish Brown 10YR6/2; loose/powdery with $CaCO_3$ cemented clasts of sand; moderate to strong reaction with HCl; dry; abrupt basal contact. Lower 1.2' - **Silty sand with minor clay;** sand - very fine to fine grained, clay ≤ 5%, well sorted; sand - arkosic; zones of microlaminations; moderately to strongly compacted/cemented, $CaCO_3$ cement, moderate to strong reaction with HCl; moist.

276.5'-279' (2.5' plus recovered) **Silty sand with minor clay;** sand - very fine to fine grained, well sorted; sand - arkosic; Moderate Yellowish Brown 10YR5/4; strongly compacted/cemented, $CaCO_3$ cement; slightly moist to moist (slough removed from top of interval was saturated).

279'-279.5' (0.5' plus recovered, driven) **Silty sand with minor clay;** sand - very fine to fine grained, well sorted; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately compacted/ cemented, $CaCO_3$ cementing; moist (slough removed from top of interval was moist).

279.5'-286' (6.5' plus recovered) **Silty sand with clay;** sand - very fine to fine grained with < 3% medium to very coarse grains, pebbles < 0.5% and ≤ 4 mm, angular to subangular, well sorted; sand - arkosic, coarser sand and pebbles - quartzite; Moderate Yellowish Brown 10YR5/4 to Moderate Brown 5YR4/4, lower 2.4' - Grayish Orange 10YR7/4 to Very Pale Orange 10YR8/2; moderately compacted to strongly cemented, $CaCO_3$ increasing/abundant in lower 2.4', moderate to very strong reaction with HCl; moist at top to moderately moist towards bottom.

286'-287' (1.5' plus recovered) **Silty sand with clay and caliche;** sand - very fine to fine grained with < 3% medium to very coarse grains, pebbles < 0.5% and ≤ 4 mm, angular to subangular, well sorted; sand - arkosic, coarser sand and pebbles - quartzite; Moderate Yellowish Brown 10YR5/4 to Moderate Brown 5YR4/4, Very Pale Orange 10YR8/2 where caliche is abundant; very strongly

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/~~320~~ 325

to moderately compacted/cemented, caliche abundant as matrix, blebs and stringers and decreases towards bottom, strong to very strong reaction with HCl, reaction decreases towards bottom; dry at top to moist towards bottom.

287'-297' (10.7' plus recovered) **Silty sand with clay and caliche;** sand - very fine to fine grained with < 3% medium to very coarse grains, pebbles < 0.5% and ≤ 4 mm, angular to subangular, well sorted; sand - arkosic, coarser sand and pebbles - quartzite, limestone; Moderate Yellowish Brown 10YR5/4 to Moderate Brown 5YR4/4 where clay is more abundant, Very Pale Orange 10YR8/2 where caliche is abundant; abundant caliche from 291' to 292' and 294.5' to 296'; moderately to strongly cemented/compacted, caliche as matrix, blebs and stringers, strong to very strong reaction with HCl; moist, dry in abundant caliche zones.

297'-307' (10.6' plus recovered) Upper 1.6' - **Clayey silty sand with caliche;** sand - very fine to fine grained with < 3% medium to very coarse grains, pebbles < 0.5% and ≤ 6 mm, angular to subangular, well sorted; sand - arkosic, pebbles - quartzite, limestone, shale; Moderate Yellowish Brown 10YR5/4 to Moderate Brown 5YR4/4; moderately to strongly compacted, caliche much less abundant than previous intervals, moderate reaction with HCl; moist; gradational basal contact. Next 5' - **Pebbly silty sand;** sand - very fine to very coarse grained, pebbles ≤ 15% and ≤ 30 mm, very poorly sorted; sand - arkosic with abundant quartz, pebbles - granite, limestone, quartzite, greenstone, shale; Moderate Yellowish Brown 10YR5/4 to Pale Yellowish Brown 10YR6/2 where siltier; loose (probably due to drilling), some moderately cemented clasts, $CaCO_3$ cement, moderate to strong reaction with HCl; very slightly moist; abrupt basal contact. Next 2.4' - **Silty sand with clay;** sand - very fine to fine grained, well sorted; sand - arkosic; Moderate Yellowish Brown 10YR5/4, Moderate Brown 5YR4/4 where clay is more abundant; moderately to strongly compacted, slight reaction with HCl; moist; abrupt basal contact. Next 0.3' - **Silty sand with pebbles**; sand - very fine to very coarse grained, predominately medium grained, pebbles < 10% and < 6 mm, angular to subangular, very poorly sorted; sand - arkosic with abundant quartz, pebbles - granite, quartzite, limestone; Moderate Yellowish Brown 10YR5/4, loose with minor clasts of $CaCO_3$ cemented sand, slight to moderate reaction with HCl; slightly moist; abrupt basal contact. Lower 1.3' - **Clay;** Moderate Brown 5YR4/4; smectite clay - very shiny; very firmly compacted, $CaCO_3$ as blebs, and as nodules ≤ 10 mm, some thin laminations, no to weak reaction with HCl; slightly moist (some moisture probably driven/baked out by sonicing as evidence of core in drill bit).

307'-317' (10.1' plus recovered) Upper 0.5' - **Clay;** Moderate Brown 5YR4/4; very shiny; very firmly compacted, no to weak reaction with HCl; slightly moist; gradational basal contact. Next 4.3' - **Clayey silty sand;** sand - very fine to fine grained, well sorted; sand - arkosic; Moderate Brown 5YR3/4; strongly to moderately compacted, weak to no reaction with HCl; moist; gradational basal contact. Next 1.8' - **Silty sand with minor clay;** sand - very fine to medium

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/~~320~~ 325

grained, moderately well sorted; Moderate Yellowish Brown 10YR5/4; sand - arkosic with abundant mica; loose, no to slight reaction with HCl; wet; abrupt basal contact. Lower 3.5' - **Clayey silty sand;** sand - very fine to fine grained, well sorted; sand - arkosic; Moderate Yellowish Brown 10YR5/4 to Moderate Brown 5YR4/4; caliche abundant in upper 0.4'; moderately to strongly compacted, caliche as nodules, stringers and blebs, also found in lower 1.2'; moderately to strongly compacted, strong to moderate reaction with HCl in upper 0.4', weak reaction in lower 3.1'; moist to very moist.

317'-319.5' (2.5' recovered) **Clayey silty sand;** sand - very fine to fine grained, clay $\leq$ 15%, well sorted; sand - arkosic with abundant mica; Moderate Yellowish Brown 10YR5/4 to Moderate Brown 5YR4/4 where clay is more abundant; $CaCO_3$ cemented sandstone nodules in core; moderately compacted, moderate reaction with HCl; moist.

319.5'-322.5' (3' recovered, driven) **Clayey silty sand with cobble;** sand - very fine to fine grained with zones of medium to very coarse grains in fine matrix, clay $\leq$ 15%, subangular to angular, well sorted except in coarser sand zones where it is poorly sorted; sand - arkosic with abundant mica; Moderate Yellowish Brown 10YR5/4; slightly laminated where clay is more abundant, clay also as blebs; moderately compacted, slight reaction with HCl; moist.

322.5'-325.5' (4.5' plus recovered, driven) **Clayey silty sand;** sand - very fine to fine grained with zones of medium to very coarse grains, clay $\leq$ 15%, one 0.5' diameter cobble at approximately 324', coarser sand - subangular to angular, boulder - subrounded, sand - well sorted, coarser sand zones - well sorted; sand - arkosic, boulder - very fine to medium grained well sorted $CaCO_3$ cemented quartz sandstone; Moderate Yellowish Brown 10YR5/4; zones of very fine to fine grained silty sand with very little to no clay at approximately 323'-324', medium to coarse grained sand zone at 325', occurs mostly as pocket (not continuous zone); moderately to strongly compacted except at 323'-324' zone where it is loose, slight to no reaction with HCl; moist to very moist, saturated from 323'-324' and at 325'.

325.5'-327' (1.5' plus recovered, driven) Upper 1' - **Silty sand with clay;** sand - very fine to fine grained, clay < 10%, well sorted; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately compacted, slight reaction with HCl; moist. Lower 0.5' - **Clay;** Moderate Brown 5YR4/4; very firmly compacted, shiny, no reaction with HCl; moist (abundant water in slough on top of interval).

327'-330' (3' recovered, driven) Upper 0.7' - **Clay;** Moderate Brown 5YR4/4; very firmly compacted, shiny, no reaction with HCl; moist. Lower 2.3' - **Silty sandy clay;** sand - approximately 5 to 30% towards bottom, predominately very fine to fine grained, contains medium to very coarse grains towards bottom, pebbles < 1% and $\leq$ 15 mm, sand - subangular to angular, pebbles - subangular to rounded; sand - arkosic, larger sand grains and pebbles - decomposing

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/~~320~~ 325

granite especially in lower 1.5', biotite very abundant; Moderate Brown 5YR4/4; strongly to moderately compacted, no to very slight reaction with HCl; moist.

Verified and edited on 14SEP93 by G. Samuel, on 07SEP93, 29DEC93 and 06JAN94 by C. Abeyta, and on 05JAN94 by J. Szalona.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Concluded*

Tech Area 2 -- TA2/NW1/320 325

Note: Core was collected from 0' to 330'.

Lithologies logged by U.S. Geological Survey geologists Cynthia Abeyta and Joe Szalona as follows:

Depth	Date	Geologist
0' to 72'	07MAR93 to 08MAR93	C. Abeyta
72' to 95'	08MAR93 to 08MAR93	J. Szalona
95' to 110'	08MAR93 to 08MAR93	C. Abeyta
110' to 160'	09MAR93 to 09MAR93	J. Szalona
160' to 330'	10MAR93 to 22MAR93	C. Abeyta

Percentage of hole logged by each geologist:

C. Abeyta	78%
J. Szalona	22%

APPENDIX A

EXAMINATION OF PORTION OF CORE
WELL TA2-NW1-325/595

Log Depth: 297-470 Ft

Well Depth	Description
297 - 300'	Sandy silt: light brown, very fine; blocky
300 - 303.5'	Pebbly sand: light gray; coarse grained; loose
303.5 - 305.5'	Sandy silt: tan to buff
305.5 - 306'	Caliche blebs in light brown clayey silt or silty clay
306 - 307'	Clayey silt or silty clay: light brown
306'	SHALLOW WATER LEVEL
307 - 314.5'	Clayey silt or silty clay: medium brown,
314.5 - 315'	Caliche blebs: poorly developed in clayey silt
315 - 323'	Silty sand: light tan to buff, very fine grained; few coarse, poorly-sorted sand streaks; hard chunks
323 - 323.5'	Sandstone: light buff, very fine grained, well-sorted; biotite & muscovite flakes; very hard & completely consolidated; 1 chunk, representing perhaps ½ to 1'; *only sandstone observed in interval studied*
323 - 325'	Silty sand; buff; very fine grained; hard, semi-consolidated (much like 317-23')
325.5 - 328.5'	Silty sand: brown, very fine grained
328.5 - 329"	Caliche-rich lithology a/a
329 - 332'	Sand: buff, clayey/silty very fine grained; blocky & hard
332 - 333.5'	Clayey silt: brown
333.5 - 337'	Pebbly sand: brown, very fine grained
337 - 337.5'	Thin caliche zone
337.5 - 339'	Pebbly sand: brown, very fine grained
339.5 - 341'	Thin caliche zone
341 - 342'	Silty sand: light brown, very fine grained
342 - 343'	Sandy silt: light brown, very fine grained, w/ small quartz & feldspar pebbles
343 - 346'	Sandy silt: light gray, very fine grained, w/ small quartz & feldspar pebbles
346 - 347'	Powdery silt: light gray, pebbly
347 - 352'	Silty sand: light brown, very fine grained
352 - 360'	Silty sand to sandy silt: brown, very fine grained, w/ few angular pebbles
360 - 362'	Pebbly silty sand: light gray, very loose
362 - 364'	Clayey & sandy silt: brown, poorly sorted, w/ angular fragments up to 1"

364 - 366' Sand: light brown to light gray, moderately sorted, coarse, w/ pebbles
366 - 70' MISSING
370 - 370.5 Pebbly sand: light gray, poorly sorted; loose & friable

370.5 - 395' (24.5') AQUITARD(?)
- 370.5 - 382' Silty clay to clayey silt; brown; some very fine grained silty-sand/sandy-silt streaks
- 382 - 386' Pebbly clayey silt: light gray
- 386 - 388' Clayey silt to silty clay: brown
- 388 - 392' Pebbly clayey silt: light gray
- 392 - 395' Silty clay: brown

395 - 398' Sand: light gray to buff, very fine grained, w/ some pebbles
398 - 400 Sand: brown; very fine
400 - 405' Sand: very light brown to buff, very fine grained
410 - 416' Sandy silt: brown; clayey; very fine grained texture; firm
416 - 419.5 Silty clay: brown; w/ few blebs of caliche
419.5 - 424.5' Silty sand to sandy silt: light buff, very fine grained
424.5 - 434.5' Silty sand: very light buff, very fine grained; well sorted

434.5 - 457' AQUITARD(?)
- 434.5 - 442.5' Clayey silt: light brown
- 442.5 - 445' Caliche: mottled, poorly developed in lithology in clayey silt a/a
- 445 - 449' Sandy silt:
- 449 - 451' Caliche: poorly developed a/a
- 451 - 452' Sandy silt, light brown; poorly sorted w/ small angular pebbles
- 452 - 457' Clayey(?) silt: brown

457 - 461' Silty sand: light brown, very fine grained
461 - 463' Silty sand: light brown; w/ some small pebbles; very firm
463 - 470' Pebbly silty sand: fine grained; firm, blocky; slight caliche development 463-63.5

Lithologic Log for borehole for monitoring well TA2-NW1-595

Drilling company	USGS Water Sciences Division
Dates of drilling	May 17 - June 25, 1993
Drilling method	Air rotary to 325 ft bgs, and continuously cored using Sonicore from 325 to 650 ft bgs.
Ground elevation, ft amsl NAVD 88	5420.0
Total depth of borehole, ft	650
Screen, ft bgs	535.0 to 555.0, and 585.0 to 595.0
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Date well developed	July 27, 1993
Initial water level, ft bgs	523
Rig Geologist	J. Szalona of the USGS.

Three descriptions:

- Composite Description from USGS combined geophysics/lithologic log.
- USGS 18-page description for TA2-NW1-595 borehole (325 to 650 ft).
- Fritts and Van Hart (March 1997) 2-page description (297 to 470 ft) for TA2-NW1-595 borehole.

Depth, ft bgs	Composite Description from USGS combined geophysics/lithologic log
0-15	Sand, silty. Moderate yellowish brown, very fine- to fine-grained, minor pebbles, caliche.
15-42	Silt, sandy. Moderate yellowish brown, very fine- to fine-grained, minor pebbles.
42-71	Sand, silty. Pale yellowish brown, very fine- to fine-grained sand, increased clay content below 60 ft, minor pebbles, cobbles.
71-95	Sand, pebbly and silty. Moderate yellowish brown, very fine- to very coarse-sand, subangular, granite, quartzite, and granite clasts.
95-120	Sand. Moderate to light brown, very fine- to fine-grained sand, minor silt and pebbles, moderately well sorted.
120-128	Silt, sandy. Moderate brown, very fine- to fine-grained sand, minor gravel.
128-162	Sand, silty. Light brown, very fine- to fine-grained sand, minor clay.
162-191	Sand, silty and clayey. Moderate to yellowish brown, very fine- to fine-grained sand, pebbly interbeds.
191-204	Sand, silty. Moderate yellowish brown, very fine- to fine-grained.
204-220	Sand, silty and clayey. Moderate yellowish brown, very fine- to fine-grained sand.
220-255	Sand, silty. Moderate yellowish brown, very fine- to fine-grained sand, limestone, quartzite, and granite clasts in interbeds, moderately sorted.
255-272	Sand, silty and clayey. Moderate yellowish brown, very fine- to fine-grained sand.
272-280	Sand, silty. Moderate yellowish brown, very fine- to fine-grained sand, well sorted.
280-313	Sand, silty. Moderate yellowish brown, very fine- to fine-grained sand, clay, caliche, trace pebbles.
313-325	Sand, silty and clayey. Moderate yellowish brown, very fine- to fine-grained sand, subangular to angular.
325-370	Sand, silty. Light brown, very fine- to fine-grained sand, pebbly below 334 ft, subangular to angular, feldspar, granite, and quartz clasts.
370-382	Clay, silty. Light brown, less than 10 percent sand, very fine- to medium-grained sand.
382-394	Silt, pebbly and sandy. Light brown, very fine- to fine-grained sand.
394-447	Sand, silty. Moderate yellowish brown, very fine- to fine-grained, angular and subangular.
447-460	Silty, clayey and sandy. Light brown, very fine- to fine-grained sand, trace pebbles.

Depth, ft bgs	Composite Description from USGS combined geophysics/lithologic log
460-510	Sand, silty. Moderate yellowish brown, very fine- to fine-grained sand with pebble interbeds, angular to subangular, feldspar, quartz, granite, and limestone clasts.
510-540	Silt, clayey and sandy. Moderate yellowish brown, very fine- to fine-grained sand, pebbly interbeds, angular to subangular, granite and limestone clasts.
540-562	Sand, pebbly. Moderate yellowish brown, very fine-to very coarse-grained sand, silty sand and silty clay interbeds, limestone, granite, quartz, and feldspar clasts.
562-576	Clay, silty and sandy. Moderate brown, very fine- to medium-grained sand, pebbles.
576-595	Sand, clayey and silty. Moderate yellowish brown, very fine- to medium-grained sand, pebbly interbeds, granite, feldspar, and quartzite clasts.

The Unified Soil Classification System symbol was not recorded on the original lithologic log or field notes.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG

Tech Area 2 -- TA2/NW1/595

Ground Elevation: 5418 feet (Estimated) Drilling Method/Fluids: Sonic/Dry or
Logged by: U.S. Geological Survey (Szalona) Cable tool/driven barrel where noted
Drilling began: 17MAY93 Drilling completed: 25JUN93 Total Depth: 650 feet
Color Chart: Goddard, E.N., and others, 1991, Rock color chart: Geological Society of America, Boulder, Colo.

Note: The hole was drilled with air-rotary to 325 feet. Core collection and descriptions began at 325 feet. See descriptions for TA2/NW1/320, hole adjacent to TA2/NW1/595, for additional descriptions. 325

325'-329' (4.4' recovered, driven) **Silty sand;** sand - very fine to medium grained; sand - arkosic; Light Brown 5YR5/6; moderately compacted to strongly compacted in lower section, strong reaction with HCl (when dry); saturated.

329'-332' (3' plus recovered, driven) **Silty sand with clay and clayey silt zones;** sand - very fine to fine grained; sand- arkosic with abundant mica; Light Brown 5YR5/6; 1' clayey silt zones near top and bottom of interval, one semi-consolidated 50 mm sandstone lens below upper clayey zone and one 70 mm sandstone lens below lower clayey zone; firmly compacted, moderate to strong reaction with HCl (when dry); very moist (saturated?).

332'-338' (5.9' plus recovered, driven) Upper 1.3' - **Silty sand;** sand - very fine to medium grained; sand - arkosic; Light Brown 5YR5/6; moderately compacted, moderate reaction with HCl; saturated(?); abrupt basal contact. Lower 4.6' - **Pebbly silty sand with minor clay;** sand - very fine to medium grained, pebbles 2 to 20% and $\leq$ 10 mm, predominately < 4 mm, angular to subangular; sand - arkosic, pebbles - feldspar, granite, minor quartz; Light Brown 5YR5/6; 50 mm conglomeratic sandstone lens 1.1' below top of section; moderately to strongly compacted, strong reaction with HCl; saturated(?).

338'-341' (3.8' recovered, driven) **Pebbly silty sand with minor clay;** sand - very fine to medium grained, pebbles 3 to 15% and $\leq$ 10 mm, predominately < 4 mm, angular to subangular; sand - arkosic, pebbles - feldspar, granite, quartz; Light Brown 5YR5/6; moderately to strongly compacted, $CaCO_3$/caliche blebs at top of interval and few scattered, strong reaction with HCl (when dry); very moist (saturated?).

341'-352' (13.1' recovered) Upper 2.8' - **Sandy silt with pebbles;** sand - very fine to fine grained with 10% medium to very coarse grains in lower section, pebbles vary downwards 3 to 15% and < 4 mm, sand and pebbles - angular to subangular, poorly sorted; sand - arkosic; pebbles - quartz, quartzite, feldspar; Light Brown 5YR5/6; moderately compacted, slight to moderate reaction with HCl; very moist; fairly abrupt basal contact. Next 3.7' - **Silty sand with pebbles;** sand - very fine

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

to medium grained with ≤ 30% medium to very coarse grains in lower section, pebbles ≤ 15% in lower section and ≤ 8mm, predominately < 3 mm, angular to subangular, poorly sorted; sand - arkosic, larger sand grains and pebbles - quartz, feldspar; Light Brown 5YR5/6; moderately compacted, moderately cemented with $CaCO_3$, strong reaction with HCl; very moist; abrupt basal contact. Next 1.5' - **Pebbly sand with silt;** sand - very fine to very coarse grained, pebbles < 3% in central section, ≤ 20% in upper and lower sections and ≤ 10 mm, predominately (85%) < 4 mm, sand and pebbles - angular to subangular, poorly sorted; sand - arkosic with abundant quartz, pebbles - quartzite, feldspar; Light Brown 5YR5/6; lower contact has 25 mm sandstone lens fragment; mostly loose, caliche moderate as matrix, strong reaction with HCl; very moist; abrupt basal contact. Lower 5.1' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; recovered as loose due to expansion, otherwise moderately compacted, weakly to moderately cemented with $CaCO_3$, strong reaction with HCl; very moist.

352'-362' (9.5' plus recovered) Upper 7.4' - **Silty sand;** sand - very fine grained in upper section, grades to very fine to medium grained; sand - arkosic; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; very moist (saturated?); abrupt basal contact. Lower 2.1' - **Silty sand with pebbles;** sand - very fine to very coarse grained, pebbles 10% and ≤ 15 mm, predominately (90%) < 4 mm, larger pebbles mostly in upper section, sand - angular to subangular, pebbles - angular to few subrounded; sand - arkosic, larger sand grains and pebbles - feldspar, granite, quartz; Moderate Yellowish Brown 10YR5/4; moderately compacted, moderately cemented with $CaCO_3$, strong reaction with HCl; very moist.

362'-366' (4' plus recovered) Upper 0.9' - **Silty sand with pebbles;** sand - very fine to very coarse grained, pebbles 10% and ≤ 15 mm, predominately (90%) < 4 mm, sand - angular to subangular, pebbles - angular to few subrounded; sand - arkosic, larger sand grains and pebbles -feldspar, granite, quartz; Moderate Yellowish Brown 10YR5/4; moderately compacted, moderately cemented with $CaCO_3$, strong reaction with HCl; saturated. Next 0.3' - **Sandy pebbles with silt;** sand - very fine to very coarse grained, pebbles 60% and ≤ 8 mm, predominately < 4 mm, sand - angular to subangular, pebbles - angular to few subrounded; larger sand grains and pebbles - feldspar, quartz, minor limestone; fine material - Light Brown 5YR5/6; moderately compacted, strong reaction with HCl (when dry); saturated; abrupt basal contact. Next 0.3' - **Sandy silt;** sand - very fine grained, very well sorted; sand - arkosic; Light Brown 5YR5/6; moderately to firmly compacted, strong reaction with HCl; saturated; very abrupt basal contact. Lower 2.5' - **Sandy pebbles with silt;** sand - very fine to very coarse grained, pebbles 70% and ≤ 15 mm, predominately (85%) < 5 mm, angular to subangular, poorly sorted; sand and smaller pebbles - quartz, feldspar, larger pebbles - granite; finer material - Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; saturated. Note: Mucked material included approximately 12 pebbles 25 to 63 mm, subangular with one subrounded; 3 types sandstone, 2 types limestone, granite, greenstone.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

366'-370' (4' recovered) Upper 1' - **Sandy pebbles with silt;** sand - very fine to very coarse grained, pebbles 70% and ≤ 15 mm, predominately (85%) < 5 mm, angular to subangular, poorly sorted; sand and smaller pebbles - quartz, feldspar, larger pebbles - granite; finer material - Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; saturated. Middle 2' - **Silty sand with pebbles;** sand - very fine to very coarse grained, pebbles 10% and < 4 mm, angular to subangular, poorly sorted; sand and pebbles - feldspar, quartz, 1 mm mica flakes abundant; Moderate Yellowish Brown 10YR5/4; moderately compacted, very strong reaction with HCl; saturated; abrupt basal contact. Lower 1' - **Silty sand with pebbles;** sand - very fine to very coarse grained, pebbles < 3% and < 5 mm, angular to subangular; sand and pebbles - feldspar, quartz, mica flakes < 2 mm; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; saturated.

370'-382' (14.2' plus recovered) **Silty clay and Clayey silt with sand;** sand ≤ 10% and very fine to medium grained; sand - arkosic; Light Brown 5YR5/6; moderately to firmly compacted, strong reaction with HCl; saturated(?).

382'-392' (11.8' plus recovered) **Pebbly sandy silt with clay;** sand - very fine to fine grained, pebbles 10 to 25% and < 20 mm, angular to subangular; sand - arkosic, pebbles - feldspar, minor granite; Light Brown 5YR5/6; moderately to firmly compacted, strong reaction with HCl (when dry); very moist.

392'-402' (11.0' plus recovered) Upper 2.5' - **Clayey silt with sand;** sand - very fine to fine grained; sand- arkosic; Light Brown 5YR5/6, moderately to strongly compacted, strong reaction with HCl; very moist; very abrupt basal contact. Next 0.5' - **Silty sand;** sand - very fine to fine grained; sand- arkosic; Light Brown 5YR6/4; contains 20 mm sandstone lens fragments; loose to moderately compacted, strong reaction with HCl; very moist; abrupt basal contact. Next 2.4' - **Silty sand with pebbles grading to Pebbly silty sand, Sandy silt, and Pebbly silty sand;** sand - very fine to fine grained, pebbles ≤ 40% increasing in lower section and ≤ 15 mm, predominately < 8 mm, angular to subangular; sand - arkosic with abundant mica, pebbles - feldspar, limestone, granite, quartz, greenstone; Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; abrupt basal contact; very moist (saturated?). Next 1.0' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl (when dry); saturated(?); fairly abrupt basal contact. Next 1.4' - **Sandy silt;** abrupt basal contact. Lower 3.2' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; firmly to moderately compacted, strong reaction with HCl; saturated(?).

402'-412' (11.9' plus recovered) Upper 2.3' - **Sandy silt;** sand - very fine grained; sand - arkosic; Light Brown 5YR5/6; moderate to firmly compacted, moderately to strongly cemented with

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

$CaCO_3$ when dry, strong reaction with HCl; saturated(?); abrupt basal contact. Next 0.4' - **Sand with silt;** sand - very fine to very coarse grained, angular to subangular; sand - arkosic with abundant quartz; Moderate Yellowish Brown 10YR5/4; moderately compacted, moderately cemented when dry, strong reaction with HCl; saturated; fairly abrupt basal contact. Middle 6.0' - **Silty sand;** sand - very fine to fine grained; sand - arkosic with zones of abundant mica flakes; Light Brown 5YR5/6; moderately to firmly compacted, moderately cemented with $CaCO_3$ when dry, strong reaction with HCl; saturated; fairly abrupt basal contact. Lower 3.2' - **Sandy silt;** sand - very fine grained; sand - arkosic with abundant mica flakes; Light Brown 5YR5/6; moderately to firmly compacted, moderately cemented when dry, strong reaction with HCl; saturated(?).

412'-419.5' (8.0' recovered, driven) **Silty sand with minor clay grading to Clayey sandy silt;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; contains siltstone lensatic blebs 1.5' from bottom of interval; firmly compacted, difficult to cut even while moist, strong reaction with HCl; saturated.

419.5'-425' (5.7' recovered, driven) Upper 3.4' - **Clayey sandy silt grading to Silty sand with clay and pebbly zone;** sand - very fine to fine grained with 10% medium to very coarse grains in pebbly zone, pebbles 0.2' zone 2.5' from top of interval, 30% and $\leq$ 4 mm, angular to subangular, poorly sorted; sand - arkosic, larger sand grains and pebbles - quartz, feldspar; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; saturated(?). Middle 1.3' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; loose to moderately compacted, expansive, strong reaction with HCl; saturated(?); fairly abrupt basal contact. Lower 1.0' - **Sandy silt;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; saturated(?).

425'-432' (5.8' recovered, driven) Upper 3.6' - **Silty sand;** sand - very fine to fine grained; sand-arkosic; Moderate Yellowish Brown 10YR5/4; 20 mm sandstone lens at base of section; strongly compacted, hard to cut even while wet, strong reaction with HCl; saturated; abrupt basal contact. Lower 2.2' - **Silty sand with clay and Clayey sandy silt;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, upper section has blebby $CaCO_3$/caliche, strong reaction with HCl; saturated.

432'-434.5' (2.4' plus recovered, driven) **Silty sand with clay;** sand - very fine grained grading to very fine to fine grained with 10% medium grains; sand - arkosic with abundant mica flakes in lower section; Moderate Yellowish Brown 10YR5/4; loose to strongly compacted in lower section, strong reaction with HCl; saturated.

434.5'-443' (9.6' plus recovered) Upper 2.6' - **Silty clay;** Moderate Brown 5YR4/4; firmly compacted, strong reaction with HCl; saturated. Lower 7.0' - **Clayey sandy silt with siltstone**

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

blebs; sand - very fine gained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; lower 0.9' is 85% siltstone blebs or semi-consolidated $CaCO_3$ cemented matrix, firmly compacted, upper and central sections are expansive, weakly to moderately cemented with $CaCO_3$ when dry, strong reaction with HCl; saturated(?).

443'-452' (9.8' plus recovered) Upper 0.9' - **Siltstone blebs in clayey sandy silt matrix;** siltstone blebs - 85%, sand - very fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; siltstone blebs or semi-consolidated $CaCO_3$ cemented matrix, firmly compacted, strong reaction with HCl; saturated(?). Next 3.2' - **Silty sand with clay and pebbles;** sand - very fine to fine grained with 5% medium grains, pebbles 10% and $\leq$ 10 mm, predominately < 4 mm, angular to subangular; sand - arkosic, pebbles - feldspar, quartz, mica; Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strongly cemented with $CaCO_3$ when dry, strong reaction with HCl; saturated; abrupt basal contact. Next 2.7' - **Clayey silt;** Light Brown 5YR5/6; firmly compacted, strongly cemented with CO_3 when dry, strong reaction with HCl; very moist/ saturated(?); fairly abrupt basal contact. Lower 3.0' - **Clayey silt with sand and pebbles;** sand 1 to 3% and very fine to medium grained, pebbles 1 to 3% and < 10 mm, angular to subangular, pebbles scattered; sand - arkosic, pebbles - feldspar, quartz; firmly compacted, moderately cemented with $CaCO_3$ when dry, strong reaction with HCl; very moist/saturated(?).

452'-460' (10.7' plus recovered) **Sandy silt with clay grading to Silty sand;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately compacted, expansive, strong reaction with HCl; very moist.

460'-467' (6.4' recovered, driven) Upper 1.2' - **Silty sand with minor clay;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; very moist; gradational basal contact. Lower 5.2' - **Pebbly silty sand;** sand - very fine to fine grained with 20% medium to very coarse grains, pebbles 10 to 20% and < 6 mm, lower 1' also includes pebbles $\leq$ 50 mm, sand - angular to subangular, pebbles - subangular to subrounded, poorly sorted; sand - arkosic, larger sand grains and smaller pebbles - feldspar, larger pebbles - limestone, weathered greenstone; Moderate Yellowish Brown 10YR5/4; firmly compacted, caliche blebs 2.5' from top of interval, strong reaction with HCl; very moist.

467'-472' (5.7' plus recovered, driven) Upper 2.7' - **Pebbly silty sand with clay;** sand - very fine to fine grained with 10% medium to very coarse grains, pebbles 10 to 50% and $\leq$ 20 mm, predominately (90%) < 6 mm, angular to subangular or angular to subrounded for larger clasts; sand - arkosic, larger sand grains and smaller pebbles - feldspar, larger pebbles - limestone, feldspar, greenstone; Moderate Yellowish Brown 10YR5/4; several irregular erosional surfaces with amplitudes approximately 10 to 15 mm; firmly compacted, strong reaction with HCl; very moist; fairly abrupt basal contact. Lower 3.0' - **Sandy clayey silt;** sand - very fine grained; sand -

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

arkosic; Moderate Brown 5YR4/4; firmly compacted, strong reaction with HCl; very moist.

472'-476' (7' recovered) Upper 3.5' - **Silty sand with minor clay;** sand - very fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; very moist; abrupt basal contact. Next 0.5' - **Pebbly silty sand with clay;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 15 to 40% and ≤ 15 mm, predominately < 5 mm, angular to subangular; sand - arkosic, larger sand grains and pebbles - feldspar, few scattered large clasts of limestone; Moderate Brown 5YR4/4; firmly to very firmly compacted, strong reaction with HCl; very moist. Next 1' - **Silty clay;** Moderate Brown 5YR4/4; firmly to very firmly compacted, strong reaction with HCl; very moist. Lower 2' - **Pebbly silty clay grading to Pebbly clayey sandy silt;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 15 to 40% and ≤ 15 mm, predominately < 5 mm, angular to subangular; sand - arkosic, larger sand grains and pebbles - feldspar, few scattered large clasts of limestone; Moderate Brown 5YR4/4; firmly to very firmly compacted, strong reaction with HCl; very moist.

476'-481' (4.2' recovered, driven) Upper 1.3' - **Pebbly sand;** sand - very fine to very coarse grained, pebbles 30% and ≤ 20 mm, predominately (90%) < 6 mm, sand - angular to subangular, pebbles - angular, few subrounded; sand - arkosic, coarser sand and pebbles - quartz, feldspar, sandstone, limestone, minor greenstone and granite; Moderate Yellowish Brown 10YR5/4; loose, strong reaction with HCl; very moist; abrupt basal contact. Next 0.1' - **Conglomerate;** lens, pebbles < 6 mm, angular to few subrounded, very little matrix; strongly cemented with $CaCO_3$. Next 0.1' - **Siltstone;** lens. Next 0.8' - **Clayey silt grading to Silty clay;** Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist; abrupt basal contact. Next 0.1' - **Siltstone;** lens. Next 0.4' - **Silty sand grading to Silty clay;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist; abrupt basal contact. Lower 1.4' - **Pebbly sand;** sand - very fine to very coarse grained, pebbles 20% and ≤ 15 mm, predominately (90%) < 6 mm, one 30 mm pebble, angular to subangular, poorly sorted; sand - arkosic, larger sand grains and pebbles - feldspar, quartz, sandstone, minor limestone and greenstone; Moderate Yellowish Brown 10YR5/4, loose to firmly compacted, lower section decomposed granite, strong reaction with HCl; very moist. NOTE: Mucked material shows this to be mostly decomposing granite.

481'-486' (5' plus recovered, driven) Upper 1' - **Silty sand grading to Silty sand with pebbles;** sand - very fine to fine grained or very fine to very coarse grained where pebbly, pebbles 10% in lower section and < 5 mm, angular to subangular; Moderate Yellowish Brown 10YR5/4; contains a 20 mm pebbly sandstone lens in central section; moderately to strongly compacted, strong reaction with HCl; very moist. Next 1' - **Clayey silt;** Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist; abrupt basal contact. Next 1' - **Pebbly sand with silt;** sand - very fine to very coarse grained, pebbles 40% and < 6 mm, angular to subangular,

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

poorly sorted; sand - arkosic, larger sand grains and pebbles - feldspar, quartz; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist; abrupt basal contact; Next 1.0' - **Clayey silt;** Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist; abrupt basal contact. Lower 1' - **Silty sand;** sand - very fine to medium grained; sand - arkosic; Light Brown 5YR5/6; firmly compacted, strong reaction with HCl; very moist.

486'-493.5' (7.0' plus recovered) Upper 0.6' - **Clayey sandy silt;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist. Next 0.4' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist. Next 2.4' - **Clayey silt with sand;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist. Next 0.8' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist. Next 0.5' - **Siltstone lenses in silty sand matrix;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; 3(?) 20 mm siltstone lenses; firmly compacted, strong reaction with HCl; very moist. Next 1.4' - **Silty clay;** Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist. Lower 0.9' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist.

493.5'-497' (3.5' plus recovered) Upper 1.0' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately to firmly compacted, strong reaction with HCl; very moist; abrupt basal contact. Next 0.2' - **Pebbly sand with silt;** sand -very fine to very coarse grained, pebbles 20% and $\leq$ 5 mm, angular to subangular; sand - arkosic, pebbles - decomposed granite (weathered feldspar still attached to quartz), very minor limestone; Moderate Yellowish Brown 10YR5/4; loose, strong reaction with HCl; very moist; abrupt basal contact. Next 1.1' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist; fairly abrupt basal contact. Next 0.7' - **Sandy clayey silt;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist; fairly abrupt basal contact. Lower 0.5' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist.

497'-498.5' (1.5' recovered, mucked) **Silty sand with pebbles grading to Sandy silt with pebbles;** sand - very fine to fine grained with 10% medium to very coarse grains, pebbles 10% and $\leq$ 5 mm, angular to subangular; sand - arkosic, larger sand grains and pebbles - decomposed granite; Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; very moist.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

498.5'-503' (5' recovered, driven) Upper 1' - **Silty clay;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, difficult to cut when moist, strong reaction with HCl; very moist; fairly abrupt basal contact. Next 2.5' - **Silty sand with clay and pebbles;** sand - very fine to fine grained with 10% medium to very coarse grains, pebbles 10 to 20% and < 15 mm, angular to subangular, poorly sorted; sand - arkosic, pebbles - decomposed granite, minor limestone; Moderate Yellowish Brown 10YR5/4; firmly compacted, difficult to cut when moist, strong reaction with HCl; very moist; fairly abrupt basal contact. Next 0.5' - **Silty sand with clay;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, difficult to cut when moist, strong reaction with HCl; very moist; fairly abrupt basal contact. Lower 1' - **Silty sand with clay and pebbles;** sand - very fine to fine grained, 10% medium to very coarse grains, pebbles 10 to 20% and < 15 mm, angular to subangular, poorly sorted; sand - arkosic, pebbles - decomposed granite, minor limestone; Moderate Yellowish Brown 10YR5/4; firmly compacted, difficult to cut when moist, strong reaction with HCl; very moist.

503'-508' (4.9' recovered, driven) Upper 1.5' - **Silty sand with clay and pebbles;** sand - very fine to fine grained with minor medium to very coarse grains, pebbles < 3% and < 12 mm, one 30 mm seam 0.6' from top of section is 30% pebbles < 4 mm and 30% coarse to very coarse sand grains, angular to subangular, pebbles scattered; sand - arkosic, larger sand grains and pebbles - feldspar, quartz, decomposed granite, few siltstone nodules < 40 mm; Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; very moist. Middle 1.6' - **Sandy silt;** sand - very fine to fine grained with < 2% medium to very coarse grains; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist; abrupt basal contact. Lower 1.8' - **Silty sandy pebbles grading to Pebbly sandy silt;** sand - very fine to very coarse grained, pebbles 60% in upper 0.5', otherwise 5 to 20% and ≤ 5 mm, angular to subangular; sand - arkosic, coarser sand grains and pebbles - decomposed granite; Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; very moist.

508'-512' (4.0' plus recovered) Upper 0.8' - **Clayey silty sand;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; very moist; abrupt basal contact. Next 1' - **Silty sand;** sand - very fine to fine grained grading to very fine to very coarse grained towards bottom, coarser sand grains - angular to subangular; sand - arkosic, coarser grains - feldspar, quartz; Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; very moist; abrupt basal contact. Next 0.1' - **Pebbles** (highly disturbed due to drilling); pebbles 60%(?) and ≤ 6 mm, angular to subangular; pebbles -decomposed granite. Next 0.5' - **Silty sand;** sand - very fine to fine; sand - arkosic; very moist; abrupt basal contact. Next 0.3' - **Silty sand with pebbles and caliche;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 10 to 20% and ≤ 12 mm,

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

angular to subangular; sand - arkosic, coarser sand grains and pebbles - decomposed granite; very moist; abrupt basal contact. Next 0.6' - **Pebbly silty sand;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 10 to 20% and ≤ 12 mm, angular to subangular; sand - arkosic, coarser sand and pebbles - decomposed granite; very moist; abrupt basal contact. Next 0.4' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; very moist; abrupt basal contact. Lower 0.3' - **Pebbly silty sand;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 10 to 20% and ≤ 12 mm, angular to subangular; sand - arkosic, coarser sand grains and pebbles - decomposed granite; very moist; abrupt basal contact.

512'-515' (3.6' recovered, driven) Upper 1.8' - **Sandy silt;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; central section and base of section have disturbed $CaCO_3$/caliche blebs; firmly compacted, strong reaction with HCl; very moist; abrupt basal contact. Lower 1.8' - **Pebbly sandy silt grading to Pebbly silty sand;** sand - very fine to fine grained with 10 to 20% medium to very coarse grains, pebbles 10 to 20% and < 18 mm, angular to subangular; sand - arkosic, coarser sand grains and pebbles - decomposed granite, very minor limestone and greenstone; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCL; very moist.

515'-524' (6.6' recovered, driven) Upper 0.6' - **Silt with sand and clay;** sand - very fine grained with 2 to 10% medium to very coarse grains; sand - arkosic, larger sand grains - feldspar, quartz; Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; very moist; abrupt basal contact. Middle 1.9' - **Pebbly sand with silt;** sand - very fine to very coarse grained, pebbles 40% and ≤ 50 mm, predominately (85%) < 8 mm, sand and pebbles - angular to subangular; coarser sand grains and small pebbles - decomposed granite, larger pebbles - limestone, weathered granite, quartzite, sandstone, chert; Moderate Yellowish Brown 10YR5/4; loose, strong reaction with HCl; very moist; abrupt basal contact. Lower 4.1' - **Clayey silt with sand grading to Clayey silt;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist.

524'-529' (5' plus recovered, driven) Upper 1' - **Silty clay;** Moderate Brown 5YR4/4; firmly to very firmly compacted, strong reaction with HCl; very moist. Next 1' - **Silty sand with clay;** sand - very fine to fine grained; sand - arkosic; Moderate Brown 5YR4/4; firmly to very firmly compacted, strong reaction with HCl; very moist. Next 1' - **Silty clay;** Moderate Brown 5YR4/4; firmly to very firmly compacted, strong reaction with HCl; very moist. Next 1' - **Clayey silt;** Moderate Brown 5YR4/4; firmly to very firmly compacted, strong reaction with HCl; very moist. Lower 1' - **Silty clay;** Moderate Brown 5YR4/4; firmly to very firmly compacted, strong reaction with HCl; very moist.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

529'-533' (4' recovered) Upper 0.5' - **Silt with sand and clay;** sand - very fine grained; sand - arkosic; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; very moist. Next 1.4' - **Silty sand with pebbles;** sand - very fine to medium grained with 15% coarse to very coarse grains, pebbles 10 to 30% and < 6 mm, angular to subangular; sand - arkosic, coarser sand and pebbles - feldspar, quartz, minor sandstone; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; very moist. Next 0.4' - **Silty sand;** sand - very fine to medium grained; sand - arkosic; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; very moist. Next 0.5' - **Pebbly silty sand;** sand - very fine to medium grained with 15% coarse to very coarse grains, pebbles 10 to 30% and < 6 mm, angular to subangular; sand - arkosic, coarser sand and pebbles - feldspar, quartz, minor sandstone; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; very moist. Next 0.5' - **Silty sand;** sand - very fine to medium grained, angular to subangular; sand - arkosic; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; very moist; abrupt basal contact. Lower 0.7' - **Clayey sandy silt**; sand - very fine to fine grained; sand - arkosic; Light Brown
5YR5/6; moderately to firmly compacted, strong reaction with HCl; very moist.

533'-537' (4' plus recovered, driven) Upper 2' - **Pebbles in sand with silt and minor clay matrix;** sand - very fine to very coarse grained, pebbles 50% and < 8 mm, < 1% 30 mm, sand - angular to subangular, very poorly sorted; coarser sand and pebbles - feldspar, quartz, larger pebbles - quartzite, sandstone, limestone, granite, greenstone; Moderate Yellowish Brown 10YR5/4; loose, strong reaction with HCl when dry; wet; abrupt basal contact. Lower 2' - **Silty sand with clay**; sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; 20 mm semi-consolidated sandstone lens 0.5' from top of section; firmly compacted, strong reaction with HCl; wet(?).

537'-541' (3' recovered, 1' dropped back in hole) Upper 0.8' - **Sandy silt with clay;** sand - very fine to medium grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; wet; abrupt basal contact. Next 0.2' - **Sandstone;** disturbed lenses, each lens is approximately 25 mm thick. Next 0.4' - **Silty sand with pebbles;** sand - very fine to fine grained with 15% medium to very coarse grains, pebbles 10 to 20% and ≤ 12 mm, predominately < 6 mm, angular to subangular; sand - arkosic, pebbles - feldspar, quartz, granite; Moderate Yellowish Brown 10YR5/4; loose to firmly compacted, strong reaction with HCl; very moist to wet; abrupt basal contact. Next 0.2' - **Pebbly silty sand with clay;** sand - very fine to fine grained with 15% medium to very coarse grains, pebbles 10 to 20% and ≤ 12 mm, predominately < 6 mm, angular to subangular; sand - arkosic, pebbles - feldspar, quartz, granite; Moderate Yellowish Brown 10YR5/4; loose to firmly compacted, strong reaction with HCl; very moist to wet; abrupt basal contact. Next 0.5' - **Pebbly silty sand;** sand - very fine to fine grained with 15% medium to very coarse grains, pebbles 10 to 20% and ≤ 12 mm, predominately < 6 mm, angular to subangular; sand - arkosic, pebbles - feldspar, quartz, granite; Moderate Yellowish Brown 10YR5/4; thin

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

stringer of very-fine grained magnetite towards bottom of section; loose to firmly compacted, strong reaction with HCl; very moist to wet; abrupt basal contact. Next 0.2' - **Sand with silt;** sand - very fine to coarse grained, angular to subangular; sand - arkosic; Moderate Yellowish Brown 10YR5/4; loose to firmly compacted, strong reaction with HCl; very moist to wet; abrupt basal contact. Next 0.4' - **Silty clay with sand;** sand - very fine to very coarse grained, angular to subangular; sand - arkosic; Moderate Yellowish Brown 10YR5/4; loose to firmly compacted, strong reaction with HCl; very moist to wet; abrupt basal contact. Next 0.3' - **Sand with pebbles and silt;** sand - very fine to very coarse grained, pebbles 10 to 20% and ≤ 12 mm, predominately < 6 mm, angular to subangular; sand - arkosic, pebbles - feldspar, quartz, granite; Moderate Yellowish Brown 10YR5/4; loose to firmly compacted, strong reaction with HCl; very moist to wet.

541'-548' (7.1' plus recovered) Upper 0.1' - **Conglomeratic sandstone;** 25 mm thick lens, very-fine to very-coarse sand grains with minor pebbles < 12 mm, well graded with minimum matrix; quartz, feldspar, biotite, mica flakes; disturbed by drilling, strongly cemented with $CaCO_3$. Next 4' - **Pebbly sand with minor silt and clay;** sand - very fine to very coarse grained, pebbles 10 to 50% and ≤ 30 mm, predominately < 15 mm, sand and smaller pebbles - angular to subangular, larger pebbles - subangular to few subrounded, poorly sorted; sand and small pebbles- feldspar, quartz, mica flakes, larger pebbles - limestone, sandstone, feldspar, quartz, chert, granite, weathered granite; Moderate Yellowish Brown 10YR5/4; loose to firmly compacted, strong reaction with HCl; wet; abrupt basal contact. Next 2' - **Silty clay with clayey silt;** Light Brown 5YR5/6; clayey silt is in central area of section; firmly compacted, strong reaction with HCl; very moist. Lower 1' - **Clayey silt with sand and pebbles and Silty clay with sand and pebbles;** sand - very fine to very coarse grained, pebbles 2 to 8% and < 5 mm, 20 mm pebbly zone 0.5' from top of section, pebbles - angular to subangular, pebbles - scattered; sand - arkosic, coarser sand and pebbles - feldspar; Light Brown 5YR5/6; poorly defined siltstone lens in lower 0.2'; firmly compacted, strong reaction with HCl; very moist.

548'-549.5' Recovery lost.

549.5'-558' (8.2' recovered, driven) Upper 1.4' - **Sandy pebbles with minor silt and clay;** sand - very fine to very coarse grained, pebbles 60% and ≤ 12 mm, predominately < 6 mm, pebbles - angular to subangular; sand - arkosic, coarser sand and pebbles - feldspar, quartz, minor limestone; Moderate Yellowish Brown 10YR5/4; loose, strong reaction with HCl; wet; abrupt basal contact. Next 0.8' - **Sand with silt and pebbles;** sand - very fine to very coarse grained, pebbles 4% and ≤ 12 mm, predominately < 8 mm, sand and pebbles - angular to subangular; sand - arkosic, coarser sand and pebbles - feldspar, quartz, minor limestone; Moderate Yellowish Brown 10YR5/4; one 20 mm thick conglomeratic sandstone lens fragment (disturbed); moderately compacted, strong reaction with HCl; wet; abrupt basal contact. Next 0.7' - **Clayey silt and Silty clay;**

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

Light Brown 5YR5/6; firmly compacted, strong reaction with HCl; very moist; abrupt basal contact. Next 0.7' - **Sand with silt;** sand - very fine to coarse grained, angular to subangular; sand - feldspar, quartz, mica; Moderate Yellowish Brown 10YR5/4; 1' Clayey silt zone in lower central section; moderately to firmly compacted, strong reaction with HCl; wet; abrupt basal contact. Next 2.6' - **Sandy silt and Silty clay.** Lower 2.0' - **Pebbles and sand in a silty clay and clayey silt matrix;** sand and pebbles10 to 60%, sand - medium to very coarse grained, pebbles ≤ 15 mm, predominately (85%) < 6 mm, sand and pebbles - angular to subangular; sand and pebbles - feldspar, quartz; Light Brown 5YR5/6 or Moderate Yellowish Brown 10YR5/4 where silty; moderately to firmly compacted, strong reaction with HCl; very moist.

558'-565' (7' recovered, driven) Upper 4' - **Pebbly sand with silt and clay;** sand - very fine to very coarse grained, pebbles 10 to 40% and ≤ 20 mm, predominately < 5 mm, sand - angular to subangular; sand - arkosic, coarser sand and pebbles - quartz, feldspar, minor limestone and sandstone; Moderate Yellowish Brown 10YR5/4; 20 mm conglomeratic lens 1' from top of section and one 30 mm conglomeratic sandstone lens near basal contact; loose to moderately compacted, strong reaction with HCl; wet; abrupt basal contact. Middle 2.3' - **Silty sand with clay;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; zones of minor clay and minor zones of Clayey silt; firmly compacted, strong reaction with HCl; very moist; abrupt basal contact. Lower 0.7' - **Clayey silt with pebbles;** pebbles < 2% and < 8 mm, pebbles - scattered, pebbles - angular to subangular; pebbles - quartz, feldspar, minor chert; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist.

565'-569' (4' plus recovered, driven) **Clayey silt with sand grading to Silty clay with sand and pebbles;** sand 5% and medium to very coarse grained, pebbles 2% and < 6 mm, pebbles 10% and < 6 mm in few 0.1' zones, sand - angular to subangular, pebbles - angular to few subrounded; sand - arkosic, coarser sand and pebbles - feldspar, quartz, minor limestone; Moderate Brown 5YR4/4; 2 siltstone lens fragments (blebs) in top and lower central sections; firmly to very firmly compacted, strong reaction with HCl when dry; very moist.

569'-572' (1.9' recovered, driven) Upper 0.9' - **Sand with silt and minor clay grading to Sand with pebbles and minor clay;** sand - very fine to medium grained in upper section, very fine to very coarse grained in lower section, pebbles < 5%, 20% in a 40 mm zone near base of interval, pebbles < 6 mm, sand and pebbles - angular to subangular; sand - arkosic, coarser sand and pebbles - feldspar; Moderate Yellowish Brown 10YR5/4; pebbly zone appears to be a conglomerate lens with decomposed $CaCO_3$ cement; loose to moderately compacted, strong reaction with HCl; saturated; abrupt basal contact. Middle 0.4' - **Silty clay with pebbles and sand;** sand 10% and medium to very coarse grained, pebbles ≤ 10% and < 10 mm, sand and pebbles - angular to subangular; sand - arkosic, coarser sand and pebbles - feldspar; firmly compacted, strong reaction with HCl; very moist; abrupt basal contact. Lower 0.6' - **Decomposed conglomeratic lenses**

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

separated by Pebbly sandy clayey silt; sand - very fine to fine grained with 10 to 30% medium to very coarse grains, pebbles 10 to 30% and < 8 mm, sand and pebbles - angular to subangular; sand - arkosic, coarser sand and pebbles - feldspar, quartz, mica, minor limestone and greenstone; Moderate Yellowish Brown 10YR5/4; moderate to firmly compacted, $CaCO_3$ cement decomposed in lenses, strong reaction with HCl; very moist to wet. Note: Conglomerate lens fragment from muck has cement partly replaced with fine grained sand-sized calcite crystals.

572'-578' (6.0' recovered) Upper 3.5' - **Silty clay grading to Silty clay with sand and pebbles, and Clayey silt with sand and pebbles;** sand - 5% and medium to very coarse grained in upper section, 15% and very fine grained in lower section, pebbles < 5% or 10 to 15% in zones in lower section, pebbles < 6 mm, sand - angular to subangular; coarser sand and pebbles - feldspar, quartz, mica, minor limestone and greenstone; Light Brown 5YR5/6; firmly compacted at top, moderately to firmly compacted towards bottom, strong reaction with HCl when dry; very moist; abrupt basal contact. Lower 2.5' - **Silty sand with clay grading to Clayey sandy silt;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately to firmly compacted, strong reaction with HCl when dry; very moist.

578'-582.5' (4.5' plus recovered, driven) **Clayey silt with sand and pebbles;** sand 5 to 15% and very fine to very coarse grained, pebbles 3 to 20% and < 6 mm, sand and pebbles - angular to subangular; sand - arkosic, coarser sand and pebbles - feldspar, quartz, weathered granite; Moderate Yellowish Brown 10YR5/4; 2 semi-consolidated pebbly siltstone lenses 0.4' and 0.2' thick, 2.5' from top of interval and at base of interval; firmly compacted, strong reaction with HCl when dry; very moist, wet(?) above 0.4' lens; abrupt basal contact.

582.5'-584.5' (2.3' plus recovered, driven) Upper 1.5' - **Clayey silt with sand and pebbles;** sand 5 to 15% and very fine to very coarse grained, pebbles 3 to 20% and < 6 mm, sand and pebbles - angular to subangular; sand - arkosic, coarser sand and pebbles - feldspar, quartz, weathered granite; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl when dry; abrupt basal contact. Lower 0.8' - **Pebbles and sand in clayey silt matrix;** sand - 20% and very fine to very coarse grained, pebbles 20% and ≤ 10 mm, predominately ≤ 4 mm, sand and pebbles - angular to subangular; sand - arkosic, coarser sand and pebbles - feldspar, quartz, minor weathered greenstone; matrix - Moderate Yellowish Brown 10YR5/4; appears weathered (chalky), moderately compacted, abundant $CaCO_3$ cement, strong to very strong reaction with HCl; very moist.

584.5'-590' (3.5' plus recovered) **Sand with pebbles, minor silt and clay;** sand - very fine to very coarse grained, poorly sorted, pebbles 15% in upper 0.5', 8% in central section, 5% in lower 0.7', mostly < 4 mm, upper section has 10% ≤ 12 mm, one 20 mm clast, sand and pebbles - angular to subangular, poorly sorted; sand - arkosic, upper central section has abundant fine grained

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

magnetite, coarser sand and pebbles - feldspar, quartz, minor limestone, greenstone, granite, sandstone, quartzite; Moderate Yellowish Brown 10YR5/4; loose, strong reaction with HCl when dry; saturated.

590'-593' (4.5' recovered, driven) Upper 0.5' - **Silty sand with clay;** sand - very fine to medium grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; wet. Next 1.5' - **Clayey silt;** Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; very moist. Next 0.5' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; very moist. Next 0.5' - **Sandy silt with minor clay;** sand - very fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; very moist. Next 0.5' - **Clayey silt;** Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; very moist. Lower 1' - **Sandy clayey silt;** sand - very fine; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; very moist.

593'-599' (6' recovered, driven) Upper 2' - **Sandy silt with clay;** sand - very fine; sand - arkosic; Light Brown 5YR5/6 to Moderate Brown 5YR4/4; firmly compacted, moderate to strong reaction with HCl when dry; very moist. Next 1.5' - **Silty sand with clay;** sand - very fine; sand - arkosic; Light Brown 5YR5/6 to Moderate Brown 5YR4/4; firmly compacted, moderate to strong reaction with HCl when dry; very moist. Next 1' - **Sandy silt with clay and pebbles;** sand - very fine to fine grained with $\leq$ 5% medium to very coarse grained, pebbles < 2% and < 4 mm, coarser sand and pebbles - angular to subangular, pebbles scattered; sand - arkosic, coarser sand and pebbles - feldspar, mica flakes; Light Brown 5YR5/6 to Moderate Brown 5YR4/4; firmly compacted, moderate to strong reaction with HCl when dry; very moist. Lower 1.5' - **Clayey silt with sand;** sand - very fine; sand - arkosic; Light Brown 5YR5/6 to Moderate Brown 5YR4/4; siltstone bleb about 0.2' from top of section; firmly compacted, moderate to strong reaction with HCl; very moist.

599'-603' (5' plus recovered, driven) Upper 3.5' - **Silty sand with clay grading to Clayey silt with sand;** sand - fine to very fine grained; sand - arkosic; Light Brown 5YR5/6 to Moderate Brown 5YR4/4; firmly compacted, strong reaction with HCl when dry; very moist. Lower 1.5' - **Silty clay;** Light Brown 5YR5/6 to Moderate Brown 5YR4/4; firmly compacted, strong reaction with HCl when dry; very moist.

603'-608' (5' plus recovered, driven) **Clayey silt with sand and pebbles grading to Silty clay with pebbles;** sand - very fine to fine grained with minor medium to very coarse grains, pebbles 3 to 15% and $\leq$ 15 mm, predominately < 8 mm, angular to subangular; sand - arkosic, coarser sand and pebbles - feldspar; Light Brown 5YR5/6 to Moderate Brown 5YR4/4; firmly compacted, moderate to strong reaction with HCl when dry; very moist.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

608'-613' (5' plus recovered, driven) **Clayey sandy silt grading to Clayey silty sand;** sand - very fine grained in upper section, very fine to fine grained with 5% medium grains in lower section; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl when dry; very moist.

613'-617' (4' recovered, driven) Upper 0.4'- **Silty sand with minor clay;** sand - very fine to medium grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately compacted; wet; abrupt basal contact. Next 0.4'- **Sand with silt, clay and pebbles;** sand - very fine to very coarse grained, pebbles 5% and < 10 mm, sand - angular to subangular, pebbles - subangular; sand - arkosic, coarser sand and pebbles - feldspar, quartz; Moderate Yellowish Brown 10YR5/4; loose; wet; abrupt basal contact. Next 0.7'- **Sandy pebbles with silt and minor clay;** sand - very fine to very coarse grained, pebbles 60% and < 25 mm, sand angular to subangular, pebbles - subangular to subrounded; sand - arkosic, coarser sand and pebbles - feldspar, granite, quartz, sandstone; Moderate Yellowish Brown 10YR5/4; loose; wet; abrupt basal contact. Note: Mucked pebbles < 55 mm, included quartzite, limestone and greenstone. Lower 2.5' - **Silty clay with sand and pebbles grading to Pebbly sandy clayey silt;** sand - very fine to fine grained, very fine to very coarse grained where pebbly, pebbles 3% at top to 25% towards bottom and ≤ 10 mm, predominately < 5 mm, angular to subangular; sand - arkosic, coarser sand and pebbles - feldspar; Moderate Yellowish Brown 10YR5/4; firmly compacted, $CaCO_3$ cemented blebs in central section, strong reaction with HCl; very moist.

617'-620.5' (5.5' plus recovered) Upper 1' - **Silty sand with clay and pebbles;** sand - very fine to fine grained, pebbles < 3% and < 6 mm, angular to subangular; sand - arkosic, pebbles - feldspar, quartz; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist. Middle 1' - **Silty sand with clay;** sand - very fine to fine grained, angular to subangular; sand - arkosic; Moderate Yellowish Brown 10YR5/4; section contains 40 mm (?) semi-consolidated siltstone lens and $CaCO_3$ bleb; firmly compacted, strong reaction with HCl; very moist. Lower 3.5' - **Clayey silt with sand;** sand - very fine to fine grained, angular to subangular; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist.

620.5'-623' (2.5' plus recovered, driven) Upper 0.5' - **Clayey silt with sand;** sand - very fine grained; sand - arkosic; Light Brown 5YR5/6; firmly compacted, strong reaction with HCl when dry; very moist; gradational basal contact. Middle 1' - **Sand and pebbles in clayey silt matrix;** sand and pebbles 50% and < 8 mm, predominately ≤ 4 mm, angular, few subangular; sand - arkosic, pebbles - quartz, feldspar; matrix - Moderate Yellowish Brown 10YR5/4; section contains 25 mm(?) disturbed siltstone lens; firmly compacted, strong reaction with HCl when dry; wet; fairly abrupt basal contact. Lower 1' - **Silty clay;** Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; very moist.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

623'-628' (6' plus recovered) Upper 3' - **Sandy silt with clay;** sand - very fine grained; sand - arkosic; Light Brown 5YR5/6; firmly compacted, strong reaction with HCl when dry; wet. Lower 3' - **Silty sand with minor clay;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; firmly compacted, strong reaction with HCl when dry; wet.

628'-631' (3' recovered, driven) **Silty sand with clay grading to Sandy silt with clay;** sand - very fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; wet.

631'-632.5' (1.5' plus recovered) Upper 1' - **Clayey silt grading to Silty clay;** Moderate Yellowish Brown 10YR5/4; contains disturbed siltstone bleb fragments; very firmly compacted, strongly cemented with $CaCO_3$ (semi-consolidated), strong reaction with HCl; wet; abrupt basal contact. Middle 0.3' - **Silty sand;** sand - very fine to medium grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; wet; abrupt basal contact. Lower 0.2' - **Pebbly sand with silt;** sand - very fine to very coarse grained, pebbles 5 to 35% and < 5 mm, sand and pebbles - angular to subangular, poorly sorted; sand - arkosic, abundant mica flakes, coarser sand and pebbles - granite, feldspar; Moderate Yellowish Brown 10YR5/4; loose, strong reaction with HCl when dry; wet.

632.5'-634.5' (2.3' plus recovered, driven) Upper 0.3' - **Silty sand;** sand - very fine to medium grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately to firmly compacted, strong reaction with HCl; wet. Middle 1'- **Clayey silt;** Light Brown 5YR5/6; very firmly compacted, strong reaction with HCl when dry; very moist; abrupt basal contact. Lower 1' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; firmly compacted, strong reaction with HCl; wet.

634.5'-640' (5' recovered, driven) Upper 1.5' - **Clayey silt with sand;** sand 5% and very fine to very coarse grained, angular to subangular; sand - arkosic; Light Brown 5YR5/6; strongly compacted, strong reaction with HCl; wet; fairly abrupt basal contact. Middle 1.5' - **Silt with clay and sand grading to Sandy silt with clay and pebbles;** sand - very fine to fine grained with 5 to 10% medium to very coarse grains in lower section, pebbles < 2% and < 12 mm, pebbles - subangular to subrounded, pebbles - scattered; sand - arkosic, coarser sand and pebbles - quartz, feldspar, minor sandstone; Moderate Yellowish Brown 10YR5/4; very firmly compacted, strong reaction with HCl; wet; abrupt basal contact. Lower 2' - **Clayey silt;** Moderate Yellowish Brown 10YR5/4; firmly compacted, well indurated with $CaCO_3$ cement, strong reaction with HCl; very moist.

640'-641.5' (1.5' plus recovered) Upper 0.5' - **Clayey silt with sand and pebbles;** sand 5 to 10% and medium to very coarse grained, pebbles < 5% and ≤ 12 mm, predominately < 6 mm, sand -

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ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

angular to subangular, poorly sorted; sand and pebbles - quartz, feldspar; Light Brown 5YR5/6; siltstone blebs in upper section; firmly compacted, strong reaction with HCl; wet; abrupt basal contact. Lower 1' - **Sand with pebbles in clayey silt matrix;** sand 60% and very fine to very coarse grained, pebbles 10% and < 15 mm at upper contact, predominately < 6 mm, sand and pebbles - angular to subangular, poorly sorted; coarser sand and pebbles - feldspar, quartz, minor greenstone; matrix - Moderate Yellowish Brown 10YR5/4; sand and pebbles are grain supported, firmly compacted, appears to be decomposed (especially greenstone) after deposition, strong reaction with HCl; very moist.

641.5'-645' (4' plus recovered, driven) **Clayey silt with sand and pebbles grading to Silty clay with sand and pebbles;** sand and pebbles 5 to 10%, pebbles ≤ 12 mm, predominately < 6 mm; sand - arkosic, coarser sand and pebbles - feldspar, quartz; Light Brown 5YR5/6 to Moderate Brown 5YR4/4; siltstone blebs about 1' below top of interval; very firmly compacted, strong reaction with HCl; very moist.

645'-650' (4.5' plus recovered, driven) Upper 0.5' - **Silty clay with sand and pebbles;** sand and pebbles 5 to 10%, pebbles ≤ 12 mm, predominately < 6 mm; sand - arkosic, coarser sand and pebbles - feldspar, quartz; Light Brown 5YR5/6 to Moderate Brown 5YR4/4; very firmly compacted, strong reaction with HCl; very moist. Lower 4' - **Silty clay;** Moderate Brown 5YR4/4; very firmly compacted, strong reaction with HCl when dry; very moist.

Verified and edited on 23DEC93, 28DEC93 and 11JAN94 by C. Abeyta and on 27DEC93 by J. Szalona.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/NW1/595

Note: Core was collected from 325' to 650'.

Lithologies logged by U.S. Geological Survey geologist Joe Szalona as follows:

Depth	Date	Geologist
325' to 650'	17MAY93 to 25JUN93	J. Szalona

Percentage of hole logged by geologist:

J. Szalona	100%

APPENDIX A

EXAMINATION OF PORTION OF CORE
WELL TA2-NW1-325/595

Log Depth: 297-470 Ft

Well Depth	Description
297 - 300'	Sandy silt: light brown, very fine; blocky
300 - 303.5'	Pebbly sand: light gray; coarse grained; loose
303.5 - 305.5'	Sandy silt: tan to buff
305.5 - 306'	Caliche blebs in light brown clayey silt or silty clay
306 - 307'	Clayey silt or silty clay: light brown
306'	SHALLOW WATER LEVEL
307 - 314.5'	Clayey silt or silty clay: medium brown,
314.5 - 315'	Caliche blebs: poorly developed in clayey silt
315 - 323'	Silty sand: light tan to buff, very fine grained; few coarse, poorly-sorted sand streaks; hard chunks
323 - 323.5'	Sandstone: light buff, very fine grained, well-sorted; biotite & muscovite flakes; very hard & completely consolidated; 1 chunk, representing perhaps ½ to 1'; *only sandstone observed in interval studied*
323 - 325'	Silty sand; buff; very fine grained; hard, semi-consolidated (much like 317-23')
325.5 - 328.5'	Silty sand: brown, very fine grained
328.5 - 329"	Caliche-rich lithology a/a
329 - 332'	Sand: buff, clayey/silty very fine grained; blocky & hard
332 - 333.5'	Clayey silt: brown
333.5 - 337'	Pebbly sand: brown, very fine grained
337 - 337.5'	Thin caliche zone
337.5 - 339'	Pebbly sand: brown, very fine grained
339.5 - 341'	Thin caliche zone
341 - 342'	Silty sand: light brown, very fine grained
342 - 343'	Sandy silt: light brown, very fine grained, w/ small quartz & feldspar pebbles
343 - 346'	Sandy silt: light gray, very fine grained, w/ small quartz & feldspar pebbles
346 - 347'	Powdery silt: light gray, pebbly
347 - 352'	Silty sand: light brown, very fine grained
352 - 360'	Silty sand to sandy silt: brown, very fine grained, w/ few angular pebbles
360 - 362'	Pebbly silty sand: light gray, very loose
362 - 364'	Clayey & sandy silt: brown, poorly sorted, w/ angular fragments up to 1"

364 - 366' Sand: light brown to light gray, moderately sorted, coarse, w/ pebbles
366 - 70' MISSING
370 - 370.5 Pebbly sand: light gray, poorly sorted; loose & friable

370.5 - 395' (24.5') AQUITARD(?)
- 370.5 - 382' Silty clay to clayey silt; brown; some very fine grained silty-sand/sandy-silt streaks
- 382 - 386' Pebbly clayey silt: light gray
- 386 - 388' Clayey silt to silty clay: brown
- 388 - 392' Pebbly clayey silt: light gray
- 392 - 395' Silty clay: brown

395 - 398' Sand: light gray to buff, very fine grained, w/ some pebbles
398 - 400 Sand: brown; very fine
400 - 405' Sand: very light brown to buff, very fine grained
410 - 416' Sandy silt: brown; clayey; very fine grained texture; firm
416 - 419.5 Silty clay: brown; w/ few blebs of caliche
419.5 - 424.5' Silty sand to sandy silt: light buff, very fine grained
424.5 - 434.5' Silty sand: very light buff, very fine grained; well sorted

434.5 - 457' AQUITARD(?)
- 434.5 - 442.5' Clayey silt: light brown
- 442.5 - 445' Caliche: mottled, poorly developed in lithology in clayey silt a/a
- 445 - 449' Sandy silt:
- 449 - 451' Caliche: poorly developed a/a
- 451 - 452' Sandy silt, light brown; poorly sorted w/ small angular pebbles
- 452 - 457' Clayey(?) silt: brown

457 - 461' Silty sand: light brown, very fine grained
461 - 463' Silty sand: light brown; w/ some small pebbles; very firm
463 - 470' Pebbly silty sand: fine grained; firm, blocky; slight caliche development 463-63.5

Lithologic log for borehole at monitoring well TA2-SW1-320

Drilling company	USGS Water Sciences Division
Dates of drilling	November 2 to 19, 1992
Drilling method	Sonicore with Drive Casing
Total depth of borehole, ft	330
Ground elevation, ft amsl NAVD 88	5410.1
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	299.6 to 319.6
Date well developed	November 19, 1992
Initial water level, ft bgs	310.93
Rig Geologist	C. Abeyta

Also see separate 17-page description.

Depth, ft bgs	Composite Description from USGS combined geophysics/lithologic log
0-15	Sand, silty. Moderate to light brown, very fine- to fine-grained, caliche, minor pebbles. Granite, quartzite, limestone.
15-30	Sand, clayey and silty. Light to moderate brown, very fine- to fine-grained.
30-50	Sand, silty and pebbly. Light brown, very fine- to fine-grained. Limestone and granite fragments.
50-75	Sand, silty. Light to moderate brown, very fine- to fine-grained, minor pebbles.
75-92	Sand, pebbly. Light to moderate brown, angular to subangular, coarse sand.
92-117	Sand, silty. Moderate brown, very fine- to fine-grained, minor pebbles and clay.
117-130	Sand, clayey and silty. Light to moderate brown, very fine- to fine-grained.
130-178	Sand, silty and Silt, sandy. Light to moderate brown, very fine- to fine-grained, well-sorted, interspersed pebbly zones. Granite, limestone, and quartzite fragments.
178-191	Silt, sandy and Sand, silty. Light brown, very fine-to fine-grained, caliche.
191-215	Sand, silty. Light brown, very fine- to fine-grained, pebbly interbeds. Quartzite, granite, and greenstone fragments.
215-255	Sand, silty and Silt, sandy. Light to moderate yellowish brown, very fine- to fine-grained, minor pebble interbeds.
255-265	Sand, pebbly and silty. Light brown, very fine- to fine-grained, caliche.
265-300	Sand, silty. Light to moderate yellowish brown, fine- to very fine-grained, caliche, pebbles interspersed throughout. Granite, limestone, and quartzite fragments.
300-330	Sand, silty and Silt, sandy. Light moderate yellowish brown, very fine- to fine-grained sand, pebbly interbeds. Feldspar, quartz, and limestone fragments.
330	Borehole Total Depth.

The Unified Soil Classification System symbol was not recorded on the original lithologic log or field notes.

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LITHOLOGIC LOG

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

Ground Elevation: 5418 feet (Estimated) Drilling Method/Fluids: Sonic/Dry or
Logged by: U.S. Geological Survey (Szalona, Abeyta) driven split spoon where noted
Drilling began: 02NOV92 Drilling completed: 19NOV92 Total Depth: 330 feet
Color Chart: Goddard, E.N., and others, 1984, Rock color chart: Geological Society of America, Boulder, Colo.

Note: 4-inch soniced core to total depth unless noted otherwise.

0'-2' (1.8' recovered, 2.5-inch driven split-spoon sample) **Silty sand;** sand - very fine to fine grained, pebbles < 0.5% and ≤ 10 mm, pebbles - subangular, well sorted; pebbles - granite, quartzite; Moderate Brown 5YR4/4; roots abundant; loose, strong reaction with HCl; very slightly moist.

2'-4' (1.3' recovered, 2.5-inch driven split-spoon sample) **Silty sand with pebbles and caliche;** sand - very fine to fine grained with < 3% medium to very coarse grains, pebbles < 1% and ≤ 50 mm, sand - subangular, pebbles - subangular to rounded, poorly sorted; sand - arkosic, pebbles - granite, quartzite, cherty limestone; Moderate Brown 5YR4/4; roots abundant; loose to moderately compacted/cemented, $CaCO_3$ cement, caliche abundant, strong reaction with HCl; very slightly moist.

4'-5' (1' plus recovered) **Pebbly silty sand with caliche;** sand - very fine to very coarse grained, pebbles approximately 15% and ≤ 60 mm, predominately < 10 mm, sand, - subangular, pebbles - subangular to rounded, very poorly sorted; sand - arkosic, pebbles - granite, cherty limestone, quartzite; Pale Yellowish Brown 10YR6/2; loose, caliche abundant, strong reaction with HCl; very slightly moist.

5'-10' (5.3' recovered) Upper 2.7' - **Pebbly silty sand with caliche;** sand - very fine to very coarse grained, pebbles approximately 15% and ≤ 50 mm, predominately < 10 mm, sand - subangular, pebbles - subangular to rounded, very poorly sorted; sand - arkosic, pebbles - limestone, granite, greenstone, metaquartzite; Pale Yellowish Brown 10YR6/2 to Moderate Yellowish Brown 10YR5/4 towards bottom; becomes less silty and more sandy towards bottom of section; loose, caliche becomes less abundant towards bottom, strong reaction with HCl; very slightly moist at top to very moist in lower 0.7'; very abrupt basal contact. Lower 2.6' - **Sandy silt with caliche;** sand - very fine to fine grained with < 1% medium to very coarse grains, pebbles < 0.5% and ≤ 6 mm, coarse sand and pebbles - subangular, fairly well sorted; pebbles and coarser sand - metaquartzite/ quartzite; Light Brown 5YR6/4; strongly compacted/cemented, caliche abundant as matrix, strong reaction with HCl; very slightly moist.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

10'-12' (1.8' recovered, 2.5-inch driven split-spoon sample) **Sandy silt;** sand - very fine to fine grained with < 1% medium to very coarse grains, pebbles < 1% and ≤ 32 mm, predominately ≤ 10 mm, subangular, moderately sorted; pebbles - limestone, quartzite; Moderate Yellowish Brown 10YR5/4 loose to moderately compacted, strong reaction with HCl; slightly moist to wet (due to water from wetting cuttings).

12'-14' - (1.7' recovered, 2.5-inch driven split-spoon sample) Split-spoon sample collected before it could be described; sample saturated with drill water in top 0.5'.

15'-17' (1.5' recovered, 2.5-inch driven split-spoon sample) **Pebbly silty sand;** sand - very fine to very coarse grained, pebbles approximately 20% and ≤ 40 mm, predominately < 10 mm, subangular, very poorly sorted; sand - arkosic, pebbles - granite, limestone; Light Brown 5YR6/4; loose, strong reaction with HCl; moderately moist.

17'-19' (2.2' recovered, 2.5-inch driven split-spoon sample) Upper 1' - **Pebbly silty sand;** sand - very fine to very coarse grained, pebbles approximately 20% and ≤ 40 mm, predominately < 10 mm, subangular, very poorly sorted; sand - arkosic, pebbles - granite, limestone; Light Brown 5YR6/4; loose, strong reaction with HCl; moderately moist; abrupt basal contact. Lower 1.2' - **Silty clayey sand;** sand - very fine to fine grained, pebbles < 0.5% increasing to approximately 1% in lower 0.2', pebbles - subangular to subrounded, well sorted; pebbles - limestone, sandstone, quartzite; Moderate Brown 5YR4/4; moderately compacted, strong reaction with HCl; very moist.

10'-15' (5' recovered, 4-inch soniced core, upper 1' - see description for 10'-12' interval previously described, 11'-15' zone did not seem to be penetrated by the split spoon, 11'-15' described below) Upper 2' - **Caliche and Silty sand with pebbles;** sand - predominately very fine to fine grained with approximately 4% very coarse sand and pebbles, pebbles ≤ 50 mm, predominately ≤ 6 mm, subangular, moderately to poorly sorted; coarse sand - arkosic, pebbles - limestone, greenstone, mica, granite; Moderate Orange Pink 5YR8/4 to Light Brown 5YR6/4; decomposing gravel in caliche matrix; moderately to strongly compacted/cemented, caliche abundant, strong reaction with HCl; moderately moist; abrupt basal contact. Middle 0.6' (possible slough from 0' - 5') - **Silty sand with pebbles;** sand - very fine to fine grained with approximately 3% coarse to very coarse grains, pebbles < 1% and ≤ 8 mm, subangular, moderately sorted; sand - arkosic, pebbles - granite, limestone; Light Brown 5YR5/6; loose, strong reaction with HCl; very moist; abrupt basal contact. Lower 1.4' - **Caliche and Silty sand with pebbles and cobble;** sand - predominately very fine to fine grained with approximately 4% very coarse sand and pebbles, pebbles ≤ 50 mm, predominately ≤ 6 mm, one cobble > 90 mm at bottom of section, subangular, moderately to poorly sorted; coarse sand - arkosic, pebbles - limestone, greenstone, mica, granite, cobble - granite; Moderate Orange Pink 5YR8/4 to Light Brown 5YR6/4; decomposing gravel in

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ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

caliche matrix; moderately to strongly compacted/cemented, caliche abundant, strong reaction with HCl; moderately moist.

15'-20' (3.2' recovered, see description for 15'-17' and 17'-19' intervals previously described, lower 1' described) **Silty sand with clay;** sand - very fine to fine grained with < 3% medium to very coarse grains, subangular, moderately well sorted; sand - arkosic, limestone; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; moist; abrupt upper contact.

20'-22' (2' recovered, 2.5-inch driven split-spoon sample) **Silty sand with pebbles;** sand - very fine to very coarse grained, pebbles approximately 3% and ≤ 10 mm, subangular, very poorly sorted; sand - arkosic, pebbles - quartzite, granite, limestone; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; very moist to wet.

22'-24' (recovery not noted, 2.5-inch driven split-spoon sample) **Silty sand;** sand - very fine to fine grained, well sorted; sand - arkosic, biotite; Light Brown 5YR5/6; moderately compacted, moderate to strong reaction with HCl; moist.

20'-25' (3.3' recovered, see description for 20'-22' and 22'-24' intervals previously described, lower 1' described) **Silty sand with pebbly zone;** sand - very fine to fine grained, well sorted; sand - arkosic, biotite; Light Brown 5YR5/6; silty sand with pebble zone 0.3' to 0.7' from top of section, sand - very fine to very coarse grained, pebbles approximately 5% and ≤ 40 mm, predominately < 10 mm, subangular, poorly sorted; Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, loose in pebbly zone, moderate to strong reaction with HCl; moist.

25'-27' (2' recovered, 2.5-inch driven split-spoon sample) **Silty sand with minor clay;** sand - very fine to fine grained, well sorted; Moderate Brown 5YR4/4; moderately compacted, strong reaction with HCl; moist.

25'-30' (3.3' recovered) **Silty sand with clay;** sand - very fine to fine grained, pebbles < 0.5% and ≤ 10 mm, well sorted; pebbles - greenstone, minor granite; Moderate Brown 5YR4/4; moderately compacted, moderate reaction with HCl; moist.

30'-32' (1.6' plus recovered, 2.5-inch driven split-spoon sample) **Silty sand with clay;** sand - very fine to fine grained, well sorted; Moderate Brown 5YR4/4; clay content increases towards bottom; moderately compacted, moderate reaction with HCl; moist.

32'-34' (2' plus recovered, 2.5-inch driven split-spoon sample) **Clayey silty sand;** sand - very fine to fine grained, grading to very fine to fine grained with approximately 5% medium to very coarse

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

grains, well sorted; Moderate Brown 5YR4/4; clay content decreases towards bottom; moderately compacted, moderate to strong reaction with HCl; moist.

34'-36' (1.3' recovered, 2.5-inch driven split-spoon sample) Upper 0.5' - **Clayey silty sand;** sand - very fine to fine grained with approximately 5% medium to very coarse grains, well sorted; Moderate Brown 5YR4/4; clay content decreases towards bottom; moderately compacted, moderate to strong reaction with HCl; moist. Lower 0.8' - **Pebbly silty sand with caliche;** sand - very fine to very coarse grained, pebbles 25% and ≤ 30 mm, subangular, very poorly sorted; sand - arkosic, pebbles predominately limestone, quartz; Light Brown 5YR6/4; loose, strong reaction with HCl; very moist.

30'-40' (5.1' recovered, 4-inch soniced core, see description for 30'-32', 32'-34', and 34'-36' intervals previously described, lower 4' described) Lower 4' - **Pebbly silty sand;** sand - very fine to very coarse grained, pebbles 25% and ≤ 60 mm, predominately ≤ 6 mm, sand - subangular to subrounded, pebbles - subangular; sand - arkosic, pebbles - greenstone, limestone; loose, strong reaction with HCl; very moist.

40'-42' (1.5' recovered, 2.5-inch driven split-spoon sample) **Pebbly silty sand;** sand - very fine to very coarse grained, pebbles 25% and ≤ 60 mm, predominately ≤ 6 mm, sand - subangular to subrounded, pebbles - subangular; sand - arkosic, pebbles - quartzite, sandstone, limestone, granite; loose, strong reaction with HCl; very moist.

42'-44' (1.1' recovered, 2.5-inch driven split-spoon sample) **Pebbly silty sand;** sand - very fine to very coarse grained, pebbles 25% and ≤ 6 mm, sand - subangular to subrounded, pebbles - subangular; sand - arkosic, pebbles - quartzite, sandstone, limestone, granite; loose, strong reaction with HCl; very moist.

40'-45' (3.8' recovered, 4-inch soniced core, see description for 40'-42' and 42'-44' intervals previously described, lower 1' described) Lower 1' - **Silty sand with clay and pebbles**; sand - very fine to fine grained, pebbles 1% (15% in a 0.3' zone in lower central section) and ≤ 10 mm, predominately ≤ 6 mm, pebbles - subangular, sand - well sorted; pebbles - limestone, granite, feldspar, greenstone; Light Brown 5YR5/6; loose to moderately compacted, strong reaction with HCl; very moist.

45'-47' (1.6' recovered, 2.5-inch driven split-spoon sample) **Silty sand with pebbles;** sand - very fine to fine grained, pebbles 5% and ≤ 8 mm, subangular; sand - arkosic, pebbles - limestone; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; very moist.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

45'-50' (3.9' recovered, 4-inch soniced core, upper 0.9' - see description for 45'-47' interval previously described) Lower 3' - **Pebbly silty sand;** sand - very fine to fine grained with 20% medium to very coarse grains, pebbles 20% and ≤ 30 mm, predominately (90%) ≤ 10 mm, subangular to subrounded; pebbles - limestone, greenstone, granite; Light Brown 5YR5/6; moderately compacted to loose; strong reaction with HCl; very moist.

50'-52' (1.7' recovered, 2.5-inch driven split-spoon sample) **Silty sand with clay and pebbles;** sand - very fine to fine grained, pebbles 5% and ≤ 4 mm, subangular; sand - arkosic; Light Brown 5YR5/6; strong reaction with HCl; very moist.

52'-54' (2.0' recovered, 2.5-inch driven split-spoon sample) Upper 1.4' - **Clayey sandy silt;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; very moist/wet. Lower 0.6' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; very moist/wet.

50'-57' (7.8' recovered, 4-inch soniced core, upper 4.8' - see description for 50'-52' and 52'-54' intervals previously described) Lower 3' - **Silty sand with minor clay and caliche;** sand - very fine to fine grained; sand - arkosic with abundant mica flakes; Light Brown 5YR5/6; moderately compacted, caliche occurs as matrix and < 1% as nodules < 10 mm, strong reaction with HCl; very moist.

57'-67' (9.8' plus recovered) Upper 0.2' - **Pebbles in silty sand matrix;** pebbles 50% and ≤ 30 mm, clast supported, sand - very fine to fine grained with 5% medium to very coarse grains, subangular to subrounded; sand - arkosic, pebbles - limestone, granite; Moderate Yellowish Brown 10YR5/4; moderately compacted, moderate reaction with HCl; very moist; very abrupt basal contact. Next 0.5'- **Silty clay and Clayey silt with pebbles;** pebbles < 5% in lower section and ≤ 4 mm, subangular; pebbles - limestone; Moderate Brown 5YR4/4; clayey laminations; moderately to strongly compacted, weak reaction with HCl; fairly abrupt basal contact. Next 6.7' - **Silty sand with minor clay and caliche;** sand - very fine to fine grained; sand - arkosic; Moderate Brown 5YR4/4; moderately compacted, moderate to strong reaction with HCl; fairly abrupt basal contract; very moist. Next 2.1' - **Pebbly sand;** sand - very fine to very coarse grained, pebbles 15% and ≤ 40 mm, sand - angular to subangular, pebbles - subangular, very poorly sorted; sand - arkosic, pebbles - limestone, metaquartzite; moderately to strongly compacted, moderate reaction with HCl; very moist; fairly gradational basal contact. Lower 0.3' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Moderate Brown 5YR4/4; moderately compacted, moderate to strong reaction with HCl; very moist.

67'-77' (9.6' plus recovered) Upper 0.4' - **Silty sand with pebbles;** sand - very fine to fine grained,

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ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

pebbles ≤ 5% and ≤ 12 mm, predominately ≤ 4 mm, pebbles - angular to subangular; sand - arkosic, pebbles - limestone, feldspar; Moderate Brown 5YR4/4; moderately compacted, moderate to strong reaction with HCl; very moist. Next 0.9' - **Sandy clayey silt;** sand - very fine to fine grained; sand - arkosic; Moderate Brown 5YR4/4; strongly compacted, weak to moderate reaction with HCl; very moist. Next 6.1' - **Silty sand with pebbles;** sand - very fine to fine grained with 10% medium to very coarse grains, pebbles < 1% and ≤ 10 mm, angular to subangular; sand - arkosic, pebbles - limestone, quartz, feldspar; Light Brown 5YR5/6; moderately to strongly compacted, strong reaction with HCl; very moist; abrupt basal contact. Lower 2.2' - **Pebbly sand**; sand - very fine to very coarse grained, pebbles 20% and ≤ 15 mm, predominately < 6 mm, ≤ 60 mm in a 0.4' zone 0.4' from top of section, sand - angular to subangular, pebbles - subangular with few subrounded; sand - arkosic, pebbles - limestone, feldspar, granite, gneiss, weathered very coarse-grained sandstone; Moderate Yellowish Brown 10YR5/4; loose, moderate reaction with HCl - very moist.

77'-86' (8.2' plus recovered) Upper 5.9' - **Pebbly sand with cobble;** sand - very fine to very coarse grained, pebbles 30% and ≤ 50 mm, predominately < 6 mm, coarser sizes to 50 mm mostly in upper 2' of interval, cobble - 80 mm, sand - angular to subangular, pebbles - subangular with some angular and subrounded; sand - arkosic with abundant mica, pebbles - limestone, greenstone, granite; Moderate Yellowish Brown 10YR5/4; loose to moderately compacted, moderate to strong reaction with HCl; very moist; fairly abrupt basal contact. Lower 2.3 - **Silty sand with pebbles and caliche;** sand - very fine to fine grained with 5% medium to very coarse grains, 15% medium to very coarse grains in upper central zone, pebbles 10% and ≤ 20 mm, predominately ≤ 6 mm, sand - angular to subangular; sand - arkosic, pebbles - limestone, quartz, feldspar; Light Brown 5YR6/4; loose to moderately compacted, caliche abundant as matrix, strong reaction with HCl; very moist.

86'-97' (11.6' plus recovered) Upper 0.5' - **Silty sand with pebbles and caliche;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 10% and ≤ 20 mm, predominately ≤ 6 mm, sand - angular to subangular; sand - arkosic, pebbles - limestone, quartz, feldspar; Light Brown 5YR6/4; loose to moderately compacted, caliche abundant as matrix, strong reaction with HCl; very moist. Next 4.0' - **Pebbly sand with minor silt and clay**; sand - very fine to very coarse grained, pebbles 25% and ≤ 40 mm, predominately (95%) < 6 mm, coarser sizes mostly near bottom of section, one 75 mm cobble near center of section; pebbles - limestone, greenstone, sandstone, metagranite; Moderate Brown 5YR4/4; loose to moderately compacted, moderate to strong reaction with HCl; upper 1.5' and lower 0.5' very moist, central 2.0' saturated; abrupt basal contact. Next 0.3' - **Pebbly silty sand with caliche;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 10% and ≤5 mm, angular to subangular; sand - arkosic; Pale Yellowish Brown 10YR6/2; caliche abundant as matrix. Next 1.2' - **Pebbly sand with minor silt**

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

and clay; sand - very fine to very coarse grained, pebbles 25% and ≤ 40 mm, predominately < 6 mm; pebbles - limestone, greenstone, sandstone, metagranite; Moderate Brown 5YR4/4; loose to moderately compacted, moderate to strong reaction with HCl; very moist; abrupt basal contact. Next 0.6' - **Silty sand with minor clay;** sand - very fine to fine grained; Light Brown 5YR5/6; moderately to strongly compacted, strong reaction with HCl; very moist; abrupt basal contact. Lower 5.0' - **Clayey silt with caliche and pebbles;** pebbles < 1%, angular to subrounded; pebbles - limestone, quartz; Light Brown 5YR5/6; moderately to strongly compacted, caliche in upper and lower areas of section, moderate to strong reaction with HCl; very moist.

97'-101' (4.1' recovered) Upper 2.1' - **Clayey silt with caliche and pebbles;** pebbles < 1%, angular to subrounded; pebbles - limestone, quartz; Light Brown 5YR5/6; moderately to strongly compacted, moderate to strong reaction with HCl; very moist. Lower 2.0' - **Sandy silt with minor clay;** sand - very fine to fine grained; Light Brown 5YR5/6; moderately compacted, moderate reaction with HCl; very moist.

101'-107' (5.7' plus recovered) **Silty sand with pebbles and minor clay;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 7% and ≤ 60 mm, predominately (90%) ≤ 6 mm, predominately subangular; coarser sand and pebbles - greenstone, granite, feldspar, weathered granite; Moderate Brown 5YR4/4; moderately compacted, moderate reaction with HCl; very moist.

107'-117' (9.3' recovered) Upper 0.6' - **Silty sand with pebbles and minor clay;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 7% and ≤ 60 mm, predominately (90%) ≤ 6 mm, pebbles - subangular; coarser sand and pebbles - greenstone, granite, feldspar, weathered granite; Moderate Brown 5YR4/4; moderately compacted, moderate reaction with HCl; very moist. Next 1.0' - **Sandy clayey silt with pebbles grading to Silty clay;** sand - very fine to fine grained, pebbles 7% in upper zone and ≤ 6 mm, pebbles - angular; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, strong reaction with HCl; very moist; abrupt basal contact. Next 2.5' - **Pebbles in silty sand matrix;** pebbles 60% and ≤ 60 mm, predominately ≤ 6 mm, sand - very fine to very coarse grained, smaller pebbles - angular to subangular, larger pebbles - subangular to subrounded, very poorly sorted; sand - arkosic, coarser sand and pebbles - greenstone, granite, limestone, weathered coarse-grained quartz sandstone; Moderate Brown 5YR4/4; very strongly compacted, moderate to strong reaction with HCl; may be saturated for degree of compaction. Lower 5.2' - **Pebbles in silty sand matrix with cobbles and caliche;** sand - very fine to very coarse grained with finer grains in caliche zones, pebbles < 60 mm, predominately (70%) ≤ 8 mm, cobbles ≤ 150 mm, sand - angular to subangular, pebbles and cobbles - subangular to subrounded, very poorly sorted; sand - arkosic, pebbles and cobbles - limestone, greenstone, sandstone, weathered granite,

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

chert; Light Brown 5YR5/6 where sandy, Yellowish Gray 5Y8/1 in caliche; recovered as powdery where caliche content is high, otherwise loose or moderately to strongly compacted, caliche content - upper 1.6' - medium, next 0.7' - low, next 0.9' - medium, next 0.9' - sparse, lower 1.1' - very high, moderately strong to strong reaction with HCl; moderately to very moist.

117'-127' (10.1' plus recovered) Upper 1.7' - **Silty sand with clay;** sand - very fine to fine grained, pebbles < 0.5% and ≤ 10 mm, subangular; sand - arkosic, pebbles - granite, limestone; Light Brown 5YR5/6; moderately compacted, weak reaction with HCl; very wet or possible saturated; fairly abrupt basal contact. Middle 3.0' - **Clayey silt with sand;** sand - very fine to fine grained, subangular; sand - arkosic; Moderate Brown 5YR4/4; moderately compacted, weak reaction with HCl; very wet or possible saturated; fairly abrupt basal contact. Lower 5.4' - **Silty sand with clay;** sand - very fine to fine grained, subangular; sand - arkosic; Light Brown 5YR5/6; moderately compacted, caliche minor as matrix and scattered nodules < 0.5% and ≤ 10 mm, moderate reaction with HCl; very wet or possible saturated.

127'-137' (9.1' recovered) Upper 1.8' - **Clayey silt;** minor sand - very fine to fine grained; well sorted; sand - arkosic; Moderate Brown 5YR4/4; moderately to strongly compacted, moderate reaction with HCl; very moist; fairly abrupt basal contact. Next 1.5' - **Sandy silt with caliche grading to Silty sand with caliche;** sand - very fine to fine grained with 5% medium to very coarse grains in lower section, pebbles < 0.5% and ≤ 20 mm, predominately (95%) < 6 mm, angular to subangular; sand - arkosic, pebbles - granite, limestone; Moderate Brown 5YR4/4 to Light Brown 5YR5/6; caliche as matrix, strong reaction with HCl; very moist; very abrupt and irregular basal contact. Next 0.1' - **Silty sand with caliche;** sand - very fine to fine grained, one 50 mm pebble, pebble - angular; sand - arkosic, pebble - limestone; Moderate Orange Pink 5YR8/4; moderately compacted, weakly cemented with $CaCO_3$, caliche abundant, strong reaction with HCl. Lower 5.7' - **Silty sand;** sand - very fine to fine grained and very fine to very coarse in 0.4' pebbly zone near bottom of section, pebbles 15% and ≤ 5 mm in pebbly zone, coarser sand and pebbles - angular; sand - arkosic, pebbles - quartz, feldspar; Light Brown 5YR5/6; 1.2' Sandy silt zone 1.8' from top of section; moderately compacted, caliche abundant in pebbly zone, moderate to strong reaction with HCl; very moist.

137'-142' (3.7' recovered) Upper 1.3' - **Silty sand and Sandy silt;** sand - very fine to fine grained, well sorted; sand - arkosic; Light Brown 5YR5/6; moderately compacted, moderate to strong reaction with HCl; very moist; abrupt basal contact. Lower 2.4' - **Sandy silt;** sand - very fine to fine grained, well sorted; sand - arkosic; Light Brown 5YR5/6; moderately compacted, moderate to strong reaction with HCl; very moist.

142'-150' (8.0' recovered) **Silty sand and Sandy silt;** sand - very fine to fine grained, well sorted;

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

sand - arkosic; Light Brown 5YR5/6; silty sand and sandy silt are interbedded; moderately compacted, moderate to strong reaction with HCl; very moist.

150'-157' (7.9' plus recovered, split spoon samples taken at 150'-152' and 152'-154') Upper 2.6' - **Silt with clay and Silty sand;** sand - very fine to fine grained, well sorted; sand - arkosic; Light Brown 5YR5/6; Silty sand zone is 0.8' thick in central section; moderately compacted, moderate reaction with HCl, strong reaction where sandy; very moist. Lower 5.3' - **Sandy silt and silty sand;** sand - very fine to fine grained, pebbles < 0.5% and < 8 mm, pebbles - angular and subangular, pebbles - scattered; sand - arkosic, pebbles - feldspar, quartz; Light Brown 5YR5/6; moderately compacted, caliche is abundant in 1.1' zone 0.8' from top of section and as nodules < 15 mm in lower section, moderate to strong reaction with HCl; very moist to nearly saturated in upper section to very moist in lower section.

157'-167' (10.7' plus recovered) Upper 0.4' - **Sandy silt;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately compacted, moderate to strong reaction with HCl; very moist. Next 0.2' - **Pebbles in sandy silt matrix;** pebbles 50% and < 30 mm, one 60 mm clast, sand - very fine to fine grained, pebbles - subangular, very poorly sorted; pebbles - limestone, sandstone, sand - arkosic; Light Brown 5YR5/6; moderately to strongly compacted, moderate reaction with HCl; very moist. Next 2.9' - **Sandy silt grading to Pebbly silty sand;** sand - very fine to fine grained grading to very fine to very coarse grained, pebbles 15% and < 8 mm in lower section or < 2% in upper section, pebbles - subangular with few subrounded; sand - arkosic; Light Brown 5YR5/6; moderately to strongly compacted to loose in lower section, moderate reaction with HCl; very moist; abrupt basal contact. Next 4.9' - **Sandy silt grading to Silty sand;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderate reaction with HCl; very moist. Lower 2.3' - **Silty sand with pebbles and cobble;** sand - very fine to very coarse grained, pebbles 5% and ≤ 30 mm, predominately ≤ 5 mm, 70 mm cobble, coarser sand, pebbles, and cobble - angular to subrounded; sand - arkosic, larger pebbles - limestone, siltstone, cobble - decomposed granite; loose with minor zones moderately well compacted, zones of minor caliche, moderate to strong reaction with HCl; very moist.

167'-180' (14.2' plus recovered) Upper 7.0' - **Silty sand;** sand - very fine to fine grained, pebbles 2% and < 50 mm in upper section, pebbles - subangular to subrounded; sand - arkosic, pebbles - granite, minor limestone and greenstone; Light Brown 5YR5/6; moderately to strongly compacted, caliche minor as matrix in lower section, moderate reaction with HCl, moderate to strong reaction with HCl in lower section; very moist; abrupt basal contact. Next 3.2' - **Sandy silt with pebbles and caliche;** sand - very fine to fine grained, pebbles 1% ranging downward to 7% and < 20 mm, predominately < 5 mm, pebbles - subangular; sand - arkosic, pebbles - quartz, feldspar, larger pebbles - greenstone; Light Brown 5YR5/6; moderate to strongly compacted, moderate to strong

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

reaction with HCl; very moist; fairly abrupt basal contact. Next 1.5' - **Pebbly silty sand with caliche;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 20% and ≤ 20 mm, predominately (70%) < 5 mm, angular to subangular, very poorly sorted; sand - arkosic, pebbles - moderately-weathered granite; Light Brown 5YR5/6; strongly compacted, caliche as matrix, strong reaction with HCl; very moist; abrupt basal contact. Lower 2.5' - **Sandy silt with pebbles;** sand - very fine to fine grained, pebbles 2-5% and < 25 mm, predominately ≤ 4 mm, pebbles - angular to subangular, larger clasts are subangular to subrounded; sand - arkosic, pebbles - limestone; Light Brown 5YR5/6; moderately to strongly compacted, caliche minor as matrix in upper 0.5' of section, moderate reaction with HCl; very moist.

180'-190' (9.0' plus recovered) Upper 4.7' - **Pebbles with cobbles in silty sand or sandy silt matrix with caliche;** pebbles 30% and predominately (65%) ≤ 8 mm, few cobbles to 90 mm, sand - very fine to fine grained with 10% medium to very coarse grains, coarser sand and pebbles - angular to subangular, pebbles and cobbles - subangular to few subrounded; sand - arkosic, pebbles and cobbles - granite, weathered granite, limestone, greenstone; Light Brown 5YR5/6; loose, strong reaction with HCl; very moist; fairly abrupt basal contact. Lower 4.3' - **Silty sand;** sand - very fine grained; sand - arkosic; Light Brown5YR5/6; loose with remnants of moderately compacted material, caliche minor as matrix, strong reaction with HCl; very moist.

190'-200' (12.9' plus recovered) Upper 1.1' - **Sandy silt with caliche and pebbles;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 2% and < 20 mm, predominately (90%) < 8 mm, angular to few subrounded; sand - arkosic, pebbles - weathered granite; Grayish Orange Pink 5YR7/2; powdery, caliche abundant as matrix, strong reaction with HCl; moderately moist; abrupt basal contact. Middle 9.9' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately compacted, minor caliche zones at upper contact, upper and lower central sections and near basal contact, strong reaction with HCl; very moist; fairly abrupt basal contract. Lower 1.9' - **Sand with silt and pebbles;** sand - very fine to very coarse grained, pebbles 2% and ≤ 15 mm, predominately (70%) < 6 mm, sand - angular to subangular, pebbles - subangular; sand - arkosic, pebbles - granite; Light Brown 5YR5/6; loose, strong reaction with HCl; very moist.

200'-207' (6.5' plus recovered, 2.5-inch split-spoon samples taken at 200'-202' and 202'-204') **Silty sand with zones of sandy silt;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately to strongly compacted, moderate reaction with HCl; very moist.

207'-217' (8.3' recovered) Upper 1.2' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately to strongly compacted, moderate reaction with HCl; very moist. Middle 6.1' - **Pebbly silty sand;** sand - very fine to fine grained with 10% medium to very coarse

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

grains, pebbles 20% in upper section to 10% in lower section and, ≤ 60 mm, predominately (60%) < 5 mm, pebbles - angular to subangular, few subrounded; sand and small pebbles - arkosic, larger pebbles - quartzite, granite, greenstone, feldspar; Moderate Yellowish Brown 10YR5/4; interbedded Pebbly sandy silt in central and lower areas of section; loose with some moderately compacted remnants, moderate to strong reaction with HCl, two 0.1' lenses in upper section and few 30 mm nodules in central section are $CaCO_3$ cemented sands and small pebbles; very moist; abrupt basal contact. Lower 1.0' - **Silty sand and sandy silt;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately to strongly compacted, moderate reaction with HCl; very moist.

217'-225' (8.0' recovered) Upper 3.1' - **Silty sand with zones of Clayey silt with sand;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately to strongly compacted, moderate to strong reaction with HCl; very moist; fairly abrupt basal contact. Middle 2.9' - **Sandy silt grading to Silty clay;** sand - very fine to fine grained with 2% coarse to very coarse grains, pebbles < 0.5% and ≤ 8 mm, $CaCO_3$ nodules < 1% and ≤ 4 mm, pebbles scattered, angular to subangular; sand - arkosic, pebbles - feldspar, granite; Light Brown 5YR5/6; moderately to strongly compacted, weak to moderate reaction with HCl; very moist (saturated?); fairly abrupt basal contact. Lower 2.0' - **Silty sand with pebbles;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 2 to 15% and < 10 mm, predominately (90%) < 4 mm, angular to subangular, few rounded; sand - arkosic, pebbles - feldspar, quartz, granite, pumice (nodules); Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, weak reaction with HCl; very moist.

225'-236' (7.7' plus recovered, 3' of core fell out from bottom of core barrel) **Silty sand with Sandy silt zones;** sand - very fine to fine grained with 2% medium to very coarse grains, pebbles < 0.5% and < 8 mm, predominately < 4 mm, angular to subangular; sand and fine pebbles - arkosic, larger pebbles - feldspar, greenstone; Light Brown 5YR5/6; one 50 mm nodule of $CaCO_3$ cemented sand near center of interval; moderately to strongly compacted, strong reaction with HCl; very moist.

236'-243' (8.5' plus recovered) **Silty sand with pebbles;** sand - very fine to fine grained with 2% medium to very coarse grains, pebbles are < 1% and < 6 mm, pebbles 7% in a 50 mm zone near basal contact, pebbles - angular to subangular; sand - arkosic, pebbles - quartz, feldspar; Light Brown 5YR5/6; moderately compacted, caliche occurs as matrix or stringers and increases towards bottom, moderate to strong reaction with HCl; very moist.

243'-250' (6.6' plus recovered) Upper 1.5' - **Silty sand with pebbles;** sand - very fine to fine grained with 2% medium to very coarse grains, pebbles < 1% and < 10 mm, predominately (90%)

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

< 4 mm, pebbles - angular to subangular; sand - arkosic, pebbles - feldspar, quartz; Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, strong reaction with HCl; very moist; abrupt basal contact. Next 0.5'- **Silty sand with caliche;** sand - very fine to fine grained; sand - arkosic; Moderate Orange Pink 5YR8/4; 50 mm zone is $CaC0_3$ cemented; loose to very strongly cemented, caliche abundant as matrix or cement, strong reaction with HCl; moderately moist. Next 0.3' - **Pebbly silty sand;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 15% and < 20 mm, predominately (90%) < 8 mm; sand - arkosic, pebbles - feldspar, quartz, granite; moderately to strongly compacted, strong reaction with HCl; very moist; abrupt basal contact. Next 1.7' - **Silty sand grading to Sandy silt;** sand - very fine to fine grained with 2% medium to very coarse grains; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, strong reaction with HCl; very moist. Next 1.1' - **Sand with silt;** sand - very fine to fine grained with 2% medium to very coarse grains; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, strong reaction with HCl; very moist. Next 0.6' - **Pebbly silty sand;** sand - very fine to fine grained with 5% medium to very coarse grains, pebbles 15% and < 15 mm, predominately (80%) < 8 mm, pebbles - angular to subangular, some subrounded; sand - arkosic, pebbles - feldspar, quartz, granite; Light Brown 5YR5/6; loose, strong reaction with HCl; abrupt basal contact. Lower 0.9' - **Silty sand;** sand - very fine to fine grained with 2% medium to very coarse grains; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, strong reaction with HCl; very moist.

250'-254' (4.9' plus recovered) Upper 2.5' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; very moist. Next 0.4' - **Sandy silt;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; very moist. Next 1.2' - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; very moist. Next 0.5' - **Silty clay;** Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; very moist. Lower 0.3' - **Silty sand;** sand - very fine to fine grained; sand - arkosic, abundant mica; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; very moist.

254'-256' (1.8' recovered, 2.5-inch split-spoon sample) **Sand with silt.**

256'-258' (1.3' recovered, 2.5-inch split-spoon sample) **Sand with silt.**

254'-261' (6.6' plus recovered) Upper 2.4' - **Sandy silt with pebbles grading to Silty sand with pebbles grading to Sand with silt and pebbles;** sand - fine very to fine grained with 10% medium to very coarse grains in lower section, pebbles vary downward from 1% to 15% and ≤ 10 mm,

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

angular to subangular; sand - arkosic, pebbles - granite, feldspar, quartz; upper section moderately to strongly compacted, lower section moderately compacted, strong reaction with HCl; saturated (?); abrupt basal contact due to high moisture and lack of caliche. Lower 4.2' - **Pebbles and Silty sand with caliche;** sand - very fine to fine grained with 30% coarse to very coarse grains, pebbles 40% and ≤ 20 mm, predominately (50%) ≤ 6 mm, angular to subangular, few subrounded; sand - arkosic, pebbles - granite, quartz, feldspar, limestone; Light Brown 5YR6/4; upper 0.4' recovered intact, lower section highly disturbed, moderately compacted where intact, otherwise loose, caliche abundant and occurs as matrix or as $CaCO_3$ cement for 30-50 mm lenses of sand and pebbles (disturbed remnants), strong reaction with HCl; moderately moist(?).

261'-266' (7.0' plus recovered) Upper 3.7' - **Pebbly sand grading to Silty sand with pebbles;** sand - very fine to fine grained with 20% coarse to very coarse grains, pebbles are 20% in upper section to 12% in lower section and ≤ 30 mm, angular to subrounded, very poorly sorted; sand and small pebbles - arkosic, larger pebbles - limestone; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl, 50 mm lens near top of interval is $CaCO_3$ cemented sand and pebbles; very moist; abrupt basal contact. Next 1.4' - **Pebbly silty sand with caliche;** sand - very fine to fine grained with 25% medium to very coarse grains, pebbles ≤ 20 mm, predominately (50%) ≤ 5 mm, 35% 5 to 12 mm, angular to subangular, few larger clasts subrounded; sand - arkosic, pebbles - granite, greenstone, feldspar; Very Pale Orange 10YR8/2; recovered as powdery, caliche abundant, strong reaction with HCl; moderately moist; abrupt basal contact. Next 0.8' - **Silty sand with pebbles**; sand - very fine to fine grained with 20% medium to very coarse grains, pebbles 12% and ≤ 5 mm, angular to subangular, very poorly sorted; sand and small pebbles - arkosic, larger pebbles - limestone; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; very moist. Lower 1.1' - **Sand with silt, pebbles, and caliche;** sand - very fine to fine grained with 15% medium to very coarse grains, pebbles 5% and ≤ 12 mm, angular to subangular; sand - arkosic, pebbles - feldspar, granite; moderately compacted, strong reaction with HCl; very moist.

266'-275' (9.5' plus recovered) Upper 1.6' - **Silty sand;** sand - very fine to fine grained, angular to subangular; sand - arkosic with abundant mica; Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, moderate to strong reaction with HCl; saturated (?). Next 0.7' - **Sand with silt and pebbles;** sand - very fine to fine grained with 5-10% medium to very coarse grains, pebbles 10% and ≤ 20 mm, predominately (90%) ≤ 8 mm, angular to subangular; sand and small pebbles - arkosic with abundant mica, larger pebbles - feldspar, granite; Light Brown 5YR5/6; moderately to strongly compacted, moderate to strong reaction with HCl; saturated (?). Next 1.0'- **Sand with minor silt;** sand - very fine to fine grained, angular to subangular; sand - arkosic with abundant mica; Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, moderate to strong reaction with HCl; saturated (?). Next 0.7' - **Silty sand with**

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

pebbles; sand -very fine to fine grained with 5-10% medium to very coarse grains, pebbles 10% and ≤ 20 mm, predominately (90%) ≤ 8 mm, angular to subangular; sand and small pebbles - arkosic with abundant mica, larger pebbles - feldspar, granite; Light Brown 5YR5/6; moderately to strongly compacted, moderate to strong reaction with HCl; saturated (?); abrupt basal contact. Lower 5.5' - **Pebbly silty sand with caliche;** sand - very fine to very coarse grained, pebbles 20% and ≤ 40 mm, 40% ≤ 6 mm, 40% 6-15 mm, angular to subangular; sand - arkosic, pebbles - granite, weathered granite, limestone, weathered greenstone (?); Light Brown 5YR6/4; loose, caliche as matrix, strong reaction with HCl; very moist.

275'-283' (7.9' plus recovered) **Silty sand with caliche;** sand - very fine to fine grained, pebbles < 0.5% and ≤ 10, predominately ≤ 5 mm, pebbles scattered or occur in 30-50 mm $CaCO_3$ cemented sand and pebble lenses near the top and center of interval, pebbles - angular; sand - arkosic, pebbles - feldspar, quartz; Light Brown 5YR5/6; moderately compacted, caliche occurs near $CaCO_3$ cemented lenses, strong reaction with HCl; very moist.

283'-286' (3.4' plus recovered) **Silty sand with pebbles;** sand - very fine to fine grained, pebbles < 0.5% at top, to 5% towards bottom, and ≤ 10 mm, predominately ≤ 5 mm, pebbles scattered, pebbles - angular; sand - arkosic, pebbles - feldspar; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; very moist.

286'-292' (3.9' plus recovered, lower 2' lost from bottom of core barrel) **Silty sand with caliche and pebbly zone;** sand - very fine to fine grained, pebbles < 0.5% and ≤ 10, predominately ≤ 5 mm, pebbles - angular; sand - arkosic, pebbles - feldspar; Light Brown 5YR5/6; 1.2' Pebbly silty sand zone 2' from top of interval, pebbles 20%; moderately compacted, strong reaction with HCl; very moist.

292'-300' (8.9' plus recovered) Upper 5.2' - **Silty sand with caliche;** sand - very fine to fine grained, pebbles < 0.5% and ≤ 5 mm, pebbles scattered, angular; sand - arkosic, pebbles - feldspar, quartz; Moderate Yellowish Brown 10YR5/4; moderately compacted, caliche occurs as matrix and as minor blebs, strong reaction with HCl; very moist; abrupt basal contact. Middle 0.9' - **Pebbles in silty sand matrix with caliche;** pebbles 45% and < 15 mm, predominately (80%) ≤ 8 mm, sand - very fine to very coarse grained, angular to subangular; sand and small pebbles - arkosic, larger pebbles - feldspar, quartz, granite, minor greenstone; loose, caliche abundant, strong reaction with HCl; very moist; abrupt basal contact. Lower 2.8' - **Silty sand with caliche;** sand - very fine to fine grained, pebbles < 0.5% and ≤ 5 mm, pebbles scattered, angular; sand - arkosic, pebbles - feldspar, quartz; Moderate Yellowish Brown 10YR5/4; moderately compacted, caliche occurs as matrix and as minor blebs, strong reaction with HCl; very moist.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

300'-302' (1.3' plus recovered, 2.5-inch split-spoon sample) **Silty sand.**

302'-304' (0.5' recovered, 2.5-inch split-spoon sample) **Silty sand over Sandy silt.**

300'-303' (4.0' recovered) Upper 2' - **Silty sand with zones of sandy silt;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; very moist; fairly abrupt basal contact. Middle 1.0' - **Sand with silt;** sand - very fine to fine grained; sand - arkosic; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; very moist; fairly abrupt basal contact. Lower 1.0' - **Silty sand with pebbles;** sand - very fine to fine grained, pebbles $\leq$ 5% and < 12 mm, pebbles - angular to subangular; sand - arkosic, pebbles - feldspar, minor quartz and chert; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; very moist.

303'-314' (11.6' plus recovered) Upper 4.1' - **Sandy silt with zones of Silty sand with clay and pebbles;** sand - very fine to fine grained, pebbles < 1% and $\leq$ 10 mm, angular to subangular; sand - arkosic, pebbles - feldspar, quartz, minor greenstone; Light Brown 5YR5/6; 30 mm lens of $CaCO_3$ cemented sand and pebbles 0.8' from top of interval; moderately to strongly compacted, strong reaction with HCl; very moist. Next 4.9 - **Silty sand**; sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately to strongly compacted, strong reaction with HCl; saturated. Next 1.2 - **Sandy silt**; sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately to strongly compacted, strong reaction with HCl; saturated. Lower 1.4 - **Silty sand;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; moderately to strongly compacted, strong reaction with HCl; saturated.

314'-327' (14.1' plus recovered) Upper 1.0' - **Sand with silt and clay;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; two (?) 30 mm lenses of $CaCO_3$ cemented sand in lower section; moderately to strongly compacted, strong reaction with HCl; very moist. Next 4.7' - **Silty sand with minor clay;** sand - very fine to fine grained; sand - arkosic; Moderate Brown 5YR4/4; moderately compacted, moderate to strong reaction with HCl; saturated; fairly abrupt basal contact. Next 2.2' - **Sand with silt and pebbles;** sand - very fine to fine grained grading downward to very fine to very coarse grained, pebbles 2% and $\leq$ 18 mm, pebbles scattered, angular to subangular; sand - arkosic, pebbles - feldspar; Moderate Yellowish Brown 10YR5/4; moderately compacted, strong reaction with HCl; saturated. Next 3.4' - **Sand with silt;** sand - very fine to fine grained with 20% medium to very coarse grains, pebbles < 0.5% and < 5 mm, pebbles scattered, sand - subangular to subrounded, pebbles - angular to subangular; sand - arkosic with abundant clear quartz, pebbles - feldspar; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; saturated; fairly abrupt basal contact. Next 1.8' - **Silty sand with minor clay;** sand - very fine to fine grained, pebbles < 0.5% and < 5 mm, pebbles scattered, sand - subangular to subrounded,

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG--*Continued*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

pebbles - angular to subangular; sand - arkosic with abundant clear quartz, pebbles - feldspar; Light Brown 5YR5/6; central section has 40 mm lens of $CaCO_3$ cemented sand and pebbles, pebbles 90% and $\leq$ 12 mm, pebbles - subangular, mostly feldspar, near horizontal bedding; moderately compacted, strong reaction with HCl; saturated. Lower 1.0' - **Sand with silt;** sand - very fine to fine grained with 20% medium to very coarse grains, pebbles < 0.5% and < 5 mm, pebbles scattered, sand - subangular to subrounded, pebbles - angular to subangular; sand - arkosic with abundant clear quartz, pebbles - feldspar; Light Brown 5YR5/6; moderately compacted, strong reaction with HCl; saturated.

327'-329' (1.1' plus recovered, 2.5-inch split spoon sample) **Silty sand with pebbles;** sand - very fine to fine grained.

327'-330' (4.2' plus recovered) Upper 2.5' - **Sandy silt with pebbles and caliche grading to Pebbly sandy silt;** sand - very fine to fine grained with 10 to 30% medium to very coarse grains, pebbles vary downward from 8% to 20% and $\leq$ 12 mm, angular to subangular, very poorly sorted; sand - arkosic, pebbles - feldspar, quartz, limestone; Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, caliche in upper section occurs as matrix and poorly-defined blebs, strong reaction with HCl; saturated (?); fairly abrupt basal contact. Lower 1.7' - **Clayey sandy silt grading to Silty clay with caliche;** sand - very fine to fine grained; sand - arkosic; Light Brown 5YR5/6; strongly to very strongly compacted near bottom of interval, moderate to strong reaction with HCl; saturated (?).

Verified and edited on 17DEC93, 23DEC93 and 29DEC93 by C. Abeyta and on 28DEC93 by J. Szalona.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC-*Concluded*

Tech Area 2 -- TA2/SW1/320
(previously named TA2-MW1)

Note: Core was collected from 0' to 330'.

Lithologies logged by U.S. Geological Survey Geologists Cynthia Abeyta and Joe Szalona as follows:

Depth	Date	Geologist
0' to 34'	02NOV92 to 03NOV92	C. Abeyta
34' to 330'	03NOV92 to 19NOV92	J. Szalona

Percentage of hole logged by each geologist:

C. Abeyta	10%
J. Szalona	90%

Lithologic logs for borehole at monitoring well TA2-W-01

Drilling company	Water Development Corporation
Dates of drilling	Phase 1: March 9, 1994 for 0 to 151 ft; plugged back with bentonite. Phase 2: June 10 – 22, 1994 for ground surface to 338 ft.
Drilling method	Phase 1: Sonicore with 5-ft long, split core barrel at 5-ft intervals; continuous core from 0 to 151 ft. Phase 2: ARCH Stratex with 24-inch long split spoon at 200 - 201, 260 - 236, and 297 - 299 ft.
Total depth of borehole, ft	338
Ground elevation, ft amsl NAVD 88	5417.4
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	312.0 to 332.0
Date well developed	June 27, 1994
Initial water level, ft bgs	314.50
Rig Geologist	Mike Wade, Rarilee Conway, and John Copland

Depth, ft bgs	Description	USCS Group
0 - 3	Silty sand, light brown to yellow-brown, dry, dense, 5 to 15% silt, less than 5% clay, very fine-grained to coarse-grained sand with quartzite, feldspar, and mica clasts, moderate to high estimated permeability, approximately 5% subrounded to subangular limestone pebbles to 0.5-inch diameter. Plant roots to 2.5 ft.	SM
3.2	Sandy gravel, light brown to locally red-brown, minor iron oxide stains at 4.5 to 4.8 ft, dry to moist, medium dense, 25 to 40% very fine-grained to coarse-grained micaceous sand, 5 to 15% silt, subrounded to subangular gravel to 2.5-inch diameter, mainly limestone, feldspar, greenstone, red dacite, and quartzite clasts, low to moderate estimated permeability.	GP
6 - 7	Mainly subrounded pebbles to 1.5-inch diameter, limestone clasts.	n.r.
7 - 10	Very coarse-grained sand, subrounded to subangular, consisting of feldspar, quartzite, and limestone clasts, mica.	n.r.
9	Greenstone and limestone clasts, subangular to 3.2 inches long, 2.5-inch diameter.	n.r.
11.5	Gravelly sand, light brown, dry, very dense, 15 to 25% subangular gravels, composed of limestone, greenstone, feldspar, and quartzite clasts, to 2-inch diameter, very fine-grained to coarse-grained micaceous sand grains, approximately 5% silt, high estimated permeability.	SM
18.25	Silty sand, yellow-brown, dry, medium dense, 20 to 25% silt, 5 to 10% clay, very fine-grained to fine-grained sand, mica, low estimated permeability. At 19.2 ft, 15 to 20% clay, very low estimated permeability.	SM
23.5 - 25.7	5 to 15% clay, 15 to 20% silt, fine-grained to very coarse-grained sand.	GM
25.7 - 27.5	5 to 20% subrounded to subangular gravel (limestone and red-mafics clasts) to 1.25-inch diameter.	GM
27.5	Gravelly sand, light brown, dry, dense, 15 to 25% subrounded to subangular gravel to 3-inch diameter limestone, greenstone, red mafics, sandstone, feldspar, and quartzite clasts, fine-grained to coarse-grained sand, 5 to 10% silt, approximately 5% clay, moderate to high estimated permeability, micaceous sand. (30.5 - 33.8 ft has approximately 5% silt, less than 5% clay).	SM
31.7 - 32.1	Subangular greenstone pebbles to 3.5-inches long and 2.5-inch diameter, also some limestone and quartzite clasts.	SM
32.5 - 33.8	Sand to silty sand interbed, very coarse-grained sand, minor pebbles to 0.25-inch diameter, less than 5 to 15% silt, high estimated permeability.	SM
37.4 - 38.9	15 to 20% silt, 5 to 10% clay, low estimated permeability.	SM

Depth, ft bgs	Description	USCS Group
38.9	Silty sand, red-brown, moist to dry, medium dense to dense, 15 to 20% silt, 10 to 15% clay, very fine-grained to medium-grained sand, low estimated permeability, approximately 5% subrounded to limestone pebbles, up to 0.25-inch diameter.	SM
40.5	Sand to gravelly sand, light brown to red-brown, dry to moist, dense, 5 to 20% subrounded to subangular pebbles to 1.5-inch diameter, limestone, greenstone, and feldspar clasts, 5 to 10% fine-grained sand, mica, moderate to high estimated permeability.	SW/SM
44.25	Silty sand, red-brown, dry to moist, dense, 15 to 20% silt, 5 to 10% clay, very fine-grained to medium-grained, locally coarse-grained, micaceous, low to moderate estimated permeability, approximately 5% subangular limestone pebbles to 0.75-inch diameter, minor caliche.	SM
47.7 - 48.9	Silty sand, interbed, could be slough says driller.	SM
48.9 - 52.6	Local caliche, subangular limestone pebbles to 0.5-inch diameter, 10 to 20% clay, 20 to 25% silt.	n.r.
52.6 - 53.75	Silty sand, interbed, light brown, dry, 15 to 25% silt, 5 to 10% clay, approximately 10% subrounded to subangular pebbles to 1-inch diameter limestone, greenstone, feldspar, and quartzite clasts, moderate estimated permeability, micaceous sand.	SM
53.75	Clayey sand to silty sand, variable, red-brown, moist, medium dense, 10 to 20% silt, 10 to 15% clay, very fine-grained to fine-grained sand, locally coarse-grained.	SC/SM
57 - 59	Moist to possibly wet. Waited 10 minutes at 59 ft - no moisture in borehole.	n.r.
58.7 – 59.0	Gravelly sand, interbed, yellow-brown, moist, dense.	SM
59.1	Silty sand, yellow to red-brown, dry, dense, 15 to 20% silt, approximately 5% clay, very fine-grained to locally coarse-grained sand, generally fine-grained, minor caliche, approximately 5% subrounded to limestone pebbles to 0.25-inch diameter, tight, low to moderate estimated permeability.	SM
62.8 - 63.2	Gravelly sand, interbed, brown, dry to moist, dense, 15 to 20% subrounded to subangular limestone pebbles to 1-inch diameter, fine-grained to coarse-grained sand, 5 to 10% silt, high estimated permeability.	SM
63.2 - 65	Gravelly sand with 5 to 10% subrounded to subangular pebbles, up to 0.5-inch diameter, limestone and quartzite clasts.	SM
66.1 – 70.0	Very fine-grained to fine-grained sand, approximately 5% subrounded limestone and quartzite pebbles to 0.25-inch diameter, 5 to 10% clay.	SM
74.0 - 74.3	Gravelly sand, interbed, light brown, dry, dense, tight.	SM
74.5 – 75.0	Gravelly sand, interbed, light brown, dry, dense, tight.	SM
76.6 - 77.3	Gravelly sand, interbed, light brown, moist.	SM
77.3	Gravelly sand, brown to light brown, dry to moist, dense, 20 to 30% subrounded to subangular pebbles, up to 2.25-inch diameter, mainly limestone with quartzite, feldspar, and greenstone clasts, 5 to 10% fines, fine-grained to coarse-grained sand, high to moderate estimated permeability.	SM
79	Silty sand, yellow brown, dry to moist, medium dense, 5 to 15% silt, 5 to 10% clay, very fine-grained to fine-grained sand, locally medium-grained, moderate estimated permeability, mica.	SM
81.3	Sand to gravelly sand, light brown, yellowish brown, dry to moist, dense to very dense, granitic gravel to 3-inch diameter, limestone, quartzite, and greenstone clasts, subangular to subrounded, 5 to 25% fine-grained to coarse-grained sand of feldspar and quartzite clasts with mica.	SW/GM
84.5 – 85.0	Silty sand, interbed, yellow brown, dry, medium dense.	SM

Depth, ft bgs	Description	USCS Group
87 - 88	Silty sand, interbed, yellow brown, dry, medium dense, minor subangular pebbles to 0.25-inch diameter.	SM
89	Silty sand, yellow brown, dry, dense, very fine-grained to fine-grained sand with mica, 10 to 15% silt, 5 to 10% clay, low to moderate estimated permeability, approximately 5% subangular to subrounded pebbles to 0.125-inch diameter.	SM
92.3 - 93.7	Subrounded to subangular pebbles to 1-inch diameter, limestone and feldspar clasts, 5 to 10% silt and clay.	n.r.
93.7	Gravelly sand, brown, moist, very dense, 10 to 20% subrounded to subangular gravels to 2-inch diameter, mainly greenstone and limestone clasts, very fine- to coarse-grained micaceous sand, 5 to 10% silt, 5 to 10% clay, moderate to high estimated permeability.	SM
95.2	Silty sand, yellow to red-brown, moist, (upper 2.5 ft, very moist), dense, 20 to 25%, silt, 15 to 20% clay, very fine-grained to medium-grained sand, locally coarse-grained, approximately 5% subrounded to subangular limestone and greenstone pebbles to 0.75-inch diameter, low estimated permeability.	SM
98.5 – 99.0	Local caliche.	n.r.
99.6 - 101.25	Gravelly sand, interbed, brown to red-brown, dry, very dense, 20 to 25% subangular gravel to 1-inch diameter, limestone, quartzite, feldspar, 5 to 10% fines, locally cemented with calcium carbonate/caliche, fine-grained to coarse-grained sand, low estimated permeability.	GM
101.25 - 103.4	Approximately 5% subrounded to subangular pebbles up to 0.75-inch diameter, limestone clasts.	n.r.
103.4 - 104.75	Sand to gravelly sand, interbed, brown to yellowish brown, very dense, 5 to 20% subrounded to subangular pebbles to 1-inch diameter limestone and greenstone clasts, fine-grained to coarse-grained sand, mica, approximately 5% clay, approximately 5% silt, tight with caliche, low to moderate estimated permeability.	SW/SM
107	Sand, brown, moist, dense, 5 to 10%, subrounded to subangular gravels up to 0.75-inch diameter, greenstone and limestone clasts, approximately 5% clay, approximately 5% silt, very fine-gravel to generally coarse-grained sand, mica, quartzite, limestone, feldspar, and greenstone clasts, high estimated permeability.	SW
109.1 - 109.3	Silty sand, interbed, yellowish brown, moist, dense.	SM
110	Sand coarsens from 110 to 113.2 ft.	n.r.
110.25 - 110.75	Silty sand, interbed, red-brown, medium dense.	SM
111.25 - 111.8	Silty sand, interbed, red-brown, medium dense.	SM
112.7 - 113.1	Silty sand, interbed, red-brown, medium dense.	n.r.
113.2	Gravelly sand, brown to light brown, moist, very dense, 15 to 25%, subrounded to subangular gravel to 3-inch diameter, large abundant limestone, minor feldspar clasts, 5 to 10% silt, approximately 5% clay, very fine-grained to coarse-grained sand, high estimated permeability, red sandstone clasts to 1.25-inch diameter.	SM
115 - 116	20 to 30% gravels, up to 3-inch diameter.	n.r.
116 - 120	No recovery. Start injecting water mist at 120 ft to aid in lifting cuttings.	n.r.
120.0 - 123.1	Large, up to 3-inch diameter, limestone and granite clasts, subangular.	SA
123.1 - 124.25	Approximately 10% subrounded to subangular pebbles to 0.5-inch diameter, fine-grained to generally coarse-grained sand.	n.r.
124.25	Silty sand, yellow-brown, dry, dense, 15 to 20% silt, 5 to 10% clay, very fine-grained to fine-grained sand with mica, local caliche, approximately 5% subrounded pebbles to 0.25-inch diameter, low estimated permeability.	SM

Depth, ft bgs	Description	USCS Group
127.0 - 127.8	Gravelly sand, interbed, dry to moist, very dense, 15 to 25% subangular to subrounded gravel, limestone, possible red dacite, sandstone, greenstone, and quartzite clasts to 2.25-inch diameter, 10 to 15% silt, very fine-grained to coarse-grained sand, moderate estimated permeability.	SM
127.8 - 130.0	Up to 25% silt, local coarse-grained sand, approximately 10 to 15% subrounded pebbles to 0.5-inch diameter, limestone, red mafics.	n.r.
130.5 – 133.5	Red-brown, 10 to 15% clay, up to 20% fine-grained. Subrounded to subangular limestone pebbles to 1-inch diameter. Local caliche.	n.r.
133.5 - 135	Very fine-grained to locally fine-grained sand, micaceous, approximately 5% subrounded pebbles to 0.25-inch diameter, limestone.	n.r.
135 - 140	Two core runs consisting of slough (poor core recovery).	n.r.
139 - 145	Very fine-grained sand, approximately 15% clay.	n.r.
144.6 - 144.75	Coarse-grained sand, lens with limestone, quartzite, mica, sulfides (possibly chalcopyrite).	n.r.
147.8 - 148.5	Gravelly sand, interbed, light to red-brown, moist to dry, dense.	SM
146.4 – 151.0	20 to 30% silt, low estimated permeability.	n.r.
150.6	Caliche zone.	n.r.
151	End of Phase 1. Total of 18 core boxes. Use thirteen 50-lb bags of bentonite pellets as backfill. Start the logging of cuttings using Stratex ARCH system.	n.r.
165 - 178	Gravel in cuttings.	n.r.
188 - 195	Gravelly zone.	n.r.
200	Gravelly sand, brown, moist (due to air mist), very dense, 10 to 20% subangular to subrounded to gravels, mainly limestone, feldspar, fine-grained to coarse-grained sand with mica, approximately 10% silt, 5 to 10% clay.	SM
260	Silty sand, light brown, dry to damp, dense, very fine-grained to locally coarse-grained sand (micaceous).	SM
297	Gravelly sand, brown, damp, very dense, 10 to 20% subangular to subrounded gravel, mainly quartzite clasts feldspar, fine-grained to coarse-grained sand with mica, approximately 10% silt and 10% clay.	SM
298.2	Sharp contact with 0.25-inch dark Streak. Gravelly sand, grey, dry, very dense, 70% subangular to subrounded gravel, mainly limestone with scattered epidote fragments, medium-grained to coarse-grained sand, approximately 5% fine-grained sand and approximately 5% silt.	SM
318	Drill bit at 318 ft with drive casing at 317 ft. Let borehole sit overnight. No water present next morning.	n.r.
310 - 338	Medium-grained to coarse-grained sand with gravel; gravelly sand. First water observed at 314.5 ft.	n.r.
338	Borehole Total Depth	

Depth, ft bgs	Description from USGS composite log	USCS Group
0 - 19	Sand, silty. Light yellow brown, very fine- to coarse-grained quartz, feldspar, mica. Greenstone clast at 9 ft. Coarsening to gravelly sand at 12 ft.	SM
19 - 39	Sand, silty. Yellow brown, very fine- to fine-grained, gravelly sand below 28 ft, red mafics, feldspar.	SM
39 - 54	Sand, silty. Reddish brown, very fine- to medium-grained, dry to moist, dense, minor caliche.	SM
54 - 59	Sand, clayey. Reddish brown very fine- to fine-grained, moist, medium dense.	SC to SM
59 - 95	Sand, silty. Yellow to reddish brown, very fine- to coarse-grained, minor caliche, few gravelly interbeds.	SM
95 - 107	Sand, silty. Yellow to reddish brown, very fine- to medium-grained, local caliche, moist, dense, coarsening downward to gravelly sand.	SM
107 - 122	Sand. Brown, generally coarse-grained, coarsening below 113 ft to gravelly sand. Granite clasts.	SW to SM
122 - 151	Sand, silty. Yellow brown, very fine- to fine-grained, local caliche, gravelly interbeds.	SM
151 - 200	No core recovered.	
200 - 203	Sand, gravelly. Brown, fine-to coarse-grained sand, subrounded to subangular gravel, composition limestone, feldspar, very dense.	SM
203 - 260	No core recovered.	n.r.
260 - 262	Sand, silty. Light brown, very fine- to coarse-grained, dry to damp, dense, micaceous.	SM
262 - 298	No core recovered.	n.r.
298 - 300	Sand, gravelly. Brown, fine- to coarse-grained sand, gravel subrounded to subangular, quartzite and feldspar clasts, thin dark streak at 298.2 ft, damp, dense.	SM
300 - 310	No core recovered.	n.r.
310 - 338	Sand, gravelly. Medium- to coarse-grained sand.	SM
338	Borehole Total Depth.	

n.r. = not recorded. The Unified Soil Classification System (USCS) symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TA2-W-19

Drilling company	Water Development Corporation
Dates of drilling	November 7 – 9, 1995
Drilling method	ARCH, cuttings logged, no cores
Total depth of borehole, ft	300 feet
Ground elevation, ft amsl NAVD 88	5349.0
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	265.9 to 285.9
Date well developed	November 29, 1995
Initial water level, ft bgs	288.00
Rig Geologist	Mike Wade

Depth, ft bgs	Description	USCS Group
0	Silty sand, light brown to brown, dry, 20 to 25% silt, 10% clay, 10 to 15% angular to subrounded limestone, quartzite, and feldspar pebbles to 0.5-inch diameter, low to very low estimated hydraulic conductivity, loose, very fine-grained to coarse-grained sand (micaceous). Medium dense at 9 ft.	SM
20	Sandy gravel, brown to light brown, dry, dense to medium dense, 20 to 30% very fine-grained to coarse-grained sand, subangular to subrounded pebbles to 3-inch diameter, approximately 10% clay, low to moderate estimated hydraulic conductivity.	GM
33	Silty sand, brown, moist to dry, medium dense, 25 to 35% silt, 5 to 10% clay, approximately 10% subrounded limestone pebbles to 0.75-inch diameter, moderate to low estimated hydraulic conductivity.	SM
57	Approximately 15% subrounded limestone pebbles.	n.r.
66	Gravelly sand, brown to dark brown, moist, dense to medium dense, 15 to 25% subrounded to subangular limestone pebbles to 1.5-inch diameter; very fine-grained to coarse-grained sand, approximately 10% clay, moderate estimated hydraulic conductivity.	SM
84	Silty sand, brown to reddish-brown, moist, 20 to 25% silt, 10 to 20% clay, very fine-grained to medium-grained sand, low to moderate? estimated hydraulic conductivity, micaceous clay with low plasticity.	SM
92-107	Minor (approximately 5%) subrounded to subangular limestone gravel to 1.5-inch diameter.	n.r.
112	Increase in clay to 15 to 20%, with 25 to 30% silt, low to moderate plasticity, very low estimated hydraulic conductivity.	n.r.
121-127	Less than 5% subrounded limestone gravel to 1.75-inch diameter.	n.r.
134 - 172	approximately 10% subrounded limestone gravel to estimated 1.5-inch diameter.	n.r.
172-185	Subrounded to subangular limestone, feldspar, and quartzite gravel to 2-inch diameter (5 to 10%).	n.r.
195	Hard drilling and driving.	n.r.
195	Gravelly sand, brown, moist, dries light brown, dense to very dense, 20-30% subrounded to subangular limestone, quartzite, and feldspar pebbles to 1.25-inch diameter, very fine-grained to coarse-grained sand with mica, 15 to 20% silt, approximately 5-10% clay, moderate? estimated hydraulic conductivity.	SM
214	Minor gravels, approximately 10%.	n.r.
219	Silty sand, brown to yellow-brown, moist to dry, dense to medium dense, 15 to 25% silt, approximately 10 to 15% clay, less than 10%, subrounded to subangular limestone, and feldspar pebbles to 0.5-inch diameter, low estimated hydraulic conductivity.	SM

Depth, ft bgs	Description	USCS Group
235 - 251	10 to 15% clay, slight plasticity, moist.	n.r.
251	Approximately 10 to 15% subrounded to subangular limestone, quartzite, and feldspar pebbles to 0.75-inch diameter, abundant feldspar pebbles, still in silty sand but locally gravely.	n.r.
251-260	Dry to moist, no saturation indicated.	n.r.
261	Dark brown, silty sand, moist.	n.r.
268	Silty sand, sand is coarse-grained, appears to be making water.	n.r.
273	Gravelly sand, dark brown, wet, dries light brown, 15 to 20% subangular to subrounded limestone, quartzite, schist, and feldspar pebbles to 0.5-inch diameter, very coarse-grained to fine-grained sand, 20 to 30% silt, approximately 10% clay, low estimated hydraulic conductivity, micaceous, dense.	SM
278	Increase in clay to 15 to 25%. Approximately 10% subangular limestone pebbles to 0.5-inch diameter.	n.r.
280	Sandy gravel, brown, wet, dense, approximately 10% clay, 10% silt, 20 to 35% very coarse-grained to medium-grained sand, locally fine-grained, subrounded to angular limestone, quartzite, and feldspar pebbles to 2-inch dimeter, moderate estimated hydraulic conductivity, micaceous, producing water.	GM
300	Borehole Total depth.	

n.r. = not recorded. The Unified Soil Classification System (USCS) symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TA2-W-24

Drilling company	Water Development Corporation
Dates of drilling	January 27 – 30, 1998
Drilling method	ARCH, cuttings logged, also split spoon cores from 60 to 61 ft, 160 to 161 ft, and 260 to 261 ft
Total depth of borehole, ft	506
Ground elevation, ft amsl NAVD 88	5361.8
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Screen, ft bgs	465.0 to 485.0
Date well developed	February 9, 1998
Initial water level, ft bgs	450.44
Rig Geologist	Mike Skelly

Depth, ft bgs	Description	USCS Group
0-6	Fine sand, pale brown to pale yellowish brown (5YR 5/2 to 10YR 6/2) well sorted / poorly graded, dry.	SP
6	Sand and gravel, moderate brown to light brown (5YR 4/4 to 5YR 5/6) dry to slightly moist, gravel consists of clasts of limestone, granite, metabasalts (greenstone), and quartzite, usually subangular.	GP
28	Silty sand, moderate reddish brown (10YR 4/6) to moderate brown (5YR 4/4), trace of coarse gravel, dry to slightly damp.	SM
51	Silty and clayey sand, similar to 28 ft above except for increasingly fine grained, slightly damp, some fine gravel.	SM/SC
61	Sand and gravel, pale yellow brown (10YR 6/2), mostly coarse sand and fine gravel (granitic), dry.	GP
73	Silty sand, moderate reddish brown (10YR 4/6) to moderate brown (5YR 4/4), trace of coarse gravel, dry to slightly damp.	SM
77	Sand and gravel, pale yellow brown (10YR 6/2), mostly coarse sand and fine gravel (granitic), dry.	GP
79	Silty sand and gravel, pale yellow brown (10YR 6/2), mostly coarse sand and fine gravel (granitic), damp to moist, some coarse sand and fine gravel.	SM
92	Silty sand and gravel, coarse gravel to 4 inches diameter, damp to moist.	SM/GP
95	Silty sand as above, some clay in 0.5-ft layers, grades to silty clay and sand, damp to moist.	SM
110	Thin clay-rich and gravel-rich interbeds in silty sand matrix.	n.r.
120	Silty sand, some clay, some fine gravel, damp to moist.	SM
128	Coarse sand and gravel, damp.	GP
136	Silty sand, some clay, some fine gravel, damp to moist.	SM
142	Coarse sand and gravel, dry, alternating with thin (less than 0.5 ft) silty sand layers and fine sand layers that are more damp.	GP
160	Silty sand, dark yellowish brown (10YR 4/2), fine to medium sand, some coarse, slightly moist, poorly sorted.	SM
170	Sand, moderate yellowish brown (10YR 5/4), very fine to coarse sand, minor fine gravel, slightly moist, poorly sorted.	GP
180	Silty sand, moderate brown to yellowish brown (5YR 4/4 to 10YR 4/2), very fine to medium sand, minor clay, moist, poorly sorted.	SM
185	Thin gravel lens.	n.r.
194	Thin clay lens.	SC

Depth, ft bgs	Description	USCS Group
196	Sand, moderate yellowish brown (10YR 5/4), fine to coarse sand, minor fine gravel, moist, poorly sorted.	GP
200	Sand, moderate yellowish brown (10YR 5/4), very fine to fine sand, minor silt, moist, well sorted.	SM
218	Sand, same as above.	SM
220	Sand and gravel, some silt and clay in thin layers, coarse gravel (to 3 inches diameter), mostly medium sand, some fine sand layers, damp to moist.	GP
240	Silty sand and gravel, as above, moist.	SM/GP
255	Silty sandy clay, moist, some fine gravel.	SM/SC
259	Silty sand and gravel, damp.	SM/GP
263	Silty sand, some silty clayey sand in thin layer, some coarse sand and fine gravel, damp to moist.	SM
277	Sand and gravel, some silt, trace clay, moist to possibly saturated, definitely water by 280 ft.	GP
294	Silty sandy clay, damp to moist, not saturated.	SM/SC
300	Not much cuttings returned, thin gravel layer (2 to 3 ft), produced water at approximately 308 ft.	n.r.
318	Silty sandy clay, damp to moist.	SM/SC
320-340	Few cuttings returned. Silty clay to approximately 332 ft. More sand below that.	n.r.
338	Silty sand and silty clay.	SM/SC
340-360	Few cuttings returned.	
360	Silty clay and sandy clay, dry to damp.	SM/SC
360-370	Loss of cuttings.	
370	Silty and sandy clay, some gravel and sand possibly at approximately 377 ft. Injecting water.	SM/SC
380	Silty and sandy clay. Possibly more sand near 400 ft. Injecting water.	SM/SC
400-420	Stopped injecting water. No cuttings returned.	
420-440	No cuttings returned while advancing casing to 440 ft. Clearing borehole at 440 ft produced coarse sand and fine gravel. Injecting water.	GP
440-460	Silty sand and gravel (up to 2 inches in diameter), occasional clay and silt balls. Injecting water.	SM/GP
460-480	Adding water, silty sand and gravel, gravel especially at approximately 470 ft, possibly making water at 480 ft. Water level measured at 475.2 ft.	SM/GP
480-500	Silty sand and gravel as above, except a tight dry clay at approximately 488 to 492 ft. Injecting water.	SM/GP SM/SC
504	Drilled 2 ft into a tight clay layer (driller comment), making water.	n.r.
506	Borehole total depth.	

n.r. = not recorded. The Unified Soil Classification System (USCS) symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TA2-W-25

Drilling company	Water Development Corporation
Dates of drilling	March 24 – 27, 1997
Drilling method	ARCH, cuttings logged, also split spoon cores from 40-42 ft, 160-162 ft, and 290-292 ft
Total depth of borehole, ft	520
Ground elevation, ft amsl NAVD 88	5372.5
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Screen, ft bgs	492.0 to 512.0
Date well developed	April 28, 1997
Initial water level, ft bgs	479.64
Rig Geologist	Mike Skelly

Depth, ft bgs	Description
0	Sand, moderate yellowish brown (10YR 5/4), very fine to medium sand, well sorted, poorly graded (possibly aeolian), dry, soft, no fines, no gravel.
15	Gravel, pale yellowish-brown matrix (10YR 6/2), some medium sand, dry, medium dense.
20	Gravel, as above, clasts are granite, limestone, and basaltic (greenstone).
28	Sand, as above only more reddish, light brown (5YR 5/6), dry, possibly aeolian.
40	Sand, light brown (5YR 5/6), dry, possibly aeolian.
48	Occasional gravel layers, pale yellowish-brown matrix (10YR 6/2), some medium sand, medium dense, dry.
54	Clay layers, cuttings balling up, some caliche.
56	Sand and gravel, light brown to pale yellowish brown (5YR 5/6) to (10YR 6/2), dry to slightly moist, poorly sorted, well graded, mostly coarse sand, fine gravel up to 0.5-inches diameter, mostly pink granite, some greenstone.
70	Alternating sandy clays, sandy gravels, individual layers range from a few inches to about one ft thick, poorly sorted, dry to slightly moist.
100	Silty gravelly sand, some thin clay layers, fine gravel predominantly dark gray limestone and pink granite, dry to slightly damp.
108	Silty sand, some clay some fine grave, mostly medium sand, dry to slightly moist, no coarse gravel.
120	Silty sand, as above, some clay layers (thin, less than 6 inches in diameter), and gravel layers (gravel up to 2-inches diameter), especially at approximately 122 to 124 ft, dry to slightly moist, possible caliche layers throughout, especially at approximately 138 ft.
140	Silty sand, as above, dry to slightly moist, gravel layers throughout, especially at approximately 155 to 160 ft, dry.
160	Fine sand (as above at 28 ft), dry to slightly moist. From 165 ft to approximately 175 ft, encounter finer grained sand with more clay and silt. No gravel.
180	Silty sand, as above, dry to slightly moist, some gravel to 1-inch diameter, slightly redder, some finer grained and coarser grained layers (less than 1-ft thick) throughout.
200	Silty sand, as above, dry to slightly moist.
208	Silty sand with some finer and coarser layers, gravel to 2-inches diameter.
220	Fine sand, as above, some silt, some gravel, dry to slightly moist (possibly aeolian).
240	Silty sand and gravel, slightly moist.
260	Silty sand and gravel, as above, slightly moist to dry.
280	Silty sand, trace of clay and gravel, dry.
285	Finer grained, started to lose return of cuttings, moist. Approximate depth.
289	Coarser sand, moist.

Depth, ft bgs	Description
290	Possibly slough consisting of a mixture of fine gravel, sand, silt and clay, slightly moist (split spoon sampler was dry).
290-295	Sand and gravel (up to 2-inches diameter), moist but apparently not saturated.
295-297	Clayey silt, moist.
297	Sand and gravel, moist.
303	More clayey and silty sand, moist but not saturated, difficulties getting cuttings returned. Fines are sticking to drill string. Approximate depth.
320	Clayey silty sand, moist, poor returns.
330	Start injecting water to increase the return of cuttings.
340	Silty sand.
360	Silty sand.
375	Sand and gravel, saturated (makes more than 5 gallons per minute). Approximate depth.
380-385	Silty clay, no groundwater produced. Need to add (inject) water to bring cuttings to the surface. Approximate depth.
400	Silty clay, adding water.
420	Silty sand clay, adding water
425	Silty sand and gravel, gravel up to 2-inches diameter, adding water. Approximate depth.
438	Less gravel. Approximate depth.
440	Silty sand, adding water, very firm drilling.
452	Sand and gravel, adding water. Approximate depth.
460	Sand and gravel, some silt, adding water.
480	Silty sand and gravel, adding water.
500	Silty sand, some gravel and clay layers above, adding water, possibly making some groundwater. Out of the deepest clay layer by approximately 497 ft.
513	Tight clay and need to inject water again.
520	Silty sandy clay, very firm, moist.
520	Borehole total depth.

The Unified Soil Classification System symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TA2-W-26

Drilling company	Water Development Corporation
Dates of drilling	January 12 – 14, 1998
Drilling method	ARCH, cuttings logged, no cores
Total depth of borehole, ft	305
Ground elevation, ft amsl, NAVD 88	5373.8
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	276.0 to 296.0
Date well developed	January 19, 1998
Initial water level, ft bgs	279.42
Rig Geologist	Mike Skelly

Depth, ft bgs	Description	USCS Group
0	Sand, moderate yellowish brown (10YR 5/4), very fine to medium sand, occasional coarse sand to fine gravel, well sorted, poorly graded, dry to slightly damp.	SP
17	Sandy gravel, pale yellowish brown (10YR 6/2), gravel up to 2 inches in diameter, clasts are limestone and granite and metamorphics (greenstone), dry.	GP
27	Sand, as above 0 to 17 ft, increasing fines with depth, to clayey and silty sand at 33 to 34 ft, moderate brown (5YR 3/4), dry.	SP
35	Sandy gravel, as above, dry.	GP
38	Sand, as above at 27 ft, dry, more medium and coarse sand.	SP
47	Sandy gravel, as above.	GP
52	Silty and clayey sand, dry to damp.	SM/SP
55	Sand, as above at 27 ft, light brown (5YR 5/6), to moderate brown (5YR 4/4), dry, trace of gravel.	SP
66	Silty and clayey sand, as above at 52 ft, dry to slightly damp.	SM/SC
71	Sand, as above at 55 ft, dry, varying gravel content.	SP
76	Sandy gravel, as above 47 ft, dry, clasts to 3 plus inches in diameter.	GP
78	Sand, as above at 55 ft, dry, thin (less than 1 ft) gravel layers at approximately 85 ft and 92 ft.	SP
101	Clayey and silty sand, as above, varying amounts of fines, dry to slightly damp, possible caliche (color change) at approximately 114 ft to 115 ft.	SM/SC
118	Sandy gravel, as above at 76 ft, finer grained at approximately 132 ft, dry to damp.	GP
132	Sandy gravel, finer grained, dry to damp.	n.r.
137	Sand and gravel, dry, clasts predominantly granitic.	GP
139	Silty sand, as above at 101 ft, alternating sands to gravels to 160 ft, some gravel to 4-inches diameter; sand is damp, gravel is dry, damp to moist sand at 160 ft.	SM/SP
160-170	Silty sand increasingly finer to 170 ft, damp.	SM/SP
178	Sandy gravel layer, slightly damp, clasts of brick-red silty sandstone.	GP
180	Silty sand, as above, damp, gravel layer at approximately 190 ft, some silty clay layers immediately below at approximately 195 to 199 ft.	SM/SP
200	Silty sand, as above at 180 ft, some gravel, damp.	SP
226	Sandy silt and clay, some gravel, damp.	SM/SC
235	Sand and gravel, as above, damp.	n.r.
244	Sandy silt and clay, damp, some coarse sand and fine gravel.	n.r.
252	Gravel and sand, dry to slightly damp.	n.r.
256	Silty sand and gravel, damp, increasing fines with depth.	n.r.

Depth, ft bgs	Description	USCS Group
270	Silty sand, damp to moist.	n.r.
285	Drilled ahead of drive casing approximately 5 to 7 ft. Sand and gravel, moist to very moist, saturated after waiting a few minutes.	n.r.
285-300	Wet cuttings, unable to differentiate lithologies, appear to be pea gravel at approximately 286 to 292 ft, tighter clay at 292 to 294 ft, then coarser from 294 to approximately 305 ft, saturated.	n.r.
305	Borehole total depth.	

n.r. = not recorded. The Unified Soil Classification System (USCS) symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TA2-W-27

Drilling company	Water Development Corporation
Dates of drilling	February 4 – 6, 1998
Drilling method	ARCH, cuttings logged, no cores
Total depth of borehole, ft	306.5
Ground elevation, ft amsl, NAVD 88	5360.8
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	275.0 – 295.0
Date well developed	February 9, 1998
Initial water level, ft bgs	274.59
Rig Geologist	Mike Sanders

Depth, ft bgs	Description	USCS Group
0-17	Gravel, sand and silt mixture, reddish brown 5YR 5/4, 20% coarse to very fine gravel less than 1-inch diameter, subangular subrounded, fragments of igneous, metamorphic, and limestone rocks, 50% very coarse to very fine sand, subangular to subrounded, poorly sorted, 30% silt, reddish brown 5YR 5/4.	GM
17-26	Gravelly sand, 50% very coarse to very fine gravel less than 3-inch diameter, subangular to subrounded, quartzite, gneiss and limestone fragments, 40% very coarse to very fine sand, reddish brown 5YR 5/3, subangular to subrounded, poorly sorted, 10% silt, reddish brown 5YR 5/3.	GP
26-66	Clayey sandy silt, reddish brown 5YR 4/3, less than 10% very fine to very coarse sand, clay content increasing from 50 ft to 53 ft, moderately damp, less than 1.5-inch diameter gravel at 66 ft only.	SC
66-85	Gravelly sand, and minor silt mixture. 60% consists of 2-inch diameter, very fine gravel, quartzite, gneiss and limestone fragments, subangular to subrounded, 30% very coarse to very fine sand, brown (7.5YR 5/4), subangular to subrounded, poorly sorted, 10% silt, brown (7.5 YR 5/4), slightly damp, trace clay.	GP
85-135	Sandy and clayey silt, brown (7.5YR 5/6), less than 10% very fine sand and clay, 10% clay content from 94 ft to 96 ft, less than 1.5-inch diameter gravel, subangular to subrounded. From 115 ft to 117 ft cuttings are moderately damp.	SM
135-150	Gravelly sand, 50% very fine gravel (0.75-inch diameter), subangular to subrounded, quartzite, Precambrian gneiss and granite, minor (less than 10%) limestone fragments, 40% very coarse to very fine sand, subangular to subrounded, poorly sorted, light brown (7.5YR 6/4), 10% silt, light brown (7.5YR 6/4), slightly damp.	SP
150-193	Sandy silt, like 85 ft to 135 ft, brown (7.5YR 5/6), less than 10% very fine to coarse sand throughout interval, clay increasing to approximately 10% from 158 ft to 163 ft, trace gravel at 175 ft to 193 ft, slightly damp.	SM
193-204	Gravel, sand, and silt mixture. 60% consists of 1-inch diameter very fine gravel, subangular to subrounded, Precambrian quartzite, gneiss, granite and minor limestone fragments, occasionally cemented gravel fragments, 30% very coarse to very fine sand, subangular to subrounded, poorly sorted, 10% silt, light brown (7.5YR 6/4), silty, damp.	GM
204-220	Sandy silt like 85 ft to 135 ft, and at 150 ft to 193 ft, 40% coarse to very fine sand, trace clay, silty damp.	SM
220-232	Clay, light brown (7.5YR 6/3) with 10 to 20% very coarse to fine sand, moderately damp, sparse returns from cyclone.	CL

Depth, ft bgs	Description	USCS Group
232-236	Gravel, sand, and silt mixture like 193 ft to 204 ft, except smaller gravel (less than 0.5-inch diameter), slightly damp.	GM
236-261	Sand and silt mixture. Percentages of sand and silt are variable throughout interval, with average of 50% very coarse to very fine sand, subrounded to subangular, and 50% silt with minor clay, brown (7.5YR 5/4), 20% coarse sand from 244 ft to 246 ft and at 255 ft. 50% coarse sand and fine gravel from 259 ft to 261 ft. Fine to coarse sand indicating water production discharged at cyclone from 250 ft onward. Moderately damp overall.	SM
261-277	Clayey silt, brown (7.5YR 5/6), occasional gravel fragments less than 2-inch diameter at 262 ft. Variable amount of fine sand from cyclone throughout interval, increasing after 274 ft. Reliable returns to 277 ft.	SC
277-306.5	Returns non-existent after 277 ft. Description based on driller observation. Mostly gravel and sand from 277 ft to 279 ft, then increasing finer material (silt and clayey silt) to TD. Split spoon sample from 305.5 ft to 306.5 ft consists of clayey silt.	GP, SM, SC?
306.5	Borehole Total Depth	

USCS = Unified Soil Classification System.

Lithologic log for borehole at monitoring well TA2-W-28

Drilling company	National EWP (Exploration Wells Pumps) Inc.
Dates of drilling	November 20 – December 5, 2014
Drilling method	ARCH, cuttings logged, no cores
Total depth of borehole, ft	338
Ground elevation, ft amsl, NAVD 88	5410.0
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	310.5 to 330.5
Date well developed	December 10, 2014
Initial water level, ft bgs	316.8
Rig Geologist	John R. Copland

See lithologic description (Visual Classification of Soils) on following page.

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Visual Classification of Soils

WELL NAME: TA2-W-28	PROJECT NAME: Tijeras Arroyo Groundwater	
WELL DEPTH: 338.35 FT BTOC	OWNER NAME: U.S. DOE	DATE STARTED: November 20, 2014
GROUND ELEVATION: 5409.99 FT AMSL	GWL: 319.2 FT BTOC	DATE COMPLETED: January 30, 2015
BOREHOLE DEPTH: 338 FT BGS	DTW: 316.8 FT BGS	
LOWEST SAMPLING DEPTH: NA*	GEOLOGIST: John R. Copland	PAGE: 1 of 7
DRILLING METHOD: Air Rotary Casing Hammer		REVIEWER: Michael F. Skelly

DEPTH (feet) bgs	LITHOLOGIC DESCRIPTION BASED ON CUTINGS	LITHOLOGIC SYMBOL	USCS SYMBOL
0	Silty sand, moderately sorted, yellowish brown 10 YR 5/4, dry. 80% very fine to medium sand, 10% coarse to pebbly sand, 10% silt and clay. Source rocks: granitic, metamorphics (quartzite), limestone, minor mafics. Subangular to subrounded grains. Occasional limestone gravel to 0.75-inch diameter, angular.		
10	Silty sand, poorly sorted, light brown 7.5 YR 6/4, slightly damp. 80% very fine to medium sand, 10% coarse to pebbly sand, 10% silt and clay. Source rocks: granitic, metamorphics (quartzite), limestone, minor mafics. Subangular to subrounded grains.		
20	Silty sand, poorly sorted, light brown 7.5 YR 6/4, slightly damp. 80% very fine to medium sand, 10% coarse to pebbly sand, 10% silt and clay. Source rocks: granitic, metamorphics (quartzite), limestone, minor mafics. Subangular to subrounded grains.		SM
30			
40	Silty sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 50% very fine to medium sand, 20% coarse sand, 30% silt and clay. Source rocks: granitic, metamorphics (quartzite and greenstone), limestone, minor mafics. Subangular to subrounded grains.		
50			

NOTES: Water in screen after development was at 316.8 ft bgs.

Sandia National Laboratories

Visual Classification of Soils

WELL NAME: TA2-W-28	PROJECT NAME: Tijeras Arroyo Groundwater	
WELL DEPTH: 338.35 FT BTOC	OWNER NAME: U.S. DOE	DATE STARTED: November 20, 2014
GROUND ELEVATION: 5409.99 FT AMSL	GWL: 319.2 FT BTOC	DATE COMPLETED: January 30, 2015
BOREHOLE DEPTH: 338 FT BGS	DTW: 316.8 FT BGS	
LOWEST SAMPLING DEPTH: NA*	GEOLOGIST: John R. Copland	PAGE: 2 of 7
DRILLING METHOD: Air Rotary Casing Hammer		REVIEWER: Michael F. Skelly

DEPTH (feet) bgs	LITHOLOGIC DESCRIPTION BASED ON CUTINGS	LITHOLOGIC SYMBOL	USCS SYMBOL
50			
60	Silty sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 50% very fine to medium sand, 20% coarse sand, 30% silt and clay. Source rocks: granitic, metamorphics (quartzite and greenstone), limestone, minor mafics. Subangular to subrounded grains.		
70			SM
80	Silty sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 50% very fine to medium sand, 20% coarse sand, 30% silt and clay. Source rocks: granitic, metamorphics (quartzite and greenstone), limestone, minor mafics. Subangular to subrounded grains.		
90			
100			

NOTES: Water in screen after development was at 316.8 ft bgs.

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Visual Classification of Soils

WELL NAME: TA2-W-28	PROJECT NAME: Tijeras Arroyo Groundwater	
WELL DEPTH: 338.35 FT BTOC	OWNER NAME: U.S. DOE	DATE STARTED: November 20, 2014
GROUND ELEVATION: 5409.99 FT AMSL	GWL: 319.2 FT BTOC	DATE COMPLETED: January 30, 2015
BOREHOLE DEPTH: 338 FT BGS	DTW: 316.8 FT BGS	
LOWEST SAMPLING DEPTH: NA*	GEOLOGIST: John R. Copland	PAGE: 3 of 7
DRILLING METHOD: Air Rotary Casing Hammer		REVIEWER: Michael F. Skelly

DEPTH (feet) bgs	LITHOLOGIC DESCRIPTION BASED ON CUTINGS	LITHOLOGIC SYMBOL	USCS SYMBOL
100	Silty sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 50% very fine to medium sand, 30% silt and clay, 20% coarse sand. Source rocks: mostly granitic, few metamorphics (quartzite and greenstone), minor mafics. Subangular to subrounded grains.		SM
110	Gravelly sand, poorly sorted, medium brown 10 R 4/6, dry. 70% coarse to pebbly sand, 20% gravel, 5% very fine to medium sand, 5% silt and clay. Source rocks: graniti metamorphics (quartzite and greenstone), limestone, minor mafics. Subangular to subrounded grains. Driller mentions start of harder drilling.		SW
120	Gravelly sand, poorly sorted, medium brown 10 R 4/6, dry. 70% coarse to pebbly sand, 20% gravel 5% very fine to medium sand, 5% silt and clay. Source rocks: granitic, metamorphics (quartzite and greenstone), limestone, minor mafics. Subangular to subrounded grains.		
130	Silty sand, medium brown, medium brown 10 R 4/6, slightly damp. 60% very fine to fine sand, 25% medium to coarse sand, 15% silt and clay. Source rocks: granitic, lesser metamorphics (quartzite and greenstone), minor mafics. Angular to subrounded grains. Driller mentions return to easier drilling.		SM
140	Silty sand, medium brown, medium brown 10 R 4/6, slightly damp. 60% very fine to fine sand, 25% medium to coarse sand, 15% silt and clay. Source rocks: granitic, lesser metamorphics (quartzite and greenstone), minor mafics. Angular to subrounded grains.		
150			

NOTES: Water in screen after development was at 316.8 ft bgs.

Sandia National Laboratories

Visual Classification of Soils

WELL NAME: TA2-W-28	PROJECT NAME: Tijeras Arroyo Groundwater	
WELL DEPTH: 338.35 FT BTOC	OWNER NAME: U.S. DOE	DATE STARTED: November 20, 2014
GROUND ELEVATION: 5409.99 FT AMSL	GWL: 319.2 FT BTOC	DATE COMPLETED: January 30, 2015
BOREHOLE DEPTH: 338 FT BGS	DTW: 316.8 FT BGS	
LOWEST SAMPLING DEPTH: NA*	GEOLOGIST: John R. Copland	PAGE: 4 of 7
DRILLING METHOD: Air Rotary Casing Hammer		REVIEWER: Michael F. Skelly

DEPTH (feet) bgs	LITHOLOGIC DESCRIPTION BASED ON CUTINGS	LITHOLOGIC SYMBOL	USCS SYMBOL
150			SM
160	Silty sand, medium brown, medium brown 10 R 4/6, slightly damp. 60% very fine to fine sand, 25% medium to coarse sand, 15% silt and clay. Source rocks: granitic, lesser metamorphics (quartzite and greenstone), minor mafics. Angular to subrounded grains.		SW
	Gravelly sand, poorly sorted, medium brown 10 R 4/6, dry. 70% coarse to pebbly sand, 20% gravel 5% very fine to medium sand, 5% silt and clay. Source rocks: granitic, metamorphics (quartzite and greenstone), limestone, minor mafics. Subangular to subrounded grains.		
170	Silty sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 50% medium sand, 30% very fine to fine, 10% coarse sand, 10% silt and clay. Source rocks: granitic, lesser metamorphics (quartzite and greenstone), minor mafics. Subangular to subrounded grains.		SM
180	Silty sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 50% very fine to medium, 10% coarse sand, 40% silt and clay. Source rocks: granitic, lesser metamorphics (quartzite and greenstone), minor mafics. Subangular to subrounded grains.		
	Gravelly sand, poorly sorted, medium brown 10 R 4/6, dry. 70% coarse to pebbly sand, 20% gravel, 5% very fine to medium sand, 5% silt and clay. Source rocks: granitic, metamorphics (quartzite and greenstone), limestone, minor mafics. Subangular to subrounded grains.		
190	Coarse to pebbly sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 60% coarse to pebbly sand, 30% very fine to medium sand, 10% silt and clay. Source rocks: granitic, lesser metamorphics (quartzite and greenstone), few limestone and sandstone, minor mafics. Subangular to subrounded grains.		SW
	Coarse to pebbly sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 60% coarse to pebbly sand, 30% very fine to medium sand, 10% silt and clay. Source rocks: granitic, limestone and sandstone, lesser metamorphics (quartzite and greenstone), minor mafics. Angular to subrounded grains. Occasional granitic gravel up to 1-inch diameter and limestone gravel up to 1-inch diameter, angular.		
200			

NOTES: Water in screen after development was at 316.8 ft bgs.

Sandia National Laboratories

Visual Classification of Soils

WELL NAME: TA2-W-28	PROJECT NAME: Tijeras Arroyo Groundwater	
WELL DEPTH: 338.35 FT BTOC	OWNER NAME: U.S. DOE	DATE STARTED: November 20, 2014
GROUND ELEVATION: 5409.99 FT AMSL	GWL: 319.2 FT BTOC	DATE COMPLETED: January 30, 2015
BOREHOLE DEPTH: 338 FT BGS	DTW: 316.8 FT BGS	
LOWEST SAMPLING DEPTH: NA*	GEOLOGIST: John R. Copland	PAGE: 5 of 7
DRILLING METHOD: Air Rotary Casing Hammer		REVIEWER: Michael F. Skelly

DEPTH (feet) bgs	LITHOLOGIC DESCRIPTION BASED ON CUTINGS	LITHOLOGIC SYMBOL	USCS SYMBOL
200	Silty sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 80% very fine to medium sand, 10% coarse sand, 10% silt and clay. Source rocks: granitic and metamorphics (quartzite and greenstone), minor mafics. Subangular to subrounded grains.		
210			SM
220	Silty sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 60% very fine to medium sand, 30% coarse sand, 10% silt and clay. Source rocks: granitic and metamorphics (quartzite and greenstone), minor mafics. Subangular to subrounded grains.		
230	Coarse sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 60% coarse sand, 20% very fine to medium sand, 10% pebbly sand, 10% silt and clay. Source rocks: predominantly metamorphics (quartzite and greenstone) and granitic, few limestone and sandstone, minor mafics. Angular to subrounded grains.		
240	Coarse sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 60% coarse sand, 20% very fine to medium sand, 10% pebbly sand, 10% silt and clay. Source rocks: predominantly metamorphics (quartzite and greenstone) and granitic, few limestone and sandstone, minor mafics. Angular to subrounded grains. Occasional granitic gravel to 0.5-inch diameter.		SW
250			

NOTES: Water in screen after development was at 316.8 ft bgs.

Sandia National Laboratories

Visual Classification of Soils

WELL NAME: TA2-W-28	PROJECT NAME: Tijeras Arroyo Groundwater	
WELL DEPTH: 338.35 FT BTOC	OWNER NAME: U.S. DOE	DATE STARTED: November 20, 2014
GROUND ELEVATION: 5409.99 FT AMSL	GWL: 319.2 FT BTOC	DATE COMPLETED: January 30, 2015
BOREHOLE DEPTH: 338 FT BGS	DTW: 316.8 FT BGS	
LOWEST SAMPLING DEPTH: NA*	GEOLOGIST: John R. Copland	PAGE: 6 of 7
DRILLING METHOD: Air Rotary Casing Hammer		REVIEWER: Michael F. Skelly

DEPTH (feet) bgs	LITHOLOGIC DESCRIPTION BASED ON CUTINGS	LITHOLOGIC SYMBOL	USCS SYMBOL
250	Medium sand, moderately sorted, medium brown 10 R 4/6, slightly damp. 60% very fine to medium sand, 35% coarse to pebbly sand, 5% silt and clay. Source rocks: predominantly granitic and metamorphics (quartzite and greenstone), minor mafics. Angular to subrounded grains.		
260	Medium sand, moderately sorted, medium brown 10 R 4/6, slightly damp. 80% very fine to medium sand, 15% coarse to pebbly sand, 5% silt and clay. Source rocks: granitic and metamorphics (quartzite and greenstone), minor mafics. Subangular to subrounded grains. Occasional limestone gravel to 0.75-inch diameter, angular.		
270			SP
280	Coarse sand, poorly sorted, medium brown 10 R 4/6, dry. 75% coarse to pebbly sand, 20% very fine to medium sand, 5% silt and clay. Source rocks: granitic, metamorphics (quartzite and greenstone), few limestone and sandstone, minor mafics. Angular to subrounded grains. Occasional granitic gravel up to 0.5-inch diameter, subrounded. Driller mentions harder drilling.		
290	Silty sand, slightly damp, poorly sorted, medium brown 10 R 4/6, slightly damp. 70% very fine to medium sand, 10% coarse to pebbly sand, 20% silt and clay. Source rocks: granitic, limestone, and metamorphics (quartzite and greenstone), few sandstone, minor mafics. Subangular to rounded grains. Driller mentions easier drilling.		SM
300			

NOTES: Water in screen after development was at 316.8 ft bgs.

Sandia National Laboratories

Visual Classification of Soils

WELL NAME: TA2-W-28	PROJECT NAME: Tijeras Arroyo Groundwater	
WELL DEPTH: 338.35 FT BTOC	OWNER NAME: U.S. DOE	DATE STARTED: November 20, 2014
GROUND ELEVATION: 5409.99 FT AMSL	GWL: 319.2 FT BTOC	DATE COMPLETED: January 30, 2015
BOREHOLE DEPTH: 338 FT BGS	DTW: 316.8 FT BGS	
LOWEST SAMPLING DEPTH: NA*	GEOLOGIST: John R. Copland	PAGE: 7 of 7
DRILLING METHOD: Air Rotary Casing Hammer		REVIEWER: Michael F. Skelly

DEPTH (feet) bgs	LITHOLOGIC DESCRIPTION BASED ON CUTINGS	LITHOLOGIC SYMBOL	USCS SYMBOL
300	Silty sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 80% very fine to medium sand, 10% coarse sand, 10% silt and clay. Source rocks: granitic and metamorphics (quartzite and greenstone), minor mafics. Subangular to subrounded grains.		
310	Silty sand, poorly sorted, medium brown 10 R 4/6, slightly damp. 70% very fine to medium sand, 10% coarse sand, 20% silt and clay. Source rocks: granitic, limestone, and metamorphics (quartzite and greenstone), few sandstone, minor mafics. Subangular to rounded grains.		SM
320	Clay, 85% clay, 15% very fine to fine sand, medium plasticity (crumbles into small pieces), medium brown 10 R 4/6, damp. Driller starts adding water for the increasingly harder drilling.		CL
	Slightly clayey sand, medium brown 10 R 4/6, medium plasticity, damp. 80% very fine to fine sand, 10% coarse sand, 10% silt and clay, occasional pebbles.		CL
330	Slightly sandy clay, medium brown 10 R 4/6, medium plasticity, damp. 90% clay, 10% very fine sand. Driller adding much water because of increasing clay content.		CL
	Clay, medium brown 10 R 4/6, medium plasticity (crumbles into small pieces), damp. 100% clay. Driller calls top of dense clay because of great difficulty in hammering the drive casing.		CH
340	Clay, medium brown 10 R 4/6, medium plasticity (crumbles into small pieces), very dense, damp. 100% clay. Borehole TD.		
350			

NOTES: Water in screen after development was at 316.8 ft bgs.

Lithologic log for borehole at monitoring well TJA-1

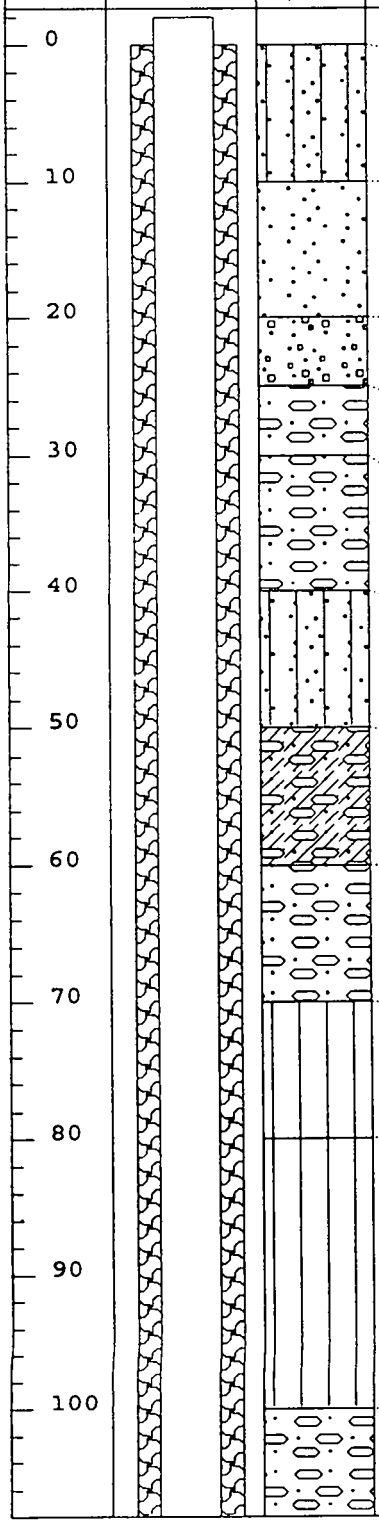
Drilling company	USGS Water Sciences Division
Dates of drilling	June 8 – 21, 1994
Drilling method	Mud Rotary, cuttings logged, 10-ft long core barrel for continuous coring from 220 to 295 ft
Total depth of borehole, ft	310
Ground elevation, ft amsl NAVD 88	5351.3
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	275.0 to 295.0
Date well developed	June 25, 1994
Initial water level, ft bgs	271.00
Rig Geologist	Walt Foutz

Also refer to the 3-page Lithologic Description from SAND94-3012 Report

Depth, ft bgs	Composite Description from USGS Geophysical Log	USCS Group
0-10	Silty sand. Light brown with very coarse sand, rounded to subrounded, dusty, dry, air drilled to 25 ft.	SM
10-20	Sand. Light brown, fine-to very fine-grained, very dry, hole caving at 20 ft.	SP
20-23	Silty and gravelly sand. Light brown, predominantly gravel wash.	SW
23-40	Sandy gravel. No fines due to mud rotary. Sieving samples to 200 mesh. Clasts composed of milky quartz, feldspar, dark metamorphics, no limestone.	GW
40-50	Silty sand. Light brown, fine- to very fine-grained, well sorted, subrounded, in sticky silty clay matrix	SM
50-70	Gravelly and silty sand. Sand is fine-grained, well graded, rounded to subrounded.	GC
70-100	Silty and sandy clay. Sand mostly fine-grained, minor coarse-grained.	ML
100-110	Sandy gravel. Well graded, minor silt.	GW
110-120	Silty and gravelly sand. Light to reddish brown, minor clay.	SM
120-130	Silty and sandy gravel. Well graded, gravel to 0.5-inch diameter.	GM
130-170	Silty sand. Light brown, minor small gravel, well graded interval. (140 to 160 ft is SM)	SW
170-210	Silty and clayey sand. Light brown, well graded, minor clay, and minor coarse-grained sand.	SW
210-220	Gravelly sand. Sand coarse- to very coarse-grained.	GP
220-230	Sandy and gravelly silt. Cored interval. Damp to very damp.	SM
230-240	Silty sand. Cored interval. Light to medium brown, few water-saturated coarse-grained sand interbeds.	SM
240-250	Sand. Well graded, minor silt.	SW
250-260	Silty sand. Light brown, well graded, minor clay.	SM
260-280	Sandy silt. Cored interval. Sand very fine- to coarse-grained, very damp, three sand interbeds, wet sandy gravel interbed from 272.5 to 272.7 ft.	SM
280-282	Silty sand. Cored interval. Well graded, damp to wet.	SW
282-290	No recovery. Possible sandy gravel.	GW
300-310	Sandy silt.	n.r.
310	Borehole Total Depth.	

n.r. = not recorded. The Unified Soil Classification System (USCS) symbol was not recorded on the original lithologic log or field notes.

WELL NAME: **TJA-1**			PAGE 1 of 3
LOCATION: **TIJERAS ARROYO**	TOTAL DEPTH: **310'**		
PROJECT: **SWHC**	CASING DEPTH: **305'**	GROUND ELEVATION: **5350.53**	
DRILLING METHOD: **MUD ROTARY**	HOLE DIAMETERS: **7 7/8"**	TOP OF CASING: **NA**	
DRILLING CONTRACTOR: **USGS**		REMARKS: **P & A**	
DATE DRILLED: **6-8-94**	LOGGED BY: **WALT FOUTZ**		
DATE COMPLETED: **6-22-94**	REVIEWED BY: **JOHN MCCORD**		



LITHOLOGIC DESCRIPTION AND REMARKS

SM
silty sand, light brown, (7.5YR 6/4), dusty dry, (air-drilled), w/very coarse sand, round to sub-round.

SP
sand, light brown, (7.5YR 6/4), fine to very fine grained, very dry (air-drilled to 20'), hole caving at 20', will mud up.

SW
sand, light brown as above, very silty with small gravel, predominantly granite wash, Last air-drilled sample 20-25'.

GW
sandy gravel, no fines in sample due to mud rotary drilling method and washing sample in 200 mesh sieve.

GW
sandy gravel as above, fines washed out. Gravel/ sand varies from milky quartz, feldspar, dark metamorphics, no limestone. Incr. grain size.

SM
silty sand, light brown, decreasing large grains, increasing silt/clay matrix. Sand mostly fine to very fine grained in sticky silty clay matrix, well sorted, subrounded.

GC
sandy gravel with some silt, mostly fine grained, well sorted, round to subround sand, well graded.

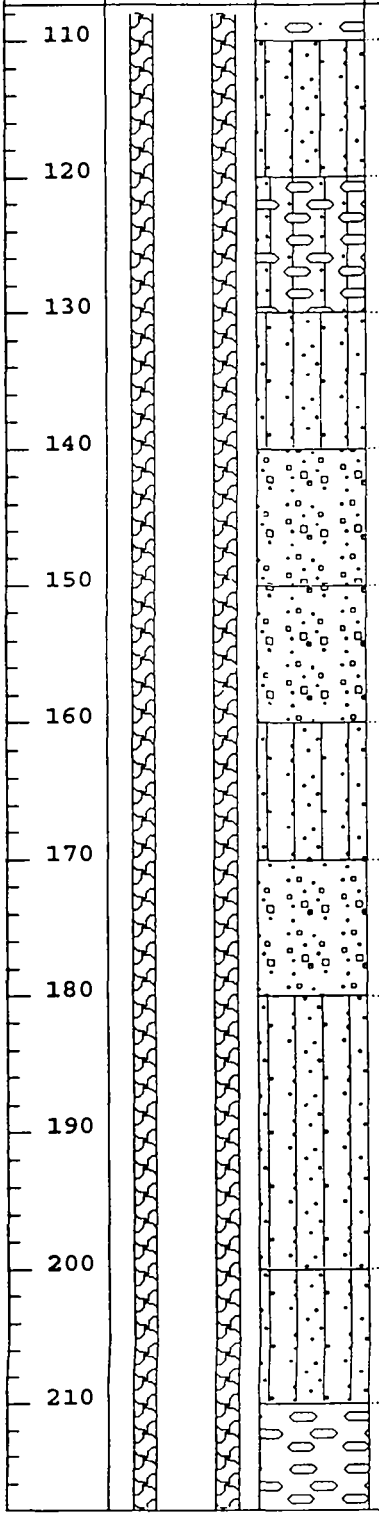
GW
sandy gravel, well graded, very little silt, fine grained, sandy matrix.

ML
silty sand w/ some clay matrix, sticky hand sample, sand well sorted, fine grained, w/ some very coarse sand to fine gravel.

ML
sandy silt, light brown as above, sticky silty clay matrix w/ well sorted very fine grain sand, notable absence of coarse sand/gravel.

GW
sandy gravel, well graded, relatively clean, trace of silt, gravel medium to coarse grained.

WELL NAME: TJA-1			PAGE 2 of 3
LOCATION: TIJERAS ARROYO	TOTAL DEPTH: 310'		
PROJECT: SWHC	CASING DEPTH: 305'	GROUND ELEVATION: 5350.53	
DRILLING METHOD: MUD ROTARY	HOLE DIAMETERS: 7 7/8"	TOP OF CASING: NA	
DRILLING CONTRACTOR: USGS		REMARKS: P & A	
DATE DRILLED: 6-8-94	LOGGED BY: WALT FOUTZ		
DATE COMPLETED: 6-22-94	REVIEWED BY: JOHN MCCORD		



LITHOLOGIC DESCRIPTION AND REMARKS

110 – 120: SM
silty sand, light to reddish brown, fine gravel in silty sand matrix, trace of clay.

120 – 130: GM
sandy gravel w/some silt, larger gravel to 1/2", well graded from sitl to coarse gravel, increasing silt.

130 – 140: SM
silty sand, light brown w/trace small gravel.

140 – 150: SW
well graded sand, very fine to very coarse, some silt matrix.

150 – 160: SW
sand, well graded, very fine to very coarse, as above.

160 – 170: SM
silty sand, predominantly very fine grain sand to silt, w/very coarse sand to trace gravel.

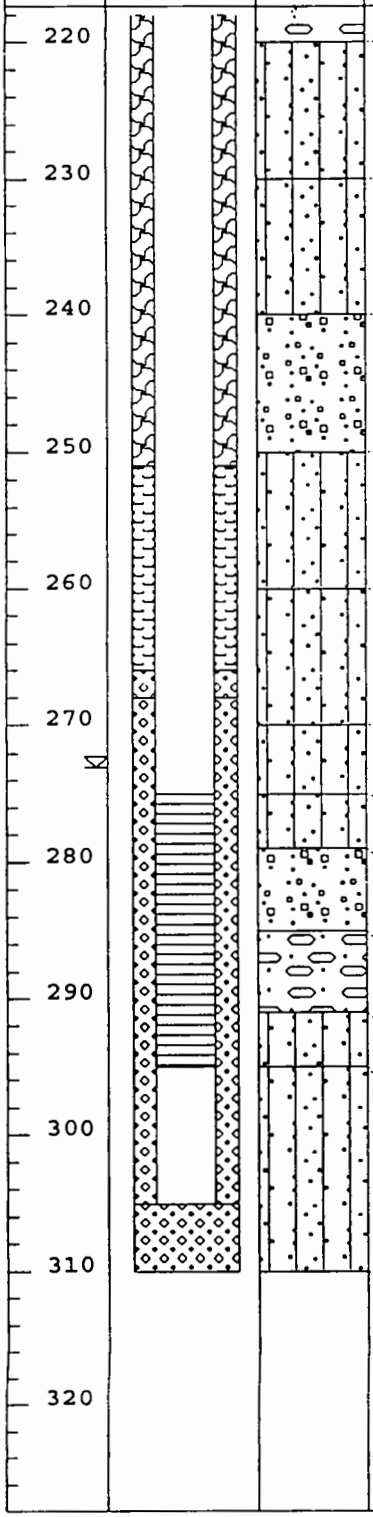
170 – 180: SW
sand, well graded, w/ very fine to coarse grained, some silt, slight stickiness indicates trace clay.

180 – 200: SM
silty sand, light brown, w/ some clay matrix, sticky, uniform w/trace small gravel to very coarse sand.

200 – 210: SM
silty sand, light brown, sticky silt/clay matrix w/fine to coarse sand, mostly fine sand.

210 – : GP
gravelly sand, mostly coarse to very coarse grained sand, some fine gravel, very little silt matrix.

WELL NAME: **TJA-1**			
LOCATION: **TIJERAS ARROYO**	TOTAL DEPTH: **310'**		
PROJECT: **SWHC**	CASING DEPTH: **305'**	GROUND ELEVATION: **5350.53**	
DRILLING METHOD: **MUD ROTARY**	HOLE DIAMETERS: **7 7/8"**	TOP OF CASING: **NA**	
DRILLING CONTRACTOR: **USGS**		REMARKS: **P & A**	
DATE DRILLED: **6-8-94**	LOGGED BY: **WALT FOUTZ**		
DATE COMPLETED: **6-22-94**	REVIEWED BY: **JOHN MCCORD**		



LITHOLOGIC DESCRIPTION AND REMARKS

SM
cored interval - see complete description
mostly soft sandy to clayey silt, damp to very damp.
notable absence of coarse grained intervals.

SM
cored interval - recovery 10'
generally light to medium brown sandy silt/silty sand, damp, with few thin-bedded coarse sand stingers, <.5 feet thick. Coarser intervals are saturated.

SW
sand, well graded, fine to very coarse grained, w/some gravel, very little silt.

SM
silty sand, light brown(7.5YR 4/6), fine to medium grained, finer than above, in silt matrix w/some clay.

SM
cored interval 260-270, 10' recovery.
generally sandy silt w/sand size ranging from very fine to coarse. Very damp. 3 sand zones <.5 ft. each

SM
cored interval 270-275, 3.8' recovery.
homogeneous sandy silt w/increasing clay matrix 273-275. Wet sandy gravel zone 272.5-272.7.

SM
cored interval 275-285, 6.1' recovery,
sandy silt as above to 279. Very damp to wet, no obvious saturation.

SW
well graded sand, varying amounts of silt, soft, damp to wet, some gravel. Driller said 281-285 was sandy gravel, fell out of core barrel.

GW
cored interval 285-291, no recovery. Loose sample fell out of core barrel.

SM
cored interval 291-295, recovery 3.8'. Sandy silt, very damp. 292.9-293.2 is coarse SW sand w/calcite cementation, indicates saturated flow has occured in this zone.

SM
very poor sample - 70% 10/20 filter pack sand from temporary completion. Total depth 310'.

Lithologic log for borehole at monitoring well TJA-2

Drilling company	USGS Water Sciences Division
Dates of drilling	July 9 – 11, 1994
Drilling method	Mud Rotary, cuttings logged, coring from 285 to 290 ft
Total depth of borehole, ft	310
Ground elevation, ft amsl NAVD 88	5351.3
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	275.0 to 295.0
Date well developed	July 12, 1994
Initial water level, ft bgs	274.00
Rig Geologist	Walt Foutz

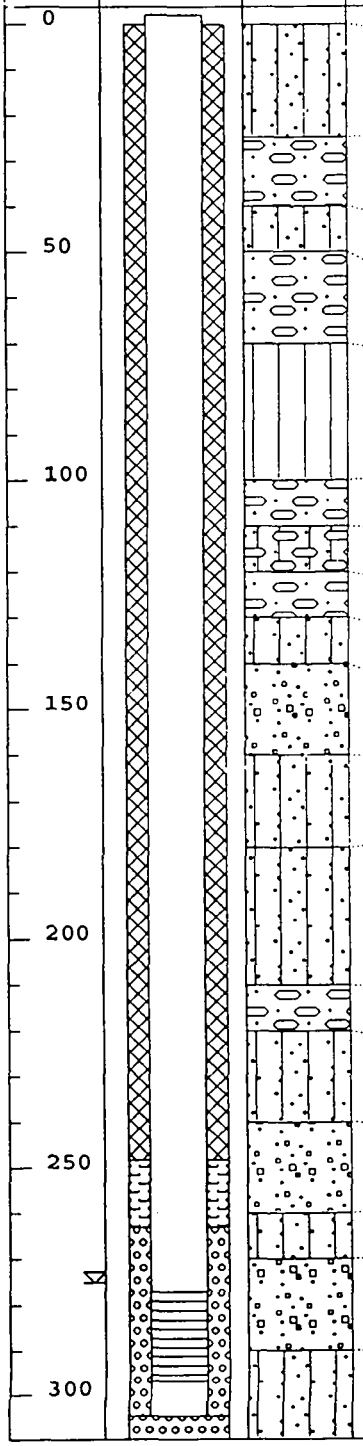
Also refer to the 1-page Lithologic Description from SAND94-3012 Report.

Depth, ft bgs	Composite Description from USGS Geophysical Log	USCS Group
0-25	Silty sand. Light brown, dusty dry, fine to very coarse-grained.	SM
25-40	Sandy gravel. Mud rotary drilled with no fines discernible, all size fractions are relative.	GW
40-50	Silty sand. Light brown, fine- to very fine-grained, well sorted	SM
50-70	Sandy gravel. Well graded, minor silt	GW
70-100	Clayey sand. Light brown, fine-grained, sticky clay matrix.	ML
100-110	Sandy gravel. Medium- to coarse-grained, clean, well graded.	GW
110-120	Gravel (silty, clayey, and sandy).	GM
120-130	Sandy gravel. Clasts to 0.5-inch diameter, well graded.	GW
130-140	Silty and pebbly sand.	SM
140-160	Silty sand. Very fine- to very coarse-grained, well graded.	SW
160-210	Silty sand. Very fine- to very coarse-grained, sticky clay matrix increasing in bottom of interval.	SM
210-220	Pebbly sand. Fine- to very coarse-grained, well graded, little silt.	GW
220-240	Clayey and sandy silt. No coarse grains. Damp to very damp.	SM
240-260	Pebbly sand. Fine- to very coarse-grained, well graded sand.	SW
260-270	Sandy silt. Much less coarse material, no clay.	SM
270-290	Pebbly sand. Fine- to very coarse-grained, well graded, fining upwards, little silt, wet. Cored 285 to 290 ft.	SW
290-310	Silty sand. Very fine- to very coarse-grained, increasing silty/clayey matrix.	SM
310	Borehole Total Depth.	

Depth, ft bgs	Core Description
285 to 290	Recovered 3.4 ft of gravelly sand, very little silt, wet.

USCS = Unified Soil Classification System.

WELL NAME: TJA-2			PAGE 1 of 1
LOCATION: TIJERAS ARROYO	TOTAL DEPTH: 310'		
PROJECT: SWHC	CASING DEPTH: 305'	GROUND ELEVATION: 5348.58	
DRILLING METHOD: MUD ROTARY	HOLE DIAMETERS: 7 7/8"	TOP OF CASING: 5350.53	
DRILLING CONTRACTOR: USGS		REMARKS:	
DATE DRILLED: 7-9-74	LOGGED BY: WALT FOUTZ		
DATE COMPLETED: 7-12-74	REVIEWED BY: JOHN McCORD		



	LITHOLOGIC DESCRIPTION AND REMARKS
0	SM silty sand, light brown, (7.5YR 6/4), dusty dry, fine to very coarse sand in silty matrix
	GW sandy gravel, fines washed out by mud rotary method, large grain size fraction probably exaggerated; grain size fractions will be relative
50	SM silty sand, light brown, fine to very fine grained, well sorted, increased silt/clay matrix
	GW sandy gravel, fine grained, well graded, some silt
	ML sandy silt, light brown, fine grained, well sorted sand in sticky clay matrix, no coarse grains
100	GW sandy gravel, med to coarse gr, clean, well graded
	GM silty sand with fine gravel, trace of clay
	GW sandy gravel, to 1/2", well graded
	SM silty sand with w/trace fine gravel
150	SW sand, well graded, very fine to v coarse, some silt
	SM silty sand, very fine to coarse, increasing clay
	SM silty sand, light brown, mostly fine gr, some coarse gr, sticky silt/clay matrix
200	GW gravelly sand, well graded, fine to vcg, little silt
	SM sandy to clayey silt, damp to very damp, no coarse gr
250	SW sand, well graded, fine to v coarse, some gravel
	SM sandy silt, much less coarse material, some clay
	SW sand, well graded, fine to v coarse grained, fining upward, driller noticed gravel at 273. Cored 285-290, recovered 3.4 ft. gravelly sand, very little silt, wet
300	SM silty sand, varying grain size from v fine to coarse, increasing silt/clay matrix

Figure 6. Generalized Lithologic Log and Well Completion at TJA-2

Lithologic log for borehole at monitoring well TJA-3

Drilling company	Water Development Corporation
Dates of drilling	August 14 – 26, 1998
Drilling method	ARCH, cuttings logged, also split spoon cores from 37-39 ft, 99-101 ft, 137-139 ft, and 314-316 ft, 512-514 ft
Total depth of borehole, ft	522
Ground elevation, ft amsl, NAVD 88	5387.8
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Screen, ft bgs	496.0 to 516.0
Date well developed	December 4, 1998
Initial water level, ft bgs	495.25
Rig Geologist	Mike Skelly and Mike Sanders

Depth, ft bgs	Description
0-3	Fine sand, pale yellowish brown (10YR 6/2) to grayish orange (10YR 7/4), some coarse sand and fine gravel, dry.
3-9	Sand and gravel, pale yellowish brown (10YR, 6/2), dry, gravel to 3-inch diameter.
9-17	Fine sand and silty sand, moderate brown (5YR 4/4), some coarse sand, fine gravel, dry to slightly damp.
17-25	Sand and gravel, damp.
25-28	Gravel to 3-inches diameter, dry to damp.
28-37	Sand and gravel interbedded with silty sand (sometimes clayey silty sand), damp.
37-48	Interbedded silty sand with sand and gravel, as above, damp.
48-53	Sand and gravel, gravel to 2-inches diameter, damp.
53-57	Silty sand, some coarse sand and fine gravel, poorly sorted, damp.
57-77	Silty sand with fine sand, better sorted than immediately above, thin interbedded clayey zones especially at approximately 69 ft and 75 ft, usually less than 6-inches thick, damp, little to no gravel.
77-97	Silty sand, varying amounts of dry and fine gravel, gravel up to 0.5-inch diameter, damp to wet with added water, firm drilling especially at approximately 93 ft.
97-117	Silty sand and wet silty sandy clay, no gravel, wet. (Added water to return cuttings).
117-137	Silty sand and silty sandy clay, some interbedded sand and gravel starting about 132 ft, wet (Added water to return cuttings).
137-151	Sand and gravel to 2-inches diameter, little to no fines in upper part, wet. (Added water to return cuttings).
151-157	Silty sand and silty sandy clay, trace of fine gravel, wet. (Added water to return cuttings).
157-173	Silty sand and silty sandy clay, trace to some fine gravel, wet. (Added water to return cuttings).
173-174	Sand and gravel to 1-inch diameter, some fines, wet. (Added water to return cuttings).
177-192	Sand and gravel, as above, wet. (Added water to return cuttings).
192-197	Silty sand and silty sandy clay, some fine gravel in thin layers, wet. (Added water to return cuttings).
197-217	Silty sand and silty sandy clay, thin layers (less than 6-inch diameter) with gravel up to 1-inch diameter, wet. (Added water to return cuttings).
217-237	Silty sand and silty sandy clay, increasing coarse sand content, some gravel layers, wet. (Added water to return cuttings).
237-242	Silty sand, some silty and sandy clay layers, little to some gravel, wet. (Added water to return cuttings).

Depth, ft bgs	Description
242-250	Coarse sand and gravel, trace to few fines, although adding water - also appears to be making water starting at approximately 245 ft (based on driller's comments and possible return of cuttings without adding water). Dry the next day.
250-264	Coarse sand and gravel, some coarse gravel, dry.
264-272	Silty sand with some fine gravel, dry.
272-292	Interbedded silty sand and fine sand, damp to very damp, trace of fine gravel, some silty and sandy clay layers, possibly making water in fine sand at 292 ft.
292-323	Silty sand and silty sandy clay, little to no gravel, damp to very damp.
323-330	Clay to silty clay (later - distinctive kick on both neutron and gamma geophysical logs).
330-377	Silty sand and silty clay, like 292 ft to 323 ft.
377-406	Sandy silt, clayey silty sand, very little gravel.
406-410	10% silt, 50% fine to coarse sand, and 40% fine to coarse gravel less than 1-inch diameter, making some (1 to 2 gallons per minute) water.
410-412	Caliche, looks like fine-grained sandstone, strong hydrochloric acid reaction, dries rock hard.
412-421	Sandy clay, very sparse returns, continue injecting water to lift cuttings.
421-456	Sandy silt at top of interval, grading into silty fine to medium sand at bottom of interval, less than 10% fine to medium sand, intermittent throughout interval.
456-460	Silty clay and clayey silt with less than 5% fine to medium sand.
460-474	Gravelly and clayey silt at top of interval, grading into sandy silt with no gravel at bottom of interval.
474-482	Clay and silty clay, no gravel. Not good water-producing zone or material.
482-521	Interbedded silty sand, clean fine to medium sand, and sand with gravel. At 492 ft gravel increases; 40% gravel less than 1-inch diameter with clean sand at 498 ft. Gravel decreases and is not present by 502 ft. Mainly fine to coarse sand at 502 ft to 521 ft with locally abundant (approximately 50%) at 513 ft and 518 ft. Minor (less than 20%) clay from 510 ft to 512 ft. Good aquifer material throughout interval.
521-522	Silty and clayey sand, with some gravel.
522	Borehole Total Depth.

The Unified Soil Classification System symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TJA-4

Drilling company	Water Development Corporation
Dates of drilling	July 28 – 31, 1998
Drilling method	ARCH, cuttings logged; also split-spoon cores from 57.0 to 58.5 ft, 157.0 to 158.5 ft, 259.0 to 261.0 ft, and 399.0 to 401.0 ft
Total depth of borehole, ft	399
Ground elevation, ft amsl, NAVD 88	5338.5
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Screen, ft bgs	360.0 to 380.0
Date well developed	December 1, 1998
Initial water level, ft bgs	314.90
Rig Geologist	Mike Skelly

Depth, ft bgs	Description
0-8	Fine sand, pale yellowish brown (10YR 6/2), well sorted - poorly graded, occasional medium to coarse sand, trace of fine gravel, dry.
8-19	Sand and gravel, moderate brown, medium to coarse sand, gravel to 2-inches diameter, coarser toward bottom.
19-33	Gravel, some coarse sand, mostly fine gravel to 1-inch diameter with some coarse gravel to 3-inches diameter, lithology of coarse sand consists of greenstone, limestone and granite.
33-41	Silty sand, mostly fine sand as above 0 ft to 8 ft, moderate brown (5YR 4/4), dry to damp.
41-43	Thin silty clay layers in silty sand beds, damp.
43-51	Silty sand as above, dam, some gravel to 1-inches diameter, damp.
51-60	Sand and gravel, as above 8 ft to 19 ft, gravel to 3-inches diameter and mostly greenstone, damp.
60-77	Silty sand and gravel (variable with depth), moderate brown (5YR 4/4 to 5YR 3/4), some thin clayey silty sand layers (less than 2-inches diameter thick) near 75 ft, damp.
77-85	Silty sand and gravel as above, damp
85-92	Sand and gravel as above, mostly coarse sand and fine gravel, with trace coarse gravel to 3-inches diameter
92-97	Silty sand and gravel as above, some clay in balls, damp.
97-117	Silty sand and gravel as above, damp.
117-125	Silty sand and gravel as above, damp.
125-137	Fine sand, trace of fine gravel, slight color change to grayish red (10YR 4/2) and moderate brown (5YR 4/4).
137-157	Fine sand as above, damp, varying amounts of fine gravel.
157-177	Silty sand and gravel, as above, increasing clay content with depth, clayey sand in layers 3- to 6-inches diameter thick, varying amounts of fine gravel.
177-197	Silty sand, sandy clay, fine grave. Gravels especially at approximately 182 and 193 ft are mostly pea gravel, wet (added water). Sieved sample.
197-217	Silty sand, fine gravels, gravels especially at approximately 205 ft and 212 ft, some coarse gravel to 2-inches diameter, considerably less clay than previous interval. From 212 to 217 ft mostly fine sand, draining through the sieve, wet (added water). Sieved sample.
217-228	Fine sand, as above, little to no gravel, dry to damp.
228-235	Silty and sandy clay, some fine gravel with coarse sand, damp.
235-239	Silty sand, as above, damp.
239-245	Silty sand, as above, damp.
245-252	Sand and gravel as above, damp, gravel to 1.5-inches diameter.
252-256	Silty sandy clay, as above, some fine gravel, dry to damp.

Depth, ft bgs	Description
256-259	Silty sand, as above, some fine gravel, damp to possibly wet. Split spoon had varying amounts of silt, clay, sand, and fine gravel.
263-272	Silty sand and gravel, damp to wet.
272-276	Silty and sandy clay with trace of gravel, damp.
276-289	Silty sand and gravel. Wet.
280-299	Sand and gravel, moderately well sorted, mostly coarse sand and fine gravel, wet to saturated, trace of fines, some coarse gravel to 1-inch diameter.
300-312	Sand and gravel as above, saturated.
312-319	Silty sandy clay and silty sand, adding water, possibly damp.
319-339	Mostly silty sand with some silty and sandy clay layers up to 8-inch thick. Few gravel with sand layers, wet (added water). Sieved sample.
339-359	Mostly silty sand, silty sand and clay, occasional sand and gravel layers with gravel to 1.5-inch diameter. Sieved sample.
359-379	Silty sand, silty and sandy clay, fine gravel throughout, possibly making some water, coarser grained sand near 379 ft. Sieved sample.
379-392	Silty sand, silty sandy clay, some sand and gravel layers, possibly making water. Sieved samples.
392-399	Sand and gravel, making water at 5 to 10 gallons per minute.
399	Borehole Total Depth.
399.0 - 399.8	Split spoon sample, sand and gravel, saturated.
399.8 - 400.5	Split spoon sample, silty sand, silty sandy clay, damp to saturated.

The Unified Soil Classification System symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TJA-5

Drilling company	Water Development Corporation
Dates of drilling	August 5 - 7, 1998
Drilling method	ARCH, cuttings logged, no cores
Total depth of borehole, ft	298
Ground elevation, ft amsl, NAVD 88	5338.5
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Screen, ft bgs	267.0 – 287.0
Date well developed	December 2, 1998
Initial water level, ft bgs	267.80
Rig Geologist	Mike Sanders

Depth, ft bgs	Description	USCS Group
0-9	Silty fine sand, pale yellow brown (10YR 6/2), well sorted, less than 10% coarse sand. Very fine to fine gravel near bottom of interval.	SM
9-17	Silty, very fine to medium sand (70%) and fine to coarse gravel, less than 1.5-inch diameter (30%), light brown (5YR 6/4), gravel composed of mixed limestone and Precambrian granite and gneiss.	SP
17-26	Coarse sand and fine to medium gravel with minor (less than 20% silt). Silt is light brown (5YR 6/4). Gravel composed of limestone and Precambrian igneous and metamorphic rocks.	GM
26-40	Silty, very fine sand, moderately yellow brown (10YR 5/4), slightly damp.	SM
40-49	Clayey silt and silty clay, moderately brown (5YR 4/4), damp.	SC
49-58	Gravel, sand, and silt mixture. Silt 20%, pale yellow brown (10YR 6/2), very fine-coarse sand 30%, and fine to coarse pebbles to gravel 50%. Dusty out of cyclone. Gravel is mainly limestone and minor gneiss and greenstone up to 2-inch diameter.	GM
58-80	Clayey silt and silty clay like 40 ft to 49 ft, clay balls up in cyclone. Interval from 69 ft to 72 ft is 40% very fine to coarse sand and fine gravel. Dusty out of cyclone. Clay content increasing below 72 ft, damp overall.	n.r.
80-95	30% silt to fine sand, moderately yellow brown (10YR 5/4), 40% medium to coarse sand, 30% fine to coarse pebble to gravel less than 1.5-inch diameter. Pebbles and gravel consists mainly of limestone and minor Precambrian igneous and metamorphic rocks. Partially damp.	GM
95-105	Silty clay and clayey silt, moderately brown (5YR 4/4), damp, minor (less than 10%) coarse sand throughout.	SC
105-110	30% silt to fine sand, moderately yellow brown (10YR 5/4), 40% medium to coarse sand, 30% fine to coarse pebbles and gravel less than 2.5-inch diameter. Mainly limestone and minor Precambrian igneous and metamorphic rocks. Dusty out of cyclone.	GM
110-168	Clayey silt and silty sand, moderate yellow brown (10YR 5/4), damp, 30% coarse sand and fine gravel at 127 ft to 130 ft, poorly sorted.	SC/SM
168-196	Gravel, sand, and silt mixture, moderately yellow brown (10YR 5/4), 30% silt, 50% very coarse sand, 20% very fine sand up to pea gravel. Composed of limestone and Precambrian fragments, also occasional gravel fragments less than 1.5-inch diameter.	GM
196-227	Silty sand and sandy silt, moderately yellow brown (10YR 5/4), damp.	SM
227-232	Clayey and silty sand, moderately yellow brown (10YR 5/4), damp.	n.r.

Depth, ft bgs	Description	USCS Group
232-275	Silty clayey sand, moderately yellow brown (10YR 5/4). Thin zones with less than 30% coarse sand and fine gravel at 237 ft, from 252 ft to 255 ft, and 260 ft to 263 ft, damp.	SM/SC
275-298	Gravel, sand, and silt mixture. 20% silt is moderate yellow brown (10YR 5/4), decreasing percentage with depth, 40% fine to very coarse sand, 40% gravel is fine to coarse, less than 1-inch diameter. Coarse sand and gravel increasing with depth, silt decreasing, damp to wet.	GM
298	Borehole Total Depth.	

n.r. = not recorded. The Unified Soil Classification System (USCS) symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TJA-6

Drilling company	Water Development Corporation
Dates of drilling	January 16 - 30, 2001
Drilling method	ARCH initially with cuttings logged from 0 to 245 ft. Mud rotary with cuttings logged from 245 to 503 ft. Also, split-spoon cores from 45.5 to 47.0 ft, 95.5 to 97.0 ft, 145.5 to 147.0 ft, 195.5 to 197.0 ft, and 245.5 to 247.0 ft
Total depth of borehole, ft	503
Ground elevation, ft amsl, NAVD 88	5340.6
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Screen, ft bgs	454.9 to 474.9
Date well developed	February 4, 2001
Initial water level, ft bgs	450.50
Rig Geologist	Joe Fritts and Mike Skelly

Depth, ft bgs	Description	USCS Group
0-10	Clayey silt, dry.	ML
10-40	Clayey silt, trace fine sand, subrounded, poorly sorted - well graded, dry.	ML
40-59	Clayey silt, dry, interbedded with caliche from 47 ft to 52 ft.	ML
59-72	Sandy gravel, dry. Gravel is fine, poorly graded, well sorted, subangular. Sand is fine to coarse, well graded, poorly sorted, subangular.	GP
72-96	Silty clay, dry to slightly moist.	ML
96-102	Sandy gravel, dry. Gravel is fine, poorly graded. Sand is fine to coarse, well graded - poorly sorted, sand and gravel are subangular.	GP
102-115	Clay, slightly moist.	CL
115-124	Silty clay, slightly moist.	CL
124-146	Clayey silt, some fine sand, dry. Sand is fine, poorly graded - well sorted, subrounded.	ML
146-160	Sand, some fine gravel, dry. Sand is fine to coarse, poorly sorted - well graded, subangular. Fine, subangular gravel.	SW
160-191	Sandy silt, dry. Fine to medium, subangular sand.	SM
191-197	Silty sand, some gravel, well graded - poorly sorted, subangular, dry. Sand is fine to coarse grained. Gravel is fine and subangular.	SM
197-208	Silt, dry.	ML
208-225	Silty clay, dry.	CL
225-232	Silty clay, moist.	n.r.
232-246	Sandy silt, some clay, dry.	ML
246-256	Silty sand, fine to coarse sand, poorly sorted - well graded, subangular.	SM
256-272	Sand, some silt, medium to coarse sand, poorly sorted - well graded, subangular.	SM
272-306	Sandy silt, fine grained sand, well sorted - poorly graded, subangular sand.	
306-318	Sandy silt, fine grained sand, well sorted, subangular to subrounded.	SM
318-328	Driller notes softer drilling at 318 ft. Start of silty sand. Continued soft to approximately 328 ft.	SM
328	Sandy silt as above, increasingly finer with depth.	SM
340-350	Sandy and clayey silt, cuttings balling up. Sand mostly fine, some medium gravel.	SM/SC
350-360	Sandy and clayey silt, as above.	n.r.
360-376	Silty clay, some medium sand, well sorted, subangular.	CL

Depth, ft bgs	Description	USCS Group
376-384	Sandy silt, some clay, fine to medium sand, subangular.	ML
384-408	Silty clay, some fine to medium sand, subangular.	CL
408-420	Silty sand, medium to coarse sand, poorly sorted, subrounded to subangular.	SM
420-480	Silty sand, medium to coarse sand, poorly sorted, subrounded to subangular.	SM
480-503	Silty sand, medium to coarse sand, poorly sorted, subrounded to subangular.	SM
503	Borehole Total Depth.	

n.r. = not recorded. The Unified Soil Classification System (USCS) symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well TJA-7

Drilling company	Layne Environmental Inc.
Dates of drilling	March 2-7, 2001
Drilling method	ARCH with cuttings logged. Also split-spoon cores from 45 to 47 ft, 95 to 97 ft, 145 to 147 ft, 195 to 197 ft, 245 to 247 ft, and 295 to 297 ft
Total depth of borehole, ft	316
Ground elevation, ft amsl NAVD 88	5388.4
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	290.5 to 310.5
Date well developed	March 12? 2001
Initial water level, ft bgs	298.70
Rig Geologist	Joe Fritts

Depth, ft bgs	Description	USCS Group
0-20	Sandy gravel, some caliche. Well sorted fine gravel, subrounded to subangular. Poorly sorted fine to coarse sand, subrounded to subangular. Dry.	GP
20-30	Sand, some fine gravel, poorly sorted fine to coarse sand. Sand and gravel subrounded to subangular, some caliche.	SW
30-40	Sand, poorly sorted fine to coarse sand, subangular, dry.	SW
40-50	Sandy gravel. Well sorted, fine subangular gravel. Poorly sorted, fine to coarse sand, subangular, dry.	GP
50-60	Sandy silt, well sorted, fine, subrounded sand, dry.	ML
60-78	Sand, poorly sorted, fine to coarse sand, subrounded to subangular, dry.	SW
78-82	Clayey silt, trace, fine sand, sand subrounded to subangular.	ML
82-115	Sandy gravel, mostly fine but some coarse, subangular to subrounded gravel. Poorly sorted sand, fine to medium, subrounded to subangular.	GP
115-126	Silt, some sand, poorly sorted sand, fine to coarse, subangular.	ML
126-145	Silty clay, some coarse subangular sand.	CL
145-147	Sandy gravel, poorly sorted, fine to coarse gravel, sand is fine to coarse poorly sorted, sand and gravel subangular.	GW
147-172	Silty sand, well sorted, fine, subrounded sand, trace coarse sand.	SM
172-175	Sandy gravel, well sorted, fine, subangular gravel. Sand is poorly sorted, fine to coarse, subrounded to subangular.	GP
175-200	Sandy silt, sand is fine, well sorted, subrounded, dry.	ML
200-240	Silty sand, some clay, sand is fine, well sorted, subrounded, slightly moist.	SM
240-260	Sand, some silt, poorly sorted, fine to coarse sand, subrounded to subangular, possible streaks of fine gravel.	SW
260-290	Silty sand, fine to medium sand, subrounded, moist.	SM
290-300	Silty sand, fine to medium sand, subrounded, moist.	SM
300-316	Clayey silt, very little returns.	ML
316	Borehole total depth.	

The Unified Soil Classification System (USCS) symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well cluster WYO-1 and WYO-2

Drilling company	USGS Water Sciences Division
Dates of drilling	August 15 - 27, 1995
Drilling method	Mud Rotary with cuttings logged. No cores. Both well casings were installed in a single borehole. Annular seal (grout) installed from 299 to 476 ft.
Total depth of borehole, ft	650
Ground elevation, ft amsl NAVD 88	5390.4
Completion zone	WYO-1: Regional Aquifer, in Santa Fe Group sediments WYO-2: Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs, WYO-1	510.0 to 560.0
Screen, ft bgs, WYO-2	265.0 to 285.0
Date well WYO-1 developed	August 28, 1995
Date well WYO-2 developed	September 26, 1995
Initial water level, ft bgs, WYO-1	513.42
Initial water level, ft bgs, WYO-2	272.90
Rig Geologist	Joe Fritts

Depth, ft bgs	Description from USGS combination log	USCS Group
0-10	Gravelly sand, coarse to very coarse sand, 10% gravel, no fines, possible fill (disturbed), 10YR 8/3, very pale brown.	SW
10-20	Silty sand, very fine sand to 20 mm, gravel in silt matrix, gravel 30%, 10YR 6/3 pale brown.	SM
20-30	Silty sand, fine to very fine sand. 10% gravel, well sorted, 10YR 6/3, pale brown.	SM
30-40	Gravel, fine to coarse grained to 50 mm, no silt, well graded, more than 50% fine pebbles. 10YR 8/3, very pale brown.	GW
40-80	Sandy to gravelly clay, probably interbedded clay and gravely sand, more than 50% fine to very fine sand. 10YR 6/3, pale brown, 10% gravel to 10mm, inconsistent drilling rate.	SC
80-100	Sand, well graded, very fine to very coarse-grained sand in silt matrix, more than 25%, minor clay, slightly sticky, 10YR 7/4, very pale brown.	SW
100-120	Silty sand, predominantly fine to very fine grained with 10% very coarse sand, minor clay, slightly sticky, slow drilling, 10YR 7/4 very pale brown.	SM
120-140	Clayey sand, predominantly fine to very fine sand grading to silt, minor very coarse angular sand, possibly gravel broken by bit, clay matrix, 10YR 7/4, very pale brown.	SC
140-150	Silty sand, fine and very coarse grained, decreasing fines, 10YR 7/4, very pale brown.	SM
150-160	Sand, very fine to very coarse sand, well graded, minor silt, high estimated hydraulic conductivity, 10YR 7/3, very pale brown.	SW
160-170	Sand, very coarse-grained sand in silt matrix, poorly sorted, grading to fine gravel, 10YR 7/3, very pale brown.	SP
170-180	Silty sand, very fine and very coarse grained, minor clay, 10YR 7/3, very pale brown.	SM
180-190	Sand, fine to coarse grained, well graded, minor silt and clay, 10YR 7/3, very pale brown.	SW

Depth, ft bgs	Description from USGS combination log	USCS Group
190-200	Clayey sand, fine to very fine grained, grading to silt; silty clay matrix, 10YR 6/4, light yellowish brown.	SC
200-220	Sand, coarse to very coarse, poorly sorted, only trace gravel and silt, very clean, high estimated hydraulic conductivity, 10YR 8/3, very pale brown.	SP
220-240	Sandy silt, fine to coarse, poorly sorted, subangular, minor fine, subangular gravel, 10YR 5/3 brown.	ML
240-270	Sandy silt to silty sand, fine to coarse, poorly sorted, subangular to subrounded, 10YR 7/4 very pale brown to 10YR 6/4, light yellowish brown, trace fine gravel.	SM
270-280	Silty clay, 10YR 6/3, pale brown, trace fine sand. Started coring at 279 ft. See separate description.	CL
280-290	Clayey silt, 10YR 6/3, pale brown, trace fine sand.	ML
290-360	Silty clay to sandy clay, 10YR 6/3 pale brown, trace silt and fine sand.	CL
360-370	Silty sand, medium to coarse, subrounded, 10YR 7/3, very pale brown.	SM
370-400	Silty sand, fine to coarse sand, subrounded, 10YR 7/2 light gray to 10YR 8/2, very pale brown, micaceous.	SM
400-440	Silty sand, fine to coarse, well graded, poorly sorted subrounded, 10YR 8/2 very pale brown to 10YR 7/1, light gray, trace fine sand, subrounded to subangular gravel.	SM
440-450	Clay, 10YR 7/3, very pale brown.	CL
450-460	Sandy silt, fine to coarse sand, subrounded, well graded, poorly sorted, 10YR 7/3, very pale brown.	ML
460-490	Silty sand, fine to coarse sand, subangular, poorly sorted, well graded, 10YR 7/3, very pale brown, trace fine gravel. Coring stopped at 470 ft.	SM
490-500	Silty clay, 10YR 7/3, very pale brown.	CL
500-510	Silty sand, fine, well sorted, poorly graded, subangular, 10YR 7/2, light gray	SM
510-520	Sandy silt, 10YR 7/3, very pale brown, fine sand, well sorted, poorly graded, subangular.	ML
520-530	Gravelly sand, fine to coarse, poorly sorted, well graded, subangular, 10YR 7/2, light gray, minor silt.	SW
530-540	Silty sand, fine to coarse sand, poorly sorted, well graded, subangular, 10YR 7/2, light gray, trace fine gravel.	SM
540-550	Silty clay, 10YR 7/3, very pale brown.	CL
550-650	Sandy silt to clayey silt, 10YR 7/3, very pale brown, fine to minor medium sand, well sorted, poorly graded, subangular.	ML
650	Borehole Total Depth.	

USCS = Unified Soil Classification System.

Lithologic log for borehole at monitoring well WYO-3

Drilling company	Water Development Corporation
Dates of drilling	July 24 – 31, 2001
Drilling method	ARCH with cuttings logged. No cores
Total depth of borehole, ft	555
Ground elevation, ft amsl NAVD 88	5390.0
Completion zone	Regional Aquifer, in Santa Fe Group sediments
Screen, ft bgs	520.0 to 540.0
Date well developed	October 10, 2001
Initial water level, ft bgs	524.04
Rig Geologist	Robert (Bob) Cooper

Depth, ft bgs	Description	USCS Group
0 - 5	Sandy silt, 30 to 40% medium to coarse sand, light brown.	ML
10	As above with 5 to 10% fine pebble gravel, less than 1% of 0.5 to 1-inch diameter, gravel, subangular.	ML
15	As above with 5 to 10% of 0.25 to 0.5-inch diameter gravel.	n.r.
20	As above with 10 to 20% of 0.25 to 0.5-inch diameter gravel.	ML
25	Silt, medium brown.	ML
30	Sandy silt, 10 to 20% medium to very coarse sand, light brown.	ML
35	As above with 5 to 10% of 0.25 to 0.5-inch diameter gravel.	ML
40	Slightly sandy silt, 5 to 10% medium to coarse sand.	ML
45	Slightly sandy silt, 5 to 10% medium to coarse sand.	ML
50	Slightly sandy silt, 5 to 10% medium to coarse sand.	ML
55	Slightly sandy silt, 5 to 10% medium to coarse sand.	ML
60	Slightly sandy silt, 5 to 10% medium to coarse sand.	ML
65	Slightly sandy silt, 5 to 10% medium to coarse sand.	ML
70	Slightly sandy silt, 5 to 10% medium to coarse sand.	ML
75	Slightly sandy silt, 5 to 10% medium to coarse sand.	ML
80	Slightly sandy silt, 5 to 10% medium to coarse sand.	ML
85	Slightly sandy, gravelly silt, 10% medium sand, 20 to 30% fine pebble gravel, medium brown, 7.5YR 5/4.	ML
90	Silty, sandy gravel, well graded, mostly 0.25 to 0.75-inch diameter, 20 to 25% silt, 20 to 30% sand, medium brown, 7.5YR 5/4.	GM
95	Silty sand, well graded, medium to very coarse sand, 30 to 40% silt, pale brown, 10YR 8/3.	SM
100	Slightly sandy silt, less than 5% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
105	Slightly sandy silt, less than 5% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
110	Gravelly silty sand, well graded, medium to coarse sand, 30 to 40% silt, 5 to 10% less than 0.25-inch diameter gravel, pale brown, 10YR 8/3.	SM
115	Slightly sandy, silt less than 5% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
120	Slightly sandy, silt less than 5% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
125	Slightly sandy, silt less than 5% medium to coarse sand, pale brown, 10YR 8/3.	ML
130	Slightly sandy, silt less than 5% medium to coarse sand, medium brown, 7.5YR 5/4.	ML

Depth, ft bgs	Description	USCS Group
135	Slightly sandy silt less than 5% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
140	Slightly sandy silt less than 5% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
145	Very silty sand, moderately graded, medium to coarse sand, subangular, 40 to 50% silt, pale brown, 10YR 8/3.	ML
150	Sandy silt, 10 to 20% medium to very coarse sand, medium brown, 7.5YR 5/4.	ML
155	Silty sandy gravel, well graded, fine pebble gravel mostly 0.25 to 0.75-inch diameter, with less than 5% being greater than 0.75-inch diameter, 20 to 30% medium to very coarse sand, 10% silt, subangular.	GW
160	Slightly sandy silt, less than 5% medium to coarse sand, medium brown, 7.5YR 5/4	ML
165	Sandy silt as above with more sand (less than 10%).	ML
170	As above, slightly more sand.	ML
175	As above with 10 to 20% sand.	ML
180	As above with 30 to 40% sand.	ML
185	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
190	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
195	Silty gravelly sand, well graded, medium to very coarse, 10 to 20% of 0.25 to 0.5-inch diameter fine pebble gravel, with 10 to 20% silt, subangular, pale brown.	SM
200	Slightly sandy silt, less than 5% medium to coarse sand, pale brown.	ML
205	Sandy silt, 40 to 50% medium to coarse sand, pale brown.	ML
210	Sandy silt, 40 to 50% medium to coarse sand, pale brown.	ML
215	Sandy silt, 40 to 50% medium to coarse sand, pale brown.	ML
220	Sandy silt, 40 to 50% medium to coarse sand, pale brown.	ML
225	Slightly sandy silt, less than 5% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
230	Slightly sandy silt, less than 5% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
235	Slightly sandy silt, less than 5% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
240	Slightly sandy silt, less than 5% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
245	Slightly sandy silt, less than 5% medium to coarse sand, medium brown, 7.5YR 5/4.	ML
250	Sandy silt, 10 to 20% medium to coarse sand and trace of gravel (less than 5% of 0.25-inch diameter gravel).	ML
255	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
260	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
265	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
270	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
275	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
280	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
285	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
290	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
295	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
300	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
305	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
310	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
315	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML

Depth, ft bgs	Description	USCS Group
320	Slightly sandy silt, less than 5% medium to coarse sand, medium brown.	ML
325	Sandy and clayey silt, 10 to 20% medium to coarse sand with varying clay content. Using composite 20-foot samples because cuttings are not being blown into the Cyclone until reaching the bottom of the 20-foot run. Pale brown, 10YR 8/3. Injecting water to lift cuttings to surface.	ML
335	Sandy and clayey silt to sandy and silty clay, low plasticity. Composite 20 foot samples of cuttings, light to medium brown, 7.5YR 6/6 to 7.5YR 5/4. Cyclone clogging up.	n.r.
350	Gravel zone between 330 ft and 350 ft.	n.r.
365	As above, interbedded sand and gravel zones, thin beds.	ML
395	Interbedded sand and gravel zones, thin beds. Cuttings still mixed.	ML
425	Interbedded sand and gravel zones, thin beds.	ML
455	Interbedded sand and gravel zones, thin beds.	ML
470	Gravel, well graded pebble gravel 0.25 to 2.5-inch diameter, subangular, clean, dry.	GW
475	Sandy clayey silt, medium brown, 7.5YR 5/4, samples are clayey and still hard to bring up, clogging up Cyclone at 480 ft.	ML
485	Sandy clayey silt, medium brown, 7.5YR 5/4, samples are clayey and still hard to bring up.	ML
515	Sandy clayey silt, medium brown, 7.5YR 5/4, samples are clayey and still hard to bring up.	ML
545	As above with increasing sand content but still mostly clayey silt.	ML
555	Borehole Total Depth.	

n.r. = not recorded. The Unified Soil Classification System (USCS) symbol was not recorded on the original lithologic log or field notes.

Lithologic log for borehole at monitoring well WYO-4

Drilling company	Water Development Corporation
Dates of drilling	July 21 – 23, 2001
Drilling method	ARCH with cuttings logged. No cores
Total depth of borehole, ft	305
Ground elevation, ft amsl NAVD 88	5390.2
Completion zone	Perched Groundwater System, in Santa Fe Group sediments
Screen, ft bgs	275.0 to 295.0
Date well developed	October 16, 2001
Initial water level, ft bgs	276.30
Rig Geologist	Robert (Bob) Cooper

Depth, ft bgs	Description	USCS Group
5	Silty sand, poorly graded, medium to coarse graded, subangular, very pale brown, 10YR 8/3.	SM
10	Caliche-hard white calcium carbonate containing medium to coarse sand, 10YR 8/1.	n.r.
15	Silty gravel sand, well graded, fine to very coarse grained subangular, very pale brown, less than 10%, silt and gravel, 10YR 8/3.	SM
20	Sandy silt, 20-30% medium- to coarse-grained sand.	ML
25	Slightly sandy silt, less than 10%, fine to medium sand, pale brown, 10YR 6/3.	n.r.
30	Silty gravelly sand, well graded fine to very coarse sand with less than 10% fine gravel and minor silt.	SM
35	Slightly silty, sandy gravel, well graded, fine to medium gravel with 30 to 40% medium to coarse sand, all subangular, minor silt, very pale brown, 10YR 8/3.	GM-GW
40	As above.	GM-GW
45	Sandy silt, 20 to 30% fine to medium sand, subangular, light brown, 7.5YR 6/4.	ML
50	Silt, light brown, 7.5YR 6/4.	ML
55	Silt, pale brown, 10YR 8/3.	ML
60	Silt as above.	ML
65	Silt, pale brown as above.	ML
70	Silt, brownish yellow, 10YR 6/6.	ML
75	Clayey silt, light brown, more consistent than above, 7.5YR 6/4.	ML
80	Slightly sandy silt, less than 10% sand, pale brown, 10YR 8/3.	ML
85	Sandy silt, 20 to 30% sand, fine- to medium-grained, subangular, light brown, 7.5YR 6/6.	ML
90	Clayey silt, light brown, 7.5YR 6/6.	ML
95	Silty, gravelly, sand, well-graded, fine to coarse grained, subangular with 20 to 30% fine gravel.	SM
100	As above but contains 30 to 40% fine to medium gravel.	SM
105	Silt, trace sand and gravel, medium brown, 7.5YR 5/4.	ML
110	As above, trace sand, no gravel.	ML
115	Silty sand, poorly graded, medium to coarse grained subangular, trace gravel.	SM
120	Silt, reddish brown, 2.5YR 4/6 to 2.5YR 4/8.	ML
125	Silt, pale brown with less than 1% medium sand, 10YR 8/3.	ML
130	Silt as above.	ML
135	Silt as above.	ML
140	Silt as above.	ML

Depth, ft bgs	Description	USCS Group
145	As above but light brown, 7.5YR 6/4.	ML
150	Silty, gravelly sand, well graded, fine to coarse grained, subangular with 10-20% fine gravel.	SM
155	Clayey silt, less than 10% clay, light brown, 7.5YR 6/7	ML
160	Silty sand, poorly graded, fine to medium grained, subangular, very pale brown, 10YR 7/4.	SP-SM
165	Silt, light brown, 7.5YR 6/4.	ML
170	Silt as above.	ML
175	Silt, brownish yellow, 10YR 6/8.	ML
180	Clayey silt, less than 10% clay light brown, 7.5YR 6/4.	ML
185	Silty, gravelly sand, well graded, fine to medium grained with less than 10% coarse grained sand and fine gravel 20-30% silt, subangular.	SW
190	Slightly sandy silt, 10-20% fine grained sand, light brown, 7.5YR 6/4.	ML
195	Sand, well graded, fine- to coarse-grained, subangular.	SW
200	Slightly sandy silt, coarse grained sand, light brown, 7.5 YR6/4.	ML
205	As above.	ML
210	Sand, well graded, fine to very coarse, subangular.	SW
215	Silt, yellowish brown, 10YR 5/8.	ML
220	Silt as above.	ML
225	Silt, medium brown, 7.5YR 5/4.	ML
230	Silty sand, well graded, fine to very coarse, subangular.	SM
235	Silt, light brown, 7.5YR 6/4.	ML
240	Silt, yellowish brown, 10YR 5/8.	ML
245	Sandy silt, 30 to 40% fine sand medium brown, 7.5YR 5/4.	ML
250	Clayey silt, low plasticity, medium brown, 7.5YR 5/4.	ML
255	Sandy silt, 10 to 20% fine to medium sand, medium brown, 7.5YR 5/4.	ML
260	Slightly silty sand, moderately graded, mostly medium sand, containing 10 to 20% very fine to fine sand.	SP-SM
265	Silt to clayey silt, increasing clay content from very slightly clayey at 265 ft to clayey at 290 ft, medium brown, 7.5YR 6/4.	ML
275	Clayey silt, medium brown, 7.5YR 5/4.	ML
280	As above with slightly more clay.	ML
285	As above with slightly more clay.	ML
290	As above with slightly more clay.	ML
295	Clayey to silty, gravely sand. Coarse to very coarse sand with 10 to 20% fine sand and silt, and 10-20% clay (sticky).	SM
300	Silty and gravelly sand to coarse grained and with less than 10% fine gravel, subangular.	SM
305	Borehole Total Depth.	

USCS = Unified Soil Classification System.

Unified Soil Classification System

Compiled by B. W. Pipkin, University of Southern California

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS More than half of material is larger than no. 200 sieve size.	GRAVELS More than half of coarse fraction is larger than no. 4 sieve size.	Clean gravels	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.
		Gravels with fines	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures.
	SANDS More than half of coarse fraction is smaller than no. 4 sieve size.	Clean sands	SW	Well-graded sands, gravelly sands, little or no fines.
			SP	Poorly graded sands, gravelly sands, little or no fines.
		Sands with fines	SM	Silty sands, sand-silt mixtures.
			SC	Clayey sands, sand-clay mixtures.
FINE-GRAINED SOILS More than half of material is smaller than no. 200 sieve size.	SILTS AND CLAYS	Low liquid limit.	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts, with slight plasticity.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL	Organic silts and organic silty clays of low plasticity.
		High liquid limit.	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays.
			OH	Organic clays of medium to high plasticity, organic silts.
Highly organic soils			Pt	Peat and other highly organic silts.

NOTES:

1. Boundary Classification: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example, GW-GC, well-graded gravel-sand mixture with clay binder.
2. All sieve sizes on this chart are U.S. Standard.
3. The terms "silt" and "clay" are used respectively to distinguish materials exhibiting lower plasticity from those with higher plasticity. The minus no. 200 sieve material is silt if the liquid limit and plasticity index plot below the "A" line on the plasticity chart (next page), and is clay if the liquid limit and plasticity index plot above the "A" line on the chart.
4. For a complete description of the Unified Soil Classification System, see "Technical Memorandum No. 3-357," prepared for Office, Chief of Engineers, by Waterways Equipment Station, Vicksburg, Mississippi, March 1953. (See also Data Sheet 29.)

First published by GSA Engineering Geology Division.

AGI-DS-rvd-82

ATTACHMENT 6
Well Diagrams for Monitoring Wells near the TAG AOC

Well Name: EUBANK-1
Project Name: COA ENVIRON. HEALTH
NMOSE Well File Code:
Owner Name: CITY OF ALBUQUERQUE
Date Drilling Started: JUL 11, 1988
Date Well Dev. Completed: JUL 16, 1988

Drilling Contractor: RODGERS AND COMPANY
Drilling Method: MUD ROTARY
Borehole Depth (FBGS): 630.00
Casing Depth (FBGS): 615.00
Geo Location: NW CRN INACT EUBANK LANDFILL
Completion Zone: SILTY SANDY GRAVEL
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date:
Surveyed By: COA
State Plane Coordinates: NAD 83
(X) Easting: 1555458.59
(Y) Northing: 1473430.27

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing:
Top of Inner Well Casing: 5460.02
Concrete Pad:
Ground Surface: 5458.1

Calculated Depths and Elevations

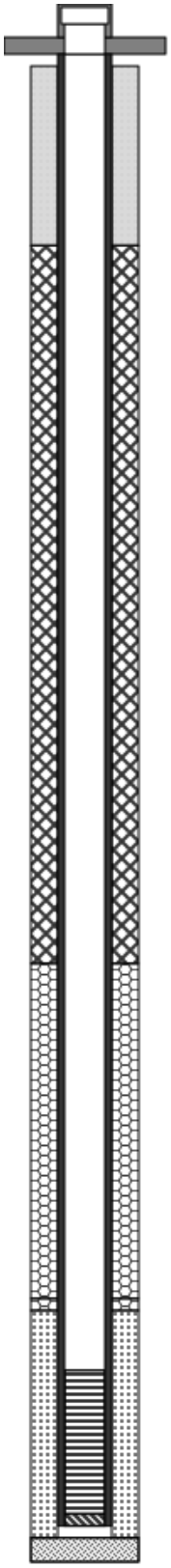
Initial Depth to Water (FBGS) 552.00
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 4913.27
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.): 0.02
Date Updated: 07-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

GRADUAL WATER LEVEL DECLINE OF SLIGHTLY OVER 1 FOOT IN 1990. 0-5 FT CEMENT SEAL. SNL MONITORS WATER QUALITY. WATER LEVEL ELEVATION DOES NOT MATCH HYDROGRAPH IN WELL FILE JANUARY 2010--DATA TRANSMITTED TO NMED/HWB INCLUDED A TOP OF PVC CASING ELEVATION OF 5457.35 FT AMSL. THIS IS BASED ON RECORDS RESEARCH CONDUCTED BY M. SANDERS IN DECEMBER 2009. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2

Interval	Material	Start	Stop	Length	ID	OD
SCREEN	STAINLESS STEEL	550.0	610.0	60.0	4	
BOREHOLE		0.0	630.0	630.0	8	
GROUT/BACKFILL	GROUT	5.0	80.0	75.0		
SEAL	BENTONITE	80.0	380.0	300.0		
SECONDARY GRO...	GROUT	380.0	520.0	140.0		
SECONDARY GRO...	BENTONITE	520.0	525.0	5.0		
PRIMARY PACK	10/20 SILICA SAND	525.0	620.0	95.0		
SUMP	STAINLESS STEEL	610.0	615.0	5.0		
PLUG BACK	NATURAL BACKF...	620.0	630.0	10.0		
CASING	STAINLESS STEEL	0.0	615.0	615.0	4	4.5

Well Name: PGS-1
Project Name: SWHC
NMOSE Well File Code:
Owner Name: SNL/NM
Date Drilling Started: JUL 21, 1994
Date Well Dev. Completed: OCT 12, 1994

Drilling Contractor: USGS
Drilling Method: MUD ROTARY
Borehole Depth (FBGS): 750.00
Casing Depth (FBGS): 538.00
Geo Location: TA-I NORTH OF KAFB
Completion Zone: SANDY GRAVEL AND SILTY SAND
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date: NOV 14, 1994
Surveyed By: GREINER
State Plane Coordinates: NAD 83
(X) Easting: 1550727.28
(Y) Northing: 1475413.94

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5407.87
Top of Inner Well Casing: 5407.41
Concrete Pad: 5407.87
Ground Surface: 5407.9

Calculated Depths and Elevations

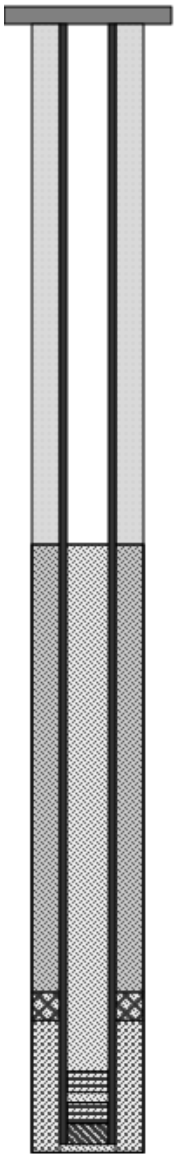
Initial Depth to Water (FBGS) 524.00
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 4878.89
Date Last Measured: JAN 24, 1996

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 07-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

WATER LEVEL DECLINES BELOW SCREEN. PLUGGED AND ABANDONED APRIL 98. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup:

Interval	Material	Start	Stop	Length	ID	OD
GROUT/BACKFI...	VOLCLAY SLURRY	0.0	465.0	465.0		
PRIMARY PACK	10/20 SILICA SAND	478.5	542.0	63.5		
SUMP	STAINLESS STEEL	528.0	538.0	10.0	5	
BOREHOLE	STAINLESS STEEL	0.0	750.0	750.0		9.875
SCREEN	STAINLESS STEEL	503.0	513.0	10.0	5	
SEAL	BENTONITE PELL...	465.0	478.5	13.5		
PLUG BACK	BENTONITE PELL...	542.0	750.0	-292.0		
SCREEN	STAINLESS STEEL	518.0	528.0	10.0	5	
CASING	STAINLESS STEEL	0.0	538.0	538.0	5	

Plugged and Abandoned

Well Name: PGS-2
Project Name: SWHC
NMOSE Well File Code: RG-90065, Point of Diversion: 43
Owner Name: SNL/NM
Date Drilling Started: SEP 09, 1995
Date Well Dev. Completed: SEP 22, 1995

Drilling Contractor: USGS
Drilling Method: MUD ROTARY
Borehole Depth (FBGS): 660.00
Casing Depth (FBGS): 655.00
Geo Location: SOUTH OF PARADE GROUNDS
Completion Zone: SILTY SAND
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date: OCT 27, 1995
Surveyed By: GREINER, INC.
State Plane Coordinates: NAD 83
(X) Easting: 1550727.55
(Y) Northing: 1475443.08

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5408.66
Top of Inner Well Casing: 5408.29
Concrete Pad: 5407.94
Ground Surface: 5407.9

Calculated Depths and Elevations

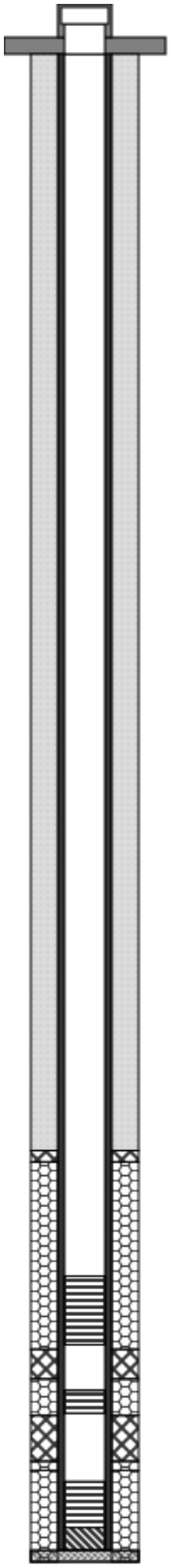
Initial Depth to Water (FBGS) 546.30
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 4872.18
Date Last Measured: OCT 03, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 14-DEC-17
Date Printed from EDMS: DEC 14, 2017

Comments:

REPLACEMENT WELL. 3 SCREEN INTERVALS (535-565,585-595,625-645) SEPARATED BY BENTONITE CHIPS. VIDEO LOGGED ON 10/20/2017 BY ERFO; MUCH CORROSION AND/OR BIOFOULING ON UPPER SCREEN, ALL THREE SCREENS HAVE MUCH GROUT INTRUSION WITH ABOUT 8 FT. OF GROUT IN SUMP. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 0.4

Interval	Material	Start	Stop	Length	ID	OD
CASING	SS, SCH 80	0.0	655.0	655.0	5	
GROUT/BACKFI...	VOLCLAY	0.0	480.0	480.0		
SEAL	BENTONITE PELL...	480.0	485.0	5.0		
SAND PACK	10/20 SAND	485.0	567.0	82.0		
SEAL	BENTONITE CHIPS	567.0	580.0	13.0		
SAND PACK	10/20 SAND	580.0	596.0	16.0		
SEAL	BENTONITE CHIPS	596.0	616.0	20.0		
SAND PACK	16/40 SAND	616.0	620.0	4.0		
SAND PACK	10/20 SAND	620.0	660.0	40.0		
SCREEN	SS, SCH 80	535.0	565.0	30.0	5	
SCREEN	SS, SCH 80	585.0	595.0	10.0	5	
SCREEN	SS, SCH 80	625.0	645.0	20.0	5	
SUMP	SS, SCH 80	645.0	655.0	10.0	5	
PLUG BACK	10/20 SAND	655.0	660.0	5.0		
BOREHOLE		0.0	660.0	660.0		9.625

Well Name: TA1-W-01
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 60
Owner Name: SNL/NM
Date Drilling Started: MAR 06, 1997
Date Well Dev. Completed: MAR 22, 1997

Drilling Contractor: WATER DEVELOPMENT CORPORATION
Drilling Method: AIR ROTARY-CASING HAMMER
Borehole Depth (FBGS): 613.00
Casing Depth (FBGS): 600.00
Geo Location: TA-I
Completion Zone: SILTY SAND AND GRAVEL
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date: MAY 23, 1997
Surveyed By: GREINER, INC.
State Plane Coordinates: NAD 83
(X) Easting: 1550618.99
(Y) Northing: 1472486.16

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5404.53
Top of Inner Well Casing: 5403.82
Concrete Pad: 5402.06
Ground Surface: 5401.8

Calculated Depths and Elevations

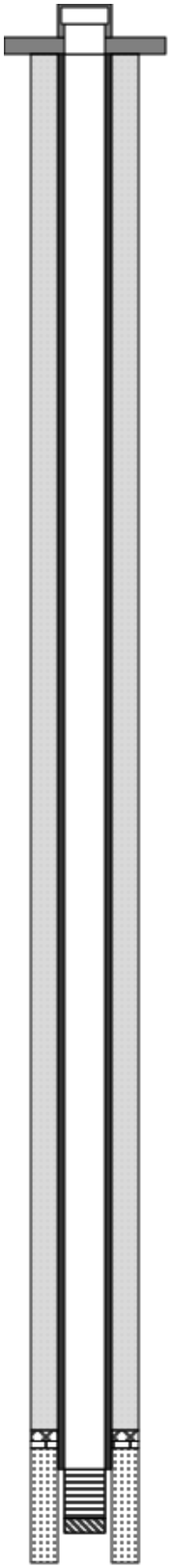
Initial Depth to Water (FBGS) 539.57
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 4870.58
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 07-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.1

Interval	Material	Start	Stop	Length	ID	OD
CASING	PVC SCHEDULE 80	0.0	575.0	575.0	4.75	5.62
GROUT/BACKFILL	VOLCLAY GROUT	0.0	559.2	559.2		
SEAL	1/4" BENT PELLE...	559.2	563.6	4.4		
SECONDARY PA...	30-70 SILICA SAND	563.6	566.5	2.9		
PRIMARY PACK	10-20 SILICA SAND	566.5	613.0	46.5		
SCREEN	PVC SCHEDULE 80	575.0	595.0	20.0	4.75	
SUMP	SCHEDULE 80 PVC	595.0	600.8	5.8	4.75	
BOREHOLE		0.0	613.0	613.0		10
null		0.0	0.0	0.0		

Well Name: TA1-W-02
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 61
Owner Name: SNL/NM
Date Drilling Started: FEB 11, 1998
Date Well Dev. Completed: FEB 27, 1998

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: AIR ROTARY/CASING HAMMER
Borehole Depth (FBGS): 578.00
Casing Depth (FBGS): 565.60
Geo Location: TA-1
Completion Zone: SANDS,GRAVELS, CLAY
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date: APR 09, 1998
Surveyed By: SANTIAGO ROMERO JR.
State Plane Coordinates: NAD 83
(X) Easting: 1552539.22
(Y) Northing: 1471982.04

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5416.90
Top of Inner Well Casing: 5416.62
Concrete Pad: 5416.90
Ground Surface: 5416.9

Calculated Depths and Elevations

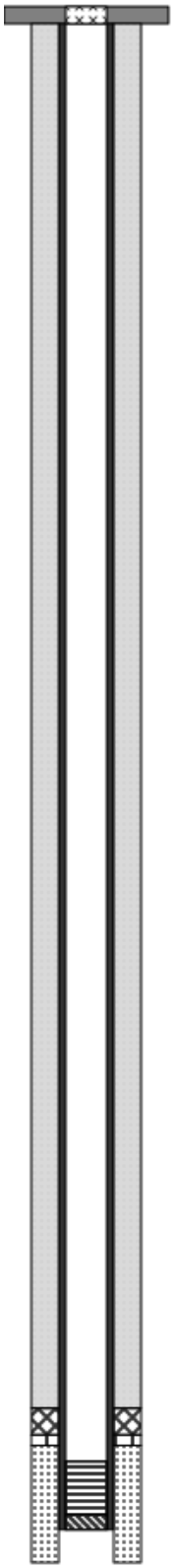
Initial Depth to Water (FBGS) 528.40
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 4896.87
Date Last Measured: OCT 03, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

WELL HAS VAULT IN PAVED PARKING LOT.
1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: -0.3

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		200.0	578.0	378.0		10
CASING	5" SCH. 80 PVC	0.0	565.6	565.6	5	5.5
GROUT/BACKFILL	BENTONITE PELLE...	0.0	520.0	520.0		
SEAL	1/4" BENT. PELLETS	520.0	530.0	10.0		
SECONDARY PA...	30/70 SILICA SAND	530.0	534.0	4.0		
SCREEN	SCHEDULE 80 PVC	540.0	560.0	20.0	5	
SUMP	SCHEDULE 80 PVC	560.0	565.6	5.6	5	
BOREHOLE		0.0	200.0	200.0		12
PRIMARY PACK	10/20 SILICA SAND	534.0	578.0	44.0		

Well Name: TA1-W-03
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 62
Owner Name: SNL/NM
Date Drilling Started: JAN 19, 1998
Date Well Dev. Completed: JAN 27, 1998

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: AIR ROTARY/CASING HAMMER
Borehole Depth (FBGS): 363.00
Casing Depth (FBGS): 362.60
Geo Location: TA-1
Completion Zone: SANDS, GRAVELS,CLAY
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: APR 09, 1998
Surveyed By: SANTIAGO ROMERO JR.
State Plane Coordinates: NAD 83
(X) Easting: 1555303.70
(Y) Northing: 1473270.46

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5457.58
Top of Inner Well Casing: 5457.03
Concrete Pad: 5455.33
Ground Surface: 5454.9

Calculated Depths and Elevations

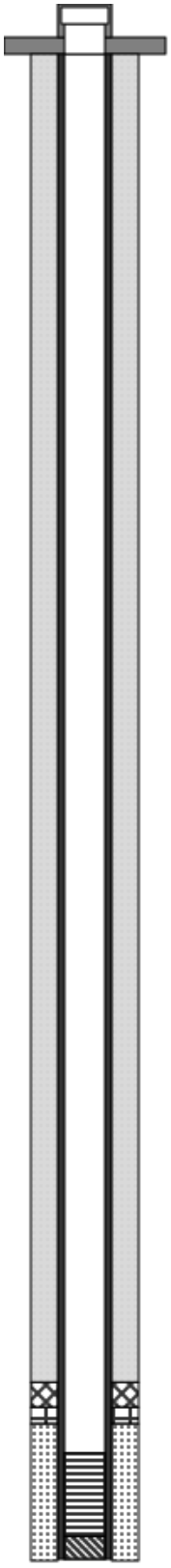
Initial Depth to Water (FBGS) 337.74
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5100.19
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

2/17/10 - WELL RE-DEVELOPED ON FEB. 8 AND 9, 2010. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.2

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		100.0	363.0	263.0		10
CASING	5" SCH. 80 PVC	0.0	362.6	362.6	5	5.5
GROUT/BACKFILL	BENTONITE GROUT	0.0	320.0	320.0		
SEAL	1/4" BENT. PELLETS	320.0	326.0	6.0		
SECONDARY PACK	30/70 SILICA SAND	326.0	330.0	4.0		
PRIMARY PACK	10/20 SILICA SAND	330.0	363.0	33.0		
SUMP	SCH. 80 PVC	357.0	362.6	5.6	5	
BOREHOLE		0.0	100.0	100.0		12
SCREEN	SCH. 80 PVC	337.0	357.0	20.0	5	

Well Name: TA1-W-04
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 63
Owner Name: SNL/NM
Date Drilling Started: SEP 08, 1998
Date Well Dev. Completed: OCT 06, 1998

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: AIR ROTARY/CASING HAMMER
Borehole Depth (FBGS): 630.00
Casing Depth (FBGS): 601.70
Geo Location: SW CORNER EUBANK AND G AVENUE
Completion Zone: SILTY GRAVELLY SAND
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date: JAN 15, 1999
Surveyed By: BOHANNAN HUSTON INC.
State Plane Coordinates: NAD 83
(X) Easting: 1555059.04
(Y) Northing: 1474770.57

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5461.37
Top of Inner Well Casing: 5460.98
Concrete Pad: 5458.33
Ground Surface: 5458.3

Calculated Depths and Elevations

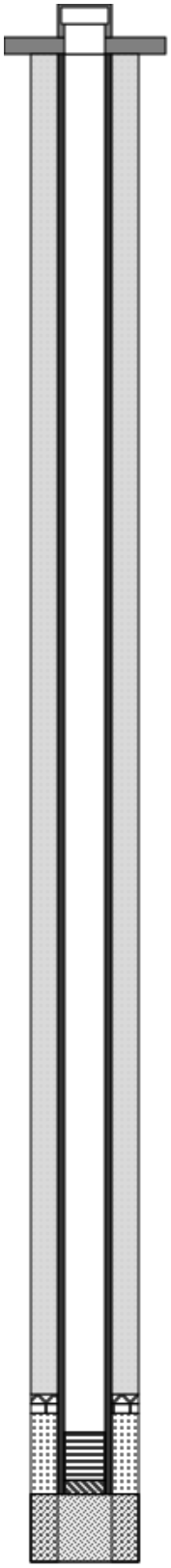
Initial Depth to Water (FBGS) 572.00
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 4894.65
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

DRILLED AT 3 LOCATIONS BEFORE BOREHOLE WAS SUCCESSFULLY COMPLETED. NO PROBLEMS WITH WELL. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.7

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	630.0	630.0		9.625
CASING	SCH. 80 PVC	0.0	601.7	601.7	5	5.5
SEAL	3/8" BENTONITE P...	560.0	564.0	4.0		
SECONDARY PA...	30/70 SILICA SAND	564.0	568.0	4.0		
PRIMARY PACK	10/20 SILICA SAND	568.0	630.0	62.0		
SCREEN	SCH. 80 PVC	576.0	596.0	20.0	5	
PLUG BACK	10/20 SILICA SAND	601.7	630.0	28.3		
GROUT/BACKFI...	BENTONITE GROUT	0.0	560.0	560.0		
SUMP	SCH. 80 PVC	596.0	601.7	5.7	5	

Well Name: TA1-W-05
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 64
Owner Name: SNL/NM
Date Drilling Started: OCT 08, 1998
Date Well Dev. Completed: NOV 16, 1998

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: AIR ROTARY/CASING HAMMER
Borehole Depth (FBGS): 625.00
Casing Depth (FBGS): 623.20
Geo Location: N. SIDE F AVENUE
Completion Zone: FINE COARSE SAND
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date: JAN 15, 1999
Surveyed By: BOHANNAN HUSTON, INC.
State Plane Coordinates: NAD 83
(X) Easting: 1553004.41
(Y) Northing: 1475445.21

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5434.21
Top of Inner Well Casing: 5433.84
Concrete Pad: 5434.14
Ground Surface: 5434.2

Calculated Depths and Elevations

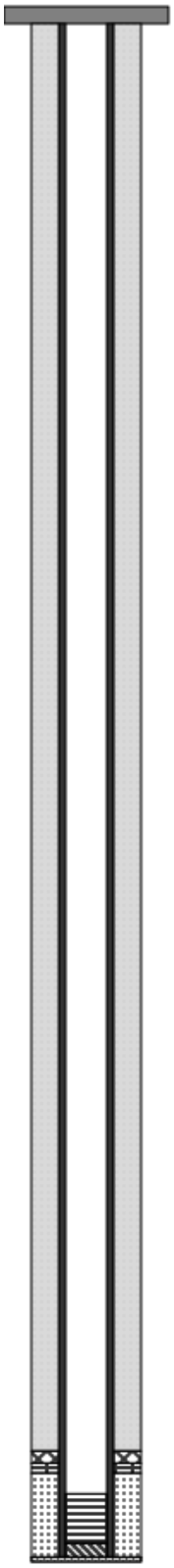
Initial Depth to Water (FBGS) 575.62
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 4873.94
Date Last Measured: OCT 03, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

DRILLED AT 2 LOCATIONS BEFORE BOREHOLE COMPLETED. CASING INSTALLED AT 1ST LOCATION WAS ABANDONED DUE TO DROPPED TREMIE. NO PROBLEMS ENCOUNTERED DURING 2ND INSTALLATION. 4/15/10 - RISER_LENGTH NOT CALCULATED BUT OBTAINED FROM OTHER SOURCES. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup:

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	625.0	625.0		9.625
CASING	SCH. 80 PVC	0.0	623.2	623.2	5	5.5
GROUT/BACKFI...	BENTONITE GROUT	0.0	580.0	580.0		
SECONDARY PA...	30/70 SILICA SAND	585.0	589.0	4.0		
PRIMARY PACK	10/20 SILICA SAND	589.0	623.2	34.2		
SCREEN	SCH. 80 PVC	597.5	617.5	20.0	5	
SUMP	SCH. 80 PVC	617.5	623.2	5.7	5	
SEAL	3/8" BENTONITE P...	580.0	585.0	5.0		
PLUG BACK	10/20 SILICA SAND	623.2	625.0	1.8		

Well Name: TA1-W-06
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 65
Owner Name: SNL/NM
Date Drilling Started: FEB 24, 1998
Date Well Dev. Completed: FEB 27, 1998

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: AIR ROTARY/CASING HAMMER
Borehole Depth (FBGS): 330.00
Casing Depth (FBGS): 325.60
Geo Location:
Completion Zone: SANDS, GRAVELS, CLAY
Completion Formation: SANTA FE GROUP-PERCHED SYSSTEM

Survey Data

Survey Date: APR 09, 1998
Surveyed By: SANTIAGO ROMERO JR.
State Plane Coordinates: NAD 83
(X) Easting: 1552576.98
(Y) Northing: 1471981.88

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5417.38
Top of Inner Well Casing: 5417.10
Concrete Pad: 5417.38
Ground Surface: 5417.4

Calculated Depths and Elevations

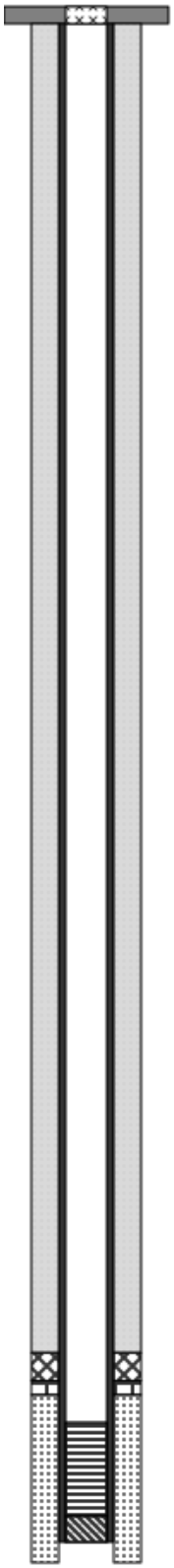
Initial Depth to Water (FBGS) 299.75
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5108.22
Date Last Measured: OCT 03, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

WELL VAULT IN TA-1 PAVED PARKING LOT.
1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: -0.3

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	330.0	330.0		10
CASING	SCH. 80 PVC	0.0	325.6	325.6	5	5.5
GROUT/BACKFILL	BENTONITE GROUT	0.0	285.0	285.0		
SEAL	1/4" BENT. PELLETS	285.0	291.0	6.0		
SECONDARY PACK	30/70 SILICA SAND	291.0	294.0	3.0		
PRIMARY PACK	10/20 SILICA SAND	294.0	330.0	36.0		
SCREEN	SCH. 80 PVC	300.0	320.0	20.0	5	
SUMP	SCH. 80 PVC	320.0	325.6	5.6	5	

Well Name: TA1-W-07
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 66
Owner Name: SNL/NM
Date Drilling Started: AUG 11, 1998
Date Well Dev. Completed: DEC 03, 1998

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: AIR ROTARY/CASING HAMMER
Borehole Depth (FBGS): 290.00
Casing Depth (FBGS): 289.10
Geo Location: TA-1
Completion Zone: SILTY CLAYEY SAND
Completion Formation: SANTA FE GROUP- PERCHED SYSTEM

Survey Data

Survey Date: JAN 15, 1999
Surveyed By: BOHANNAN HUSTON, INC.
State Plane Coordinates: NAD 83
(X) Easting: 1550691.83
(Y) Northing: 1472485.96

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5405.41
Top of Inner Well Casing: 5404.92
Concrete Pad: 5402.80
Ground Surface: 5402.8

Calculated Depths and Elevations

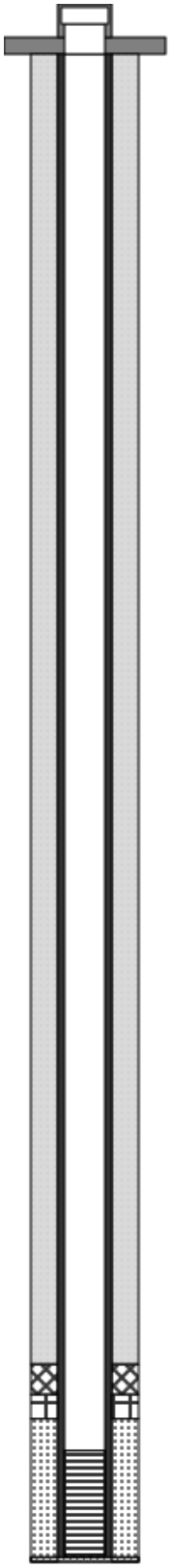
Initial Depth to Water (FBGS) 274.00
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5118.50
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

VERY LOW PRODUCER. NO PROBLEMS ENCOUNTERED DURING WELL INSTALLATION.
1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.2

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	290.0	290.0		9.625
GROUT/BACKFI...	BENTONITE GROUT	0.0	252.0	252.0		
SEAL	3/8" BENTONITE P...	252.0	257.8	5.8		
PRIMARY PACK	10/20 SILICA SAND	262.5	290.0	27.5		
PLUG BACK	10/20 SILICA SAND	289.1	290.0	0.9		
SUMP	SCH. 80 PVC	288.6	289.1	0.5	5	
CASING	SCH. 80 PVC	0.0	289.1	289.1	5	5.5
SCREEN	SCH. 80 PVC	268.6	288.6	20.0	5	
SECONDARY PA...	30/70 SILICA SAND	257.8	262.5	4.7		

Well Name: TA1-W-08
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 67
Owner Name: SNL/NM
Date Drilling Started: AUG 01, 2001
Date Well Dev. Completed: OCT 10, 2001

Drilling Contractor: WATER DEVELOPMENT CORP
Drilling Method: ARCH
Borehole Depth (FBGS): 335.00
Casing Depth (FBGS): 327.00
Geo Location: NORTH EDGE OF TA-1
Completion Zone: SILTY SAND GRAVELLY SAND
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: OCT 05, 2001
Surveyed By: V. JIRIK
State Plane Coordinates: NAD 83
(X) Easting: 1553032.72
(Y) Northing: 1475437.51

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5434.68
Top of Inner Well Casing: 5434.19
Concrete Pad: 5434.63
Ground Surface: 5434.7

Calculated Depths and Elevations

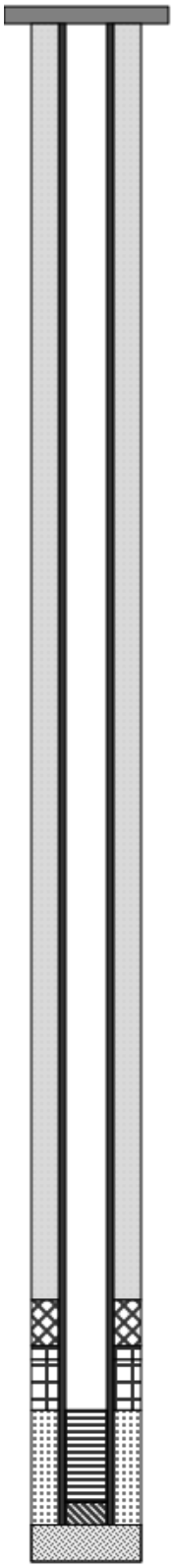
Initial Depth to Water (FBGS) 306.70
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5122.43
Date Last Measured: OCT 03, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

NORTH OF TA-I AND EAST OF PARADE GROUND. RISER_LENGTH NOT CALCULATED BUT OBTAINED FROM OTHER SOURCES - 4/15/10. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup:

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	335.0	335.0		10
CASING	SCHEDULE 80 PVC	0.0	327.0	327.0	4.5	5
GROUT/BACKFI...	WYO-BEN GROUT	0.0	278.0	278.0		
SEAL	3/8" BENTONITE CH...	278.0	288.0	10.0		
SECONDARY PA...	30/70 SILICA SAND	288.0	291.0	3.0		
SECONDARY PA...	2/12 SILICA SAND	291.0	302.0	11.0		
PRIMARY PACK	10/20 SILICA SAND	302.0	327.0	25.0		
SCREEN	SCHEDULE 80 PVC	302.0	322.0	20.0	4.5	
SUMP	SCHEDULE 80 PVC	322.0	327.0	5.0	4.5	
PLUG BACK	BOREHOLE SLOUGH	327.0	335.0	8.0		

Well Name: TA2-NW1-325
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 68
Owner Name: SNL/NM
Date Drilling Started: MAR 07, 1993
Date Well Dev. Completed: APR 01, 1993

Drilling Contractor: USGS
Drilling Method: AIR ROTARY/DRIVE CASING
Borehole Depth (FBGS): 330.90
Casing Depth (FBGS): 330.30
Geo Location: NW CORNER TA-II
Completion Zone: SAND
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: NOV 09, 1993
Surveyed By: GREINER
State Plane Coordinates: NAD 83
(X) Easting: 1553085.06
(Y) Northing: 1470842.87

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5422.50
Top of Inner Well Casing: 5421.94
Concrete Pad: 5419.98
Ground Surface: 5420.0

Calculated Depths and Elevations

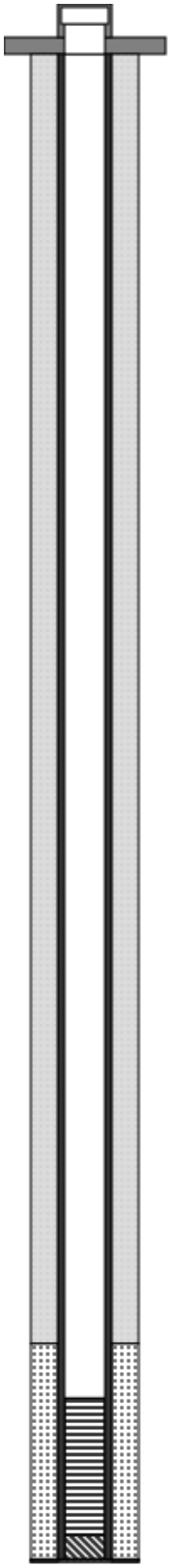
Initial Depth to Water (FBGS) 306.54
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5102.45
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.): 0.01
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 13, 2017

Comments:

CONTINOUS SONIC WITH DRIVE CASING TO 330 FBGS. WATER LEVEL MEASURED ON 07-OCT-93.
1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: 2

Interval	Material	Start	Stop	Length	ID	OD
SCREEN	SCH 80 PVC	295.0	325.0	30.0	4.75	
BOREHOLE		0.0	330.9	330.9		11
PLUG BACK		330.3	330.9	0.6		
SUMP	SCH 80 PVC	325.0	330.3	5.3	4.75	
CASING	SCH 80 PVC	0.0	330.3	330.3	4.75	5.563
GROUT/BACKFI...	VOLCLAY	0.0	283.0	283.0		
PRIMARY PACK	40/60 MESH SILI...	283.0	330.9	47.9		

Well Name: TA2-NW1-595
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 69
Owner Name: SNL/NM
Date Drilling Started: MAY 17, 1993
Date Well Dev. Completed: JUL 27, 1993

Drilling Contractor: USGS
Drilling Method: AIR ROTARY AND SONIC-DC
Borehole Depth (FBGS): 650.00
Casing Depth (FBGS): 598.00
Geo Location: NW CORNER TA-II
Completion Zone: SAND
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date: NOV 09, 1993
Surveyed By: GREINER
State Plane Coordinates: NAD 83
(X) Easting: 1553073.76
(Y) Northing: 1470855.03

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5421.92
Top of Inner Well Casing: 5421.26
Concrete Pad: 5419.95
Ground Surface: 5420.0

Calculated Depths and Elevations

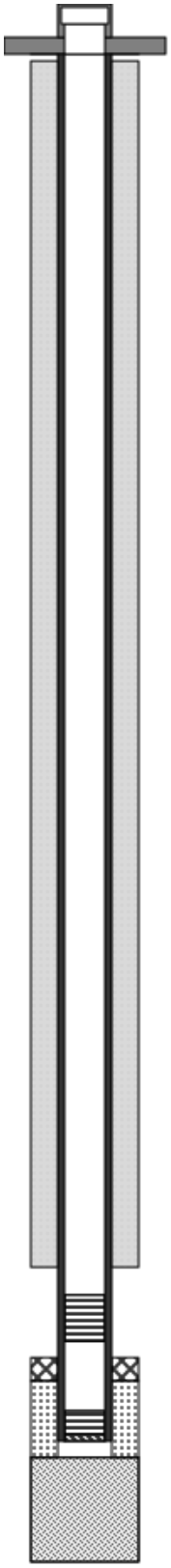
Initial Depth to Water (FBGS) 528.00
Date Initial Depth Measured: OCT 07, 1993
Last Measured Water Elevation (FAMSL): 4902.22
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.): 0.01
Date Updated: 11-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

ARCH FROM SURFACE TO 325 FBGS.
CONTINOUS SONIC CORE WITH DRIVE CASING
FROM 325 TO 650 FBGS. TWO SCREENS. 1/1/11 -
ORIGINAL STATE PLANE FEET NAD27/NGVD29
SURVEY COORDINATES HAVE BEEN
RE-PROJECTED IN STATE PLANE FEET
NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: 1.3

Interval	Material	Start	Stop	Length	ID	OD
SCREEN	SCH 80 PVC	535.0	555.0	20.0	4.75	
SEAL	VOLCLAY	562.0	572.0	10.0		
PLUG BACK	BENTONITE PELL...	605.0	650.0	45.0		
BOREHOLE		0.0	650.0	650.0		10
SCREEN	SCH 80 PVC	585.0	595.0	10.0	4.75	
SUMP	N/A	595.0	598.0	3.0	4.75	
PRIMARY PACK	40/60 SILICA SAND	572.0	605.0	33.0		
CASING	SCH 80 PVC	0.0	598.0	598.0	4.75	5.563
GROUT/BACKF...	VOLCLAY	3.0	523.0	520.0		
null		0.0	0.0	0.0		

Well Name: TA2-SW1-320
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 70
Owner Name: SNL/NM
Date Drilling Started: NOV 02, 1992
Date Well Dev. Completed: NOV 19, 1992

Drilling Contractor: USGS
Drilling Method: AIR ROTARY/DRIVE CASING/SONIC
Borehole Depth (FBGS): 330.00
Casing Depth (FBGS): 324.60
Geo Location: SW CORNER TA-II
Completion Zone: SAND
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: NOV 09, 1993
Surveyed By: GREINER
State Plane Coordinates: NAD 83
(X) Easting: 1552796.36
(Y) Northing: 1469732.72

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5412.70
Top of Inner Well Casing: 5411.85
Concrete Pad: 5410.03
Ground Surface: 5410.1

Calculated Depths and Elevations

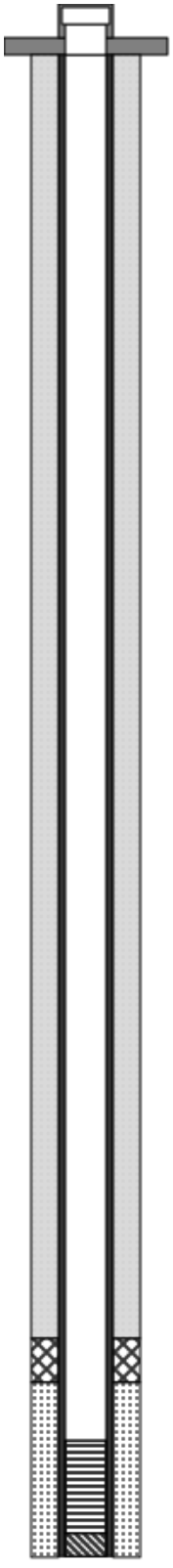
Initial Depth to Water (FBGS) 310.93
Date Initial Depth Measured: OCT 07, 1993
Last Measured Water Elevation (FAMSL): 5093.33
Date Last Measured: OCT 09, 2014

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 11-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

CONTINOUS SONIC WITH DRIVE CASING TO 330 FBGS. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES. DEC. 2012 GROUNDWATER SAMPLE WAS HIGHLY TURBID; DEDICATED PUMP WAS REMOVED AND HAD GROUT ON PUMP HOUSING. JAN. 2013 VIDEO LOGGING SHOWED CRACKED CASING JOINTS AT 61 AND 102 FBTOC WITH VISIBLE GROUT; REMAINDER OF CASING AND SCREEN IN GOOD CONDITION. 12/12/14 - THE WELL CASING WAS PLUGGED WITH BENTONITE GROUT AND THE WELL HEAD WAS REMOVED.



Completion Data Measured Depths (FBGS)

Casing Stickup: 1.8

Interval	Material	Start	Stop	Length	ID	OD
CASING	SCH 80 PVC	0.0	324.6	324.6	3.826	4.5
SUMP	SCH 80 PVC	319.6	324.6	5.0	3.826	
GROUT/BACKFI...	VOLCLAY	0.0	277.5	277.5		
SCREEN	SCH 40 PVC	299.6	319.6	20.0	3.826	
SEAL	VOLCLAY PELLE...	277.5	287.0	9.5		
BOREHOLE		0.0	330.0	330.0		11
PRIMARY PACK	10/20 MESH SILICA	287.0	324.8	37.8		

Plugged and Abandoned

Well Name: TA2-W-01
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 71
Owner Name: SNL/NM
Date Drilling Started: JUN 10, 1994
Date Well Dev. Completed: JUN 27, 1994

Drilling Contractor: WATER DEVELOPMENT
Drilling Method: ARCH AND SONIC
Borehole Depth (FBGS): 338.00
Casing Depth (FBGS): 332.00
Geo Location: TA2 CENTRAL
Completion Zone: SILTY SAND/GRAVEL
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: AUG 05, 1994
Surveyed By: GREINER, INC.
State Plane Coordinates: NAD 83
(X) Easting: 1553478.10
(Y) Northing: 1470182.23

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5420.17
Top of Inner Well Casing: 5419.99
Concrete Pad: 5417.67
Ground Surface: 5417.4

Calculated Depths and Elevations

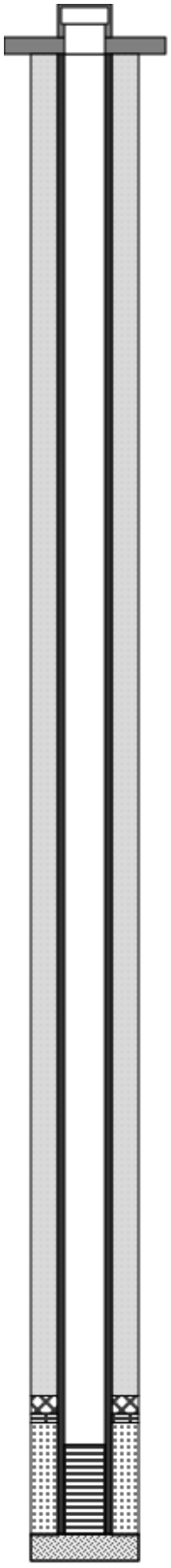
Initial Depth to Water (FBGS) 314.50
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5090.05
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

PHASE 2 DRILLING (ARCH) JUNE 10-22. NEUTRON SHOWED SATURATION AT 314.5 AND BELOW SAND AND GRAVEL IN CUTTINGS IN SCREENED ZONE. WELL RE-DEVELOPED IN OCTOBER 2010 (PHASE 1 DRILLING WITH SONICORE FROM 0 TO 151 FT.; MARCH 9, 1994). 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.6

Interval	Material	Start	Stop	Length	ID	OD
GROUT/BACKF...	VOLCLAY GROUT	0.0	301.0	301.0		
SEAL	BENTONITE PELL...	301.0	305.0	4.0		
CASING	PVC SCH 80	0.0	332.0	332.0	4.77	5.56
SECONDARY P...	60 SAND	305.0	307.0	2.0		
SCREEN	PVC SCH 80	312.0	332.0	20.0	4.77	
PLUG BACK	SLOUGH	332.0	338.0	6.0		
PRIMARY PACK	40/60 SAND	307.0	332.3	25.3		
BOREHOLE		0.0	338.0	338.0		11.75

Well Name: TA2-W-19
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 72
Owner Name: SNL/NM
Date Drilling Started: NOV 07, 1995
Date Well Dev. Completed: NOV 29, 1995

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: AIR-CASING ROTARY HAMMER
Borehole Depth (FBGS): 300.00
Casing Depth (FBGS): 285.87
Geo Location: TIJERAS ARROYO;SE TA-II/TA-VI
Completion Zone: GRAVELLY SAND/SANDY GRAVEL
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: DEC 08, 1995
Surveyed By: GREINER INC.
State Plane Coordinates: NAD 83
(X) Easting: 1554409.20
(Y) Northing: 1468689.72

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5351.82
Top of Inner Well Casing: 5351.21
Concrete Pad: 5349.28
Ground Surface: 5349.0

Calculated Depths and Elevations

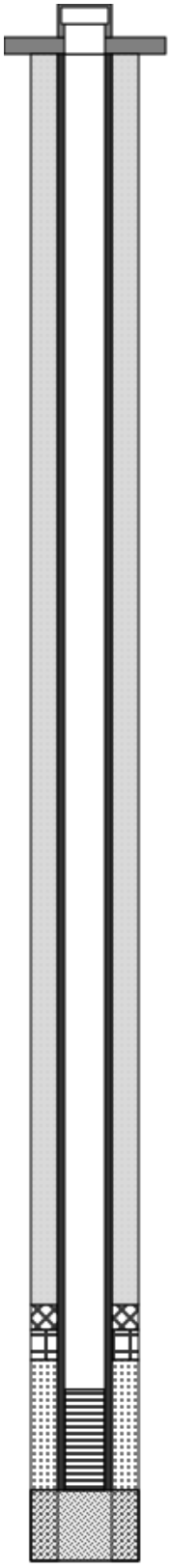
Initial Depth to Water (FBGS) 288.00
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5077.93
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

WELL DEVELOPED ON 29-NOV-95; CLEANED UP WELL W/TURBIDITY AT 2.6 (TCE=8.1 PPB).
WELL RE-DEVELPED IN OCTOBER 2010. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.2

Interval	Material	Start	Stop	Length	ID	OD
SEAL	BENTONITE CHIPS	249.0	254.0	5.0		
SECONDARY PACK	40/60	254.0	260.0	6.0		
PRIMARY PACK	12/20	260.0	300.0	40.0		
PLUG BACK	SAND 12/20	285.9	300.0	14.1		
BOREHOLE		0.0	300.0	300.0		10
SCREEN	PVC	265.9	285.9	20.0	4.8	
GROUT/BACKFILL	VOLCLAY GROUT	0.0	249.0	249.0		
CASING	PVC	0.0	285.9	285.9	4.8	5.25

Well Name: TA2-W-24
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 73
Owner Name: SNL/NM
Date Drilling Started: JAN 27, 1998
Date Well Dev. Completed: FEB 09, 1998

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: AIR ROTARY/CASING HAMMER
Borehole Depth (FBGS): 506.00
Casing Depth (FBGS): 490.60
Geo Location:
Completion Zone: SANDS, GRAVELS CLAY
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date: APR 09, 1998
Surveyed By: SANTIAGO ROMERO JR.
State Plane Coordinates: NAD 83
(X) Easting: 1554725.42
(Y) Northing: 1469668.98

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5364.15
Top of Inner Well Casing: 5363.66
Concrete Pad: 5361.93
Ground Surface: 5361.8

Calculated Depths and Elevations

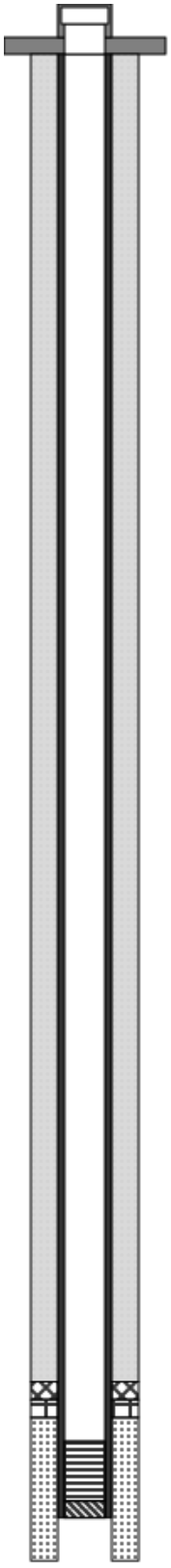
Initial Depth to Water (FBGS) 450.44
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 4922.80
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 1.9

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		160.0	506.0	346.0		10
CASING	5" SCH. 80 PVC	0.0	490.6	490.6	5	5.5
GROUT/BACKFILL	BENTONITE GROUT	0.0	445.0	445.0		
SEAL	BENTONITE GROUT	445.0	451.0	6.0		
SECONDARY PACK	30/70 SILICA SAND	451.0	457.0	6.0		
PRIMARY PACK	10/20 SILICA SAND	457.0	505.0	48.0		
SCREEN	5" SCH. 80 PVC	465.0	485.0	20.0	5	
SUMP		485.0	490.6	5.6	5	
BOREHOLE		0.0	160.0	160.0		12

Well Name: TA2-W-25
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 74
Owner Name: SNL/NM
Date Drilling Started: MAR 24, 1997
Date Well Dev. Completed: APR 28, 1997

Drilling Contractor: WATER DEVELOPMENT CORPORATION
Drilling Method: AIR ROTARY-CASING HAMMER
Borehole Depth (FBGS): 520.00
Casing Depth (FBGS): 517.80
Geo Location: TIJERAS ARROYO
Completion Zone: SILTY SAND AND GRAVEL
Completion Formation: UPPER SANTA FE GROUP-REG. AQ.

Survey Data

Survey Date: MAY 23, 1997
Surveyed By: GREINER, INC.
State Plane Coordinates: NAD 83
(X) Easting: 1555507.60
(Y) Northing: 1470502.32

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5375.36
Top of Inner Well Casing: 5374.86
Concrete Pad: 5372.89
Ground Surface: 5372.5

Calculated Depths and Elevations

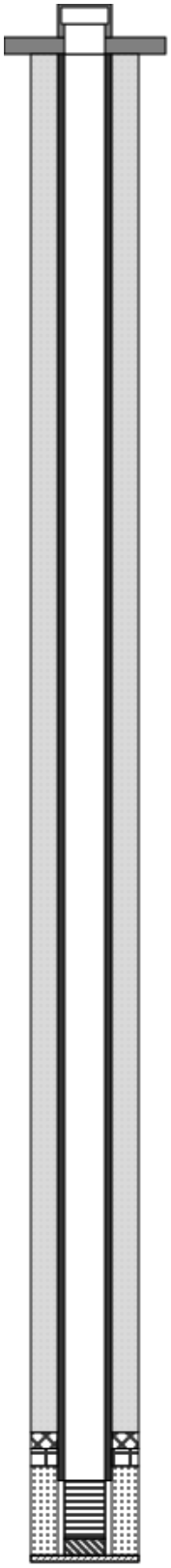
Initial Depth to Water (FBGS) 479.64
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 4908.82
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

WELL DEVELOPMENT COMPLETED ON 4/28/97. ONE STAINLESS STEEL CENRALIZER ABOVE AND BELOW SCREEN. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.4

Interval	Material	Start	Stop	Length	ID	OD
SEAL	1/4" BENTONITE P...	475.4	481.0	5.6		
PRIMARY PACK	10-20 SILICA SAND	487.0	517.8	30.8		
SCREEN	SCHEDULE 80 PVC	492.0	512.0	20.0	4.75	
BOREHOLE		0.0	520.0	520.0		10
CASING	SCHEDULE 80 PVC	0.0	492.0	492.0	4.75	5.62
SECONDARY P...	30-70 SILICA SAND	481.0	487.0	6.0		
GROUT/BACKFI...	VOLCLAY GROUT	0.0	475.4	475.4		
SUMP	SCHEDULE 80 PVC	512.0	517.8	5.8	4.75	
PLUG BACK	SLOUGH	517.8	520.0	2.2		

Well Name: TA2-W-26
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 75
Owner Name: SNL/NM
Date Drilling Started: JAN 12, 1998
Date Well Dev. Completed: JAN 19, 1998

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: AIR ROTARY/CASING HAMMER
Borehole Depth (FBGS): 305.00
Casing Depth (FBGS): 301.60
Geo Location: POWERLINE ROAD
Completion Zone: SANDS, GRAVELS, CLAY
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: APR 09, 1998
Surveyed By: SANTIAGO ROMERO JR.
State Plane Coordinates: NAD 83
(X) Easting: 1555510.96
(Y) Northing: 1470552.39

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5376.35
Top of Inner Well Casing: 5375.77
Concrete Pad: 5374.14
Ground Surface: 5373.8

Calculated Depths and Elevations

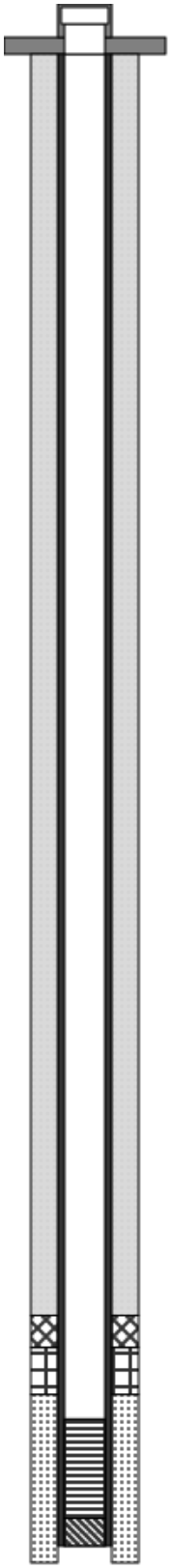
Initial Depth to Water (FBGS) 279.42
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5086.80
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: 2

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	305.0	305.0		10
CASING	SCH. 80 PVC	0.0	301.6	301.6	5	5.5
GROUT/BACKFILL	BENTONITE GROUT	0.0	255.0	255.0		
SEAL	BENT. PELLETS	255.0	261.5	6.5		
SECONDARY PACK	30/70 SILICA SAND	261.5	271.0	9.5		
PRIMARY PACK	10/20 SILICA SAND	271.0	305.0	34.0		
SUMP	SCH. 80 PVC	296.0	301.6	5.6	5	
SCREEN	SCH. 80 PVC	276.0	296.0	20.0	5	

Well Name: TA2-W-27
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 76
Owner Name: SNL/NM
Date Drilling Started: FEB 04, 1998
Date Well Dev. Completed: FEB 09, 1998

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: AIR ROTARY/CASING HAMMER
Borehole Depth (FBGS): 306.50
Casing Depth (FBGS): 300.60
Geo Location:
Completion Zone: SANDS, GRAVELS, CLAY
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: APR 09, 1998
Surveyed By: SANTIAGO ROMERO JR.
State Plane Coordinates: NAD 83
(X) Easting: 1554760.23
(Y) Northing: 1469679.90

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5363.30
Top of Inner Well Casing: 5362.85
Concrete Pad: 5361.04
Ground Surface: 5360.8

Calculated Depths and Elevations

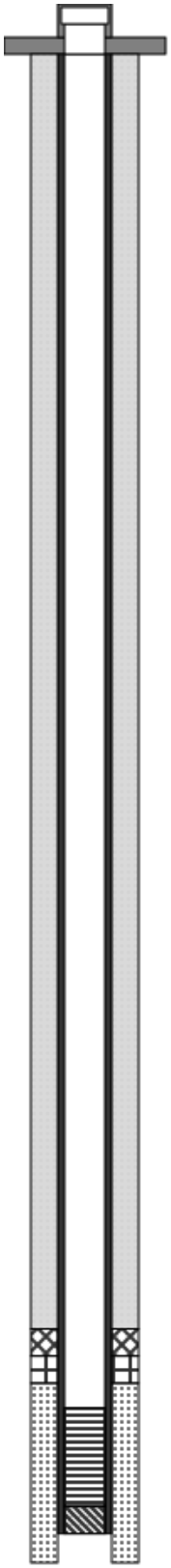
Initial Depth to Water (FBGS) 274.59
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5081.27
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.1

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	306.5	306.5		10
CASING	SCH. 80 PVC	0.0	300.6	300.6	5	5.5
GROUT/BACKFILL	BENTONITE GROUT	0.0	259.0	259.0		
SEAL	1/4" BENT. PELLETS	259.0	264.5	5.5		
SECONDARY PACK	30/70 SILICA SAND	264.5	270.0	5.5		
PRIMARY PACK	10/20 SILICA SAND	270.0	306.5	36.5		
SCREEN	SCH. 80 PVC	275.0	295.0	20.0	5	
SUMP	SCH. 80 PVC	295.0	300.6	5.6	5	

Well Name:	TA2-W-28	**Drilling Contractor:**	NATIONAL EWP
Project Name:	TIJERAS ARROYO GW	**Drilling Method:**	AIR ROTARY CASING HAMMER
NMOSE Well File Code:	RG-90065, POINT OF DIVERSION: 125	**Borehole Depth (FBGS):**	338.00
Owner Name:	SNL/NM	**Casing Depth (FBGS):**	335.45
Date Drilling Started:	NOV 20, 2014	**Geo Location:**	TA-II
Date Well Dev. Completed:	DEC 10, 2014	**Completion Zone:**	ALLUVIAL FAN LITHOFACIES
		Completion Formation:	SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: JAN 30, 2015
Surveyed By: STEPHEN TOLER
State Plane Coordinates: NAD 83
(X) Easting: 1552812.11
(Y) Northing: 1469713.90

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5412.83
Top of Inner Well Casing: 5412.41
Concrete Pad: 5410.26
Ground Surface: 5410.0

Calculated Depths and Elevations

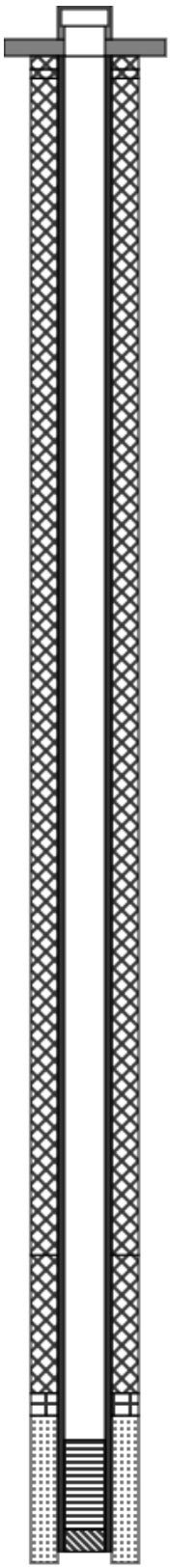
Initial Depth to Water (FBGS) 316.80
Date Initial Depth Measured: DEC 10, 2014
Last Measured Water Elevation (FAMSL): 5091.86
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 04-JAN-18
Date Printed from EDMS: JAN 04, 2018

Comments:

WELL INSTALLED TO REPLACE NEARBY WELL TA2-SW1-320 WHICH HAD CRACKED PVC CASING ABOVE THE SCREEN AS SHOWN BY VIDEO LOGGING.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.4

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	338.0	338.0	9.625	
CASING	SCHEDULE 80 PVC	0.0	335.5	335.5	4.75	5.5
SEAL	CONCRETE	0.0	3.0	3.0		
SEAL	BENTONITE CHIPS	3.0	5.0	2.0		
SEAL	BENTONITE GRO...	5.0	269.0	264.0		
SEAL	BENTONITE CHIPS	269.0	300.0	31.0		
SECONDARY PA...	#60 SAND	300.0	305.0	5.0		
PRIMARY PACK	#10-20 SAND	305.0	338.0	33.0		
SCREEN	SCHEDULE 80 PVC	310.5	330.5	20.0	4.75	
SUMP	SCHEDULE 80 PVC	330.5	335.5	5.0	4.75	

Well Name: TJA-1
Project Name: SWHC
NMOSE Well File Code:
Owner Name: SNL/NM
Date Drilling Started: JUN 08, 1994
Date Well Dev. Completed: JUN 25, 1994

Drilling Contractor: USGS
Drilling Method: MUD ROTARY
Borehole Depth (FBGS): 310.00
Casing Depth (FBGS): 305.00
Geo Location: TIJERAS ARROYO
Completion Zone: GRAVELLY SAND 200-290 FT.
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: JUN 12, 2017
Surveyed By: M. BARTHEL
State Plane Coordinates: NAD83
(X) Easting: 1555574.29
(Y) Northing: 1468657.83

Surveyed Evaluations (FAMSL)

Protective Casing:
Top of Inner Well Casing:
Concrete Pad:
Ground Surface: 5351.3

Calculated Depths and Elevations

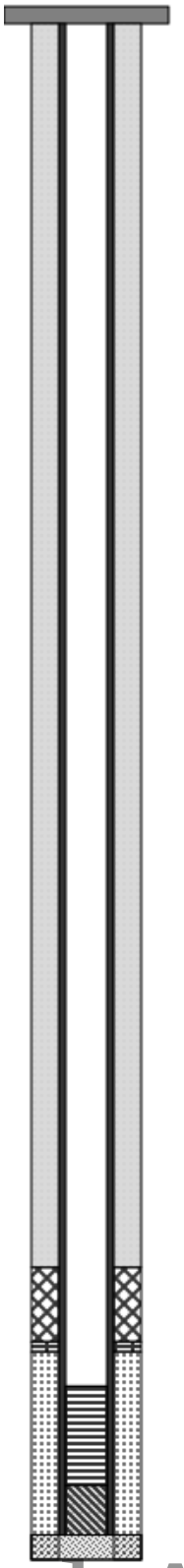
Initial Depth to Water (FBGS) 271.00
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL):
Date Last Measured:

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 11-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

TWO TEMPORARY COMPLETIONS BEFORE PERMANENT CASING INSTALLED. CASING FAILURE AT 226 FEET (GROUT INTRUCION) RESULTED IN PLUGGING AND ABANDONMENT 7/9/94. REPLACED BY TJA-2 IN JULY 1994. TJA-1 CONCRETE PAD SURVEYED IN JUNE 2017 FOR NORTHING AND EASING. GROUND ELEVATION ESTIMATED FROM ADJACENT TJA-2.



Completion Data Measured Depths (FBGS)

Casing Stickup:

Interval	Material	Start	Stop	Length	ID	OD
CASING	SCHEDULE 80 PVC	0.0	305.0	305.0	3.829	4.5
BOREHOLE		0.0	310.0	310.0	7.825	
GROUT BACKFI...	SODIUM BENTON...	0.0	251.0	251.0		
SEAL	BENTONITE PELL...	251.0	266.0	15.0		
SECONDARY P...	16-40 SAND	266.0	268.0	2.0		
PRIMARY PACK	10/20 SAND	268.0	310.0	42.0		
SCREEN	SCHEDULE 80 PVC	275.0	295.0	20.0	3.829	4.5
SUMP	SCHEDULE 80 PVC	295.0	305.0	10.0	3.829	
PLUG BACK	SLOUGH	305.0	310.0	5.0		

Plugged and Abandoned

Well Name: TJA-2
Project Name: SWHC
NMOSE Well File Code: RG-90065, Point of Diversion: 86
Owner Name: SNL/NM
Date Drilling Started: JUL 09, 1994
Date Well Dev. Completed: JUL 12, 1994

Drilling Contractor: USGS
Drilling Method: MUD ROTARY
Borehole Depth (FBGS): 310.00
Casing Depth (FBGS): 305.00
Geo Location: TIJERAS ARROYO
Completion Zone: GRAVELLY SAND
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: JAN 01, 1997
Surveyed By: HALL ENGINEERING COMPANY
State Plane Coordinates: NAD 83
(X) Easting: 1555588.70
(Y) Northing: 1468683.66

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5354.27
Top of Inner Well Casing: 5353.20
Concrete Pad: 5351.50
Ground Surface: 5351.3

Calculated Depths and Elevations

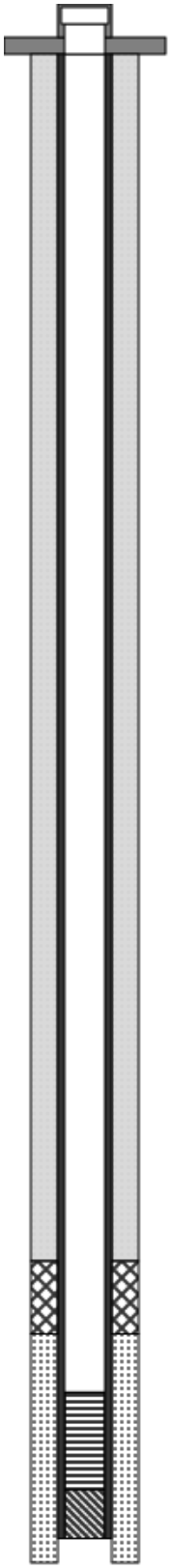
Initial Depth to Water (FBGS) 274.00
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5074.79
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 11-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

THIS WELL REPLACES FAILED WELL TJA-1. JANUARY 2010--DATA TRANSMITTED TO NMED/HWB INCLUDED A TOP OF PVC CASING ELEVATION OF 5350.53 FT AMSL. THIS IS BASED ON RECORDS RESEARCH CONDUCTED BY M. SANDERS IN DECEMBER 2009. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: 1.9

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	310.0	310.0		7.875
SCREEN	SCH 80 PVC	275.0	295.0	20.0	3.829	
GROUT/BAC...	VOLCLAY BENT. S...	0.0	248.0	248.0		
PRIMARY PA...	10/20 SILICA SAND	263.0	310.0	47.0		
SUMP	SCH 80 PVC	295.0	305.0	10.0	3.829	
CASING	SCH 80 PVC	0.0	305.0	305.0	3.829	4.5
SEAL	1/4" BENT. PELLETS	248.0	263.0	15.0		

Well Name: TJA-3
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 87
Owner Name: SNL/NM
Date Drilling Started: AUG 14, 1998
Date Well Dev. Completed: DEC 04, 1998

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: AIR ROTARY/CASING HAMMER
Borehole Depth (FBGS): 522.00
Casing Depth (FBGS): 521.70
Geo Location: WEST OF TA-IV
Completion Zone: SAND AND GRAVEL
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date: JAN 15, 1999
Surveyed By: BOHANNAN HUSTON, INC.
State Plane Coordinates: NAD 83
(X) Easting: 1551951.55
(Y) Northing: 1467564.85

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5391.29
Top of Inner Well Casing: 5390.56
Concrete Pad: 5387.99
Ground Surface: 5387.8

Calculated Depths and Elevations

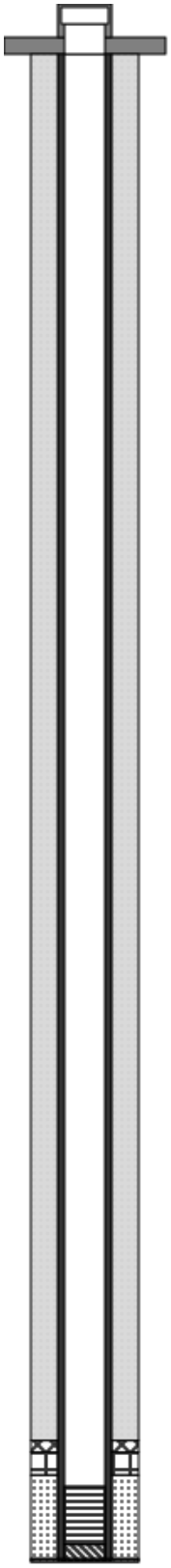
Initial Depth to Water (FBGS) 495.25
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 4891.86
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

WELL DEVELOPED 04-DEC-98. NO PROBLEMS ENCOUNTERED DURING WELL INSTALLATION.
PROTECTIVE CASING EXTENDED 2/16/99.
1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.8

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	522.0	522.0		9.625
CASING	SCH. 80 PVC	0.0	521.7	521.7	5	5.5
GROUT/BACKFI...	BENTONITE GROUT	0.0	480.0	480.0		
SEAL	3/8" BENTONITE P...	480.0	484.0	4.0		
PRIMARY PACK	10/20 SILICA SAND	492.0	521.0	29.0		
SCREEN	SCH. 80 PVC	496.0	516.0	20.0	5	
SECONDARY PA...	30/70 SILICA SAND	484.0	492.0	8.0		
SUMP	SCH. 80 PVC	516.0	521.7	5.7	5	
PLUG BACK	SLOUGH	521.0	522.0	1.0		

Well Name: TJA-4
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 88
Owner Name: SNL/NM
Date Drilling Started: JUL 28, 1998
Date Well Dev. Completed: DEC 01, 1998

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: AIR ROTARY/CASING HAMMER
Borehole Depth (FBGS): 399.00
Casing Depth (FBGS): 385.70
Geo Location: WEST OF POWERLINE ROAD
Completion Zone: SILTY GRAVELLY SAND
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date: JAN 15, 1999
Surveyed By: BOHANNAN HUSTON INC.
State Plane Coordinates: NAD 83
(X) Easting: 1555381.08
(Y) Northing: 1467217.42

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5341.98
Top of Inner Well Casing: 5341.16
Concrete Pad: 5338.57
Ground Surface: 5338.5

Calculated Depths and Elevations

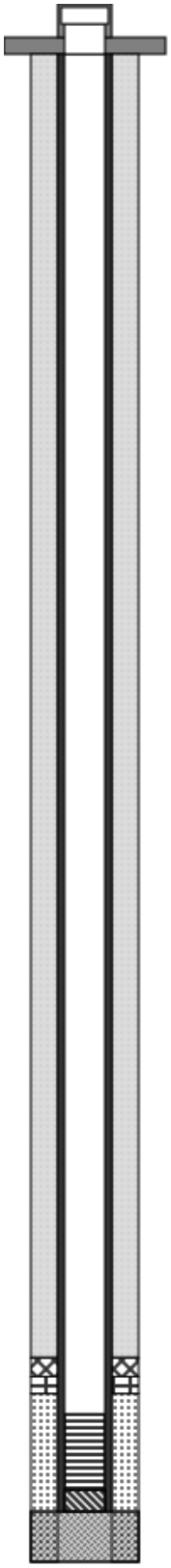
Initial Depth to Water (FBGS) 314.90
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5040.92
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 14-DEC-17
Date Printed from EDMS: DEC 14, 2017

Comments:

NO PROBLEMS WITH WELL INSTALLATION.
WELL COMPLETED IN INTERMEDIATE ZONE.
PROTECTIVE CASING EXTENDED 2/16/99. 1/1/11
- ORIGINAL STATE PLANE FEET NAD27/NGVD29
SURVEY COORDINATES HAVE BEEN
RE-PROJECTED IN STATE PLANE FEET
NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.7

Interval	Material	Start	Stop	Length	ID	OD
GROUT/BACKFI...	BENTONITE GROUT	0.0	345.0	345.0		
SEAL	3/8" BENTONITE P...	345.0	350.0	5.0		
BOREHOLE		0.0	399.0	399.0		9.625
SECONDARY PA...	30/70 SILICA SAND	350.0	354.5	4.5		
PRIMARY PACK	10/20 SILICA SAND	354.5	399.0	44.5		
PLUG BACK	10/20 SILICA SAND	385.7	399.0	13.3		
SCREEN	SCH. 80 PVC	360.0	380.0	20.0	5	
CASING	SCH.80 PVC	0.0	385.7	385.7	5	5.5
SUMP	SCH. 80 PVC	380.0	385.7	5.7	5	

Well Name: TJA-5
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 89
Owner Name: SNL/NM
Date Drilling Started: AUG 05, 1998
Date Well Dev. Completed: DEC 02, 1998

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: AIR ROTARY/CASING HAMMER
Borehole Depth (FBGS): 298.00
Casing Depth (FBGS): 292.70
Geo Location: W. OF POWERLINE RD. S.SIDE TJA
Completion Zone: SAND AND GRAVEL
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: JAN 15, 1999
Surveyed By: BOHANNAN HUSTON, INC.
State Plane Coordinates: NAD 83
(X) Easting: 1555374.63
(Y) Northing: 1467199.57

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5342.23
Top of Inner Well Casing: 5341.33
Concrete Pad: 5338.61
Ground Surface: 5338.5

Calculated Depths and Elevations

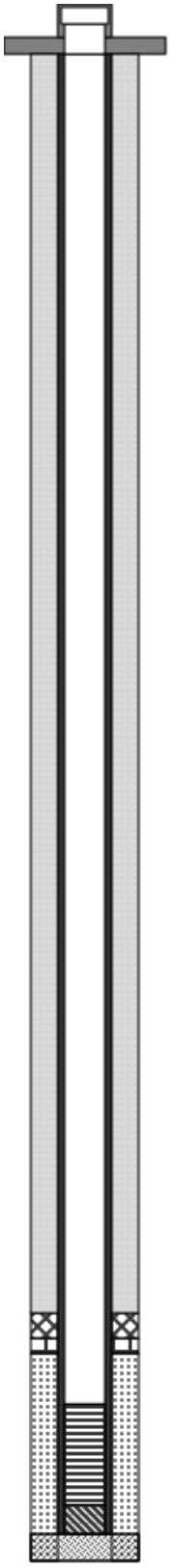
Initial Depth to Water (FBGS) 267.80
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5070.95
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

PROTECTIVE CASING EXTENDED 2/16/99. JANUARY 2010--DATA TRANSMITTED TO NMED/HWB INCLUDED A TOP OF PVC CASING ELEVATION OF 5338.66 FT AMSL. THIS IS BASED ON RECORDS RESEARCH CONDUCTED BY M. SANDERS IN DECEMBER 2009. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.9

Interval	Material	Start	Stop	Length	ID	OD
CASING	SCH. 80 PVC	0.0	292.7	292.7	5	5.5
SEAL	3/8" BENTONITE P...	249.0	254.0	5.0		
SECONDARY PA...	30/70 SILICA SAND	254.0	257.0	3.0		
SCREEN	SCH. 80 PVC	267.0	287.0	20.0	5	
SUMP	SCH. 80 PVC	287.0	292.7	5.7	5	
PRIMARY PACK	10/20 SILICA SAND	257.0	298.0	41.0		
GROUT/BACKFI...	BENTONITE GROUT	0.0	249.0	249.0		
PLUG BACK	10/20 SILICA SAND	292.7	298.0	5.3		
BOREHOLE		0.0	298.0	298.0		9.625

Well Name: TJA-6
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 90
Owner Name: SNL/NM
Date Drilling Started: JAN 16, 2001
Date Well Dev. Completed: FEB 04, 2001

Drilling Contractor: LAYNE
Drilling Method: ARCH-ODEX & MUD ROTARY
Borehole Depth (FBGS): 503.00
Casing Depth (FBGS): 480.70
Geo Location: S. OF TA IV, N OF TIJERAS ARYO
Completion Zone: SILTY SAND
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date: JUN 19, 2001
Surveyed By: ASCI, VLADIMIR JIRIK
State Plane Coordinates: NAD 83
(X) Easting: 1552680.02
(Y) Northing: 1467039.44

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5343.78
Top of Inner Well Casing: 5343.16
Concrete Pad: 5340.95
Ground Surface: 5340.6

Calculated Depths and Elevations

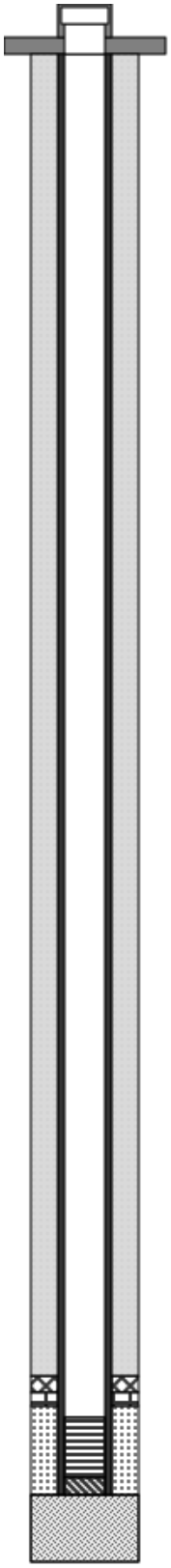
Initial Depth to Water (FBGS) 450.50
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 4892.22
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 11-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

ODEX DRIVE CASING FRM 0 TO 245 FT. DRIVE CASING SHEARED OFF AND LEFT IN BOREHOLE FROM 175 TO 220 FT. MUD ROTARY FROM 245-300 FEET WITH 8 INCH TRICONE.
1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.6

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	245.0	245.0		10
CASING	SCHEDULE 80 PVC	0.0	480.7	480.7	5	5.5
GROUT/BACKFI...	VOLCLAY GROUT	0.0	441.0	441.0		
SEAL	1/4" BENTONITE PE...	441.0	446.5	5.5		
SECONDARY PA...	20-40 SILICA SAND	446.5	451.0	4.5		
PRIMARY PACK	10-20 SILICA SAND	451.0	480.7	29.7		
SCREEN	SCHEDULE 80 PVC	454.9	474.9	20.0	5	
SUMP	SCHEDULE 80 PVC	474.9	480.7	5.8	5	
PLUG BACK	10-20 SILICA SAND	480.7	503.0	22.3		
BOREHOLE		245.0	503.0	258.0		8

Well Name: TJA-7
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 91
Owner Name: SNL/NM
Date Drilling Started: MAR 02, 2001
Date Well Dev. Completed: MAR 12, 2001

Drilling Contractor: LAYNE
Drilling Method: ODEX-ARCH
Borehole Depth (FBGS): 317.00
Casing Depth (FBGS): 316.30
Geo Location: SW OF TA IV, N OF TIJERAS ARYO
Completion Zone: SILTY SAND / CLAYEY SILT
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: JUN 19, 2001
Surveyed By: ASCI, VLADIMIR JIRIK
State Plane Coordinates: NAD 83
(X) Easting: 1551982.99
(Y) Northing: 1467606.90

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5391.85
Top of Inner Well Casing: 5391.27
Concrete Pad: 5388.73
Ground Surface: 5388.4

Calculated Depths and Elevations

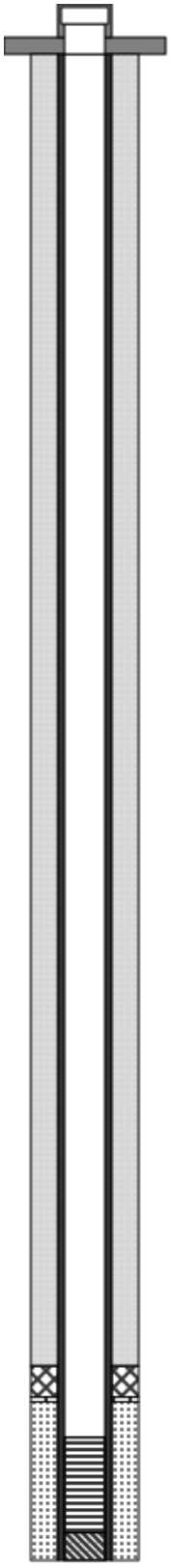
Initial Depth to Water (FBGS) 298.70
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5087.25
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

TWO DRY BOREHOLES WERE DRILLED. A THIRD BOREHOLE FOUND PERCHED WATER AND THE WELL WAS INSTALLED. DEVELOPMENT DATE IS APPROXIMATELY MARCH 12, 2001. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.9

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	317.0	317.0		8
CASING	SCHEDULE 80 PVC	0.0	316.3	316.3	5	5.5
GROUT/BACKFI...	VOLCLAY GROUT	0.0	275.5	275.5		
SECONDARY PA...	20-40 SAND	282.0	283.0	1.0		
PRIMARY PACK	10-20 SAND	283.0	316.3	33.3		
SCREEN	SCHEDULE 80 PVC	290.5	310.5	20.0	5	
SUMP	SCHEDULE 80 PVC	310.5	316.3	5.8	5	
SEAL	1/4" BENTONITE PE...	275.5	282.0	6.5		

Well Name: WYO-1
Project Name: SWHC
NMOSE Well File Code:
Owner Name: SNL/NM
Date Drilling Started: AUG 15, 1995
Date Well Dev. Completed: AUG 28, 1995

Drilling Contractor: USGS
Drilling Method: ROTARY MUD
Borehole Depth (FBGS): 650.00
Casing Depth (FBGS): 570.00
Geo Location: N. OF WYOMING AND PENNSYLVANIA
Completion Zone: SILTY SAND
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date: OCT 27, 1995
Surveyed By: GREINER, INC.
State Plane Coordinates: NAD 83
(X) Easting: 1550205.83
(Y) Northing: 1470090.06

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5392.96
Top of Inner Well Casing: 5392.50
Concrete Pad: 5390.52
Ground Surface: 5390.4

Calculated Depths and Elevations

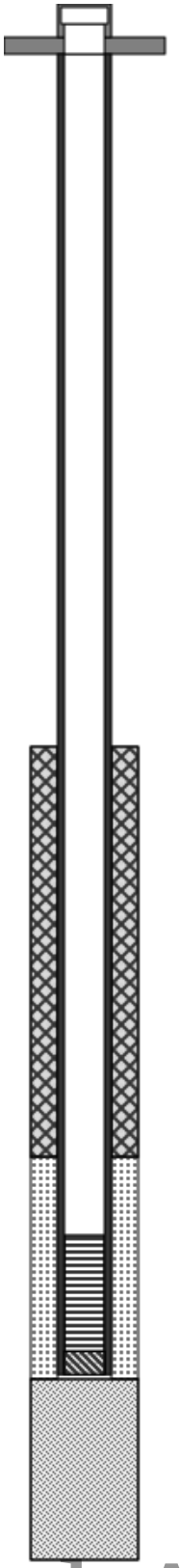
Initial Depth to Water (FBGS) 513.42
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 4867.95
Date Last Measured: JUN 29, 2001

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

PLUGGED AND ABANDONED JULY 2001. DUAL COMPLETION IN A SINGLE BOREHOLE WITH WYO-2. BENTONITE SEAL BETWEEN THE TWO WELL CASINGS WAS NOT EFFECTIVE, AND WATER FROM THE TWO ZONES MINGLED.
1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.1

Interval	Material	Start	Stop	Length	ID	OD
GROUT/BACKFI...	BENTONITE CHI...	299.0	476.0	177.0		
SEAL	BENTONITE CHI...	299.0	476.0	177.0		
PRIMARY PACK	10/20 SILICA SA...	476.0	572.0	96.0		
SCREEN	SCH 80 PVC	510.0	560.0	50.0	4.25	
CASING	SCH 80 PVC	0.0	570.0	570.0	4.25	4.75
PLUG BACK	BENTONITE CHI...	572.0	650.0	78.0		
BOREHOLE		0.0	650.0	650.0		9.875
SUMP	SCH 80 PVC	560.0	570.0	10.0	4.25	

Plugged and Abandoned

Well Name: WYO-2
Project Name: SWHC
NMOSE Well File Code:
Owner Name: SNL/NM
Date Drilling Started: AUG 15, 1995
Date Well Dev. Completed: AUG 26, 1995

Drilling Contractor: USGS
Drilling Method: MUD ROTARY
Borehole Depth (FBGS): 650.00
Casing Depth (FBGS): 295.00
Geo Location: N OF WYOMING & PENN. BLVDS
Completion Zone: SILTY SAND ETC
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: OCT 27, 1995
Surveyed By: GREINER, INC.
State Plane Coordinates: NAD 83
(X) Easting: 1550205.83
(Y) Northing: 1470090.06

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5392.96
Top of Inner Well Casing: 5392.50
Concrete Pad: 5390.52
Ground Surface: 5390.4

Calculated Depths and Elevations

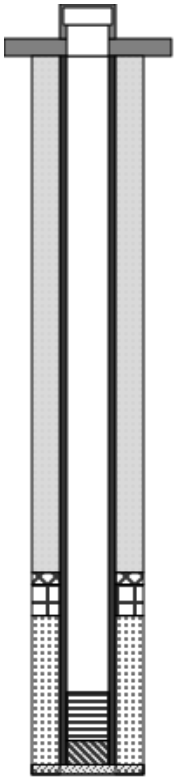
Initial Depth to Water (FBGS) 272.90
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5116.16
Date Last Measured: JUN 29, 2001

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

PLUGGED AND ABANDONED JULY 2001. DUAL COMPLETION IN A SINGLE BOREHOLE WITH WYO-1. BENTONITE SEAL BETWEEN THE TWO CASINGS (WYO-1 AND WYO-2) WAS NOT EFFECTIVE, AND WATER FROM THE TWO ZONES MINGLED. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.1

Interval	Material	Start	Stop	Length	ID	OD
CASING	SCH 80 PVC	0.0	295.0	295.0	2	
GROUT/BACKFILL	VOLCLAY	0.0	215.0	215.0		
SECONDARY PA...	16/40 SAND	220.0	233.0	13.0		
PRIMARY PACK	10/20 SILICA SAND	233.0	299.0	66.0		
SCREEN	SCH 80 PVC	265.0	285.0	20.0	2	
SUMP	SCH 80 PVC	285.0	295.0	10.0	2	
PLUG BACK	10/20 SAND	295.0	299.0	4.0		
SEAL	.25" BENT PELLE...	215.0	220.0	5.0		
BOREHOLE		0.0	650.0	650.0		9.875

Plugged and Abandoned

Well Name: WYO-3
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 97
Owner Name: SNL/NM
Date Drilling Started: JUL 24, 2001
Date Well Dev. Completed: OCT 10, 2001

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: ARCH
Borehole Depth (FBGS): 555.00
Casing Depth (FBGS): 545.00
Geo Location: W. OF TAII -->SEE WELL COMMENT
Completion Zone: SANDY CLAYEY SILT
Completion Formation: SANTA FE GROUP-REGIONAL AQ.

Survey Data

Survey Date: OCT 05, 2001
Surveyed By: V. JIRIK
State Plane Coordinates: NAD 83
(X) Easting: 1550113.42
(Y) Northing: 1470088.75

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5392.43
Top of Inner Well Casing: 5392.09
Concrete Pad: 5390.27
Ground Surface: 5390.0

Calculated Depths and Elevations

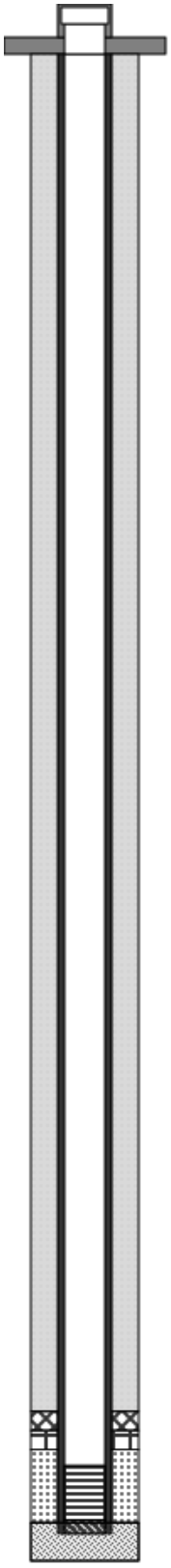
Initial Depth to Water (FBGS) 524.04
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 4870.02
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

REPLACEMENT OF WYO-1. WEST OF TA-II, SW OF WYOMING & ORDNANCE ROAD. DEVELOPED OCT 10, 2001. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.1

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	555.0	555.0		10
CASING	SCHEDULE 80 PVC	0.0	545.0	545.0	4.5	5
GROUT/BACKF...	WYO-BEN WELL GR...	0.0	500.0	500.0		
SEAL	3/8" BENTONITE CHI...	500.0	507.0	7.0		
SECONDARY P...	30/70 SILICA SAND	507.0	514.0	7.0		
PRIMARY PACK	10/20 SILICA SAND	514.0	541.0	27.0		
SCREEN	SCHEDULE 80 PVC	520.0	540.0	20.0	4.5	
SUMP	SCHEDULE 80 PVC	540.0	545.0	5.0	4.5	
PLUG BACK	SLOUGH	541.0	555.0	14.0		

Well Name: WYO-4
Project Name: TIJERAS ARROYO GW
NMOSE Well File Code: RG-90065, Point of Diversion: 98
Owner Name: SNL/NM
Date Drilling Started: JUL 21, 2001
Date Well Dev. Completed: OCT 16, 2001

Drilling Contractor: WATER DEVELOPMENT CORP.
Drilling Method: ARCH
Borehole Depth (FBGS): 305.00
Casing Depth (FBGS): 300.00
Geo Location: W. OF TA2 - SEE WELL COMMENT
Completion Zone: CLAYEY SILT
Completion Formation: SANTA FE GROUP-PERCHED SYSTEM

Survey Data

Survey Date: OCT 05, 2001
Surveyed By: V. JIRIK
State Plane Coordinates: NAD 83
(X) Easting: 1550158.19
(Y) Northing: 1470088.46

Surveyed Evaluations (FAMSL) NAVD 88

Protective Casing: 5393.06
Top of Inner Well Casing: 5392.57
Concrete Pad: 5390.70
Ground Surface: 5390.2

Calculated Depths and Elevations

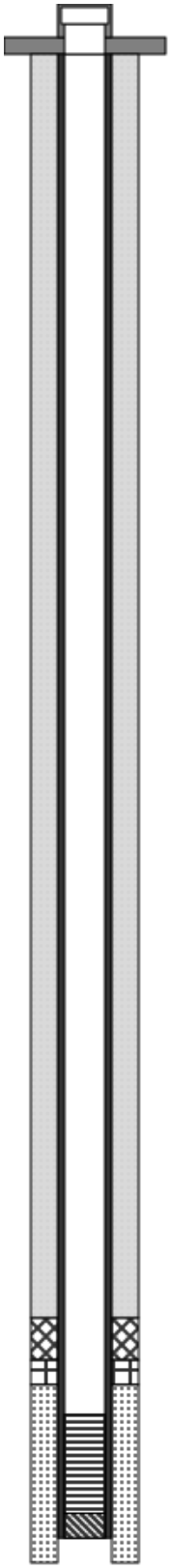
Initial Depth to Water (FBGS) 276.30
Date Initial Depth Measured:
Last Measured Water Elevation (FAMSL): 5098.32
Date Last Measured: OCT 02, 2017

Miscellaneous Information

Screen Slot Size (in.):
Date Updated: 08-DEC-17
Date Printed from EDMS: DEC 11, 2017

Comments:

REPLACEMENT OF WYO-2. W. OF TA-II, SW OF WYOMING & ORDNANCE ROAD. 1/1/11 - ORIGINAL STATE PLANE FEET NAD27/NGVD29 SURVEY COORDINATES HAVE BEEN RE-PROJECTED IN STATE PLANE FEET NAD83/NAVD88 COORDINATES.



Completion Data Measured Depths (FBGS)

Casing Stickup: 2.4

Interval	Material	Start	Stop	Length	ID	OD
BOREHOLE		0.0	305.0	305.0		10
CASING	SCHEDULE 80 PVC	0.0	300.0	300.0	4.5	5
SEAL	3/8" BENTONITE CHI...	255.5	264.0	8.5		
SECONDARY P...	30/70 SILICA SAND	264.0	269.0	5.0		
PRIMARY PACK	10/20 SILICA SAND	269.0	305.0	36.0		
SCREEN	SCHEDULE 80 PVC	275.0	295.0	20.0	4.5	
SUMP	SCHEDULE 80 PVC	295.0	300.0	5.0	4.5	
GROUT/BACKF...	WYO-BEN WELL GR...	0.0	255.5	255.5		