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Technical Area 16 Well Network Evaluation and Recommendations

Prepared by the Environmental Programs Directorate

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EXECUTIVE SUMMARY

This monitoring well network evaluation addresses the adequacy of the existing groundwater monitoring network for detecting the migration of contaminants from sources at Technical Area 16 (TA-16) at Los Alamos National Laboratory. The subject sources are consolidated units, solid waste management units, areas of concern, and material disposal areas (MDAs) at TA-16. The recommendations that derive from this evaluation are intended to capture the monitoring requirements necessary to protect groundwater and water-supply wells, to support completion of ongoing investigations, and to support the selection of corrective measures alternatives for applicable sites at TA-16.

Specific goals of the monitoring network include the following:

- Evaluate the adequacy of the existing groundwater monitoring network to support the selection of groundwater-protection alternatives for the corrective measures evaluation report for Consolidated Unit 16-021(c)-99 (the 260 Outfall and other related or collocated units)
- Evaluate the adequacy of the existing groundwater monitoring network to support ongoing investigations of Cañon de Valle, S-Site, and Upper Water Canyon Aggregate Areas
- Evaluate whether the existing network provides for detection of potential contamination upgradient of existing water supply wells

For this evaluation, TA-16 sources are prioritized by their potential to impact groundwater as follows:

- High priority: Cañon de Valle and the 260 Outfall pond and drainage
- Medium priority: the 30s Line and 90s Line high explosives (HE) retention ponds, the losing reach within Fishladder Canyon, and the westernmost losing reach within S-Site/Martin Spring Canyon
- Low priority: the alluvial aquifer in Water Canyon, the TA-16-430 drainage, the TA-16-460 drainage, the HE retention pond at V-Site, MDA P and the TA-16 Burning Ground, MDA R, K-Site, and the Zia shops drum storage area

The high- to medium-priority sources at TA-16 are the most important locations to characterize and monitor for groundwater protection, and they are the focus of this network evaluation. The lower-priority sources at TA-16 are considered to present little or no threat to groundwater and are not included in the network evaluation.

This report includes an evaluation of the physical and geochemical performance of each screened interval in existing well screens, recommendations for disposition of existing “parked” wells and Westbay wells, and a hydrogeologic analysis of known and potential groundwater flow paths. Based on this evaluation, existing intermediate and regional wells in the current monitoring network downgradient of TA-16 are generally performing well. It is recommended that monitoring of the majority of these existing wells should continue in accordance with the current Interim Facility-Wide Groundwater Monitoring Plan. Additional recommendations include the following:

- Direct current–resistivity profiling in Cañon de Valle to identify potential recharge pathways and to better define the lateral extent of deep-perched groundwater
- Conversion of multiscreen wells CdV-R-15-3 and CdV-R-37-2 to single-screen wells to improve the reliability and representativeness of water data through the use of purgeable sampling systems

- Conversion of two-screen well CdV-16-4ip to a single-screen well, retaining the upper screen, to ensure that cross-flow does not occur between two separate deep-perched groundwater zones
- Installation of a new deep-perched monitoring well to bound the nature and extent of HE-contaminated deep-perched groundwater north of Cañon de Valle
- Installation of proposed regional aquifer well R-47 at a location north of Cañon de Valle between regional wells R-18 and R-63 to characterize contaminant flow paths to the regional aquifer and detect maximum concentrations of hexahydro-1,3,5-trinitro-1,3,5 triazine in the regional aquifer downgradient of the major infiltration zone beneath Cañon de Valle
- Installation of a new regional groundwater monitoring well in the southern part of TA-16 to augment the existing well network by increasing the detection efficiency for contaminants originating from S-Site Canyon and Fishladder Canyon

CONTENTS

1.0 INTRODUCTION 1

2.0 MONITORING OBJECTIVES AND EVALUATION APPROACH 1

3.0 CONCEPTUAL MODEL FOR TA-16 2
3.1 Contaminant Sources 2
3.2 Hydrology and Contaminant Transport 4
3.3 Data Gaps in the Site Conceptual Model with Respect to the Monitoring Network 6

4.0 MONITORING NETWORK ASSESSMENT 7

5.0 RECOMMENDATIONS 14
5.1 DC-Resistivity Profiling in Cañon de Valle 14
5.2 Disposition of Existing Wells 15
5.3 Recommendations for New Wells 18

6.0 SCHEDULE 20

7.0 REFERENCES 20

Figures

Figure 1.0-1 The TA-16 area showing the perched-intermediate and regional wells discussed in this network evaluation 23

Figure 3.1-1 Major contaminant sources and infiltration zones discussed in this report 24

Figure 3.2-1 The TA-16 area showing hypothesized extent of the upper and lower deep-perched groundwater zones, regional water table, and the geology at the regional water table 25

Figure 3.2-2 Conceptual cross-section showing the distribution of groundwater in the vicinity of Cañon de Valle at TA-16 26

Tables

Table 3.1.1 TA-16 Contaminant Sources and Ranking Based on their Potential to Impact Groundwater 27

Appendixes

Appendix A Physical and Hydrologic Attributes of Existing Perched-Intermediate and Regional Aquifer Monitoring Wells at Technical Area 16

Appendix B Geochemical Performance of the Technical Area 16 Network Wells

Appendix C Analysis of Technical Area 16 Regional Aquifer Monitoring Network Based on Numerical Simulations of Potential Contaminant Transport

Appendix D Contaminant Sources at Technical Area 16

Appendix E Analysis of Temporal Fluctuations of the Intermediate and Regional Water Levels Near Technical Area 16

Acronyms and Abbreviations

3-D	three-dimensional
AOC	area of concern
ARSL	American Radiation Services International
bgs	below ground surface
CME	corrective measures evaluation
CMI	corrective measures implementation
CMR	combinable magnetic resonance
COPC	chemical of potential concern
CV	casing volume
DC	direct current
DNX	hexahydro-1,3,5-trinitro-1,3,5 triazine
DO	dissolved oxygen
DOE	U.S. Department of Energy
FEHM	Finite Element Heat and Mass (transfer code)
FMI	Formation Micro-Imager
GBIR	Groundwater Background Investigation Report
GSP	gear-driven submersible pump
HE	high explosives
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HSA	hollow-stem auger
I.D.	inside diameter
IFGMP	Interim Facility-Wide Groundwater Monitoring Plan
LANL or the Laboratory	Los Alamos National Laboratory
MADS	Model Analysis & Decision Support (software)
MDA	material disposal area
MDL	method detection limit
MNX	mononitrosodimethylamine
MP	multiple port
MTBE	methyl tert-butyl ether
NMED	New Mexico Environment Department
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity unit
O.D.	outside diameter

ORP	oxygen-reduction potential
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PQL	practical quantitation limit
PVC	polyvinyl chloride
RC	reverse circulation
RCRA	Resource Conservation and Recovery Act
RDX	hexahydro-1,3,5-trinitro-1,3,5 triazine
RPF	Records Processing Facility
SAPP	sodium-acid pyrophosphate
SL	screening level
SOP	standard operating procedure
SU	standard unit
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TA	technical area
TATB	triaminotrinitrobenzene
TCE	trichloroethene
TD	total depth
TDS	total dissolved solids
TNT	2,4,6-trinitrotoluene
TNX	hexahydro-1,3,5-trinitroso-1,3,5-triazine
TOC	total organic carbon
UMTL	University of Miami Tritium Laboratory
VCA	voluntary corrective action
VOC	volatile organic compound
wt%	weight by percent
WWII	World War II
WWTP	waste water treatment plant

1.0 INTRODUCTION

This monitoring well network evaluation for Technical Area 16 (TA-16) at the Los Alamos National Laboratory (LANL or the Laboratory) is being conducted pursuant to a requirement set forth by the New Mexico Environment Department's (NMED's) letter, "Well Evaluation and Network Recommendations Study Technical Area 16 and Upper Water Canyon Watershed Los Alamos National Laboratory," dated January 31, 2011 (NMED 2011, 111749). A previous network evaluation was conducted in 2007 and 2008 for Consolidated Unit 16-021(c)-99 (the 260 Outfall), located at TA-16 (LANL 2007, 095787; LANL 2008, 101330).

This network evaluation addresses the adequacy of the existing perched-intermediate and regional groundwater monitoring network for detecting releases from known or potential contaminant sources at TA-16 to support ongoing investigations and a future corrective measures evaluation (CME) implemented under the Compliance Order on Consent. The perched-intermediate and regional wells that are considered as part of this network evaluation are shown in Figure 1.0-1. Solid waste management units (SWMUs) and areas of concern (AOCs) at TA-16 are addressed with particular emphasis on high explosives (HE) contamination associated with the 260 Outfall area, which includes SWMUs 16-003(k) and 16-021(c) that make up Consolidated Unit 16-021(c)-99. The recommendations presented from this evaluation are intended to provide a data set to support the evaluation and selection of corrective measures for applicable sites at TA-16.

Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to NMED in accordance with U.S. Department of Energy policy.

2.0 MONITORING OBJECTIVES AND EVALUATION APPROACH

The purpose of this report is to evaluate the existing groundwater monitoring-well network that supports investigations and potential corrective measures for SWMUs and AOCs at TA-16. The recommendations presented in section 5 are made in the context of the specific objectives described below.

1. Evaluate the adequacy of the existing groundwater monitoring network to support the selection of groundwater-protection alternatives for the CME report for Consolidated Unit 16-021(c)-99 (the 260 Outfall and other related or collocated units).

   This objective is focused on an evaluation of the network from the perspective of whether there are data gaps specifically with respect to the nature and extent of contamination in both the deep-perched and regional groundwater that would affect the selection of remedial alternatives. Key aspects of nature and extent include the distribution of contaminants of concern, specifically RDX (hexahydro-1,3,5-trinitro-1,3,5 triazine), and the lateral and vertical distribution of contaminated deep-perched and regional groundwater. Investigations conducted to date for the 260 Outfall show concentrations of RDX at levels above the U.S. Environmental Protection Agency tap water screening level (SL) of 6.1 μg/L (based on a 10^{-5} cancer risk) (EPA 2011, 204336) in shallow and deeper perched-intermediate groundwater. In addition, concentrations of RDX in regional well R-18 are increasing, indicating a complete pathway for RDX transport to the regional aquifer. Therefore, further refinement of the nature and extent of contamination in both the deep-perched and regional groundwater zones is important to support an assessment of potential remedial alternatives for protection of the regional aquifer.

2. Evaluate the adequacy of the existing groundwater monitoring network to support ongoing investigations of Cañon de Valle, S-Site, and Upper Water Canyon Aggregate Areas.

   This objective focuses on assessments of other potential TA-16 sources of groundwater contamination in the upper Water Canyon, S-Site, and Cañon de Valle areas. These assessments evaluate process knowledge and supporting site investigation data to inform a general ranking (or likelihood) of groundwater contamination from these specific contaminant sources. The ranking of these sites is presented in section 3 of this report. A formal evaluation is conducted to determine the detection efficiency of the monitoring network for medium- and high-priority sources in these areas.

3. Evaluate whether the existing network provides for detection of potential contamination upgradient of existing water supply wells, which are located at distances of 2.4 mi (3.8 km) or greater east of TA-16.

The document includes an evaluation of the physical and geochemical performance of each screened interval in existing wells screens, recommendations for disposition of existing “parked” wells and Westbay wells, and a hydrogeologic analysis of known and potential groundwater flow paths.

3.0 CONCEPTUAL MODEL FOR TA-16

This section presents an overview of the principal sources of contamination at TA-16 and of the Laboratory’s current conceptual model for the fate and transport of contaminants in the subsurface. More detailed descriptions of sources and conceptual models for hydrology and contaminant transport are presented in the Investigation Report for Water Canyon/Cañon de Valle (LANL 2011, 207069) and references therein. Section 3.1 provides a brief summary of SWMUs and AOCs at TA-16 specifically with respect to their potential to impact groundwater. The contaminant sources are described in detail in Appendix D and ranked relative to their potential for impacting groundwater in section 3.1. Section 3.2 presents a summary of the aspects of the site hydrologic and contaminant transport conceptual model relevant for this network evaluation.

3.1 Contaminant Sources

Major TA-16 contaminant sources with the potential to impact groundwater are summarized in Table 3.1-1 and are shown in Figure 3.1-1. These sources include the losing reach of Cañon de Valle downstream from the 260 Outfall, the former retention pond at the 260 Outfall, other HE retention ponds, HE process building outfalls and drainages, contaminated alluvial aquifers, and large surface materials disposal areas (MDAs). This evaluation of contaminant sources that may impact groundwater focuses on the potential infiltration zones for these sources rather than on the individual SWMUs.

For this evaluation, the sources are grouped and ranked by their potential to impact groundwater. The sources and the justification for their prioritization are discussed below and in Appendix D. Sources ranked as having high potential for groundwater impact are known to have received large quantities of contaminants, particularly RDX and other HE, at concentrations that are orders of magnitude above risk-screening levels; to have received large volumes of water that provide a significant hydrologic driving force for infiltration of contaminants into deep perched-intermediate zones at TA-16; and to show evidence of sediment contamination in neighboring canyons located downgradient of the source areas. Because RDX is the only constituent that has migrated to deep-perched groundwater at TA-16 at levels consistently greater than SLs, this evaluation focuses on the sources of RDX.

Sources with high potential for groundwater impact include the most highly contaminated reach in Cañon de Valle and the 260 Outfall pond and drainage. These are hypothesized to be the principal sources for the large contaminated deep-perched aquifer located at a depth of greater than 700 ft beneath Cañon de Valle and the northern portion of TA-16 (LANL 2011, 207069). Sediment investigations show elevated concentrations of RDX for more than 3 mi (5 km) below the 260 Outfall drainage along the length of Cañon de Valle and extending into Water Canyon.

Sources categorized as having medium potential for groundwater impact have known contaminants in water at levels greater than risk drivers, either for HE or organic solvents (particularly tetrachloroethene [PCE]). These sources have received large volumes of water, providing a hydrologic driving force for contaminant infiltration into the vadose zone, and show evidence of sediment contamination in neighboring canyons downgradient of the source area (LANL 2011, 207069). These sites are not known to have contributed to contamination in the deep-perched aquifer at TA-16 but are still of potential concern. Sources with medium potential impact include the 30s Line and 90s Line HE retention ponds (LANL 2010, 108279); the losing reach within Fishladder Canyon (LANL 2009, 105061.17), particularly downgradient of the TA-16 Burning Ground; and the westernmost losing reach within S-Site/Martin Spring Canyon (LANL 2011, 207069). Sediment investigations show elevated contaminant concentrations in Fishladder Canyon and S-Site/Martin Spring Canyon, indicating transport of contaminants along these canyons.

Sources with low potential for groundwater impact either lack known large contaminant concentrations (particularly RDX) or lack large volumes of water to provide a hydrologic driving force to promote contaminant infiltration. If soil or sediment contamination is present, it is located near the original source or drainage area rather than downgradient in neighboring canyons. The lower-priority sources include the alluvial aquifer in Water Canyon, the TA-16-430 drainage, the TA-16-460 drainage, the HE retention pond at V-Site, MDA P and the TA-16 Burning Ground, MDA R, K-Site, and the Zia shops drum storage area. These sites are discussed in detail in Appendix D. Many additional potential sources of contamination not associated with large volumes of water or not exhibiting high levels of contamination are considered low-priority sources (LANL 2006, 091450; LANL 2010, 110409; LANL 2011, 111810.32). For many of the lower-priority sources, ongoing studies as part of the Cañon de Valle, S-Site, and Upper Water Canyon Aggregate Area investigations will further evaluate their ranking.

The high- to medium-priority sources at TA-16 are the most important locations to characterize and monitor for groundwater protection, and they are the focus of this network evaluation. For completeness, some lower-priority sources at TA-16 are also described in Appendix D, but these sites present little or no threat to groundwater and are not included as part of the network evaluation.

NMED requested the Laboratory include combined sources in the Upper Water Canyon Aggregate Area in the network evaluation (NMED 2011, 111749; NMED 2011, 111827). Sediment investigations have been conducted in Water Canyon and its tributaries above the confluence with Cañon de Valle that address these sources. These investigations found no detects of RDX in canyon-bottom sediment, except in Martin Spring Canyon close to Martin Spring (LANL 2011, 207069). At TA-16, the presence of RDX or PCE in soil and sediment samples is an effective indicator for the locations of medium- to high-priority sources. Therefore, the lack of these contaminants in upper Water Canyon sediment deposits supports the ranking of sources in the Upper Water Canyon Aggregate Area as lower priority for their potential to impact groundwater (Appendix D).

3.2 Hydrology and Contaminant Transport

This section describes aspects of the site-specific conceptual model for hydrology and contaminant transport that are most important to this network evaluation. A more detailed description is presented in section 7 of the Investigation Report for Water Canyon/Cañon de Valle (LANL 2011, 207069) and in references therein. Figure 3.2-1 is a map of the TA-16 area that shows key features of the hydrogeologic conceptual model such as the hypothesized extents of the two deep-perched groundwater zones, the regional water table, and the geology at the regional water table at TA-16. A conceptual cross-section showing the hydrogeology and groundwater occurrences for the area near Cañon de Valle is presented in Figure 3.2-2.

The most significant anthropogenic water sources at TA-16 include the former waste water treatment plant (WWTP) (releases of about 6.6 million gal./yr), TA-16-300 (5.3 million gal./yr), TA-16-460 (3.9 million gal./yr), TA-16-340 (3.6 million gal./yr), steam plant (about 3.1 million gal./yr), and the 260 Outfall (2.5 million gal./yr). These effluent volumes represent a snapshot dating from 1994 (LANL 1994, 076858); flow volumes earlier in the history of TA-16 were presumably larger when HE production levels were much greater. Effluents from the former WWTP and steam plant are water sources that could mobilize contaminants, but these effluents are not considered to be contaminant sources.

The nature and volume of effluent released from outfalls varied over time as a result of changes in research activities at the Laboratory, changes in water treatment methods, and changes in environmental standards. As a result, the present-day distribution of contaminants in the watershed reflects the geochemical properties of individual contaminants, the history of releases from multiple Laboratory sites, and heterogeneous hydrogeological and mineralogical properties of alluvium and aquifer material.

Much of the contamination released from the 260 Outfall was transported to Cañon de Valle by surface-water flow. Based on the extent of perennial surface water and alluvial groundwater, the main infiltration pathway for contaminated water in Cañon de Valle is located downcanyon of the major release site at the 260 Outfall and extends east to the vicinity of MDA P. Infiltration of surface water and alluvial groundwater into bedrock units results in the vertical transport of contaminants into the suballuvium vadose zone. Transport of contaminants to these deeper zones is generally limited to soluble constituents such as RDX, other HE components, boron, and other organic compounds.

Water percolation into bedrock is greater beneath the canyon floors than the mesa tops because surface flow and alluvial groundwater provide hydrologic drivers for infiltration. However, mesas have local areas of increased infiltration where sufficient hydrologic drivers exist, such as beneath ponds (e.g., the 90s Line Pond and 260 Outfall pond) or beneath tributary drainages that flow during snowmelt and storm events or that received effluent in the past.

Groundwater in the springs and shallow bedrock at TA-16 is probably largely recharged by infiltration of surface water along the Pajarito fault zone, particularly where the fault zone crosses large wet drainages such as Cañon de Valle (Newman et al. 1998, 076883; LANL 2003, 077965; Dale et al. 2005, 102785). Some of the infiltrated water is diverted laterally along partings and surge beds in the upper portion of the Tshirege Member, forming the shallow perched groundwater zones (<200-ft depth) at TA-16.

The deep-perched groundwater zones (>200 ft below ground surface [bgs]) beneath TA-16 probably represent multiple zones with poor vertical hydraulic connection. Deep-perched groundwater occurs in a variety of geologic units, including the Cerro Toledo interval, Otowi Member, and Puye Formation. Of these deep-perched zones, the two that occur beneath middle Cañon de Valle near well R-25 are the most important in terms of contaminant pathways and of possible sources of contaminated recharge to the regional aquifer (Figure 3.2-2). The two deep-perched zones near well R-25 are referred to as upper

deep-perched groundwater (approximately 700 to 1000 ft bgs) and lower deep-perched groundwater (approximately 1140 to 1215 ft bgs) in this report (Figures 3.2-1 and 3.2-2).

The maximum lateral extent of the deep-perched groundwater zones is defined by wells and information from borings in the TA-16 area (Figures 3.2-1 and 3.2-2). Lateral and vertical information is known for deep-perched groundwater occurrences for the area south of the Cañon de Valle recharge area, but little is known about the area north of Cañon de Valle. Water-level data indicate the presence of a recharge mound in the upper deep-perched groundwater beneath Cañon de Valle, and symmetry in the shape of the mounded deep-perched groundwater can be inferred to the north of Cañon de Valle. The presence of contaminants such as RDX and HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) in deep-perched groundwater at widely spaced locations at TA-16 indicates local infiltration of surface water also occurs downgradient of outfalls from buildings used for HE processing (such as the 260 Outfall) and beneath mesa-top ponding areas (such as the 90s Line Pond). This local recharge comingles with and contaminates naturally occurring groundwater in the perched zones.

Well CdV-16-2(i)r is the easternmost well that contains significant HE contamination (Figures 3.2-1 and 3.2-2). Deep-perched groundwater in wells R-47i, CdV-37-1(i), and R-27i, located farther to the east, show no evidence of HE contamination. The distribution of HE contamination in deep-perched groundwater indicates the main infiltration pathway for contaminated water is located in Cañon de Valle west of well R-47i. Where data are available for the lower deep-perched zone (R-25 and CdV-16-4ip), RDX concentrations are lower than in the upper deep-perched zone. Contamination in the lower deep-perched zone likely represents leakage from the upper deep-perched zone, although local recharge along pathways that bypass the upper deep-perched zone cannot be ruled out.

Flow direction in the two deep-perched zones in the vicinity of wells R-25 and CdV-16-4ip is likely controlled, in part, by the dip of silt beds in the Puye Formation that appear to be the perching horizons and by the spatial and temporal distribution of groundwater recharge. Dips of beds in the Puye Formation (determined from borehole Formation Micro-Imager logs) are highly variable, but most beds dip generally eastward, with directions ranging from northeast to southeast. A north and south component of groundwater flow may occur because of focused infiltration directly beneath Cañon de Valle.

The vertical hydraulic communication between the lower deep-perched zone and the regional aquifer near R-25 and CdV-16-4ip is unknown. Regional groundwater is located 1000 to 1300 ft (300 to 400 m below ground surface [bgs]) at TA-16. The water table is primarily in the Puye Formation in the area beneath Cañon de Valle and is within thick Tschicoma dacite lavas in the southern part of TA-16 (Figure 3.2-1). The predominant direction of groundwater flow in the regional aquifer is generally from west to east. However, water table maps indicate there is locally a northeastern and southeastern gradient to flow along the water table east of well R-25 because of mounding in the regional aquifer potentially associated with lateral and vertical distribution of groundwater recharge along the mountain front (including the Pajarito fault zone) and Cañon de Valle (Figure 3.2-1). Variations in groundwater flow directions are likely also affected by three-dimensional heterogeneities in the aquifer media, including the presence of lavas at the water table beneath the southern portion of TA-16. Water-supply pumping on the Pajarito Plateau to the east of TA-16 does not seem to impact aquifer flow directions beneath TA-16.

As discussed in Appendix E, the water levels in the deep-perched zones declined at a rate of about 1 ft/yr (Table E-1); the water levels also declined in the regional aquifer but at a smaller rate (~0.2 ft/yr; Table E-1). The highest water decline in the deep-perched zones was measured at CdV-16-1(i) (~2 ft/yr). The well is located north of R-25 in Cañon de Valle. R-25b and R-25 screens 1 and 2 showed declines of about 1 ft/yr. Deep-perched zone water-level declines diminished to the east of well R-25 (about 0.2 ft/yr in well CdV-16-2(i)r and about 0.1 ft/yr in well R-47i). These observations suggest the water-level decline

near CdV-16-1(i) and R-25 results from diminishing groundwater recharge of the perched zones instead of potential well-construction issues.

Data for RDX in wells R-18 and R-63 show elevated RDX concentrations (LANL 2011, 207069). The values are below the SL (6.1 µg/L), but in well R-18 RDX concentrations have steadily increased from 0.15 µg/L to 1.2 µg/L since 2006, indicating a likely connection to higher concentrations in one or both of the deep-perched groundwater zones. It is uncertain whether the pathway to R-18 is driven by gradients on and within the mounded perched groundwater or whether the pathway is dominated by regional aquifer gradients.

3.3 Data Gaps in the Site Conceptual Model with Respect to the Monitoring Network

Despite extensive work already performed at the site, there are important data gaps in the site conceptual model with respect to the monitoring network at TA-16 (Figure 3.2-2). These data gaps are described below and actions to address them are presented in the recommendations in section 5.

The most significant data gap relevant to the groundwater monitoring network is uncertainty in the nature and extent of HE-contaminated deep-perched groundwater beneath Cañon de Valle. Existing wells penetrating deep-perched groundwater are either located in Cañon de Valle or on the mesa south of the canyon. Because of local recharge along Cañon de Valle, deep-perched groundwater may be distributed symmetrically about the axis of the canyon. Contaminated deep-perched groundwater may extend north of Cañon de Valle and is a potential secondary source for RDX detected in the regional aquifer at well R-18. Further refinement of the nature and extent of RDX in the deep-perched zone is important to assessing potential remedial alternatives for protection of the regional aquifer.

Water-level data from existing wells indicate that groundwater mounding is likely within the deep-perched and regional groundwater systems beneath Cañon de Valle. Mounding can significantly influence local groundwater flow directions and may affect the optimal placement of monitoring wells. Additional water-level data for the deep-perched and regional groundwater systems north of Cañon de Valle are needed to construct reliable water-table maps, particularly for the areas downgradient of the 260 Outfall release site and the Cañon de Valle infiltration zone. The additional water-level data will better delineate local groundwater gradients.

The nature and extent of HE in the regional aquifer is poorly constrained by the existing monitoring-well data. The increasing trend in RDX concentrations at well R-18 suggests a persistent source of contamination reaches the regional aquifer near Cañon de Valle. The RDX concentrations detected at wells R-18 and R-63 likely represent diluted values because the well screens are located 70 ft and 63 ft below the water table, respectively. Much higher concentrations of RDX are likely at the water table close to the breakthrough location, which is assumed to be between the Cañon de Valle infiltration zone and well R-18. More information about RDX concentrations at the top of the regional aquifer close to the contaminant breakthrough location will support an assessment of potential remedial alternatives in the CME report for the 260 Outfall.

The 260 Outfall and Cañon de Valle are important contaminant sources that have high potential to impact groundwater at TA-16. These sources received large quantities of contaminants at high concentrations and large volumes of water that provided a significant hydrologic driving force for infiltration of contaminants. The current monitoring network reflects the importance of the 260 Outfall/Cañon de Valle sources. Less is known about the possible impacts that medium-potential sources may have on TA-16 groundwater and whether the monitoring network is sufficient to detect releases from the southern half of the TA-16 area.

4.0 MONITORING NETWORK ASSESSMENT

This section summarizes the evaluation of the physical and geochemical performance of the group of wells considered for TA-16 in the context of the monitoring objectives described in section 2.0. The physical and hydrologic criteria include the effectiveness of wells and associated sampling systems to provide data to meet the objectives. Also included are reviews of factors evaluated in the context of the conceptual model and monitoring objectives, such as screen positions and screen length. A more detailed discussion of the physical and hydrologic conditions is presented in Appendix A. Geochemical criteria consider conditions within the aquifer related to drilling operations that may result in sample data that do not meet monitoring objectives, focusing on key contaminants of concern for TA-16. A more detailed discussion of the geochemical conditions and evaluation criteria is presented in Appendix B.

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
Groundwater Monitoring in the Vicinity of TA-16 (Regional Aquifer)		
CdV-R-15-3 screen 4	Meets objectives. Straddles the regional piezometric surface. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. Redeveloped in May 2011 as part of Westbay study; only one post-redevelopment sample is available (LANL 2011, 205233). Oxic conditions are present. Both pre- and post-study water chemistries are similar to that at other locations used to characterize area-specific background groundwater. Boron, tritium, chlorinated solvents, and HE are not detected. Toluene detected in the post-study sample was not present in pre-study samples and was likely introduced during redevelopment activities; it is expected to disappear over time. Barium is not detected above local background groundwater concentrations.
CdV-R-15-3 screen 5	Does not meet objectives. Bentonite is next to the lower 6.3 ft of the 6.9-ft-long well screen (see Appendix A), interfering with the free flow of water through the screen.	Does not meet objectives. Redeveloped in May 2011 as part of Westbay study; only one post-redevelopment sample is available (LANL 2011, 205233). Pre- and post-study major-ion chemistries are both distinctly different from area-specific background groundwater. Both chemistries are also characterized by elevated concentrations of manganese, barium, and strontium, which may indicate this well screen remains compromised by bentonite. Boron, tritium, chlorinated solvents, and HE are not detected. Toluene detected in the post-study sample was not present in pre-study samples and was likely introduced during redevelopment activities. Barium is not detected above local background groundwater concentrations.

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
CdV-R-15-3 screen 6	Meets objectives. The well screen is submerged 398 ft below the regional piezometric surface. Despite the downward shift of screens during well construction (see Appendix A), screen 6 is located in relatively porous sediments. The placement and hydrogeologic setting of the screen is representative of aquifer conditions and meets monitoring goals. Although the primary filter pack is longer than the optimum well design (extending 33.9 ft above the well screen), it meets the monitoring goals for a deeply submerged well screen in a heterogeneous aquifer where potential groundwater flow paths are poorly known.	Potentially meets objectives. Redeveloped in May 2011 as part of Westbay study; only one post-redevelopment sample is available (LANL 2011, 205233). Pre- and post-study water chemistries are both similar to area-specific background groundwater. Manganese concentrations exceed background levels. Boron, tritium, chlorinated solvents, and HE are not detected. Toluene detected in the post-rehabilitation sample was likely introduced during the rehabilitation activities and is expected to disappear over time. Barium is not detected above local background groundwater concentrations.
CdV-R-37-2 screen 2	Meets objectives. Straddles the regional water table. Screen is representative of aquifer conditions characterized by dacite flow breccia and lava. Lower 5 ft of screen is within relatively impermeable dacite lava. Screen length, placement, and filter pack meet monitoring goals.	Potentially meets objectives. Redeveloped in April 2011 as part of Westbay study; only one post-redevelopment sample is available (LANL 2011, 205233). Post-study water chemistry is similar to area-specific background groundwater, but manganese concentrations exceed background levels and may indicate this well screen remains compromised. Tritium, chlorinated solvents, and HE are not detected. Toluene detected in the post-rehabilitation sample was likely introduced during the rehabilitation activities and is expected to disappear over time. Barium exceeded local background groundwater concentrations before redevelopment but not following redevelopment. Boron has not been detected above background levels.
CdV-R-37-2 screen 3	Meets objectives. The well screen is submerged 160 ft below the regional piezometric surface. Screen is representative of aquifer conditions characterized by dacite flow breccia and lava. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. Redeveloped in April 2011 as part of Westbay study; only one post-redevelopment sample is available (LANL 2011, 205233). Oxic conditions are present. Both pre- and post-study water chemistries are similar to that at other locations used to characterize area-specific background groundwater. Tritium, chlorinated solvents, and HE are not detected, Toluene detected in the post-study sample was not present in pre-study samples and was likely introduced during redevelopment activities; it is expected to disappear over time.

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
CdV-R-37-2 screen 4	Meets objectives. The well screen is submerged 444.2 ft below the regional piezometric surface. Screen is representative of aquifer conditions characterized by dacite flow breccia and lava. Screen length, placement, and filter pack meet monitoring goals.	Potentially meets objectives. Redeveloped in April 2011 as part of Westbay study; only one post-redevelopment sample is available (LANL 2011, 205233). Post-study water chemistry is similar to area-specific background groundwater. Tritium, chlorinated solvents, HE, and boron are not detected; barium is not detected above local background groundwater concentrations. Toluene detected in the post-rehabilitation sample was likely introduced during the rehabilitation activities. A longer period of record is needed to determine whether or not redevelopment resulted in sustainable improvement in geochemical conditions.
R-18	Meets objectives. Screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Screen length and filter pack meet monitoring goals. The screen is placed somewhat deeper in the aquifer than most other single-screen wells in the monitoring network (70 ft of submergence). Nonetheless, R-18 successfully detects HE in the upper part of the regional aquifer and meets monitoring goals.	Meets objectives. Oxic conditions are present. Other than slightly higher concentrations of nitrate, water chemistry is similar to that at locations used to characterize area-specific background groundwater. RDX is detected consistently, and 1,3,5-dinitrotoluene has also been detected in recent samples. Tritium was detected at low levels in three of the nine samples collected since 2008. Chlorinated solvents and boron are not detected.
R-25 screen 5	Meets objectives. The well screen is submerged 12.7 ft below the regional piezometric surface. Screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. The well is instrumented with a nonpurgeable Westbay sampling system. Conditions are slightly reducing, which appears to be representative of groundwater chemistry in this zone. Chemicals of potential concern (COPCs) including HE, methyl tert-butyl ether (MTBE), and boron, are detected; and low levels of tritium are present. Barium is not detected above local background groundwater concentrations. Major-ion chemistry is distinctly different from area-specific background groundwater chemistry. Elevated phosphate concentrations may indicate the presence of residual sodium acid pyrophosphate (SAPP) used during well development.
R-25 screen 6	Meets objectives. The well screen is submerged 123 ft below the regional piezometric surface. Screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. The well is instrumented with a nonpurgeable Westbay sampling system, but screen conditions are consistently oxic. Inorganic water chemistry differs slightly from that at locations used to characterize area-specific background groundwater, which may be related to the presence of residual SAPP used during well development. Tritium, chlorinated solvents, and HE are not detected; barium and boron are not detected above local background groundwater concentrations.

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
R-25 screen 7	Meets objectives. The well screen is submerged 323 ft below the regional piezometric surface. Screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. The well is instrumented with a nonpurgeable Westbay sampling system but screen conditions are consistently oxic, and field parameters and inorganic water chemistry are similar to those at other locations used to characterize area-specific background groundwater. Low concentrations of 2,4,6-trinitrotoluene (TNT) are detected consistently. Tritium, chlorinated solvents, and boron are not detected.
R-25 screen 8	Meets objectives. The well screen is submerged 513 ft below the regional piezometric surface. Screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. The well is instrumented with a nonpurgeable Westbay sampling system, but screen conditions are consistently oxic, and field parameters and inorganic water chemistry are similar to those at other locations used to characterize area-specific background groundwater. Tritium, chlorinated solvents, HE, and boron are not detected.
R-27	Meets objectives. The well screen is submerged 36.1 ft below the regional piezometric surface. Screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. Oxic conditions are present. Water chemistry is similar to that at other locations used to characterize area-specific background groundwater. Tritium, chlorinated solvents, and HE are not detected. Barium and boron are not detected above local background levels.
R-48	Meets objectives. Screen is representative of aquifer conditions characterized by dacite flow breccia and lava. Screen length, placement, and filter pack meet monitoring goals. Although 146.9 ft below the regional piezometric surface, the well screen is within the uppermost transmissive zone at this location. Overlying massive lavas are aquitards and unsuitable for monitoring purposes.	Meets objectives. Oxic conditions are present. Inorganic water chemistry differs slightly from that at locations used to characterize area-specific background groundwater. A steady decrease in sulfate concentrations indicates the screen is still reequilibrating from drilling and construction activities. Chlorinated solvents and HE are not detected. Low tritium activities have been detected in only two of nine sampling events. Barium and boron are not detected above local background groundwater concentrations.
R-63	Meets objectives. Screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Screen length and filter pack meet monitoring goals. The screen is placed somewhat deeper in the aquifer than most other single-screen wells in the monitoring network (63 ft of submergence). Nonetheless, R-3 successfully detects HE in the upper part of the regional aquifer and meets monitoring goals.	Meets objectives. R-63 completed four rounds of characterization sampling in December 2011; the assessment is based on data for the last three sampling events when the well had completed reequilibrating. Oxic conditions are present. Field parameters and water chemistry are similar to that at locations used to characterize area-specific background groundwater. RDX is detected consistently. Tritium, chlorinated solvents, and boron are not detected.

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
Groundwater Monitoring in the Vicinity of TA-16 (Perched-Intermediate Zones)		
16-26644	Meets objectives. Screen placement is dictated by the limited vertical extent of shallow perched groundwater in welded and fractured tuff. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. Oxic conditions are present. COPCs including chlorinated solvents, HE, and barium are consistently detected as well as low levels of tritium. Major-ion chemistry is distinctly different from area-specific background chemistry but similar to that at other locations at which these COPCs are present.
CdV-16-1(i)	Meets objectives. The well screen is within the upper part of the upper deep-perched groundwater zone. Screen is representative of aquifer conditions characterized by fractured nonwelded tuff deposits. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. Oxic conditions are present. COPCs including HE, chlorinated solvents, MTBE, and toluene are detected consistently as are concentrations of boron and nitrate above those in area-specific background groundwater. Low levels of tritium are present. Barium is not detected above local background groundwater concentrations. Major-ion chemistry is distinctly different from area-specific background chemistry but similar to that at other locations where these COPCs are present.
CdV-16-2(i)r	Meets objectives. The well screen is within the upper deep-perched groundwater zone. Screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. Oxic conditions are present. COPCs including chlorinated solvents and HE are consistently detected as well as low levels of tritium. Major-ion chemistry is slightly different from area-specific background chemistry but similar to that at other locations at which these COPCs are present.
CdV-16-4ip screen 1	Meets objectives. The well screen is within the upper part of the upper deep-perched groundwater zone. The screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Well CdV-16-4ip was originally designed as a pumping well for hydrologic testing, and the 63.6-ft length of the well screen is longer than that typically used to monitor perched groundwater. Nonetheless, the well is useful for assessing contaminant distributions and temporal trends. The screen length, placement, and filter pack meet monitoring goals.	Meets objectives. Oxic conditions are present. COPCs including HE, HE-degradation products, chlorinated solvents, MTBE, toluene, nitrate, and boron are consistently detected as well as low levels of tritium. Major-ion chemistry is distinctly different from area-specific background chemistry but similar to that at other locations where these COPCs are present.

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
CdV-16-4ip screen 2	Meets objectives. The well screen is within the lower deep-perched groundwater zone. The screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. The screen length, placement, and filter pack meet monitoring goals.	Potentially meets objectives. Oxic conditions are present. The chemistry of the first sample (September 2010) is dominated by cross-flow from screen 1. Subsequent samples (November 2010 and March 2011) show steadily decreasing proportions of cross-flow chemistry. Major-ion chemistries of the most recent samples are similar to area-specific background groundwater.
CdV-37-1i	Meets objectives. The well screen is within a deep-perched groundwater zone. Screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Screen length, placement, and filter pack meet monitoring goals.	Potentially meets objectives. The most recent sample indicates that water chemistry in the screen interval may still be reequilibrating following well construction and development activities. Oxic conditions are present; manganese and sulfate concentrations are elevated but steadily decreasing to background levels. Major-ion chemistry is similar to area-specific background groundwater. Tritium, chlorinated solvents, and HE are not detected.
CdV-R-15-3 screen 1	Not applicable (n/a). The well screen has been dry since it was installed.	Screen historically dry
CdV-R-15-3 screen 2	n/a. The well screen has been dry since it was installed.	Screen historically dry
CdV-R-15-3 screen 3	n/a. The well screen has been dry since it was installed.	Screen historically dry
CdV-R-37-2 screen 1	n/a. The well screen has been dry since it was installed.	Screen historically dry
R-25 screen 1	Meets objectives. The well screen is within the upper part of the upper deep-perched groundwater zone. Screen is representative of aquifer conditions characterized by nonwelded tuff deposits. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. The well is instrumented with a nonpurgeable Westbay sampling system. Screen interval is impacted by steel corrosion products manifested by elevated concentrations of nickel, chromium, cobalt, total iron, and manganese, which are not COPCs. Conditions are slightly reducing. COPCs that are consistently detected include HE, HE-degradation products, chlorinated solvents, MTBE, and boron; low tritium activities are present. Barium is not detected above local background groundwater concentrations. Major-ion chemistry is distinctly different from area-specific background groundwater chemistry but similar to that at other locations where these COPCs are present.

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
R-25 screen 2	Meets objectives. The well screen is within the central part of the upper deep-perched groundwater zone. Screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. The well is instrumented with a nonpurgeable Westbay sampling system. Screen interval is impacted by steel corrosion products but to a greater extent than for screen 1, with elevated concentrations of chromium, cobalt, iron, manganese, and nickel, which are not COPCs. Conditions are slightly reducing. COPCs including HE, HE-degradation products, chlorinated solvents, MTBE, and boron are detected; low levels of tritium are present. Barium is not detected above local background groundwater concentrations. Major-ion chemistry is distinctly different from area-specific background groundwater chemistry but similar to that at other locations where these COPCs are present.
R-25 screen 4	Meets objectives. The well screen is within the lower deep-perched groundwater zone. Screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. The well is instrumented with a nonpurgeable Westbay sampling system. Screen interval is impacted by steel corrosion products manifested by elevated concentrations of nickel, chromium, cobalt, total iron, and manganese, which are not COPCs. Conditions are slightly reducing. COPCs including HE, HE-degradation products, chlorinated solvents, MTBE, and boron are detected; low levels of tritium are present. Barium is not detected above local background groundwater concentrations. Major-ion chemistry is distinctly different from area-specific background groundwater chemistry but similar to that at other locations where these COPCs are present.
R-25b	Meets objectives. The upper well screen straddles the water table in the upper deep-perched groundwater zone. Screen is representative of aquifer conditions characterized by nonwelded tuff deposits. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. Oxic conditions are present. COPCs including HE and boron are consistently detected as well as tritium activities and sporadic detections of PCE. Major-ion chemistry is distinctly different from area-specific background chemistry but is similar to that at other locations where these COPCs are present.
R-26 PZ-1	n/a. The well screen has been dry since it was installed.	Historically dry screen
R-26 PZ-2	Does not meet objectives. This 1-in.–outside diameter piezometer in shallow perched groundwater is difficult to sample because of its small diameter and poor flow characteristics. Water samples are extremely turbid.	Does not meet objectives. The piezometer cannot be purged because of a very low recharge rate, and its small diameter necessitates the use of a bailer to collect water samples, which affects the reliability of volatile organic compound (VOC) data. Generally insufficient water is available to bail more than 1 casing volume, which is about 0.5 gal., and only a limited analytical suite can be collected. Water chemistry is distinctly different from area-specific background groundwater and also is differs from the water chemistry in deep groundwater locations at which local contaminants are present. Turbidity is very high, and concentrations of cobalt, manganese, molybdenum, nickel, and zinc are variably high. PCE is detected consistently. HE, other VOCs, and boron are not detected.

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
R-26 screen 1	Meets objectives. The well screen is in the upper part of a thick deep-perched groundwater zone. Screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Although the primary filter pack is longer than the optimum well design (extending 31.8 ft above the well screen), it meets the monitoring goals for a well screen in a heterogeneous aquifer where potential groundwater flow paths are poorly known.	Meets objectives. Redeveloped in June 2011 as part of the Westbay study (LANL 2011, 205233); three post-study samples are available. Oxic conditions are present. Both pre- and post-study water chemistries are similar to that at other locations used to characterize area-specific background groundwater. Tritium, chlorinated solvents, and HE are not detected.
R-47i	Meets objectives. The well screen is within the upper deep-perched groundwater zone. Screen is representative of aquifer conditions characterized by coarse-grained sedimentary deposits. Screen length, placement, and filter pack meet monitoring goals.	Meets objectives. Oxic conditions are present. Geochemical effects arising from drilling and construction activities are apparent in the first water-quality sample collected following development (LANL 2011, 201564). However, geochemical trends from subsequent sampling show steady improvement. For the most recent sampling events, residual effects are limited to TOC and a few inorganic constituents: sodium, sulfate, chloride, manganese, and molybdenum. Otherwise, field parameters and water chemistry are similar to those at locations used to characterize area-specific background groundwater. Tritium, chlorinated solvents, and HE are not detected; barium and boron are not detected above local background concentrations.

5.0 RECOMMENDATIONS

The following sections discuss recommendations for the TA-16 monitoring network. Phased implementation of these recommendations will help to characterize the nature and extent of contaminants and to refine the hydrogeologic conceptual model to meet the objectives stated in section 2.0. Section 5.1 describes a direct current– (DC-) resistivity survey to better define the extent of deep-perched groundwater, particularly to the north of Cañon de Valle. Section 5.2 presents the recommended actions and rationale for each of the existing wells evaluated as part of this report. Section 5.3 recommends the installation of new wells to address uncertainties in the hydrology and nature and extent of contamination to support the development of a revised CME report. The DC-resistivity survey results may provide key information to support drilling targets discussed in section 5.3.

5.1 DC-Resistivity Profiling in Cañon de Valle

The object of DC-resistivity profiling in Cañon de Valle is to identify potential recharge pathways for HE-contaminated groundwater through the vadose zone and to better define the lateral extent of deep-perched groundwater downgradient of the 260 Outfall. HE-contaminated deep-perched groundwater occurs in wells in Cañon de Valle [well CdV-16-1(i)] and on the south rim of the canyon [wells R-25, R-25b, CdV-16-2(i)r, CdV-16-4ip], but the nature and extent of perched groundwater north of

Cañon de Valle is not known. Various potential options for mitigating contaminated groundwater beneath TA-16 may be considered for the CME for Consolidated Unit 16-021(c)-99. These options are all likely to require more information about the nature and extent of contaminated deep-perched groundwater zone(s), specifically to the north of Cañon de Valle.

The proposed DC-resistivity profiles will map the electrical structure of the vadose zone near Cañon de Valle, and this information may be useful for determining the extent of perched saturation or the distribution of conductive silt- and clay-rich confining beds. Two shallow DC-resistivity surveys conducted in Cañon de Valle in 1999 and 2001 were successful in delineating the extent of the alluvial aquifer and mapped the electrical structure of bedrock tuffs to a depth of about 50 ft (LANL 2003, 077965). The geophysical survey proposed in this report will have a practical depth of investigation of approximately 1000 to 1100 ft, which is sufficient to map the electrical structure of the vadose zone at depths where deep-perched groundwater is known to occur. Resistivity profiles will be collected both perpendicular and parallel to Cañon de Valle. The resistivity data will also be used to evaluate a potential recharge mound beneath Cañon de Valle. Interpretation of the resistivity profiles will incorporate hydrogeologic and geophysical information from existing wells and geologic data (e.g., faults) depicted in detailed geologic maps for the area. Interpreted DC-resistivity data will be used to determine the location of a proposed perched-intermediate well described in section 5.3.

5.2 Disposition of Existing Wells

This section presents the recommended actions and rationale for each of the existing wells evaluated in section 4.0. These recommendations are based on the physical, geochemical, and hydrologic factors considered in the context of monitoring objectives 2 and 3 in section 2.0. Section 4 identifies wells that require reconfiguration to better support the monitoring well network. This section discusses the recommendations for well reconfiguration and the rationale.

Based on the assessment in section 4.0, most wells in the current monitoring network downgradient of TA-16 meet monitoring requirements. Except as noted below, it is recommended that the existing wells should continue to be monitored in accordance with the most current Interim Facility-Wide Groundwater Monitoring Plan (IFGMP).

Multiple-screen wells CdV-R-15-3 and CdV-R-37-2 are currently “parked” with their screens isolated by packers following removal of their Westbay sampling systems and redevelopment. This report recommends reconfiguring both wells as single-screen wells, which are easier to purge and sample than the previous Westbay configuration. The reconfiguration of wells CdV-R-15-3 and CdV-R-37-2 meets the objectives of the TA-16 monitoring network and improves the reliability and representativeness of water data through the use of purgeable sampling systems.

Screen 4 at CdV-R-15-3 is selected for retention because it yields representative samples of groundwater, and it monitors the top of the regional aquifer downgradient of major infiltration areas for HE-contaminated surface water and alluvial groundwater in Cañon de Valle. The recommendation to plug and abandon CdV-R-15-3 screen 5 is based on the poor quality of groundwater samples that is probably due to the impact of bentonite on the well screen. Although CdV-R-15-3 screen 6 yields representative samples of groundwater, the recommendation to plug and abandon is based on the deep submergence of the well screen (398 ft) in an area that is proximal to infiltration of contaminated groundwater.

Although relatively deeply submerged (160 ft), CdV-R-37-2 screen 3 is selected for retention because it yields representative samples of groundwater and is within a porous zone of dacite breccia. CdV-R-37-2 screen 2 straddles the water table, but the lower 5 ft of the screened interval is within relatively impermeable dacite lava. Also, screen 2 has low dissolved oxygen and high manganese, indicating

reducing conditions. CdV-R-37-2 screen 4 is deeply submerged (444.2 ft) and therefore is less suitable than screen 3 for monitoring groundwater downgradient of source areas at TA-16.

Well R-25 is also a multiple-screen well that is being sampled using the Westbay sampling system. It has seven operational screens that provide water-quality and water-level data for deep-perched and regional groundwater. This report recommends continued monitoring of well R-25 in accordance with the IFGMP in its current configuration. It is located in an area where HE contamination is known to occur in groundwater, and it provides water-quality data that meet monitoring objectives.

Well CdV-16-4ip is a two-screen well that is currently "parked" with the screens isolated by packers. This report recommends reconfiguring CdV-16-4ip to a single-screen well by retaining the upper screen and abandoning the lower well screen. The well screens are located in two separate deep-perched groundwater zones, and the hydraulic head in the upper zone is substantially greater than the lower zone (Figure 3.2-2). Also, the available water-quality data suggest the upper-perched zone contains much higher HE concentrations than the lower zone. The recommendation to plug and abandon screen 2 is based on the Laboratory's experience with packer failures in multiscreen wells that resulted in significant cross-flow between groundwater zones. Although packer failures are infrequent, loss of hydraulic isolation at CdV-16-4ip would be especially significant because cross-flow between screens 1 and 2 is estimated to be 6150 gal./d and would result in significantly contaminated groundwater being introduced near the regional aquifer. While multiscreen wells are used at the Laboratory as a cost-effective approach to monitoring multiple groundwater zones, their use is generally avoided in situations where accidental cross-flow could result in contamination of deeper groundwater zones, particularly near or at the regional aquifer. Therefore, recommendation to plug and abandon the lower screen is a measure to ensure the cross-flow does not occur between zones and to protect the regional aquifer. The need to further characterize and monitor the lower deep-perched groundwater zone in the area around CdV-16-4ip will be evaluated as new data from new and existing wells are available.

The following summary recommends actions for existing wells.

Well Name	Recommended Action	Rationale
Groundwater Monitoring in the Vicinity of TA-16 (Regional Aquifer)		
CdV-R-15-3 screen 4	Convert CdV-R-15-3 to single-screen well and retain screen 4.	This screen monitors the top of the regional aquifer downgradient of major infiltration areas for HE-contaminated surface water and alluvial groundwater in Cañon de Valle.
CdV-R-15-3 screen 5	Convert CdV-R-15-3 to single-screen well and plug and abandon screen 5.	This screen is thoroughly impacted by bentonite and does not meet monitoring objectives.
CdV-R-15-3 screen 6	Convert CdV-R-15-3 to single-screen well and plug and abandon screen 6.	This screen is deeply submerged in the regional aquifer (398 ft) and is less suitable for monitoring groundwater downgradient of infiltration areas in Cañon de Valle than screen 4.
CdV-R-37-2 screen 2	Convert CdV-R-37-2 to single-screen well and pack off screen 2.	This screen is within relatively tight lavas and even after extensive redevelopment, it has low dissolved oxygen and high manganese, indicating reducing conditions.
CdV-R-37-2 screen 3	Convert CdV-R-37-2 to single-screen well and retain screen 3.	This screen is within relatively porous brecciated lavas and the water chemistry is consistently good. The screen is submerged 160 ft in an area with a component of downward gradient.

Well Name	Recommended Action	Rationale
CdV-R-37-2 screen 4	Convert CdV-R-37-2 to single-screen well and plug and abandon screen 4.	This screen is deeply submerged in the regional aquifer (444.2 ft) and is less suitable for monitoring groundwater downgradient of source areas at TA-16 than screen 3.
R-18	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
R-25 screen 5	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
R-25 screen 6	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
R-25 screen 7	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
R-25 screen 8	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
R-27	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
R-48	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
R-63	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
Groundwater Monitoring in the Vicinity of TA-16 (Perched-Intermediate Zones)		
16-26644	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
CdV-16-1(i)	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
CdV-16-2(i)r	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
CdV-16-4ip screen 1	Convert CdV-16-4ip to single-screen well and retain screen 1.	This screen monitors the top of the upper deep-perched groundwater zone downgradient of major infiltration areas for HE-contaminated surface water and alluvial groundwater in Cañon de Valle.
CdV-16-4ip screen 2	Convert CdV-16-4ip to single-screen well and plug and abandon screen 2.	Failure of packers or other well components could lead to the introduction of highly contaminated water to the lower perched zone that is in close proximity to the regional aquifer.
CdV-37-1i	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
CdV-R-15-3 screen 1	No action	Screen historically dry
CdV-R-15-3 screen 2	No action	Screen historically dry
CdV-R-15-3 screen 3	No action	Screen historically dry
CdV-R-37-2 screen 1	No action	Screen historically dry
R-25 screen 1	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
R-25 screen 2	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
R-25 screen 4	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
R-25b	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
R-26 PZ-1	No Action	Piezometer historically dry
R-26 PZ-2	Explore alternative sampling systems or techniques	Piezometer does not meet monitoring objectives. It cannot be purged because of a very low recharge rate, and its small diameter requires sampling with bailer, which likely results in VOC concentrations that are biased low. Turbidity is very high and some trace-metal concentrations are highly variable.

Well Name	Recommended Action	Rationale
R-26 screen 1	Continue to monitor as part of the IFGMP	Well meets monitoring objectives
R-47i	Continue to monitor as part of the IFGMP	Well meets monitoring objectives

5.3 Recommendations for New Wells

The regional network assessment presented in Appendix C supports the recommendations for new groundwater monitoring wells presented in this section.

A new deep-perched monitoring well is proposed north of Cañon de Valle (Figure 3.1-1). The proposed well supports the CME for Consolidated Unit 16-021(c)-99 by further bounding the extent of contaminated deep-perched groundwater to the north of Cañon de Valle (Figure 3.2-1). This well is proposed to meet objective 1 identified in section 2.0. At least two distinct deep-perched groundwater zones are present south of Cañon de Valle (Figure 3.2-2). The proposed deep-perched monitoring well will be drilled to a sufficient depth to determine whether similar perched zones are present north of Cañon de Valle. A preliminary location for the proposed deep-perched monitoring well is shown in Figure 3.1-1, but a final location will be selected after the results of the DC-resistivity survey described in section 5.1 are evaluated. A work plan describing the proposed well installation will be prepared. The well will likely be completed with a relatively long screen to increase the potential for retaining a long-lived monitoring point in heterogeneous and potentially ephemeral perched-intermediate groundwater. A longer screen will also make the well potentially more beneficial in the event of implementation of a pump-and-treat remedial alternative in the CME. The well-specific work plan will propose approaches to drilling that will allow characterization of multiple deep-perched zones. A decision to install an additional well may be made if multiple deep-perched zones are present based on data collected during drilling of the proposed well.

This assessment also recommends that one new regional groundwater monitoring well be installed to augment the existing well network to better define the RDX contamination flow paths to the regional aquifer north of Cañon de Valle (Figure 3.1-1; well “W11” in Appendix C). The assessment presented in Appendix C also demonstrates that the previously proposed location for regional well R-47, near the intermediate well R-47i, does not improve the detection of TA-16 contaminants. Newly installed well R-63, which was placed west of the proposed R-47 location, provides better monitoring efficiency than the originally proposed R-47 location. The Laboratory no longer proposes a regional well near intermediate well R-47i. Instead, the proposed location for well R-47 should be moved to the location of well “W11” (Figure 3.1-1; Appendix C). The proposed regional well will be installed with a screen near the water table to characterize contamination flow paths and detect maximum RDX concentrations in the regional aquifer downgradient of the major infiltration zone beneath Cañon de Valle. Existing wells where RDX has been detected (wells R-18 and R-63) are screened 63 ft to 70 ft below the water table and probably do not represent maximum RDX concentrations in the regional aquifer. Groundwater moving downgradient of the potential breakthrough location is expected to flow predominantly in the uppermost section of the regional aquifer towards the east, northeast, or southeast depending on aquifer conditions, including mounding, and the location(s) where the contaminants potentially reach the aquifer. The proposed location is driven by the increasing trends for RDX in R-18. The presence or absence of deep-perched groundwater at this location will be determined during drilling to the regional aquifer, providing an additional opportunity to assess the nature and extent of deep-perched groundwater north of Cañon de Valle. Data from the well will support the selection of remedial alternatives for the CME for Consolidated Unit 16-021(c)-99 by helping to constrain the extent of contamination in the regional aquifer and may provide insights on the pathway(s) between the contaminated deep-perched groundwater and R-18. This well is proposed to meet objective 1 identified in section 2.0. Installation of this well should

follow completion of the proposed deep-perched well, which will provide information about the extent of potential secondary contaminant sources in the lower vadose zone.

This assessment also recommends installing a new regional groundwater monitoring well to augment the existing well network by increasing the detection efficiency for contaminants originating from S-Site Canyon and Fishladder Canyon (Figure 3.1-1; well "W38" in Appendix C). This well is proposed to meet objective 2 identified in section 2.0. Installation of this well will increase the overall detection efficiency of the TA-16 monitoring network to a minimum of 95% for the high- and medium-priority sources at TA-16 (Appendix C). Water-level data at this location will also help to constrain the shape of the regional water table and groundwater flow directions at TA-16. The presence or absence of deep-perched groundwater will be determined during drilling to the regional aquifer, providing an opportunity to assess hydrogeologic conditions in this area.

The following summary presents recommendations for installation of new wells. The recommendations are made to address gaps in the capability of the existing network to fulfill the objectives of the monitoring network.

Well Name	Recommended Action	Rationale
Deep-perched Well(s)	Install a deep-perched well to the north of Cañon de Valle. A specific location will be selected based on results of the DC-resistivity survey proposed for Cañon de Valle and presented in a well-specific work plan. The proposed well will characterize the nature and extent of deep-perched zones north of Cañon de Valle. A decision to install an additional well will be made if multiple deep-perched zones are present based on data collected during drilling of the proposed well.	The primary purpose of this well is to determine the northern extent of HE-contaminated deep-perched groundwater affected by local recharge beneath Cañon de Valle. The new well will provide information about size and characteristics of deep-perched groundwater for evaluation of CME alternatives.
Regional Aquifer Well	Install single-screen regional groundwater monitoring well R-47 within or downgradient of the primary potential breakthrough location beneath Cañon de Valle. The well location should be near the location identified as "W11" in Appendix C.	Installation of this well will provide a proximal monitoring location downgradient of the most significant contamination identified in deep-perched groundwater beneath TA-16. Groundwater data from this well and from existing nearby regional wells will further refine the nature and extent of HE contamination in the regional aquifer and provide information necessary to evaluate CME alternatives with respect to the regional aquifer. Water-level data from "W11" will also constrain the shape of the regional water table and groundwater flow directions in this area.
Regional Aquifer Well	Install a new single-screen regional groundwater monitoring well downgradient of the potential breakthrough location for S-Site Canyon and Fishladder Canyon. The well location should be near the location identified as "W38" in Appendix C.	Installation of this well will increase the overall detection efficiency of the TA-16 monitoring network to a minimum of 95% for the high- and medium-priority sources at TA-16. Water-level data from "W38" will also constrain the shape of the regional water table and groundwater flow directions in this area.

The evaluation of sources presented in section 3 and in Appendix D supports the ranking of the sources upgradient and within upper Water Canyon as low-priority sources with respect to their potential for impacting groundwater. This ranking is based on process knowledge and sediment data that show minimal contamination and no PCE or RDX detects from this portion of the watershed. Therefore, this network analysis does not recommend the installation of intermediate or regional wells specifically for monitoring the Upper Water Canyon Aggregate Area, as NMED previously requested (NMED 2011, 111749; NMED 2011, 111827). This evaluation satisfies objective 2 for sources in the Upper Water Canyon Aggregate Area.

Similarly, monitoring is not proposed at this time for other TA-16 sites that are considered low priority in this evaluation. If additional investigations at these sites identify contamination that may impact groundwater, the need for additional monitoring will be reassessed.

The previous revision of the TA-16 well network analysis (LANL 2007, 100113; LANL 2008, 101875.5) concluded that the existing network of near- and far-field regional monitoring wells has a greater than 95% chance of detecting TA-16 contaminants before they reach water-supply wells. That conclusion is further supported by the updated evaluation in Appendix C that indicates high detection efficiency for all high- and medium-priority TA-16 sources with the addition of regional monitoring well “W38” recommended above. Therefore, the recommended network will satisfy objective 3 to provide for the detection of potential contaminants upgradient of water-supply wells.

6.0 SCHEDULE

Upon NMED’s approval of the recommendations presented in this report, the Laboratory will submit work plan(s) for implementing the recommended actions. Each work plan will contain specific information for each of the actions and will propose a schedule for implementation. As directed in NMED’s approval with modification for the hydrologic testing report for Consolidated Unit 16-021(c)-99 (NMED 2011, 209247), a work plan describing the proposed DC resistivity survey will be submitted to NMED by April 30, 2012. Reconfiguration of well CdV-16-4ip and the installation of a permanent sampling system will be completed by March 13, 2013, as approved by NMED (2012, 211304).

The priority for the recommended actions in section 5.0 is as follows:

1. Conduct DC-resistivity profiling in Cañon de Valle
2. Install a deep-perched intermediate well north of Cañon de Valle
3. Install regional well R-47 at location “W11” north of Cañon de Valle
4. Reconfigure well CdV-16-4ip to a single completion well
5. Reconfigure well CdV-R-15-3 to a single completion well
6. Reconfigure well CdV-R-37-2 to a single completion well
7. Install a regional well at location “W38” in southern TA-16

7.0 REFERENCES

The following list includes all documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate’s Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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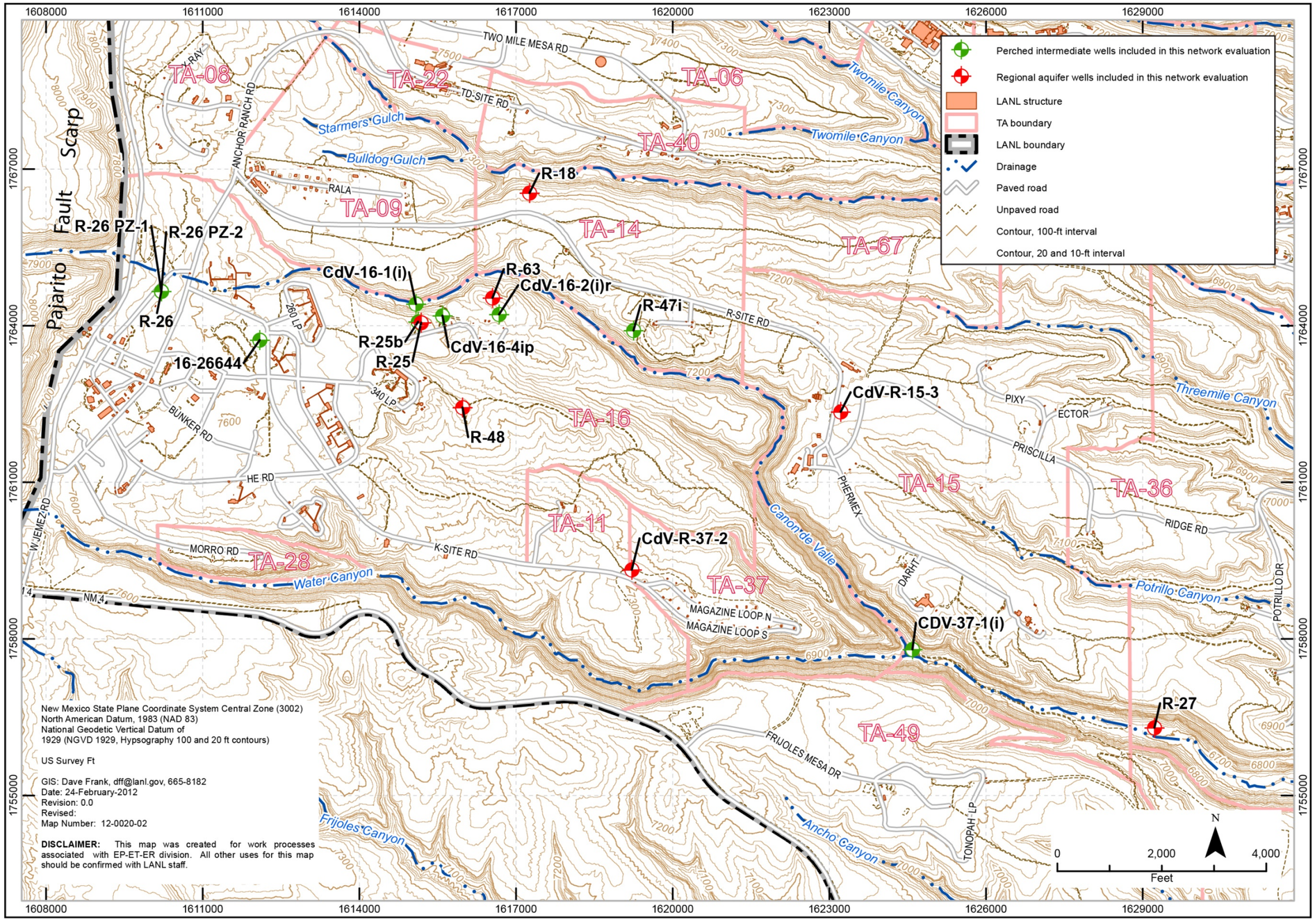
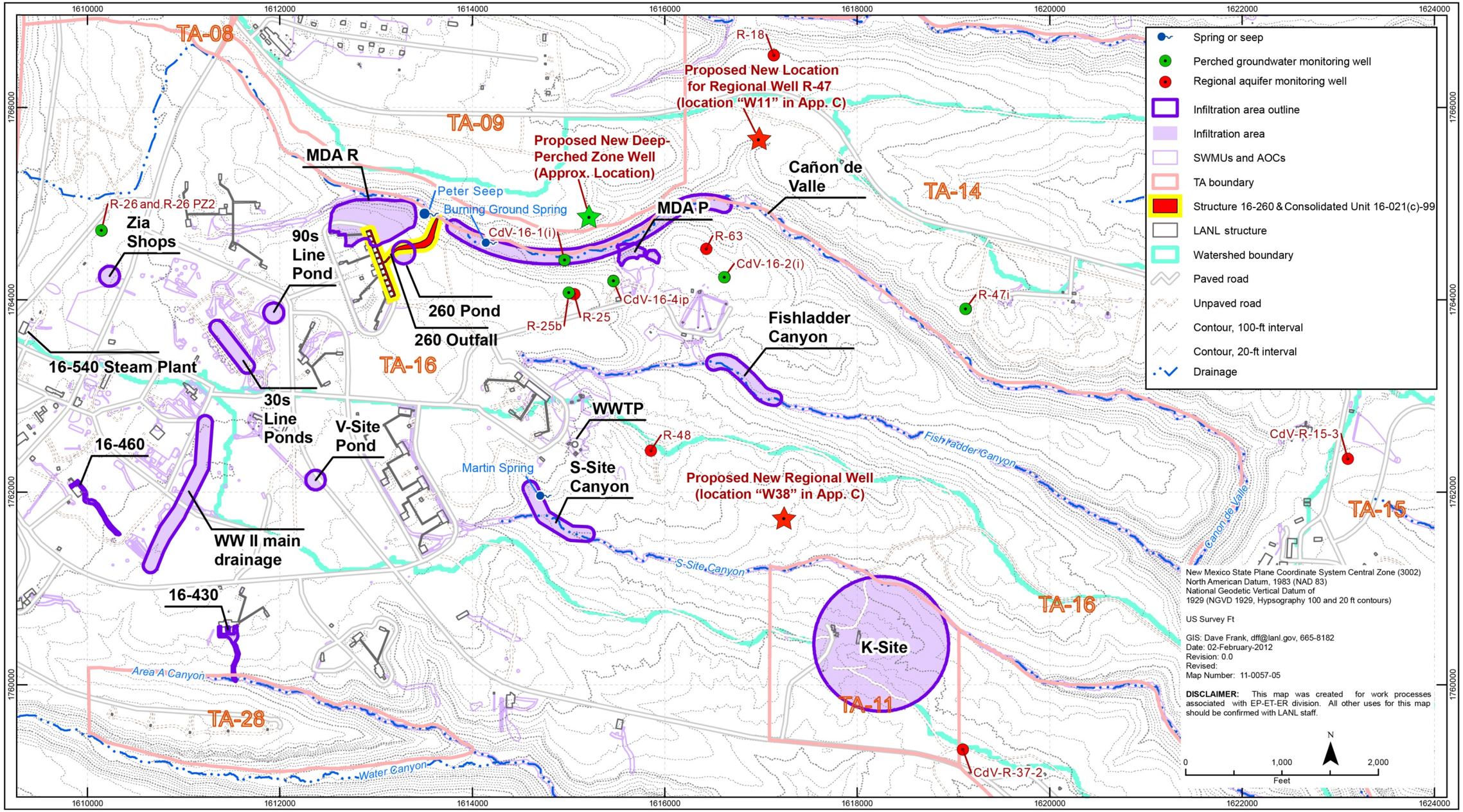


Figure 1.0-1 The TA-16 area showing the perched-intermediate and regional wells discussed in this network evaluation



Note: The locations of proposed new deep-perched and regional groundwater wells are also shown; these are discussed in section 5.3 of this report.

Figure 3.1-1 Major contaminant sources and infiltration zones discussed in this report

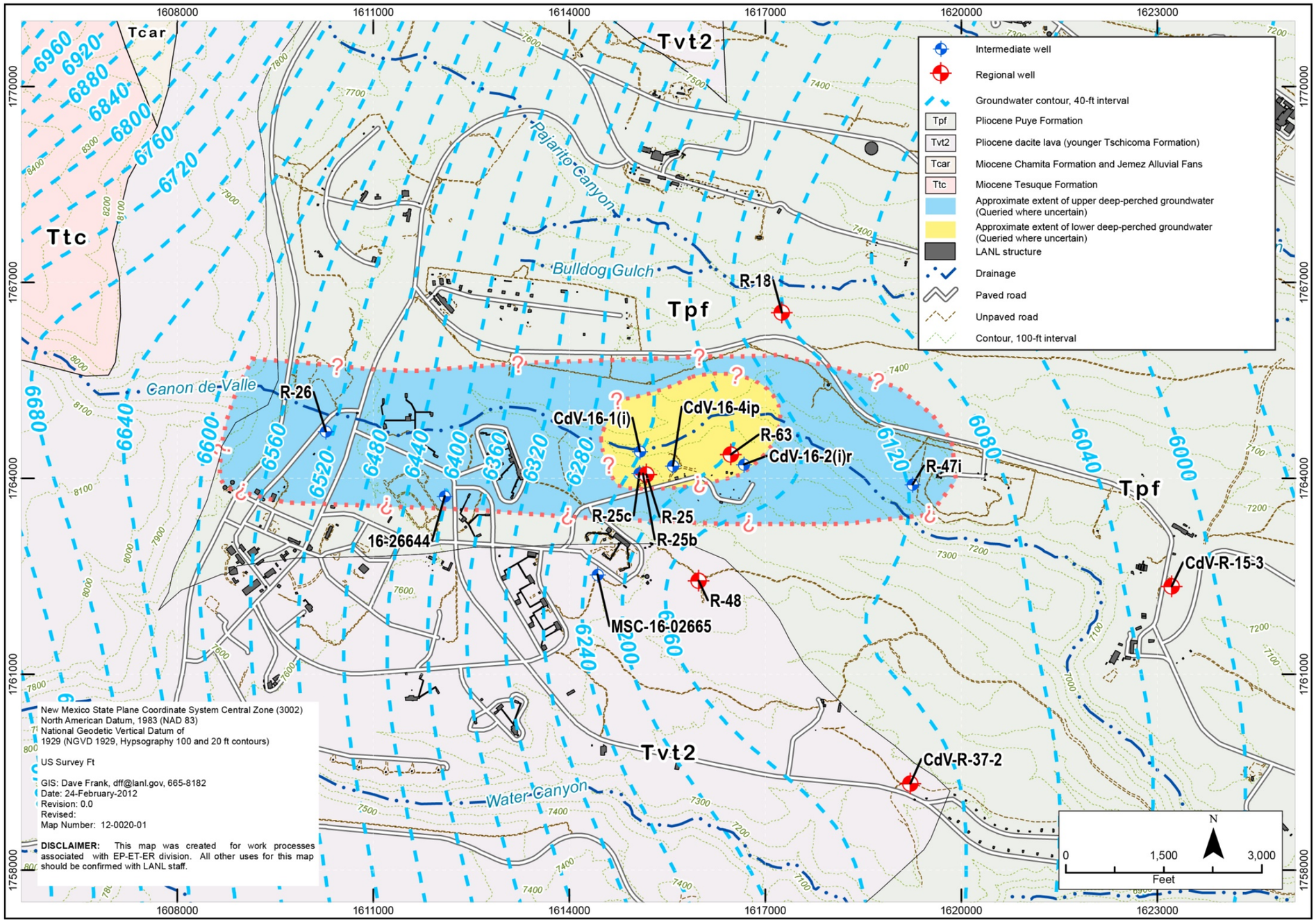
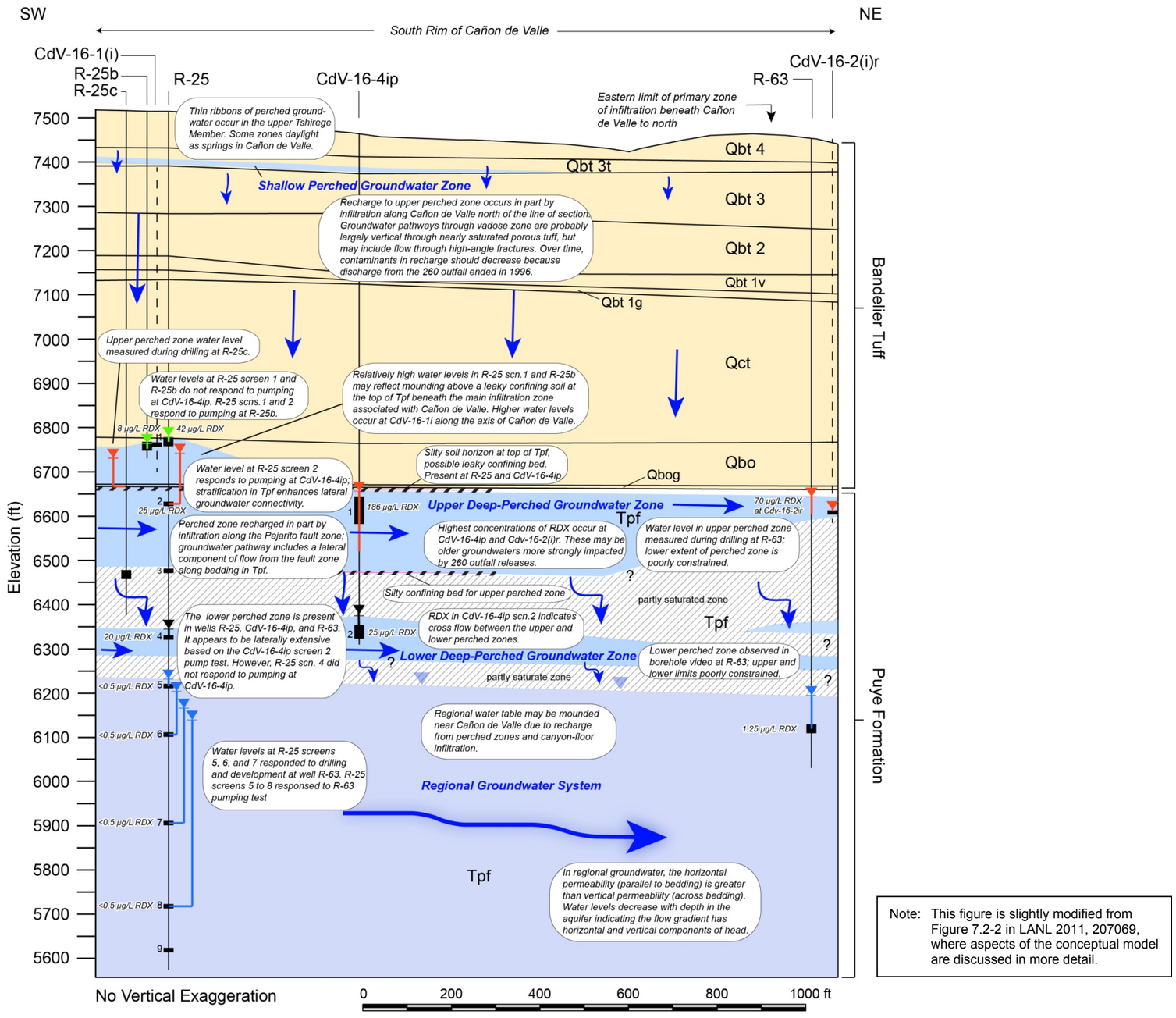


Figure 3.2-1 The TA-16 area showing hypothesized extent of the upper and lower deep-perched groundwater zones, regional water table, and the geology at the regional water table



Note: This figure is slightly modified from Figure 7.2-2 in LANL 2011, 207069, where aspects of the conceptual model are discussed in more detail.

Figure 3.2-2 Conceptual cross-section showing the distribution of groundwater in the vicinity of Cañon de Valle at TA-16

Table 3.1.1
TA-16 Contaminant Sources and Ranking Based on their Potential to Impact Groundwater

Potential Source	COPCs (Large Inventory and/or Mobile)	Ranking	Rationale for Ranking
Cañon de Valle (alluvial system)	RDX, other HE, barium, solvents	High	Highest-water volumes at TA-16, elevated RDX and other HE, evidence of vadose-zone infiltration
TA-16-260 pond	RDX, other HE, barium, solvents	High	Very large (1000s of kg) historical HE source. Historical water ponding zone. Known vadose zone migration
S-Site Canyon (alluvial system)/300s Line drainage/Martin Spring	RDX, other HE, boron, solvents	Medium	High water volumes, elevated RDX and other HE
30s Line/90s Line ponds	RDX, other HE, solvents	Medium	Intermittent water ponding. Historical water ponding. Moderate/large historical HE source. Known vadose zone migration.
Fishladder Canyon (alluvial system)	Solvents (PCE), RDX, other HE	Medium	Moderate (intermittently saturated) current water volume. Historically higher water volumes. Moderate solvent/HE source
TA-16-460 drainage	RDX, other HE, solvents	Low	Historically high water volumes. Low HE/solvent source.
TA-16-430 drainage	RDX, other HE	Low	Historically moderate water volumes. Low HE.
World War II Area Main Drainage (aka Mother Ditch)	RDX, other HE	Low	Historically moderate/high water volumes. Unknown historical HE concentrations
Water Canyon (alluvial system)	RDX, other HE (?)	Low	Historically high water volumes. Minimal sediment contamination.
MDA P/Burning Ground	RDX, other HE, barium, solvents	Low	Historically large HE, barium source. Intermittent/low water ponding (precipitation only)
MDA R	RDX, other HE, barium	Low	Historically moderate HE, barium source. Intermittent/low water ponding (precipitation only)
K-Site	RDX, other HE, barium	Low	Historically moderate HE source. Intermittent/low water ponding (precipitation. only)
V-Site pond	RDX, other HE, boron	Low	Historically low/moderate HE source. Historical ponding area
Zia shops drum storage	Solvents	Low	Historical solvent source. Intermittent/low water ponding (precipitation only). Possible migration in vadose zone.
Other HE-processing building outfalls (TA-16-220, 280, 400, 410, 360, 370, 380, etc.) and historic process building outfalls	RDX, other HE, barium, solvents other COPCs	Low	Historically low HE, other COPC sources. Intermittent/low water ponding (low-flow outfalls and precipitation)

Appendix A

Physical and Hydrologic Attributes
of Existing Perched-Intermediate and
Regional Aquifer Monitoring Wells at Technical Area 16

INTRODUCTION

This appendix describes the physical and hydrologic attributes of perched-intermediate and regional monitoring wells located at Technical Area 16 (TA-16) and in adjacent areas at Los Alamos National Laboratory (LANL or the Laboratory).

REGIONAL AQUIFER WELL CdV-R-15-3

Summary of Well Screen Information, CdV-R-15-3

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	617.7–624.5	6.8	Otowi Member, Bandelier Tuff	20/40 sand 604–626	Perched water zone	Well screen dry
2	800.8–807.8	7.0	Contact of Guaje Pumice Bed and Puye Formation	20/40 sand 785–806	Perched water zone	Well screen dry
3	964.8–980.9	16.1	Cerros del Rio basalt	20/40 sand 944–975	Perched water zone	Well screen dry
4	1235.1–1278.9	43.8	Puye Formation	8/12 sand 1212–1282	Top of saturation in regional aquifer	Screen straddles top of regional aquifer
5	1348.4–1355.3	6.9	Puye Formation	6/9 sand 1321–1349	Permeable zone in regional aquifer	Top of screen is submerged 108.5 ft below the water table
6	1637.9–1644.8	6.9	Puye Formation	8/12 sand 1604–1649	Permeable zone in deepest part of borehole	Top of screen is submerged 398 ft below the water table

Notes: During well construction, the six screens were inadvertently placed 9 ft deeper than intended because of a tally error on well casing during construction. The shift resulted in screens 2, 3, and 5 being partially covered with bentonite.

CdV-R-15-3 Drilling and Well Construction

	Description	Evaluation
Drilling Method	CdV-R-15-3 was drilled using a combination of hollow-stem auger (HAS) and fluid-assisted air-rotary reverse-circulation (RC) drilling methods. Drilling fluid consisted of municipal water mixed with QUIK-FOAM and EZ-MUD PLUS polymers. Drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.	Geologic conditions encountered during drilling are summarized in Figure A-1 and in the well completion report (Kopp et al. 2002, 073179). CdV-R-15-3 was drilled entirely open-hole. The pilot hole was augered to 30 ft with a 9-in.–outside diameter (O.D.) HSA and then to 20 ft with a 23-in.-O.D. auger to set surface casing. A 16-in. tricone bit on 7-in. dual wall RC rods was advanced to 722 ft. Casing (13.375 in.) was then tripped into the borehole and landed at 722 ft to isolate a potential perched water zone. A 12.25-in. tricone bit on 7-in. RC rods was then advanced to a total depth of 1722 ft. Before geophysical logging, the string of 13.375-in. casing was removed. Below 20-ft depth, drilling was by fluid-assisted, air-rotary dual-wall RC methods. Compressed air and drilling fluid were pumped down into the annular space located between the inner and outer drill-pipe walls, with the returns coming up the center pipe.
General Well Characteristics	CdV-R-15-3 is a six-screen well constructed of 5-in.-O.D. stainless-steel well casing.	The well design is shown in Figure A-2. The stainless-steel materials used at CdV-R-15-3 are chemically inert.

	Description	Evaluation
Well Screen Construction	The pipe-based screens are constructed of 304 perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.010-in. slots.	Pipe-based screen provides structural stability to well screens that might be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screen was used after two rod-based well screens were damaged during installation of well R-25. A drawback to pipe-based screens is that water surged into the filter pack and formation during development may be less effective in those areas that are not next to holes in the well casing. Also, the wire wrap on the CdV-R-15-3 well screen contains 0.010-in. slots. Later wells were installed with 0.020-in. slots to facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in.-slot wire-wrapped pipe-based screen to develop properly must be judged on the quality of groundwater data collected from the wells.
Screen Length and Placement	Screen 1 extends from 617.7 to 624.5 ft (length 6.8 ft) and targets potential perched-intermediate groundwater; it has been dry since well installation. Screen 2 extends from 800.8 to 807.8 ft (length 7 ft) and targets potential perched-intermediate groundwater; it has been dry since well installation. Screen 3 extends from 964.8 to 980.9 ft (length 16.1 ft) and targets perched-intermediate groundwater; it has been dry since well installation. Screen 4 extends from 1235.1 to 1278.9 ft (length 43.8 ft), and it straddles the regional water table. Screen 5 extends from 1348.4 to 1355.3 ft (length 6.9 ft) and targets regional groundwater. Screen 6 extends from 1637.9 to 1644.8 ft (length 6.9 ft) and targets regional groundwater.	Well CdV-R-15-3 is designed to provide water-quality and water-level data, and the screen length and placement were selected to achieve the following goals: • Characterize water quality of perched-intermediate and regional groundwater downgradient of high explosives (HE) sources in the vicinity of TA-16 • Monitor water levels to detect whether groundwater responds to seasonal infiltration events in Cañon de Valle and to pumping by municipal wells on the Pajarito Plateau During well construction, the six well screens were inadvertently placed 9 ft deeper than intended because of a tally error on well casing during construction. The tally error was not discovered until after annular materials were installed during well construction. Consequently, the well screens are not only located deeper than originally planned, but the well screen are shifted downward relative to their associated sand filter packs. Impacts of the incorrect pipe tally on the function of the well screens are discussed below. Screen 1 targeted potential perched-intermediate groundwater. Possible perched-intermediate groundwater was first encountered at a depth of 611 ft in the upper part of the Otowi Member of the Bandelier Tuff. At a borehole depth of 622 ft, water-level depth was again monitored through the drill rods with an electric probe and found to be 602 ft. Screen 1 has been dry since well installation. The downward shift of the well screen from the pipe tally error is probably not the cause of the dry well screen because the well-screen interval substantially overlaps the potential zone of saturation that was encountered when the borehole was 622 ft deep. Open-hole videos dated March 25, 2000, April 27, 2000, and May 1, 2000, were reviewed for this report, and no evidence of the presence of groundwater in the targeted or screened interval was found. Screen 2 targeted potential perched-intermediate groundwater in the Guaje Pumice Bed. Screen 2 placement was based on borehole combinable magnetic resonance (CMR) logs showing increasing free-fluid porosity down section through the Guaje Pumice Bed. Fluid-based CMR total porosity (30%–40%) approaches density porosity (45%–50%), suggesting conditions approaching saturation might exist near the base of the Guaje Pumice Bed. However, saturated conditions were not observed in open-borehole video logs. Screen 2 has been dry since well installation. The target horizon for screen 2 was the Guaje Pumice Bed, but the downward shift of screens during well installation placed 0.8 ft of screen 2 in the Guaje Pumice Bed and 6.2 ft of screen 2 in the underlying Puye Formation. Open-hole videos dated March 25, 2000,

	Description	Evaluation
		April 27, 2000, and May 1, 2000, were reviewed for this report, and no evidence of the presence of groundwater in the targeted or screened interval was found. Screen 3 targeted potential perched-intermediate groundwater in Cerros del Rio lavas. The placement of screen 3 was based on borehole CMR and neutron logs showing increased free-fluid porosity in a zone of massive dacite and basalt lava flows and interflow breccias. Free-fluid CMR porosity ranges from 10%–15% in this zone. However, density porosity is 25%–35%, suggesting moisture in this zone does not represent saturated conditions. Screen 3 has been dry since well installation. The target horizon for screen 3 was porous rubble zones in this volcanic sequence. Despite the downward shift of screens during well construction, screen 3 straddles the zone of maximum CMR free-fluid porosity. However, the pipe tally error resulted in the placement of bentonite next to the lower 5.9 ft of the 16.1-ft-long well screen. Despite these construction problems, it appears unlikely that perched-intermediate groundwater is present in these lavas and rubble zones. Open-hole videos dated March 25, 2000, April 27, 2000, and May 1, 2000, were reviewed for this report, and no evidence of the presence of groundwater in the targeted or screened interval was found. Screen 4 targets the top of the regional groundwater system and straddles the regional water table. The amount of submerged screen is 39 ft. Screen 4 is designed to monitor regional groundwater downgradient of HE sources in the vicinity of TA-16. The main goal for this screen was to determine if infiltration beneath Cañon de Valle results in contamination of regional groundwater. Thus, screen 4 was designed to straddle the water table to detect the highest concentrations of contaminants before becoming diluted by mixing with uncontaminated groundwater. The screen is located within Pliocene Puye Formation sedimentary deposits that include stacked beds of boulders, cobbles, and sandy gravels (Figure A-3). Total porosities within the screen interval range between 15% and 30%, and effective porosities range between 5% and 10%. The electrical resistivity image (Formation Micro-Imager [FMI] log) shows these deposits are thick bedded and generally very coarse grained. The electrical resistivity of these deposits is high, indicating they contain little to no silt or clay (Figure A-3). Despite the downward shift of screens during well construction, screen 4 straddles the water table as originally planned, and the well screen is properly enclosed in its sand filter pack. The placement and hydrogeologic setting of screen 4 is representative of aquifer conditions and meets all characterization and monitoring goals. Screen 5 targets the upper part of the regional groundwater system about 108.5 ft below the regional water table. Screen 5 is designed to monitor deeper regional groundwater pathways downgradient of HE sources in the vicinity of TA-16, to assess vertical pressure gradients in the regional aquifer, and to determine if there are pressure responses to pumping of municipal supply wells on the Pajarito Plateau. The screen is located within Pliocene Puye Formation deposits that include stacked beds of boulders, cobbles, sandy gravels, and thin silts (Figure A-4). The downward shift of screens during well construction resulted in the placement of bentonite next to the lower 6.3 ft of the 6.9-ft-long well screen. Access of groundwater to screen 5 is severely limited because 91% of the screen interval is next to bentonite. Screen 5 does not meet characterization and monitoring goals.

	Description	Evaluation
		Screen 6 targets the upper part of the regional groundwater system about 398 ft below the regional water table. Screen 6 is designed to monitor deep regional groundwater pathways downgradient of HE sources in the vicinity of TA-16, to assess vertical pressure gradients in the regional aquifer, and to determine if there are pressure responses to pumping of municipal supply wells on the Pajarito Plateau. The screen is located within Pliocene Puye Formation deposits that include stacked beds of sands, silts, and gravels (Figure A-5). Total porosities within the screen interval range between 20% and 40%, and effective porosities range between 10% and 35%. The electrical resistivity image (FMI log) shows these deposits are thick bedded and less coarse grained than the deposits of screens 4 and 5. The electrical resistivity of these deposits is relatively low, suggesting they contain appreciable silt and/or clay (Figure A-5). Despite the downward shift of screens during well construction, screen 6 is located in relatively porous sediments as originally planned, and the well screen is properly enclosed in its sand filter pack. The placement and hydrogeologic setting of screen 6 is representative of aquifer conditions and meets all characterization and monitoring goals.
Filter Pack Materials and Placement	The filter packs and their placements for the six well screens are discussed in the column to the right.	The screen 1 primary filter pack is made up of 20/40 sand from 604 to 626 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 598 to 604 ft and 626 to 629 ft, respectively. The primary filter pack extends 13.7 ft above and 1.5 ft below the well screen. Screen 1 has been dry since installation. The screen 2 primary filter pack is made up of 20/40 sand from 785 to 806 ft. A secondary filter pack of 30/70 sand was placed above the primary filter pack from 780 to 785 ft. The primary filter pack extends 15.8 ft above the well screen. The downward shift of screens during well construction resulted in the placement of bentonite adjacent to the lower 1.8 ft of the 7-ft-long well screen. Screen 2 has been dry since installation. The screen 3 primary filter pack is made up of 20/40 sand from 944 to 975 ft. A secondary filter pack of 30/70 sand was placed above the primary filter pack from 938 to 944 ft. The primary filter pack extends 20.8 ft above the well screen. The downward shift of screens during well construction resulted in the placement of bentonite next to the lower 5.9 ft of the 16.1-ft-long well screen. Screen 3 has been dry since installation. The screen 4 primary filter pack is made up of 8/12 sand from 1212 to 1282 ft. A secondary filter pack of 20/40 sand was placed above and below the primary filter pack from 1207 to 1212 ft and 1282 to 1287 ft, respectively. The primary filter pack extends 23.1 ft above and 3.1 ft below the well screen. Placement of the filter pack relative to the screen is within the optimum design for the well screen. The screen 5 primary filter pack is made up of 6/9 sand from 1321 to 1349 ft. There is no secondary filter pack at this screen. The primary filter pack extends 27.4 ft above the well screen. The downward shift of screens during well construction resulted in the placement of bentonite next to the lower 6.3 ft of the 6.9-ft-long well screen. Access of groundwater to screen 5 is severely limited because 91% of the screen interval is next to bentonite. The screen 6 primary filter pack is made up of 8/12 sand from 1604 to 1649 ft. There is no secondary filter pack at this screen. The primary filter pack extends 33.9 ft above and 4.2 ft below the well screen. The

	Description	Evaluation
		filter pack above the well screen is longer than the optimum design of 5 ft of filter pack above the well screen. The long filter pack above the well screen may actually be advantageous for such a deeply placed screen because the excess filter pack allows water to be drawn into the well screen from a larger variety of potential groundwater flow paths within heterogeneous aquifer materials.
Sampling System	Westbay multiple port (MP) sampling system	Westbay is a low-flow sampling system that allows groundwater sampling of multiple well screens within a single well installation. Well screens are isolated by packers and sampled individually. Westbay is the only sampling system capable of sampling three or more screens in a multiscreen well. It is particularly effective for monitoring water levels at multiple depths within a well. Flow-through cells for measuring field parameters cannot be used at multiscreen wells containing the Westbay sampling system. Effective development and removal of residual drilling fluids are critical before installation of Westbay wells because groundwater is collected in proximity to the well because of low-flow sampling and the inability to purge the well before sampling. Samples collected from Westbay wells are particularly prone to water-quality problems that develop if residual drilling fluids are hydraulically connected to the screen interval.
Other Issues That Could Affect the Performance of the Well	See notes in the column to the right.	Development of the well (screens 4, 5, and 6 only) was accomplished by scrubbing with a wire brush, bailing, and pumping next to the three well screens. The pumping phase of development was conducted without using packers to isolate the three regional aquifer well screens. Consequently, pumping development was probably most effective for the well screen that yielded the most water and least effective for the poorest producing well screen.
Additives Used during Drilling		Air Municipal water QUIK-FOAM EZ-MUD
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal. Cement was used to create stable floors to support the weight of annular bentonite at depths of 875 to 890 ft, 1045 to 1076 ft, and 1490 to 1497 ft. A cement grout surface seal was placed from 0 to 77 ft.

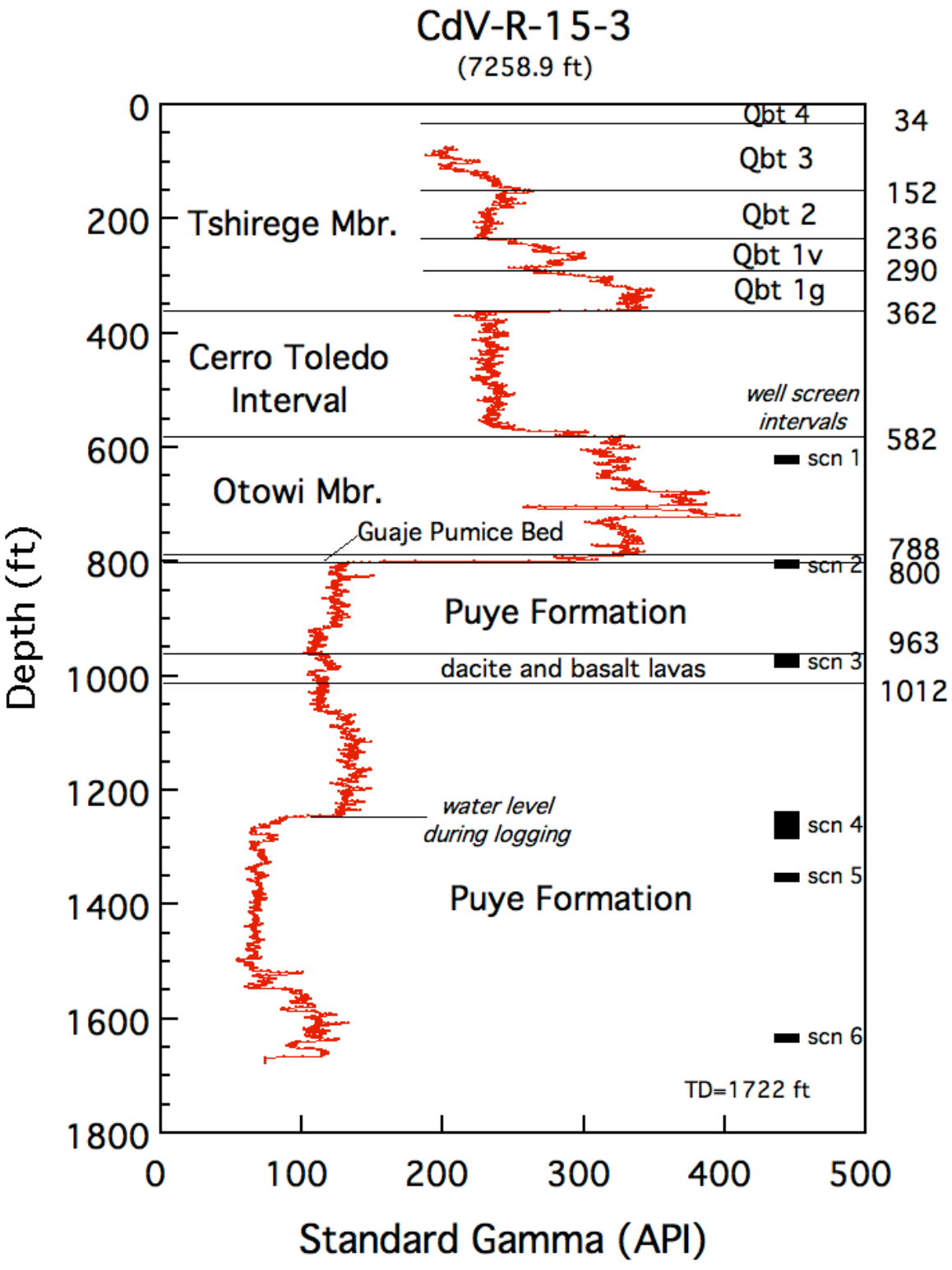


Figure A-1 Well CdV-R-15-3 geology and borehole gamma log

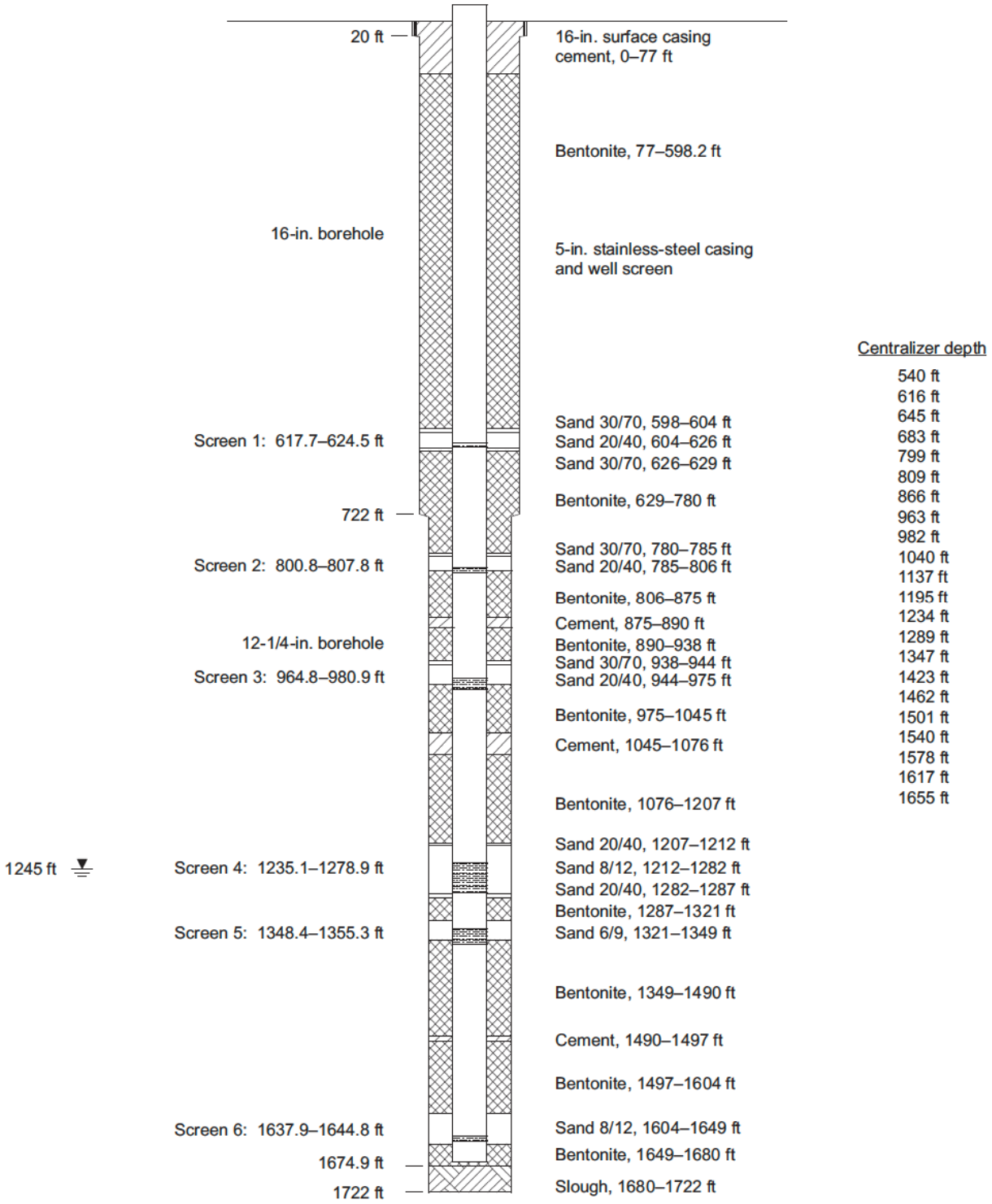


Figure A-2 CdV-R-15-3 well design

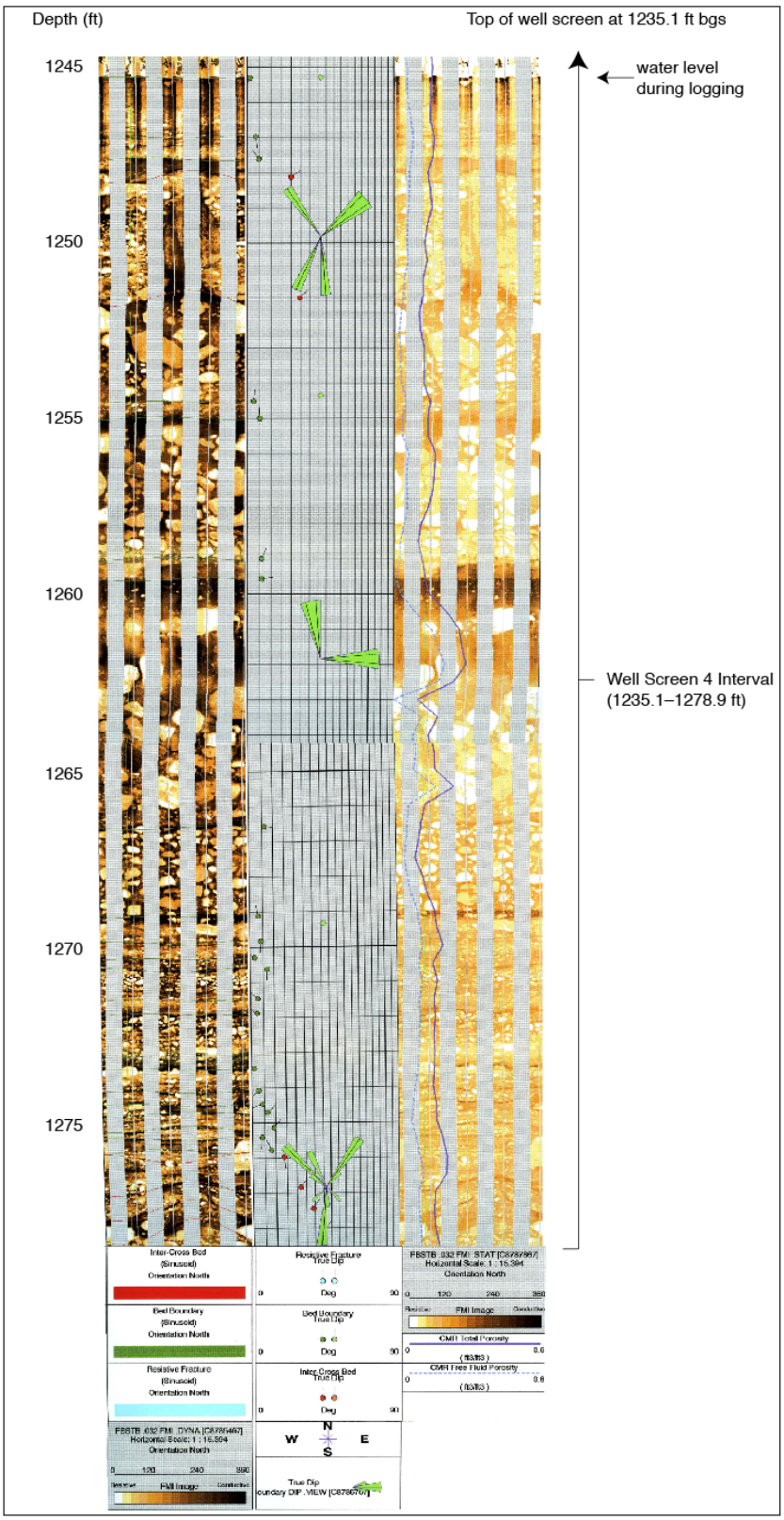


Figure A-3 Well CdV-R-15-3 FMI log showing lithology, bedding attitudes, electrical resistivity, and CMR porosity for screen 4

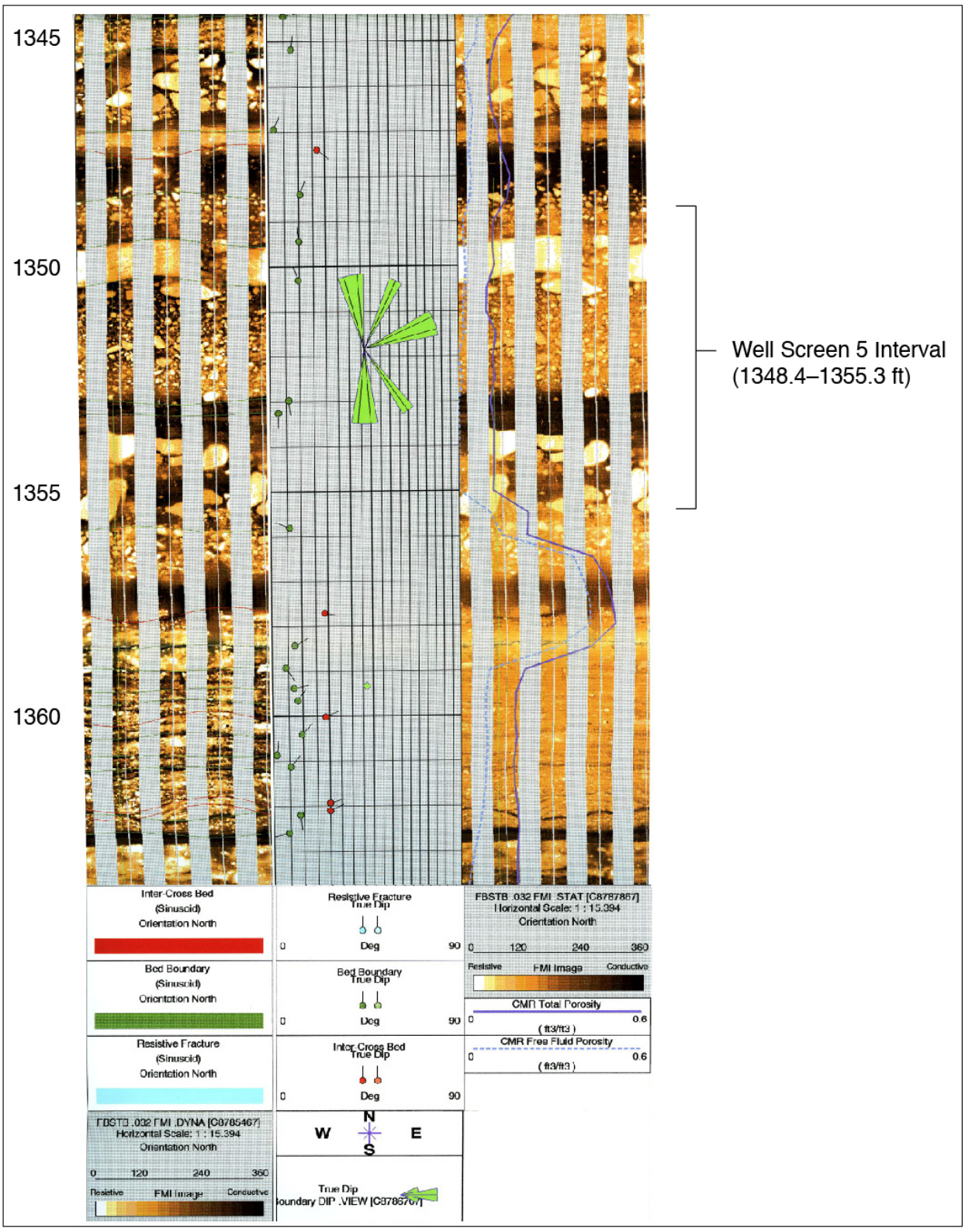


Figure A-4 Well CdV-R-15-3 FMI log showing lithology, bedding attitudes, electrical resistivity, and CMR porosity for screen 5

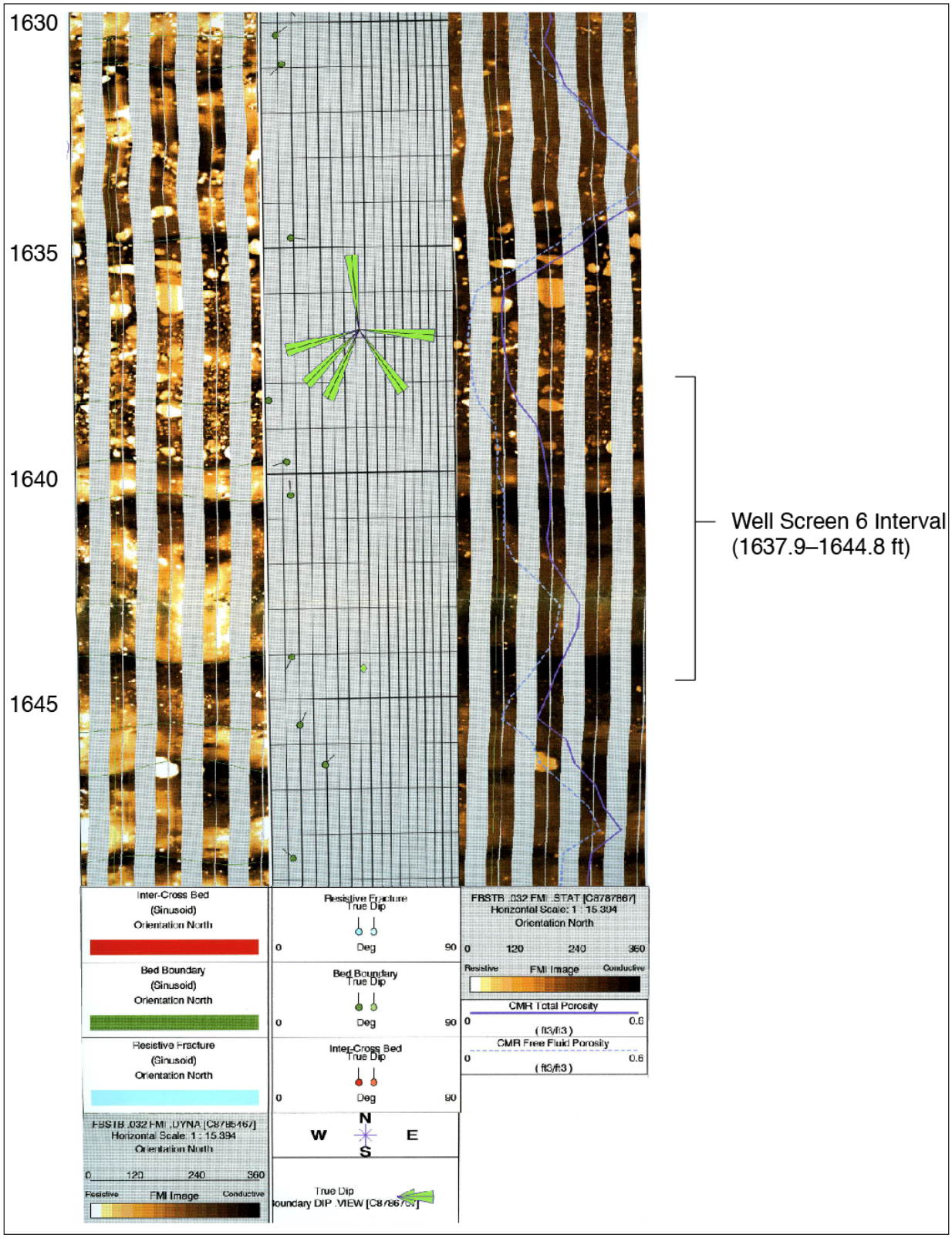


Figure A-5 Well CdV-R-15-3 FMI log showing lithology, bedding attitudes, electrical resistivity, and CMR porosity for screen 6

REGIONAL AQUIFER WELL CdV-R-37-2

Summary of Well Screen Information, CdV-R-37-2

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	914.4–939.5	25.1	Puye Formation	20/40 sand 904.2–943.8	Perched water zone	Well screen dry
2	1188.7–1213.8	25.1	Tschicoma dacite breccia and lava	20/40 sand 1179.6–1221	Top of saturation in regional aquifer	Screen straddles top of regional aquifer
3	1353.7–1377.1	23.4	Tschicoma dacite breccia	8/12 sand 1343–1382	Permeable zone in regional aquifer	Top of screen is submerged 160 ft below the water table
4	1549.3–1556.0	6.7	Tschicoma dacite breccia	8/12 sand 1539.7–1560.7	Permeable zone in deepest part of borehole	Top of screen is submerged 444.2 ft below the water table

CdV-R-37-2 Drilling and Well Construction

	Description	Evaluation
Drilling Method	CdV-R-37-2 was drilled using fluid-assisted air-rotary RC drilling methods with casing advance. Drilling fluid consisted of municipal water mixed with QUIK-FOAM and EZ-MUD PLUS polymers. Drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.	Geologic conditions encountered during drilling are summarized in Figure A-6 and in the well completion report (LANL 2002, 073707). A pilot hole was drilled to 40 ft with a 16-in. tricone bit; it was then reamed to a 24-in. diameter before cementing in 18-in. surface casing to a depth of 25.8 ft bgs. An open borehole was advanced to 794 ft bgs using a 16-in. tricone carbide button bit. Casing (13.375 in.) was then tripped into the borehole and advanced to 825 ft to stabilize the borehole. A 12.25-in. open borehole was drilled from 825 to 1644 ft total depth (TD) using a combination of tricone and down-the-hole hammer bits. Below 25.8 ft depth drilling was by fluid-assisted, air-rotary dual-wall reverse-circulation methods. Compressed air and drilling fluid were pumped down into the annular space located between the inner and outer drill-pipe walls, with the returns coming up the center pipe.
General Well Characteristics	CdV-R-37-2 is a four-screen well constructed of 5-in.-O.D. stainless-steel well casing.	The well design is shown in Figure A-7. The stainless-steel materials used at CdV-R-37-2 are chemically inert.
Well Screen Construction	The pipe-based screens are constructed of 304 perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.010-in. slots.	The screen openings were constructed by drilling 0.5-in.-diameter holes in 10-ft sections of well casing and welding a wire wrap (0.010-in. gap) over the perforated interval. The final O.D. of the screens was 5.56 in. Pipe-based screen provides structural stability to well screens that might be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screen was used after two rod-based well screens were damaged during installation of well R-25.

	Description	Evaluation
		A drawback to pipe-based screens is that water surged into the filter pack and formation during development may be less effective in those areas that are not adjacent to holes in the well casing. Also, the wire wrap on the CdV-R-37-2 well screen contains 0.010-in. slots. Later wells were installed with 0.020-in. slots to facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in.-slot wire-wrapped pipe-based screen to develop properly must be judged on the quality of groundwater data collected from the wells.
Screen Length and Placement	Screen 1 extends from 914.4 to 939.5 ft (length 25.1 ft) and targets perched-intermediate groundwater; it has been dry since well installation. Screen 2 extends from 1188.7 to 1213.8 ft (length 25.1 ft), and it straddles the regional water table. Screen 3 extends from 1353.7 to 1377.1 ft (length 23.4 ft) and targets regional groundwater. Screen 4 extends from 1549.1 to 1556.0 ft (length 6.7 ft) and targets regional groundwater.	Well CdV-R-37-2 is designed to provide water-quality and water-level data, and the screen length and placement were selected to achieve the following goals: • Characterize water quality of perched-intermediate and regional groundwater downgradient of HE sources in the vicinity of TA-16 • Monitor water levels to investigating the direction of groundwater flow and hydraulic gradients within the regional and perched aquifers Screen 1 targeted potential perched-intermediate groundwater near the top of the Puye Formation, but the screen has been dry since well installation. The rationale for placing a well screen in this depth interval is not clearly explained in the well completion report. Borehole geophysical logs indicate near-saturation conditions occur in this interval. The potential saturation identified in this zone may represent ephemeral groundwater or water introduced to the borehole during drilling. Screen 2 targets the top of the regional groundwater system and straddles the regional water table. The amount of submerged screen is 20.1 ft. Screen 2 is designed to monitor regional groundwater downgradient of HE sources in the vicinity of TA-16. The main goal for this screen was to determine if Laboratory contamination occurs at the top of regional groundwater. The screen is located within Pliocene Tschicoma volcanic deposits that include breccias and massive lava (Figure A-8). Neutron porosities within the screen interval range between 20% and 40%. The electrical resistivity image (FMI log) shows these deposits consist of clast-supported angular dacite blocks up to 2 ft in diameter. The lower 5 ft of the screen is next to flow-banded lava. The electrical resistivity of these deposits is high, indicating the rock matrix contains little to no silt or clay (Figure A-8). The placement and hydrogeologic setting of screen 2 is representative of aquifer conditions and meets all characterization and monitoring goals. Screen 3 targets the upper part of the regional groundwater system about 160 ft below the regional water table. Screen 3 is designed to monitor deeper regional groundwater pathways downgradient of HE sources in the vicinity of TA-16, to assess vertical pressure gradients in the regional aquifer, and to determine if there are pressure responses to pumping of municipal supply wells on the Pajarito Plateau. The screen is located within Pliocene Tschicoma volcanic deposits (Figure A-9). Neutron porosities within the screen interval range between 20% and 50%. The electrical resistivity image (FMI log) shows that deposits in this interval consist of matrix-supported angular dacite blocks up to 1 ft in diameter. The electrical resistivity of these deposits is relatively low, indicating the rock matrix may contain appreciable silt or clay (Figure A-9). The placement and

	Description	Evaluation
		hydrogeologic setting of screen 3 is representative of aquifer conditions and of aquifer conditions and meets all characterization and monitoring goals. Screen 4 targets a relatively deep part of the regional groundwater system about 444.2 ft below the regional water table. Screen 4 is designed to monitor deep regional groundwater pathways downgradient of HE sources in the vicinity of TA-16, to assess vertical pressure gradients in the regional aquifer, and to determine if there are pressure responses to pumping of municipal supply wells on the Pajarito Plateau. The screen is located within Pliocene Tschicoma volcanic deposits (Figure A-10). Neutron porosities within the screen interval range between 20% and 40%. The electrical resistivity image (FMI log) shows that deposits in this interval consist of matrix-supported angular dacite blocks up to 2 ft in diameter. The electrical resistivity of these deposits is high indicating the rock matrix contains little to no silt or clay (Figure A-10). The placement and hydrogeologic setting of screen 4 is representative of aquifer conditions and meets all characterization and monitoring goals.
Filter Pack Materials and Placement	The filter packs and their placements for the four well screens are discussed in the column to the right.	The screen 1 primary filter pack is made up of 20/40 sand from 904.2 to 943.8 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 902.2 to 904.2 ft and 943.8 to 945.8 ft, respectively. The primary filter pack extends 10.2 ft above and 4.3 ft below the well screen. Screen 1 has been dry since installation. The screen 2 primary filter pack is made up of 20/40 sand from 1179.6 to 1221 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 1177.4 to 1179.6 ft and 1221 to 1223 ft, respectively. The primary filter pack extends 9.1 ft above and 7.2 ft below the well screen. Placement of the filter pack relative to the screen is within the optimum design for the well screen. The screen 3 primary filter pack is made up of 8/12 sand from 1343 to 1382 ft. A secondary filter pack of 20/40 sand was placed above and below the primary filter pack from 1340 to 1343 ft and 1382 to 1386.5 ft, respectively. The primary filter pack extends 10.7 ft above and 4.9 ft below the well screen. Placement of the filter pack relative to the screen is within the optimum design for the well screen. The screen 4 primary filter pack is made up of 8/12 sand from 1539.7 to 1560.7 ft. A secondary filter pack of 20/40 sand was placed above and below the primary filter pack from 1537.3 to 1539.7 ft and 1560.7 to 1563.3 ft, respectively. The primary filter pack extends 9.6 ft above and 7.3 ft below the well screen. Placement of the filter pack relative to the screen is within the optimum design for the well screen.
Sampling System	Westbay MP sampling system	Westbay is a low-flow sampling system that allows groundwater sampling of multiple well screens within a single well installation. Well screens are isolated by packers and sampled individually. Westbay is the only sampling system capable of sampling three or more screens in a multiscreen well. It is particularly effective for monitoring water levels at multiple depths within a well. Flow-through cells for measuring field parameters cannot be used at multiscreen wells containing the Westbay sampling system. Effective development and removal of residual drilling fluids are critical before installation of Westbay wells since groundwater is collected in proximity to the well because of low-flow sampling and the inability to purge the well before sampling. Samples collected from Westbay wells are particularly

	Description	Evaluation
		prone to water-quality problems that develop if residual drilling fluids are hydraulically connected to the screen interval.
Other Issues That Could Affect the Performance of the Well	See notes in the column to the right.	CdV-R-37-2 was developed in two phases. Preliminary development involved wire brushing, bailing, and surging. Final development was done by pumping. Phase I development of the well screens 2, 3, and 4 was accomplished by scrubbing with a wire brush, bailing, and surging with a stainless-steel surge block attached to a wire line. Phase II development was accomplished by withdrawing water using a 7.5 horsepower submersible pump. Development by pumping involved two stages. First, the pump was set in a single position next to screens 3 and 4 and water was discharged for approximately 4 h. Next, the intake was set and the pump operated within each 1-ft interval of the open portion of screens 3 and 4. Screen 2 straddles the water table and was not developed by pumping. The pumping phase of development was conducted without using packers to isolate the three regional aquifer well screens. Consequently, pumping development was probably most effective for the well screen that yielded the most water and least effective for the poorest producing well screen.
Additives Used during Drilling		Air Municipal water QUIK-FOAM EZ-MUD
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal. Cement was used to create stable floors to support the weight of annular bentonite at depths of 445.5 to 457 ft and 1027.1 to 1045 ft. A cement grout surface seal was placed from 0 to 77 ft.

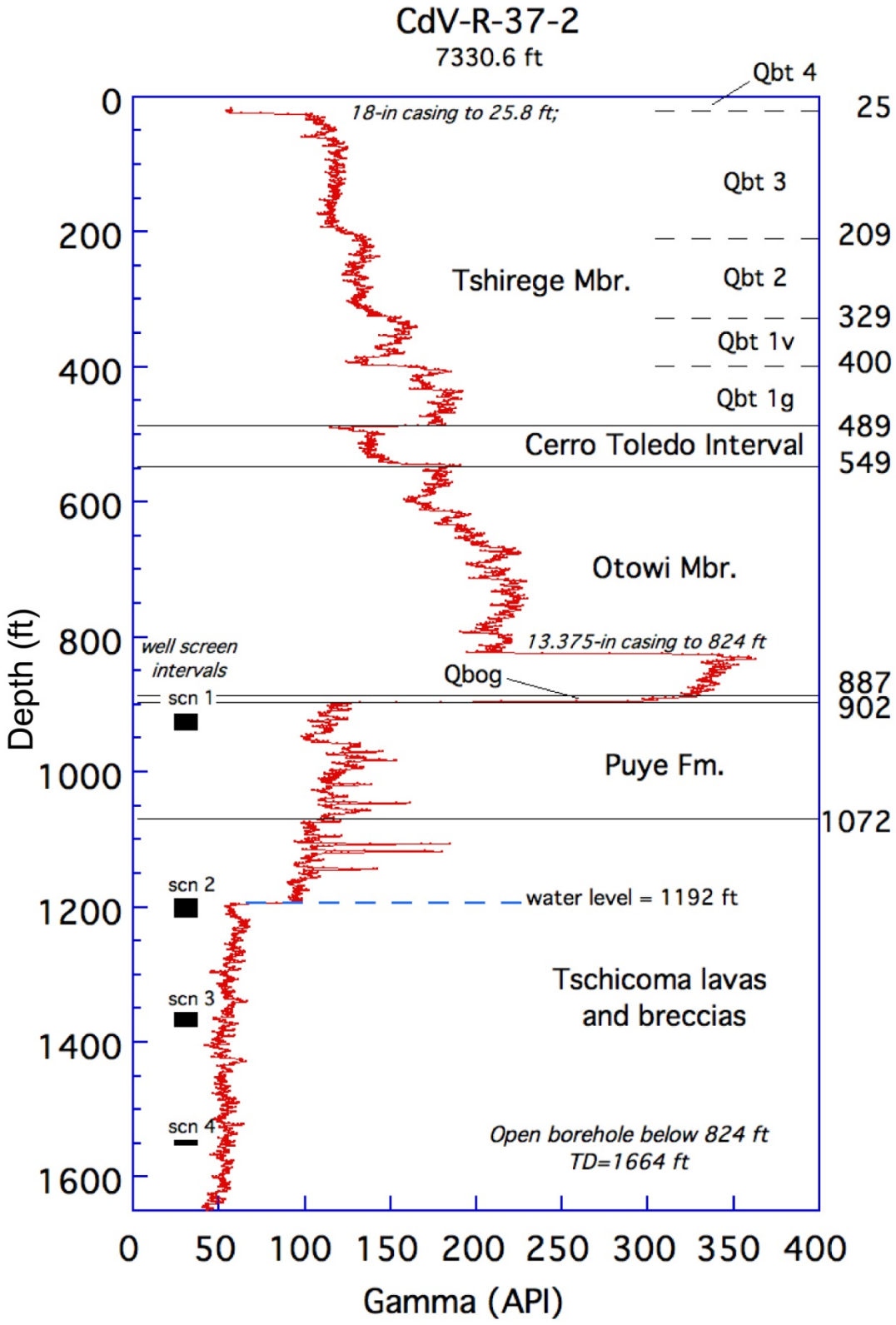


Figure A-6 Well CdV-R-37-2 geology and borehole gamma log

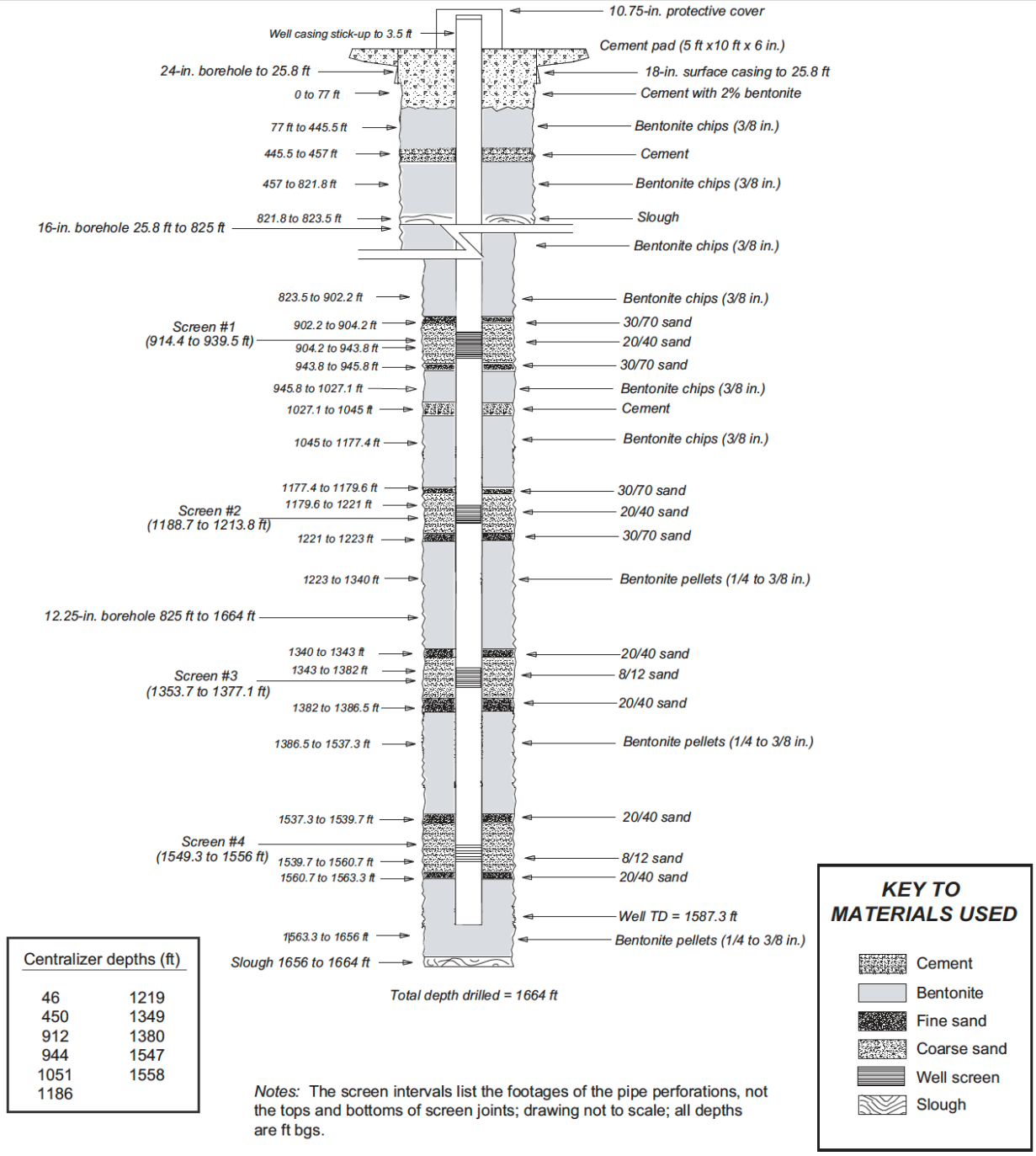


Figure A-7 CdV-R-37-2 well design

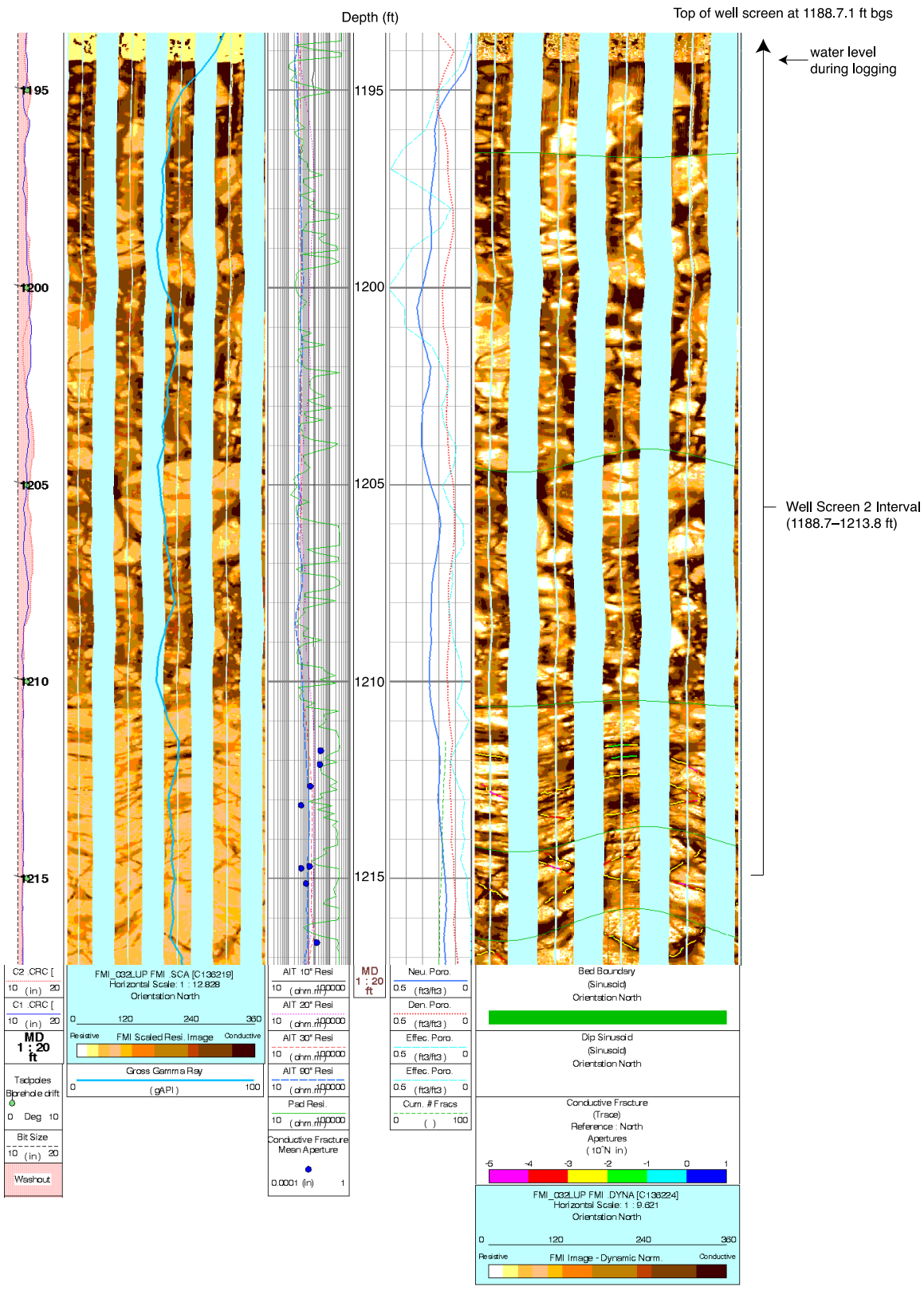


Figure A-8 Well CdV-R-37-2 FMI log showing lithology, electrical resistivity, and porosity for screen 2

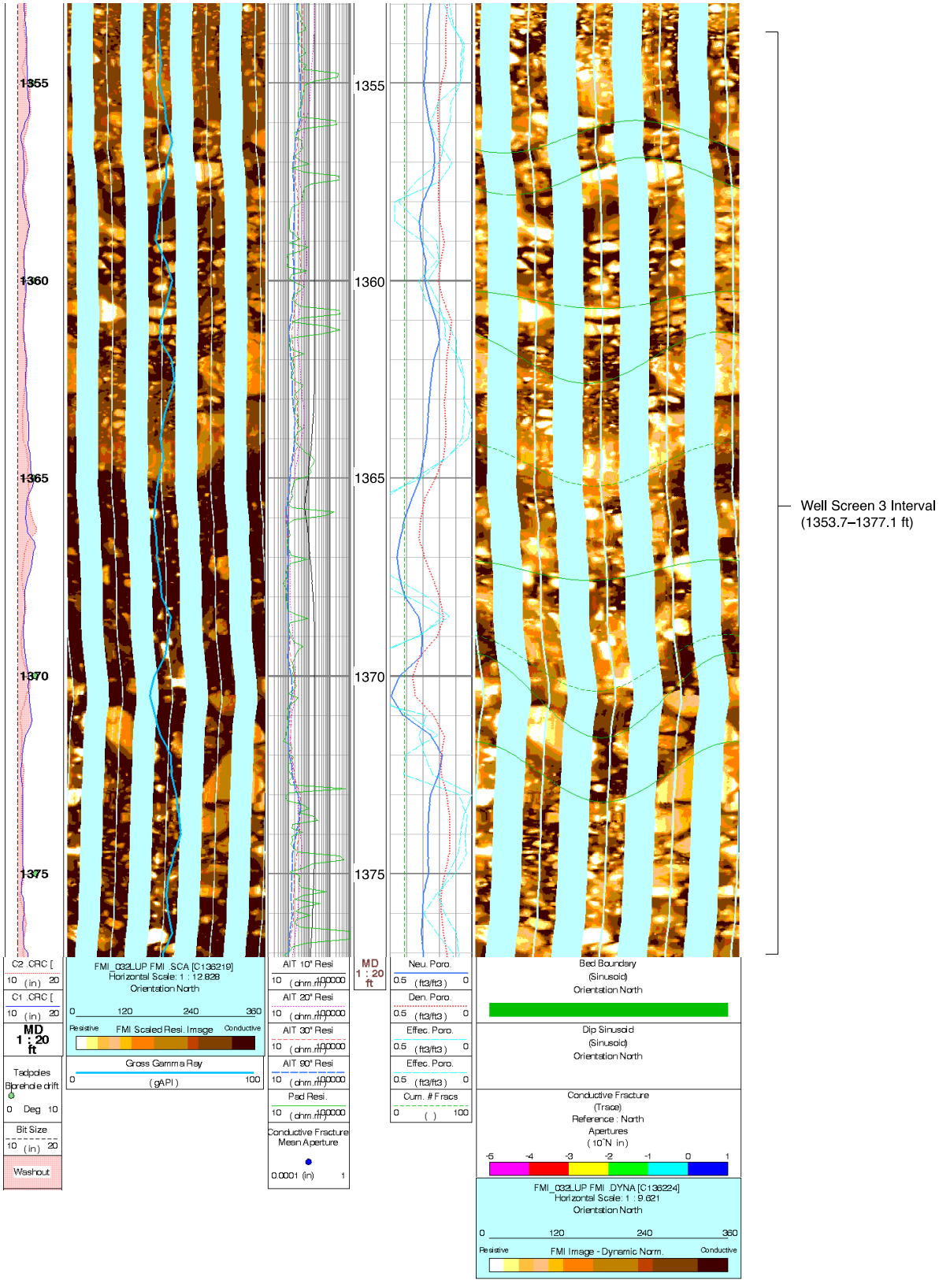


Figure A-9 Well CdV-R-37-2 FMI log showing lithology, electrical resistivity, and porosity for screen 3

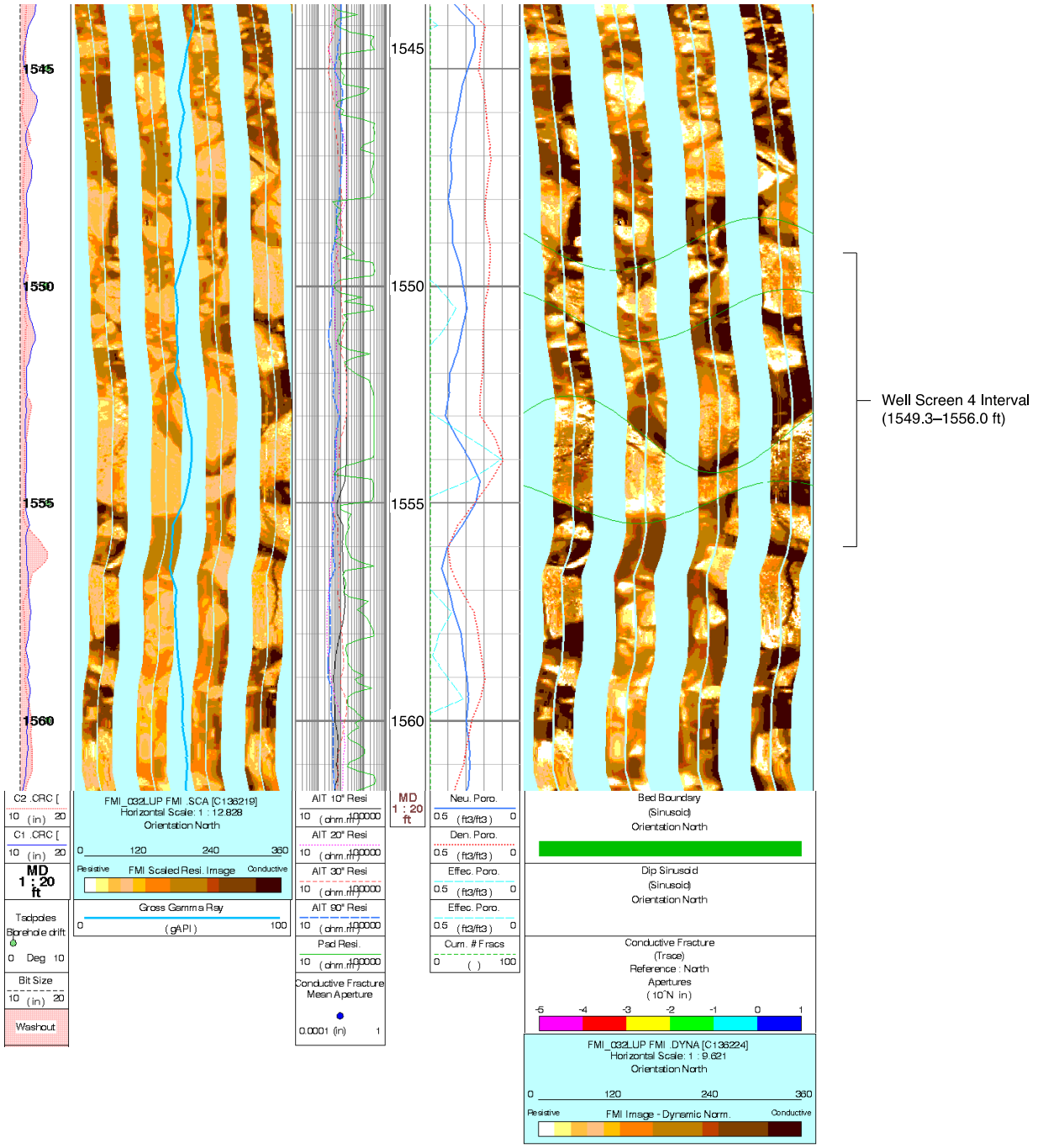


Figure A-10 Well CdV-R-37-2 FMI log showing lithology, electrical resistivity, and porosity for screen 4

REGIONAL AQUIFER WELL R-18

Summary of Well Screen Information, R-18

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	1358.0–1381.0	23.0	Puye Formation	10/20 sand 1349–1388	Upper part of the regional zone of saturation	Top of screen is submerged 70 ft below the water table

R-18 Drilling and Well Construction

	Description	Evaluation
Drilling Method	R-18 was drilled using fluid-assisted air-rotary drilling methods. Drilling fluid consisted of municipal water mixed with QUIK-FOAM and EZ-MUD PLUS polymers. Drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.	Geologic conditions encountered during drilling are summarized in Figure A-11 and in the well completion report (Kleinfelder 2005, 092415). A pilot hole was drilled to 25 ft with a 9.875-in. button bit; it was then reamed to 22 in. to a depth of 8.5 ft bgs before cementing in 16-in. surface casing to a depth of 6 ft bgs. An open borehole was drilled to 763 ft bgs using a 12.25-in. tricone bit. An open hole was drilled from 763 to 1440 ft TD using a 12.25-in. down-the-hole hammer bit.
General Well Characteristics	R-18 is a single-screen well constructed of 4.5-in.–inside diameter (I.D.)/5-in.-O.D. stainless-steel well casing.	The well design is shown in Figure A-12. The stainless-steel materials used at R-18 are chemically inert.
Well Screen Construction	Well R-18 was constructed with stainless-steel rod-based wire-wrapped screens with 0.020-in. slots.	Wire-wrapped screen with 0.020-in. slots is considered the optimum design for promoting the free flow of water during well development and sampling.
Screen Length and Placement	The R-18 well screen extends from 1358.0 to 1381.0 ft (length 23 ft) and targets regional groundwater.	Well R-18 is designed to provide water-quality and water-level data, and the screen length and placement were selected to achieve the following goals: • Characterize water quality of regional groundwater downgradient of HE sources in the vicinity of TA-09 and TA-16 • Monitor water levels to investigate the direction of groundwater flow and hydraulic gradients within the regional aquifer The well screen was placed near the top of the regional groundwater system to monitor groundwater downgradient of potential HE release sites. The main goal for this screen was to determine if Laboratory contamination occurs at the top of regional groundwater. The screen is located within the Pliocene Puye Formation sedimentary deposits that include stacked beds of boulders, cobbles, and sandy gravels (Figure A-13). Total porosities within the screen interval range between 15% and 40%. Effective porosities range mostly between 2% and 10% but a few thin intervals are as

	Description	Evaluation
		high as 30%. The electrical resistivity image (FMI log) shows that these deposits are thick bedded and generally very coarse grained. The electrical resistivity of these deposits is high, indicating they contain little to no silt or clay (Figure A-13). At 70 ft below the piezometric surface, the well screen is somewhat deeper in the aquifer than most other single-screen wells in the monitoring network. The well screen was placed at these depths because the Schlumberger borehole logs indicated the water table might be as high as 1302 ft bgs, but more definitive evidence of full saturation occurred below 1352 ft bgs. The water level in the completed well was 1288 ft bgs. The placement and hydrogeologic setting of this screen is representative of aquifer conditions and meets all characterization and monitoring goals. Though placed 70 ft below the piezometric surface, the well screen is located within the uppermost permeable horizon that could be clearly delineated in the regional groundwater system. Consideration was given to the placing the screen higher in the aquifer, but this approach was rejected because there was considerable risk this interval might be dry once the well was installed. Although it is deeply submerged, the R-18 well screen is distal to the potential upgradient contaminant sources, and groundwater is likely to disperse in the aquifer downgradient of infiltration zones.
Filter Pack Materials and Placement	The filter pack and its placement for the well screen are discussed in the column to the right.	The primary filter pack is made up of 10/20 sand from 1349 to 1388 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 1345.5 to 1349 ft. The primary filter pack extends 9 ft above and 7 ft below the well screen. Placement of the filter pack relative to the screen is within the optimum design for the well screen.
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and, to some degree, near-well formation materials. Water can pumped at relatively highly rates, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a
Additives Used during Drilling		Air Municipal water QUIK-FOAM EZ-MUD

	Description	Evaluation
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal. A cement grout surface seal was placed from 0 to 82 ft.

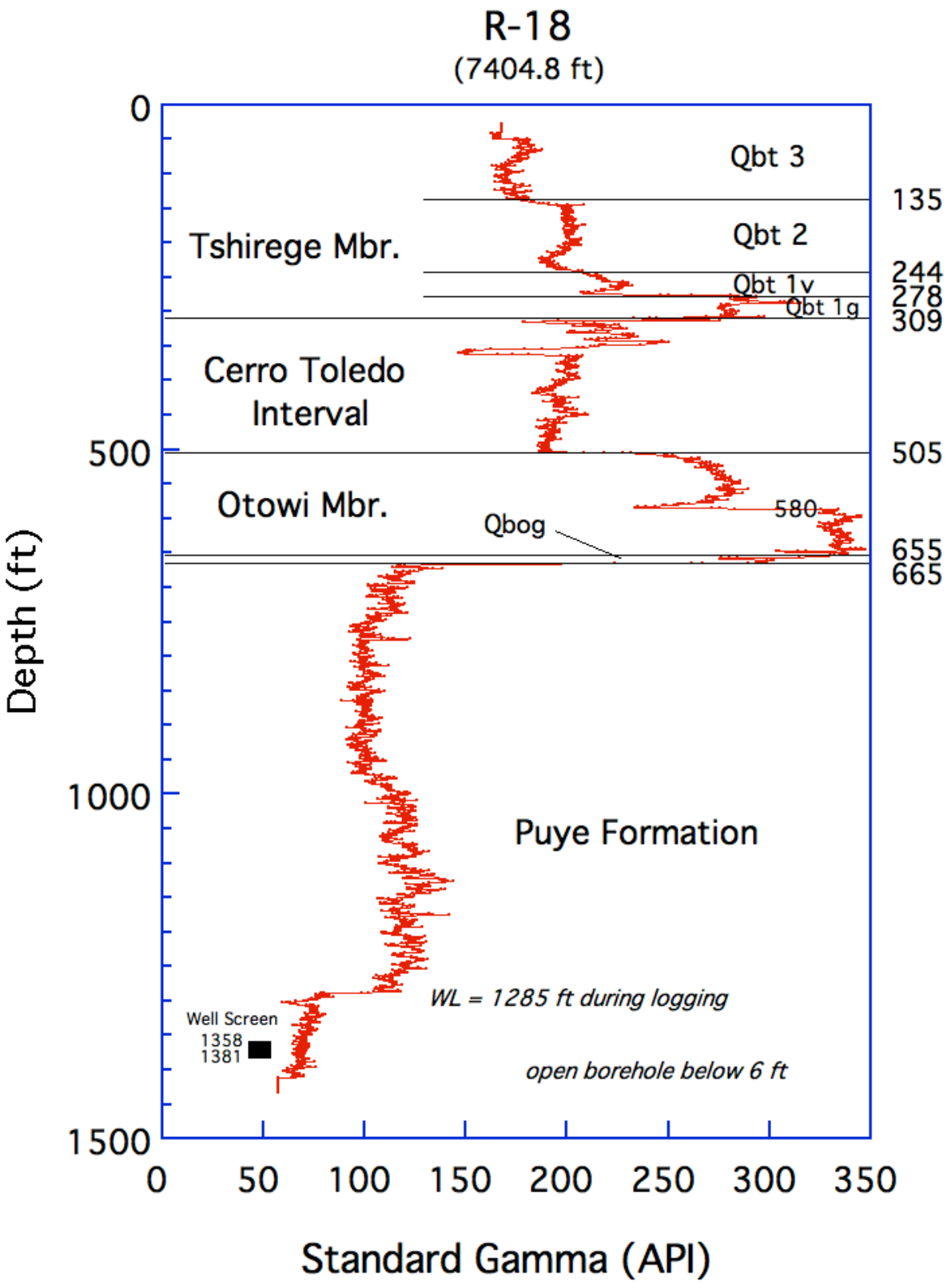


Figure A-11 Well R-18 geology and borehole gamma log

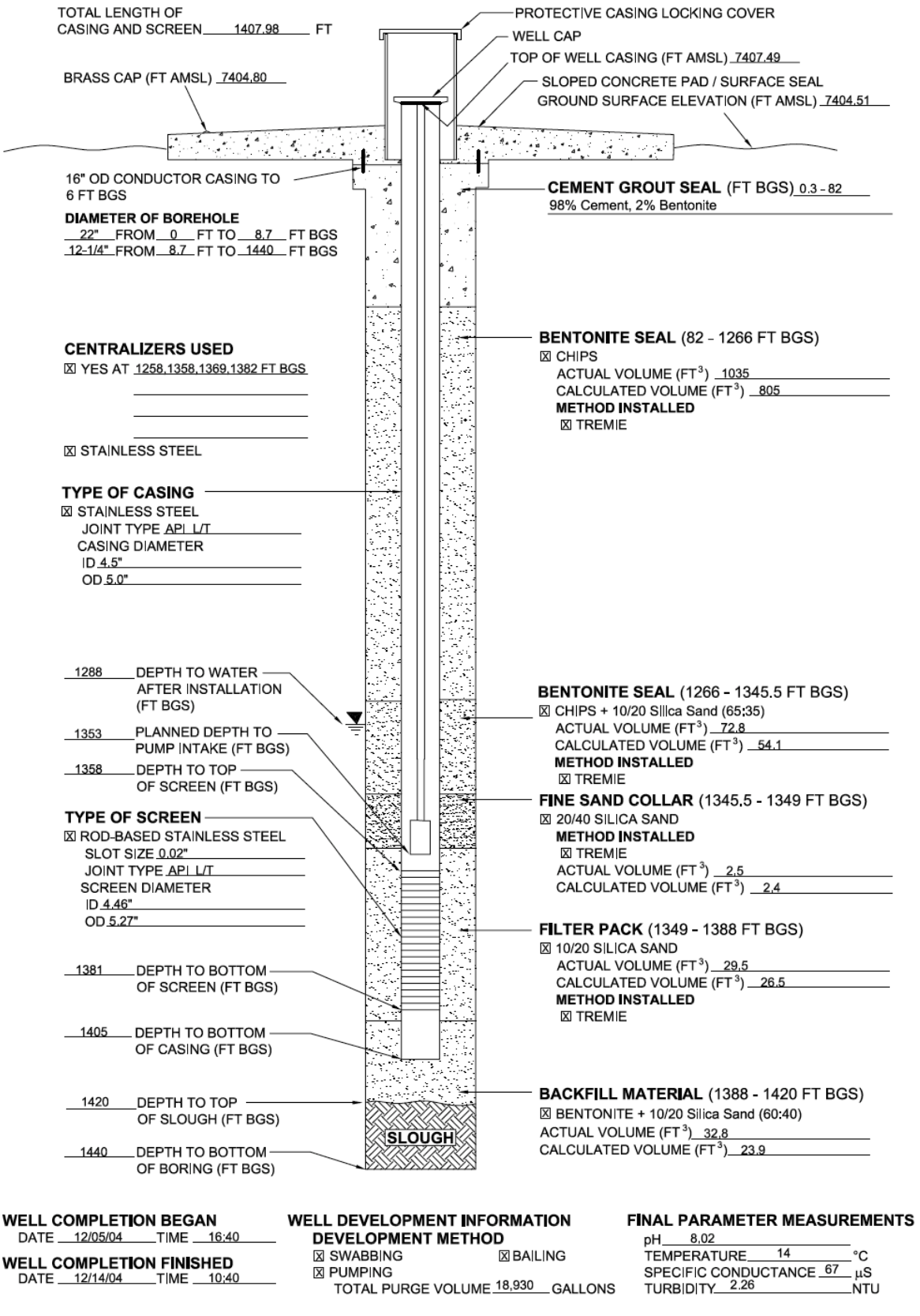


Figure A-12 R-18 well design

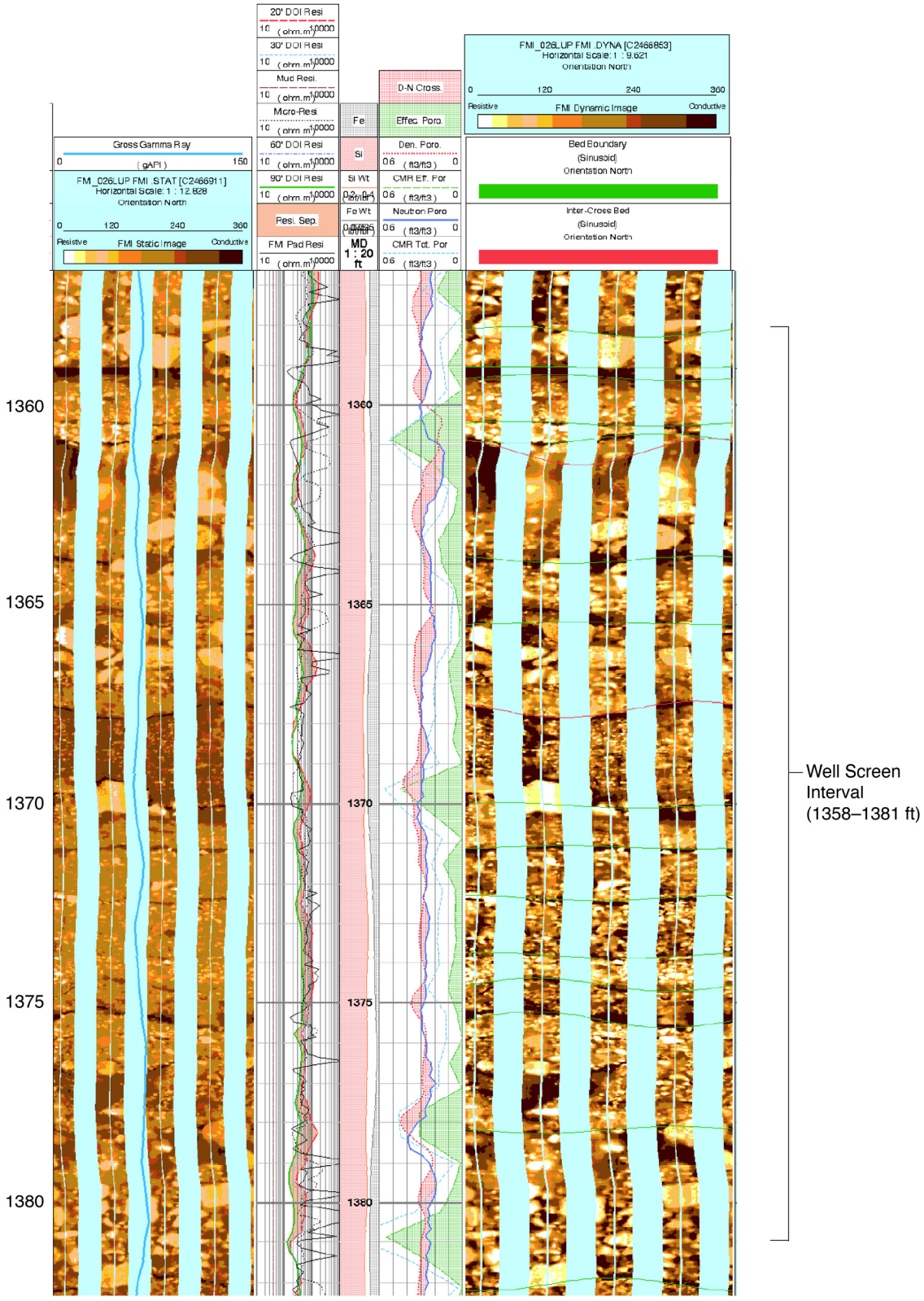


Figure A-13 Well R-18 FMI log showing lithology, electrical resistivity, and porosity for the well screen

REGIONAL AQUIFER WELL R-25

Summary of Well Screen Information, R-25

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	737.6–758.4	20.8	Otowi Member	20/40 sand 732.0–762.0	Perched water zone	Water level is about 1.5 ft above top of screen
2	882.6–893.4	10.8	Puye Formation	20/40 sand 878.0–897.0	Perched water zone	Water level is about 108.5 ft above top of screen
3	1054.6–1064.6	10.0	Puye Formation	20/40 sand 1046.0–1070.0	Perched water zone	Well screen damaged and dry
4	1184.6–1194.6	10.0	Puye Formation	20/40 sand 1180.0–1191.0	Perched water zone	Water level is about 13 ft above top of screen
5	1294.7–1304.7	10.0	Puye Formation	20/40 sand 1290.0–1307.0	Top of regional zone of saturation	Top of screen is submerged about 12.6 ft below the water table
6	1404.7–1414.7	10.0	Puye Formation	20/40 sand 1398.0–1415.0	Regional zone of saturation	Top of screen is submerged about 122.6 ft below the water table
7	1604.7–1614.7	10.0	Puye Formation	20/40 sand 1600.0–1618.0	Regional zone of saturation	Top of screen is submerged about 322.6 ft below the water table
8	1794.7–1804.7	10.0	Puye Formation	20/40 sand 1786.0–1805.0	Regional zone of saturation	Top of screen is submerged about 512.6 ft below the water table
9	1894.7–1904.7	10.0	Puye Formation	20/40 sand 1889.0–1930.0	Deepest possible position for a screen in the regional zone of saturation	Well screen damaged; not accessible

Well R-25 Drilling and Well Construction

	Description	Evaluation
Drilling Method	R-25 was drilled using HSA and fluid-assisted air-rotary RC drilling methods with casing advance. Drilling fluid consisted of municipal water mixed with QUIK-FOAM, EZ-MUD	Geologic conditions encountered during drilling are summarized in Figure A-14 and in the well completion report (Broxton et al. 2002, 072640) The techniques used to drill R-25 consisted of air-rotary coring, solid-stem auger placement of a surface casing, and air-rotary under-reamer advance of three different casing strings. The HSA drilling technique was used to install the 16-in. steel surface conductor casing to 10 ft bgs. After the 16-in.-diameter surface casing was installed, three

	Description	Evaluation
	PLUS polymers, fibrous materials, and TORKEASE. Drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.	telescoped casing strings were installed to advance the borehole and to prevent perched groundwater from communicating downhole as the borehole advanced. Air-rotary methods, including downhole percussion hammers on 4.5-in.- and 7-in.-O.D. dual-wall casings to drill open hole; air-rotary coring using a Longyear 134-mm coring system; air-rotary Holte and Stratex casing advance systems and downhole percussion hammers to drill and advance casing in the borehole simultaneously. The 13.375-in. casing was landed in unsaturated Otowi Member tuff at 578 ft. This casing began to tighten up in the borehole when the Otowi Member was first encountered at 509 ft, and the casing finally became stuck at 578 ft. The 11.75-in. casing was then advanced to 1175 ft within a zone of alternating wet and dry conditions. A bentonite grout seal was pressure-injected to seal the casing in place temporarily. The 9.625-in. casing was then advanced to the TD of 1942 ft. After the 13.375-in. casing became stuck in the hole at 578 ft, the 11.75-in. casing was advanced within the 13 3/8-in. casing to 1026 ft. Attempts were then made to free the 13.375-in. casing before proceeding further. A retract hammer and spear assembly was deployed down the borehole to loosen the 13.375-in. casing. When it became apparent the entire casing could not be removed, the hammer and spear assembly was used to separate the casing joint at 508 ft, leaving the lowermost 70 ft of casing (508 to 578 ft) in the hole. Air-rotary advancement of drill casing was performed without fluid assist until 588 ft. After that depth various combinations of water, bentonite, fibrous material, and TORKease were added for lubricity down to a depth of 1427 ft. From 1507.5 ft to 1547 ft, QUIK-FOAM and EZ-MUD PLUS were also added for lubricity.
General Well Characteristics	R-25 is a nine-screen well constructed of 4.5-in.-I.D./5-in.-O.D. stainless-steel well casing. Well screens 3 and 9 are damaged and cannot be used for monitoring.	The well design is shown in Figure A-15. The stainless-steel materials used at R-25 are chemically inert.
Well Screen Construction	Well R-25 was constructed with stainless-steel rod-based wire-wrapped screens with 0.010-in. slots.	Wire-wrapped screen is considered the optimum design for promoting the free flow of water during well development and sampling. Two types of wire-wrapped screens (5.17-in.-I.D./5.98-in.-O.D. stainless steel) were used at well R-25. Screens 1 and 2 vertical rod diameters were 0.250 in., and horizontal wrap wire was 0.118 in. in diameter, yielding 7.9% open area. Screens 3 through 9 have vertical rods and horizontal wrap wire 0.093 in. in diameter, yielding 10.4% open area. The wire wrap screens have 0.010-in. slots. Later wells were installed with 0.020-in. slots to facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in.-slot wire-wrapped screen to develop properly must be judged on the quality of groundwater data collected from the wells.
Screen Length and Placement	Screen 1 extends from 737.6 to 758.4 ft (length 20.8 ft) and targets perched-intermediate groundwater.	Well R-25 is designed to provide water-quality and water-level data, and the screen length and placement were selected to achieve the following goals: • Characterize water quality of perched-intermediate and regional groundwater downgradient of HE sources in the vicinity of TA-16 • Monitor water levels to investigate the direction of groundwater flow and hydraulic gradients within the regional and perched aquifers

	Description	Evaluation
	Screen 2 extends from 882.6 to 893.4.4 ft (length 10.8 ft) and targets perched-intermediate groundwater. Screen 3 extends from 1054.6 to 1064.6 ft (length 10 ft) and targets perched-intermediate groundwater; it was damaged during well construction and is dry. Screen 4 extends from 1184.6 to 1194.6 ft (length 10.8 ft) and targets perched-intermediate groundwater. Screen 5 extends from 1294.7 to 1304.7 ft (length 10 ft) and targets the top of regional saturation. Screen 6 extends from 1404.7 to 1414.7 ft (length 10 ft) and targets regional groundwater. Screen 7 extends from 1604.7 to 1614.7 ft (length 10 ft) and targets regional groundwater. Screen 8 extends from 1794.7 to 1804.7 ft (length 10 ft) and targets regional groundwater. Screen 9 extends from 1894.7 to 1904.7 ft (length 10 ft) and targets regional groundwater.	• Provide hydrologic and geologic information in a previously poorly characterized area of the Laboratory The screens at R-25 were sited based on driller's observations of water production, water-level measurements during drilling, borehole video logs for segments of the borehole, lithologic descriptions of cuttings, HE analyses for borehole water samples, and limited geophysical logs (gamma and induction). Screen 1 targets potential perched-intermediate groundwater in the Otowi Member of the Bandelier Tuff. The top of the well screen was initially submerged 15.5 ft below the perched water table, but water levels have declined and the top of the screen is currently 1.5 ft above the water table. This screen was placed near the top of perched groundwater to establish the distribution of HE contaminants and to determine vertical head data for this zone in conjunction with deeper well screens. The well screen is located in massive nonwelded vitric ash-flow tuff deposits. An open borehole video shows that a near-vertical open fracture is present in the well-screen interval below 749 ft depth. The placement and hydrogeologic setting of screen 4 is representative of groundwater conditions and meets all characterization and monitoring goals. Screen 2 targets perched-intermediate groundwater in the Puye Formation. This screen was placed in the lower part of perched groundwater to establish the distribution of HE contaminants and to determine vertical head data for this zone in conjunction with other well screens. Lithologic logs for cuttings indicate this perched zone occurs in gravels and cobbles with a silty sand matrix. The placement and hydrogeologic setting of screen 2 is representative of groundwater conditions and meets all characterization and monitoring goals. Screen 3 targeted suspected perched-intermediate groundwater in the Puye Formation. The screen was designed to establish the distribution of HE contaminants and to determine vertical head data for this zone in conjunction with other well screens. Lithologic logs for cuttings indicate this perched zone occurs in gravels and cobbles with a silty sand matrix. Screen 3 was damaged during well construction, as described below under "Other Issues That Could Affect the Performance of the Well." Screen 3 is dry and cannot be used for monitoring groundwater. Screen 4 was placed in a variably saturated zone believed to contain perched groundwater to establish the distribution of HE contaminants and to determine vertical head data for this zone. The top of the well screen is 13.5 ft below the perched water table. Screen 4 is designed to monitor regional groundwater downgradient of HE sources in the vicinity of TA-16. Lithologic logs for cuttings indicate this perched zone occurs in gravels and cobbles with a silty sand matrix. The placement and hydrogeologic setting of screen 4 is representative of aquifer conditions and meets all characterization and monitoring goals. Screen 5 targets the top of the regional groundwater system in the Puye Formation. The top of the well screen is 12.7 ft below the regional water table. Screen 5 is designed to monitor shallow regional groundwater pathways downgradient of HE sources in the vicinity of TA-16, to assess vertical pressure gradients in the regional aquifer, and to determine if there are pressure responses to pumping of municipal supply wells on the Pajarito Plateau. Lithologic logs for cuttings indicate this perched zone occurs in gravels and cobbles with a silty sand matrix. The placement and hydrogeologic setting of screen 5 is

	Description	Evaluation
		representative of aquifer conditions and meets all characterization and monitoring goals. Screen 6 targets the regional groundwater system in Puye Formation sedimentary deposits about 123 ft below the regional water table. Screen 6 is designed to monitor shallow regional groundwater pathways downgradient of HE sources in the vicinity of TA-16, to assess vertical pressure gradients in the regional aquifer, and to determine if there are pressure responses to pumping of municipal supply wells on the Pajarito Plateau. Lithologic logs for cuttings indicate this perched zone occurs in gravels and cobbles with a silty sand matrix. The placement and hydrogeologic setting of screen 6 is representative of aquifer conditions and meets all characterization and monitoring goals. Screen 7 targets the regional groundwater system in Puye Formation sedimentary deposits about 323 ft below the regional water table. Screen 7 is designed to monitor deep regional groundwater pathways downgradient of HE sources in the vicinity of TA-16, to assess vertical pressure gradients in the regional aquifer, and to determine if there are pressure responses to pumping of municipal supply wells on the Pajarito Plateau. Lithologic logs for cuttings indicate this perched zone occurs in gravels and cobbles with a silty sand matrix. The placement and hydrogeologic setting of screen 7 is representative of aquifer conditions and meets all characterization and monitoring goals. Screen 8 targets the regional groundwater system in Puye Formation sedimentary deposits about 513 ft below the regional water table. Screen 8 was designed to monitor deep regional groundwater pathways downgradient of HE sources in the vicinity of TA-16, to assess vertical pressure gradients in the regional aquifer, and to determine if there are pressure responses to pumping of municipal supply wells on the Pajarito Plateau. Lithologic logs for cuttings indicate this perched zone occurs in gravels and cobbles with a silty sand matrix. The placement and hydrogeologic setting of screen 8 is representative of aquifer conditions and meets all characterization and monitoring goals. Screen 9 targeted the regional groundwater system in Puye Formation sedimentary deposits about 613 ft below the regional water table. Screen 9 was designed to monitor regional groundwater in the deepest part of the R-25 borehole downgradient of HE sources in the vicinity of TA-16, to assess vertical pressure gradients in the regional aquifer, and to determine if there are pressure responses to pumping of municipal supply wells on the Pajarito Plateau. Lithologic logs for cuttings indicate this perched zone occurs in gravels and cobbles with a silty sand matrix. Screen 9 was damaged during well construction as described below under “Other Issues That Could Affect the Performance of the Well.” Screen 9 cannot be used to monitor groundwater or water levels.
Filter Pack Materials and Placement	The filter packs and their placements for the nine well screens are discussed in the column to the right.	The screen 1 primary filter pack is made up of 20/40 sand from 732 to 762 ft. A secondary filter pack of 30/70 sand was placed above the primary filter pack from 726 to 732 ft. The primary filter pack extends 5.6 ft above and 3.6 ft below the well screen. Placement of the filter pack relative to the screen is within the optimum design for the well screen. The screen 2 primary filter pack is made up of 20/40 sand from 878 to 897 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 865 to 878 ft and 897 to 905 ft,

	Description	Evaluation
		respectively. The primary filter pack extends 4.6 ft above and 3.6 ft below the well screen. Placement of the filter pack relative to the screen is within the optimum design for the well screen. The screen 3 primary filter pack was originally installed as 20/40 sand from 1046 to 1070 ft. A secondary filter pack of 30/70 sand was placed above the primary filter pack from 1040 to 1046 ft. Cement was pressure injected in the filter pack during the screen 3 repair (see "Other Issues that Could Affect the Performance of the Well" below). Screen 3 is dry and cannot be used for monitoring groundwater. The screen 4 primary filter pack is made up of 20/40 sand from 1184.6 to 1194.6 ft. A secondary filter pack of 30/70 sand was placed below screen 4 from 1191 to 1202 ft. The primary filter pack extends 4.6 ft above and 3.6 ft below the well screen. Placement of the filter pack relative to the screen is within the optimum design for the well screen. The screen 5 primary filter pack is made up of 20/40 sand from 1290 to 1307 ft. A secondary filter pack of 30/70 sand was placed above the primary filter pack from 1284 to 1290 ft. A grout seal was placed below the primary filter pack from 1307 to 1308 ft. The primary filter pack extends 4.7 ft above and 2.3 ft below the well screen. Placement of the filter pack relative to the screen is within the optimum design for the well screen. The screen 6 primary filter pack is made up of 20/40 sand from 1398 to 1415 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 1394 to 1398 ft and 1415 to 1424 ft, respectively. The primary filter pack extends 6.7 ft above and 0.3 ft below the well screen. Placement of the filter pack relative to the screen is within the optimum design for the well screen. The screen 7 primary filter pack is made up of 20/40 sand from 1600 to 1618 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 1595 to 1600 ft and 1618 to 1625 ft, respectively. The primary filter pack extends 4.7 ft above and 3.3 ft below the well screen. Placement of the filter pack relative to the screen is within the optimum design for the well screen. The screen 8 primary filter pack is made up of 20/40 sand from 1786 to 1805 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 1781 to 1786 ft and 1805 to 1813 ft, respectively. The primary filter pack extends 8.7 ft above and 0.3 ft below the well screen. Placement of the filter pack relative to the screen is within the optimum design for the well screen. The screen 9 primary filter pack is made up of 20/40 sand from 1889 to 1930 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 1885 to 1889 ft and 1930 to 1934 ft, respectively. The primary filter pack extends 8.7 ft above and 0.3 ft below the well screen. Because the top of the screen separated from the well casing, screen 9 was isolated by installing a detachable inflatable packer above the well screen and is not usable (see "Other Issues That Could Affect the Performance of the Well" below).

	Description	Evaluation
Sampling System	Westbay MP sampling system	Westbay is a low-flow sampling system that allows groundwater sampling of multiple well screens within a single well installation. Well screens are isolated by packers and sampled individually. Westbay is the only sampling system capable of sampling three or more screens in a multiscreen well. It is particularly effective for monitoring water levels at multiple depths within a well. Flow-through cells for measuring field parameters cannot be used at multiscreen wells containing the Westbay sampling system. Effective development and removal of residual drilling fluids are critical before Westbay wells are installed because groundwater is collected in proximity to the well because of low-flow sampling and the inability to purge the well before sampling. Samples collected from Westbay wells are particularly prone to water-quality problems that develop if residual drilling fluids are hydraulically connected to the screen interval.
Other Issues That Could Affect the Performance of the Well	See notes in the column to the right.	During R-25 well construction, 1180 ft of dual tremie (1.19-in. A and 2.19-in. BQ) rods were dropped down the well annulus, possibly damaging backfill materials outside of the well casing. The BQ rod penetrated annular materials to a depth of about 1860 ft (between screens 8 and 9) and the A rod penetrated to a depth of 1584 ft (between screens 6 and 7). Fishing operations successfully recovered the BQ rod and all but the lower 52 ft (1532- to 1584-ft depth) of the A rod. The unrecovered piece of A rod is located in bentonite between screens 6 and 7 and should be isolated from groundwater. The displacement of bentonite by the dropped tremies was expected to heal naturally as the bentonite hydrates and fills any voids. Recent pressure transducer readings from the Westbay MP sampling system indicate that all well screens are hydraulically isolated. Damage to screen 3 was discovered when a borehole video log was conducted after annular fill materials were emplaced in the well. The well screen underwent a spiral collapsed over an interval of slightly greater than 1 ft at the bottom of the screen. Clearance through the collapsed screen barely allowed passage of a borehole camera with a diameter of 1.75 in. The collapse of screen 3 was significant because the 4.3-in.-diameter packers for the Westbay sampling system could not be installed through the constriction. A number of options were considered before a decision was made to repair screen 3 with sufficient clearance for the installation of the Westbay sampling system. An inflatable detachable packer was inserted several feet below screen 3, and sand was added above the packer to protect it from cement that was used to encase the screen. Micro Matrix and Portland cements were pumped into the well screen and annulus to stabilize the damaged screen. The cemented screen was drilled and reamed until a 4.3-in.-diameter, 3.5-ft-long pipe could be passed through to verify that the interval would be large enough for installation of the Westbay MP sampling system. The Westbay MP sampling system was successfully deployed through the repaired screen, but screen 3 remained unusable for groundwater monitoring. Well R-25c, located on the south rim of Cañon de Valle at TA-16 about 100 ft west of well R-25, was completed in September 2008 to satisfy a requirement to install a replacement screen at a depth equivalent to screen 3 at well R-25 (NMED 2007, 095394; LANL 2008, 103165). R-25c was drilled to a TD of 1140 ft bgs and completed with a single-screened interval between 1039.6 ft and 1060 ft bgs within the Otowi Member (LANL 2008, 103408). Well R-25C has been dry since well installation supporting the current interpretation that this part of the Puye Formation is an unsaturated

	Description	Evaluation
		interval between two perched groundwater systems (LANL 2011, 207069). Damage to screen 9 was discovered by borehole video after repairs to screen 3 were completed. The stainless-steel well casing had separated from the top of screen 9 at 1894.7 ft. Because the offset screen would not allow the installation of the Westbay MP sampling system, the borehole annulus was filled with 30/70 sand from the top of existing annular materials below screen 9 to the depth at which the casing had separated. Screen 9 and the sump below were filled with 30/70 sand up to a depth of 1875.5 ft and included 19.2 ft of sand within the well casing above the separation. A 7-ft inflatable detachable packer was placed above the separation at a depth of 1862.2 to 1865.0 ft to hydraulically isolate the lowermost part of the well. Before the screen was repaired, the following well development activities were performed. Screens 1, 2, 4, 5, 6, 7, and 8 were pressure washed with a water solution containing sodium acid pyrophosphate (SAPP). The lower part of the well below the screen 3 was purged by introducing 900 gal. of water into the well and removing 1200 gal. by airlifting. In addition, screens 2 and 8 were partially developed by airlifting water before screens 3 and 9 were repaired. After screens 3 and 9 were repaired, development activities continued. Screens 1 and 2 were scrubbed with a wire brush, and all the screens, except 3 and 9, were jetted. A pump was lowered to 1760 ft, and the well was purged. Screens 1 and 2 were again scrubbed. Water in the well was then airlifted from just above 1850 ft. A submersible pump was then used to target screens 4, 5, 6, 7, and 8 by pumping next to the screens. Pumping development was conducted without using packers to isolate the well screens. Consequently, pumping development was probably most effective for the well screen that yielded the most water and least effective for the poorest producing well screen.
Additives Used during Drilling		Air Municipal water QUIK-FOAM Ben Seal bentonite Bentonite Gel Aqua-Guard Bentonite Cellophane Mag Fiber Nylon EZ-MUD PLUS TORKease (used to free stuck casing in the Bandelier Tuff)
Annular Fill Other Than Filter and Transition Sands		Granular bentonite mixed with 20/40 sand (50/50 mix) was used to create an annular seals between the well screens. A cement grout surface seal was placed from 0 to 50 ft.

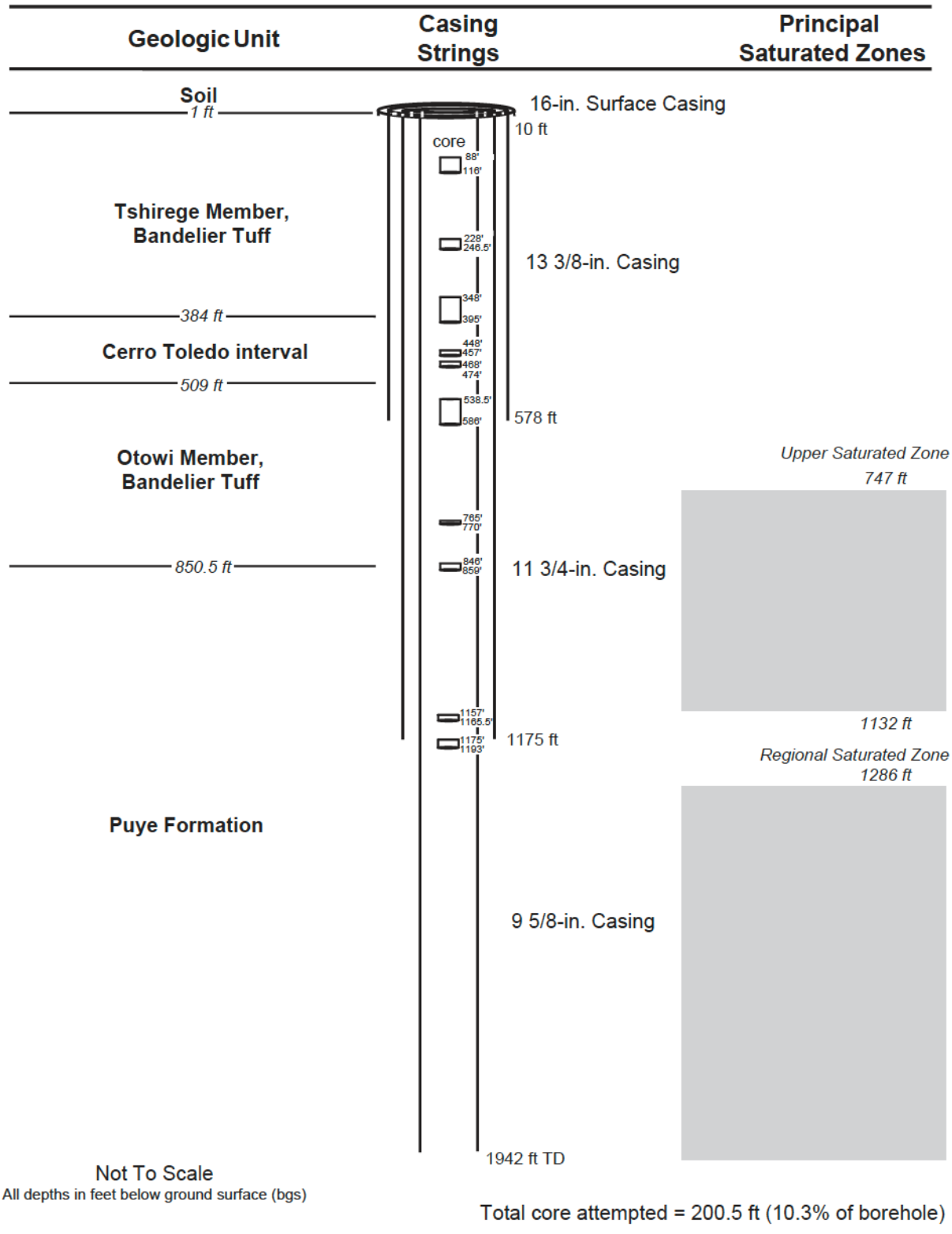


Figure A-14 Well R-25 geology, groundwater zones, drill casings, and core intervals

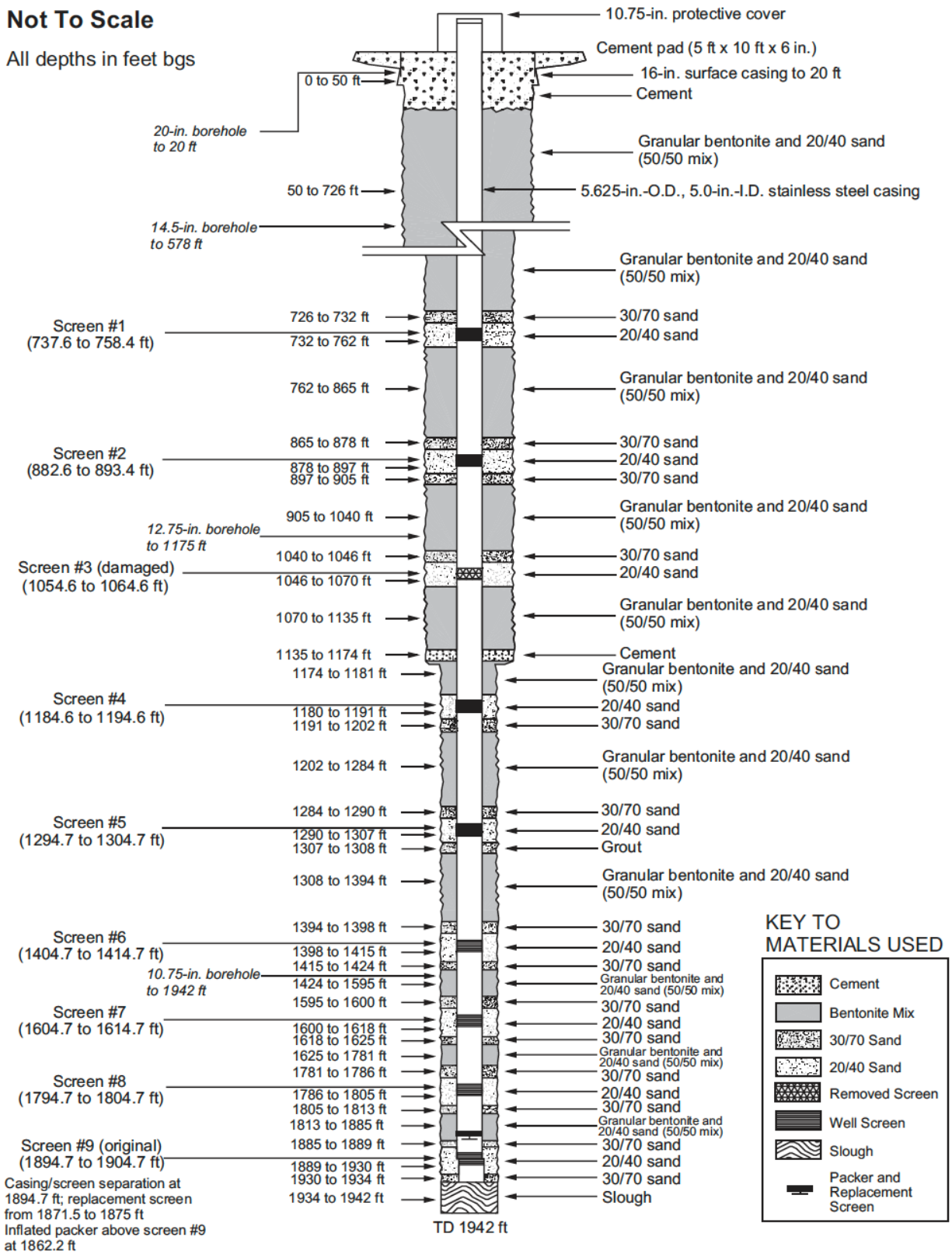


Figure A-15 R-25 well design

REGIONAL AQUIFER WELL R-27

Summary of Well Screen Information, R-27

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	852.0–875.0	23.0	Puye Formation	10/20 sand 842–885	Upper part of the regional zone of saturation	Top of screen is submerged 36.1 ft below the water table

R-27 Drilling and Well Construction

	Description	Evaluation
Drilling Method	R-27 was drilled using open-hole fluid-assisted air-rotary drilling methods. Drilling fluid consisted of municipal water mixed with QUIK-FOAM and EZ-MUD polymers. Drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.	Geologic conditions encountered during drilling are summarized in Figure A-16 and in the well completion report (Kleinfelder 2006, 092488). A pilot hole was drilled to 43 ft with a 12.25-in. button bit; it was then reamed to 24-in. to a depth of 25 ft bgs before cementing in 16-in. surface casing to a depth of 19.7 ft bgs. An open borehole was drilled to 28 ft bgs using a 15-in. chisel-tooth button bit before the surface casing slipped and had to be recemented in place. An open hole was drilled from 28 to 640 ft using a 12.25-in. chisel-tooth bit. An open hole was drilled from 640 to 757 ft using a 12.25-in. down-the-hole hammer bit. The bottom of the hammer bit broke off downhole and the hole was tagged at a depth of 730 ft. A 12.25-in. chisel-tooth bit was used to clean the hole to a depth of 752 ft. After repairs to a frayed 0.75-in. drill-rig cable and several fishing attempts, the hammer bit was retrieved from the borehole. An open hole was drilled 752 to 987 ft using a 12.25-in. down-the-hole hammer bit. Drilling was terminated at 987 ft depth because of borehole instability and concerns the drill string might become stuck.
General Well Characteristics	R-27 is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. stainless-steel well casing.	The well design is shown in Figure A-17. The stainless-steel materials used at R-27 are chemically inert.
Well Screen Construction	Well R-27 was constructed with stainless-steel rod-based wire-wrapped screens with 0.020-in. slots.	Wire-wrapped screen with 0.020-in. slots is considered the optimum design for promoting the free flow of water during well development and sampling.
Screen Length and Placement	The R-27 well screen extends from 852.0 to 875.0 ft (length 23 ft) and targets regional groundwater.	Well R-27 is designed to provide water-quality and water-level data, and the screen length and placement were selected to achieve the following goals: • Characterize water quality of regional groundwater downgradient of HE sources in the vicinity of TA-16 and surrounding areas • Monitor water levels to investigate the direction of groundwater flow and hydraulic gradients within the regional aquifer The well screen was placed near the top of the regional groundwater system to monitor groundwater downgradient of potential HE release

	Description	Evaluation
		sites. The main goal for this screen was to determine if Laboratory contamination occurs at the top of regional groundwater. The screen is located within the Pliocene Puye Formation sedimentary deposits that include stacked beds of boulders, cobbles, and sandy gravels (Figure A-18). Total porosities within the screen interval range between 20% and 40%. Effective porosities range mostly between 10% and 25%, but one 2-ft interval is 40%. The electrical resistivity image (FMI log) shows these deposits are thick bedded and generally very coarse grained, but silt beds up to 0.2-ft thick are intercalated in these coarse deposits. For the most part the deposits in the screen interval are electrically resistive (>100 ohm-m), indicating they contain minimal silt and clay (Figure A-18). The lower 2.5 ft of the well-screen interval is more conductive (20 to 100 ohm-m) and silts and clays are probably more prevalent in the rock matrix. The top of the well screen is 36.1 ft below the piezometric surface. Given the distal location of well R-27 relative to HE-infiltration zones at TA-16, the depth and hydrogeologic setting of this screen meet all characterization and monitoring goals.
Filter Pack Materials and Placement	The filter pack and its placement for the well screen are discussed in the column to the right.	The primary filter pack is made up of 10/20 sand from 842 to 885 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 840.5 to 842 ft. The primary filter pack extends 10 ft above and 10 ft below the well screen. The length and placement of the filter pack relative to the well screen meet the design goals for this well.
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and, to some degree, near-well formation materials. Water can pumped at relatively highly rates, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a
Additives Used during Drilling		Air Municipal water QUIK-FOAM EZ-MUD
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal. A cement grout surface seal was placed from 2 to 78 ft.

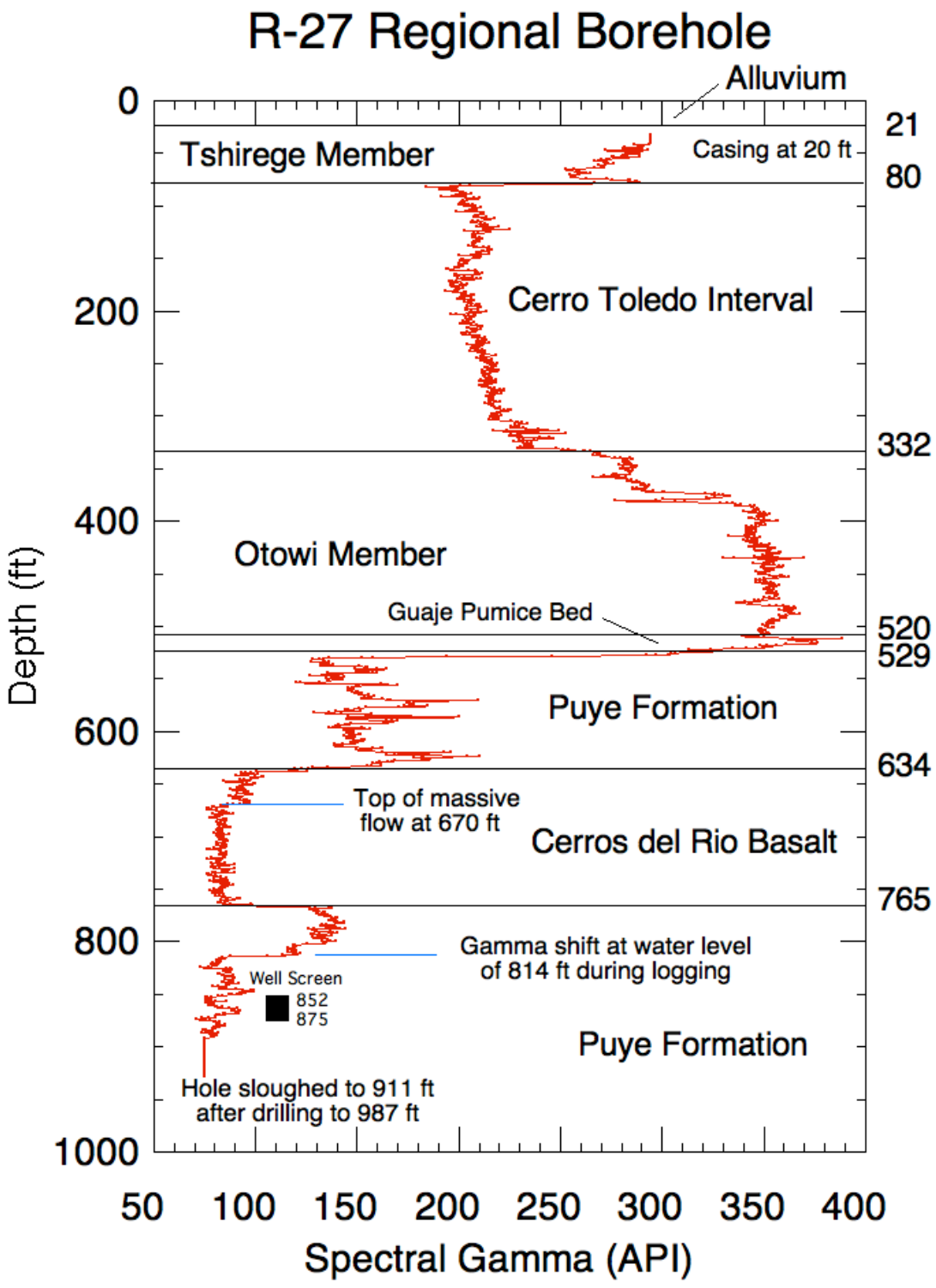


Figure A-16 Well R-27 geology and borehole gamma log

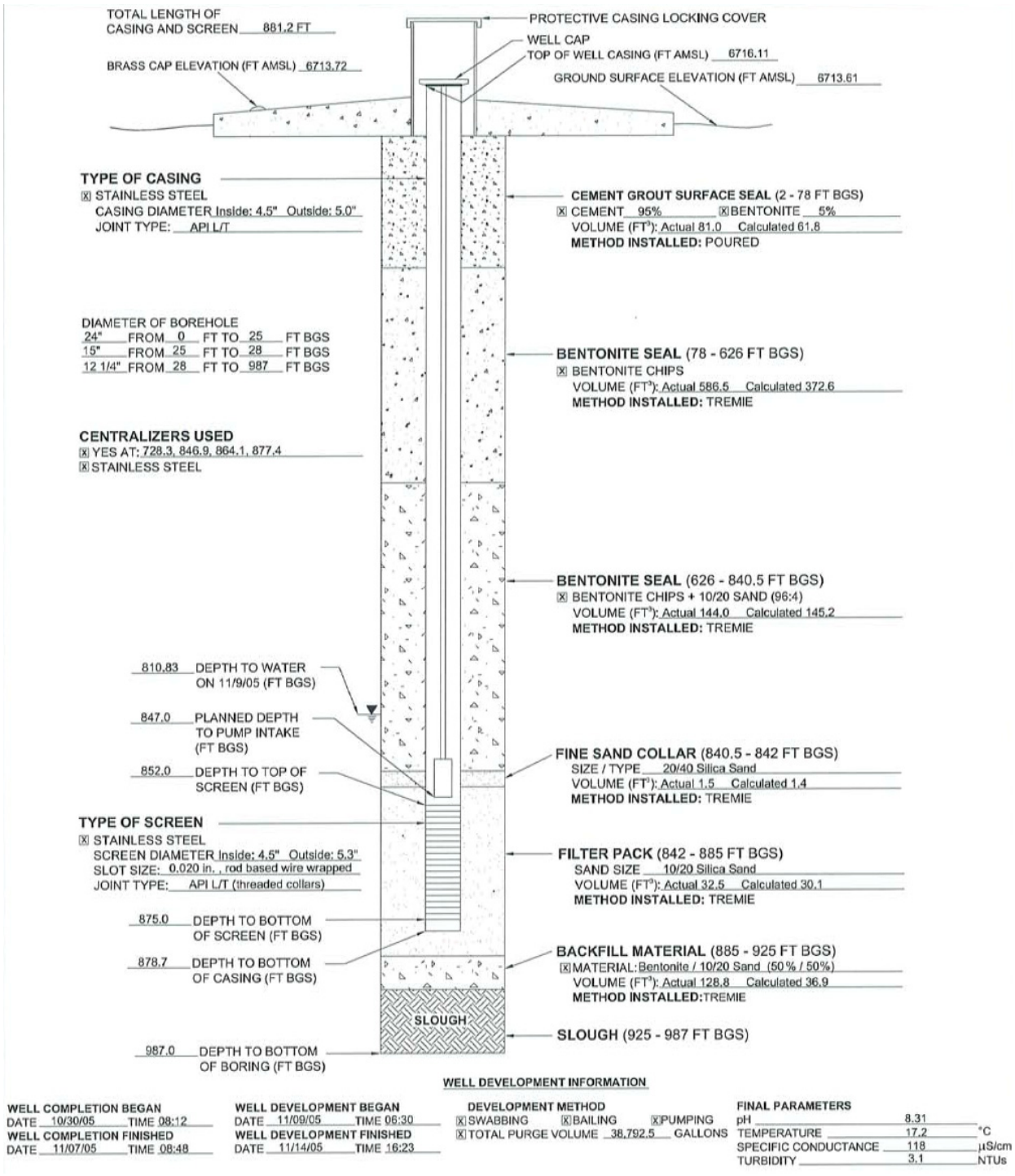


Figure A-17 R-27 well design

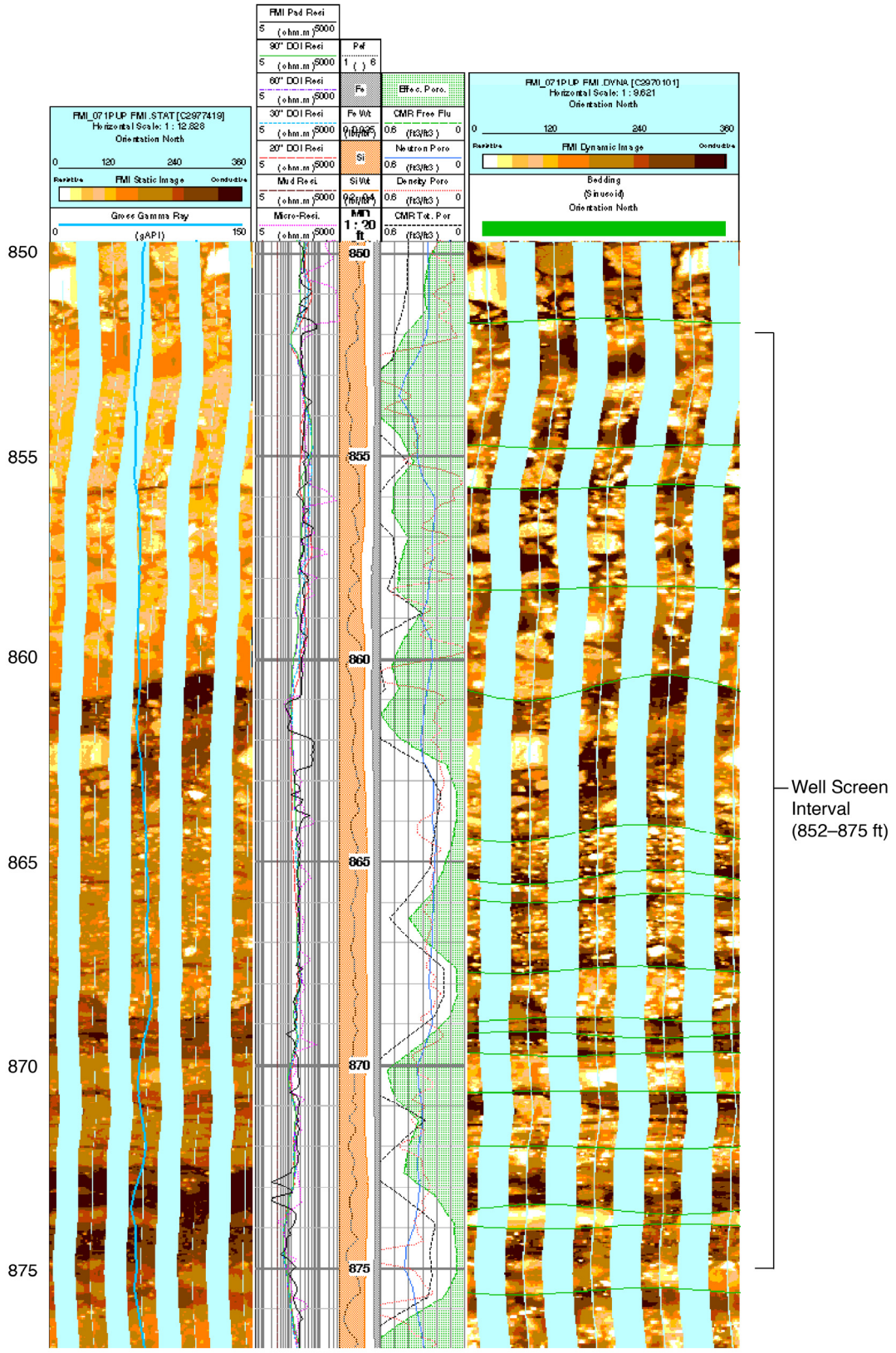


Figure A-18 Well R-27 FMI log showing lithology, electrical resistivity, and porosity for the well screen

REGIONAL AQUIFER WELL R-48

Summary of Well Screen Information, R-48

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	1500.0–1520.6	20.6	Tschicoma Formation	10/20 sand 1495–1525	Uppermost permeable zone in the regional zone of saturation	Top of screen is submerged 146.9 ft below the water table

R-48 Drilling and Well Construction

	Description	Evaluation
Drilling Method	R-48 was drilled using open-hole fluid-assisted air-rotary drilling methods. Drilling fluid consisted of municipal water mixed with QUIK-FOAM and EZ-MUD polymers. Drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.	Geologic conditions encountered during drilling are summarized in Figure A-19 and in the well completion report (LANL 2010, 108778). R-48 originally was designated CdV-16-3(i) in a suite of three intermediate boreholes that included CdV-16-1(i) and CdV-16-2(i). These three boreholes were drilled to better characterize contaminant distribution, principally HE compounds, at TA-16. Intermediate wells were installed at CdV-16-1(i) and CdV-16-2(i), but no perched water was found at CdV-16-3(i). Unlike the other two boreholes in this set of three, CdV-16-3(i) was advanced to regional aquifer in December 2003 and January 2004; the borehole encountered poorly transmissive dacite layers at a TD of 1405 ft without producing significant water. Because water was observed entering the well at very slow rates, the borehole was left open for observation. In 2009, the CdV-16-3(i) borehole was deepened to a TD of 1705 ft under the New Mexico Environment Department's (NMED's) direction to determine whether sufficient transmissive saturation might be found to construct a regional monitoring well at this site. The well installed in the deepened borehole was called R-48 to be consistent with the naming convention used for regional aquifer monitoring wells installed by Environmental Programs Directorate (formerly the Environmental Restoration Project) at the Laboratory. Phase 1 drilling of the CdV-16-3(i) borehole took place in December 2003 and January 2004. A pilot hole was drilled to 22 ft with a 12.25-in. button bit and 13.375-in. conductor casing was installed to a depth of 12 ft bgs. An open borehole was drilled from 22 to 1163 ft bgs using a 12.25-in. button-toothed tricone bit and fluid-assisted air-rotary methods. From 1163 to 1405 ft TD, drilling switched to a 12.25-in. down-the-hole hammer bit to better penetrate dense dacite lavas of the Tschicoma Formation. Because of the impermeable nature of dacite lavas that make up the aquifer at this location, water recharged the borehole at very low rates, and the depth of regional groundwater was uncertain. Drilling operations were halted, and over the next several years water levels in the open borehole were monitored and water samples were collected. Phase 2 drilling took place between June and September 2009. The principal objective for deepening the existing borehole was to determine whether a sufficiently transmissive zone occurs within

	Description	Evaluation
		dacite lavas of the Tschicoma Formation to construct a monitoring well at this location. After initial problems with plugged jets in the drill bit and poor circulation, an open hole was drilled from 1405 to 1445 ft using an 11.625-in. button-tooth tricone bit. At 1445 ft bgs, the tricone bit was tripped out of the hole and a hammer bit was tripped in. Before drilling could be restarted, the hammer bit became detached from the drill string downhole. The hammer bit was successfully recovered after extended fishing operations. An open hole was drilled from 1445 to 1508 ft using an 11.625-in. hammer bit. Because the down-the-hole hammer stopped firing at 1508 ft bgs, the hammer bit was tripped out and replaced with a 9.875-in. tricone bit. The tricone bit was used to drill from 1508 to 1705 ft TD.
General Well Characteristics	R-48 is a single-screen well constructed of 5.047-in.-I.D./5.563-in.-O.D. type A304 stainless-steel well casing.	The well design is shown in Figure A-20. The stainless-steel materials used at R-48 are chemically inert.
Well Screen Construction	Well R-48 was constructed with stainless-steel rod-based wire-wrapped screens with 0.020-in. slots.	Wire-wrapped screen with 0.020-in. slots is considered the optimum design for promoting the free flow of water during well development and sampling.
Screen Length and Placement	The R-48 well screen extends from 1500.0 to 1520.6 ft (length 20.6 ft) and targets regional groundwater.	Well R-48 is designed to provide water-quality and water-level data, and the screen length and placement were selected to achieve the following goals: • Characterize water quality of regional groundwater downgradient of HE sources in the vicinity of TA-16 and surrounding areas • Monitor water levels to investigate the direction of groundwater flow and hydraulic gradients within the regional aquifer The well screen is placed in the uppermost transmissive zone in the regional groundwater system to monitor groundwater downgradient of potential HE release sites. The main goal for this screen is to determine if Laboratory contamination occurs in the upper part of regional groundwater. The screen is located within the dacite lava of the Pliocene Tschicoma Formation. The Tschicoma Formation consists of massive dense lava flows from the regional water table (at a depth of 1353 ft) to a depth of 1495 ft. There are no apparent flow breaks or interflow breccias in these massive lava flows. From 1495 to 1705 ft bgs, the Tschicoma Formation is a flow breccia that is made up of angular boulder-sized clast-supported dacite blocks (Figure A-21). There is no obvious bedding in the flow breccia, but a crude layering occurs from gradational changes in the sizes of the dacite blocks. Total porosities are much greater in the dacite flow breccia than in the overlying massive lava. Array porosity sonde near/far neutron porosity averages about 25% and CMR data indicates that pores are large (millimeter in size). The top of the well screen is 146.9 ft below the piezometric surface. Ordinarily well screens are placed closer to piezometric surface to better detect contaminants soon after they enter the regional aquifer in areas proximal to potential release sites. Unfortunately, the dacite lava that makes up the upper part of the regional aquifer is an aquitard and is not suitable for a well. The deep well screen at R-48

	Description	Evaluation
		is located in the uppermost transmissive zone within the regional aquifer and in the most appropriate media for monitoring groundwater and water levels in this area.
Filter Pack Materials and Placement	The filter pack and its placement for the well screen are discussed in the column to the right.	The primary filter pack is made up of 10/20 sand from 1495 to 1525 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 1493 to 1495 ft. The primary filter pack extends 5 ft above and 4.4 ft below the well screen. The length and placement of the filter pack relative to the well screen meet the design goals for this well.
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and, to some degree, near-well formation materials. Water can pumped at relatively highly rates, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison with low-flow systems, and the likelihood of obtaining water from zones beyond potential near-well drilling effects is greater. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a
Additives Used during Drilling		Air Municipal water QUIK-FOAM EZ-MUD
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal. A cement grout surface seal was placed from 6 to 66 ft.

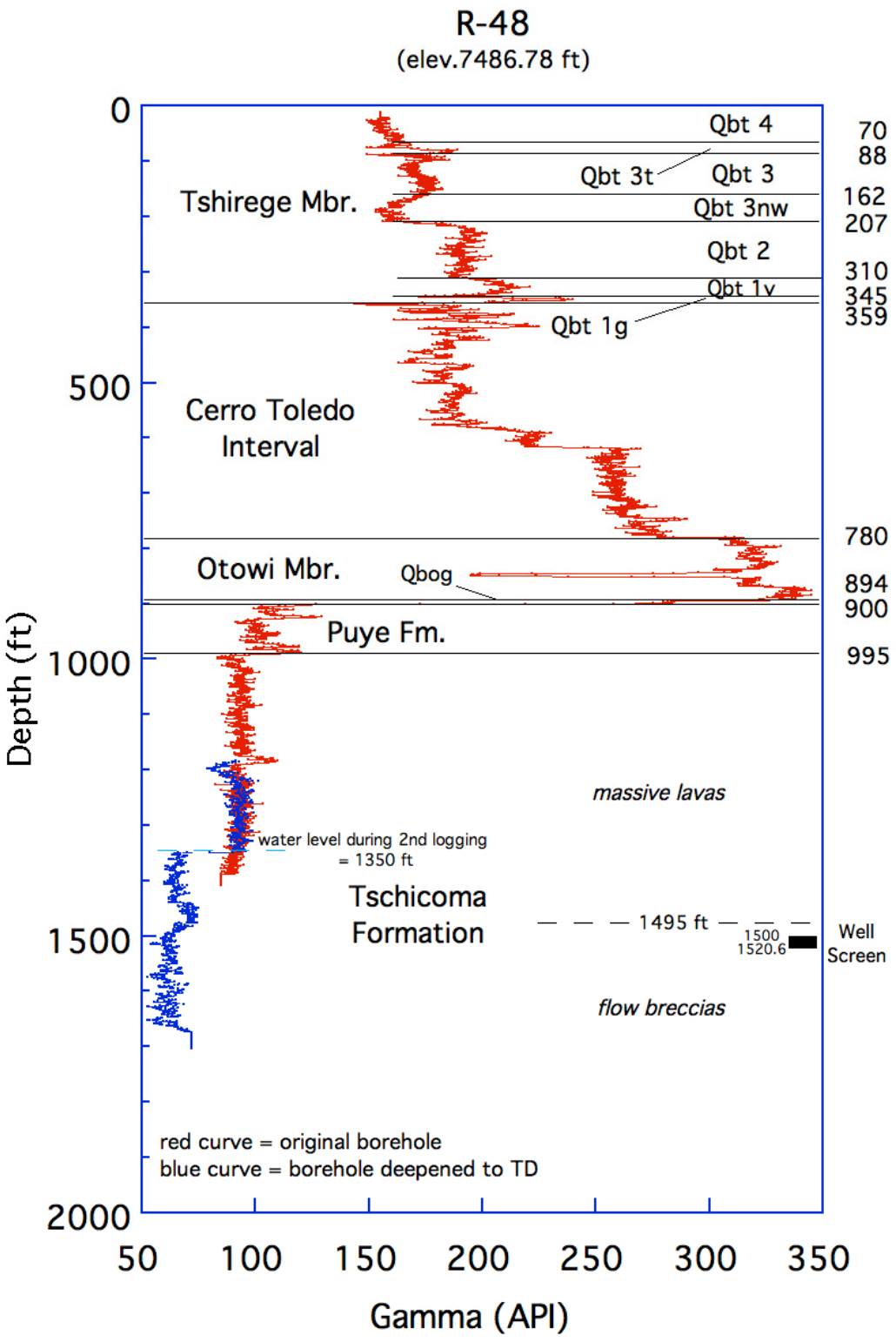


Figure A-19 Well R-48 geology and borehole gamma log

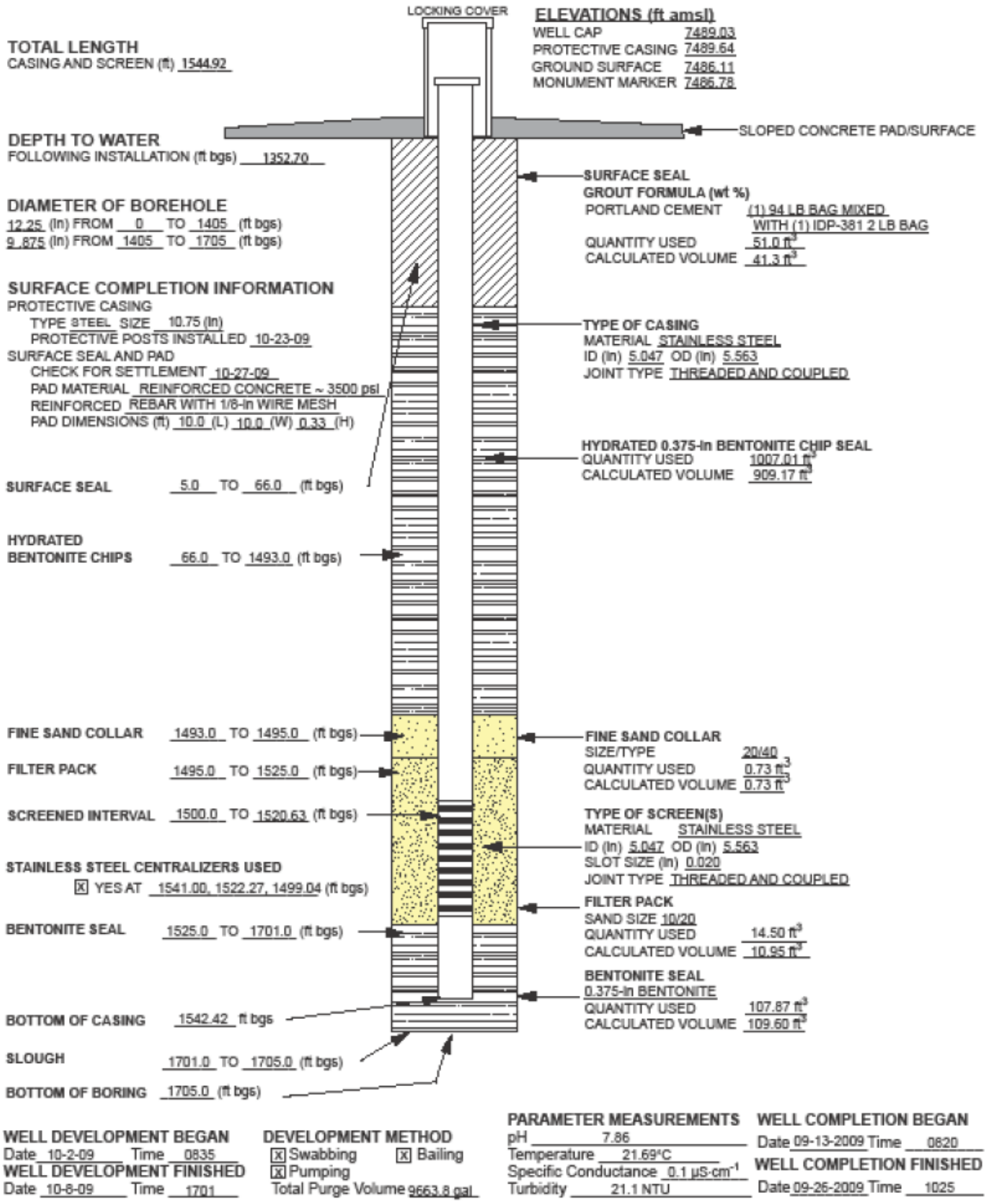


Figure A-20 R-48 well design

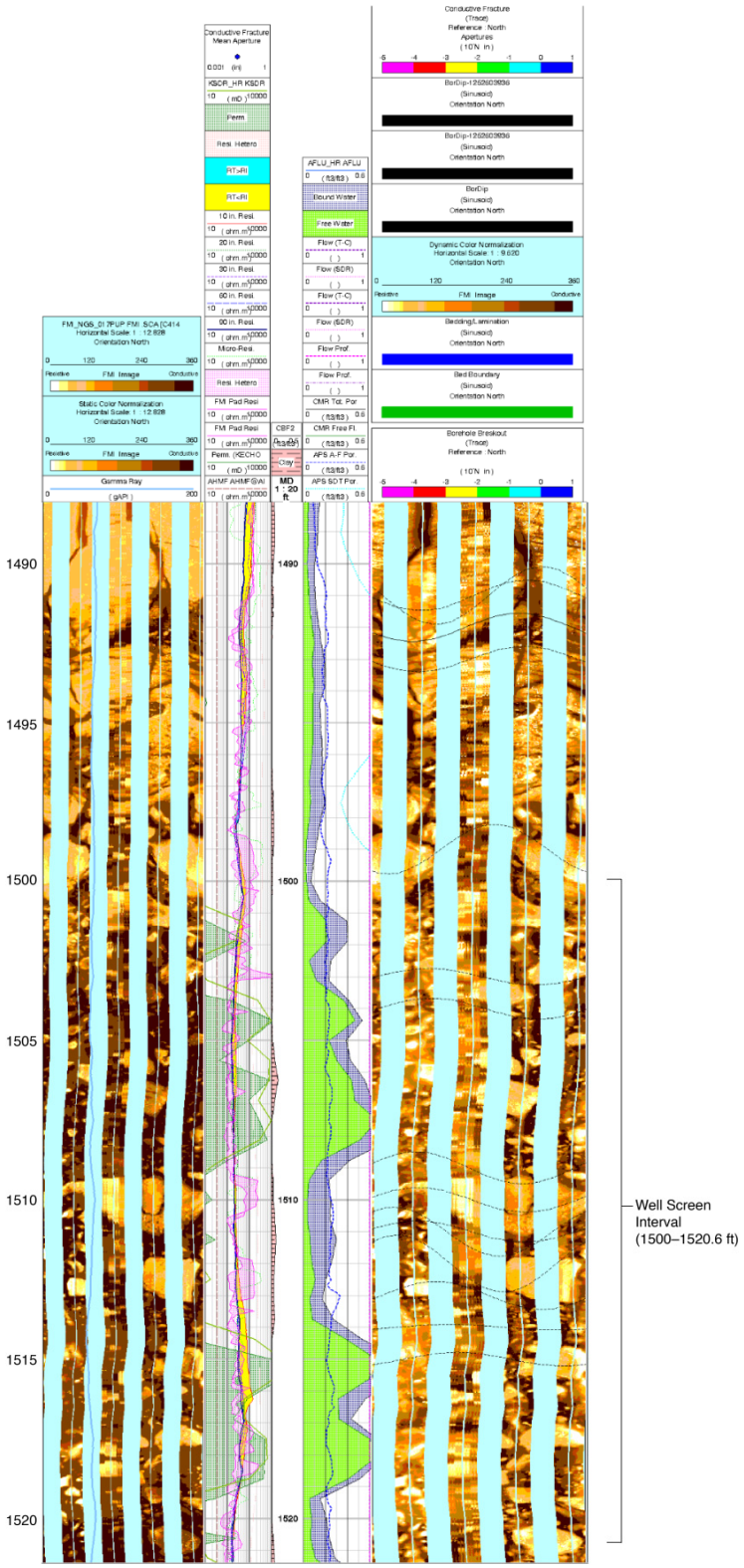


Figure A-21 Well R-48 FMI log showing lithology, electrical resistivity, and porosity for the well screen

REGIONAL AQUIFER WELL R-63

Summary of Well Screen Information, R-63

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	1325.0–1345.3	20.3	Puye Formation	10/20 sand 1318.5–1352.5	Upper part of the regional zone of saturation	Top of screen is submerged 62.9 ft below the water table

R-63 Drilling and Well Construction

	Description	Evaluation
Drilling Method	R-63 was drilled using open-hole fluid-assisted air-rotary drilling methods with casing advance. Drilling fluid consisted of municipal water mixed with QUIK-FOAM. Drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.	Geologic conditions encountered during drilling are summarized in Figure A-22 and in the well completion report (LANL 2011, 204541). The R-63 borehole was drilled using a Schramm, Inc., T130XD Rotadrill dual-rotary drilling rig with casing rotator. The dual-rotary system allows for advancement of casing with the casing rotator while drilling with conventional air/mist/foam methods with the drill string. The Schramm T130XD drill rig was equipped with conventional 5.5-in.-O.D. dual-wall drill pipe, tricone bits, downhole hammer bits, and general drilling equipment. Casing sizes used in drilling activities included 24, 18, and 12 in. The dual-rotary and standard rotary (open hole) techniques used filtered, compressed air and fluid-assisted air to evacuate cuttings from the borehole. Conductor casing 24-in. in diameter was advanced to 57.7 ft depth and set into competent Bandelier Tuff. An additional 18-in. casing was set to 59.4 ft below ground surface(bgs), and the annulus between the two casings was sealed with hydrated bentonite chips. An 17-in. open borehole was drilled to 867.5 ft bgs where hole instability and sloughing between 855 to 860 ft bgs resulted in setting 12-in. casing to 864.1 ft. Dual-rotary casing advance was used to drill a 14.3-in. borehole from 867.5 to 1074.7 ft bgs and the 12-in. casing was set to 1145 ft bgs. Open-hole drilling proceeded from 1145 ft to the TD of 1423.8 ft bgs using an 11.6-in. drill bit. The use of foam as a drilling additive was discontinued at 1212 ft bgs, approximately 41 ft above the regional aquifer. Ordinarily the use of foam is discontinued 100 ft above the regional aquifer, but the water table was approximately 59 ft higher than predicted by water-levels maps for this area.
General Well Characteristics	R-63 is a single-screen well constructed of 5.047-in.-I.D./ 5.563-in.-O.D. passivated type A304 stainless-steel well casing.	The well design is shown in Figure A-23. The stainless-steel materials used at R-63 are chemically inert.

	Description	Evaluation
Well Screen Construction	Well R-63 was constructed with stainless-steel rod-based wire-wrapped screens with 0.020-in. slots.	Wire-wrapped screen with 0.020-in. slots is considered the optimum design for promoting the free flow of water during well development and sampling.
Screen Length and Placement	The R-63 well screen extends from 1325.0 to 1345.3 ft (length 20.3 ft) and targets regional groundwater.	Well R-63 is designed to provide water-quality and water-level data, and the screen length and placement were selected to achieve the following goals: • Characterize water quality of regional groundwater downgradient of HE sources in the vicinity of TA-16, particularly the 260 Outfall • Monitor water levels to investigate the direction of groundwater flow and hydraulic gradients within the regional aquifer • Provide information supporting the regional groundwater monitoring network for the 260 Outfall corrective measures evaluation The well screen is placed in the upper part of the regional groundwater system to monitor groundwater downgradient of potential HE release sites. The main goal for this screen is to determine if Laboratory contamination occurs in the upper part of regional groundwater. The screen is located within the Pliocene Puye Formation sedimentary deposits that include stacked beds of boulders, cobbles, and sandy gravels (Figure A-24). Total porosities within the screen interval range between 15% and 40%. The electrical resistivity image (FMI log) shows that these deposits are thick bedded and generally very coarse grained. Except for a few thin intercalated beds, the electrical resistivity of the deposits in the screen interval is high (>100 ohm-m), indicating they contain little to no silt or clay (Figure A-24). The top of the well screen is 62.9 ft below the piezometric surface. Ordinarily well screens targeting the uppermost part of the regional aquifer are placed 20 to 30 ft below the piezometric surface, particularly when, like well R-63, they are located proximal to expected infiltration zones. Shallow well screens are better suited to detect contaminants entering the regional aquifer before significant dilution takes place. The well screen at R-63 was placed deeper than normal because there was uncertainty about the depth of the regional piezometric surface before well construction. Water levels in the borehole were consistently measured at 1263 ft bgs over a period several days, but these measurements were taken while perched groundwater cascaded into the borehole from above and were believed to represent composite readings. Additionally, the top of the regional zone of saturation was predicted to occur between depths of about 1305 to 1322 ft based on water table maps of the area. Thus, the measured water level of 1263 ft was about 42 to 59 ft higher than predicted. Based on geophysical logs and drillers' observations of water production, the regional water

	Description	Evaluation
		table was believed to occur at a depth of approximately 1305 ft. The well design was based on a 1305-ft water level. Although the well screen at R-63 is deeper than optimum, dispersion should allow contaminants to be detected downgradient from infiltration entry points, though perhaps at somewhat diluted concentrations.
Filter Pack Materials and Placement	The filter pack and its placement for the well screen are discussed in the column to the right.	The primary filter pack is made up of 10/20 sand from 1318.5 to 1352.5 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 1316.3 to 1318.5 ft. The primary filter pack extends 6.5 ft above and 7.2 ft below the well screen. The length and placement of the filter pack relative to the well screen meet the design goals for this well.
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and, to some degree, near-well formation materials. Water can pumped at relatively highly rates, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison with low-flow systems, and the likelihood of obtaining water from zones beyond potential near-well drilling effects is greater. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a
Additives Used during Drilling		Air Municipal water QUIK-FOAM
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal. A cement grout surface seal was placed from 2 to 69.6 ft.

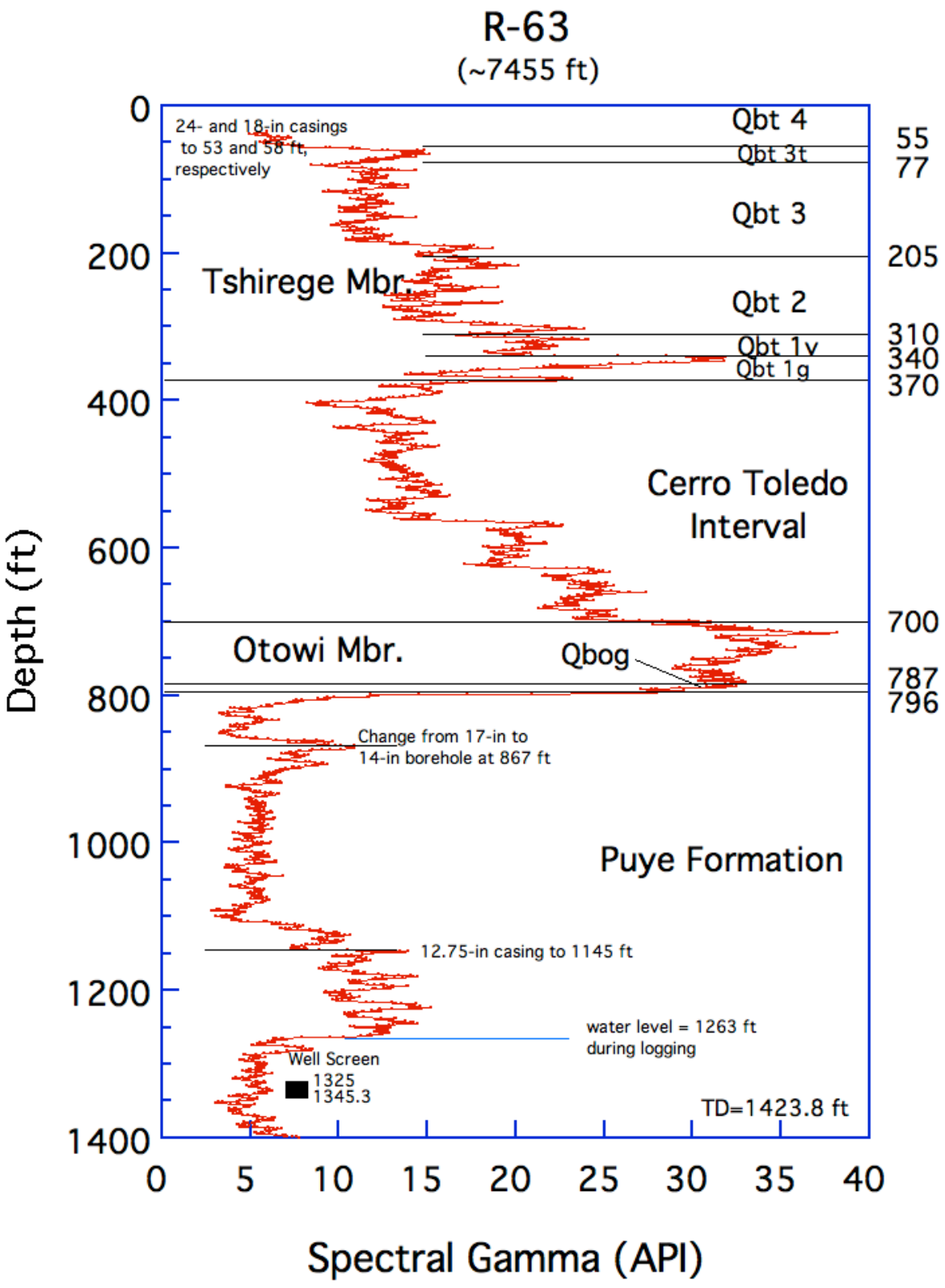


Figure A-22 Well R-63 geology and borehole gamma log

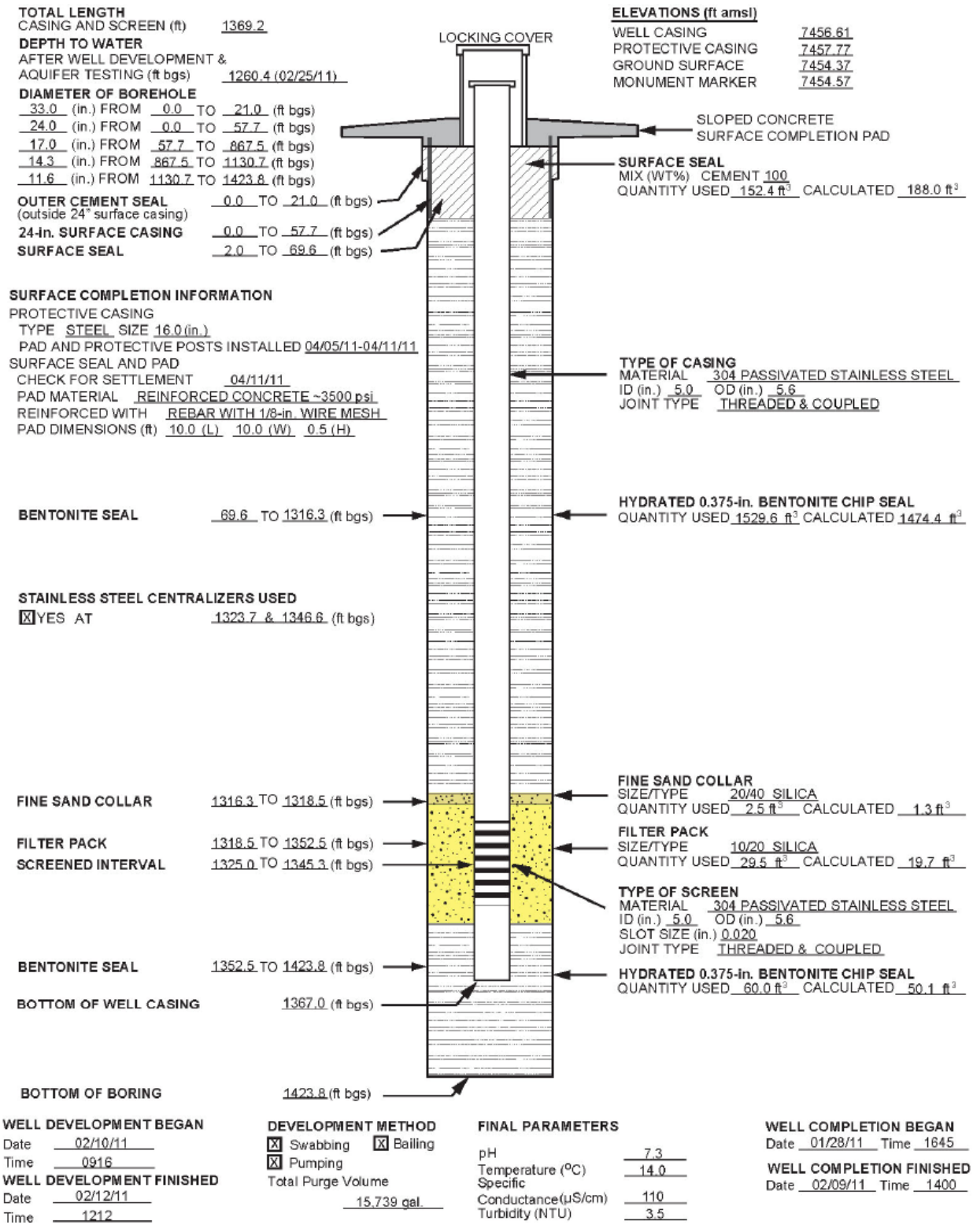


Figure A-23 R-63 well design

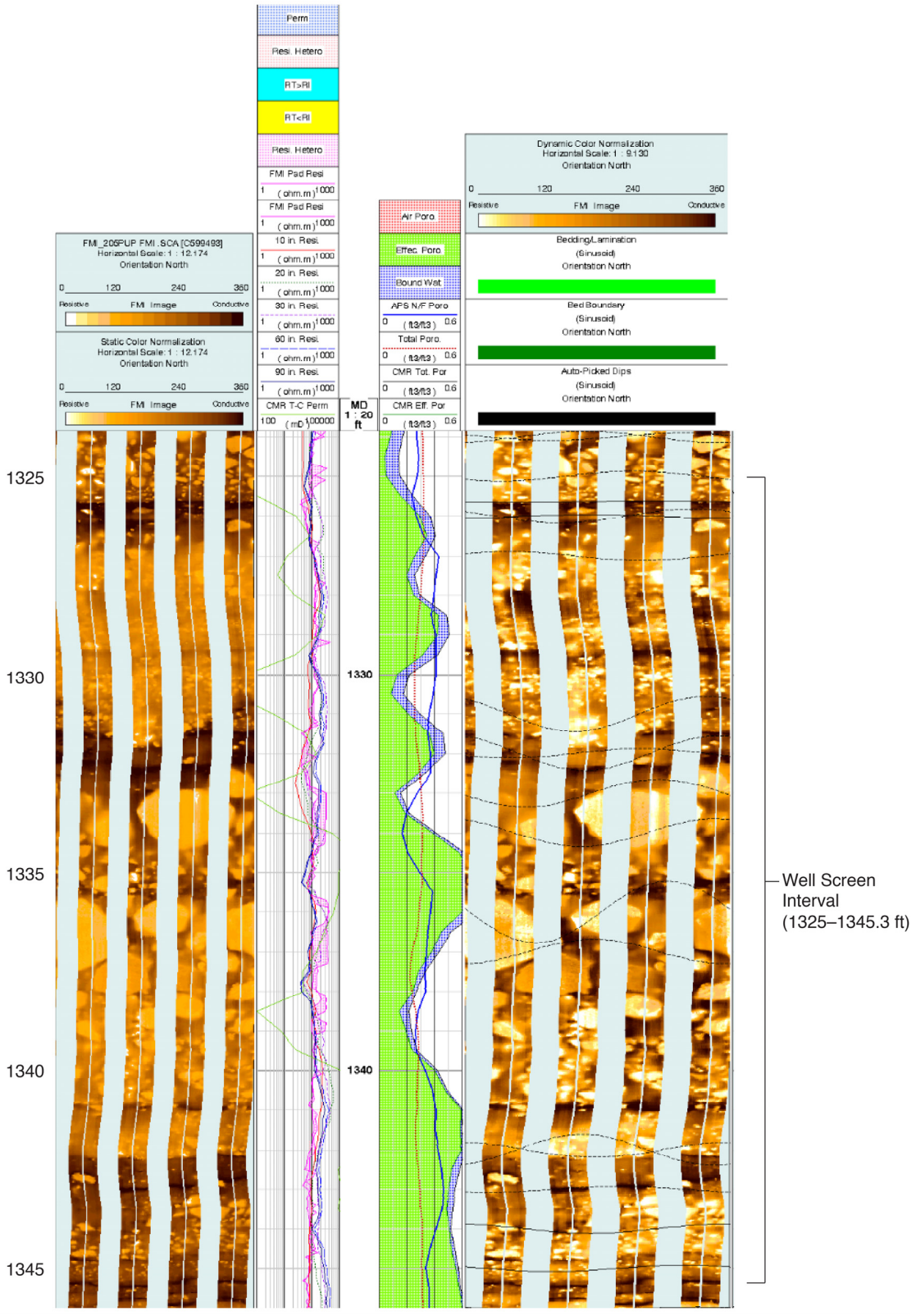


Figure A-24 Well R-63 FMI log showing lithology, electrical resistivity, and porosity for the well screen

PERCHED-INTERMEDIATE WELL 16-26644

Summary of Well Screen Information, Well 16-26644

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	130.0–145.0	15.0	Tshirege Member, Bandelier Tuff (subunit Qbt 3)	10/20 sand 127–147	Perched water in the upper vadose zone	Top of screen is submerged 4 to 11 ft below the perched water level

16-266644 Drilling and Well Construction

	Description	Evaluation
Drilling Method	Well 16-26644 was drilled using HSA dry coring and air-rotary wire-line coring methods. No drilling fluids were used.	Well 16-26644 is located on the mesa top near the 90s Line Pond (LANL 2008, 102052.18). It was drilled using a CME-85 HSA dry coring-drill rig, with 4.25-in.-I.D. augers equipped with a split-barrel sampler. The sample barrel was connected to a cable on a hexagonal rod that extends through the augers. The split-sample barrels were 5 ft in length and provided continuous 3-in.-O.D. cores. When the HSA met refusal in densely welded Bandelier Tuff, the CME-85 was converted to a 94-mm air-rotary wire-line coring system. The air-coring system also produced continuous 5-ft core samples. During drilling, a saturated interval was identified from 140 to 145 ft bgs. The 16-26644 borehole was drilled to 150 ft bgs. After the drill string was pulled from the hole, standing water was measured at 138 ft bgs. The well has consistently contained water when checked. Several nearby boreholes and wells drilled to similar depth are dry.
General Well Characteristics	16-26644 is a single-screen well constructed of 2-in.-I.D. threaded schedule 40 polyvinyl chloride (PVC).	The well design is shown in Figure A-25.
Well Screen Construction	Well 16-26644 was constructed with preslotted, flush-joint PVC screen with a slot width of 0.010 in.	The PVC screen has 0.010-in. slots. Wells installed with 0.020-in. slots are considered optimal because the larger slot size facilitates the movement of water through the well screen when the well is surged and pumped during development. The ability of 0.010-in.-slot well screen to develop properly must be judged on the quality of groundwater data collected from the wells.
Screen Length and Placement	The 16-26644 well screen extends from 130.0 to 145.0 ft (length 15 ft) and targets perched-intermediate groundwater.	Well 16-26644 is designed to monitor the potential infiltration of HE-contaminated surface water from the 90s Line Pond groundwater. The main goal for this screen is to investigate the possibility that the 90s Line Pond was contributing to HE contamination in shallow perched groundwater. The well screen is located within the Quaternary Tshirege Member of the Bandelier Tuff. The saturated zone occurs in densely welded, fractured (clay-filled) ash-flow tuff of Tshirege subunit Qbt 3. The water level in well 16-26644 varies seasonally, and the top of the well screen is generally submerged 4 to 11 ft below the perched water level. The well-screen length and placement meet monitoring goals for the well.

	Description	Evaluation
Filter Pack Materials and Placement	The filter pack and its placement for the well screen are discussed in the column to the right.	The primary filter pack is made up of 10/20 sand from 127 to 147 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 123 to 125 ft. The primary filter pack extends 3 ft above and 2 ft below the well screen. The length and placement of the filter pack relative to the well screen meet the design goals for this well.
Sampling System	Dedicated Bennett pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and, to some degree, near-well formation materials. Water can pumped at relatively highly rates, greatly facilitating effective purging and efficient sampling.
Other Issues That Could Affect the Performance of the Well	None	n/a
Additives Used during Drilling		None
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal above the filter pack.

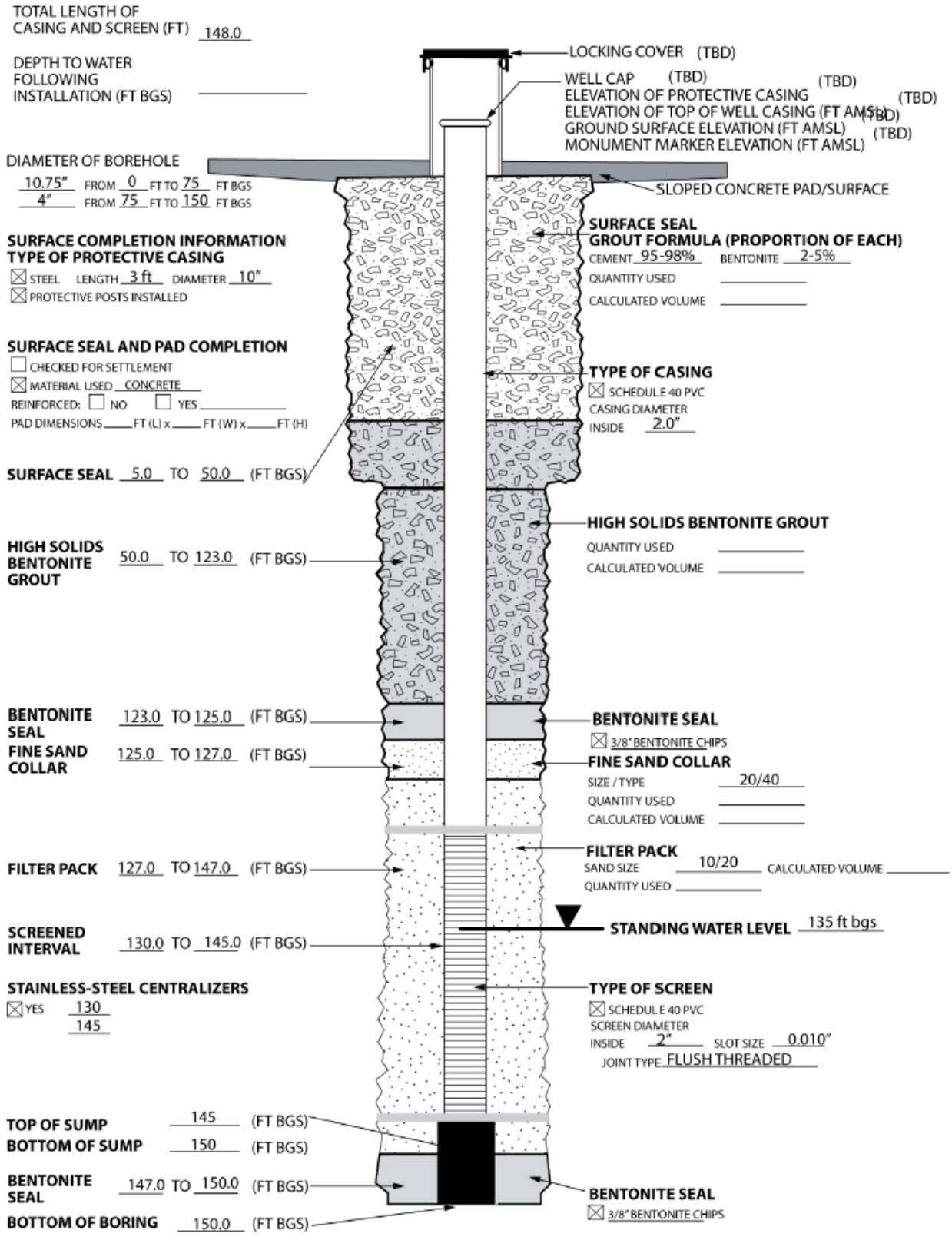


Figure A-25 16-26644 well design

PERCHED-INTERMEDIATE WELL CDV-16-1(i)

Summary of Well Screen Information, CdV-16-1(i)

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	624.0–634.0	10.0	Otowi Member, Bandelier Tuff	10/20 sand 613–644	Perched water in the lower vadose zone	Top of screen is submerged 46 to 55 ft below the perched water level

CdV-16-1(i) Drilling and Well Construction

	Description	Evaluation
Drilling Method	CdV-16-1(i) was drilled using HSA and fluid-assisted air-rotary drilling methods. Drilling fluid consisted of municipal water mixed with QUIK-FOAM and EZ-MUD. Drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.	Drilling at CdV-16-1(i) took place in two phases as described in the well completion report (Kleinfelder 2004, 087844). During Phase I, a core hole was drilled to a depth of 200 ft by HSA and air-rotary coring methods to collect tuff samples for contaminant analysis. After coring was completed, a temporary piezometer was installed in the open core hole to monitor a potential zone of perched water indicated by wet core samples collected between 50 and 75 ft bgs during Phase I drilling. The water level in the piezometer was near the bottom of the well screen. Water levels declined from 0.9 ft to 0.2 ft above the bottom of the well screen over a period of several months after the piezometer was installed. A well diagram for the temporary piezometer is shown in Figure A-26. During Phase 2, a new borehole was drilled about 15 ft northeast of the core hole to install a monitoring well in deep-perched groundwater. During Phase 2 drilling, a 12.25-in. button-tooth tricone bit was used to advance an open borehole to 14.5 ft and 13.375-in. drill casing was advance to a depth of 12 ft before it met refusal. The remainder of the borehole was drilled by open-hole fluid-assisted air-rotary methods to a depth of 683 ft TD using a 12.25-in. button-tooth tricone bit.
General Well Characteristics	CdV-16-1(i) is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. type A304 stainless-steel well casing.	The well design for the deep-perched groundwater well is shown in Figure A-27. The stainless-steel materials used at CdV-16-1(i) are chemically inert.
Well Screen Construction	Well CdV-16-1(i) was constructed with stainless-steel rod-based wire-wrapped screens with 0.020-in. slots.	Wire-wrapped screen with 0.020-in. slots is considered the optimum design for promoting the free flow of water during well development and sampling.

	Description	Evaluation
Screen Length and Placement	The CdV-16-1(i) well screen extends from 624 to 634 ft (length 10 ft) and targets perched groundwater.	Well CdV-16-1(i) is designed to provide water-quality and water-level data, and the screen length and placement were selected to achieve the following goals: • Characterize water quality of deep-perched groundwater beneath Cañon de Valle downgradient of the major HE source at the 260 outfall • Monitor water levels to investigate seasonal recharge through the canyon bottom and to determine direction of groundwater flow and hydraulic gradients within the perched groundwater zone • Provide information supporting the groundwater monitoring network for the 260 Outfall corrective measures evaluation The well screen is designed to monitor the upper part of a thick perched groundwater zone downgradient of potential HE release sites. The main goal for this screen is to determine the nature and extent of HE contamination in deep-perched groundwater affected by infiltration of contaminated surface water and alluvial groundwater in Cañon de Valle. The screen is located within the Quaternary Otowi Member of the Bandelier Tuff. The well screen is located within poorly welded ash-flow tuff that is cut by a nearly vertical fracture that dips to the northwest (Figure A-28). The screen interval has a total porosity of about 40% and an effective porosity between 10% and 18%. The electrical resistivity image (FMI log) shows that these tuffs are generally thick bedded and massive although there is faint bedding in the well-screen interval. The electrical resistivity of the deposits in the screen interval is high (>300 ohm-m), indicating they contain little to no silt or clay (Figure A-28). However, the fracture is electrically conductive and may be clay filled or clay lined. The top of the well screen is submerged 46 to 55 ft below the water level of the perched zone. This places the well screen in the upper part of this perched groundwater zone. The well screen length and placement meet monitoring goals for the well.
Filter Pack Materials and Placement	The filter pack and its placement for the well screen are discussed in the column to the right.	The primary filter pack is made up of 10/20 sand from 614 to 644 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 611 to 613 ft. The primary filter pack extends 11 ft above and 10 ft below the well screen. The length and placement of the filter pack relative to the well screen meet the design goals for this well.
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and, to some degree, near-well formation materials. Water can pumped at relatively highly rates, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison with low-flow systems, and the likelihood of obtaining water from zones beyond potential near-well drilling effects is greater. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a

	Description	Evaluation
Additives Used during Drilling		Air Municipal water QUIK-FOAM EZ-MUD KBr (added to the drilling fluid as a tracer to detect possible zones of groundwater influx)
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal above the filter pack. A cement grout surface seal was placed from 0 to 70 ft.

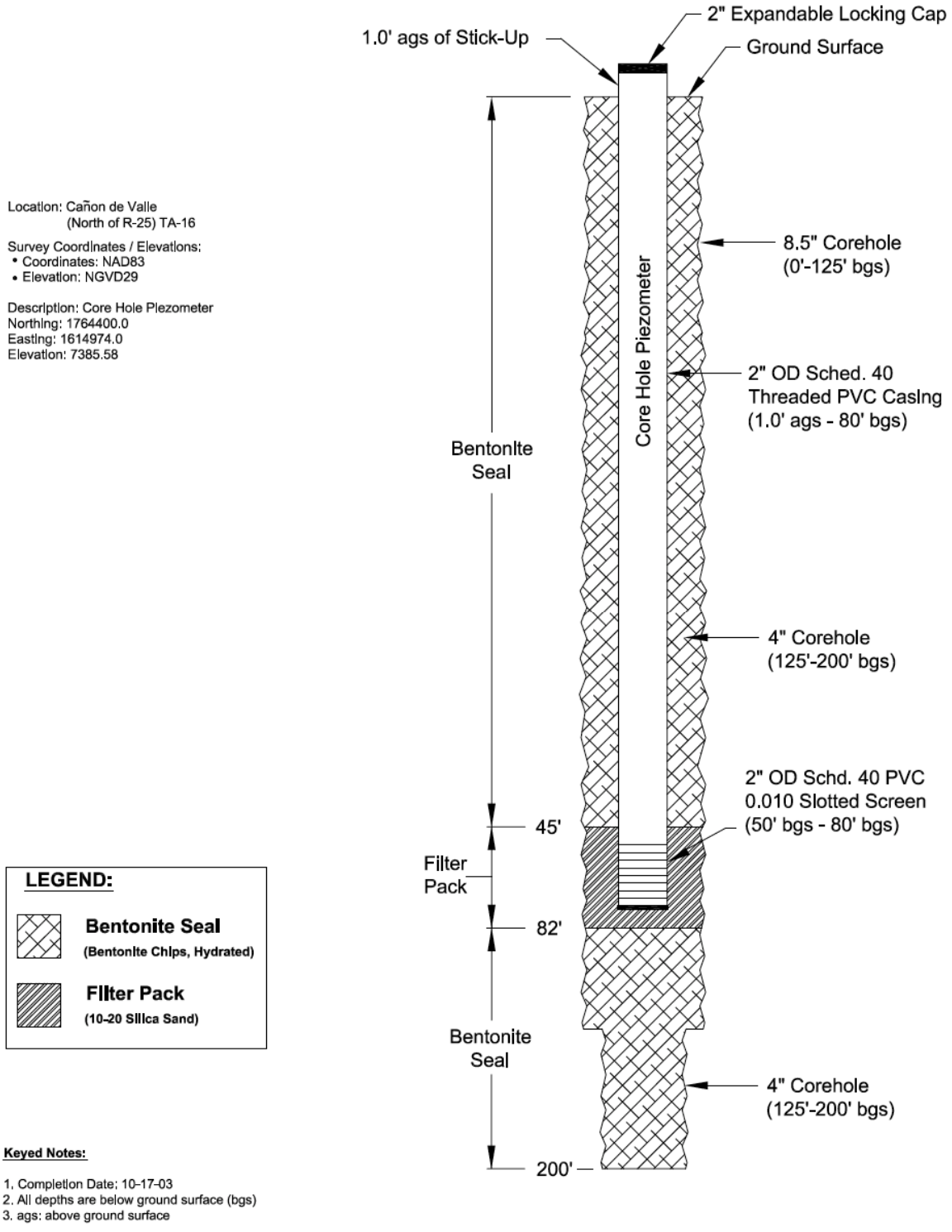


Figure A-26 Design of temporary piezometer at CdV-16-1(i)

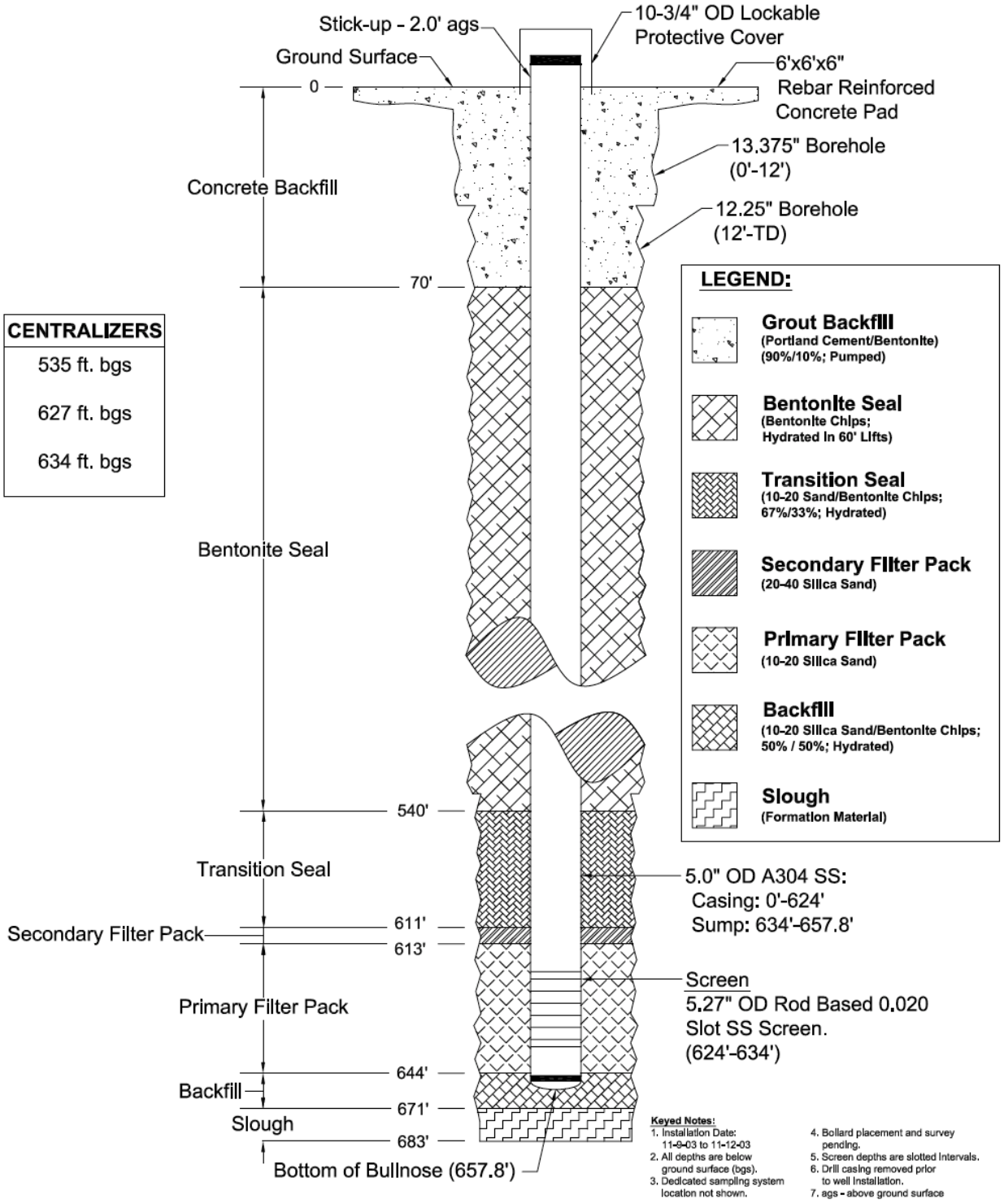


Figure A-27 CdV-16-1(i) well design

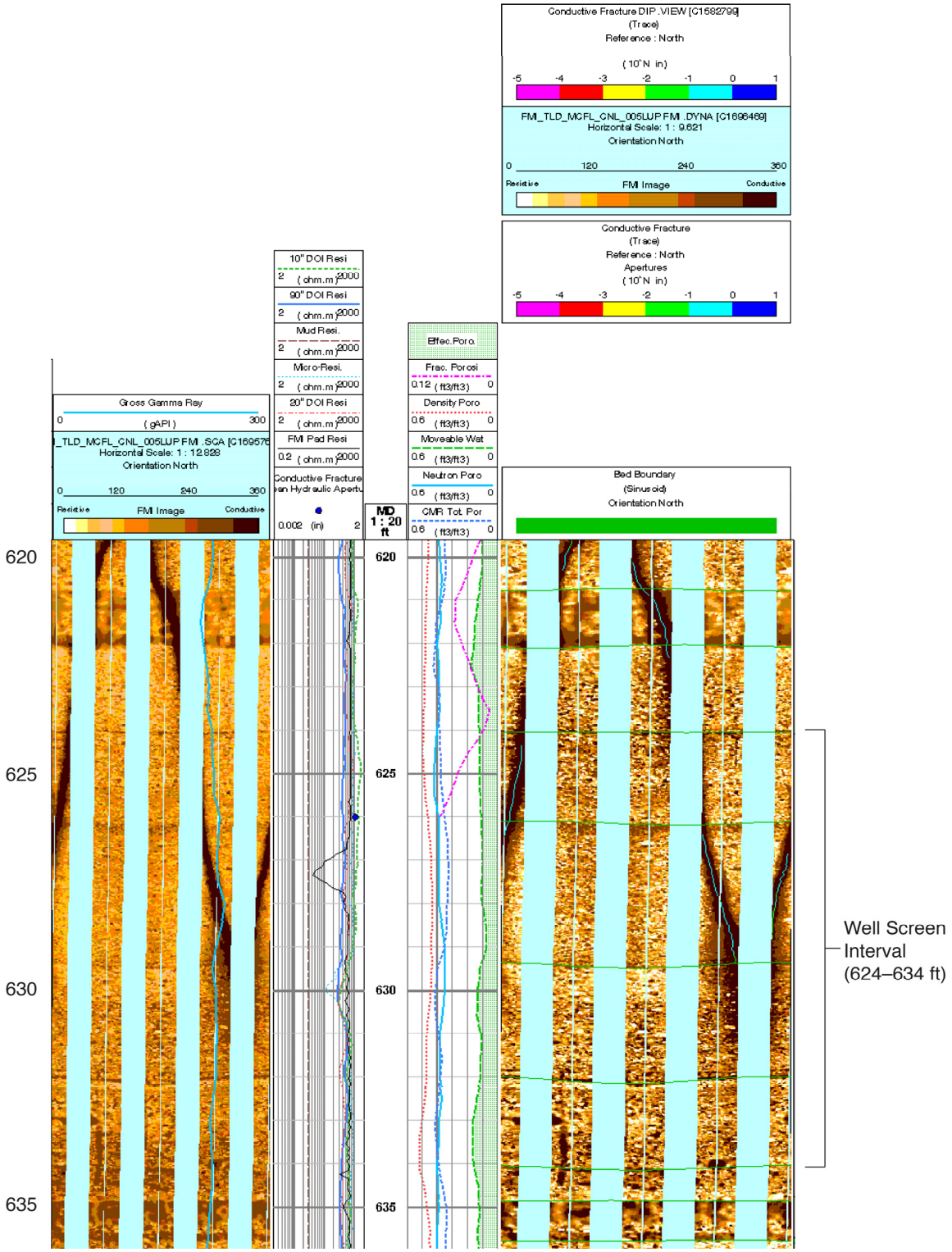


Figure A-28 Well CdV-16-1(i) FMI log showing lithology, electrical resistivity, and porosity for the well screen

PERCHED-INTERMEDIATE WELL CdV-16-2(i)r

Summary of Well Screen Information, CdV-16-2(i)r

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	850.0–859.7	9.7	Puye Formation	10/20 sand 841–865.5	Perched water in the lower vadose zone	Top of screen is submerged 12.8 ft below the perched water level

CdV-16-2(i)r Drilling and Well Construction

	Description	Evaluation
Drilling Method	CdV-16-2(i)r was drilled using open-hole fluid-assisted air-rotary drilling methods. Drilling fluid consisted of municipal water mixed with QUIK-FOAM/VersaFoam and EZ-MUD. Drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.	Geologic conditions encountered during drilling are summarized in Figure A-29 and in the well completion report (Kleinfelder 2005, 093665). The CdV-16-2(i)r borehole was drilled using a Speedstar 50K drill rig. The rig was equipped with conventional drilling rods, tricone bits, down-the-hole hammer bits, air compressors, and support equipment. CdV-16-2(i)r was drilled using air-rotary and fluid-assisted air-rotary drilling techniques. Drilling fluids were used, as needed, to improve borehole stability, to minimize fluid loss, and to facilitate cuttings removal from the borehole. Drilling fluids consisted of a mixture of municipal water with QUIK-FOAM/ VersaFoam surfactant and EZMUD polymer. The borehole was advanced to 10 ft depth using a 12.25-in. tricone bit and temporary 13.378-in. drill casing was driven to 9.6 ft bgs. An open borehole was drilled to the total depth of 872 ft using a 12.25-in. tricone bit.
General Well Characteristics	CdV-16-2(i)r is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. type A304 stainless-steel well casing.	The well design is shown in Figure A-30. The stainless-steel materials used at CdV-16-2(i)r are chemically inert.
Well Screen Construction	Well CdV-16-2(i)r was constructed with stainless-steel rod-based wire-wrapped screens with 0.020-in. slots.	Wire-wrapped screen with 0.020-in. slots is considered the optimum design for promoting the free flow of water during well development and sampling.
Screen Length and Placement	The CdV-16-2(i)r well screen extends from 850 to 859.7 ft (length 9.7 ft) and targets perched groundwater.	Well CdV-16-2(i)r replaces well CdV-16-2(i), located 72 ft to the northeast, that targeted the same groundwater zone but was dry after installation. The primary filter pack at well CdV-16-2i probably breached the confining layer, and the well was plugged and abandoned. Well CdV-16-2(i)r is designed to provide water-quality and water-level data, and the screen length and placement were selected to achieve the following goals: • Characterize water quality of deep-perched groundwater beneath Cañon de Valle downgradient of the major HE source at the 260 Outfall

	Description	Evaluation
		• Monitor water levels to investigate seasonal recharge through the canyon bottom and to determine the direction of groundwater flow and hydraulic gradients within the perched groundwater zone • Provide information supporting the groundwater monitoring network for the Consolidated Unit 16-021(c)-99 260 Outfall corrective measures evaluation The well screen is designed to monitor the upper part of a deep-perched groundwater zone downgradient of potential HE release sites at TA-16. The main goal for this screen is to determine the nature and extent of HE contamination in deep-perched groundwater affected by infiltration of contaminated surface water and alluvial groundwater in Cañon de Valle. The screen is located within the Pliocene Puye Formation sedimentary deposits that include stacked beds of boulders, cobbles, and sandy gravels. Epithermal neutron porosities within the screen interval range between 10% and 15%, but these values are probably too low because the zone was drained before logging (Figure A-31). The density porosity for the screen interval ranges between 20% and 35%. The top of the well screen is submerged about 12.8 ft below the water level of the perched zone. The well-screen length and placement meet monitoring goals for the well.
Filter Pack Materials and Placement	The filter pack and its placement for the well screen are discussed in the column to the right.	The primary filter pack is made up of 10/20 sand from 841 to 865.5 ft. Secondary filter packs of 20/40 sand were placed above and below the primary filter pack from 839 to 841 ft and 865.5 to 867.5 ft, respectively. The primary filter pack extends 9 ft above and 5.8 ft below the well screen. The length and placement of the filter pack relative to the well screen meet the design goals for this well.
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and, to some degree, near-well formation materials. Water can pumped at relatively highly rates, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison with low-flow systems, and the likelihood of obtaining water from zones beyond potential near-well drilling effects is greater. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a

	Description	Evaluation
Additives Used during Drilling		Air Municipal water QUIK-FOAM/VersaFoam EZ-MUD Defoaming Agent
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal. A cement grout surface seal was placed from 12 to 75 ft.

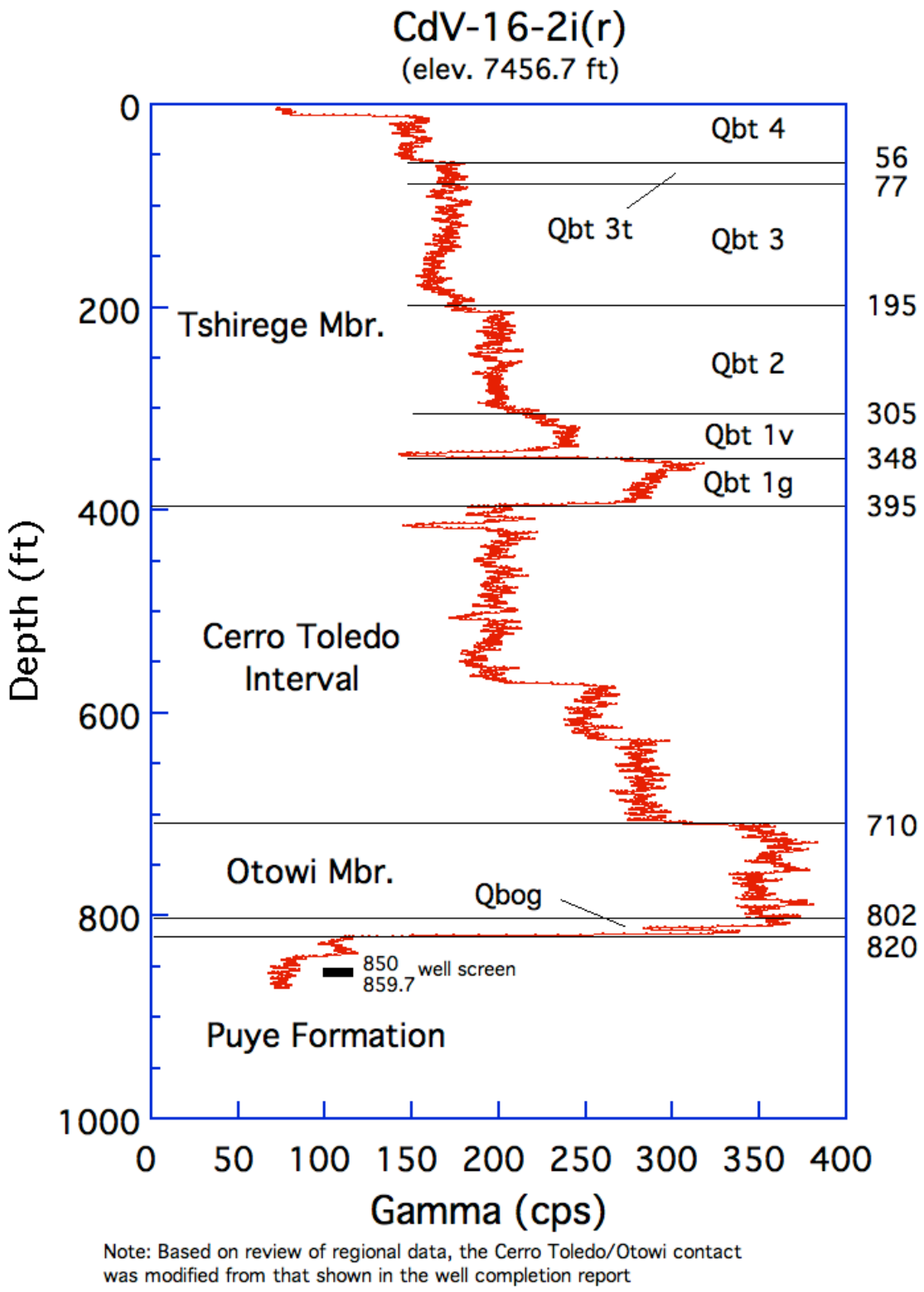


Figure A-29 Well CdV-16-2(i)r geology and borehole gamma log

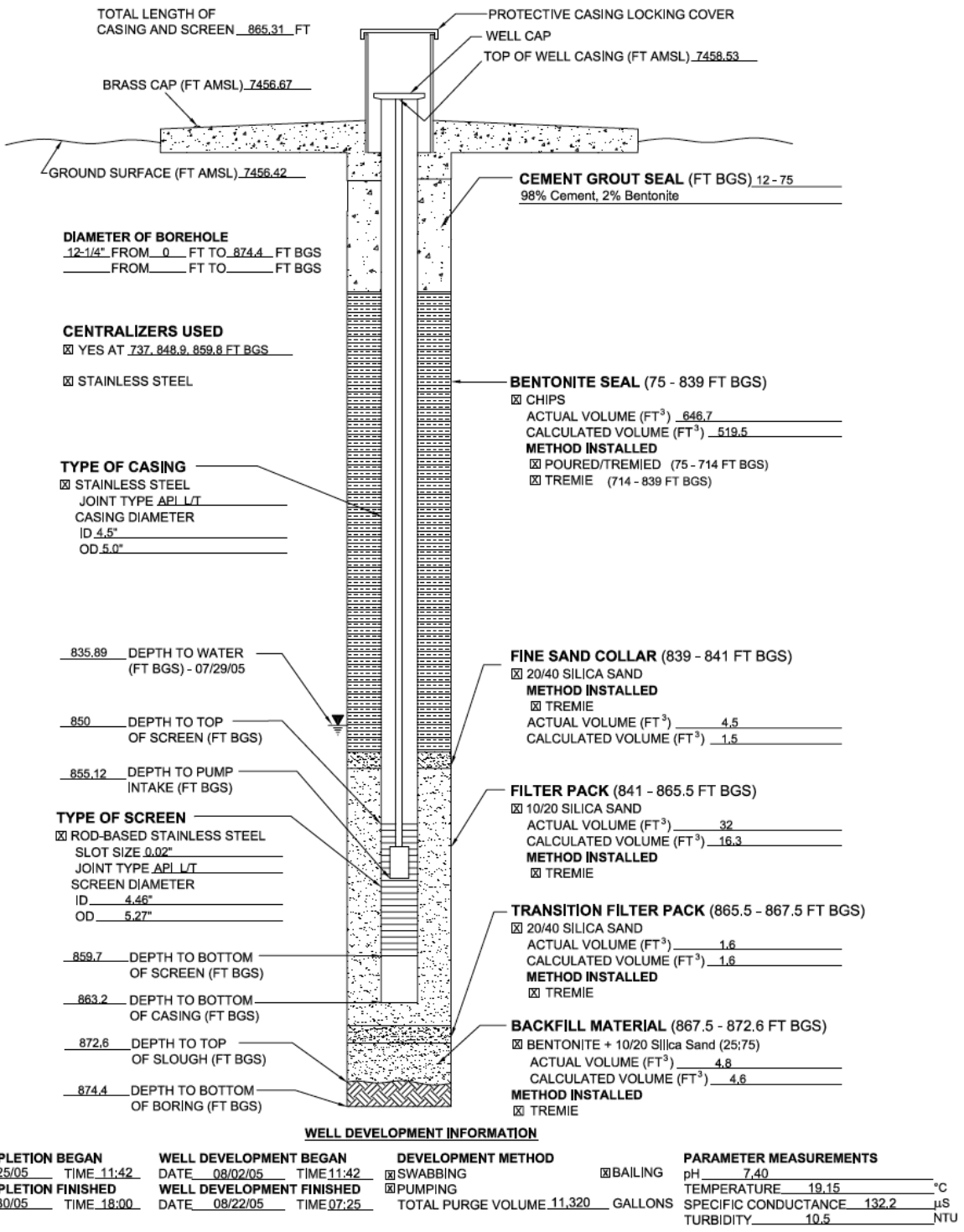
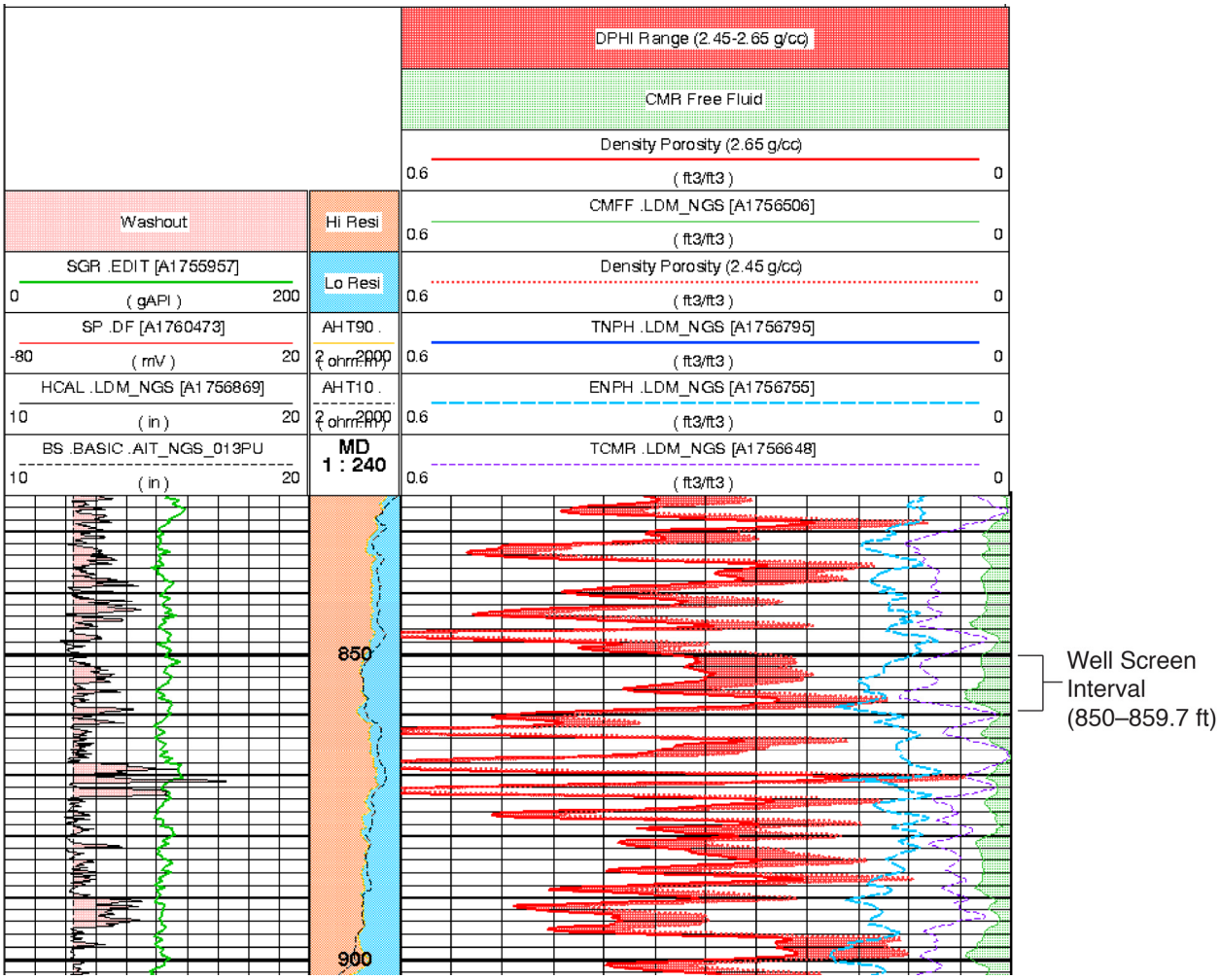


Figure A-30 CdV-16-2(i)r well design



Note: Borehole CdV-16-2(i) is located 72 ft northeast of well CdV-16-2(i)r.

Figure A-31 Borehole CdV-16-2(i) geophysical logs showing gamma, electrical resistivity, and porosity for the well screen

PERCHED-INTERMEDIATE WELL CDV-16-4ip

Summary of Well Screen Information, CdV-16-4ip

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	815.6–879.2	63.6	Puye Formation	10/20 sand 809.8–884.9	Upper perched water in the lower vadose zone	Top of screen is submerged 7.4 ft below the perched water level
2	1110–1141.1	31.1	Puye Formation	10/20 sand 1105.3–1145.1	Lower perched water in the lower vadose zone	Top of screen is submerged 21.1 ft below the perched water level

CdV-16-4ip Drilling and Well Construction

	Description	Evaluation
Drilling Method	CdV-16-4ip was drilled using open-hole fluid-assisted air-rotary drilling methods. Drilling fluid consisted of municipal water mixed with AQF-2 foam. Drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.	Geologic conditions encountered during drilling are summarized in Figure A-32 and in the well completion report (LANL 2011, 111608). The CdV-16-4ip borehole was drilled using a Schramm T130XD Rotadrill dual-rotary drilling rig with casing rotator. The rig was equipped with conventional 5.5-in.-O.D. dual-wall drill pipe, tricone bits, down-the-hole hammer bits, air compressors, and support equipment. CdV-16-4ip was drilled using air-rotary and fluid-assisted air-rotary drilling techniques. Drilling fluids were used, as needed, to improve borehole stability, to minimize fluid loss, and to facilitate removing cuttings from the borehole. Drilling fluids consisted of a mixture of municipal water with AQF-2 foam. The AQF-2 foam was used between ground surface and a depth of 603 ft. A 24-in. surface casing was advanced to 60 ft bgs and set into competent rock, after which 18-in. casing was placed to the same depth and the annulus was sealed with bentonite chips between the two casings. A 17-in. open borehole was drilled to a depth of 623 ft, and then 12-in. drill casing was set to 625.2 ft bgs. An 11.625-in. open borehole was drilled from 625.2 to 1153.7 ft TD.
General Well Characteristics	CdV-16-4ip is a two-screen well constructed of 5-in.-I.D./5.6-in.-O.D. passivated type A304 stainless-steel well casing.	The well design is shown in Figure A-33. The stainless-steel materials used at CdV-16-4ip are chemically inert.
Well Screen Construction	Both CdV-16-4ip well screens were constructed with stainless-steel rod-based wire-wrapped screens with 0.020-in. slots.	Wire-wrapped screen with 0.020-in. slots is considered the optimum design for promoting the free flow of water during well development and sampling.

	Description	Evaluation
Screen Length and Placement	CdV-16-4ip well screen 1 extends from 815.6 to 879.2 ft (length 63.6 ft) and targets an upper perched groundwater in the lower vadose zone. CdV-16-4ip well screen 2 extends from 1110 to 1141.1 ft (length 31.1 ft) and targets a lower perched groundwater in the lower vadose zone.	CdV-16-4ip was installed to be a pumping well as part of a hydrologic testing program to evaluate the properties of the deep-perched groundwater zone at the 260 Outfall. The tests were designed to provide field-scale measurements of aquifer parameters for deep-perched groundwater and to assess the potential for pumping and treatment of contaminants in perched groundwater downgradient of the 260 Outfall. Key objectives of the pumping tests included the following: • Acquire field-scale measurements of hydrogeologic properties, such as formation transmissivity and storage coefficient, necessary to evaluate the viability of the pump-and-treat remedial alternative for groundwater remediation • Evaluate lateral and vertical hydraulic connectivity within the perched zone • Provide data regarding concentrations of contaminants in the vicinity of the test well • Potentially evaluate heterogeneity/anisotropy of the flow medium • Evaluate boundary conditions to assess the lateral extent of the deep perched zone potentially providing information about the hydraulic connectivity between the deep perched zone and the regional aquifer. Hydrologic tests are now completed and this report proposes to reconfigure the well to monitor deep-perched groundwater downgradient of potential HE release sites at TA-16. The main goal for converting CdV-16-4ip to a monitoring well is to determine the nature and extent of HE contamination in deep-perched groundwater affected by infiltration of contaminated surface water and alluvial groundwater in Cañon de Valle. Both well screens are located within the Pliocene Puye Formation sedimentary deposits that include stacked beds of boulders, cobbles, and sandy gravels. Screen 1 neutron porosities are <10%, but these values are unrealistically low and probably represent drainage of the zone before logging. Deep water-filled porosity (deep resistivity porosity curve shown in Figure A-34) ranges between 25% and 42% and is probably more representative of the formation. The electrical resistivity of the deposits in the screen interval is high (>100 ohm-m) indicating they contain little to no silt or clay (Figure A-34). Screen 2 total porosity ranges between 5% and 40%. CMR effective porosity ranges between 15% and 40% in this interval. The FMI image shows that screen 2 deposits are characterized by 3- to 5-ft-thick beds of boulders, cobbles, and gravels separated by <1-ft-thick silt-rich beds (Figure A-35). The electrical resistivity in the screen interval is generally high (>100 ohm-m) in the thick coarse-grained deposits, indicating they contain little to no silt or clay (Figure A-35). The thin silt-rich horizons have lower electrical resistivity, indicating their higher content of silt and/or clay. The 63.6-ft length of screen 1 is longer than that typically used to monitor perched groundwater on the Pajarito Plateau. The long well screen will provide an integrated water sample through the upper part of the upper perched zone but may not provide discrete sampling of the highest contaminant concentrations that might occur

	Description	Evaluation
		in the uppermost part of the perched groundwater system. Nonetheless, screen 1 will be useful in assessing contaminant distributions and temporal trends in the upper deep-perched groundwater zone, and it meets the monitoring goals for the well. The length and placement of well screen 2 are appropriate for assessing contaminant distributions and temporal trends in the lower deep-perched groundwater zone and meet monitoring goals for the well.
Filter Pack Materials and Placement	The filter packs and their placement for the two well screens are discussed in the column to the right.	The screen 1 primary filter pack is made up of 10/20 sand from 809.8 to 884.9 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 805.7 to 809.8 ft. The primary filter pack extends 5.8 ft above and 5.7 ft below the well screen. The screen 2 primary filter pack is made up of 10/20 sand from 1105.3 to 1145.1 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 1098.3 to 1105.3 ft. The primary filter pack extends 4.7 ft above and 4 ft below the well screen. The length and placement of the filter packs relative to both well screens meet the design goals for this well.
Sampling System	A sampling system has not yet been installed in well CdV-16-4ip. A temporary packer is set between screens 1 and 2.	n/a
Other Issues That Could Affect the Performance of the Well	None	n/a
Additives Used during Drilling		Air Municipal water AQF-2 foam
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal. A cement grout surface seal was placed from 3 to 59.3 ft.

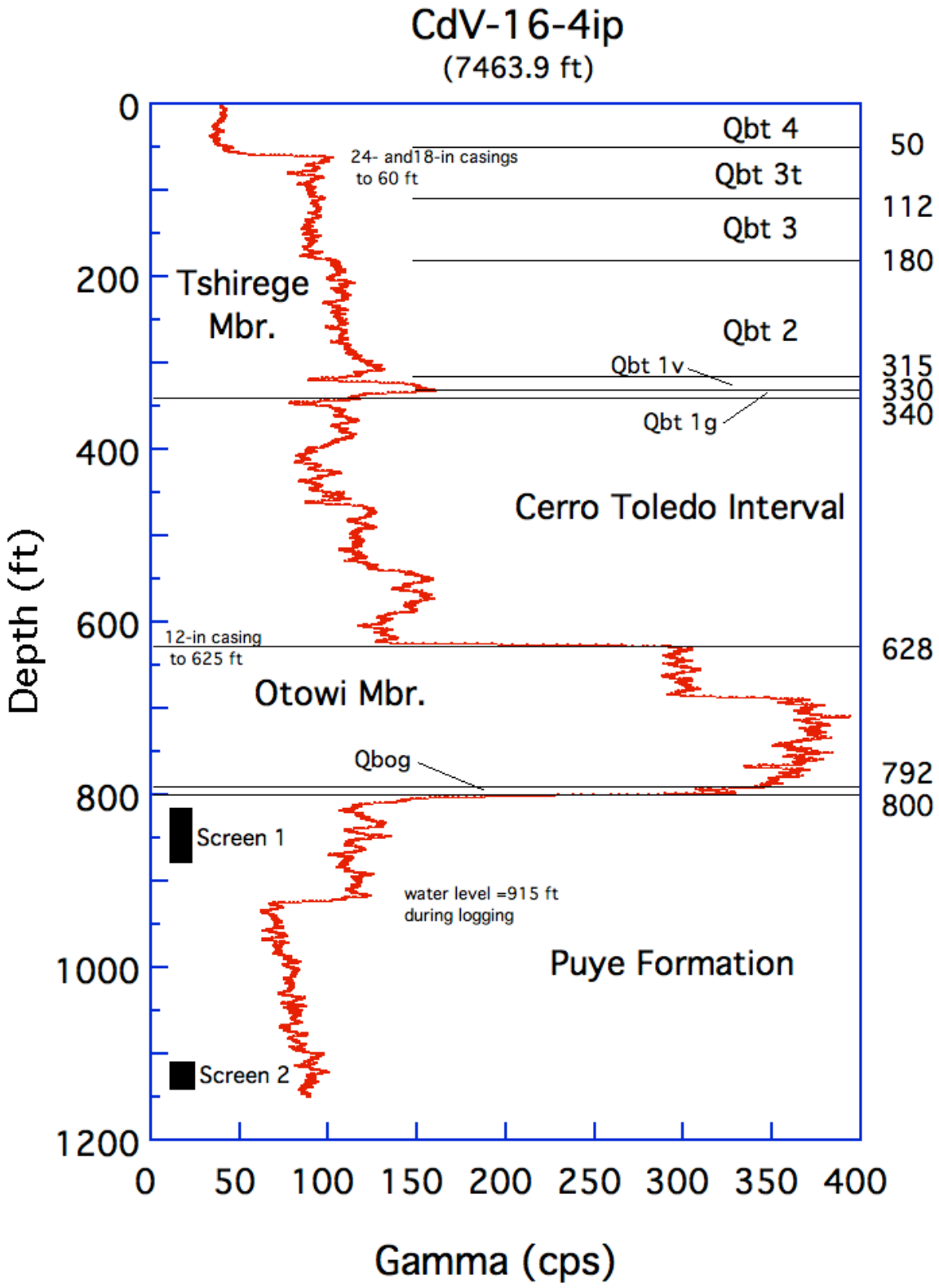


Figure A-32 Well CdV-16-4ip geology and borehole gamma log

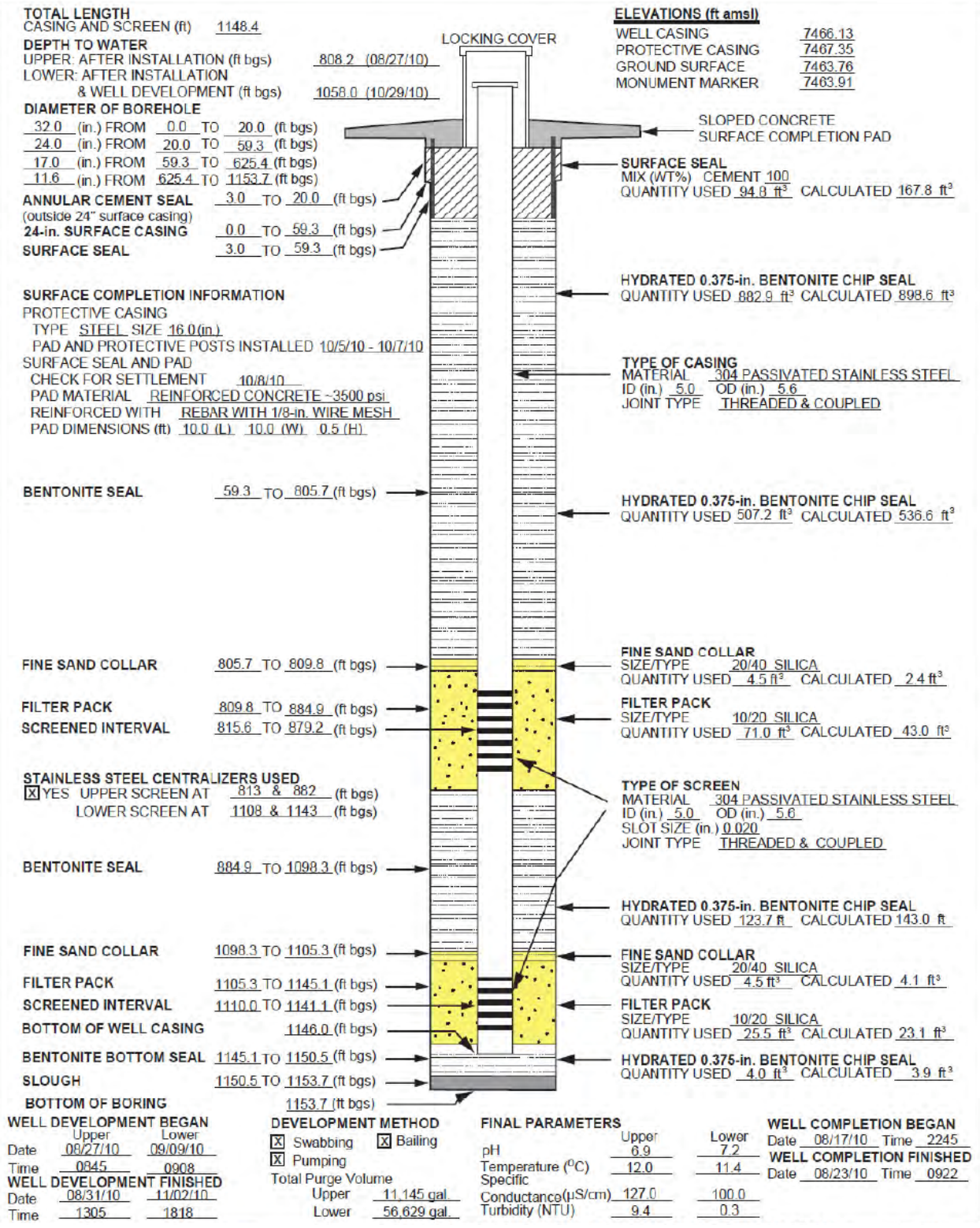


Figure A-33 CdV-16-4ip well design

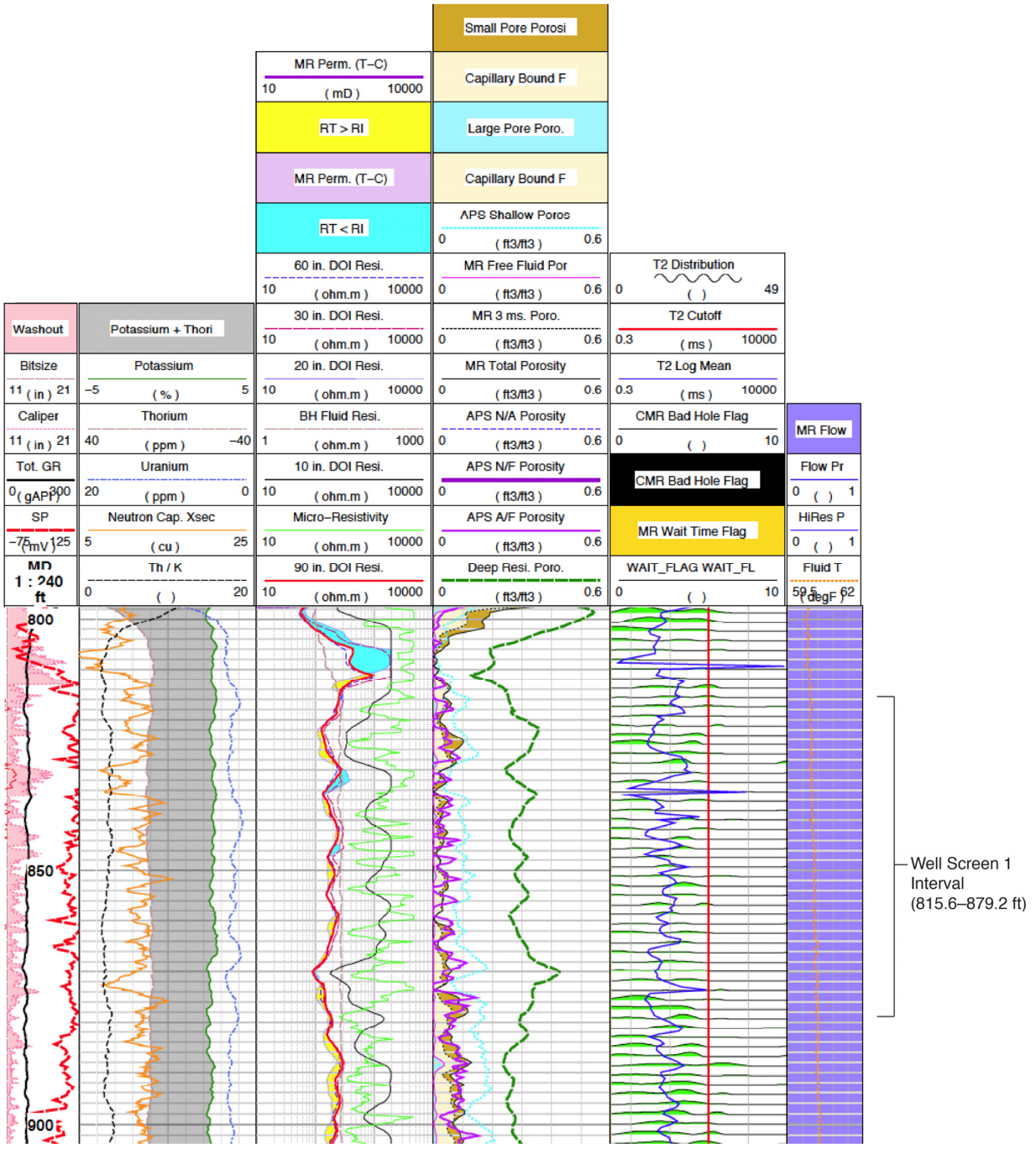


Figure A-34 Well CdV-16-4ip geophysical logs showing gamma, electrical resistivity, and porosity for well screen 1

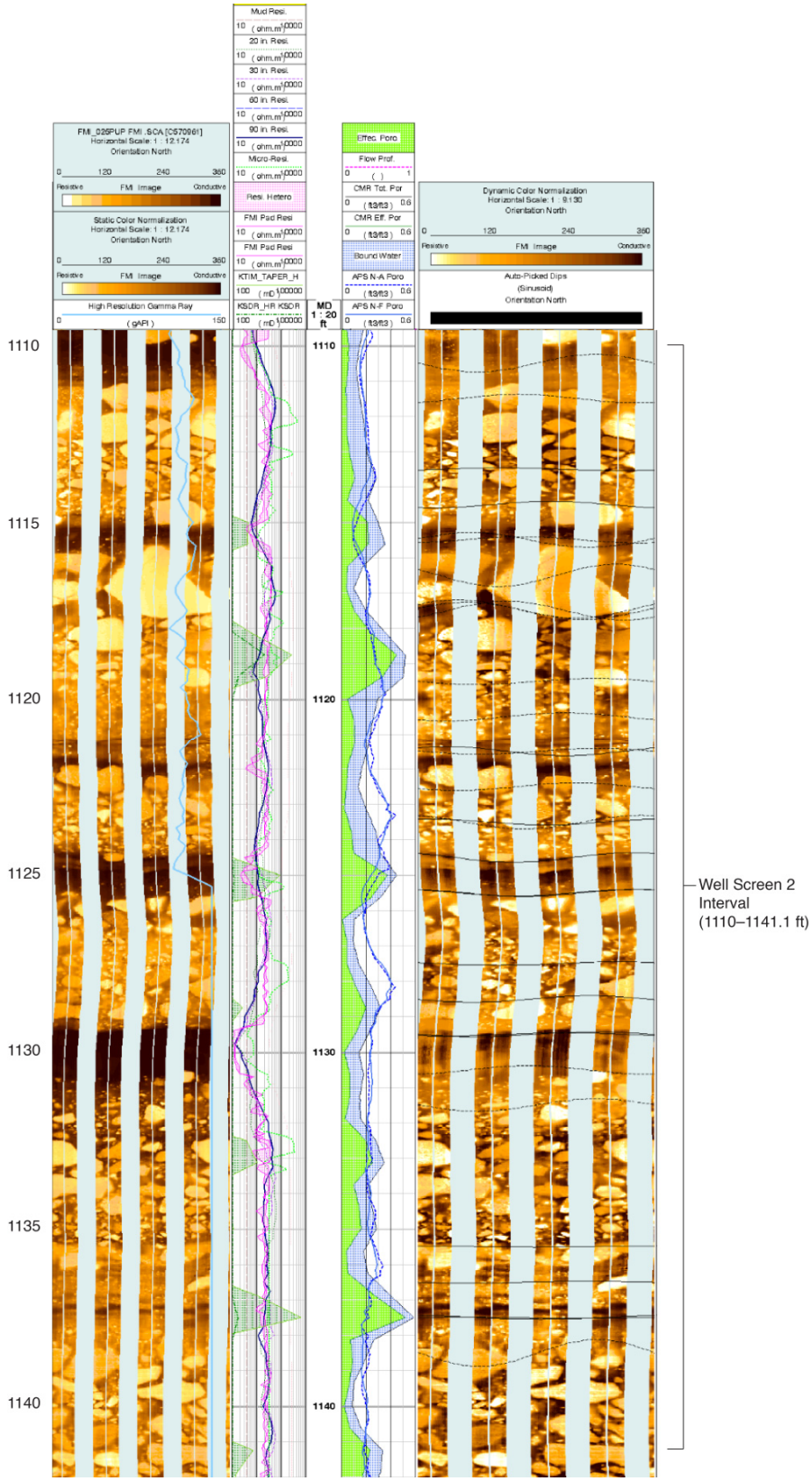


Figure A-35 Well CdV-16-4ip FMI log showing lithology, electrical resistivity, and porosity for well screen 2

PERCHED-INTERMEDIATE WELL CdV-37-1i

Summary of Well Screen Information, CdV-37-1i

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	632–652.5	20.5	Puye Formation	10/20 sand 625.9–657.8	Perched water in sedimentary deposits above Cerros del Rio basalt	Top of screen is submerged 3.5 ft below the perched water level

CdV-37-1i Drilling and Well Construction

	Description	Evaluation
Drilling Method	CdV-37-1i was drilled using fluid-assisted air-rotary drilling methods with casing advance. Drilling fluid consisted of municipal water mixed with AQF-2 foam. Drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.	Geologic conditions encountered during drilling are summarized in Figure A-36 and in the well completion report (LANL 2010, 109428). A separate core hole was drilled using a a track-mounted PS-600C sonic drilling rig equipped with both 6.0- and 4.25-in.-O.D. core barrels and 7.0-in. casing. No fluids were used during sonic drilling/coring, and the TD of the core hole was 305 ft. The core hole was abandoned with 3/8-in. bentonite chips (hydrated) backfill from TD to 50.1 ft bgs. Portland cement grout was placed above the bentonite backfill to ground surface. Backfill materials were added as the 7-in. casing was retracted. The CdV-37-1i borehole was drilled using a Foremost DR-24HD drill rig. The rig was equipped with conventional drilling rods, tricone bits, down-the-hole hammer bits, air compressors, and support equipment. CdV-37-1i was drilled using air-rotary and fluid-assisted air-rotary drilling techniques with casing advance. Drilling fluids were used, as needed, to improve borehole stability, to minimize fluid loss, and to facilitate cuttings removal from the borehole. Drilling fluids consisted of a mixture of municipal water with AQF-2 foam. Use of the foaming agent was terminated at 490.0 ft bgs, and no additives, other than municipal water, were used to drill below this depth An 18-in. casing was set to a depth of 90.1 ft bgs using dual-rotary methods and a 16.75-in. tricone bit. A 16-in. drill casing was advanced to 395 ft bgs using a 15.75-in. tricone bit where the casing was landed because of high rotational torque. The 12-in. casing was advanced to 691.4 ft bgs using an 11.625-in. downhole hammer. An open borehole was drilled from 691.4 ft to TD of 803 ft using the 11.625-in. downhole hammer.
General Well Characteristics	CdV-37-1i is a single-screen well constructed of 5-in.-I.D./5.56-in.-O.D. type A304 passivated stainless-steel well casing.	The well design is shown in Figure A-37. The stainless-steel materials used at CdV-37-1i are chemically inert.

	Description	Evaluation
Well Screen Construction	Well CdV-37-1i was constructed with a stainless-steel rod-based wire-wrapped screen with 0.020-in. slots.	Wire-wrapped screen with 0.020-in. slots is considered the optimum design for promoting the free flow of water during well development and sampling.
Screen Length and Placement	The CdV-37-1i well screen extends from 632 to 652.5 ft (length 20.5 ft) and targets perched groundwater.	Well CdV-37-1i was installed to monitor perched groundwater at the confluence of Water Canyon and Cañon de Valle, downgradient of contaminant release sites at TA-16. It is designed to provide water-quality and water-level data, and the screen length and placement were selected to achieve the following goals: • Characterize water quality of deep-perched groundwater downgradient of the major HE sources at TA-16 with an emphasis on defining the eastern extent of contaminated perched-intermediate groundwater • Monitor water levels to investigate seasonal recharge through the canyon bottom and to determine the direction of groundwater flow and hydraulic gradients within the perched groundwater zone The main goal for this screen is to determine the nature and extent of HE contamination in deep-perched groundwater affected by infiltration of contaminated surface water and alluvial groundwater in Cañon de Valle and Water Canyon. The screen is located within the Pliocene Puye Formation above Cerros del Rio basalt. Borehole videos indicate the screen interval is made up of coarse gravels with little fine-grained matrix. The top of the well screen is submerged about 3.5 ft below the water level of the perched zone. The well-screen length and placement meet monitoring goals for the well.
Filter Pack Materials and Placement	The filter pack and its placement for the well screen are discussed in the column to the right.	The primary filter pack is made up of 10/20 sand from 625.9 to 657.8 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 624 to 625.9 ft. The primary filter pack extends 6.1 ft above and 5.3 ft below the well screen. The length and placement of the filter pack relative to the well screen meet the design goals for this well.
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at relatively highly rates, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison with low-flow systems, and the likelihood of obtaining water from zones beyond potential near-well drilling effects is greater. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a

	Description	Evaluation
Additives Used during Drilling		Air Municipal water AQF-2 foam
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal. A cement grout surface seal was placed from 3 to 457.9 ft.

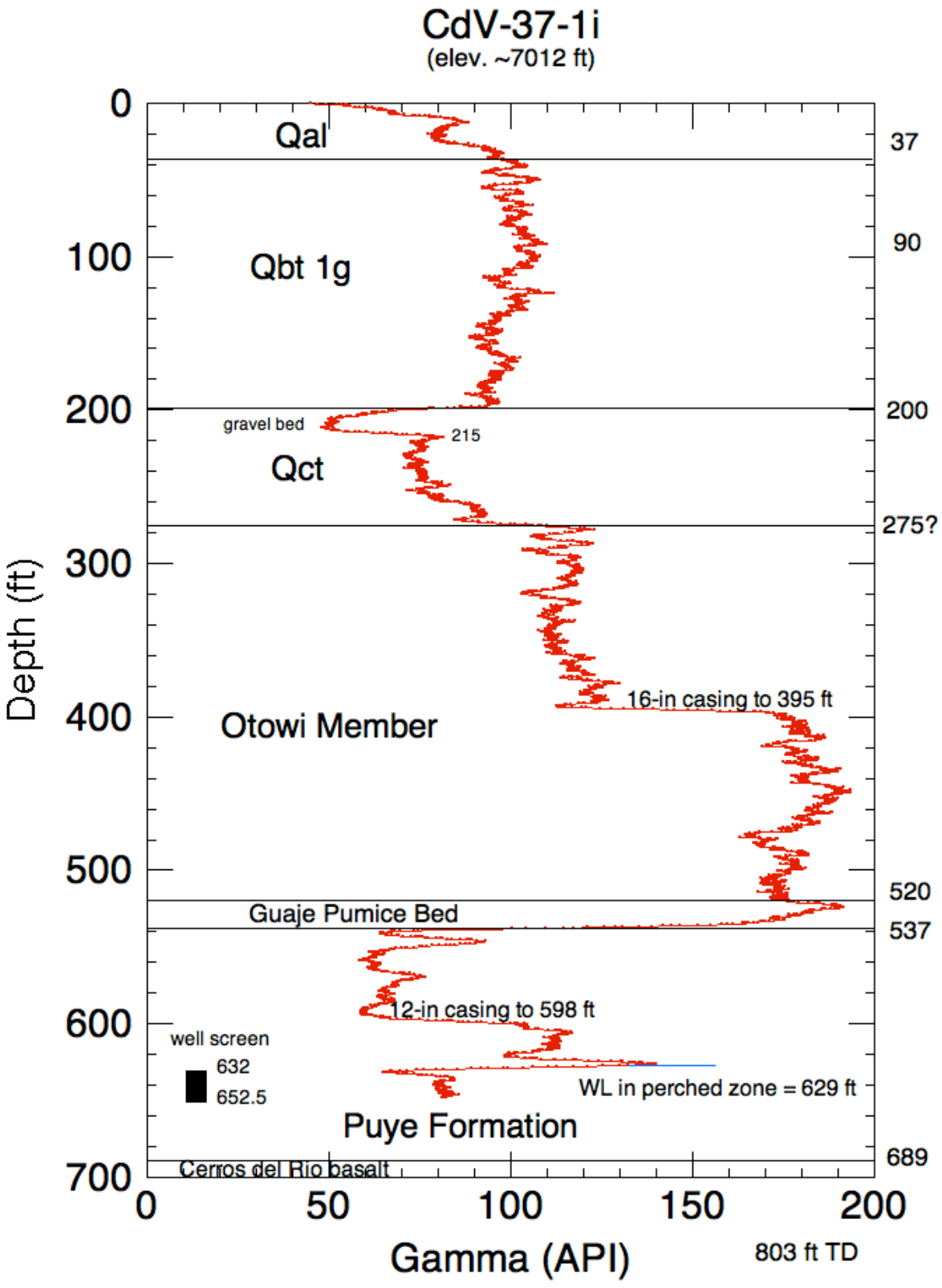


Figure A-36 Well CdV-37-1i geology and borehole gamma log

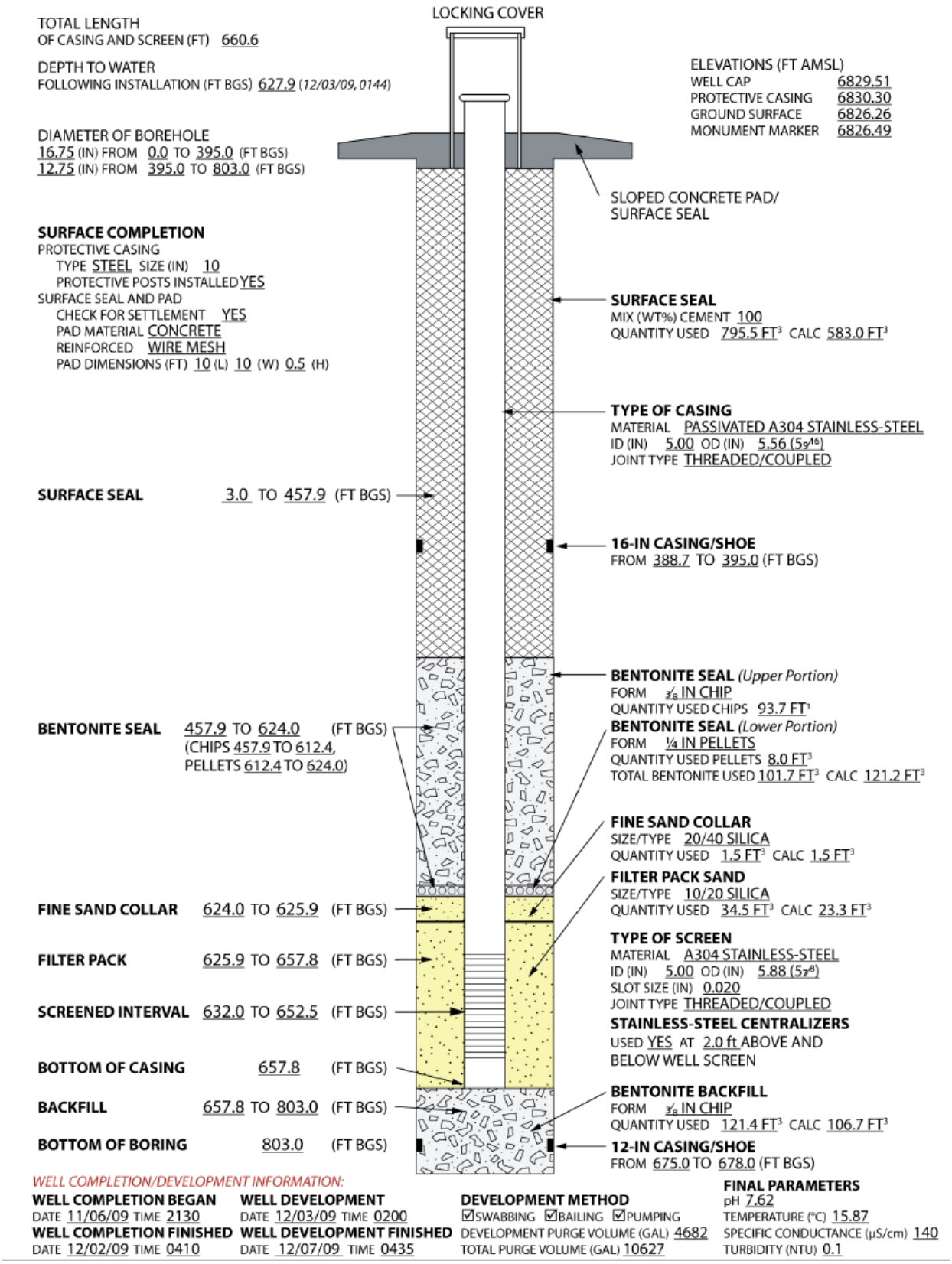


Figure A-37 CdV-37-1i well design

PERCHED-INTERMEDIATE WELL R-25b

Summary of Well Screen Information, R-25b

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	750–770.8	20.8	Otowi Member, Bandelier Tuff	10/20 sand 745–776	Perched water in the lower vadose zone	The perched water level is 1 ft below the top of the well screen

R-25b Drilling and Well Construction

	Description	Evaluation
Drilling Method	R-25b was drilled using fluid-assisted air-rotary drilling methods with casing advance. Drilling fluid consisted of municipal water mixed with AQF-2 foam. Drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.	Geologic conditions encountered during drilling are summarized in Figure A-38 and in the well completion report (LANL 2008, 105018). The R-25b borehole was drilled using a Failing Co. Speedstar 50K drill rig. R-25b was drilled using air-rotary and fluid-assisted air-rotary drilling techniques with casing advance. Drilling fluids were used, as needed, to improve borehole stability, to minimize fluid loss, and to facilitate cuttings removal from the borehole. Drilling fluids consisted of a mixture of municipal water with AQF-2 foam. Use of the foaming agent was restricted to the interval between 145 and 524 ft bgs, and no additives, other than municipal water, were used to drill below these depths. A 16-in. surface casing was set to a depth of 18.7 ft bgs and grouted in place. A 14.75-in.-diameter open borehole was advanced to 524 ft bgs with a tricone button bit, roller stabilizer, and drill collar assembly using air and water to lift the drill cuttings. To minimize circulation and borehole stability problems, 11.75 in. drill casing was set from the surface to 524 ft bgs in the open borehole. The 11.75-in. casing was then advanced to the borehole TD of 786 ft bgs using a STRATEX drive shoe and underreamer.
General Well Characteristics	R-25b is a single-screen well constructed of 5-in.-I.D./5.56-in.-O.D. type A304 stainless-steel well casing.	The well design is shown in Figure A-39. The stainless-steel materials used at R-25b are chemically inert.
Well Screen Construction	R-25b was constructed with a stainless-steel rod-based wire-wrapped screen with 0.020-in. slots.	Wire-wrapped screen with 0.020-in. slots is considered the optimum design for promoting the free flow of water during well development and sampling.
Screen Length and Placement	The R-25b well screen extends from 750 to 770.8 ft (length 20.8 ft) and targets perched groundwater.	Well 25b was installed to monitor perched groundwater downgradient of HE releases from the 260 Outfall at TA-16. It is designed to provide water-quality and water-level data, and the screen length and placement were selected to achieve the following goals: • Characterize water quality of deep-perched groundwater downgradient of the major HE sources at TA-16

	Description	Evaluation
		• Monitor water levels to investigate seasonal recharge of the perched zone and to determine direction of groundwater flow and hydraulic gradients within the perched groundwater zone • Provide information supporting the groundwater monitoring network for the 260 Outfall corrective measures evaluation The well screen is designed to monitor the upper part of a deep-perched groundwater zone downgradient of potential HE release sites at TA-16. Well R-25b augments and potentially replaces well R-25 screen 1 that was impacted by repair activities to R-25 screen 3 (see well R-25 above). The main goal for R-25b is to determine the nature and extent of HE contamination in deep-perched groundwater affected by infiltration of contaminated surface water and alluvial groundwater in Cañon de Valle. The screen is located within the Quaternary Otowi Member of the Bandelier Tuff. The well screen is located within poorly welded ash-flow tuff. The screen interval has an estimated water-filled porosity of 25% to 30% (Figure A-40). However, these porosity values are probably too low because the water level was below the screen interval during logging and pores near the borehole probably drained. A water-filled porosity of 40% was measured in similar rocks at well CdV-16-1(i) where logs were collected in a water-filled borehole. The perched water level is 1 ft below the top of the well screen. The well-screen length and placement meet monitoring goals for the well.
Filter Pack Materials and Placement	The filter pack and its placement for the well screen are discussed in the column to the right.	The primary filter pack is made up of 10/20 sand from 745 to 776 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 742.5 to 745 ft. The primary filter pack extends 5 ft above and 5.2 ft below the well screen. The length and placement of the filter pack relative to the well screen meet the design goals for this well.
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and, to some degree, near-well formation materials. Water can pumped at relatively highly rates, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison with low-flow systems, and the likelihood of obtaining water from zones beyond potential near-well drilling effects is greater. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a
Additives Used during Drilling		Air Municipal water AQF-2 foam
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal. A cement grout surface seal was placed from 8 to 84 ft.

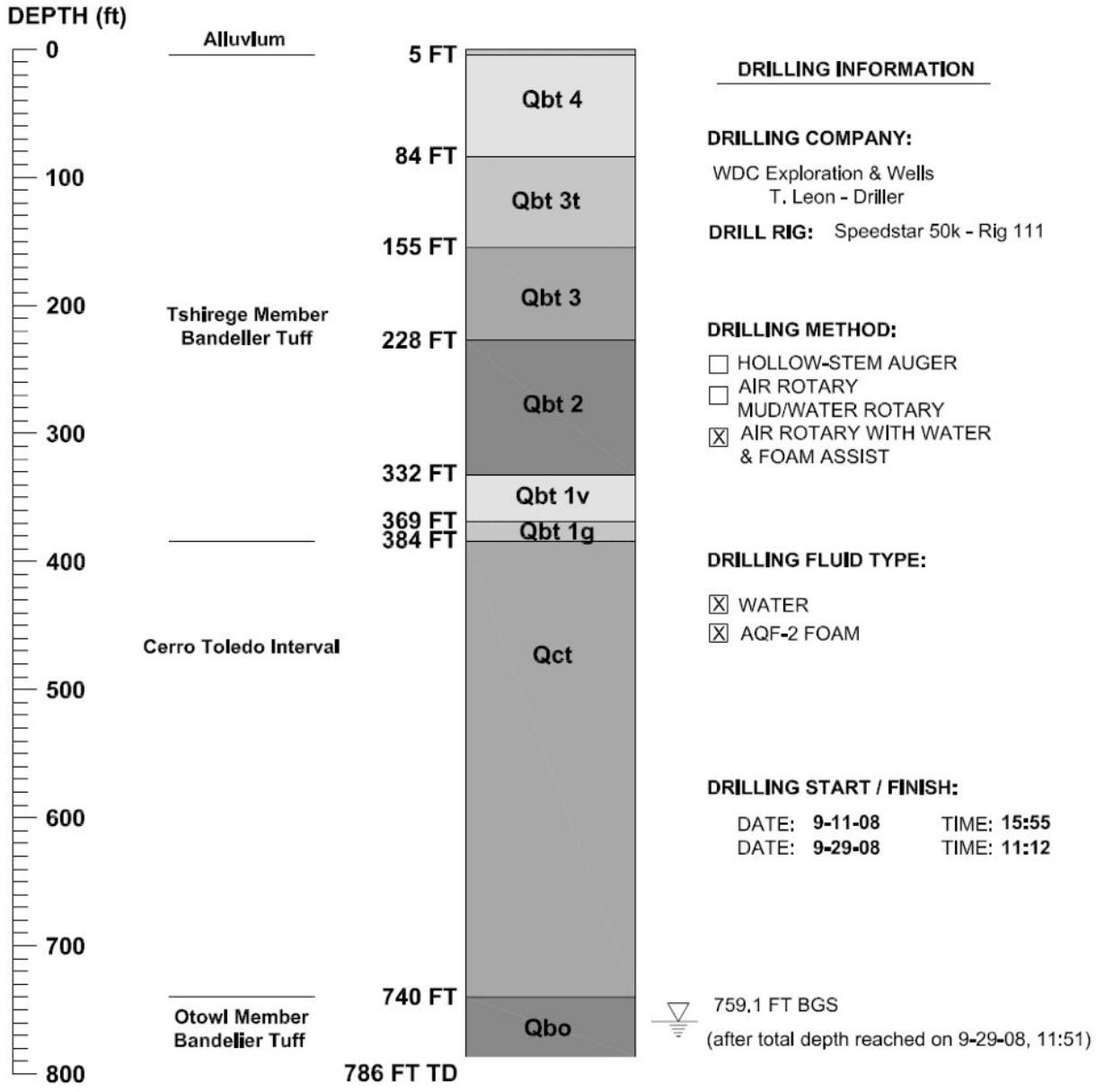


Figure A-38 Well R-25b geology

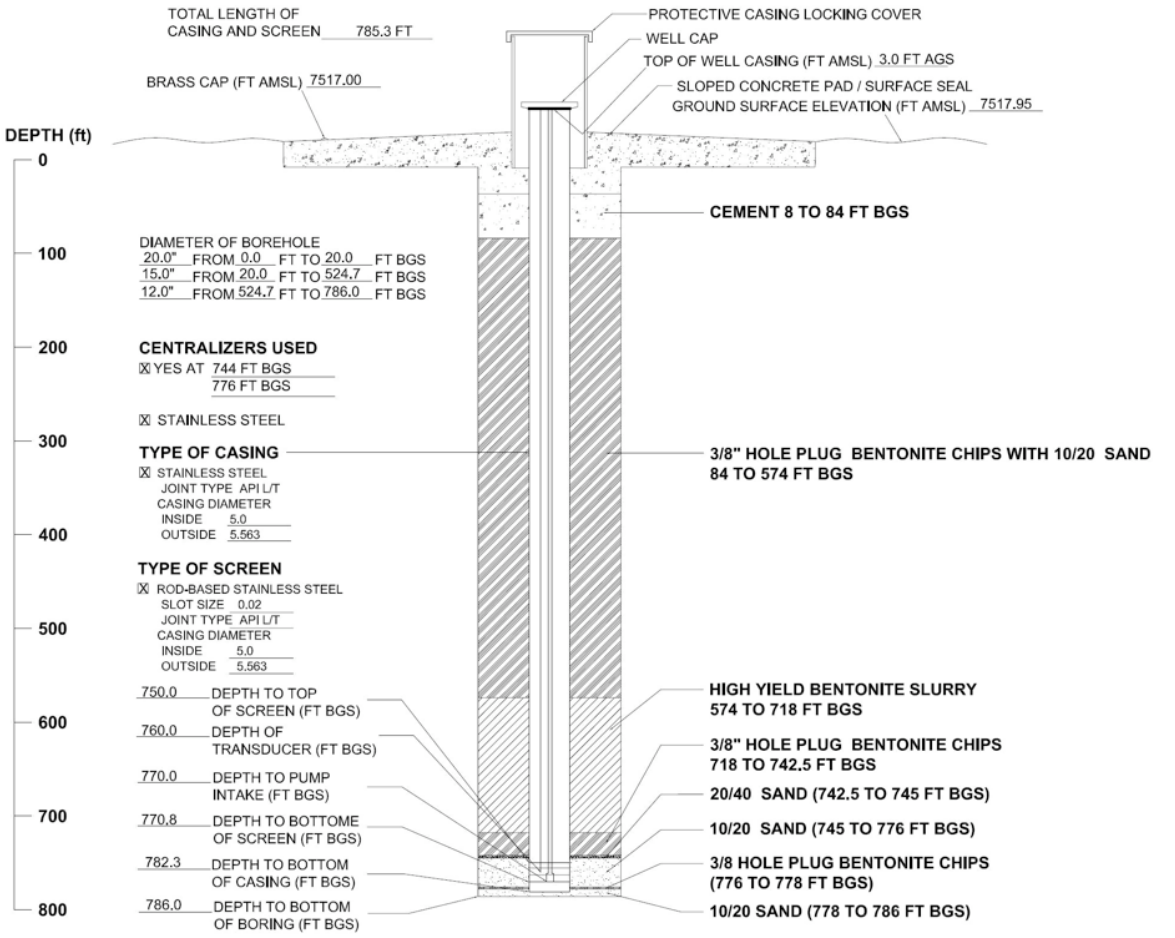


Figure A-39 R-25b well design

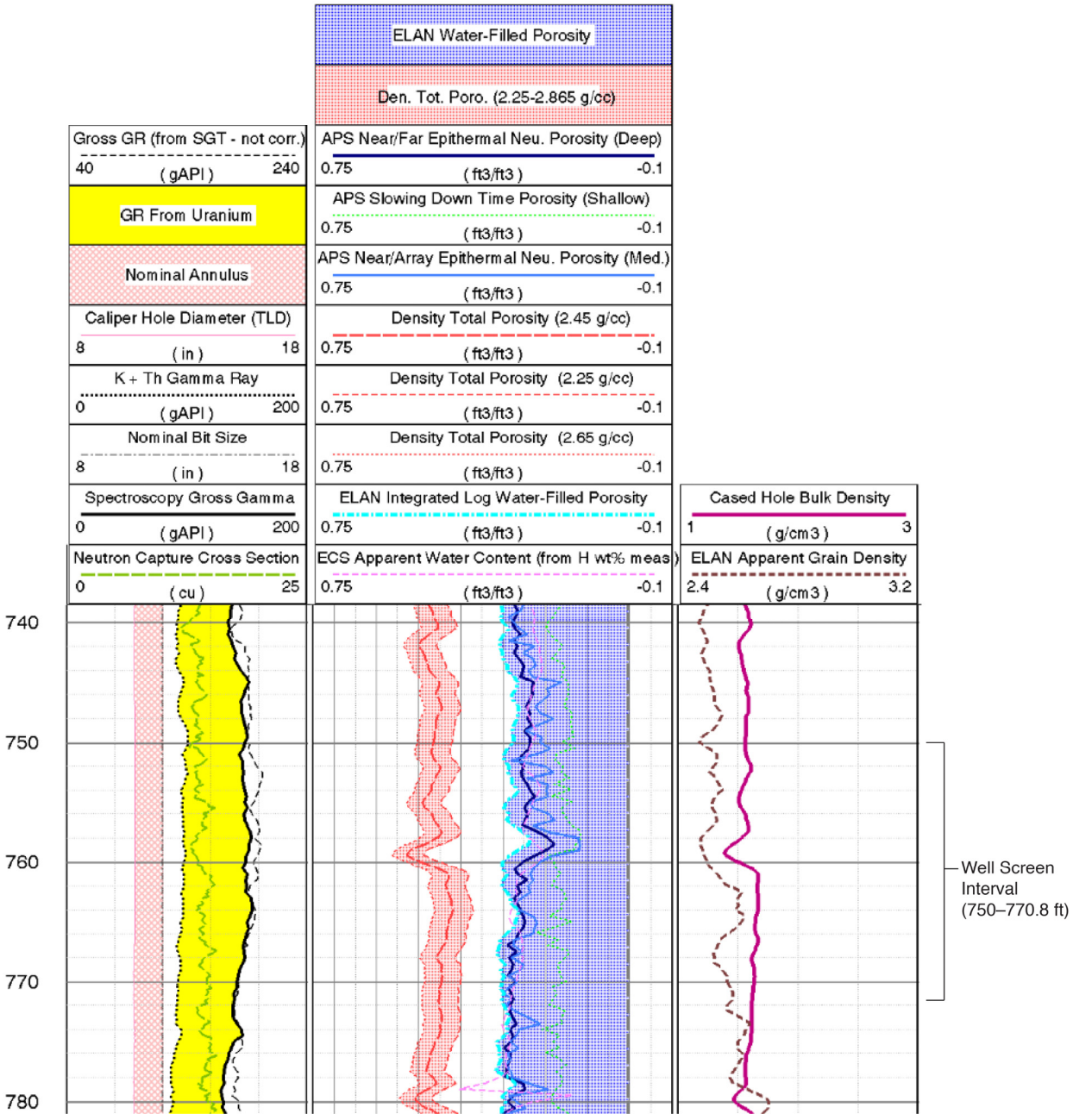


Figure A-40 Well R-25b geophysical logs showing gamma, porosity, and bulk density for the well-screen interval

PERCHED-INTERMEDIATE WELL R-26 AND PIEZOMETERS R-26 PZ-1 AND PZ-2

Summary of Well Screen Information, Well R-26 and Piezometers R-26 PZ-1 and PZ-2

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
R-26 PZ-1	230–250	20	Tshirege, Bandelier Tuff, subunit Qbt 3t	20/40 sand 604–626	Upper vadose zone perched water zone	Well screen dry
R-26 PZ-2	150–180	30	Tshirege, Bandelier Tuff, subunit Qbt 3t	20/40 sand 785–806	Upper vadose zone perched water zone	Water level in perched zone is typically 20 to 25 ft below the top of screen; water level responds to seasonal snowmelt.
R-26 screen1	651.8–669.9	18.1	Cerro Toledo interval	20/40 sand 620–672	Middle vadose zone perched water zone	Water level in perched zone is 44.5 ft above the top of screen

Well R-26 and Piezometers R-26 PZ-1 and PZ-2 Drilling and Well Construction

	Description	Evaluation
Drilling Method	R-26 PZ-1 and PZ-2 were installed in a core hole that was drilled using HSA and air-rotary coring methods. The R-26 well was drilled by air-rotary, fluid-assisted air-rotary, and mud-rotary drilling methods. Drilling fluid consisted of municipal water mixed with QUIK-FOAM, EZ-MUD, bentonite, soda ash, N-Seal, and Pac-L polyanionic cellulose.	Geologic conditions encountered during drilling are summarized in Figure A-41 and in the well completion report (Kleinfelder 2005, 087846). Drilling at CdV-16-1(i) took place in two phases. During Phase I, a core hole was drilled to a depth of 250 ft by HSA and air-rotary coring methods to collect tuff samples for anion leachate analysis. Nested piezometers R-26 PZ-1 and PZ-2 were installed in the core hole to monitor potential perched groundwater zones identified during coring. A well diagram for R-26 PZ-1 and PZ-2 piezometer is shown in Figure A-42. During Phase II, a new borehole was drilled to install a regional aquifer well using a Dresser T70W drill rig. A 13.375-in. surface casing was set to a depth of 70 ft bgs. Air-rotary open hole drilling advanced the borehole to 140 ft bgs using a 12.25-in. tricone bit. Air-rotary open hole drilling advanced the borehole from 140 to 205 ft bgs using a hammer bit. Open-hole fluid-assisted air-rotary drilling with a hammer bit advanced the borehole to 720 ft. Fluids were added to air to improve circulation of cuttings. Fluids included municipal water, QUIK-FOAM, and EZ-MUD. Open-hole fluid-assisted air-rotary drilling with a combination of 12.25-in. tricone mill-tooth and button bits advanced the borehole from 720 to 1000 ft. At 1000 ft, the Phase II drilling method switched to mud-rotary drilling because of borehole instability. A batch of mud consisting of municipal water, Aqua-Gel powdered bentonite, Pac-L, and soda ash was introduced into the borehole, but there was substantial fluid loss to the formation. The borehole was reamed using water and QUIK-FOAM to a depth of 1005 ft using an 8-in. tricone bit and an 8-in. roller-reamer positioned above the drill bit. Drill casing 9.625-in. in diameter was set to 1000 ft to seal off the lost-circulation zones;

	Description	Evaluation
		the casing slipped to 1005 ft bgs. Another batch of drilling mud was introduced into the borehole and open-hole mud-rotary drilling with an 8.5-in. tricone bit advanced the borehole to 1485 ft bgs. The intrval from 1485 to 1490.5 ft TD was drilled by open-hole mud-rotary methods with an 4.5-in. tricone pilot bit with a 2.5-in. side reamer. The borehole below 1400 ft was then reamed using a 14-in. hydraulic reamer and a 4.5-in. tricone pilot bit.
General Well Characteristics	R-26 PZ-1 and PZ-2 are nested piezometers constructed of 1-in.-O.D. schedule 40 PVC. R-26 was completed as a two-screen well constructed of 4.43-in.-I.D./5-in.-O.D. A304 stainless-steel well casing.	The well design for the R-26 PZ-1 and R-26 PZ-2 nested piezometers is shown in Figure A-42. The well design for R-26 is shown in Figure A-43. The stainless-steel materials used at well R-26 are chemically inert.
Well Screen Construction	The R-26 PZ-1 and PZ-2 well screens are constructed of 1-in.-O.D. schedule 40 0.010-in. slotted PVC R-26 well screen 1 is a pipe-based constructed of A304 5.53-in.-O.D. perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.010-in. slots. R-26 well screen 2 was constructed with a stainless-steel rod-based wire-wrapped screen with 0.020-in. slots.	R-26 PZ-1 has been dry since the piezometer was installed, and it should be plugged and abandoned. R-26 PZ-2 was constructed with a 1-in.-O.D. slotted PVC well screen. Water is produced at a very low rate during purging and sampling. It also contains 0.010-in. slots that may inhibit water movement during pumping. The pipe-based screen used in R-26 screen 1 provides structural stability in situations where the well screen might be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screen was used after two rod-based well screens were damaged during installation of well R-25. A drawback to pipe-based screens is that water surged into the filter pack and formation during development may be less effective in those areas that are not next to holes in the well casing. Also, the wire wrap on screen 1 contains 0.010-in. slots. Later wells were installed with 0.020-in. slots to facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in.-slot wire-wrapped pipe-based screen to develop properly must be judged on the quality of groundwater data collected from the wells. R-26 screen 2 was severely impacted by bentonite (possibly drilling mud), and it was plugged and abandoned in 2011.
Screen Length and Placement	The R-26 PZ-1 well screen extends from 230 to 250 ft (length 20 ft) and targets perched groundwater; it has been dry since well installation. The R-26 PZ-2 well screen extends from 150 to 180 ft (length 30 ft) and targets perched groundwater.	R-26 PZ-1 and R-26 PZ-2 were installed in the R-26 core hole after two potential perched groundwater zones were identified in welded ash-flow tuffs of Tshirege Member subunit Qbt 3t during coring operations. Despite recognized limitations because of their small size, the two piezometers were installed as wells of opportunity to monitor water quality and water levels in the shallow perched groundwater. R-26 PZ-1 has been dry since installation. R-26 PZ-2 contains water is in a zone of persistent saturation. Well R-26 was originally intended to be a single-screen well designed to provide water-quality and water-level data for the regional aquifer upgradient of known Laboratory contaminant sources. However, a significant perched groundwater zone was encountered in the Cerro Toledo interval during drilling, and the

	Description	Evaluation
	R-26 screen 1 extends from 651.8 to 669.9 ft (length 18.1 ft) and targets perched groundwater.	Laboratory decided to install well screens in both the regional aquifer and the perched groundwater zone. The length and placement of well screens were designed to meet following goals: • Characterize water quality of perched-intermediate and regional groundwater upgradient of HE sources in the vicinity of TA-16 • Monitor water levels to detect whether groundwater responds to seasonal infiltration events R-26 screen 1 targets perched-intermediate groundwater in the Cerro Toledo interval. The upper part of the screen interval from 651.8 to 663 ft bgs consists of stacked beds of sands and silts (Figure A-44). The upper beds have low electrical resistivity (<100 ohm-m) and probably contain significant silt and/or clay. The neutron porosity of these upper beds ranges between 30% and 45% and CMR effective porosities are 10% to 30% (Figure A-44). The lower part of the well screen between 663 to 669.9 ft bgs is within a massive homogenous bed that may be either sand or tuff. This lower bed is electrically resistive (>100 ohm-m), indicating the silt and clay content is low. The neutron porosity of this lower beds ranges between 35% and 40%, but the CMR effective porosities are <5% (Figure A-44).
Filter Pack Materials and Placement	The filter packs and their placements for the three well screens are discussed in the column to the right.	The R-26 PZ-1 well screen primary filter pack is made up of 10/20 sand from 225 to 250 ft. There is no secondary filter pack. The primary filter pack extends 5 ft above the well screen. The bottom of the filter pack coincides with the bottom of the well screen. R-26 PZ-1 has been dry since installation. The R-26 PZ-2 well screen primary filter pack is made up of 10/20 sand from 145 to 185 ft. There is no secondary filter pack. The primary filter pack extends 5 ft above and 5 ft below the well screen. The length and placement of the filter pack relative to the well screen meet the design goals for this well. The R-26 screen 1 primary filter pack is made up of 10/20 sand from 620 to 672 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 618 to 620 ft. The primary filter pack extends 31.8 ft above and 2.1 ft below the well screen. The filter pack above the well screen is longer than normal but does not adversely affect the suitability of the well screen to collect monitoring samples. The longer filter pack increases the effective length of the well screen, allowing sampling of a thicker vertical cross-section of the perched zone. The length and placement of the filter pack relative to the well screen meet the design goals for this well.
Sampling System	Dedicated submersible pump	When well R-26 was a two-screen well, it was sampled using a Westbay low-flow sampling system. The Westbay system was removed and screen 2 was plugged and abandoned in 2011. R-26 screen 1 is now sampled using a dedicated submersible pump. Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and, to some degree, near-well formation materials. Water can pumped at relatively highly rates, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen

	Description	Evaluation
		in comparison with low-flow systems, and the likelihood of obtaining water from zones beyond potential near-well drilling effects is greater. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	See notes in the column to the right.	A significant amount of drilling mud and other fluid additives was lost to the formation during mud-rotary drilling, especially in the interval from 70 to 1000 ft bgs. Residual drilling fluids could affect the water quality of samples collected from R-26 screen 1.
Additives Used during Drilling		Air Municipal water QUIK-FOAM EZ-MUD Bentonite drilling mud Soda ash N-Seal Pac-L
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal. A cement grout surface seal was placed from 0 to 70 ft in well R-26.

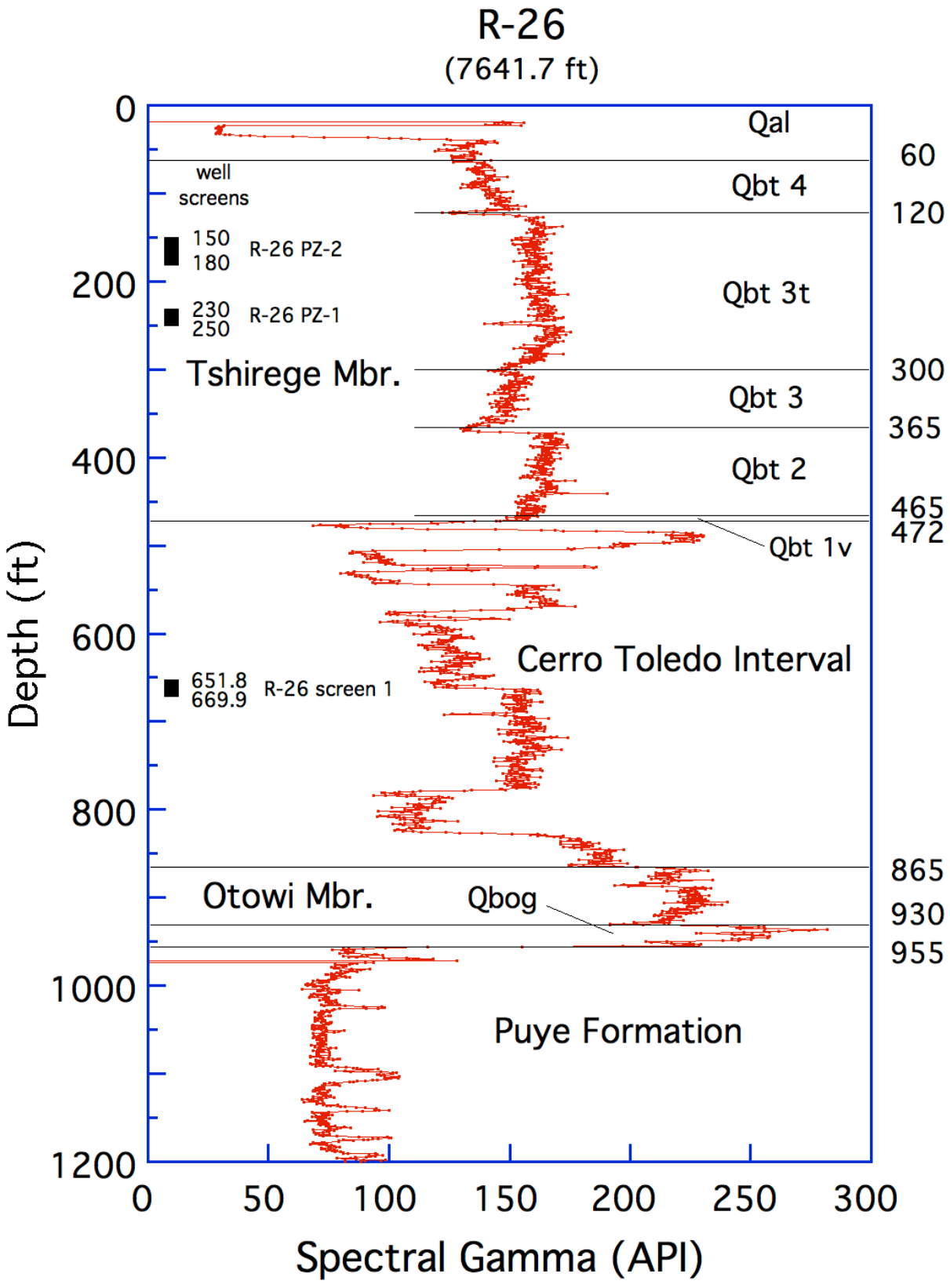


Figure A-41 Well R-26 and piezometers R-26 PZ-1 and PZ-2 geology and borehole gamma log

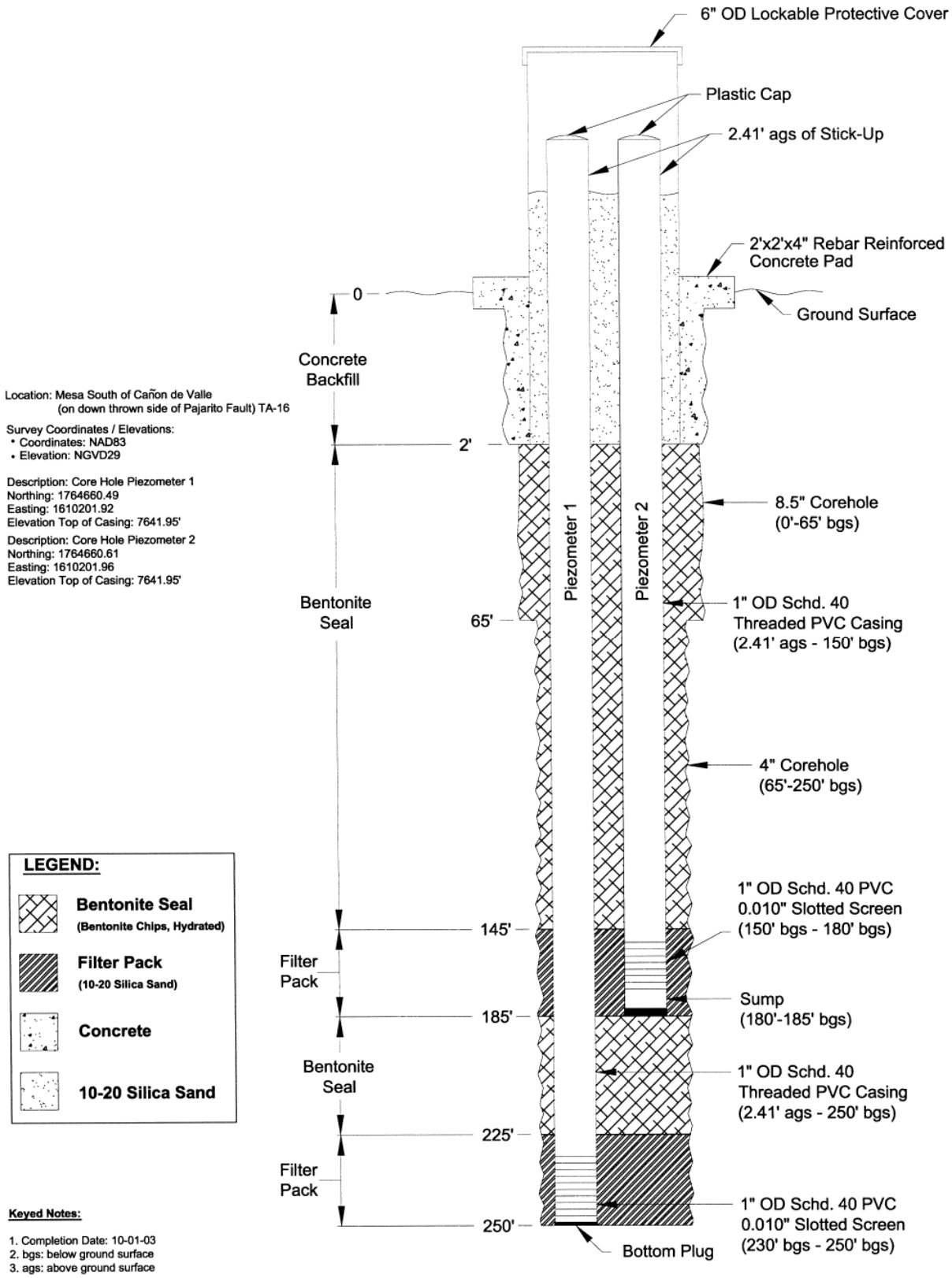


Figure A-42 Piezometers R-26 PZ-1 and PZ-2 well design

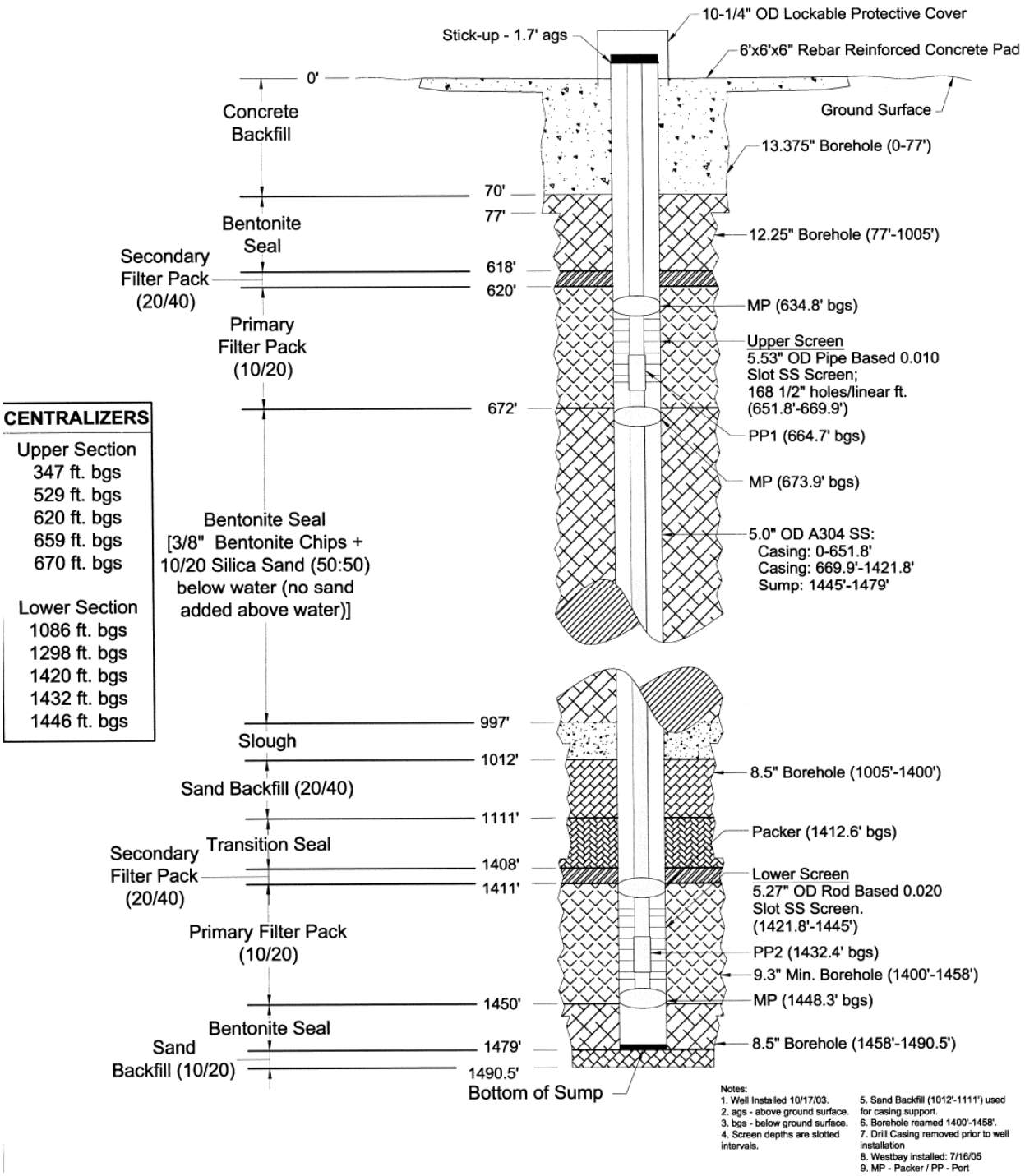


Figure A-43 R-26 well design

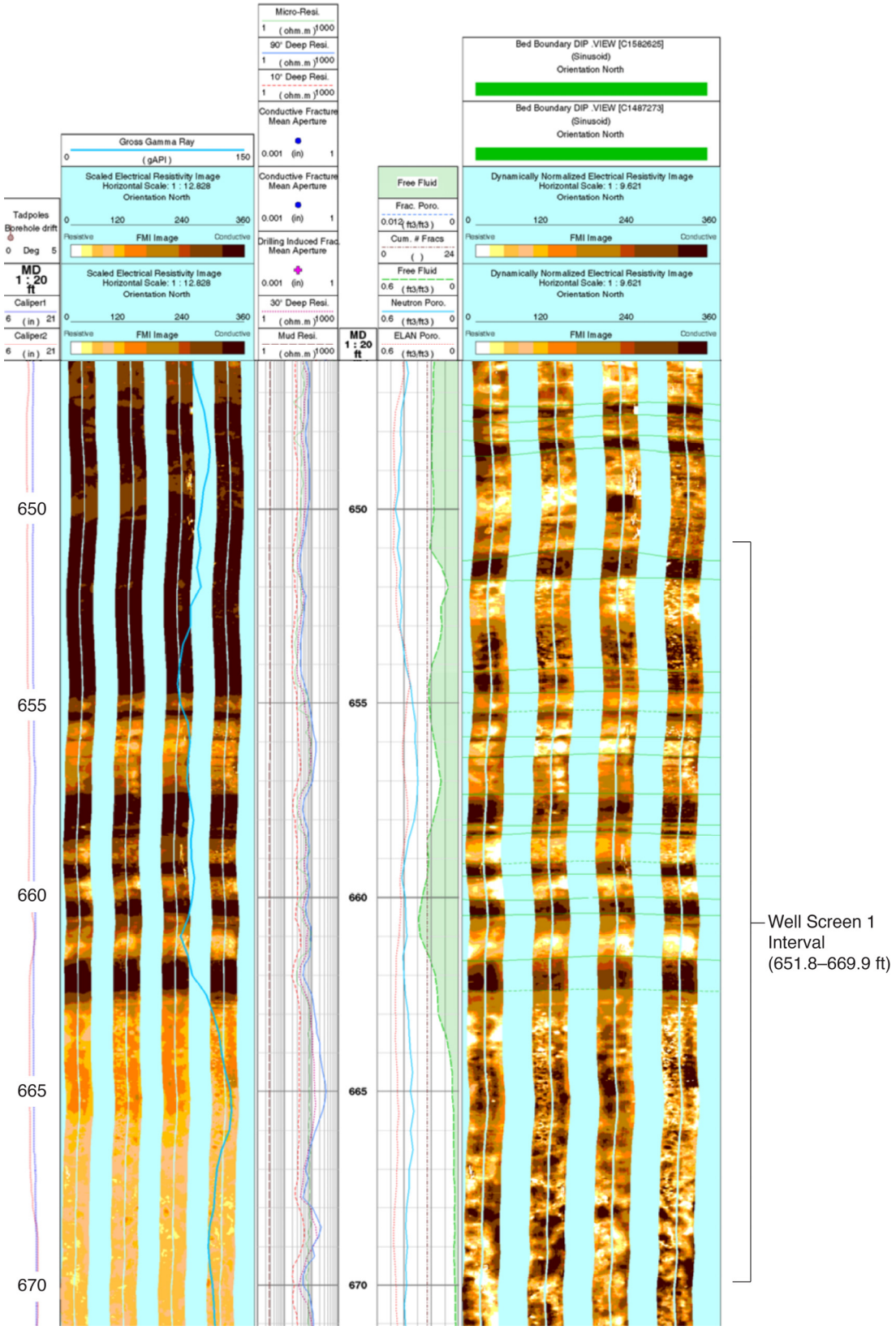


Figure A-44 Well R-26 FMI log showing lithology, bedding attitudes, electrical resistivity, and CMR porosity for screen 1

PERCHED-INTERMEDIATE WELL R-47i

Summary of Well Screen Information, R-47i

Screen	Depth Interval (ft)	Screen Length (ft)	Geologic Unit	Primary Sand-Pack Gradation and Depth Interval (ft)	Hydrogeologic Target of Screen	Comments
1	840–860.6	20.6	Puye Formation	10/20 sand 835–866	Perched water in the lower vadose zone	Top of screen is submerged 11.1 ft below the perched water level

R-47i Drilling and Well Construction

	Description	Evaluation
Drilling Method	R-47i was drilled using fluid-assisted air-rotary drilling methods with casing advance. Drilling fluid consisted of municipal water mixed with AQF-2 foam. Drilling fluid was added to the compressed-air circulating medium to help remove cuttings and stabilize the hole.	Geologic conditions encountered during drilling are summarized in Figure A-45 and in the well completion report (LANL 2010, 109188). The original drilling work plan for R-47 called for completion of a monitoring well in the regional aquifer. The R-47 borehole reached TD of 1348 ft and well construction was initiated using an NMED-approved well design. However, construction was halted when borehole video logs showed that annular bentonite fill had intruded the regional aquifer well screen. The R-47 stainless-steel regional well components were extracted from the borehole to assess the degree of bentonite intrusion into the well screen target zone. In consultation with NMED, it was determined that collecting representative water-quality data in the future would probably be compromised by the intrusion of bentonite into the well-screen interval. As a result, the decision was made to plug and abandon the lower part of the R-47 borehole and to install perched-intermediate well R-47i in the upper portion of the borehole. The R-47i borehole was drilled using a Schramm, Inc., T130XD Rotadrill dual-rotary drilling rig with casing rotator. The rig was was originally equipped with conventional 4-in. drill pipe drilling rods, tricone bits, down-the-hole hammer bits, air compressors, and support equipment. Following segregation of the 4-in. drill pipe, 5.5-in. dual-wall drill pipe was used. R-47i was drilled using air-rotary and fluid-assisted air-rotary drilling techniques with casing advance. Drilling fluids were used, as needed, to improve borehole stability, to minimize fluid loss, and to facilitate cuttings removal from the borehole. Drilling fluids consisted of a mixture of municipal water with AQF-2 foam. Use of the foaming agent was terminated at 1175 ft bgs, and no additives, other than municipal water, were used to drill below this depth The borehole was advanced from ground surface to 101 ft bgs using a 17.875-in. button-tooth, tricone bit, and 18-in casing. As the drilling string was being tripped out, the pin on the second joint of pipe from the top of the string broke, leaving 82.6 ft of tooling in the hole. Fishing operations successfully recovered the remaining tooling in the borehole. The borehole was advanced from 101 to 241 ft bgs using a 17.875-in. button-tooth, tricone bit, and 18-in casing. Repairs to the casing rotator and doublepin sub on the drill rig's quill temporarily halted work. When drilling resumed, conventional rotary

	Description	Evaluation
		drilling advanced the borehole to 748 ft bgs, and 12-in. casing was installed to 731 ft bgs. Preparations were made to resume dual-rotary drilling methods, including reinstalling the casing rotator. The borehole was advanced from 748 to 840 ft bgs using a 13-in. bit, hammer, and drill string. While drillers attempted to advance past 840 ft bgs, the pin on the top joint of drill pipe sheared and the tools were left in the borehole. Fishing operations successfully recovered the tooling in the borehole. All 4-in. drill pipe was taken out of service, and drilling resumed using 5.5-in. drill pipe. A 5.5-in. bit, hammer, collars, and drill pipe were tripped into the borehole, and the borehole was advanced from 840 to 1035 ft bgs where it was found the drill bit could not be retracted into the drill casing. Both the casing and drill string were tripped out of the hole, and it was discovered the casing shoe was missing and the leading edge of the casing was fractured and bent, thus preventing the bit from retracting into the casing. The 12-in. casing was reinstalled and advanced using an underreamer to a depth of 1035 ft, where it was landed in bentonite to seal off perched water encountered above. An open borehole was drilled to 1200 ft where a borehole video showed water coming into the borehole around the 12-in. casing shoe at 1035 ft. The borehole was backfilled to 1050 ft bgs with sand and an inflatable packer was tripped into to the bottom of the 12-in. casing before bentonite grout was pumped into the borehole above the packer in an attempt to seal off the lower 10 ft of annular space around the outside of the casing. The sealing operation was successful and the packer was tripped out of the borehole. Drilling resumed and the borehole was advanced to 1280 ft using open hole methods. Because borehole conditions were unstable, dual-rotary methods were used to advance 10-in casing from 1280 to 1350.5 ft TD.
General Well Characteristics	R-47i is a single-screen well constructed of 5-in.-I.D./5.56-in.-O.D. type A304 passivated stainless-steel well casing.	The well design is shown in Figure A-46. The stainless-steel materials used at R-47i are chemically inert.
Well Screen Construction	Well R-47i was constructed with a stainless-steel rod-based wire-wrapped screen with 0.020-in. slots.	Wire-wrapped screen with 0.020-in. slots is considered the optimum design for promoting the free flow of water during well development and sampling.
Screen Length and Placement	The R-47i well screen extends from 840 to 860.6 (length 20.6 ft) and targets perched groundwater.	The R-47i perched-intermediate well is designed to provide water-quality and water-level data, and the screen length and placement were selected to achieve the following goals: • Characterize water quality of deep-perched groundwater downgradient of the major HE sources at TA-16 with emphasis on defining the eastern extent of contaminated perched-intermediate groundwater • Monitor water levels to investigate seasonal recharge through the canyon bottom and to determine the direction of groundwater flow and hydraulic gradients within the perched groundwater zone

	Description	Evaluation
		The main goal for this screen is to determine the nature and extent of HE contamination in deep-perched groundwater affected by infiltration of contaminated surface water and alluvial groundwater in Cañon de Valle. The screen is located within the Pliocene Puye Formation. Significant perched-intermediate groundwater was encountered at a depth of about 832 ft while drilling R-47. The perched water was observed issuing from crudely stratified boulders, cobbles, and gravels of the Puye Formation in a borehole video. The perching horizon for this zone is not known with certainty but may be in the rocks below 873 ft where larger clasts such as cobbles and boulders are supported in a matrix of silt or fine sand. The top of the well screen is submerged about 11.1 ft below the water level of the perched zone. The well-screen length and placement meet monitoring goals for the well.
Filter Pack Materials and Placement	The filter pack and its placement for the well screen are discussed in the column to the right.	The primary filter pack is made up of 10/20 sand from 835 to 866 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 832 to 835 ft. The primary filter pack extends 5 ft above and 5.4 ft below the well screen. The length and placement of the filter pack relative to the well screen meet the design goals for this well.
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and, to some degree, near-well formation materials. Water can pumped at relatively highly rates, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison with low-flow systems, and the likelihood of obtaining water from zones beyond potential near-well drilling effects is greater. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a
Additives Used during Drilling		Air Municipal water AQF-2 foam
Annular Fill Other Than Filter and Transition Sands		Bentonite was used to create an annular seal. A cement grout surface seal was placed from 3 to 73 ft.

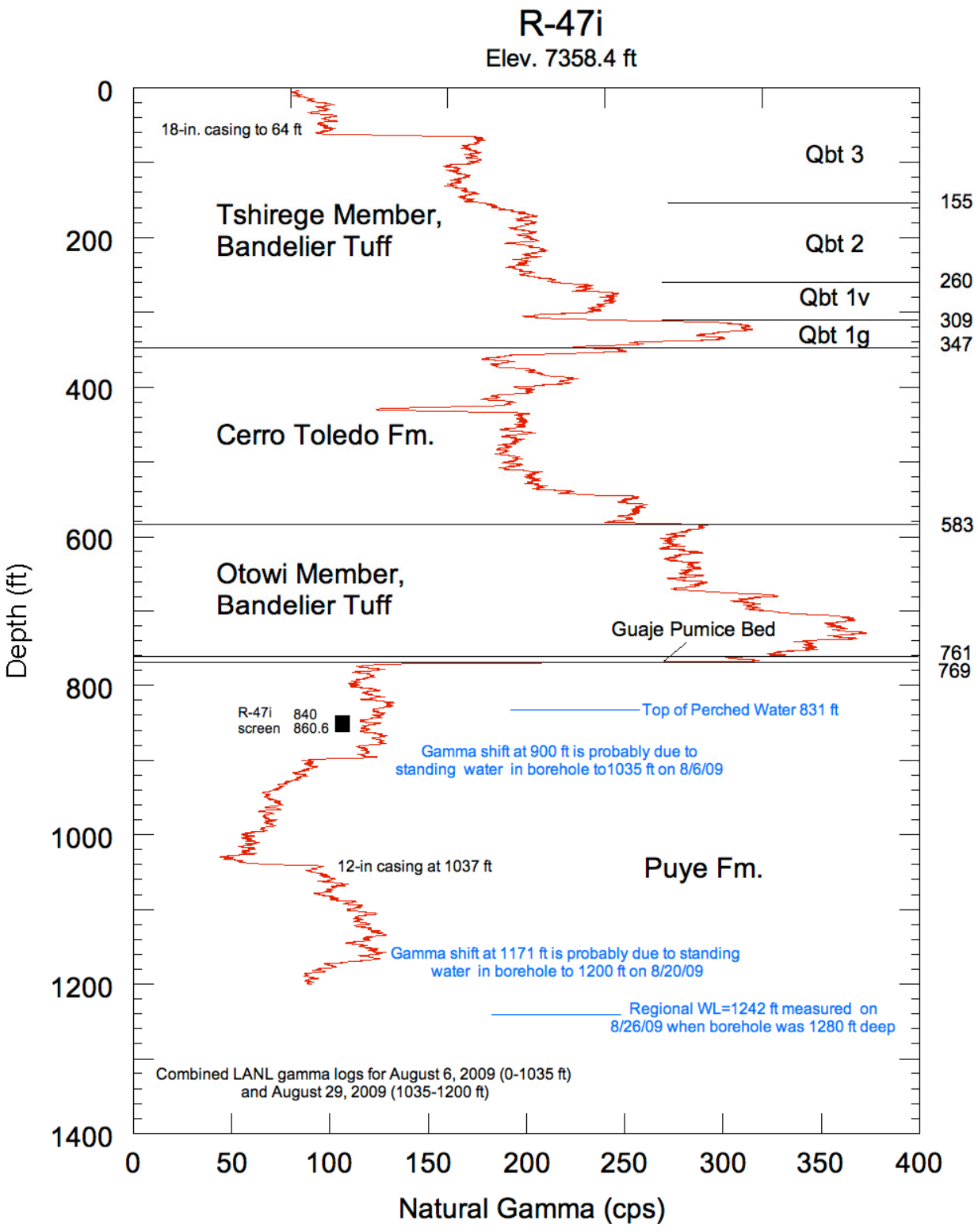


Figure A-45 Well R-47i geology and borehole gamma log

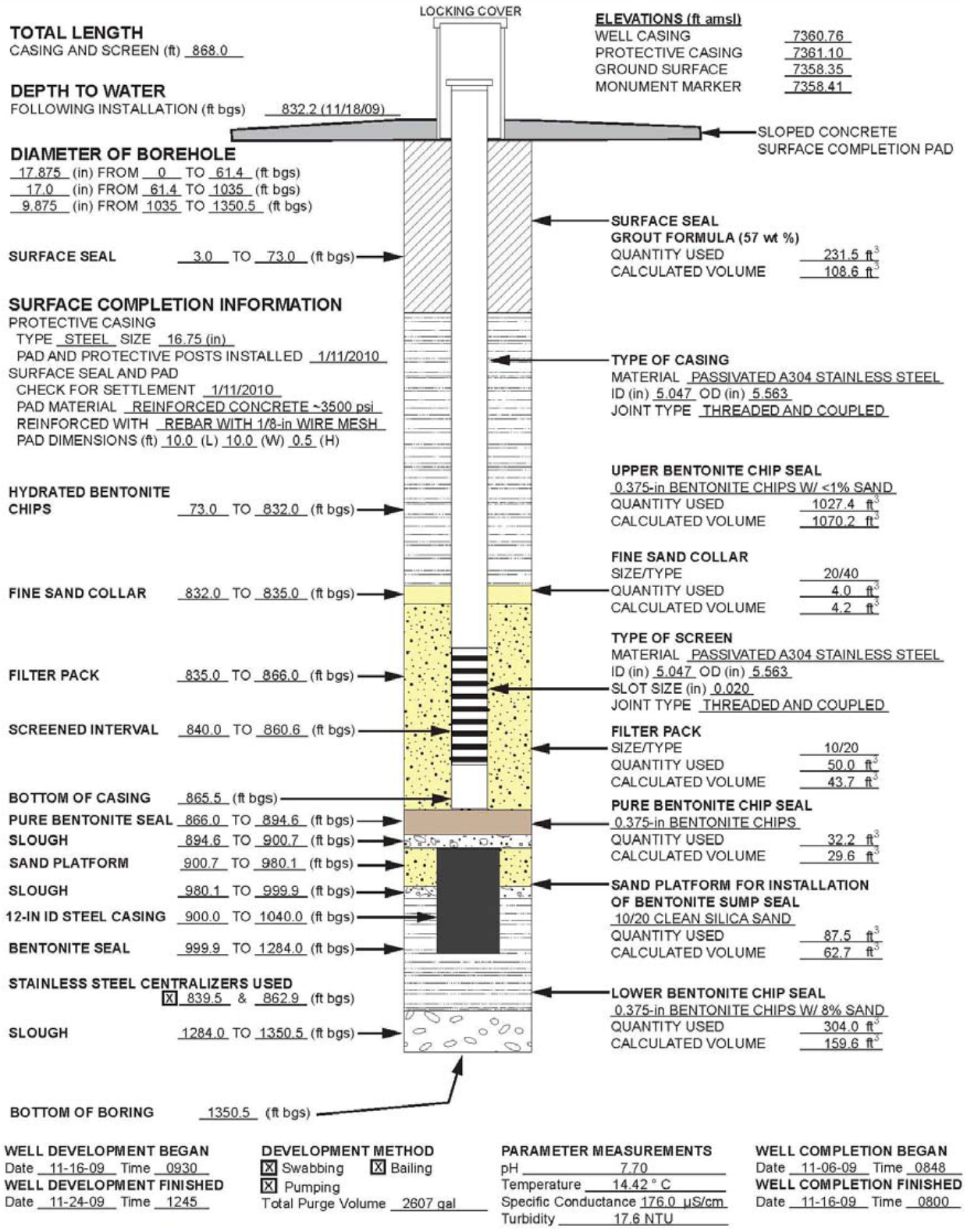


Figure A-46 R-47i well design

REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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Appendix B

Geochemical Performance of the Technical Area 16 Network Wells

B-1.0 PURPOSE

This appendix presents the results obtained in the evaluation of the representativeness of water-quality samples from groundwater monitoring wells assigned to monitoring for contaminants released from sources in Technical Area 16 (TA-16). Groundwater monitoring at Los Alamos National Laboratory (LANL or the Laboratory) is currently conducted in accordance with the 2011 Interim Facility-Wide Groundwater Monitoring Plan, Revision 1 (hereafter, the 2011 IFGMP R1) (LANL 2011, 208811). Wells scheduled for sampling under the IFGMP R1 that are part of the TA-16 monitoring network include the following 16 perched-intermediate and regional wells:

- 8 active single-screen wells in perched-intermediate groundwater: 16-26644, CdV-16-1(i), CdV-16-2(i)r, CdV-37-1(i), R-25b, R-26, R-26 PZ-2, and R-47i;
- 4 active single-screen wells in the regional aquifer: R-18, R-27, R-48, and R-63;
- 1 active multiscreen well (R-25) with 3 perched-intermediate screens and 4 regional groundwater screens; and
- 3 wells pending final configuration designs: perched-intermediate well CdV-16-4ip and regional groundwater wells CdV-R-15-3 and CdV-R-37-2.

Table B-1.0-1 summarizes information about screened intervals and sampling systems installed in these monitoring wells and the range of dates for which validated water-quality data are available for characterization and monitoring samples.

The objective of the evaluation is to determine whether the screened intervals in these wells are currently capable of providing samples representative of predrilling conditions for chemicals of potential concern (COPCs) originating from TA-16 sources, focusing on contaminants historically released from Consolidated Unit 16-021(c)-99 (the 260 Outfall) and other sources: high explosive (HE) compounds, barium, and volatile organic compounds (VOCs) (section 3.1). This evaluation updates the previous network evaluation conducted in 2007 and 2008 for the 260 Outfall (LANL 2007, 100113; LANL 2008, 101875.5). The previous evaluation included 7 of the 16 wells discussed in this report: CdV-16-1(i), CdV-16-2(i)r, CdV-R-15-3, CdV-R-37-2, R-18, R-25, and R-27. Samples through December 2006 were evaluated at that time using an approach described in the “Well Screen Analysis Report, Revision 1” (LANL 2007, 095043). The present evaluation is conducted following the approach applied to the assessment of wells in several recent reports, including R-47i (LANL 2011, 201564); three Westbay wells that were redeveloped in 2010 (LANL 2011, 205233); and TA-54 monitoring network wells as part of corrective measures evaluations for TA-54 Material Disposal Areas G, H, and L (LANL 2011, 206324; LANL 2011, 205756; LANL 2011, 206319). The primary differences are that the current approach considers a broader set of geochemical indicators than were used in the earlier evaluation and that it compares these concentrations with those in area-specific background locations instead of facility-wide background locations. However, although the evaluation protocol used in this report differs from that used for the previous evaluation, the two approaches reach similar conclusions.

B-2.0 RELIABILITY ASSESSMENT PROTOCOL

The specific objective of a reliability assessment is to determine the current effectiveness of a deep well (including its sampling system) as it relates to the water-quality data objectives of the specific monitoring network to which it is assigned, which, in this case, is the TA-16 monitoring network. An important component of the reliability assessment is comparison of water-quality data with those from groundwater

background locations, as described in section B-3.0. In general, a well capable of producing reliable water-quality data that meet monitoring objectives will have the following characteristics.

- Water-quality samples can be collected from the well in accordance with the prescribed sampling protocol.
- At locations where local contaminants are absent,
    - ❖ oxic conditions are present after the target volume of water has been purged;
    - ❖ analytical concentrations are generally stable and reproducible from one event to another (or vary in a predictable way), at least for constituents present above the practical quantitation limit (PQL);
    - ❖ concentrations of inorganic constituents generally fall within the ranges detected at area-specific background locations; and
    - ❖ target organic compounds are not detected consistently, if at all.
- At locations where local contaminants are present, some or none of the above characteristics may be present. In these cases, professional judgment is required to determine whether the observed geochemical concentrations and trends are consistent with a conceptual understanding of local contaminant sources and transport characteristics.

A well may be characterized as capable of producing reliable water-quality data even if minor issues are present, provided the conditions do not compromise data reliability for COPCs, or if these conditions are expected to resolve within the near future. The caveat “potentially capable” is applied to those wells for which insufficient data are available to determine whether an issue of concern has been or will be resolved.

The focus is on water-quality data obtained for the most recent sampling events. The types of data examined for the assessment include the following.

- Time-series data for field parameters monitored during purging are examined for stability by the end of purging. Time-series trends are also compared for a sequence of recent events at the same location (Figures B-2.0-1 to B-2.0-12). As appropriate, field sampling notes may be examined for observations of unusual odors, colors, or other indications of impacted water samples.
- Final field-parameter values associated with the sample at the time of collection (Table B-2.0-1) are compared with the range observed in area-specific groundwater background locations (section B-3.0). Emphasis is given to final values for dissolved oxygen (DO), specific conductivity, pH, and turbidity.
- Analytical data for common inorganic ions and trace metals (Tables B-2.0-2 and B-2.0-3) are examined for stability. Concentration profiles (hereafter, “fingerprint” plots) for each location facilitate quick visual identification of possible excursions from background geochemical conditions.
- Relative major-ion concentrations are compared with those for area-specific background groundwater on a trilinear (Piper) plot, a common graphical tool used to identify waters with similar chemistries.
- Detections of VOCs, semivolatile organic compounds (SVOCs), and HE compounds (Tables B-2.0-4 and B-2.0-5) are examined for the presence of TA-16 COPCs. The presence of

local contamination needs to be considered in the interpretation of inorganic constituents with concentrations falling outside the range of area-specific background groundwater.

- Tritium activities in groundwater (Table B-2.0-6) are commonly used to evaluate the presence of a component of modern water or local contamination. The presence or absence of tritium at a location may provide a useful tracer of flow and transport pathways because tritium travels conservatively in groundwater.
- Stable oxygen and hydrogen isotope values (Table B-2.0-7) are tracers of water source and evaporation history. Varying degrees of isotopic fractionation occurring in precipitation produce characteristic signatures in water that are used to estimate the elevation at which it originated and the extent to which it evaporated before infiltration. Some types of industrial discharges, such as from cooling towers, carry a distinctive isotopic signature as a result of evaporative enrichment of the heavier isotopes that provides a means to trace groundwater influenced by such a source.
- Stable oxygen and nitrogen isotope values in nitrate (Table B-2.0-7) are indicators of nitrate sources and microbial activity in groundwater. In a screen interval where residual organic drilling products are present, nitrate-reducing conditions commonly develop that produce distinctive heavy (more positive) stable nitrogen and oxygen isotopic values. Of particular relevance for the TA-16 monitoring well network, the stable oxygen isotopic value in nitrate associated with some TA-16 sources is considerably heavier than in normal nitrate in groundwater although the stable nitrogen isotope value is relatively unchanged (e.g., see isotopic data for CdV-16-4ip screen 1 and R-18 in Table B-2.0-7). This distinctive ^{18}O-enriched signal suggests the potential to use this signal to trace the migration of nitrate in groundwater originating from these sources at TA-16.

B-3.0 GROUNDWATER BACKGROUND VALUES FOR ASSESSMENT

For naturally occurring analytes, statistical summaries of water-quality data for background groundwater locations establish ranges of concentrations against which data from the assessed wells are compared as a preliminary assessment step. Representativeness may be assessed with specificity by comparing analytical concentrations with those in groundwater from other locations in sufficiently similar hydrogeologic settings and at which effects from downhole materials or local contaminants are absent or negligible. For the TA-16 network evaluation, area-specific groundwater background ranges are calculated using data from 12 locations:

- 4 perched-intermediate groundwater locations: PCI-2, R-26 screen 1, R-27i, Water Canyon Gallery; and
- 8 regional groundwater locations: CdV-R-15-3 screen 4, CdV-R-37-2 screen 3, R-17 screens 1 and 2, R-25 screens 7 and 8, R-27, and R-30.

Attachment B-1 (on CD) provides the data set used to calculate descriptive background statistics applicable to groundwater in the vicinity of TA-16. The preliminary data set is compiled from validated data produced by an outside analytical laboratory for recent samples from each of the 12 background locations. To create a relatively unbiased data set, each location contributes approximately the same number of samples so the background statistics are not skewed by the inclusion of a significantly larger number of results from any one location. Working backwards from the most recent sample collected from each location before December 31, 2011, earlier samples are included in the cumulative background data set until each location has contributed four results for major ions and trace metals. As a practical matter, more than four events must be included to reach this goal for some locations because only a limited set of analytical suites is collected for some events (e.g., a sample may be collected for analysis of major ions but none for trace metals).

This preliminary background data set is then examined to exclude outliers, suspect data, and data biased by the effects of drilling, construction, or development (Table B-3.0-1). These data are excluded from statistical calculations of background concentrations.

For statistical calculations, data categorized as nondetects following secondary validation are treated in one of two ways, depending upon the laboratory qualifier associated with the reported result. These data treatments are identified explicitly in Attachment B-1 using color-coded table cells:

- Results assigned a U-flag by the analytical laboratory—indicating the analyte was not detected above the minimum detection limit (MDL)—and reported by the analytical laboratory as less than the PQL were replaced with the MDL for statistical calculations.
- Results reported as detected by the analytical laboratory were used directly even if they were subsequently categorized as nondetect (U-flag) during secondary validation, provided the results are consistent with other results from that location (i.e., they are not outliers).

Descriptive statistics of the area-specific background groundwater data set are presented in Table B-3.0-2. Table B-3.0-3 presents 5th and 95th percentile values calculated from this data set. For comparison, Table B-3.0-3 also lists 95th percentile values for perched-intermediate and regional groundwater from the Groundwater Background Investigation Report, Update to Revision 4 (hereafter, GBIR, R4 Update) (LANL 2011, 207447). For all analytes (other than field parameters and total phosphate), 95th percentile concentrations of the area-specific background groundwater are less than the corresponding 95th percentiles for plateau-scale perched-intermediate and/or regional groundwater (Figure B-3.0-1). As a result of this more restricted range, area-specific background statistics provide a more discriminating screening tool than the plateau-scale background statistics for identifying potential water-quality excursions in samples from TA-16 network wells.

Relative major-ion chemistries in area-specific background groundwater cluster in distinct and well-defined fields on a trilinear (Piper) plot (Figure B-3.0-2). This characteristic reflects the common origin of background groundwaters (i.e., infiltration of mountain-front recharge with low total dissolved solids [TDS]).

Groundwater from the TA-16 monitoring network wells are compared with this area-specific groundwater background field in Figure B-3.0-3 for perched-intermediate wells and in Figure B-3.0-4 for regional wells. Many perched-intermediate and regional groundwaters plot outside the background field because of local contaminants and/or residual effects of drilling. These figures are referenced in the individual well assessments presented in section B-4.0.

B-4.0 RESULTS OF GEOCHEMICAL PERFORMANCE EVALUATION

Evaluation results are summarized below in terms of the present-day status of each screen interval with respect to its recovery from residual effects of drilling, construction, or rehabilitation activities and its present-day capability to meet geochemical monitoring objectives for the TA-16 monitoring well network. The wells are discussed in alphabetical order. The 5th and 95th percentile concentrations calculated from the area-specific groundwater background data set are included in the fingerprint plots for each location (Figures B-4.0-1 to B-4.0-27) to facilitate quick visual identification of possible excursions from background conditions.

Perched-Intermediate Well 16-26644

Well 16-26644 is capable of providing reliable water-quality data for TA-16 COPCs in groundwater based on the following observations for the most recent sampling events.

- Field parameters meet stability criteria when the screen is purged in accordance with Standard Operating Procedure (SOP) EP-DIV-SOP-20032, Groundwater Sampling (Figure B-2.0-1).
- Oxic conditions are present as indicated by consistent detection of DO between 7 mg/L and 8 mg/L (Table B-2.0-1), detectable concentrations of nitrate and perchlorate (Figure B-4.0-1 and Table B-2.0-2), and the absence of significant concentrations of iron and manganese in filtered samples (Figure B-4.0-1 and Table B-2.0-3).
- Local contaminants are present as indicated by detected concentrations of tetrachloroethene (PCE); trichloroethene (TCE); HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine); RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine); 1,3,5-trinitrobenzene; and associated HE-degradation products (Tables B-2.0-4 and B-2.0-5). Elevated concentrations of chloride and sulfate are also present because of local contaminants (Figure B-4.0-1 and Table B-2.0-2).
- Barium concentrations exceed those in area-specific background groundwater, as do perchlorate, most major ions, aluminum and nickel (Figure B-4.0-1 and Tables B-2.0-2 and B-2.0-3). Some of these geochemical conditions may be representative of shallow groundwater in Unit 3 of the Tshirege Member of the Bandelier Tuff.
- Tritium activities ranging from 14 pCi/L to 32 pCi/L (Table B-2.0-5) indicate the presence of a component of modern water.
- On trilinear and fingerprint plots, groundwater chemistry at this location is distinctly different from area-specific background chemistry but is similar to that at other locations at which TA-16 COPCs are present (Figures B-3.0-3 and B-4.0-1).
- No evidence is observed of the presence of residual organic constituents used during drilling or well construction. Total organic carbon (TOC) concentrations range up to 2.6 mg/L in recent samples (Table B-2.0-2) and generally exceed the 95th percentile value (0.9 mg/L, Table B-3.0-3) for area-specific background groundwater. However, TOC at this location is associated with local contaminants and does not indicate the presence of residual drilling effects.
- No evidence is observed of the presence of residual inorganic drilling or construction products.
- No evidence is observed of the presence of a significant quantity of formation solids in water samples. Turbidity stabilizes quickly during purging (Figure B-2.0-1), with final values less than 5 nephelometric turbidity units (NTU) (Table B-2.0-1). Minor quantities of particulates are indicated by elevated concentrations of aluminum and iron in unfiltered samples (Table B-2.0-3).

Perched-Intermediate Well CdV-16-1(i)

Well CdV-16-1(i) is capable of providing reliable water-quality data for TA-16 COPCs in groundwater based on the following observations for the most recent sampling events.

- Field parameters meet stability criteria when the screen is purged in accordance with EP-DIV-SOP-20032 (Figure B-2.0-2). Drifting specific conductance values recorded during purging for the sampling events in April and September 2011 are a consequence of effervescence in the groundwater (Table B-2.0-1).

- Oxic conditions are present as indicated by consistent detection of DO between 5 mg/L and 7 mg/L (Table B-2.0-1); detectable concentrations of nitrate and perchlorate (Figure B-4.0-2 and Table B-2.0-2); and the absence of significant concentrations of iron and manganese in filtered samples (Figure B-4.0-2 and Table B-2.0-3).
- Local contaminants present at this location include boron, methyl tert-butyl ether, PCE, toluene, HMX, RDX, and HE-degradation products (Tables B-2.0-3 to B-2.0-5). Elevated concentrations of chloride and sulfate are also present because of local contaminants (Figure B-4.0-2 and Table B-2.0-2).
- Tritium activities ranging up to 55 pCi/L (Table B-2.0-5) indicate the presence of a component of modern water.
- On trilinear and fingerprint plots, groundwater chemistry at this location is different from area-specific background chemistry but is similar to that at other locations at which TA-16 COPCs are present (Figures B-3.0-3 and B-4.0-2).
- No evidence is observed of the presence of residual organic constituents used during drilling or well construction. TOC concentrations range up to 1.3 mg/L in recent samples (Table B-2.0-2) and generally exceed the 95th percentile value (0.9 mg/L, Table B-3.0-3) for area-specific background groundwater. However, TOC at this location is associated with local contaminants and does not indicate the presence of residual drilling effects.
- No evidence is observed of the presence of residual inorganic drilling or construction products. Concentrations of most major ions extend above the 95th percentile values for area-specific background groundwater, but their stability indicates these concentrations are representative of local conditions (Figure B-4.0-2).
- No evidence is observed of the presence of a significant quantity of formation solids in water samples. Turbidity stabilizes quickly during purging (Figure B-2.0-2), with final values less than 5 NTU (Table B-2.0-1), and concentrations of aluminum and iron are negligibly low or not detected in unfiltered samples (Table B-2.0-3).

Perched-Intermediate Well CdV-16-2(i)r

Well CdV-16-2(i)r is capable of providing reliable water-quality data for TA-16 COPCs in groundwater based on the following observations for the most recent sampling events.

- Field parameters meet stability criteria when the screen is purged in accordance with EP-DIV-SOP-20032 (Figure B-2.0-3).
- Oxic conditions are present as indicated by consistent detection of DO between 6 mg/L and 8 mg/L (Table B-2.0-1); detectable concentrations of nitrate and perchlorate (Figure B-4.0-3 and Table B-2.0-2); and the absence of significant concentrations of iron and manganese in filtered samples (Figure B-4.0-3 and Table B-2.0-3).
- Local contaminants present at this location include methyl tert-butyl ether, PCE, toluene, TCE, HMX, RDX, 1,3,5-trinitrobenzene, and HE-degradation products (Tables B-2.0-4 to B-2.0-5). Elevated concentrations of sulfate (Figure B-4.0-3 and Table B-2.0-2) are also present because of local contaminants.
- Tritium activities ranging up to 7 pCi/L (Table B-2.0-6) indicate the presence of a small component of modern water.

- On trilinear and fingerprint plots, the groundwater chemistry at this location is different from area-specific background chemistry but is similar to that at other locations at which TA-16 COPCs are present (Figures B-3.0-3 and B-4.0-3).
- No evidence is observed of the presence of residual organic constituents used during drilling or well construction. TOC concentrations are consistently less than 1 mg/L (Table B-2.0-2).
- No evidence is observed of the presence of residual inorganic drilling or construction products. Concentrations of some major ions (e.g., chloride, sulfate, nitrate) extend slightly above the 95th percentile values for area-specific background groundwater but their stability indicates these concentrations are representative of local conditions (Figure B-4.0-3).
- No evidence is observed of the presence of a significant quantity of formation solids in water samples. Turbidity stabilizes during purging, consistently attaining final values less than 5 NTU (Figure B-2.0-3 and Table B-2.0-1). Minor quantities of particulates in some samples are indicated by slightly elevated concentrations of aluminum and iron in unfiltered samples (Table B-2.0-3).

Perched-Intermediate Well CdV-16-4ip Screen 1

Well CdV-16-4ip screen 1 is capable of providing reliable water-quality data for TA-16 COPCs in groundwater based on the following observations for two sampling events.

- Oxic conditions are present as indicated by detection of 9 mg/L DO (Table B-2.0-1); detectable concentrations of nitrate and perchlorate (Figure B-4.0-4 and Table B-2.0-2); and the absence of significant concentrations of iron and manganese in filtered samples (Figure B-4.0-4 and Table B-2.0-3).
- Local contaminants present at this location include boron, methyl tert-butyl ether, PCE, toluene, TCE, HMX, RDX, 1,3,5-trinitrobenzene, and HE-degradation products (Tables B-2.0-3 to B-2.0-5). Elevated concentrations of chloride and sulfate are also present because of local contaminants (Figure B-4.0-4 and Table B-2.0-2). Slightly elevated nitrate concentrations (about 1 mg/L as N, Table B-2.0-2) may also derive from TA-16 sources, based on the distinctive ^{18}O-enriched signal (+8 permil, compared with background ranging from −5 to +1 permil) (Table B-2.0-7).
- Tritium activities up to 16 pCi/L (Table B-2.0-6) indicate the presence of a component of modern water.
- On trilinear and fingerprint plots, groundwater chemistry at this location is different from area-specific background chemistry but is similar to that at other locations at which TA-16 COPCs are present (Figures B-3.0-3 and B-4.0-4).
- No evidence is observed of the presence of residual organic constituents used during drilling or well construction. TOC concentrations range up to 1.5 mg/L in recent samples (Table B-2.0-2), exceeding the 95th percentile value (0.9 mg/L, Table B-3.0-3) for area-specific background groundwater. However, TOC at this location is associated with local contaminants and does not indicate the presence of residual drilling effects.

- No evidence is observed of the presence of residual inorganic drilling or construction products. Concentrations of perchlorate and some major ions (chloride, sulfate, and nitrate) exceed the 95th percentile values for area-specific background groundwater (Figure B-4.0-4). However, these constituents are associated with local contaminants, not drilling or construction products.
- No evidence is observed of the presence of a significant quantity of formation solids in the last water sample collected from this screen. Final turbidity was less than 5 NTU (Table B-2.0-1). Concentrations of aluminum and iron are not notably elevated in unfiltered samples (Table B-2.0-3).

Perched-Intermediate Well CdV-16-4ip Screen 2

Well CdV-16-4ip screen 2 is potentially capable of providing reliable water-quality data for TA-16 COPCs in groundwater based on the following observations for three sampling events. The chemistry of the first sample (September 2010) is dominated by cross-flow from screen 1. Subsequent samples (November 2010 and March 2011) show steadily decreasing proportions of cross-flow chemistry.

- Oxic conditions are present as indicated by detection of 6 mg/L to 9 mg/L DO (Table B-2.0-1); detectable concentrations of nitrate and perchlorate (Figure B-4.0-5; Tables B-2.0-2 and B-2.0-3); and the absence of significant concentrations of iron and manganese in filtered samples (Figure B-4.0-5 and Table B-2.0-3).
- Local contaminants present in the last two samples from this location include methyl tert-butyl ether, toluene, HMX, and RDX (November 2010 and March 2011, Tables B-2.0-4 and B-2.0-5).
- Low tritium activities (Table B-2.0-6) indicate the presence of a component of modern water. Tritium activities have decreased steadily from a peak value of 19 pCi/L (similar to that measured in screen 1) in the first sample (September 2010) to 3 pCi/l in the last sample (March 2011). Nitrate concentrations and associated stable oxygen values for nitrate are similar to those in screen 1 in the first sample but close to background levels in the last one (Figure B-4.0-5; Tables B-2.0-2 and B-2.0-7).
- On trilinear and fingerprint plots, groundwater chemistry at this location is similar to that in screen 1 for the first sample and approaches the range of local background in the last sample (Figures B-3.0-3 and B-4.0-5).
- No evidence is observed of the presence of residual organic constituents used during drilling or well construction. TOC decreased to a negligible concentration of 0.4 mg/L in the last sample (March 2011, Table B-2.0-2) and is within the range of area-specific background groundwater.
- No evidence is observed of the presence of residual inorganic drilling or construction products. Concentrations of chloride, sulfate, and nitrate extend slightly above the 95th percentile values for area-specific background groundwater (Figure B-4.0-5). However, these constituents are associated with local contaminants previously carried into the screen interval by cross-flow from screen 1, not with drilling or construction products.
- No evidence is observed of the presence of a significant quantity of formation solids in the last water sample collected from this screen. In the last sample (March 2011), final turbidity is less than 1 NTU (Table B-2.0-1), and concentrations of aluminum and iron are not notably elevated in unfiltered samples (Table B-2.0-3).

Perched-Intermediate Well CdV-37-1(i)

Well CdV-37-1(i) potentially is capable of providing reliable water-quality data for TA-16 COPCs in groundwater. Groundwater in the vicinity of the screen may not have completely reequilibrated following drilling, construction, and development activities. However, water-quality trends show residual effects are decreasing and limited to only a few analytes.

- Oxic conditions are present as indicated by consistent detection of 8 mg/L DO (Table B-2.0-1); generally detectable concentrations of nitrate and perchlorate (Figure B-4.0-6; Table B-2.0-2); and the absence of significant concentrations of iron in filtered samples (Figure B-4.0-6 and Table B-2.0-3).
- Tritium, chlorinated solvents, and HE are not detected (Tables B-2.0-4 to B-2.0-6). Boron and barium are not detected above local background concentrations (Figure B-4.0-6 and Table B-2.0-3).
- On trilinear and fingerprint plots, groundwater chemistry at this location is approaching the range of local background (Figures B-3.0-3 and B-4.0-6).
- Residual organic constituents used introduced by drilling, construction, or sampling equipment may be present. TOC concentrations are within the range of area-specific background groundwater, but low concentrations of toluene have been detected in all samples, following a decreasing trend (Table B-2.0-4).
- Residual inorganic constituents derived from drilling products may be present. Decreasing sodium and sulfate concentrations still exceeding those in area-specific background groundwater (Figure B-4.0-6 and Table B-2.0-2) may reflect the presence of residual AQF-2.
- No evidence is observed of the presence of a significant quantity of formation solids in water samples collected from this well. Turbidity is less than 5 NTU (Table B-2.0-1), and concentrations of aluminum and iron detected in unfiltered samples (Table B-2.0-3) are within background levels.

Regional Aquifer Well CdV-R-15-3 Screens 4, 5, and 6

Regional screens in well CdV-R-15-3 were redeveloped in May 2011 as part of the Westbay study (LANL 2011, 205233); only one post-redevelopment sample from each screen is available. The following summary is based on the results of that study.

Screen 4 is capable of producing representative water-quality data. This conclusion is based on multiple lines of evidence provided by time-series field parameters during purging, historical water-quality data, and the geochemical stability of groundwater in this screen.

- Oxic conditions are present in samples collected before as well as after redevelopment (Table B-2.0-1; also LANL 2011, 205233).
- Water chemistry in samples collected before as well as after redevelopment is similar to chemistries at other locations used to characterize area-specific background groundwater (Figures B-3.0-2 and B-4.0-7).
- Tritium, chlorinated solvents, and HE are not detected (Tables B-2.0-4 to B-2.0-6). Toluene detected in samples collected during and after redevelopment was not present in samples collected before redevelopment and was likely introduced during redevelopment activities; it is expected to disappear over time (LANL 2011, 205233).

Screen 5 is not capable of producing representative water-quality data. This conclusion is based on multiple lines of evidence provided by time-series field parameters during purging and historical water-quality data, and groundwater geochemistry following redevelopment in this screen.

- Reducing conditions are present in samples collected before redevelopment, based on nondetects for nitrate and perchlorate and elevated concentrations of manganese (Tables B-2.0-2 and B-2.0-3; also LANL 2011, 205233). Although these conditions improved following redevelopment, low DO concentrations (2 mg/L, Table B-2.0-1) may indicate they are likely to return.
- Water chemistries in samples collected before as well as after redevelopment are distinctly different from that in area-specific background groundwater (Figures B-3.0-4 and B-4.0-8). Water quality before and after redevelopment is characterized by elevated concentrations of manganese, barium, and strontium, which may indicate this well screen remains compromised by bentonite (Appendix A, this report).
- Tritium, chlorinated solvents and HE are not detected (Tables B-2.0-4 to B-2.0-6). Toluene detected in samples collected during and after redevelopment was not present in samples collected before redevelopment and was likely introduced during redevelopment activities; it is expected to disappear over time (LANL 2011, 205233).
- Purging and redevelopment of screen 5 appears to have been effective for removing mobile fractions of residual organic and inorganic constituents but had limited effectiveness in restoring the composition and distribution of reactive mineral phases to predrilling conditions (LANL 2011, 205233).

Screen 6 may be capable of producing representative water-quality data after purging, but a longer period of record is needed to determine if manganese concentrations decrease and other parameters remain stable with time.

- During redevelopment activities, most field parameters remained stable during the 10 casing volume (CV) purge that followed the removal of cross-flow (LANL 2011, 205233).
- With the exception of manganese and perchlorate, water chemistry in samples collected before as well as after redevelopment is similar to area-specific background groundwater (Figure B-3.0-4 and B-4.0-9). Manganese concentrations exceed background levels before as well as after redevelopment.
- Tritium, chlorinated solvents, and HE are not detected (Tables B-2.0-4 to B-2.0-6). Toluene detected in samples collected during and after redevelopment was not present in samples collected before redevelopment and was likely introduced during redevelopment activities; it is expected to disappear over time (LANL 2011, 205233).

Regional Aquifer Well CdV-R-37-2 Screens 2, 3, and 4

Regional screens in well CdV-R-37-2 were redeveloped in April 2011 as part of the Westbay study (LANL 2011, 205233); only one post-redevelopment sample from each screen is available. The following summary is based largely on the results of that study.

Screen 2 may be capable of producing representative water-quality data after purging, but a longer period of record is needed to determine whether or not redevelopment resulted in sustainable improvement in geochemical conditions.

- Previous evaluations of this screen concluded it was one of the most severely impacted screens among those equipped with Westbay sampling systems (e.g., LANL 2007, 096330). This conclusion was based on multiple lines of geochemical evidence for severely reducing conditions that persisted in screen 2 since collection of the first sample on January 4, 2001.
- Water chemistry in samples collected before redevelopment is distinctly different from area-specific background groundwater, particularly for relative and absolute concentrations of major anions as well as many trace metals (Figures B-3.0-4 and B-4.0-10). Following redevelopment, the restored water chemistry is similar to area-specific background groundwater (Figure B-4.0-10).
- Iron and manganese concentrations decreased significantly as a result of redevelopment. Iron concentrations decreased from 13,100 µg/L before redevelopment to 44 µg/L afterwards, and manganese concentrations dropped from 967 µg/L to 201 µg/L (Table B-2.0-3). However, manganese concentrations still exceed background levels after redevelopment and may indicate this well screen remains compromised (Figure B-2.0-10).
- Tritium, chlorinated solvents, and HE are not detected (Tables B-2.0-4 to B-2.0-6). Boron and barium are not detected above local background concentrations after redevelopment. Toluene detected in samples collected during and after redevelopment was not present in samples collected before redevelopment and was likely introduced during redevelopment activities; it is expected to disappear over time (LANL 2011, 205233).

Screen 3 is capable of producing representative water-quality data. This conclusion is based on multiple lines of evidence provided by time-series field parameters during purging, historical water-quality data, and the geochemical stability of groundwater in this screen.

- Oxic conditions are present in samples collected before as well as after redevelopment (Table B-2.0-1; also LANL 2011, 205233).
- Water chemistry in samples collected before as well as after redevelopment is similar to chemistries at other locations used to characterize area-specific background groundwater (Figures B-3.0-2 and B-4.0-11).
- Boron, tritium, chlorinated solvents, and HE are not detected (Tables B-2.0-3 to B-2.0-6). Barium is not detected above concentrations in local background groundwater. Toluene detected in samples collected during and after redevelopment was not present in samples collected before redevelopment and was likely introduced during redevelopment activities; it is expected to disappear over time (LANL 2011, 205233).

Screen 4 may be capable of producing representative water-quality data after purging, but a longer period of record is needed to determine whether or not redevelopment resulted in sustainable improvement in geochemical conditions.

- Oxic conditions are present in samples collected before as well as after redevelopment (Table B-2.0-1; also LANL 2011, 205233).
- Water chemistry in samples collected before as well as after redevelopment is similar to area-specific background groundwater (Figures B-3.0-4 and B-4.0-12).

- Boron, tritium, chlorinated solvents, and HE are not detected (Tables B-2.0-3 to B-2.0-6). Barium is not detected above local background concentrations (Figure B-4.0-12 and Table B-2.0-3).
- Toluene detected in samples collected during and after redevelopment was not present in samples collected before redevelopment and was likely introduced during redevelopment activities; it is expected to disappear over time (LANL 2011, 205233).

Regional Aquifer Well R-18

Well R-18 is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations.

- Field parameters meet stability criteria when the well is purged in accordance with EP-DIV-SOP-20032 (Figure B-2.0-5).
- Oxic conditions are present as indicated, for example, by consistent detections of 5 mg/L to 6 mg/L DO as well as nitrate and perchlorate (Tables B-2.0-1 and B-2.0-2).
- Local contaminants present at this location include RDX as well as 1,3,5-trinitrobenzene in recent samples (Table B-2.0-5). Boron and chlorinated solvents are not detected, and barium is not detected above concentrations in local background groundwater (Figure B-4.0-13; Tables B-2.0-3 and B-2.0-4). Low levels of tritium have been detected in three of the nine samples collected since January 2009 (Table B-2.0-6). Nitrate concentrations are elevated above that in local background groundwater; the heavy stable-oxygen ratio in nitrate from this well (similar to that in nitrate at CdV-16-4ip screen 1) may indicate the presence of nitrate associated with TA-16 sources (Table B-2.0-7).
- Other than nitrate, the water chemistry is similar to area-specific background groundwater (Figures B-3.0-4 and B-4.0-13).
- No evidence is observed of the presence of residual inorganic or organic drilling or construction products. TOC is less than 1 mg/L (Table B-2.0-2).
- No evidence is observed of the presence of a significant quantity of formation solids in water quality samples. Turbidity is stable and less than 1 NTU (Table B-2.0-1). Aluminum and iron concentrations are nondetect or negligibly low in filtered and unfiltered samples (Table B-2.0-3).

Regional Aquifer Well R-25

Well R-25 is instrumented with a nonpurgeable Westbay sampling system. As discussed below, some screen intervals are impacted by steel corrosion products manifested by elevated trace-metal concentrations.

Screen 1 is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations.

- Oxic conditions are present based on consistent detection of 5-7 mg/L DO as well as nitrate and perchlorate (Figure B-4.0-14; Tables B-2.0-1 and B-2.0-2).
- Local contaminants present at this location include boron; methyl tert-butyl ether; PCE; TCE; HMX; RDX; 2,4,6-trinitrotoluene (TNT); 1,3,5-trinitrobenzene; and HE-degradation products (Tables B-2.0-3 to B-2.0-5). Low tritium activities are present (Table B-2.0-6). Elevated concentrations of chloride and sulfate are also present due to local contaminants. Barium is not

detected above local background groundwater concentrations (Figure B-4.0-14 and Table B-2.0-3).

- Major-ion chemistry is distinctly different from area-specific background groundwater chemistry but similar to that at other locations where these COPCs are present (Figures B-3.0-3 and B-4.0-14).
- Metal corrosion products present in the screened interval are responsible for elevated concentrations of nickel, manganese, cobalt, and chromium (Figure B-4.0-14 and Table B-2.0-3). As a result, turbidity is also higher than is typical of local groundwater background (Table B-2.0-1). None of these trace metals are TA-16 contaminants.

Screen 2 is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations.

- Oxic conditions are present based on consistent detection of 4 mg/L to 9 mg/L DO as well as nitrate and perchlorate (Figure B-4.0-15; Tables B-2.0-1 and B-2.0-2).
- Local contaminants present at this location include boron, methyl tert-butyl ether, TCE, HMX, RDX, and HE-degradation products (Tables B-2.0-3 to B-2.0-5). PCE, TNT, and 1,3,5-trinitrobenzene are also detected occasionally (Tables B-2.0-4 and B-2.0-5). Low tritium activities are present (Table B-2.0-6). Elevated concentrations of chloride and sulfate are also present due to local contaminants (Figure B-4.0-15 and Table B-2.0-2). Barium is not detected (Figure B-4.0-15 and Table B-2.0-3).
- Major-ion chemistry is distinctly different from area-specific background groundwater chemistry but similar to that at other locations where these COPCs are present (Figures B-3.0-3 and B-4.0-15).
- Metal corrosion products present in the screened interval are responsible for highly elevated concentrations of iron, nickel, manganese, cobalt, and chromium (Figure B-4.0-15; Table B-2.0-3). None of these are TA-16 contaminants.

Screen 4 is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations.

- Conditions in this screen may cycle between oxic and slightly reducing based on variability in the concentrations of several redox indicators, including nitrate, perchlorate, iron, and manganese (Figure B-4.0-16; Tables B-2.0-2 and B-2.0-3). This condition is likely representative of ambient water quality.
- Local contaminants present at this location include boron, methyl tert-butyl ether, RDX, and HE-degradation products (Tables B-2.0-3 to B-2.0-5). PCE, TCE, and HMX are also detected occasionally (Tables B-2.0-4 and B-2.0-5). Low tritium activities are present (Table B-2.0-6). Elevated concentrations of chloride and sulfate are also present because of local contaminants (Figure B-4.0-16 and Table B-2.0-2). Barium is not detected above concentrations in local background groundwater (Figure B-4.0-16 and Table B-2.0-3).
- Major-ion chemistry is distinctly different from area-specific background groundwater chemistry but similar to that at other locations where these COPCs are present (Figures B-3.0-3 and B-4.0-16).
- Low concentrations of metal corrosion products present in the screened interval are responsible for slightly elevated concentrations of nickel and manganese (Figure B-4.0-16 and Table B-2.0-3).

Screen 5 is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations.

- Sampling was limited to prioritized suites for four of the five most recent sampling events because the formation was sampled dry (Table B-2.0-1).
- Slightly reducing conditions are present in this screen, based on nondetects and negligibly low concentrations of nitrate and perchlorate (Figure B-4.0-17; Tables B-2.0-2 and B-2.0-3). This condition is likely representative of ambient water quality.
- Local contaminants present at this location include boron, methyl tert-butyl ether, HMX, and RDX (Tables B-2.0-3 to B-2.0-5). Low tritium activities are present (Table B-2.0-6). Elevated concentrations of chloride and sulfate are also present because of local contaminants (Figure B-4.0-17 and Table B-2.0-2). Barium is not detected above concentrations in local background groundwater (Figure B-4.0-17 and Table B-2.0-3).
- Major-ion chemistry is distinctly different from area-specific background groundwater chemistry but similar to that at other locations where these COPCs are present (Figures B-3.0-4 and B-4.0-17).
- Elevated phosphate concentrations indicate the presence of residual sodium-acid pyrophosphate (SAPP) used during well development. Over the past 3 yr, total phosphate concentrations in groundwater at this location average about 2 mg/L (as phosphorus). For comparison, this analyte was detected only in 9 of 39 samples in local groundwater background samples, with a maximum detected value of 0.2 mg/L.

Screen 6 is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations.

- Oxic conditions are present based on consistent detections of DO above 5 mg/L as well as nitrate and perchlorate (Figure B-4.0-18; Tables B-2.0-1 and B-2.0-2).
- Local contaminants are not present at this location. Tritium, chlorinated solvents, and HE are not detected (Tables B-2.0-4 to B-2.0-6); barium and boron are not detected above local background groundwater concentrations (Figure B-4.0-18 and Table B-2.0-3).
- Inorganic water chemistry differs slightly from that at area-specific background groundwater chemistry (Figures B-3.0-4 and B-4.0-18), which may be related to the presence of residual phosphate derived from SAPP used during well development. Over the past 3 yr, total phosphate concentrations in groundwater at this location have averaged about 0.7 mg/L (as phosphorus).

Screen 7 is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations.

- Oxic conditions are present based on consistent detections of DO above 7 mg/L as well as nitrate and perchlorate (Figure B-4.0-19; Tables B-2.0-1 and B-2.0-2).
- Low concentrations of TNT (about 0.2 µg/L) are detected consistently (Table B-2.0-5). Tritium, chlorinated solvents, and other HE are not detected; barium and boron are not detected above local groundwater background concentrations (Figure B-4.0-19; Tables B-2.0-3 to B-2.0-6).
- Inorganic water chemistry is similar to that at other locations used to characterize area-specific background groundwater (Figures B-3.0-2 and B-4.0-19).

Screen 8 is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations.

- Oxic conditions are present based on consistent detections of DO above 6 mg/L as well as nitrate and perchlorate (Figure B-2.0-20; Tables B-2.0-1 and B-2.0-2).
- Local contaminants are not present at this location. Tritium, chlorinated solvents, and HE are not detected; barium and boron are not detected above local background groundwater concentrations (Figure B-4.0-20; Tables B-2.0-3 to B-2.0-6).
- Inorganic water chemistry is similar to those at other locations used to characterize area-specific background groundwater (Figures B-3.0-2 and B-4.0-20).

Perched-Intermediate Well R-25b

Well R-25b is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations.

- Field parameters meet stability criteria when the well is purged in accordance with EP-DIV-SOP-20032, although field-data trends during purging indicate heterogeneity in water chemistry in the vicinity of the screen and turbidity increases during purging when the water level approaches the bottom of the screen (Figure B-2.0-6).
- Oxic conditions are present as indicated, for example, by consistent detections of DO above 4 mg/L as well as nitrate and perchlorate (Figure B-4.0-21; Tables B-2.0-1 and B-2.0-2).
- Local contaminants detected consistently at this location include boron, HMX and RDX; 4-amino-2,6-dinitrotoluene is detected in two of the five samples collected since April 2010 (Figure B-4.0-21; Tables B-2.0-3 and B-2.0-5). Low PCE concentrations are detected in 2 of the 5 samples collected since April 2010 (Table B-2.0-4). Low levels of tritium are present (Table B-2.0-6). Elevated concentrations of sulfate are also present because of local contaminants. Barium is not detected above concentrations in local background groundwater (Figure B-4.0-21 and Table B-2.0-3).
- Major-ion chemistry is distinctly different from area-specific background groundwater chemistry (Figures B-3.0-3 and B-4.0-21). Molybdenum concentrations are elevated above local background levels but show a steady decline (Figure B-4.0-21 and Table B-2.0-3)
- No clear evidence is observed of the presence of residual inorganic or organic drilling or construction products. TOC is less than 1 mg/L (Table B-2.0-2).
- Some formation solids are present in water quality samples. Final sample turbidities average about 10 NTU (Table B-2.0-1). A particulate fraction is indicated by elevated concentrations of aluminum (483 µg/L to 1250 µg/L) and iron (258 µg/L to 583 µg/L) in unfiltered samples (Table B-2.0-3).

Perched-Intermediate Well R-26 Screen 1

Well R-26 was redeveloped in June 2011 as part of the Westbay study, after which this well was reconfigured with a single screen in the perched-intermediate zone (LANL 2011, 205233). Three post-redevelopment samples are available from this screen.

Well R-26 is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations. This conclusion is based on multiple lines of evidence provided by time-series field

parameters during purging, historical water-quality data, and the geochemical stability of groundwater in this screen.

- Field parameters meet stability criteria when the well is purged in accordance with EP-DIV-SOP-20032 (Figure B-2.0-7).
- Oxic conditions are present in samples collected before as well as after redevelopment. This conclusion is based on the stability of several redox indicators, including detections of DO above 7 mg/L, detected concentrations of nitrate and perchlorate, the absence of detectable iron concentrations in filtered samples, and negligibly low concentrations of manganese (Figure B-4.0-22; Tables B-2.0-1 to B-2.0-3; also LANL 2011, 205233).
- Water chemistry in samples collected before as well as after redevelopment is similar to chemistries at other locations used to characterize area-specific background groundwater (Figures B-3.0-2 and B-4.0-22).
- Boron, tritium, chlorinated solvents, and HE are not detected (Tables B-2.0-3 to B-2.0-6). Barium is not detected above concentrations observed in other locations used to characterize area-specific background groundwater (Figure B-3.0-22).
- Toluene detected in samples collected during and after redevelopment was not present in samples collected before redevelopment and was likely introduced during redevelopment activities; it is expected to disappear over time (Table B-2.0-4; also LANL 2011, 205233). Acetone detected after redevelopment (Table B-2.0-4) was likewise absent from samples collected before redevelopment and is likely to be related to redevelopment activities. This analyte is expected to disappear within the next few months.

Perched-Intermediate Piezometer R-26 PZ-2

Piezometer R-26 PZ-2 is not capable of providing reliable water-quality data for TA-16 COPCs based on the following observations.

- The piezometer cannot be purged because of a very low recharge rate, and its small diameter necessitates the use of a bailer to collect water samples, which affects the reliability of VOC data.
- Generally insufficient water is available to bail more than 1 CV, which is about 0.5 gal. (Table B-2.0-1, Figure B-2.0-8), and only a limited analytical suite can be collected.
- Water chemistry is different from area-specific background groundwater and also differs from groundwater chemistry at other locations in the TA-16 monitoring well network where local contaminants are present (Figures B-3.0-3 and B-4.0-23).
- Turbidity is very high, generally greatly in excess of 100 NTU (Table B-2.0-1). Concentrations of cobalt, manganese, molybdenum, nickel, and zinc are variably high (Figure B-4.0-23 and Table B-2.0-3).
- PCE is detected consistently (Table B-2.0-4). HE, other VOCs, and boron are not detected (Tables B-2.0-3 to B-2.0-5). No tritium data are available for this location.

Regional Aquifer Well R-27

Well R-27 is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations.

- Field parameters meet stability criteria when the well is purged in accordance with EP-DIV-SOP-20032 (Figure B-2.0-9).
- Oxic conditions are present based on the stability of several redox indicators, including consistent detection of DO averaging 7 mg/L, detected perchlorate concentrations, and the absence of detectable iron and manganese concentrations (Figure B-4.0-24; Tables B-2.0-1 to B-2.0-3).
- Water chemistry in samples collected before and after redevelopment is similar to chemistries at other locations used to characterize area-specific background groundwater (Figures B-3.0-2 and B-4.0-24).
- Tritium, chlorinated solvents, and HE are not detected (Tables B-2.0-3 to B-2.0-6). Boron and barium are not detected above concentrations observed in other locations used to characterize area-specific background groundwater (Figure B-4.0-24 and Table B-2.0-3).

Perched-Intermediate Well R-47i

Well R-47i is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations. The reliability of water-quality data from this well was previously evaluated in March 2011 (LANL 2011, 201564). Four sampling events have occurred since that report was issued. The following summary updates the results of the earlier assessment.

- Field parameters meet stability criteria when the well is purged in accordance with EP-DIV-SOP-20032 (Figure B-2.0-10). Drifting specific conductance values recorded during purging, particularly for the April 2011 event, are a consequence of effervescence in the groundwater (Table B-2.0-1).
- Oxic conditions are present based on consistent detection of DO above 5 mg/L, detected nitrate and perchlorate concentrations, and the absence of significant concentrations of iron and manganese concentrations (Figure B-4.0-25; Tables B-2.0-1 to B-2.0-3).
- Geochemical effects arising from drilling and construction activities are apparent in the first water-quality sample collected following development (LANL 2011, 201564). Water-quality trends from subsequent sampling show steady improvement. For the most recent sampling events, residual effects are limited to elevated concentrations of TOC (2 mg/L, Table B-2.0-2) and a few inorganic constituents: sodium, sulfate, chloride, manganese, and molybdenum (Figure B-4.0-25; Tables B-2.0-2 and B-2.0-3).
- On trilinear and fingerprint plots, data points for well R-47i plot outside the cluster of points for the area-specific groundwater background wells but obviously trend toward it, consistent with the presence of a small, slowly decreasing component of residual sodium and sulfate in the vicinity of the screened interval (Figures B-3.0-3 and B-4.0-25).
- Chlorinated solvents and HE are not detected; tritium has not been detected in the four most recent samples (Tables B-2.0-4 to B-2.0-6). Boron and barium are not detected above concentrations observed in area-specific background groundwater (Figure B-4.0-25; Table B-2.0-3).

Regional Aquifer Well R-48

Well R-48 is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations.

- Field parameters meet stability criteria when the well is purged in accordance with EP-DIV-SOP-20032 (Figure B-2.0-11). Drifting specific conductance values recorded during purging are a consequence of effervescence in the groundwater (Table B-2.0-1).
- Oxic conditions are present based on the stability of several redox indicators, including consistent detection of DO above 6 mg/L, detected nitrate and perchlorate concentrations, and the absence of detectable iron and manganese in the most recent samples (Tables B-2.0-1 to B-2.0-3, Figure B-4.0-26).
- Inorganic water chemistry differs slightly from area-specific background groundwater (Figures B-3.0-4 and B-4.0-26). A steady decrease in sulfate concentrations indicates the screen is still re-equilibrating from drilling and construction activities (Figure B-4.0-26).
- Chlorinated solvents and HE are not detected (Tables B-2.0-4 and B-2.0-5). Boron and barium are not detected above concentrations in area-specific background groundwater (Figure B-4.0-26). Low tritium activities have been detected in only two of nine sampling events (Table B-2.0-6).

Regional Aquifer Well R-63

Well R-63 is capable of providing reliable water-quality data for TA-16 COPCs based on the following observations. This well completed four rounds of characterization sampling in December 2011, and a fifth sampling event occurred in January 2012. The assessment is based on data for the last four sampling events when groundwater in the screened interval had completed reequilibrating.

- Field parameters meet stability criteria when the well is purged in accordance with EP-DIV-SOP-20032 (Figure B-2.0-12).
- Oxic conditions are present based on the stability of several redox indicators, including consistent detection of DO above 6 mg/L, detected nitrate and perchlorate concentrations, and the absence of detectable iron and manganese concentrations (Figure B-4.0-27; Tables B-2.0-1 to B-2.0-3).
- Water chemistry is similar to area-specific background groundwater (Figures B-3.0-4 and B-4.0-27).
- RDX is detected consistently at 1.4 µg/L. Tritium, chlorinated solvents, other HE, and boron are not detected (Tables B-2.0-3 to B-2.0-6). Barium is not detected above concentrations in local groundwater background (Figure B-4.0-27 and Table B-2.0-3).

B-5.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative

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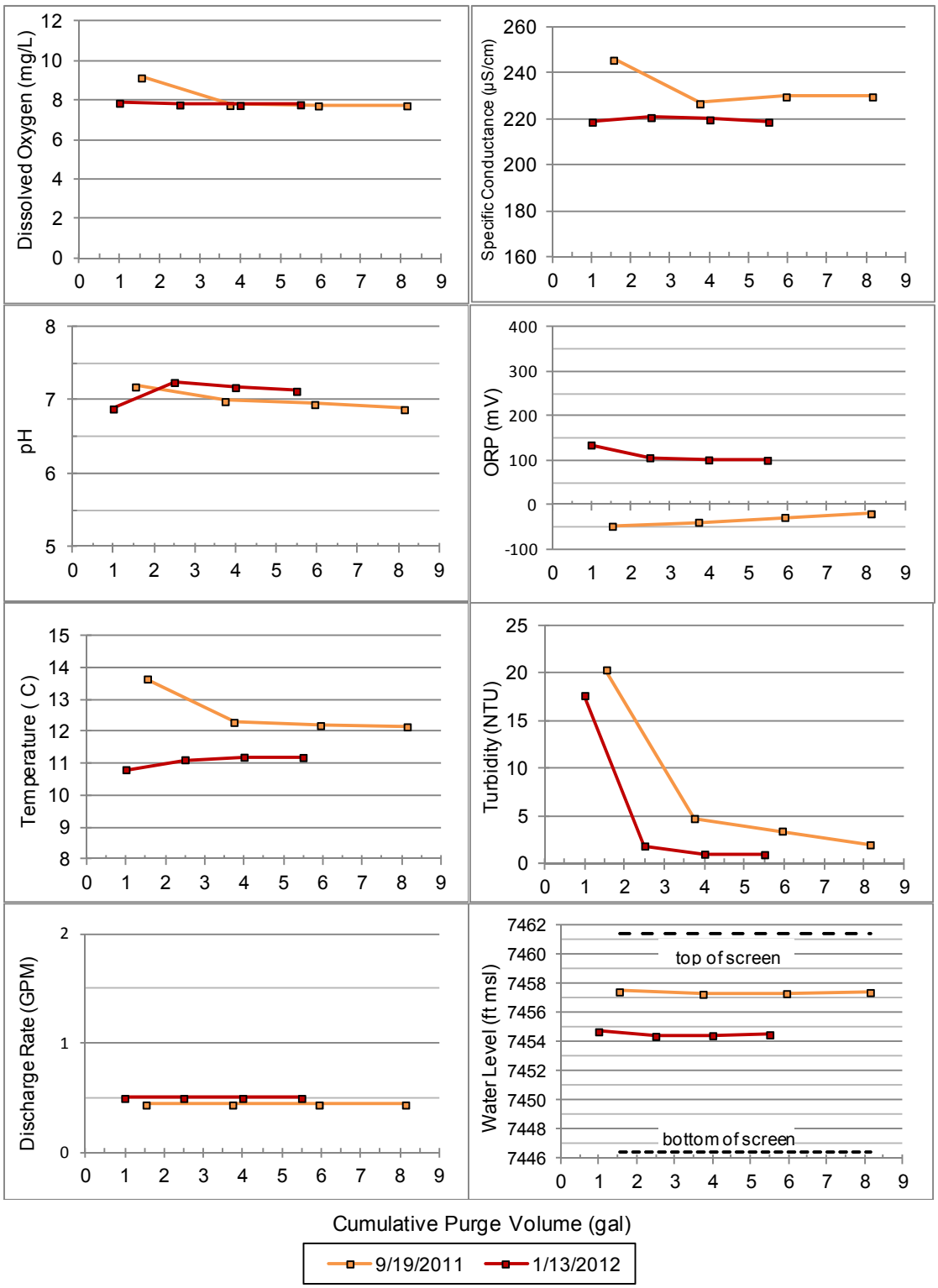
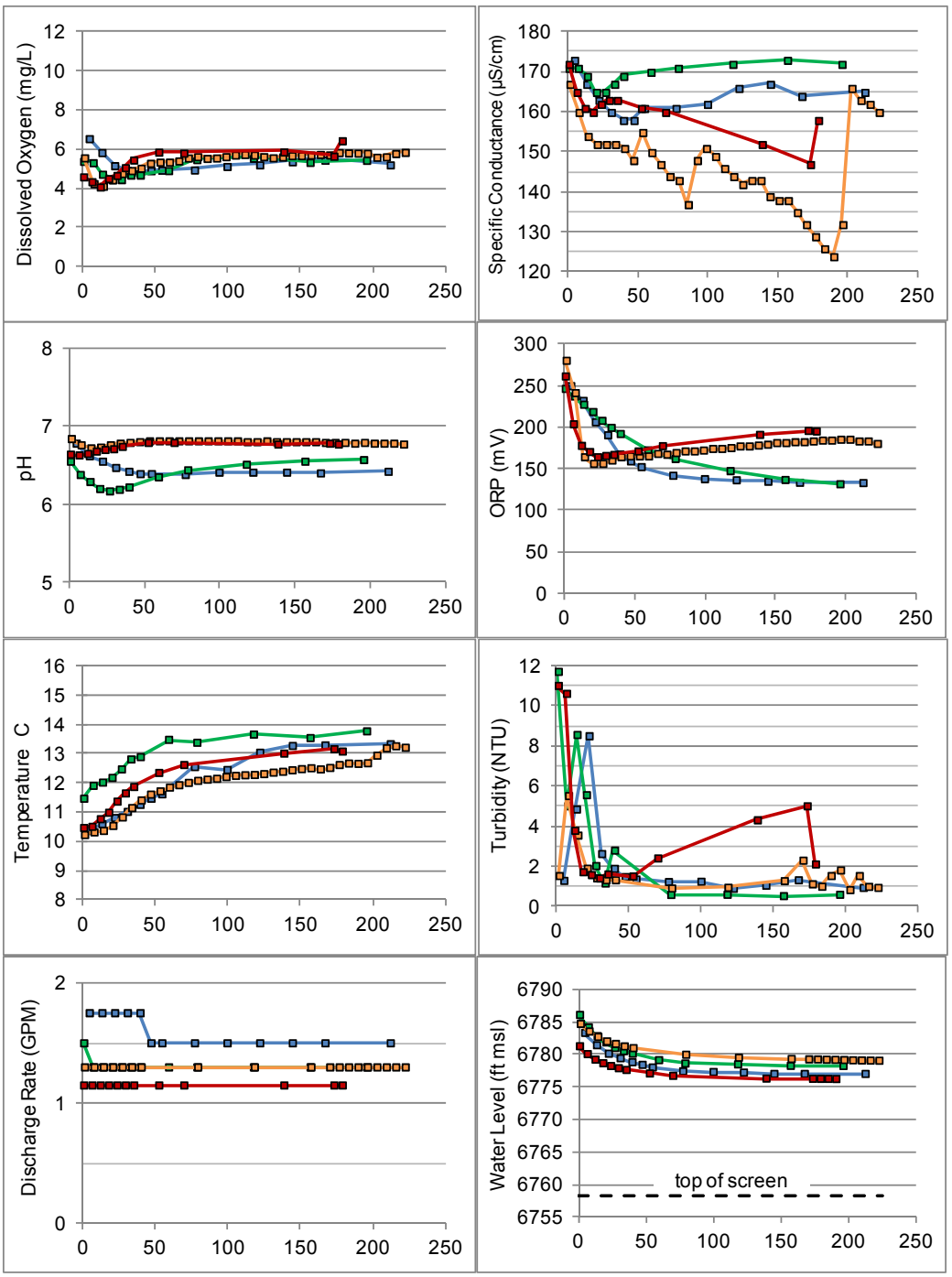
LANL (Los Alamos National Laboratory), December 2011. “2011 Interim Facility-Wide Groundwater Monitoring Plan, Revision 1,” Los Alamos National Laboratory document LA-UR-11-6958, Los Alamos, New Mexico. (LANL 2011, 208811)



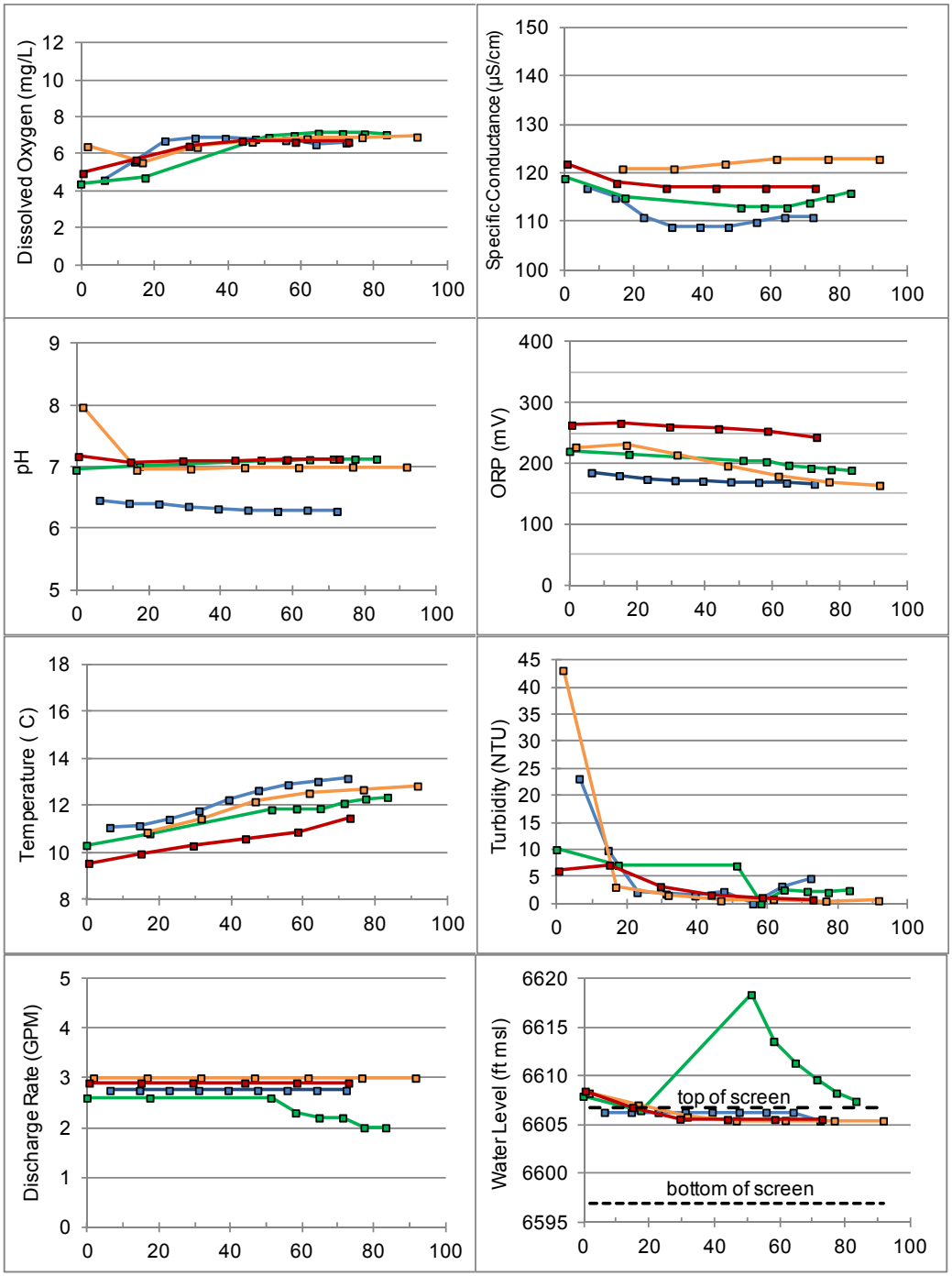
Notes: Cumulative volume purged is calculated after subtracting volume of water removed to clear the drop pipe.
1 CV = approximately 1.75 gal. Nominal depth of screen = 130 ft below ground surface (bgs).
Data source: Field summary reports.

Figure B-2.0-1 Time-series field parameters during purging of well 16-26644



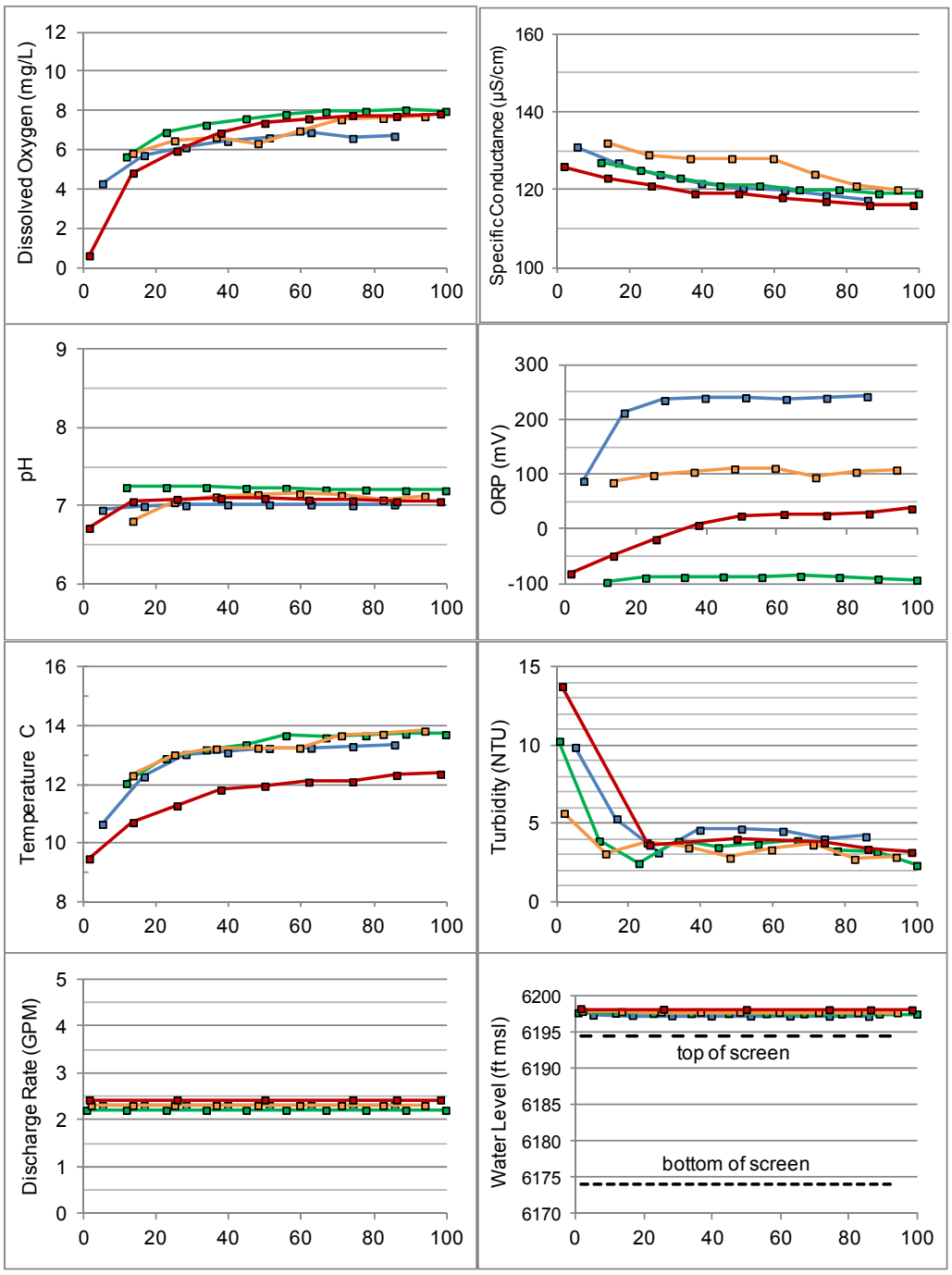
Notes: Cumulative volume purged is calculated after subtracting volume of water removed to clear the drop pipe.
1 CV = approximately 63 gal. Nominal depth of screen = 624 ft bgs.
Data source: Field summary reports.

Figure B-2.0-2 Time-series field parameters during purging of well CdV-16-1(i)



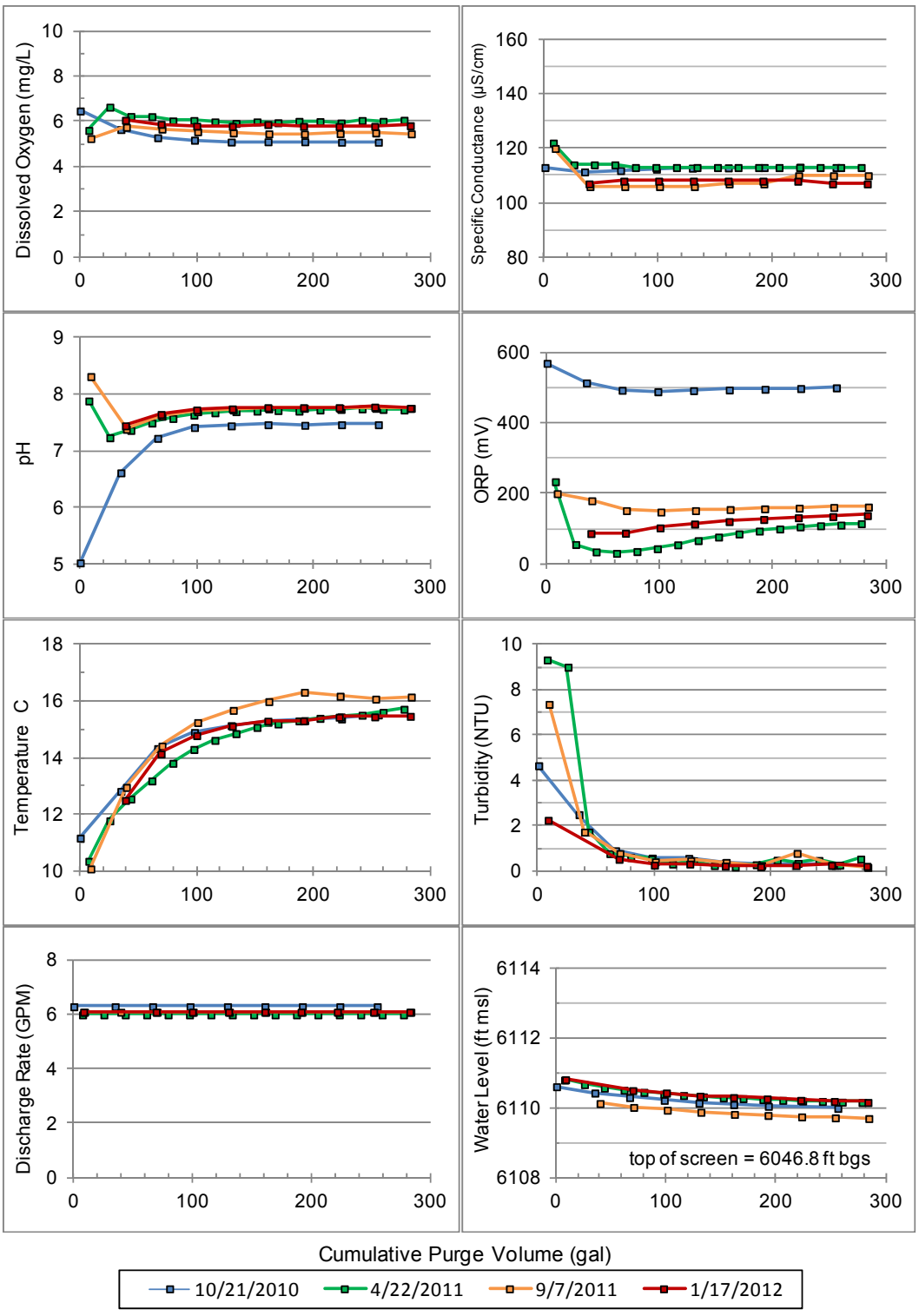
Notes: Cumulative volume purged is calculated after subtracting volume of water removed to clear the drop pipe.
1 CV = approximately 25 gal. Nominal depth of screen = 850 ft bgs.
Data source: Field summary reports.

Figure B-2.0-3 Time-series field parameters during purging of well CdV-16-2(i)r



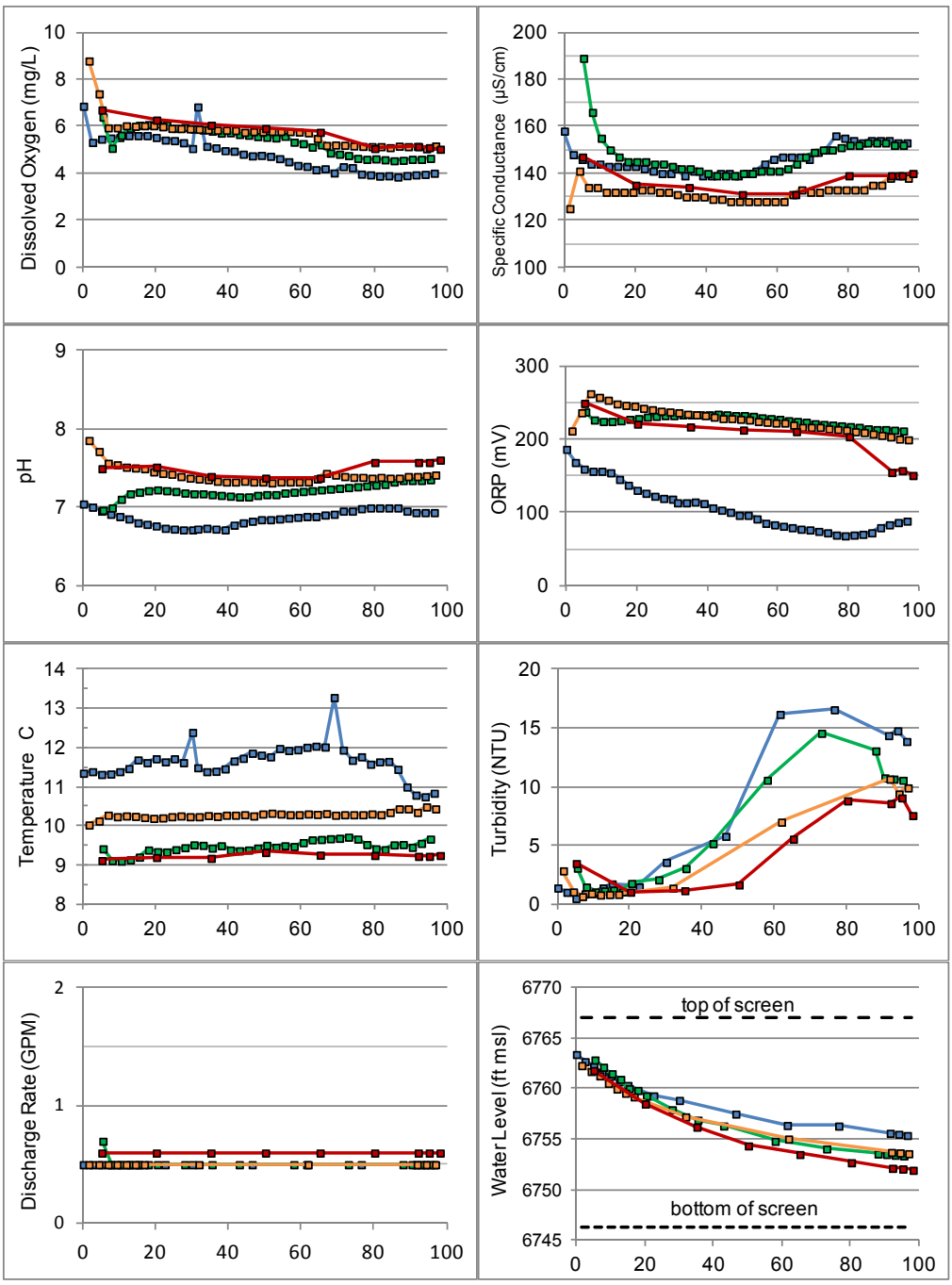
Notes: Cumulative volume purged is calculated after subtracting volume of water removed to clear the drop pipe.
1 CV = approximately 31 gal. Nominal depth of screen = 632 ft bgs.
Data source: Field summary reports.

Figure B-2.0-4 Time-series field parameters during purging of well CdV-37-1(i)



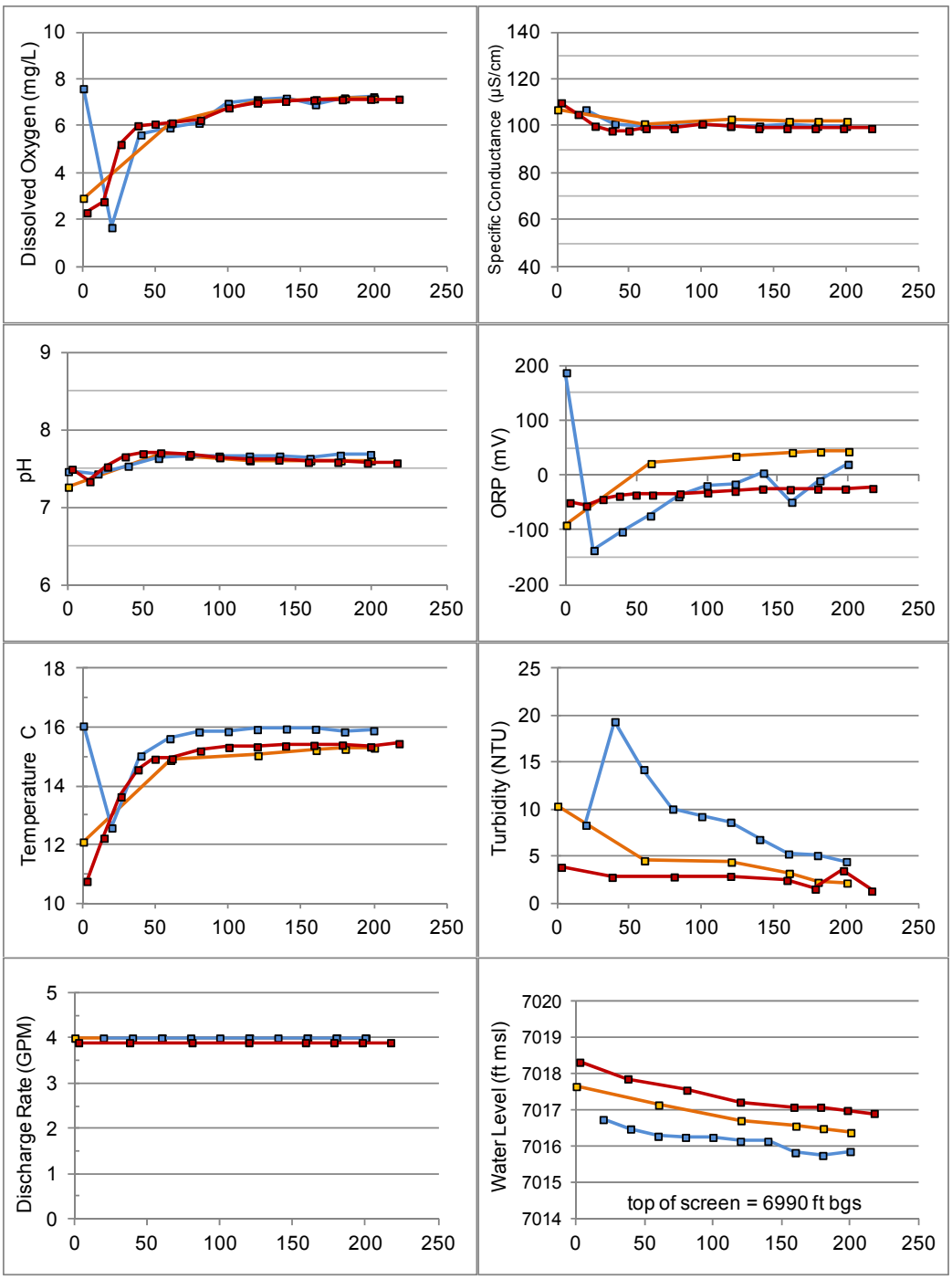
Notes: Cumulative volume purged is calculated after subtracting volume of water removed to clear the drop pipe.
1 CV = approximately 97 gal. Nominal depth of screen = 1358 ft bgs.
Data source: Field summary reports.

Figure B-2.0-5 Time-series field parameters during purging of well R-18



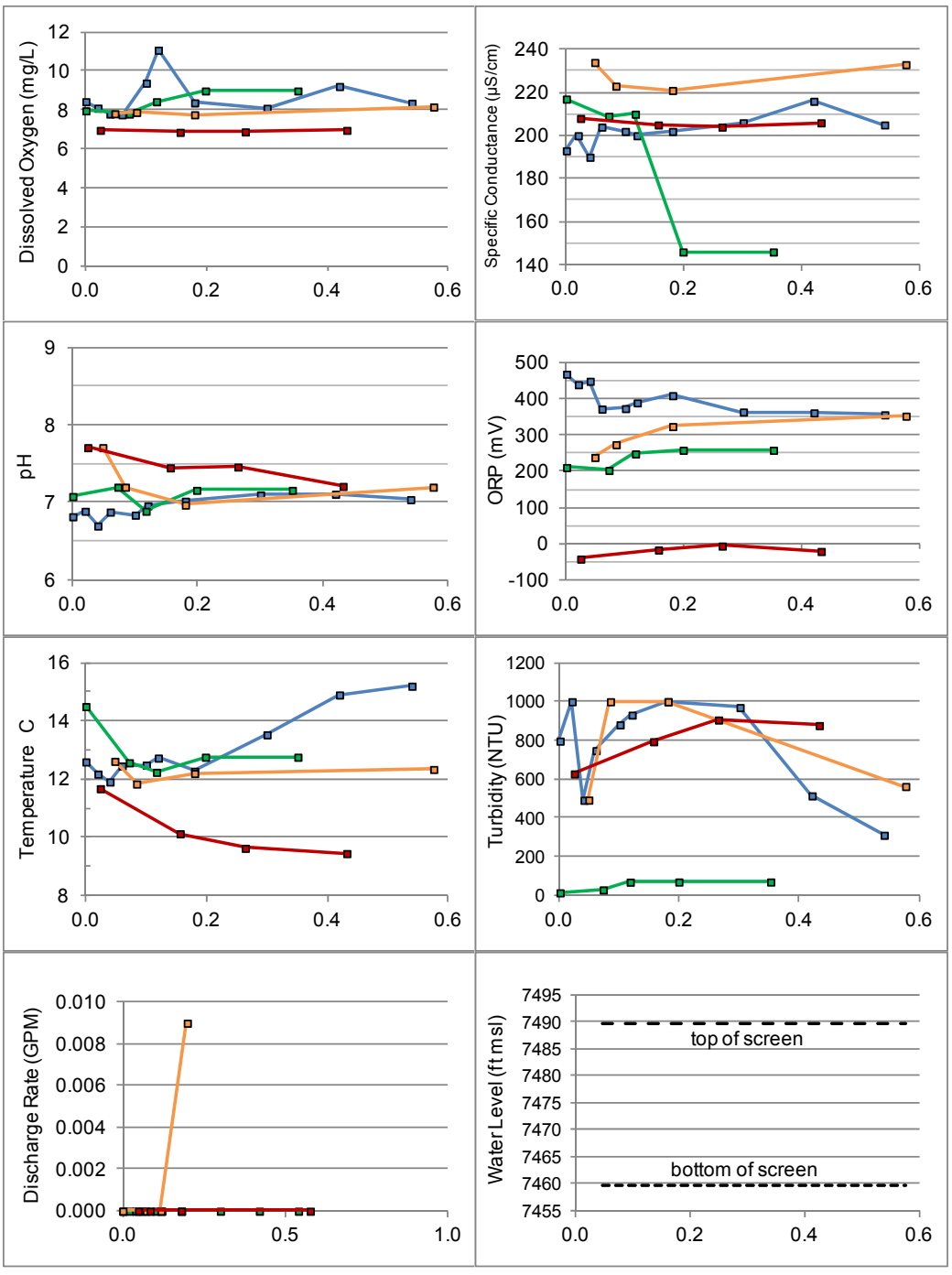
Notes: Cumulative volume purged is calculated after subtracting volume of water removed to clear the drop pipe.
1 CV = approximately 30 gal. Nominal depth of screen = 750 ft bgs.
Data source: Field summary reports.

Figure B-2.0-6 Time-series field parameters during purging of well R-25b



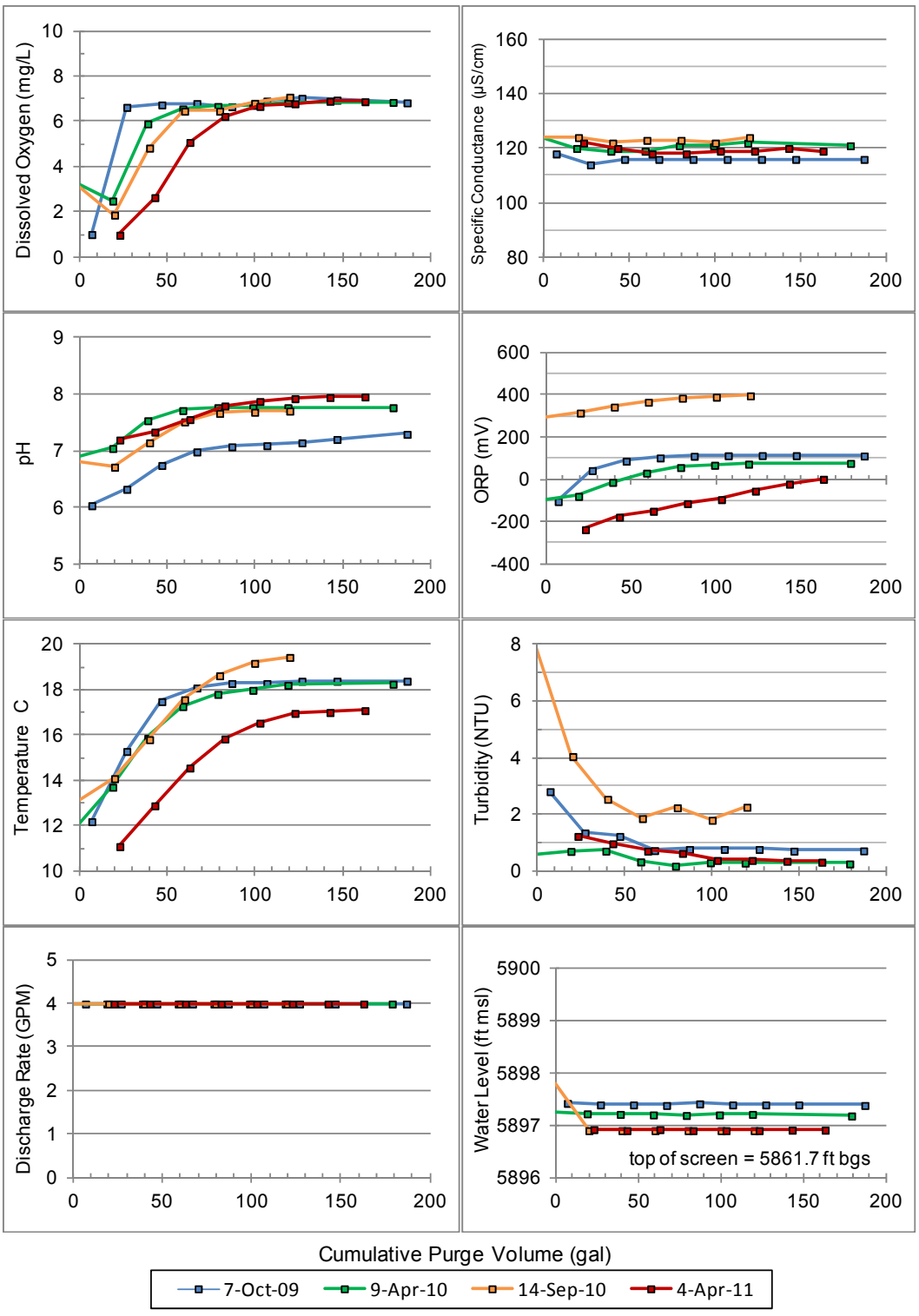
Notes: Cumulative volume purged is calculated after subtracting volume of water removed to clear the drop pipe.
1 CV = approximately 71 gal. Nominal depth of screen = 652 ft bgs.
Data source: Field summary reports.

Figure B-2.0-7 Time-series field parameters during purging of well R-26 screen 1



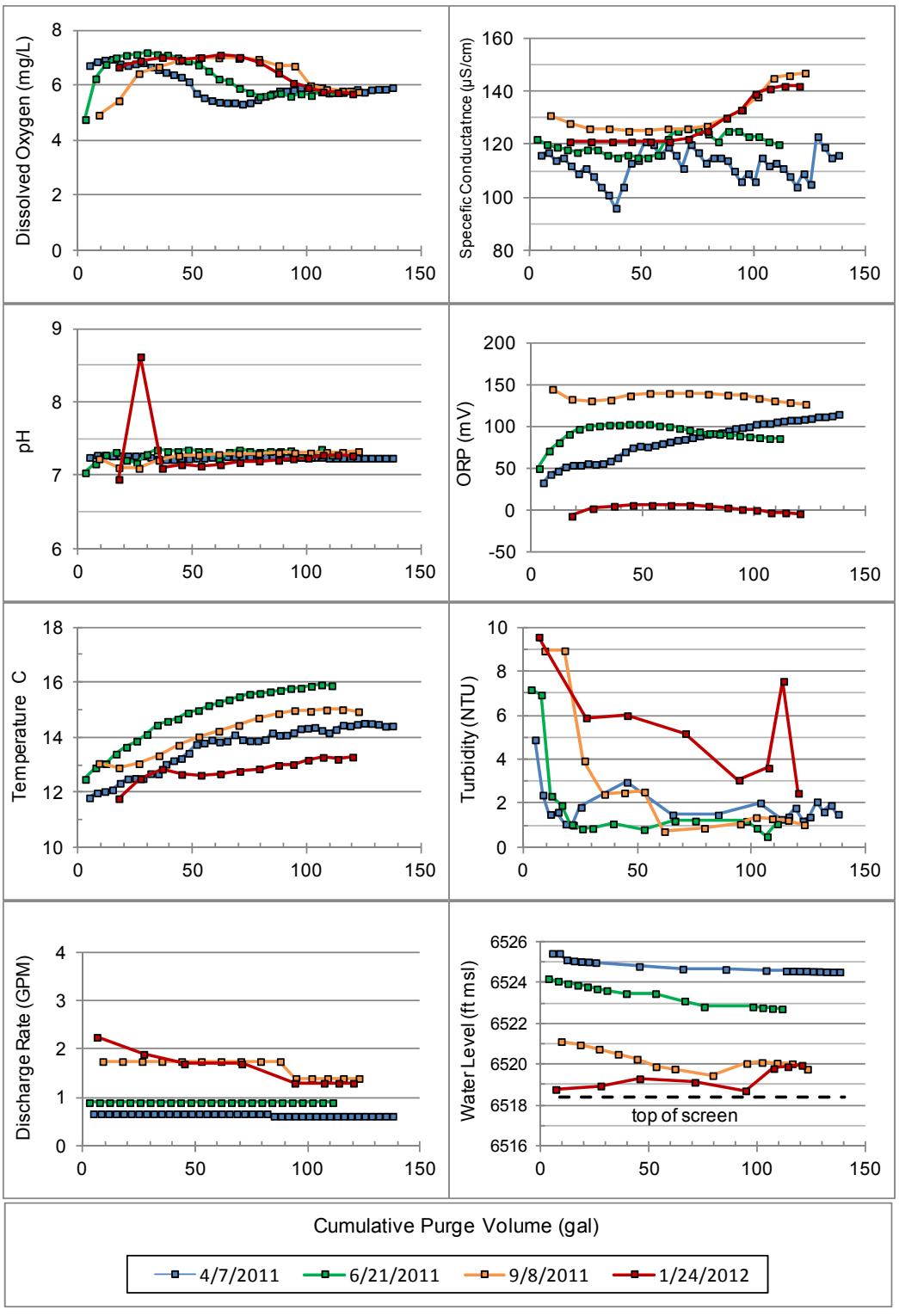
Notes: Cumulative volume purged is calculated after subtracting volume of water removed to clear the drop pipe.
1 CV = approximately 0.6 gal. Nominal depth of screen = 150 ft bgs.
Data source: Field summary reports.

Figure B-2.0-8 Time-series field parameters during purging of piezometer R-26 PZ-2



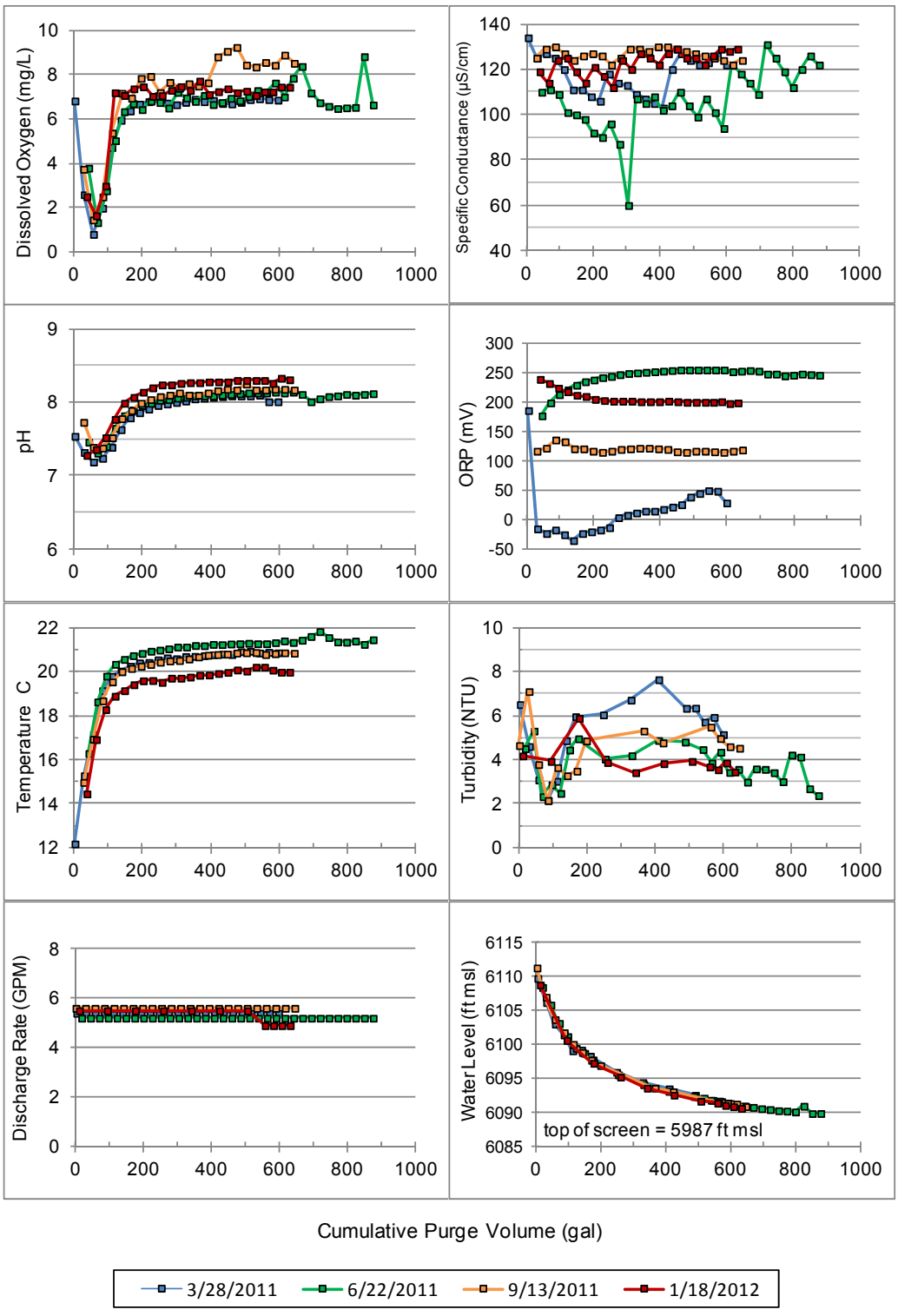
Notes: Cumulative volume purged is calculated after subtracting volume of water removed to clear the drop pipe.
1 CV = approximately 52 gal. Nominal depth of screen = 852 ft bgs.
Data source: Field summary reports.

Figure B-2.0-9 Time-series field parameters during purging of well R-27



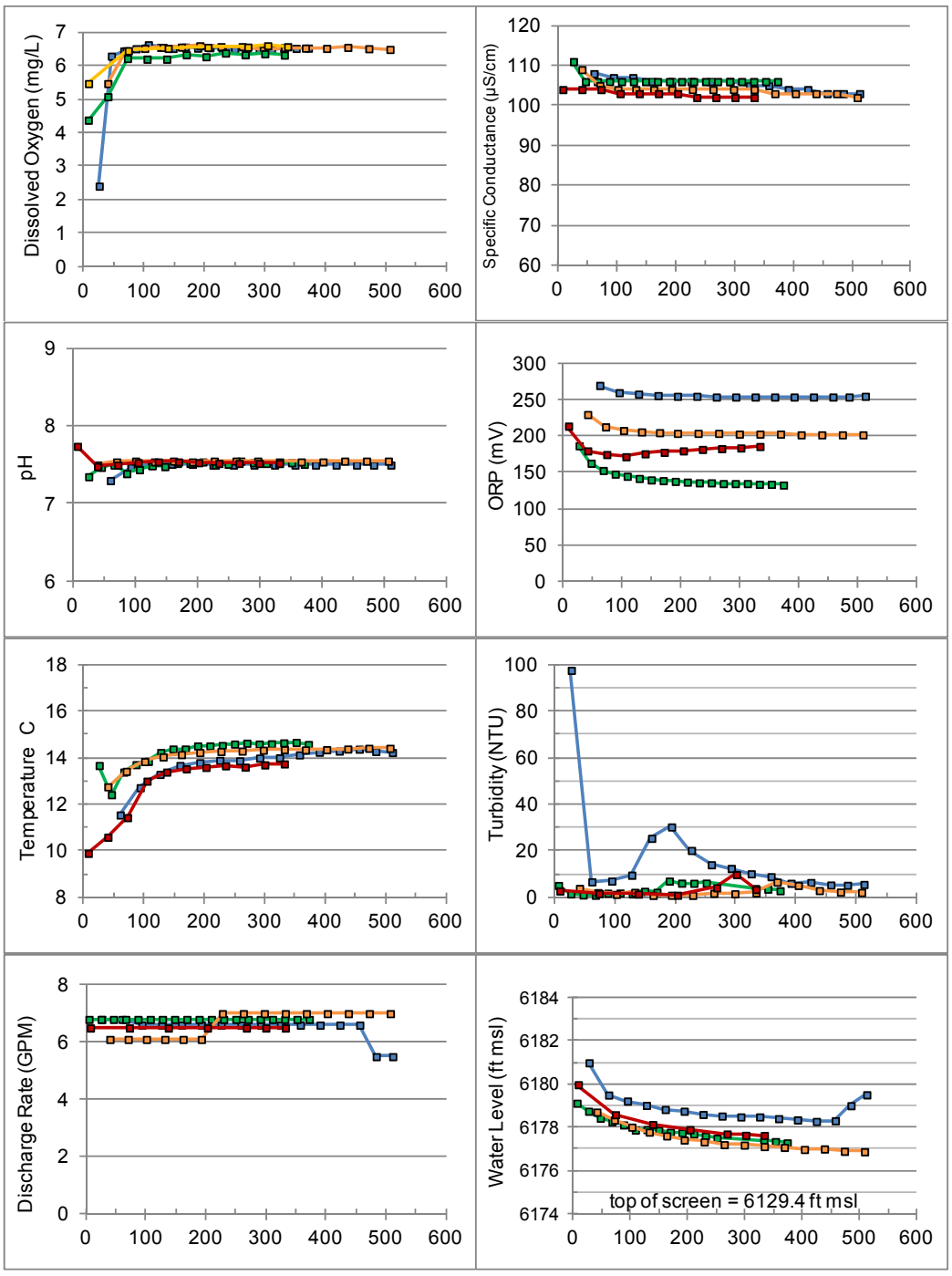
Notes: Cumulative volume purged is calculated after subtracting volume of water removed to clear the drop pipe.
1 CV = approximately 37 gal. Nominal depth of screen = 840 ft bgs.
Data source: Field summary reports.

Figure B-2.0-10 Time-series field parameters during purging of well R-47i



Notes: Cumulative volume purged is calculated after subtracting volume of water removed to clear the drop pipe.
1 CV = approximately 191 gal. Nominal depth of screen = 1500 ft bgs.
Data source: Field summary reports.

Figure B-2.0-11 Time-series field parameters during purging of well R-48



Notes: Cumulative volume purged is calculated after subtracting volume of water removed to clear the drop pipe.
1 CV = approximately 109 gal. Nominal depth of screen = 1325 ft bgs.
Data source: Field summary reports.

Figure B-2.0-12 Time-series field parameters during purging of well R-63

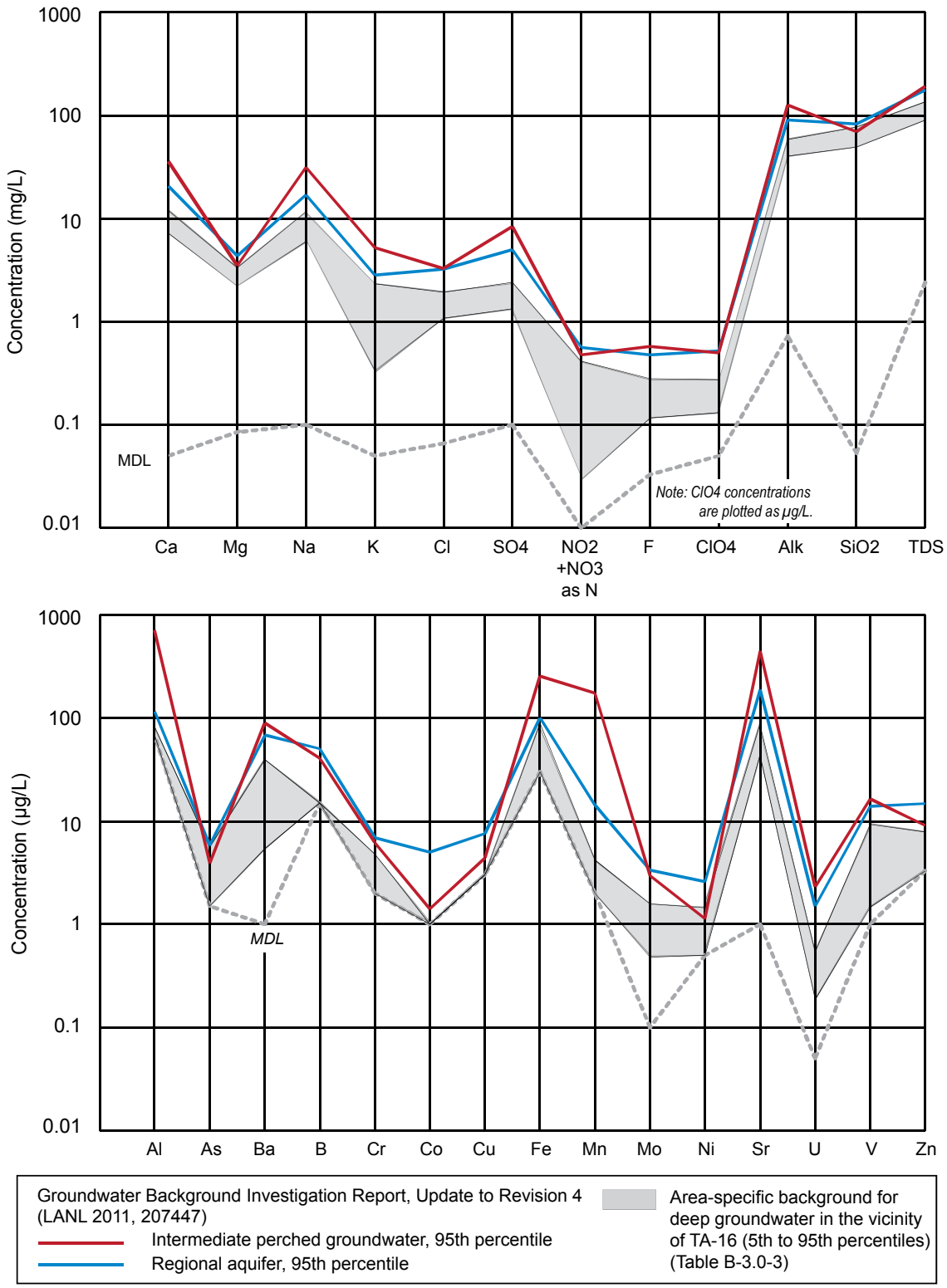
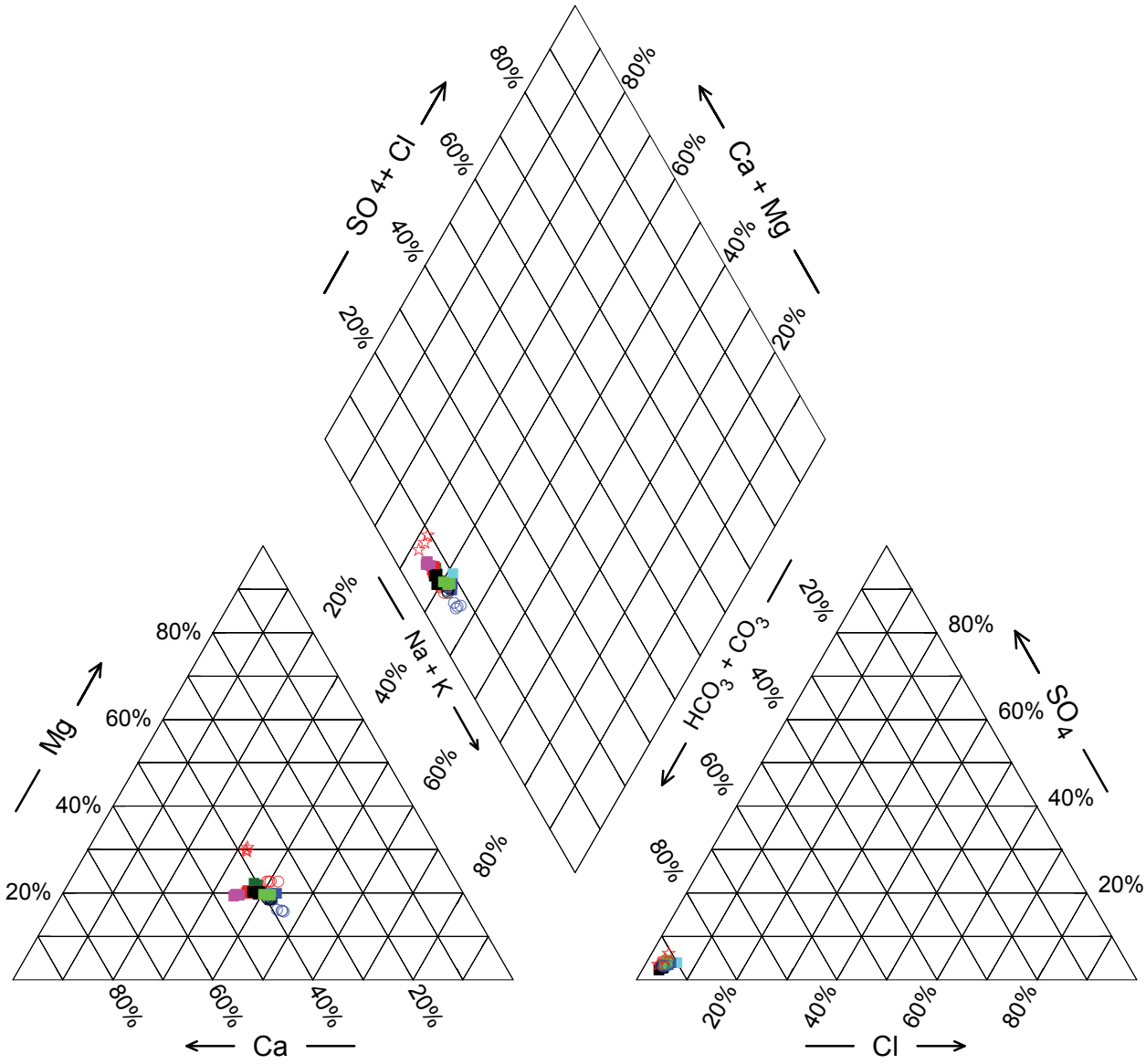


Figure B-3.0-1 Range of area-specific background concentrations for deep groundwater in the vicinity of TA-16 compared with 95th percentile background concentrations for deep groundwater beneath the Pajarito Plateau

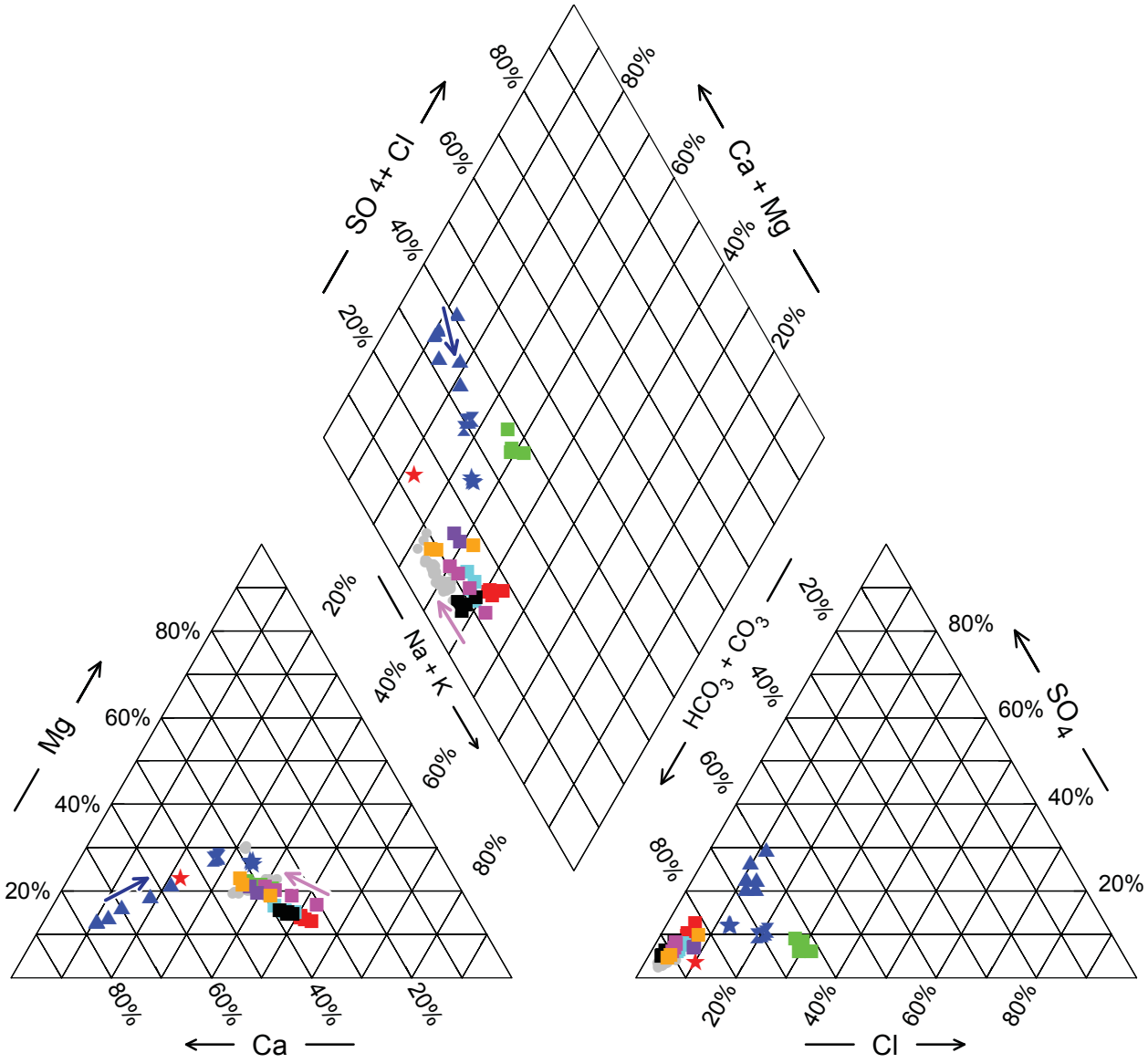


Intermediate perched groundwater
- R-26 screen 1
- R-27i
- PCI-2
- Water Canyon Gallery

Regional groundwater
- CdV-R-15-3 screen 4
- CdV-R-37-2 screen 3
- R-17 screen 1
- R-17 screen 2
- R-25 screen 7
- R-25 screen 8
- R-30

Data source: Attachment B-1.

Figure B-3.0-2 Trilinear (Piper) diagram showing the major-ion chemistry of area-specific background groundwater at locations in the vicinity of TA-16



Intermediate perched groundwater wells

Cañon de Valle west and southwest of MDA R
- R-26 PZ-2
- 16-26644

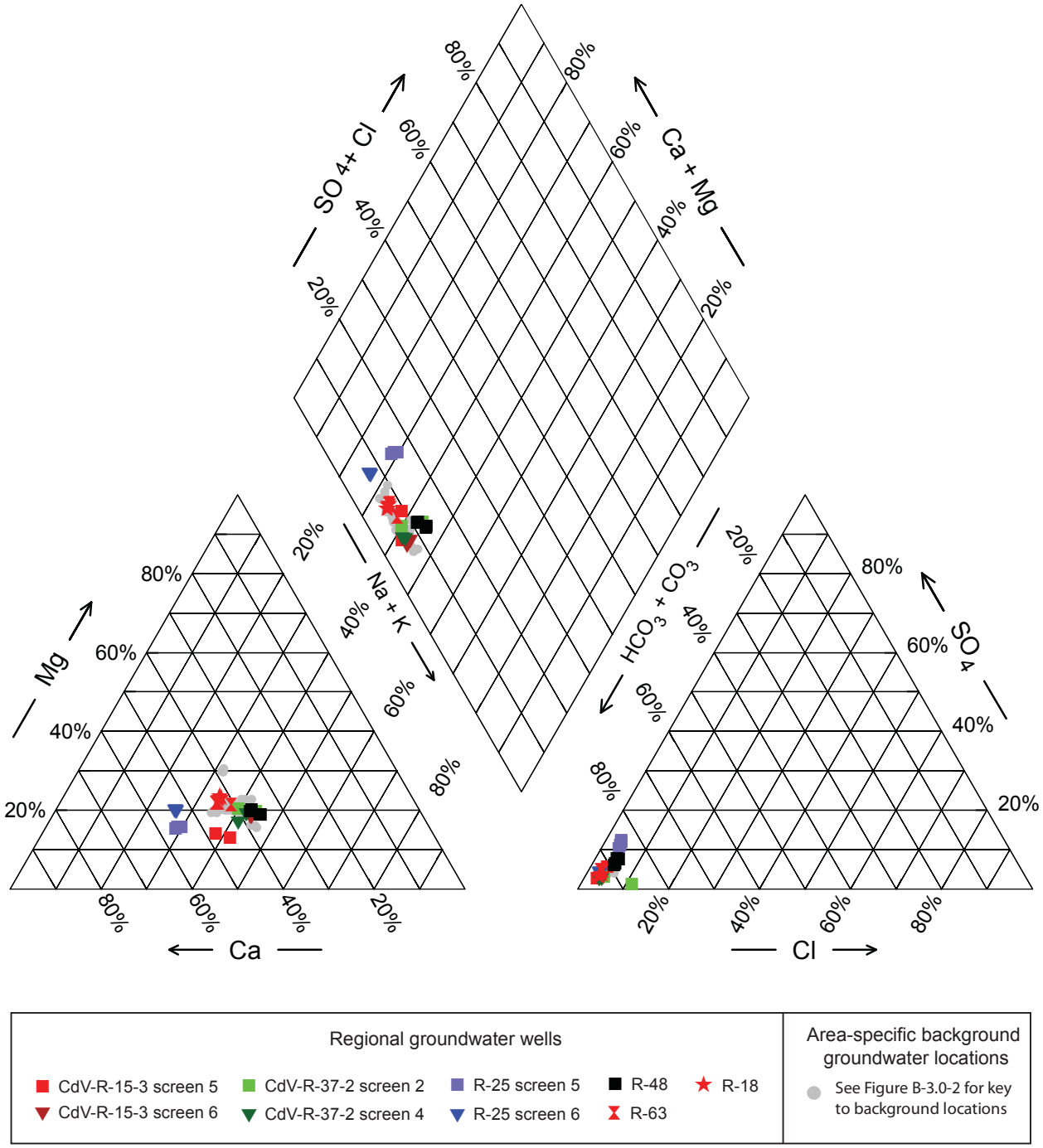
Cañon de Valle between MDA R and MDA P
- CdV-16-1(i)
- R-25b
- R-25 screen 1
- Arrow indicates direction of change in R-25b geochemistry
- R-25 screen 4
- CdV-16-4ip screen 1
- CdV-16-4ip screen 2
- Arrow indicates direction of change in R-25 screen 4 geochemistry

Cañon de Valle east of MDA P
- CdV-16-2(i)r
- R-47i
- CdV-37-1i

Area-specific groundwater background locations
- See Figure B-3.0-2 for key to background locations

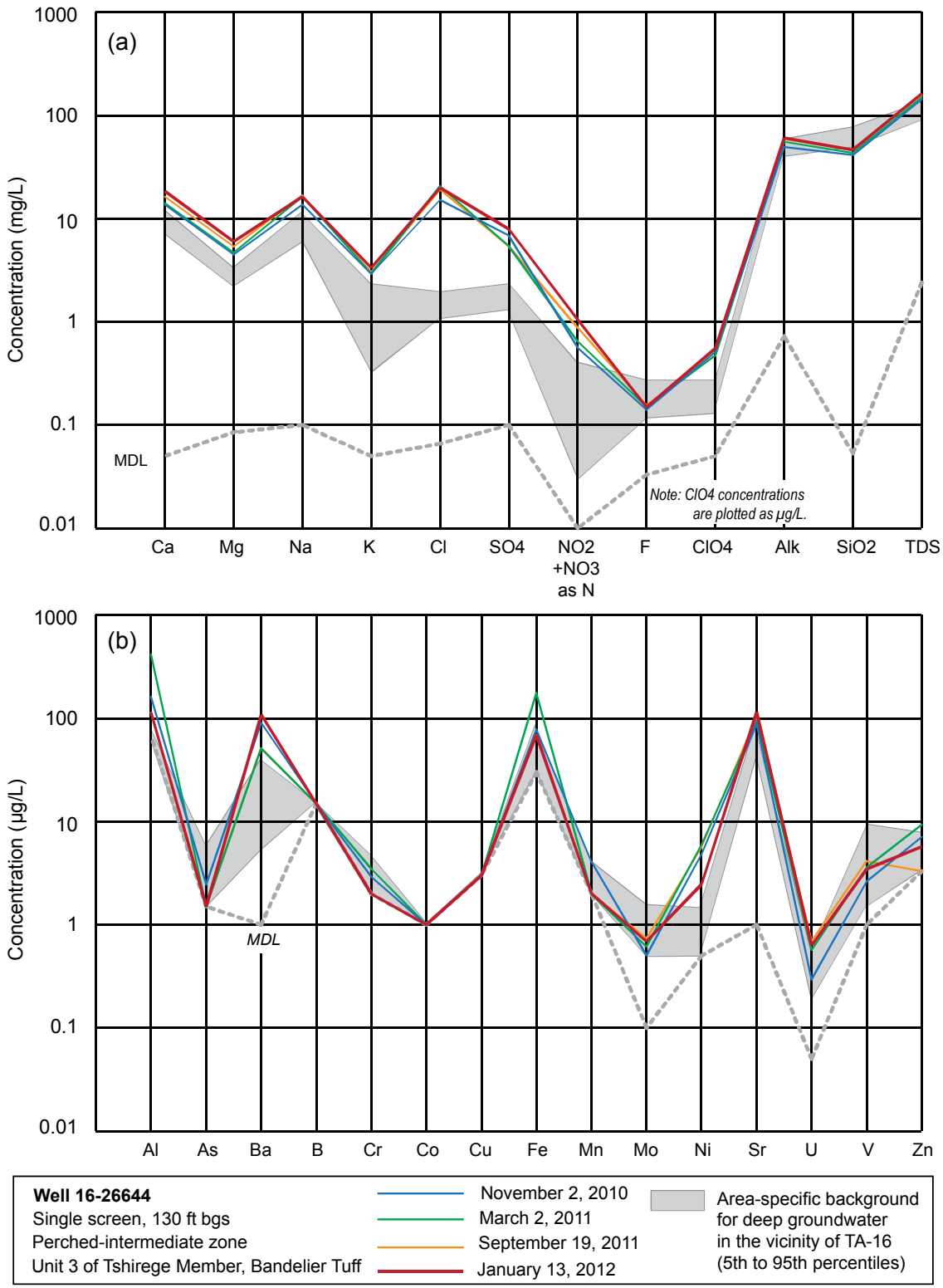
Data source: Attachment B-1.

Figure B-3.0-3 Trilinear (Piper) diagram showing the major-ion chemistry of perched-intermediate groundwater at selected locations in the TA-16 monitoring well network



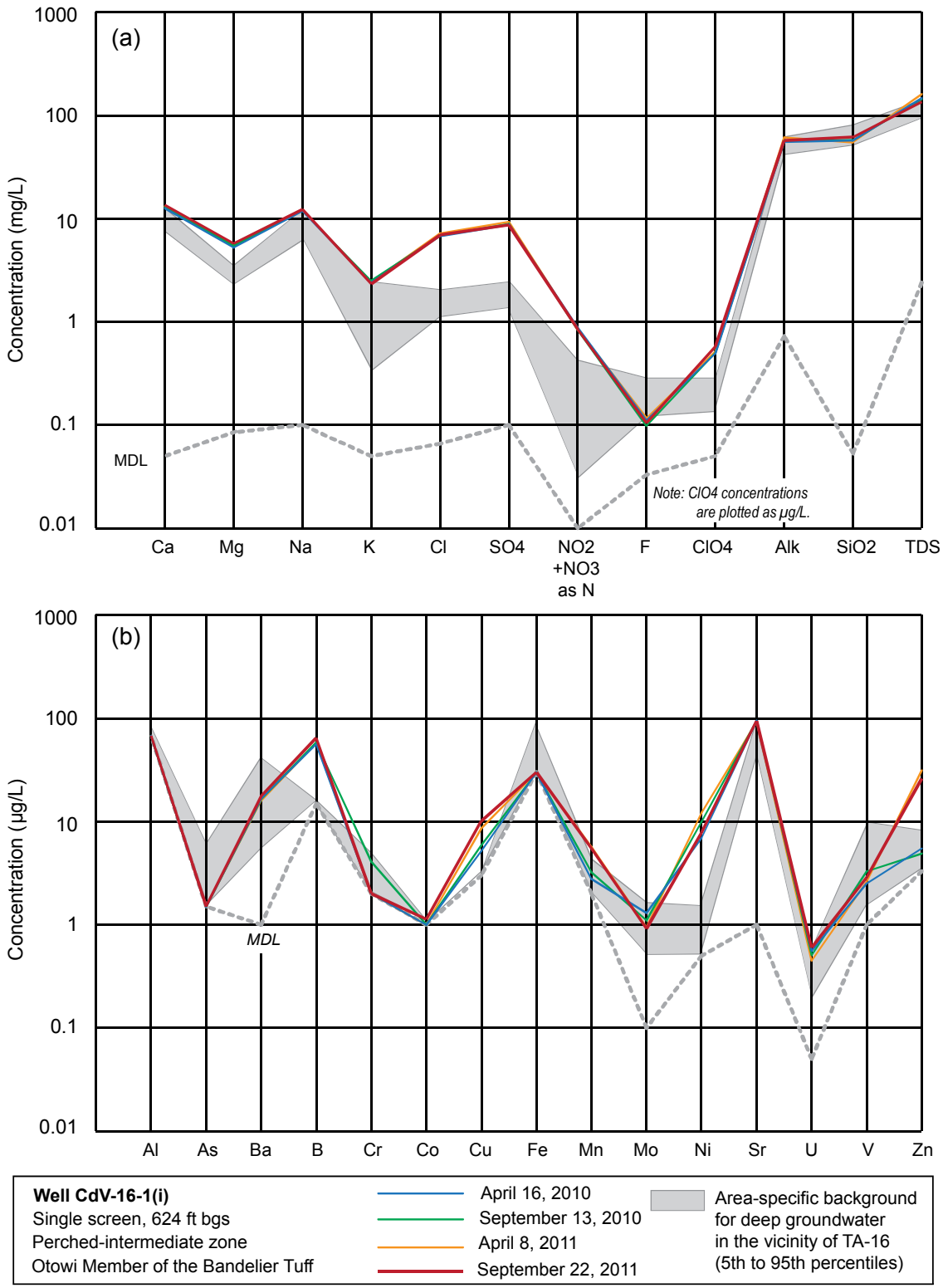
Data source: Attachment B-1.

Figure B-3.0-4 Trilinear (Piper) diagram showing the major-ion chemistry of regional groundwater at selected locations in the TA-16 monitoring well network



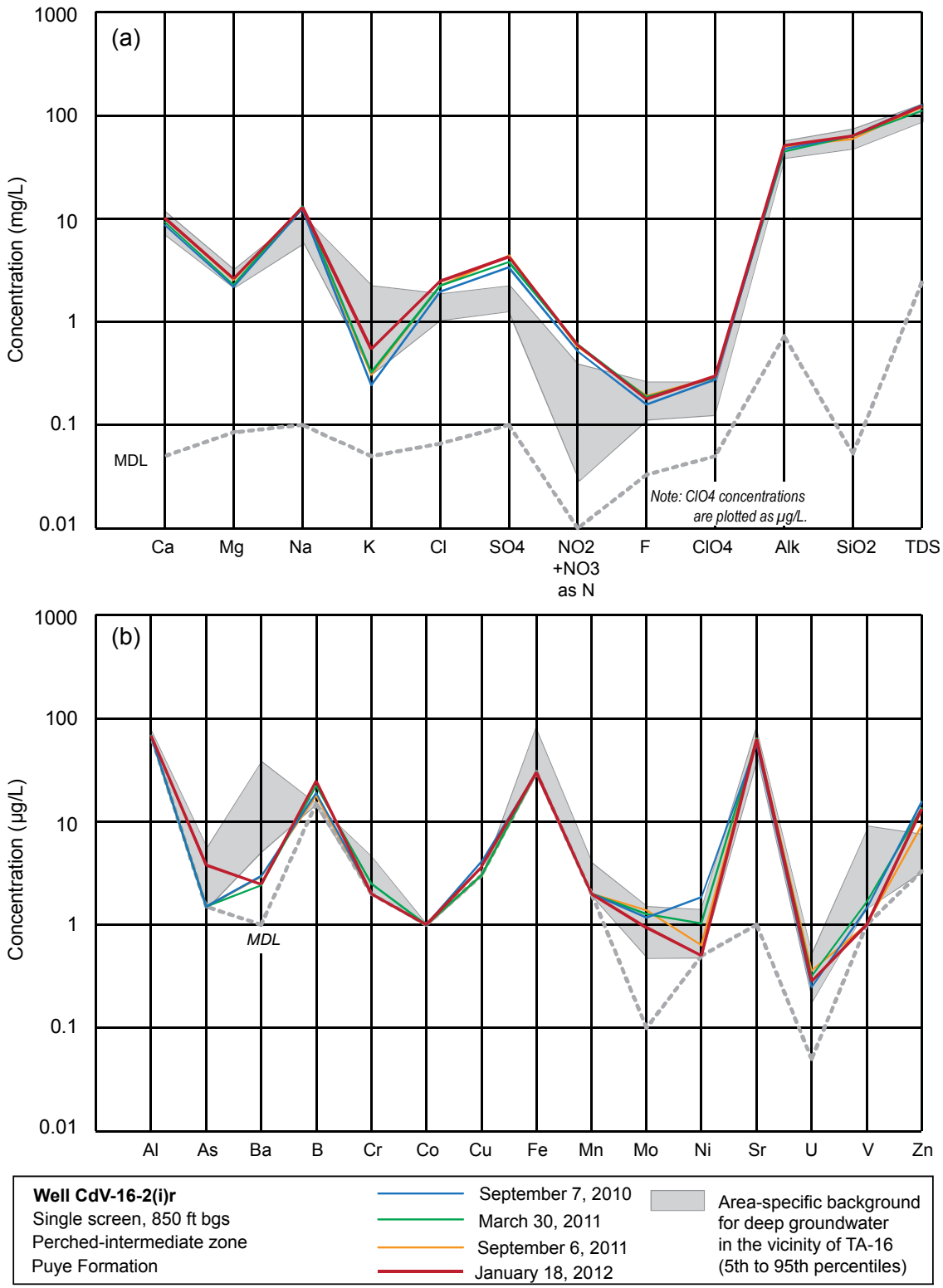
Data source: Attachment B-1.

Figure B-4.0-1 Concentrations in filtered groundwater samples from well 16-26644 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



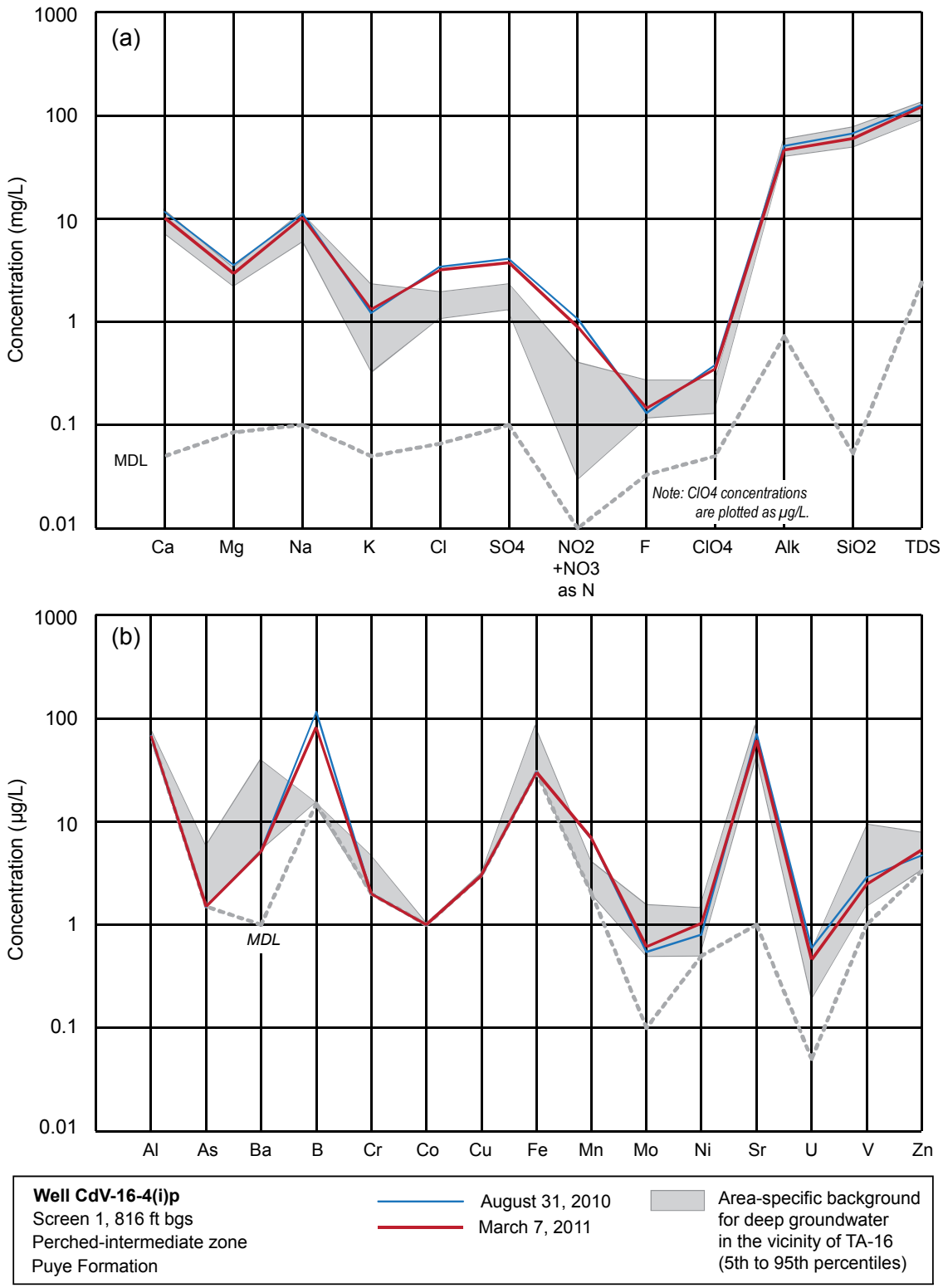
Data source: Attachment B-1.

Figure B-4.0-2 Concentrations in filtered groundwater samples from well CdV-16-1(i) compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



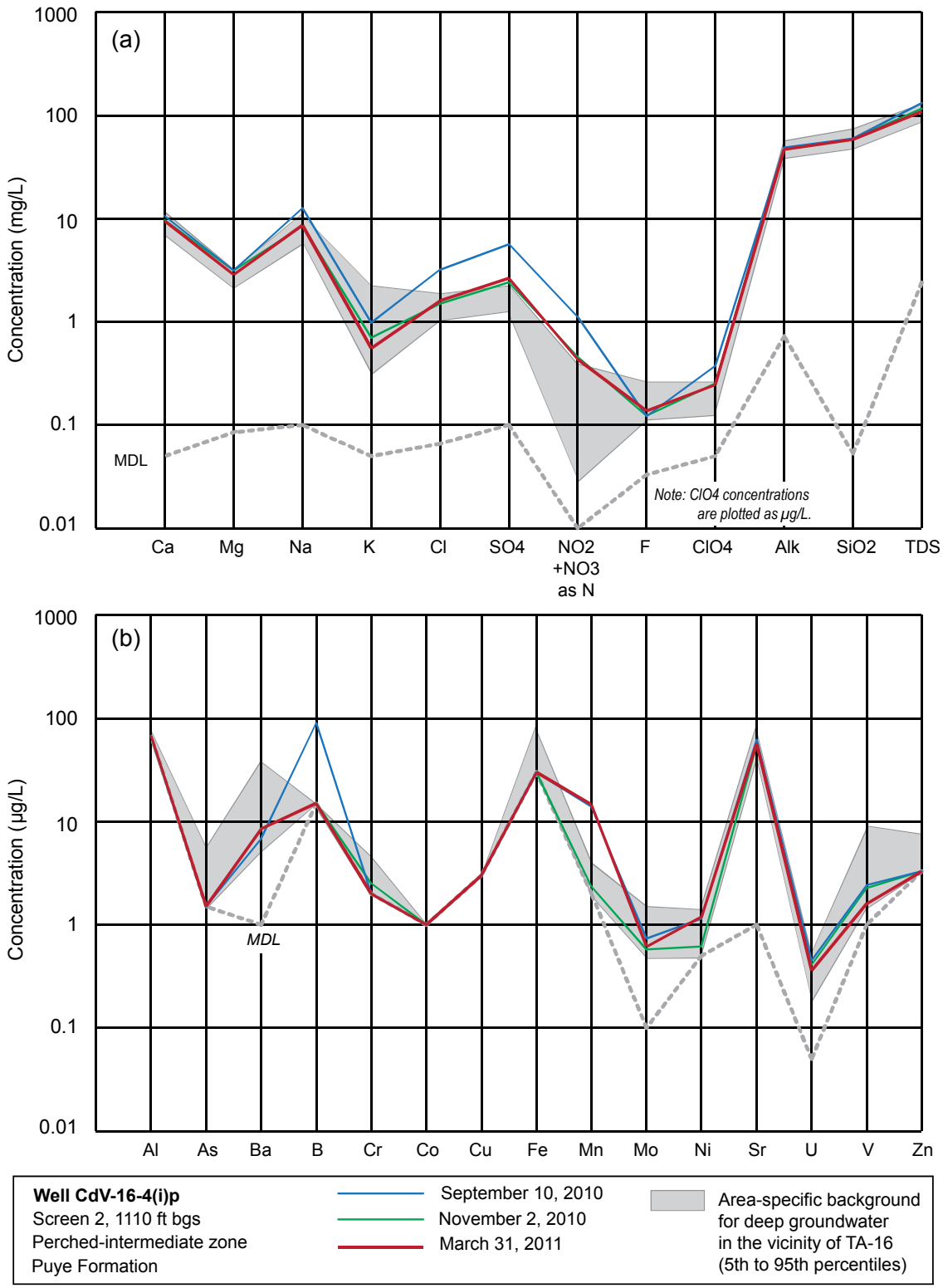
Data source: Attachment B-1.

Figure B-4.0-3 Concentrations in filtered groundwater samples from well CdV-16-2(i)r compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



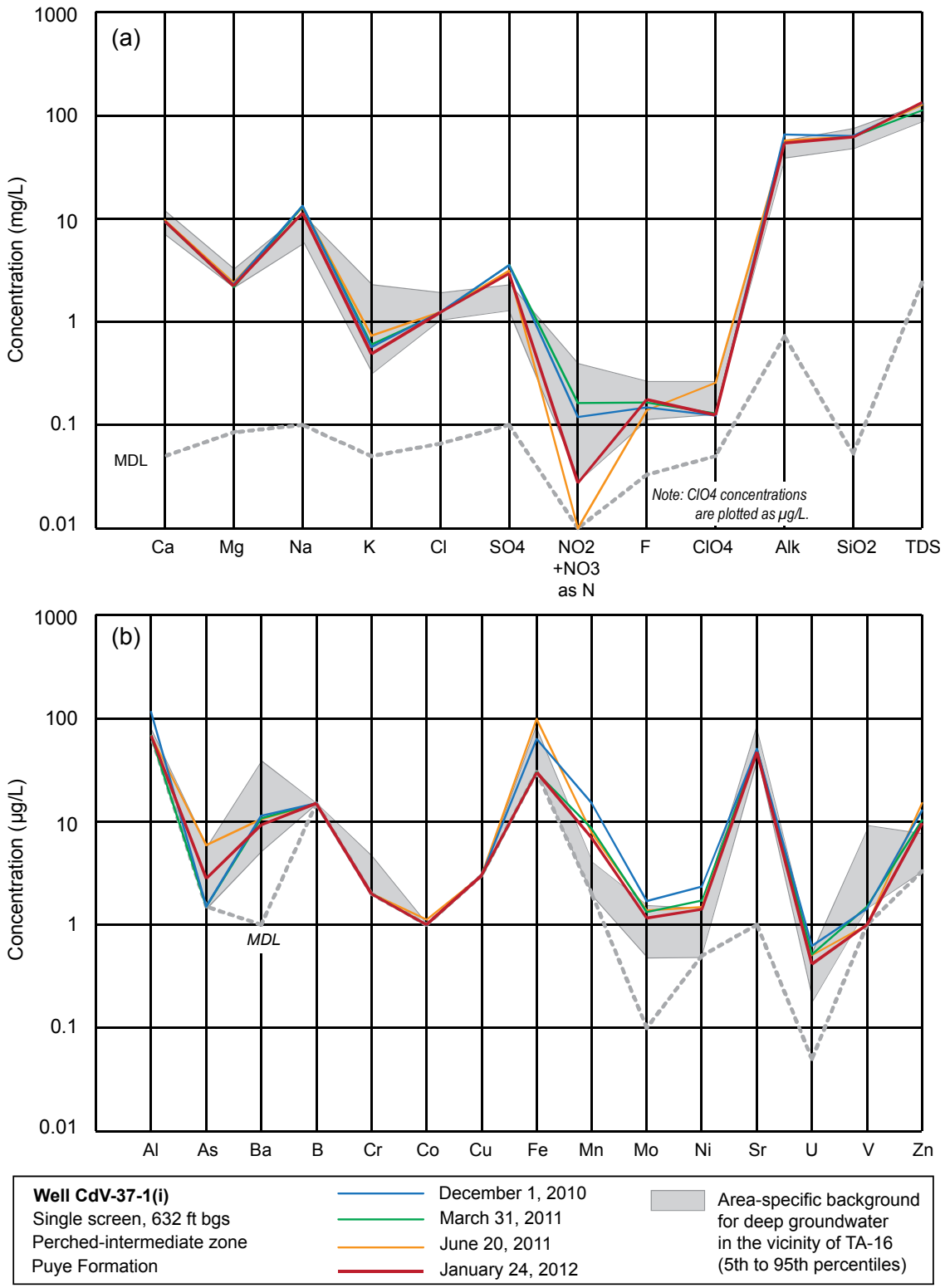
Data source: Attachment B-1.

Figure B-4.0-4 Concentrations in filtered groundwater samples from well CdV-16-4ip screen 1 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



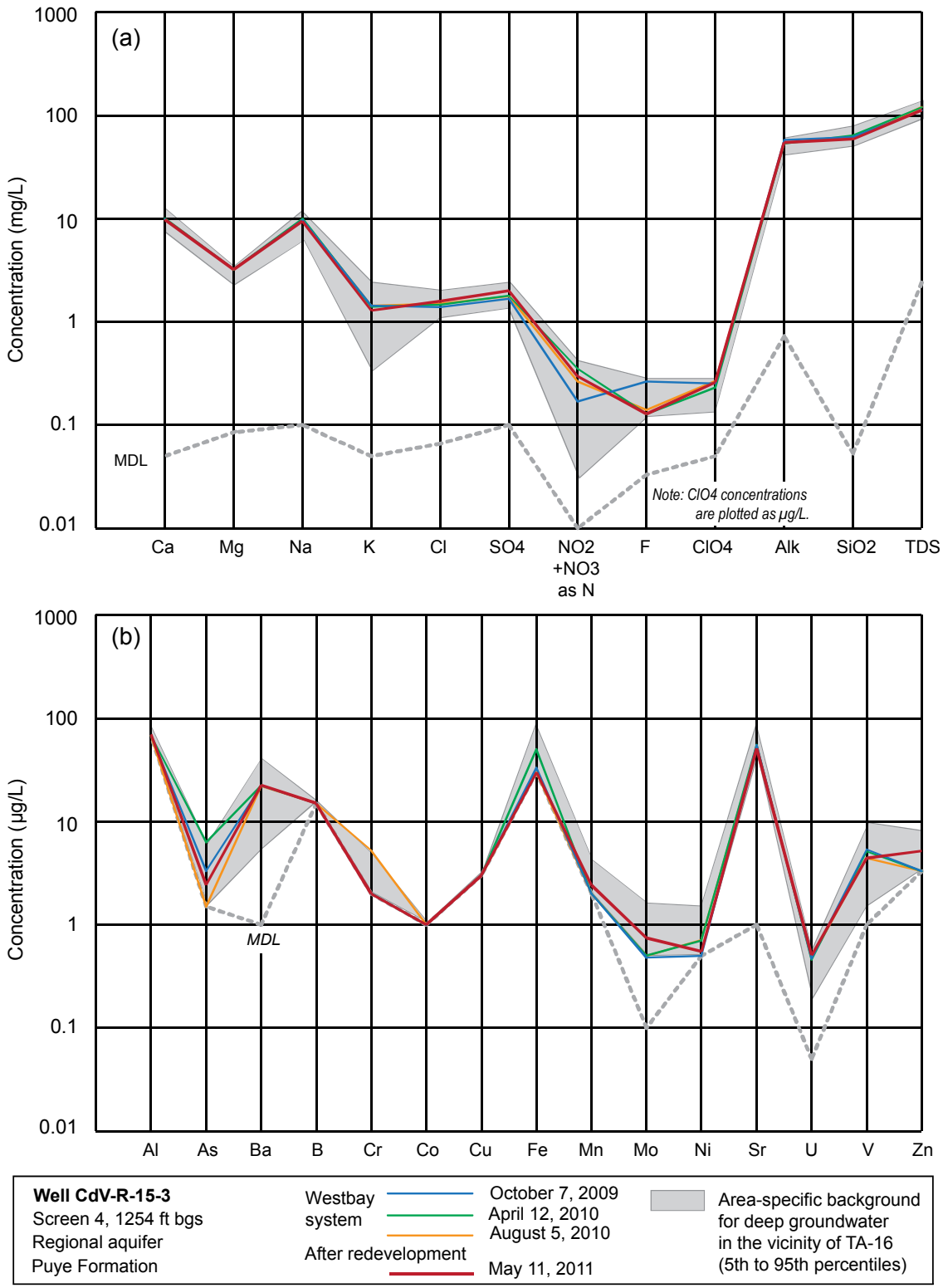
Data source: Attachment B-1.

Figure B-4.0-5 Concentrations in filtered groundwater samples from well CdV-16-4ip screen 2 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



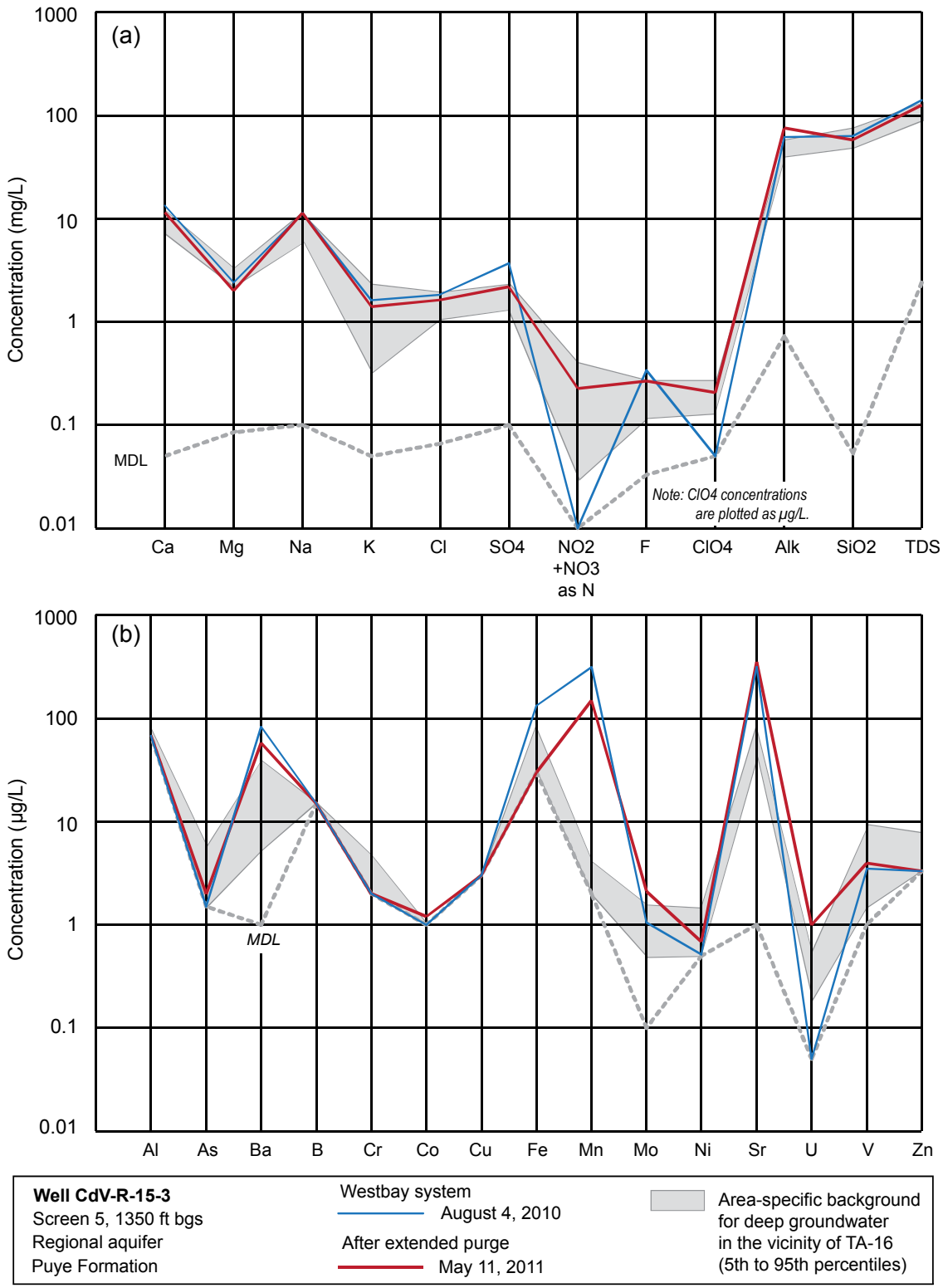
Data source: Attachment B-1.

Figure B-4.0-6 Concentrations in filtered groundwater samples from well CdV-37-1(i) compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



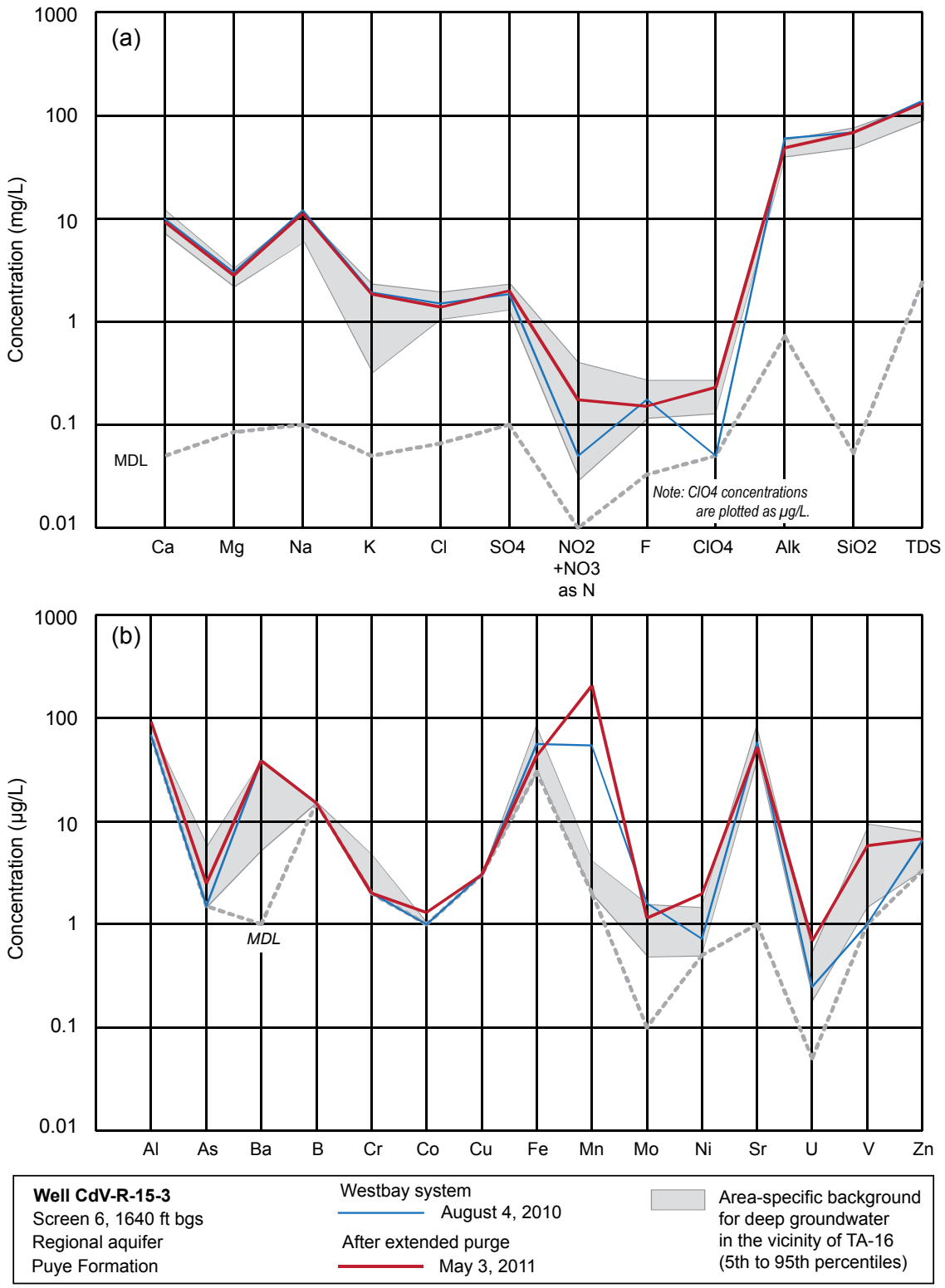
Data source: Attachment B-1.

Figure B-4.0-7 Concentrations in filtered groundwater samples from well CdV-R-15-3 screen 4 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



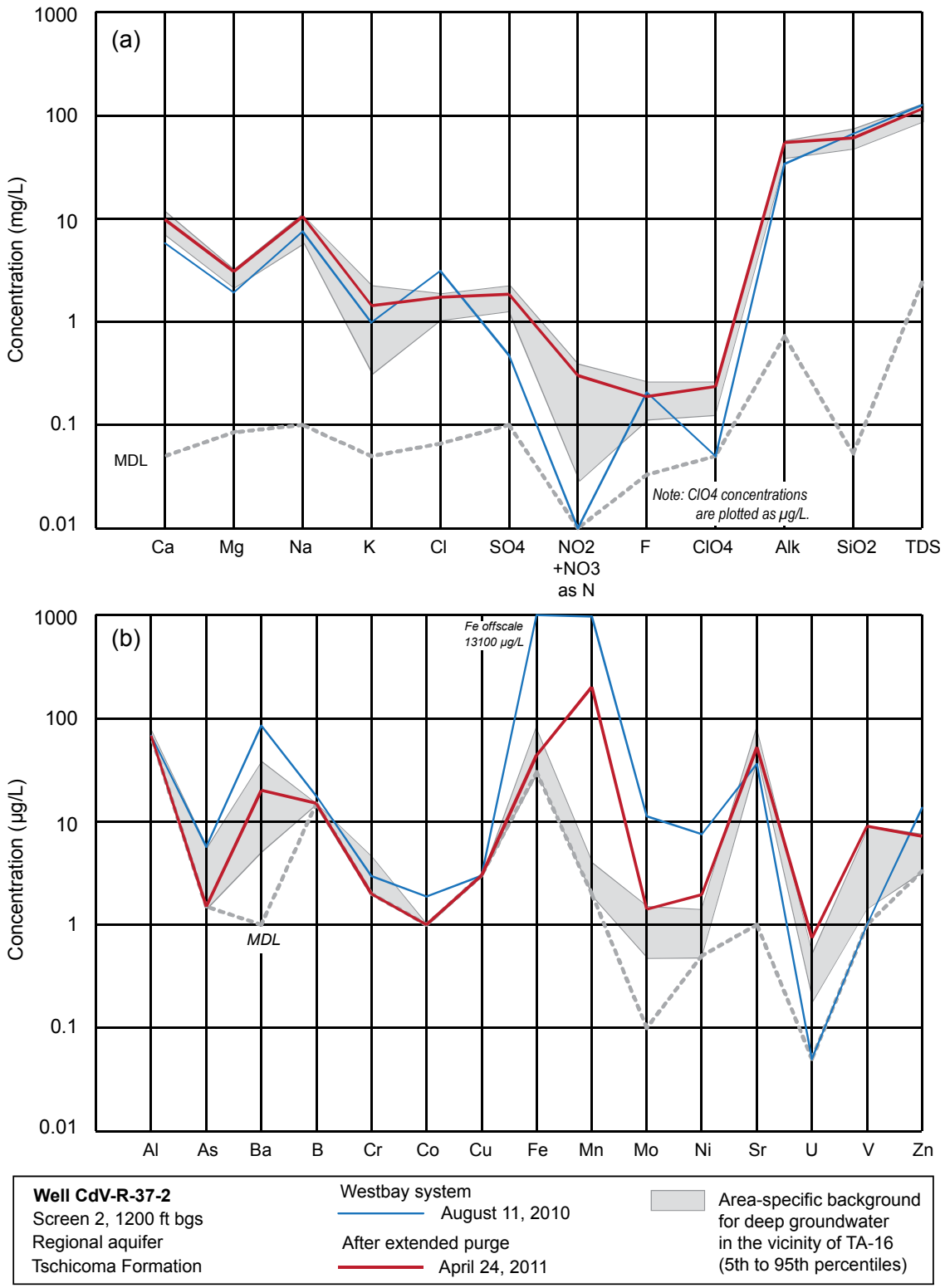
Data source: Attachment B-1.

Figure B-4.0-8 Concentrations in filtered groundwater samples from well CdV-R-15-3 screen 5 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



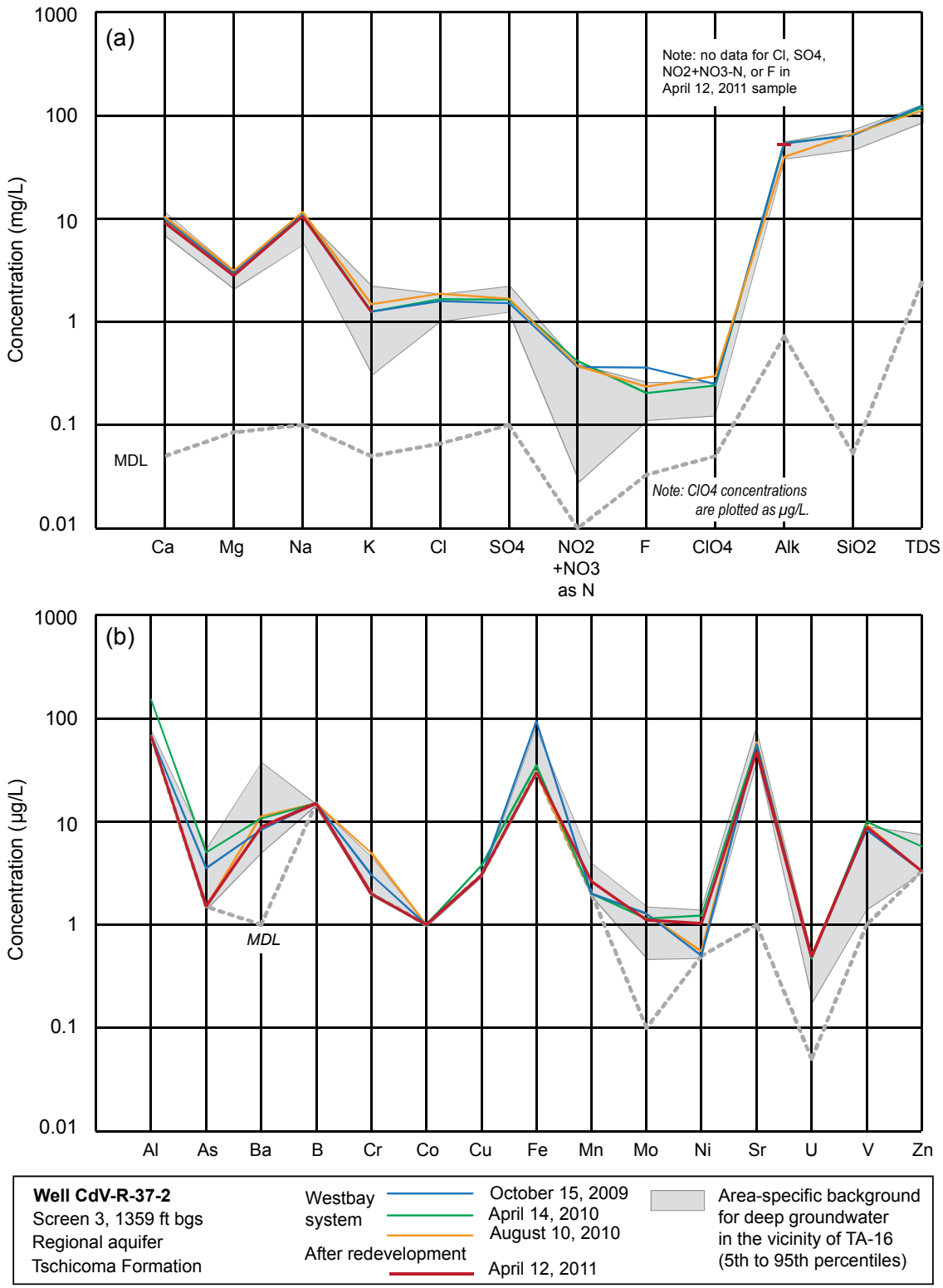
Data source: Attachment B-1.

Figure B-4.0-9 Concentrations in filtered groundwater samples from well CdV-R-15-3 screen 6 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



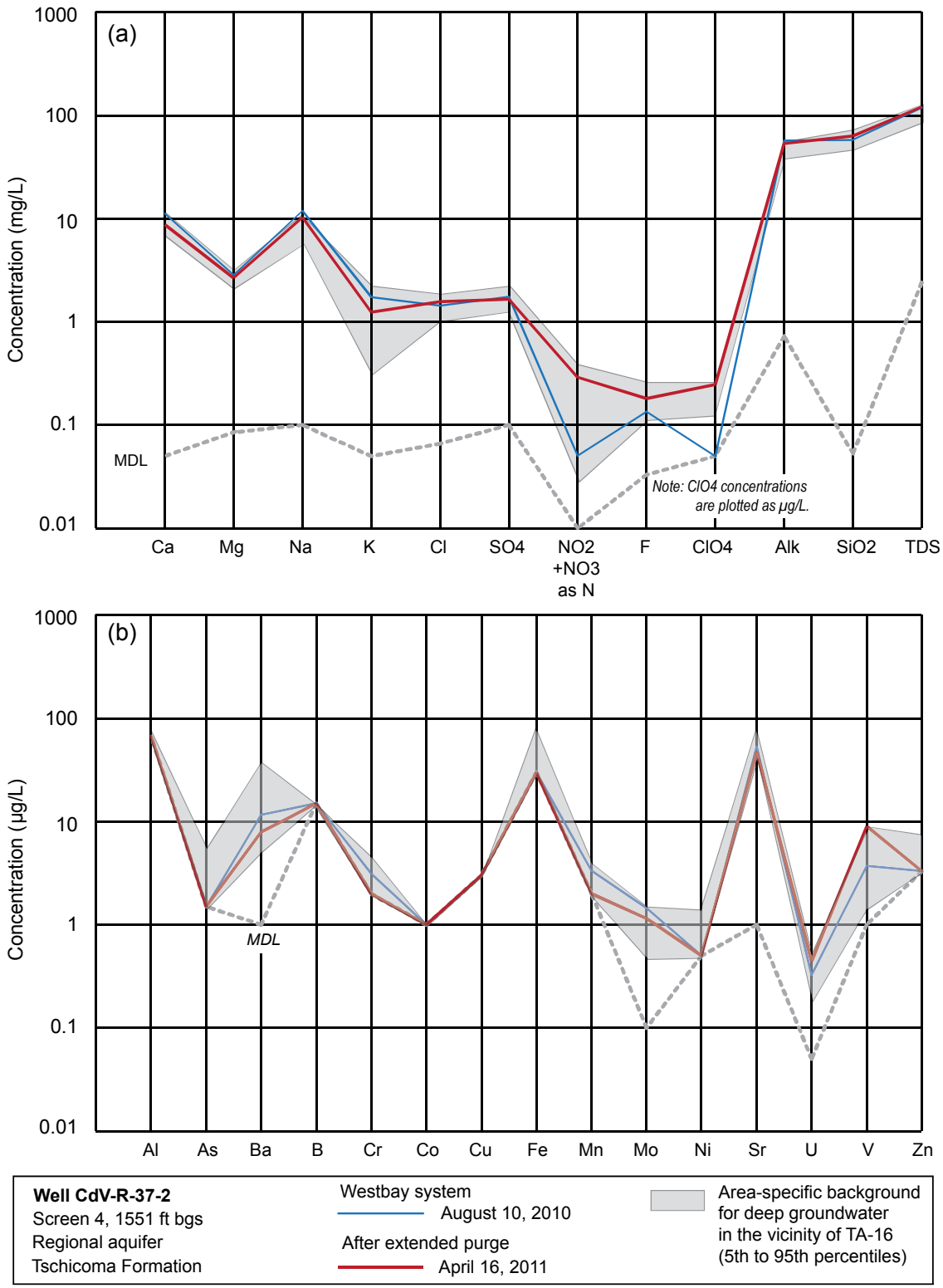
Data source: Attachment B-1.

Figure B-4.0-10 Concentrations in filtered groundwater samples from well CdV-R-37-2 screen 2 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



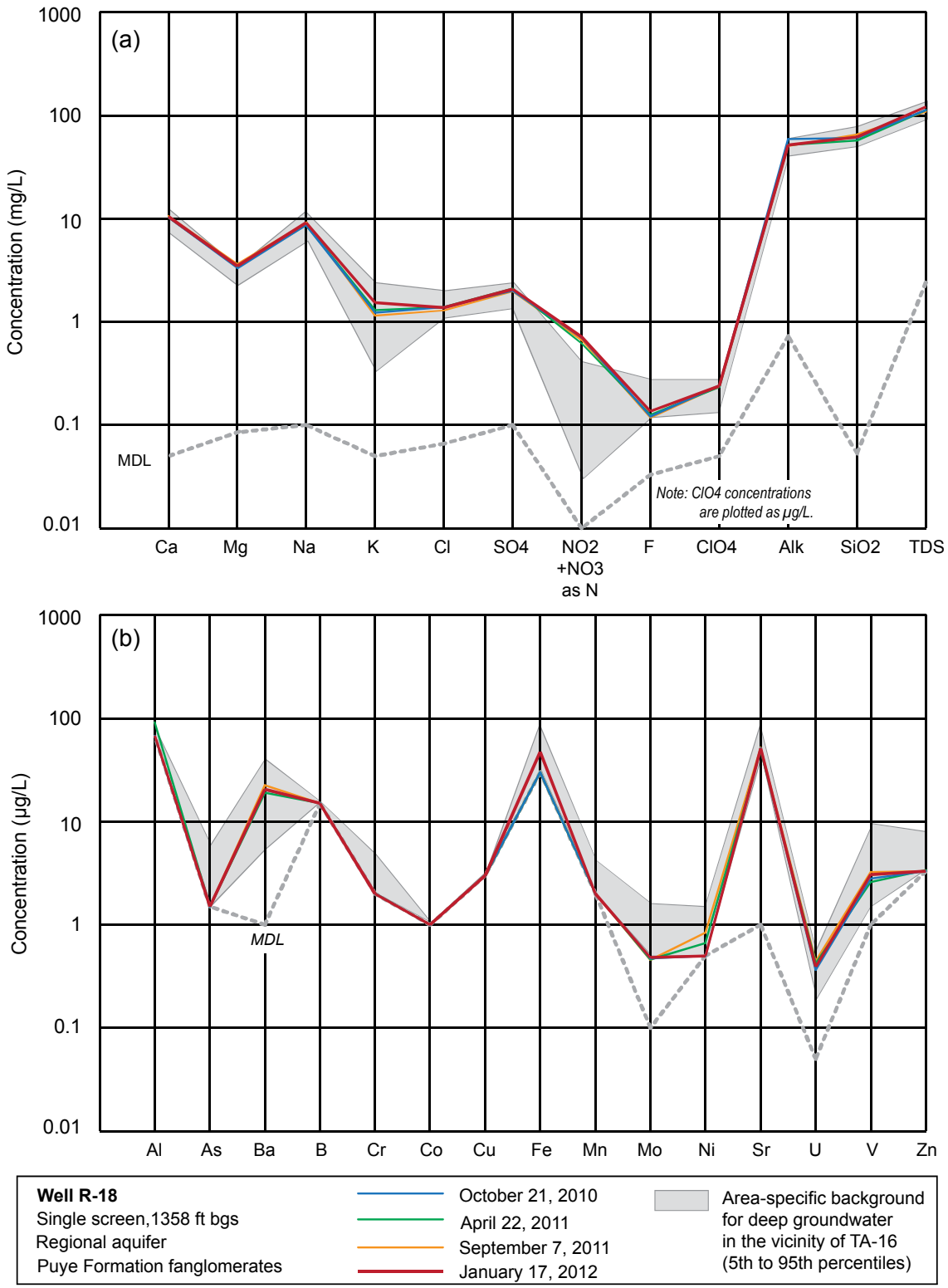
Data source: Attachment B-1.

Figure B-4.0-11 Concentrations in filtered groundwater samples from well CdV-R-37-2 screen 3 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



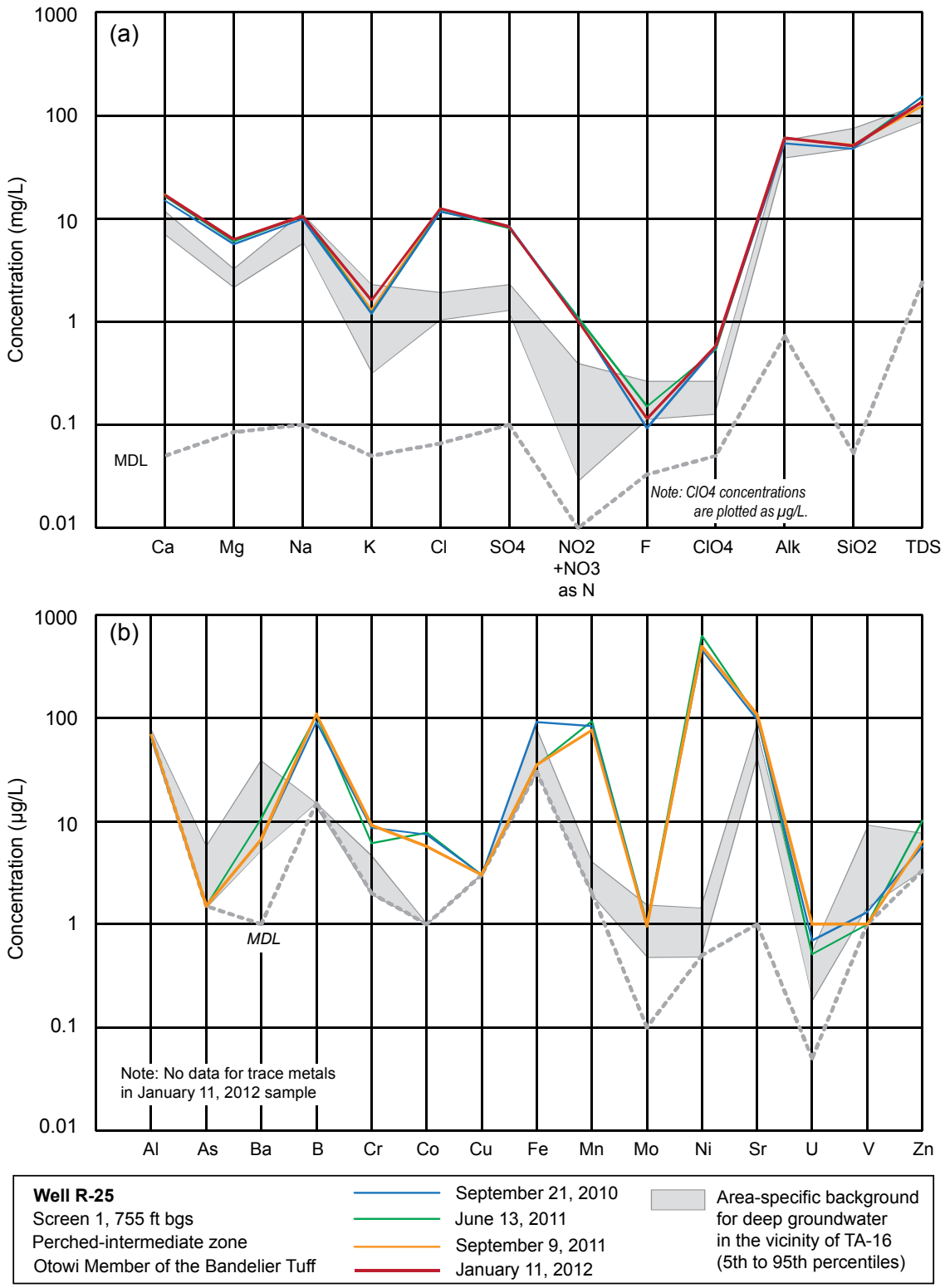
Data source: Attachment B-1.

Figure B-4.0-12 Concentrations in filtered groundwater samples from well CdV-R-37-2 screen 4 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



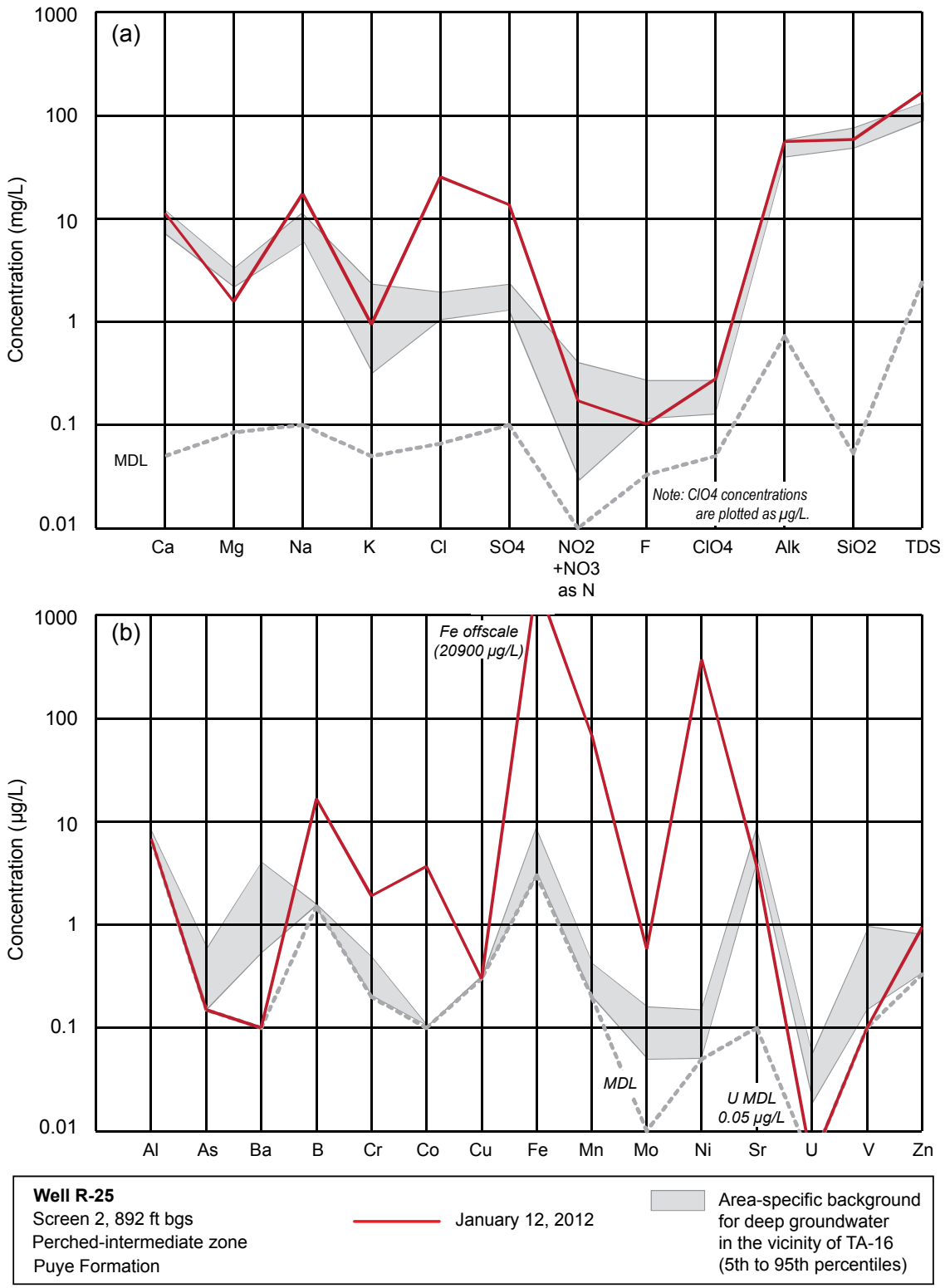
Data source: Attachment B-1.

Figure B-4.0-13 Concentrations in filtered groundwater samples from well R-18 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



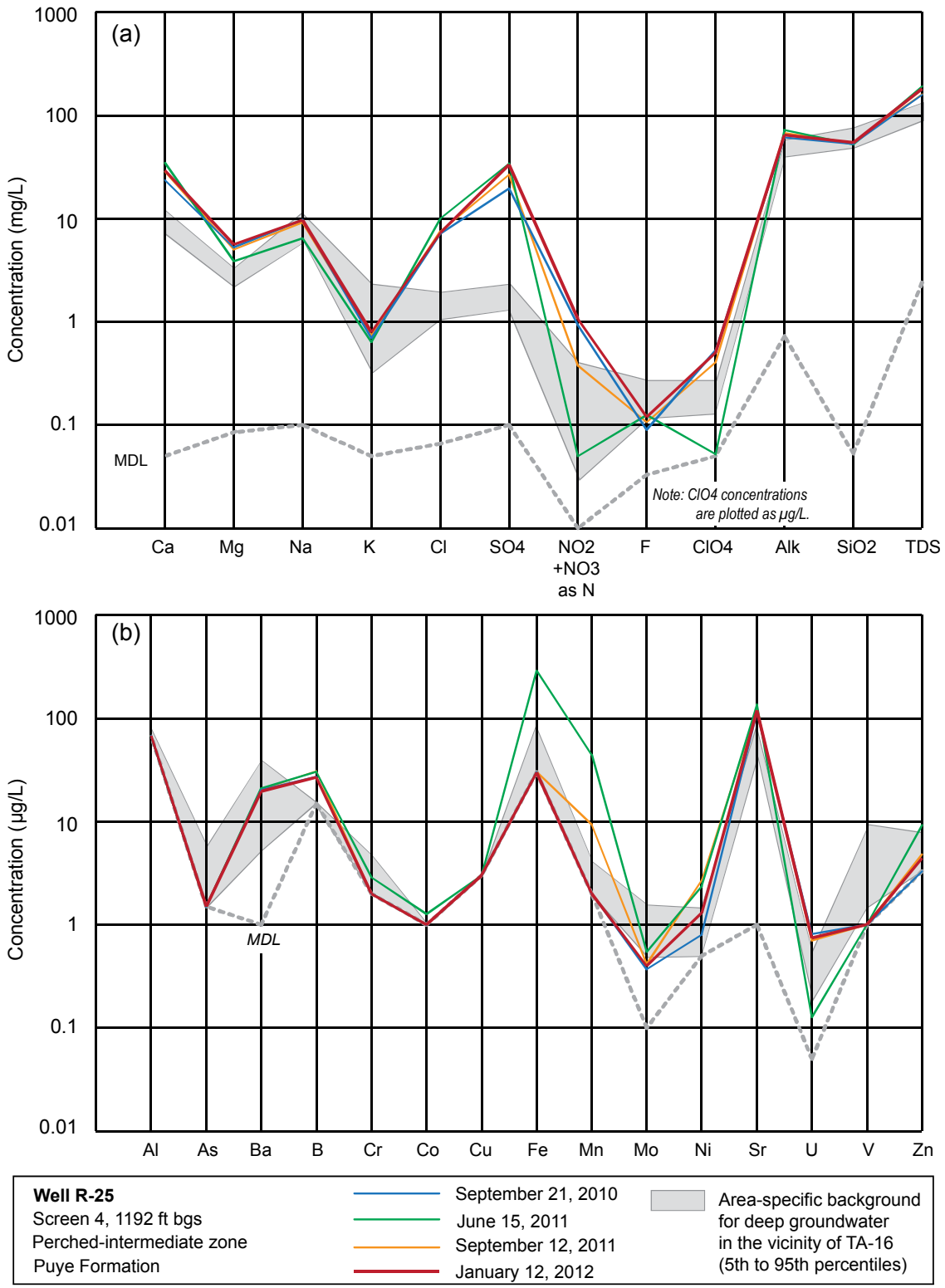
Data source: Attachment B-1.

Figure B-4.0-14 Concentrations in filtered groundwater samples from well R-25 screen 1 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



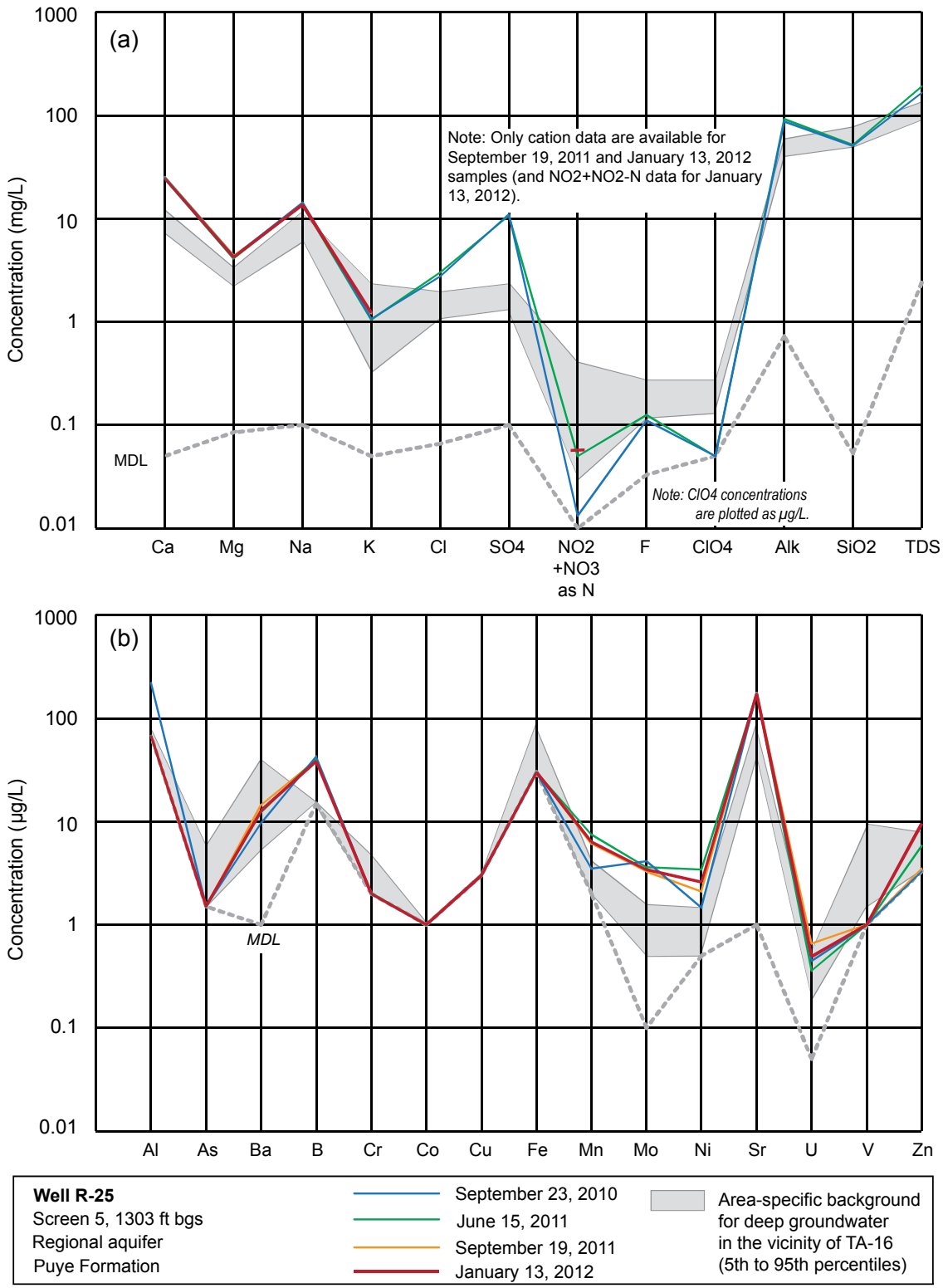
Data source: Attachment B-1.

Figure B-4.0-15 Concentrations in filtered groundwater samples from well R-25 screen 2 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



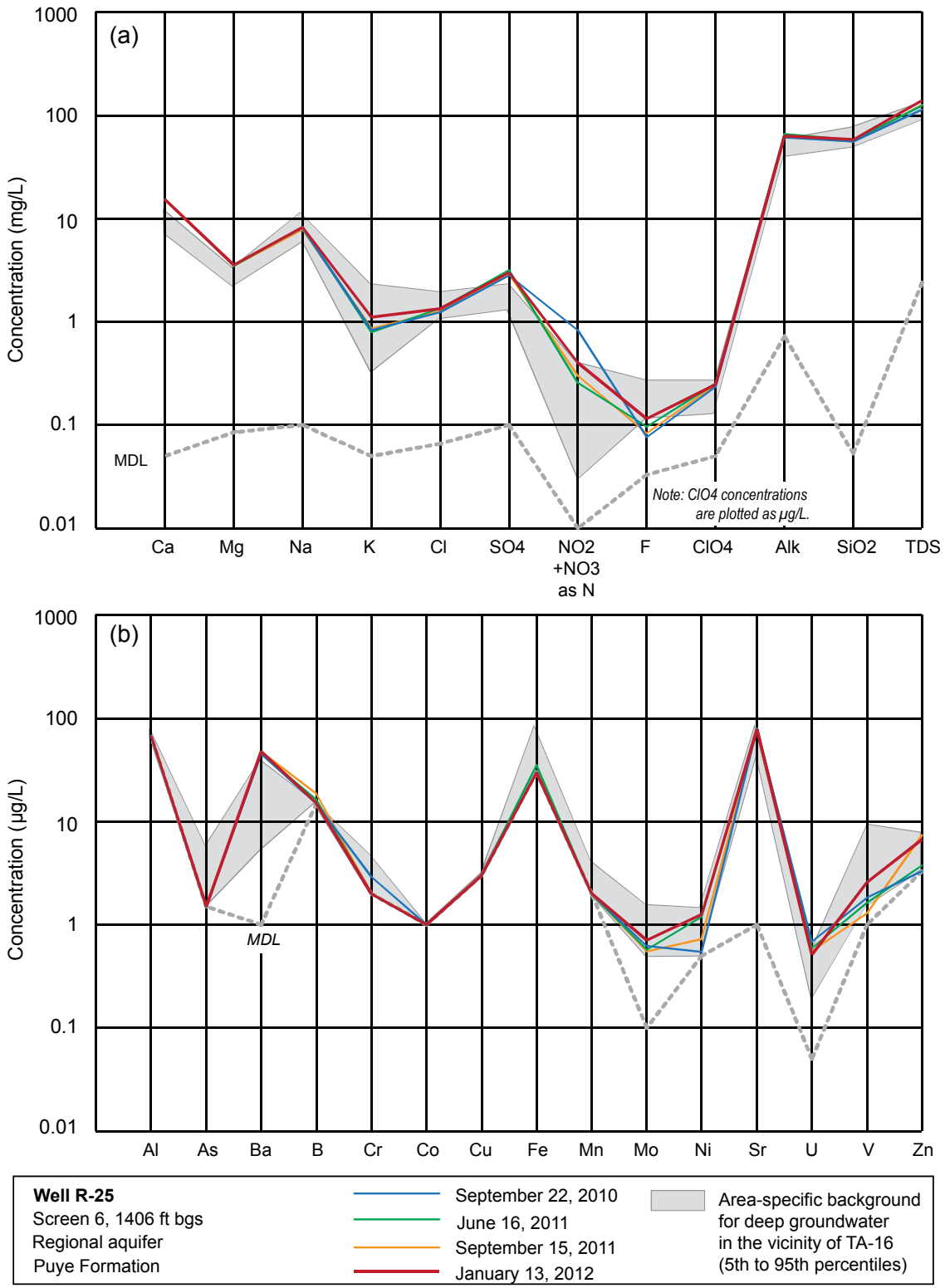
Data source: Attachment B-1.

Figure B-4.0-16 Concentrations in filtered groundwater samples from well R-25 screen 4 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



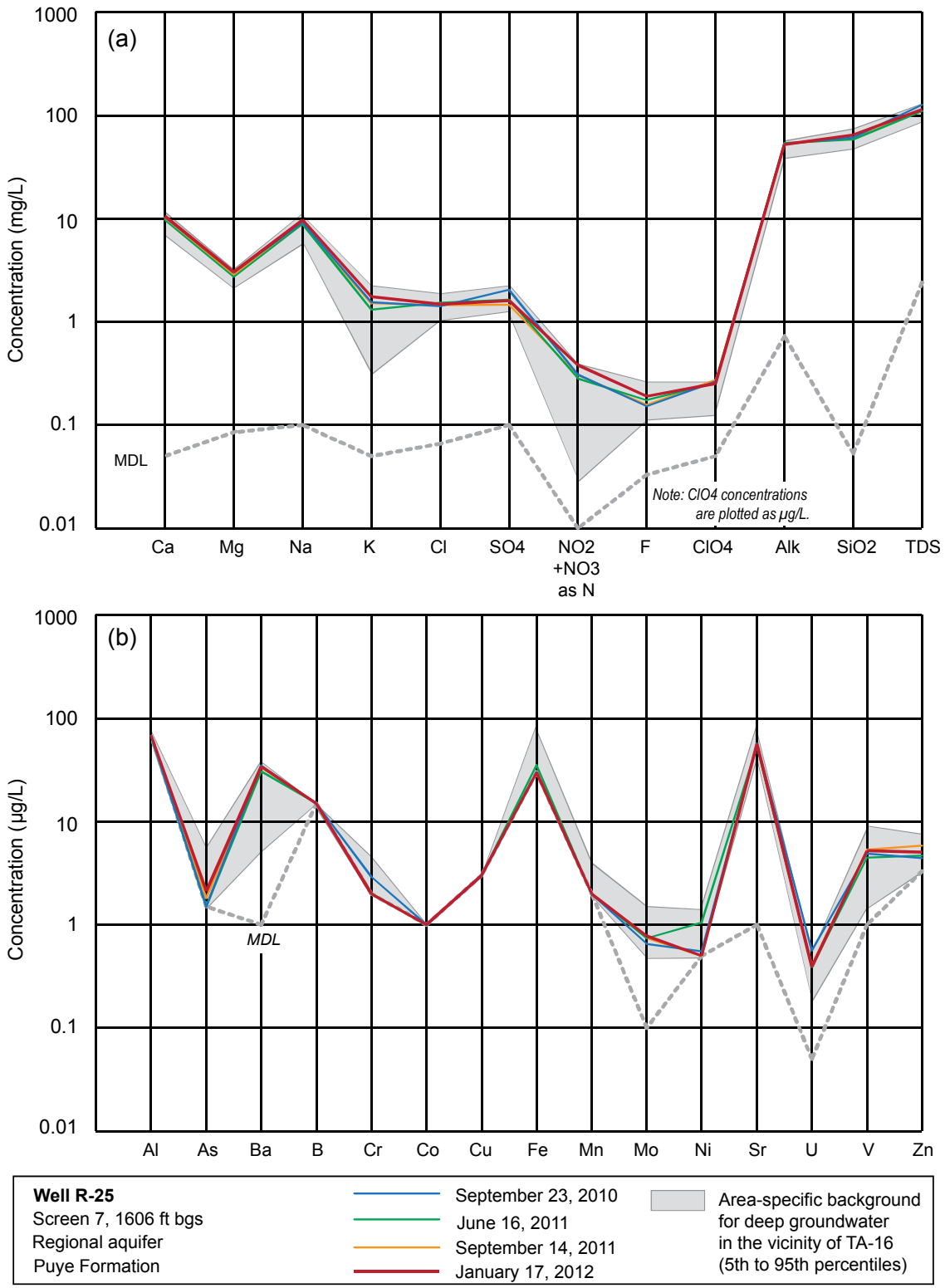
Data source: Attachment B-1.

Figure B-4.0-17 Concentrations in filtered groundwater samples from well R-25 screen 5 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



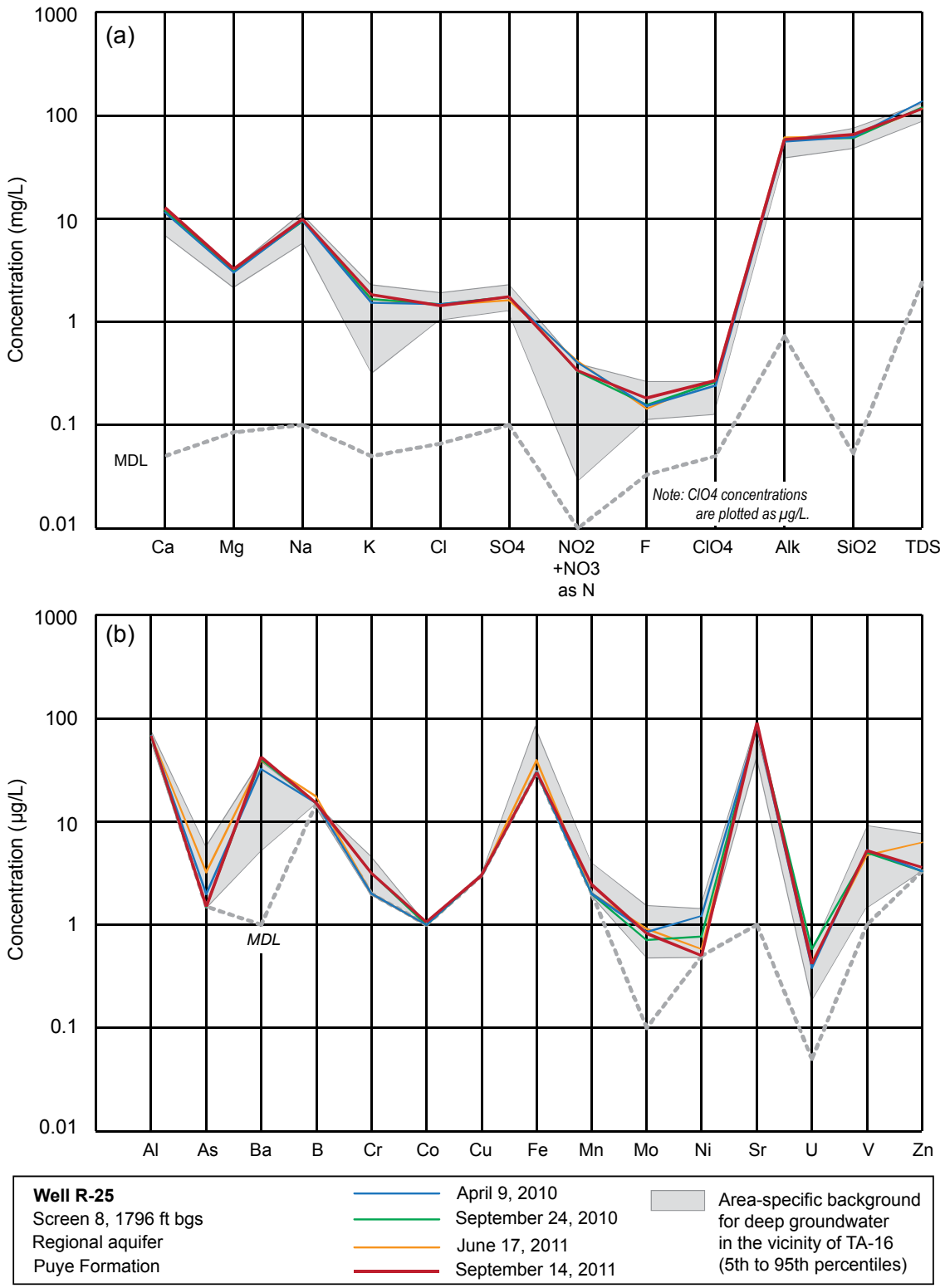
Data source: Attachment B-1.

Figure B-4.0-18 Concentrations in filtered groundwater samples from well R-25 screen 6 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



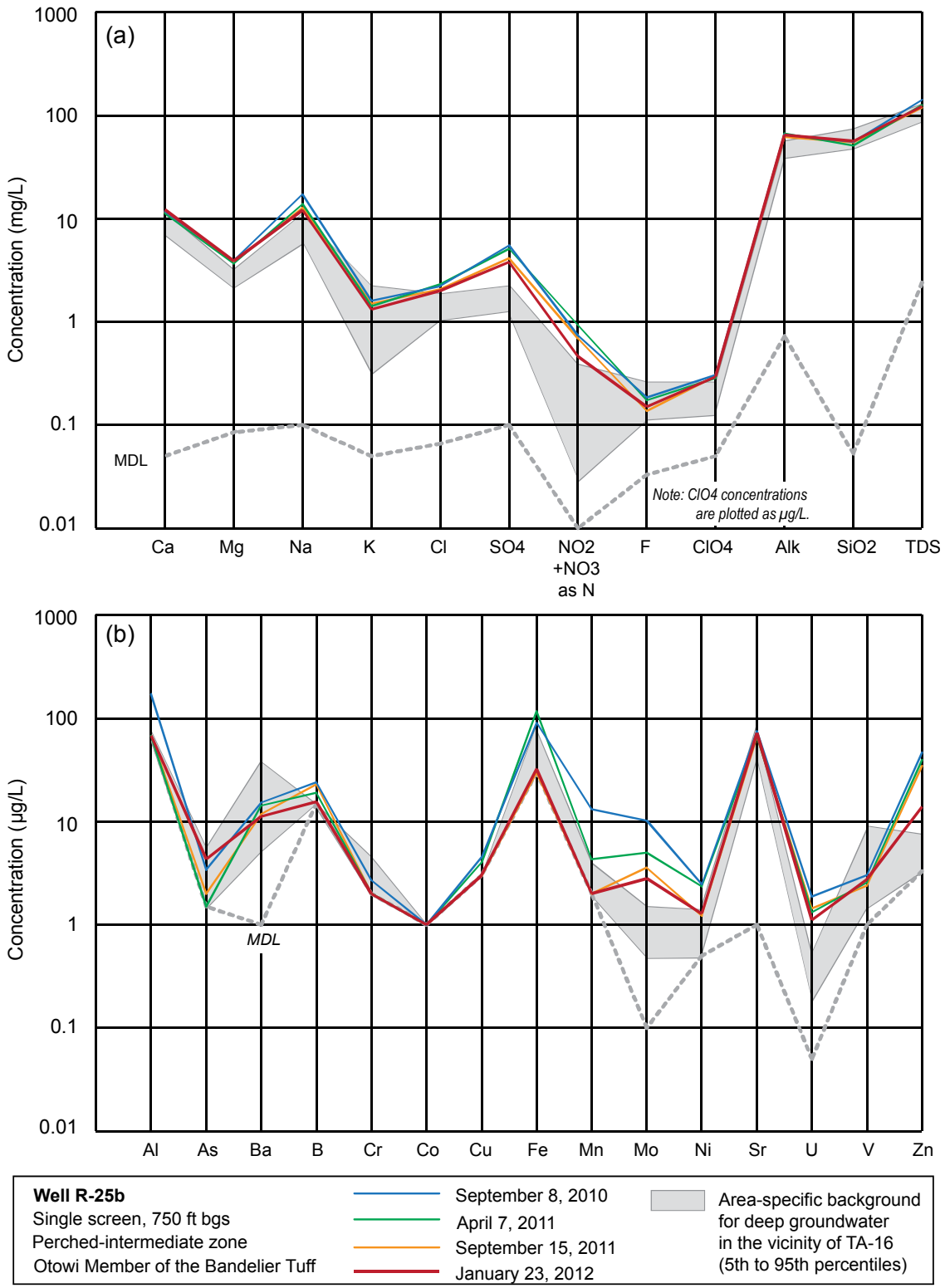
Data source: Attachment B-1.

Figure B-4.0-19 Concentrations in filtered groundwater samples from well R-25 screen 7 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



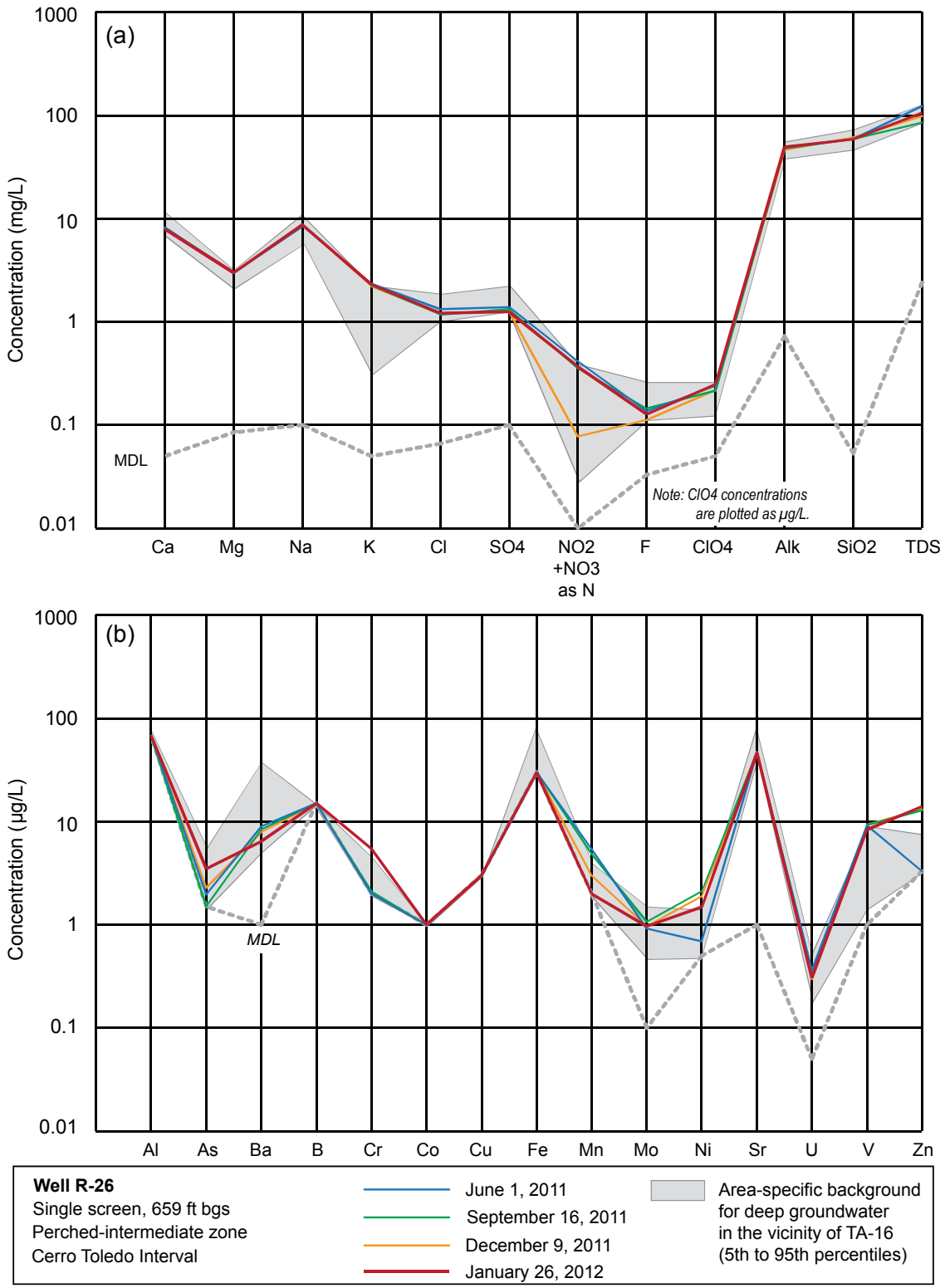
Data source: Attachment B-1.

Figure B-4.0-20 Concentrations in filtered groundwater samples from well R-25 screen 8 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



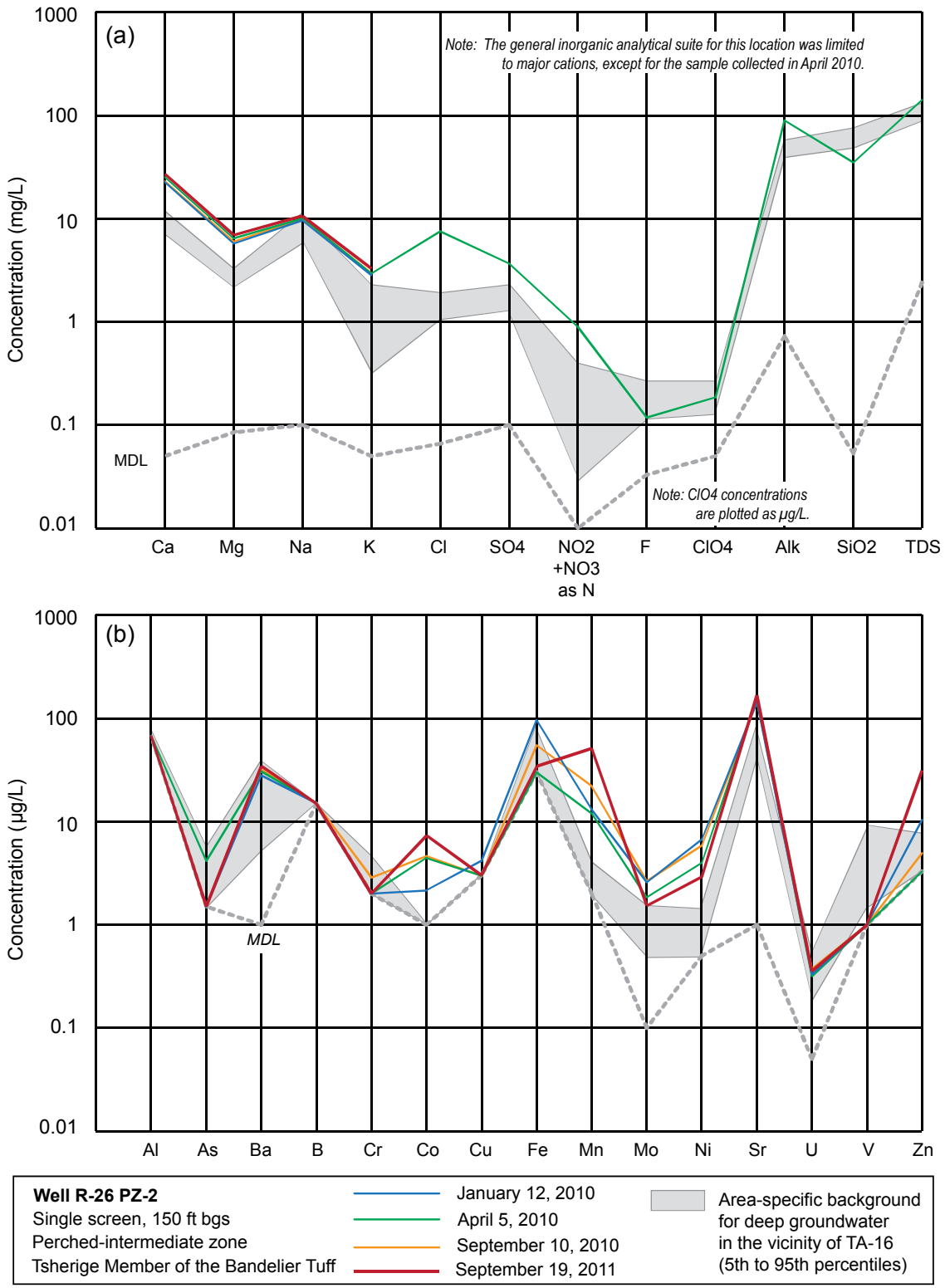
Data source: Attachment B-1.

Figure B-4.0-21 Concentrations in filtered groundwater samples from well R-25b compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



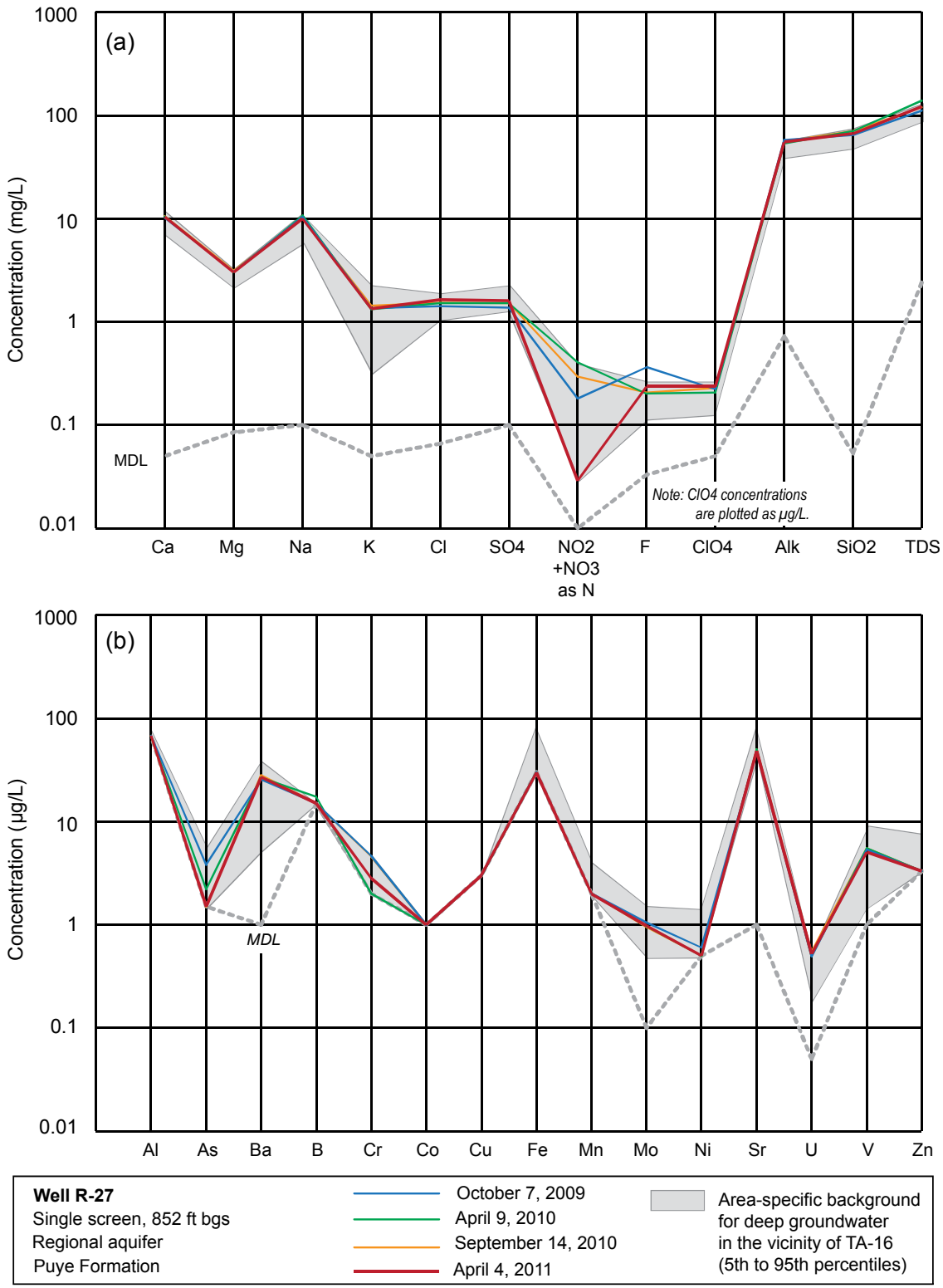
Data source: Attachment B-1.

Figure B-4.0-22 Concentrations in filtered groundwater samples from well R-26 screen 1 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



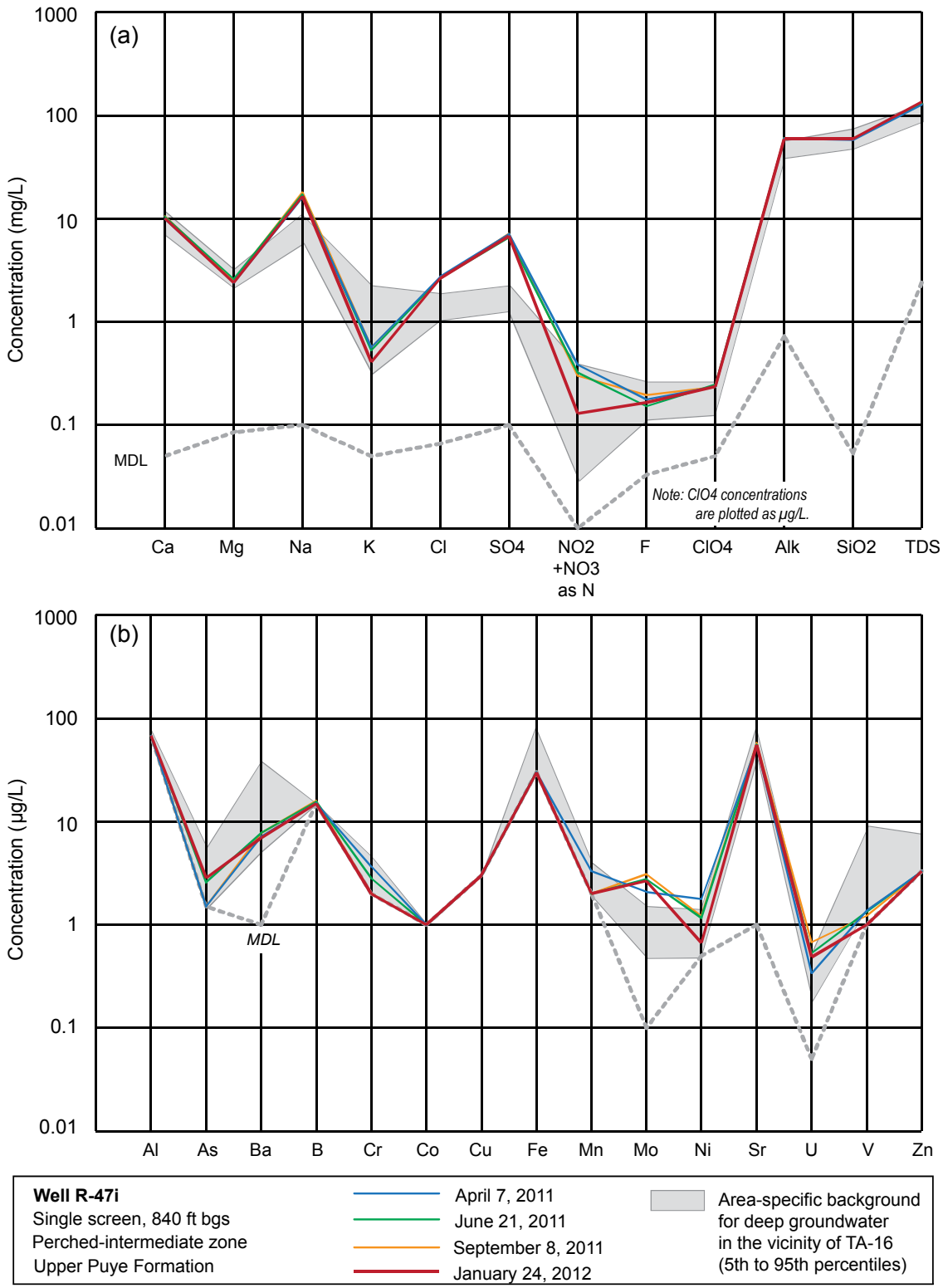
Data source: Attachment B-1.

Figure B-4.0-23 Concentrations in filtered groundwater samples from piezometer R-26 PZ-2 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



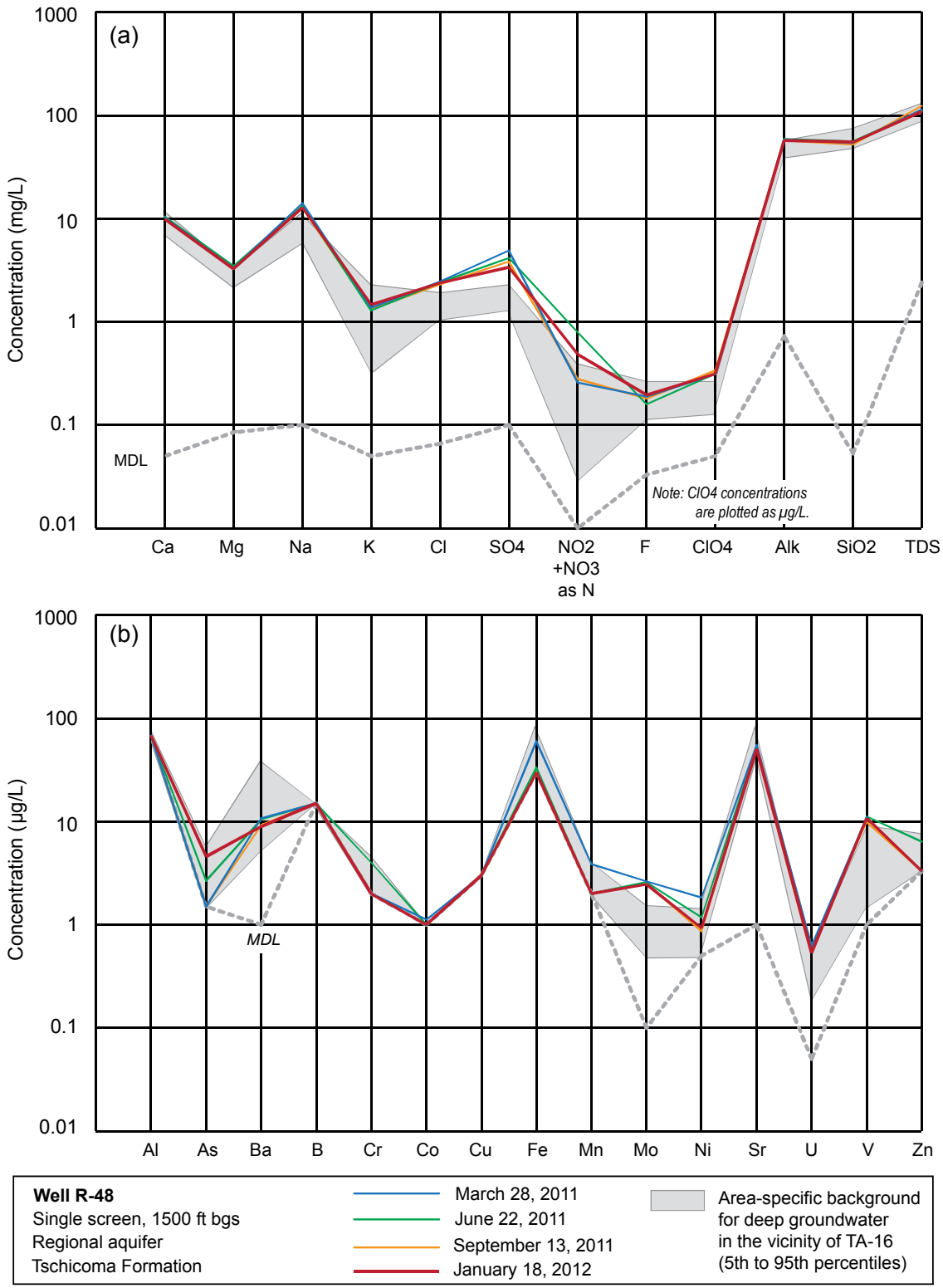
Data source: Attachment B-1.

Figure B-4.0-24 Concentrations in filtered groundwater samples from well R-27 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



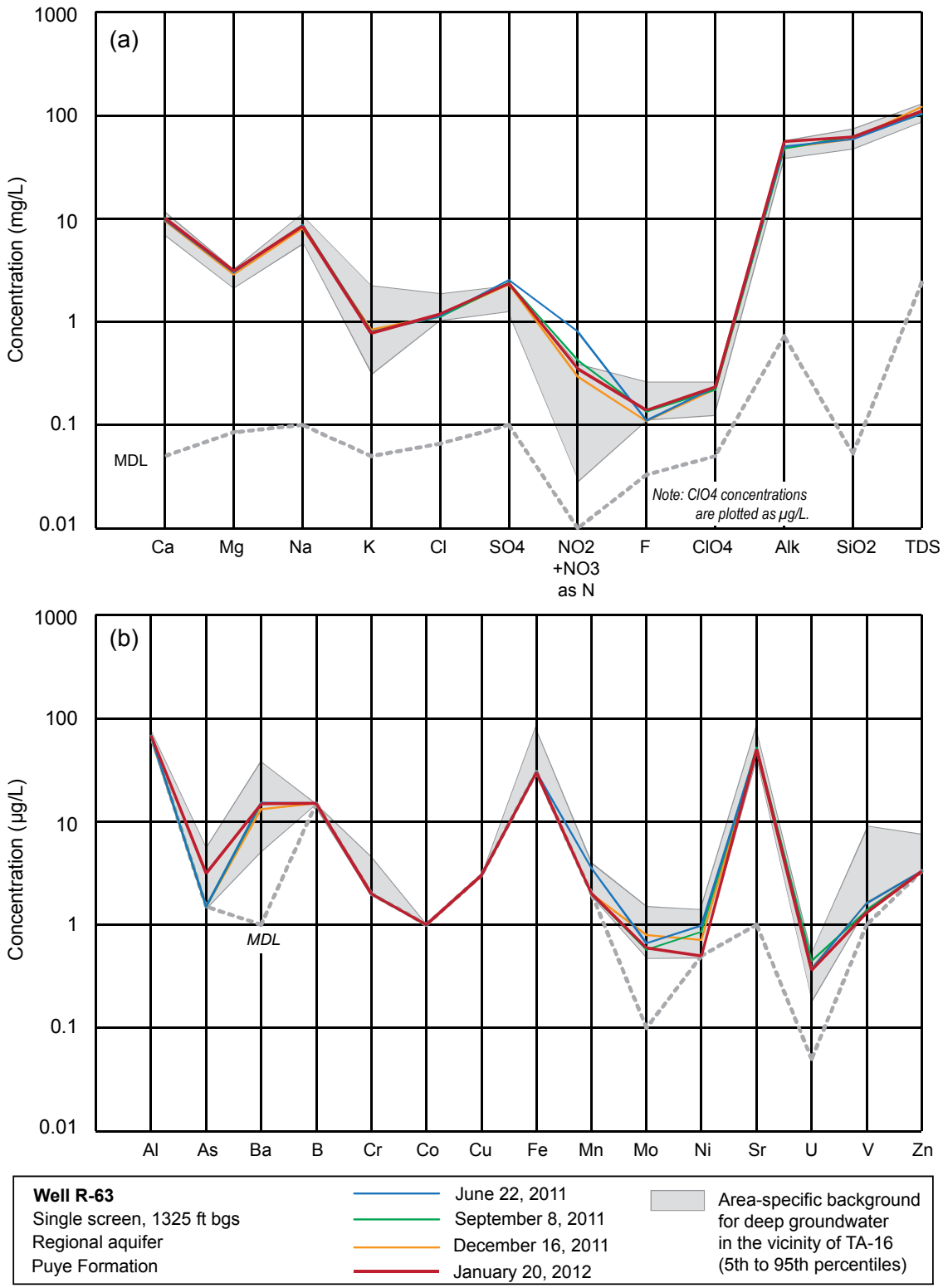
Data source: Attachment B-1.

Figure B-4.0-25 Concentrations in filtered groundwater samples from well R-47i compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



Data source: Attachment B-1.

Figure B-4.0-26 Concentrations in filtered groundwater samples from well R-48 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals



Data source: Attachment B-1.

Figure B-4.0-27 Concentrations in filtered groundwater samples from well R-63 compared with area-specific background concentrations for (a) major ions, perchlorate, silica, and TDS and (b) trace metals

Table B-1.0-1
Perched-Intermediate and Regional Wells in the TA-16 Monitoring Well Network

Well	Screen Designation	Nominal Screen Depth (ft bgs)	Hydrologic Zone	Formation Lithology in Screened Interval	Current Sampling System	Installation Date for Sampling System	Earliest Sampling Event	Most Recent Sampling Event
16-26644	Single	130	Intermediate	Qbt3	Bennett	January 2010	20-Apr-2010	13-Jan-2012
CdV-16-1(i)	Single	624	Intermediate	Qbo	GSP	5-May-2004	1-Jun-2005	22-Sep-2011
CdV-16-2(i)r	Single	850	Intermediate	Tpf	GSP	28-Oct-2005	15-Dec-2005	18-Jan-2012
CdV-16-4ip	Screen 1	815.6	Intermediate	Tpf	None	Not applicable	31-Aug-2010	7-Mar-2011
CdV-16-4ip	Screen 2	1110	Intermediate	Tpf	None	Not applicable	18-Sep-2010	31-Mar-2011
CDV-37-1(i)	Single	632	Intermediate	Tpf	GSP	16-Jan-2010	8-Feb-2010	24-Jan-2012
CdV-R-15-3	Screen 4	1254	Regional	Tpf	None	16-Sep-2002	16-Sep-2002	11-May-2011
CdV-R-15-3	Screen 5	1350	Regional	Tpf	None	17-Sep-2002	17-Sep-2002	4-May-2011
CdV-R-15-3	Screen 6	1640	Regional	Tpf	None	18-Sep-2002	18-Sep-2002	3-May-2011
CdV-R-37-2	Screen 2	1200	Regional	Tt	None	28-Jan-2002	28-Jan-2002	24-Apr-2011
CdV-R-37-2	Screen 3	1359	Regional	Tt	None	29-Jan-2002	29-Jan-2002	12-Apr-2011
CdV-R-37-2	Screen 4	1551	Regional	Tt	None	30-Jan-2002	30-Jan-2002	16-Apr-2011
R-18	Single	1358	Regional	Tpf	GSP	2005	25-Aug-2005	17-Jan-2012
R-25	MP1A	754.8	Intermediate	Qbo	Westbay	3-Oct-2000	14-Nov-2000	11-Jan-2012
R-25	MP2A	891.8	Intermediate	Tpf	Westbay	3-Oct-2000	14-Nov-2000	11-Jan-2012
R-25	MP4A	1192.4	Intermediate	Tpf	Westbay	3-Oct-2000	4-Dec-2000	12-Jan-2012
R-25	MP5A	1303.4	Regional	Tpf	Westbay	3-Oct-2000	7-Dec-2000	13-Jan-2012
R-25	MP6A	1406.3	Regional	Tpf	Westbay	3-Oct-2000	8-Dec-2000	13-Jan-2012
R-25	MP7A	1606	Regional	Tpf	Westbay	3-Oct-2000	11-Dec-2000	17-Jan-2012
R-25	MP8A	1796	Regional	Tpf	Westbay	3-Oct-2000	12-Dec-2000	17-Jan-2012
R-25b	Single	750	Intermediate	Qbo	Bennett	2009	5-Jan-2009	23-Jan-2012
R-26	MP1A	659.3	Intermediate	Qct	GSP	17-Jun-2011	13-Apr-2005	26-Jan-2012
R-26 PZ-2	R-26 PZ-2	150	Intermediate	Qbt3	Bailer	Not applicable	15-Jun-2009	26-Jan-2012

Table B-1.0-1 (continued)

Well	Screen Designation	Nominal Screen Depth (ft bgs)	Hydrologic Zone	Formation Lithology in Screened Interval	Current Sampling System	Installation Date for Sampling System	Earliest Sampling Event	Most Recent Sampling Event
R-27	Single	852	Regional	Tpf	GSP	16-Sep-2006	1-Jul-2006	4-Apr-2011
R-47i	Single	840	Intermediate	Tpf	GSP	18-Dec-2009	21-Dec-2009	24-Jan-2012
R-48	Single	1500	Regional	Tt	GSP	22-Nov-2009	23-Nov-2009	18-Jan-2012
R-63	Single	1325	Regional	Tpf	GSP	3-Apr-2011	12-Apr-2011	20-Jan-2012

Sources: Koch and Schmeer (2011, 201566); well completion reports cited in Appendix A of this report; LANL water-quality database.

Notes: bgs = Below ground surface; GSP = gear-driven submersible pump; Qbo = Otowi Member of the Bandelier Tuff, Qbt3 = Unit 3 of the Tshirege Member of the Bandelier Tuff, Qct = Cerro Toledo interval, Tp = Puye Formation, Tpf = fluvial facies of the Puye Formation, Tt = Tschicoma Formation.

Table B-2.0-1
Final Field Parameters for Recent Sampling Events

Location	Port Name	Depth (ft bgs)	Date	Purge Volume (gal.)	Purged Casing Volumes	DO (mg/L)	ORP[a] (mV)	Specific Conductance (µS/cm)	Temperature °C	Turbidity (NTU)	Field pH	Alkalinity[b] (mg/L as $CaCO_3$)
16-26644	Single	130	22-Jul-2010	—[c]	—	7.9	351	173	12	4	6.5	—
16-26644	Single	130	2-Nov-2010	—	—	7.5	334	211	12	4	6.8	—
16-26644	Single	130	2-Mar-2011	—	—	7.6	135	206	12	4	6.9	—
16-26644	Single	130	19-Sep-2011	8.7	5	7.8	-28	230	12	2	7.0	79
16-26644	Single	130	13-Jan-2012	7	4	7.8	100	219	11	1	7.1	—
CdV-16-1(i)	Single	624	16-Apr-2010	194	3	5.2	133	165	13	1	6.4	—
CdV-16-1(i)	Single	624	13-Sep-2010	205	3	5.5	132	172	14	<1	6.6	79
CdV-16-1(i)	Single	624	8-Apr-2011	221	3	5.9	180	161[d]	13	<1	6.8	81
CdV-16-1(i)	Single	624	22-Sep-2011	206	3	6.7	195	157[d]	13	2	6.8	—
CdV-16-2(i)r	Single	850	1-Apr-2010	68	3	8.1	107	115	4	3	6.8	—
CdV-16-2(i)r	Single	850	7-Sep-2010	66	3	6.6	166	111	13	5	6.3	65
CdV-16-2(i)r	Single	850	30-Mar-2011	74	3	7.1	189	116	12	2	7.1	66
CdV-16-2(i)r	Single	850	6-Sep-2011	93	4	7.0	164	123	13	<1	7.0	66
CdV-16-2(i)r	Single	850	18-Jan-2012	78	2	6.7	242	117	11	<1	7.1	—
CdV-16-4ip	P1A	815.6	31-Aug-2010	—	—	9.2	97	139	16	15	7.4	—
CdV-16-4ip	P1A	815.6	7-Mar-2011	—	—	8.8	170	124	11	5	7.8	67
CdV-16-4ip	P2A	1110	18-Sep-2010	—	—	7.0	352	144	13	92[e]	7.4	—
CdV-16-4ip	P2A	1110	2-Nov-2010	11600	180	8.5	506	115	8	1	7.3	—
CdV-16-4ip	P2A	1110	31-Mar-2011	—	—	6.1	50	108	13	<1	7.4	62
CdV-37-1(i)	Single	632	21-Sep-2010	82	3	7.7	78	129	14	5	6.6	73
CdV-37-1(i)	Single	632	1-Dec-2010	92	3	6.7	246	117	13	4	7.0	73
CdV-37-1(i)	Single	632	31-Mar-2011	108	3	7.8	-92	119	14	2	7.2	72
CdV-37-1(i)	Single	632	20-Jun-2011	97	3	7.7	109	120	14	3	7.1	68
CdV-37-1(i)	Single	632	24-Jan-2012	97	3	7.8	39	116	12	3	7.1	—
CdV-R-15-3	MP4A	1254	5-Aug-2010	—	—	6.9	—	120	19	1	8.1	—

Table B-2.0-1 (continued)

Location	Port Name	Depth (ft bgs)	Date	Purge Volume (gal.)	Purged Casing Volumes	DO (mg/L)	ORP[a] (mV)	Specific Conductance (µS/cm)	Temperature °C	Turbidity (NTU)	Field pH	Alkalinity[b] (mg/L as $CaCO_3$)
CdV-R-15-3	MP4A	1254	11-May-2011	—	—	6.0	166	119	17	<1	7.7	72
CdV-R-15-3	MP5A	1350	4-Aug-2010	—	—	3.3	—	145	22	1	7.3	—
CdV-R-15-3	MP5A	1350	4-May-2011	—	—	2.3	278	123	20	2	7.6	75
CdV-R-15-3	MP6A	1640	5-Aug-2010	—	—	11.0	—	129	23	2	7.5	—
CdV-R-15-3	MP6A	1640	3-May-2011	—	—	3.0	191	113	19	2	7.6	67
CdV-R-37-2	MP2A	1200	11-Aug-2010	—	—	3.9	—	122	24	2	6.3	—
CdV-R-37-2	MP2A	1200	24-Apr-2011	—	—	2.3	20	116	22	2	7.2	70
CdV-R-37-2	MP3A	1359	10-Aug-2010	—	—	5.8	—	120	23	<1	8.1	68
CdV-R-37-2	MP3A	1359	12-Apr-2011	—	—	7.5	132	94	21	<1	7.7	72
CdV-R-37-2	MP4A	1551	10-Aug-2010	—	—	6.9	—	127	23	1	8.5	77
CdV-R-37-2	MP4A	1551	16-Apr-2011	—	—	6.9	116	98	22	—	7.6	70
R-18	Single	1358	11-Mar-2010	300	3	9.3	276	117	14	<1	7.6	—
R-18	Single	1358	21-Oct-2010	290	3	5.1	501	113	16	<1	7.5	69
R-18	Single	1358	22-Apr-2011	292	3	6.1	114	113	16	<1	7.7	67
R-18	Single	1358	7-Sep-2011	289	3	5.5	164	109	16	<1	7.8	67
R-18	Single	1358	17-Jan-2012	293	3	5.8	139	107	15	<1	7.8	—
R-25	MP1A	754.8	31-Mar-2009	—	—	6.0	—	134	12	14	6.7	—
R-25	MP1A	754.8	21-Sep-2010	—	—	5.3	—	189	14	11	6.7	80
R-25	MP1A	754.8	14-Jun-2011	—	—	6.3	—	197	16	9	7.6	78
R-25	MP1A	754.8	9-Sep-2011	—	—	6.5	—	184	12	19	7.1	80
R-25	MP1A	754.8	11-Jan-2012	—	—	7.5	—	187	9	6	7.3	—
R-25	MP2A	891.8	6-Apr-2010	—	—	5.3	—	258	11	29	6.2	107
R-25	MP2A	891.8	21-Sep-2010	—	—	7.7	—	230	14	107	6.5	63
R-25	MP2A	891.8	15-Jun-2011	—	—	4.0	—	318	15	69	6.6	54
R-25	MP2A	891.8	12-Sep-2011	—	—	8.6[e]	—	285[e]	14[d]	92[f]	6.3[f]	27
R-25	MP2A	891.8	12-Jan-2012	—	—	8.0	—	202	9	145	6.4	—

Table B-2.0-1 (continued)

Location	Port Name	Depth (ft bgs)	Date	Purge Volume (gal.)	Purged Casing Volumes	DO (mg/L)	ORP[a] (mV)	Specific Conductance (µS/cm)	Temperature °C	Turbidity (NTU)	Field pH	Alkalinity[b] (mg/L as $CaCO_3$)
R-25	MP4A	1192.4	7-Apr-2010	—	—	7.1	—	197	12	<1	7.9	—
R-25	MP4A	1192.4	21-Sep-2010	—	—	6.6	—	207	14	2	6.9	87
R-25	MP4A	1192.4	15-Jun-2011	—	—	6.0	—	219	15	3	7.7	92
R-25	MP4A	1192.4	12-Sep-2011	—	—	4.7	—	230	16	2	7.6	84
R-25	MP4A	1192.4	12-Jan-2012	—	—	8.2	—	229	9	3	7.3	—
R-25	MP5A	1303.4	7-Apr-2010	—[g]	—	4.1	—	212	12	1	7.8	—
R-25	MP5A	1303.4	23-Sep-2010	—[g]	—	3.8	—	219	15	1	7.5	120
R-25	MP5A	1303.4	15-Jun-2011	—	—	4.6	—	222	15	<1	8.2	117
R-25	MP5A	1303.4	19-Sep-2011	—[g]	—	4.8	—	214	15	<1	7.4	—
R-25	MP5A	1303.4	13-Jan-2012	—[g]	—	6.0	—	207	10	1	7.6	—
R-25	MP6A	1406.3	8-Apr-2010	—	—	4.8	—	128	14	1	7.7	—
R-25	MP6A	1406.3	22-Sep-2010	—	—	6.3	—	154	16	3	7.9	83
R-25	MP6A	1406.3	16-Jun-2011	—	—	5.6	—	152	16	<1	7.8	81
R-25	MP6A	1406.3	15-Sep-2011	—	—	8.4	—	140	15	<1	8.0	81
R-25	MP6A	1406.3	13-Jan-2012	—	—	5.9	—	131	11	<1	8.1	—
R-25	MP7A	1606	8-Apr-2010	—	—	10.6	—	101	14	1	7.6	—
R-25	MP7A	1606	23-Sep-2010	—	—	7.9	—	119	16	<1	7.8	69
R-25	MP7A	1606	16-Jun-2011	—	—	7.1	—	106	17	<1	7.9	67
R-25	MP7A	1606	14-Sep-2011	—	—	7.6	—	115	15	<1	8.2	68
R-25	MP7A	1606	17-Jan-2012	—	—	7.8	—	110	12	<1	8.1	—
R-25	MP8A	1796	9-Apr-2010	—	—	11.2	—	121	15	2	7.8	—
R-25	MP8A	1796	24-Sep-2010	—	—	8.6	—	120	14	1	8.3	76
R-25	MP8A	1796	17-Jun-2011	—	—	6.7	—	127	15	1	8.0	75
R-25	MP8A	1796	14-Sep-2011	—	—	8.1	—	126	14	<1	8.3	75
R-25	MP8A	1796	17-Jan-2012	—	—	7.5	—	119	12	11	8.7	—
R-25b	Single	750	21-Apr-2010	190	6	4.0	66	165	12	10	7.2	—

Table B-2.0-1 (continued)

Location	Port Name	Depth (ft bgs)	Date	Purge Volume (gal.)	Purged Casing Volumes	DO (mg/L)	ORP[a] (mV)	Specific Conductance (µS/cm)	Temperature °C	Turbidity (NTU)	Field pH	Alkalinity[b] (mg/L as $CaCO_3$)
R-25b	Single	750	8-Sep-2010	110	3	4.0	89	153	11	14	7.0	90
R-25b	Single	750	7-Apr-2011	95	3	4.6	212	152	10	11	7.4	90
R-25b	Single	750	15-Sep-2011	91	3	5.2	200	138	10	10	7.4	82
R-25b	Single	750	23-Jan-2012	90	3	5.0	151	140	9	8	7.6	—
R-26	MP1A	659.3	13-Aug-2010	—	—	5.9	—	98	20	<1	8.1	—
R-26	MP1A	659.3	1-Jun-2011	—	—	7.0	212	94	22	2	8.0	60
R-26	MP1A	659.3	16-Sep-2011	213	3	7.2	-61	100	16	5	7.7	61
R-26	MP1A	659.3	9-Dec-2011	217	3	7.2	44	102	15	2	7.6	61
R-26	MP1A	659.3	26-Jan-2012	218	3	7.2	-23	99	15	1	7.6	—
R-26 PZ-2	R-26 PZ-2	150	12-Jan-2010	0.3	<1	10.2	242	121	10	220	6.7	—
R-26 PZ-2	R-26 PZ-2	150	5-Apr-2010	3	2	8.8	178	229	13	1000	7.0	—
R-26 PZ-2	R-26 PZ-2	150	10-Sep-2010	0.75	1.5	8.4	356	205	15	312	7.0	—
R-26 PZ-2	R-26 PZ-2	150	5-Apr-2011	0.4	1	9.0	259	146	13	71	7.2	—
R-26 PZ-2	R-26 PZ-2	150	19-Sep-2011	0.6	1	8.2	353	233	12	563	7.2	—
R-26 PZ-2	R-26 PZ-2	150	26-Jan-2012	0.25	1	7.0	-20	206	9	877	7.2	—
R-27	Single	852	7-Oct-2009	157	3	6.8	113	116	18	<1	7.3	—
R-27	Single	852	9-Apr-2010	190	4	6.8	78	121	18	<1	7.8	—
R-27	Single	852	14-Sep-2010	155	3	7.0	397	121	17	2	7.7	72
R-27	Single	852	4-Apr-2011	163	3	6.9	8	119	17	<1	8.0	74
R-47i	Single	840	2-Dec-2010	112	3	4.9	295	152[d]	13	3	7.1	85
R-47i	Single	840	7-Apr-2011	176	5	5.9	114	116[d]	14	2	7.2	77
R-47i	Single	840	21-Jun-2011	111	3	5.8	86	120[d]	16	1	7.3	79
R-47i	Single	840	8-Sep-2011	113	3	5.8	127	147[d]	15	1	7.3	79
R-47i	Single	840	24-Jan-2012	116	3	5.7	-4	142[d]	13	2	7.3	—
R-48	Single	1500	6-Jan-2011	692	4	6.1	-6	136[d]	20	8	7.9	80
R-48	Single	1500	28-Mar-2011	598	3	6.9	27	122[d]	21	5	8.0	77

Table B-2.0-1 (continued)

Location	Port Name	Depth (ft bgs)	Date	Purge Volume (gal.)	Purged Casing Volumes	DO (mg/L)	ORP[a] (mV)	Specific Conductance (µS/cm)	Temperature °C	Turbidity (NTU)	Field pH	Alkalinity[b] (mg/L as $CaCO_3$)
R-48	Single	1500	22-Jun-2011	944	5	6.6	246	122[d]	21	2	8.1	77
R-48	Single	1500	13-Sep-2011	573	3	8.5	118	124[d]	21	5	8.2	74
R-48	Single	1500	18-Jan-2012	576	3	7.4	200	129[d]	20	3	8.3	—
R-63	Single	1325	12-Apr-2011	502	5	6.2	255	103	14	6	7.5	66
R-63	Single	1325	22-Jun-2011	318	3	6.5	133	106	15	3	7.5	65
R-63	Single	1325	8-Sep-2011	440	5	6.5	203	103	14	7	7.5	62
R-63	Single	1325	16-Dec-2011	323	3	6.5	139	103	12	1	7.6	65
R-63	Single	1325	20-Jan-2012	330	3	6.3	186	102	14	4	7.5	—

Source: Attachment B-1 (for water-quality data); field summary reports (for purge volumes and CV calculations).

[a] ORP = Oxygen-reduction potential.

[b] Alkalinity measured by Earth and Environmental Sciences 14.

[c] — = Not available.

[d] Effervescent discharge noted throughout purge. This characteristic commonly causes drifting of specific conductance readings as bubbles collect on the surface of the probe in the flow-through cell.

[e] Turbidity high because sample was collected after restarting pump.

[f] From sample collection log for this sample.

[g] Prioritized suite collected because formation sampled dry.

Table B-2.0-2
General Inorganic Constituents in Filtered Samples and TOC

Location	Port Name	Depth (ft bgs)	Date	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	SO_4 (mg/L)	Cl (mg/L)	F (mg/L)	NO_3+NO_2-N (mg/L)	ClO_4 (µg/L)	SiO_2 (mg/L)	TDS (mg/L)	TOC (mg/L)	Alkalinity[a] (mg/L as $CaCO_3$)	Lab pH[a]
16-26644	Single	130	22-Jul-2010	14	2.9	14	4.5	6.8	15	0.14	0.56	0.51	41	144	2.6	50	7.1
16-26644	Single	130	2-Nov-2010	16	2.9	14	4.7	5.4	21	0.15	0.64	0.47	44	150	1.4	56	7.2
16-26644	Single	130	2-Mar-2011	17	3.0	16	5.4	5.4	19	0.16	0.88	0.47	47	157	0.6	59	7.2
16-26644	Single	130	19-Sep-2011	16	3.3	18	6.0	7.9	20	0.15	1.05	0.55	46	163	1.6	60	7.2
16-26644	Single	130	13-Jan-2012	17	3.2	18	5.9	5.8	20	0.15	0.93	0.46	48	163	0.8	66	7.3
CdV-16-1(i)	Single	624	16-Apr-2010	12	2.4	13	5.2	8.7	6.8	0.11	0.88	0.49	57	147	0.9	56	7.1
CdV-16-1(i)	Single	624	13-Sep-2010	12	2.5	13	5.4	8.9	6.8	0.10	0.84	0.50	58	143	0.9	57	7.2
CdV-16-1(i)	Single	624	8-Apr-2011	12	2.4	13	5.5	9.3	7.2	0.12	0.84	0.52	55	161	1.2	61	7.2
CdV-16-1(i)	Single	624	22-Sep-2011	12	2.3	14	5.7	8.7	7.0	0.10	0.84	0.58	62	136	1.3	57	7.0
CdV-16-2(i)r	Single	850	1-Apr-2010	13	0.3	9	2.2	3.2	2.0	0.17	0.50	0.24	63	125	0.6	48	7.2
CdV-16-2(i)r	Single	850	7-Sep-2010	12	0.2	9	2.2	3.4	2.0	0.16	0.52	0.28	64	126	0.8	47	7.2
CdV-16-2(i)r	Single	850	30-Mar-2011	13	<0.3	9	2.3	3.8	2.2	0.19	0.60	0.29	63	111	0.4	45	7.3
CdV-16-2(i)r	Single	850	6-Sep-2011	13	0.3	10	2.6	4.4	2.2	0.19	0.57	0.29	59	120	<1	50	7.3
CdV-16-2(i)r	Single	850	18-Jan-2012	13	0.5	10	2.6	4.3	2.5	0.18	0.60	0.30	64	123	0.7	51	7.4
CdV-16-4ip	P1A	815.6	31-Aug-2010	11	1.2	12	3.5	4.1	3.4	0.13	1.07	0.38	67	126	1.5	51	7.5
CdV-16-4ip	P1A	815.6	7-Mar-2011	10	1.3	10	2.9	3.8	3.2	0.15	0.90	0.35	60	121	0.4	46	7.1
CdV-16-4ip	P2A	1110	18-Sep-2010	13	1.0	11	3.1	5.7	3.2	0.12	1.12	0.38	60	132	0.8	49	7.4
CdV-16-4ip	P2A	1110	2-Nov-2010	8	0.7	10	3.2	2.4	1.5	0.12	0.46	0.25	59	117	0.7	48	7.5
CdV-16-4ip	P2A	1110	31-Mar-2011	9	0.6	9	2.9	2.6	1.6	0.14	0.43	0.25	58	109	0.4	47	7.6
CdV-37-1(i)	Single	632	21-Sep-2010	14	0.6	9	2.3	5.1	1.4	0.14	0.12	0.13	63	130	1.9	54	7.2
CdV-37-1(i)	Single	632	1-Dec-2010	13	0.6	9	2.3	3.5	1.2	0.15	0.12	0.12	63	131	<1.0	65	7.5
CdV-37-1(i)	Single	632	31-Mar-2011	13	0.6	9	2.2	3.6	1.2	0.17	0.16	0.13	62	112	0.9	54	7.4
CdV-37-1(i)	Single	632	20-Jun-2011	13	0.7	10	2.4	3.1	1.2	0.14	<0.25	0.26	63	127	<0.8	57	7.5

Table B-2.0-2 (continued)

Location	Port Name	Depth (ft bgs)	Date	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	SO_4 (mg/L)	Cl (mg/L)	F (mg/L)	NO_3+NO_2-N (mg/L)	ClO_4 (µg/L)	SiO_2 (mg/L)	TDS (mg/L)	TOC (mg/L)	Alkalinity[a] (mg/L as $CaCO_3$)	Lab pH[a]
CdV-37-1(i)	Single	632	24-Jan-2012	11	0.5	9	2.2	2.9	1.2	0.18	0.03	0.13	62	134	1.0	54	7.4
CdV-R-15-3	MP4A	1254	5-Aug-2010	10	1.4	10	3.2	1.8	1.5	0.14	0.26	0.27	60	121	0.4	55	8.2
CdV-R-15-3	MP4A	1254	11-May-2011	9	1.3	10	3.2	2.0	1.6	0.13	0.30	0.26	59	113	0.4	55	7.9
CdV-R-15-3	MP5A	1350	4-Aug-2010	11	1.6	13	2.4	3.7	1.8	0.34	<0.25	<0.2	63	141	2.2	62	7.5
CdV-R-15-3	MP5A	1350	4-May-2011	11	1.4	12	2.0	2.2	1.6	0.27	0.23	0.21	58	126	1.3	59	7.9
CdV-R-15-3	MP6A	1640	4-Aug-2010	12	1.9	10	3.0	1.9	1.5	0.18	0.05	<0.2	68	138	0.5	60	8.0
CdV-R-15-3	MP6A	1640	3-May-2011	11	1.9	9	2.8	2.0	1.4	0.15	0.17	0.23	68	131	1.0	50	7.8
CdV-R-37-2	MP2A	1200	11-Aug-2010	8	1.0	6	1.9	0.5	3.1	0.21	<0.25	<0.2	66	126	3.0	34	6.5
CdV-R-37-2	MP2A	1200	24-Apr-2011	11	1.4	10	3.1	1.9	1.7	0.19	0.30	0.24	61	116	0.8	54	7.6
CdV-R-37-2	MP3A	1359	10-Aug-2010	12	1.5	10	3.2	1.7	1.9	0.24	0.37	0.30	66	111	<1	40	8.2
CdV-R-37-2	MP3A	1359	12-Apr-2011	11	1.3	9	2.8	[b]							<1	52	
CdV-R-37-2	MP4A	1551	10-Aug-2010	12	1.7	11	2.8	1.8	1.4	0.14	0.05	<0.2	58	119	1.1	57	8.6
CdV-R-37-2	MP4A	1551	16-Apr-2011	10	1.2	9	2.7	1.7	1.6	0.18	0.29	0.25	<63	121	0.4	53	7.6
R-18	Single	1358	11-Mar-2010	9	1.2	10	3.4	1.9	1.2	0.11	0.63	0.22	58	118	0.8	52	7.8
R-18	Single	1358	21-Oct-2010	9	1.2	10	3.3	2.0	1.4	0.12	0.70	0.24	60	113	0.6	59	7.9
R-18	Single	1358	22-Apr-2011	9	1.3	10	3.4	2.1	1.4	0.13	0.62	0.23	57	113	0.6	52	7.7
R-18	Single	1358	7-Sep-2011	9	1.2	11	3.6	2.0	1.3	0.12	0.67	0.24	65	109	0.5	51	7.7
R-18	Single	1358	17-Jan-2012	9	1.5	11	3.5	2.1	1.4	0.14	0.72	0.24	62	121	0.5	52	7.9
R-25	MP1A	754.8	31-Mar-2009	15	1.3	10	6.0	<8.1	12	<0.13	1.24	0.51	49	129	0.9	56	7.0
R-25	MP1A	754.8	21-Sep-2010	15	1.2	10	5.6	8.4	12	0.09	1.04	0.57	48	153	1.1	54	5.7
R-25	MP1A	754.8	14-Jun-2011	16	1.2	11	6.0	8.1	12	0.15	1.09	0.53	50	151	0.8	61	7.6
R-25	MP1A	754.8	9-Sep-2011	17	1.3	11	6.2	8.3	12	0.12	1.01	0.58	52	123	1.1	60	7.2
R-25	MP1A	754.8	11-Jan-2012	11	1.6	17	6.3	7.9	12	0.13	1.19	0.56	51	136	0.8	60	7.3
R-25	MP2A	891.8	6-Apr-2010	*19*[c]	*0.8*	*12*	*0.9*	*15*	*34*	*0.24*	*0.01*	0.17	*62*		*1.1*	*37*	*6.1*

Table B-2.0-2 (continued)

Location	Port Name	Depth (ft bgs)	Date	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	SO_4 (mg/L)	Cl (mg/L)	F (mg/L)	NO_3+NO_2-N (mg/L)	ClO_4 (µg/L)	SiO_2 (mg/L)	TDS (mg/L)	TOC (mg/L)	Alkalinity[a] (mg/L as $CaCO_3$)	Lab pH[a]
R-25	MP2A	891.8	21-Sep-2010	*20*	*0.9*	*11*	*1.0*	*18*	*38*	*0.13*	*0.05*	0.09	*59*		*1.4*	*63*	*6.4*
R-25	MP2A	891.8	15-Jun-2011	*20*	*0.6*	*9*	*0.8*	*52*	*80*	*0.22*	*0.03*	0.16	*58*		*2.2*	*54*	*6.2*
R-25	MP2A	891.8	12-Sep-2011	*20*	*0.8*	*11*	*1.1*	*18*	*38*	*0.17*	*0.01*		*63*		*1.2*	*27*	*5.9*
R-25	MP2A	891.8	12-Jan-2012	17	1.0	11	1.6	14	25	0.10	0.17	0.28	58	167	1.8	56	6.5
R-25	MP4A	1192.4	7-Apr-2010	7	0.6	33	4.5	21	9.2	0.11	<0.25	0.08	53	178	0.9	74	7.0
R-25	MP4A	1192.4	21-Sep-2010	10	0.7	24	5.3	20	7.1	0.09	0.93	0.53	53	158	0.9	61	7.9
R-25	MP4A	1192.4	15-Jun-2011	6	0.6	35	3.9	34	10	0.13	<0.05	0.05	52	192	0.6	73	7.7
R-25	MP4A	1192.4	12-Sep-2011	9	0.7	29	5.0	27	7.5	0.11	0.38	0.41	54	160	<0.8	68	7.2
R-25	MP4A	1192.4	12-Jan-2012	10	0.8	29	5.6	33	7.3	0.12	1.07	0.50	55	181	0.7	64	7.6
R-25	MP5A	1303.4	7-Apr-2010	15	1.1	25	4.4	12	2.7	0.12		<0.2	51	159		88	7.7
R-25	MP5A	1303.4	23-Sep-2010	14	1.1	25	4.3	11	2.8	0.11	<0.01	<0.2	51	166	4.4	87	7.7
R-25	MP5A	1303.4	15-Jun-2011	14	1.1	24	4.1	11	3.0	0.13	<0.05	<0.2	52	192	2.7	92	7.8
R-25	MP5A	1303.4	19-Sep-2011	13	1.2	25	4.4										
R-25	MP5A	1303.4	13-Jan-2012	14	1.2	24	4.2				0.06				2.2		
R-25	MP6A	1406.3	8-Apr-2010	8	0.9	16	3.7	2.8	1.2	0.08	0.34	0.21	61	123	0.6	60	8.0
R-25	MP6A	1406.3	22-Sep-2010	8	0.8	15	3.6	2.8	1.2	0.08	0.83	0.23	56	114	0.6	61	7.9
R-25	MP6A	1406.3	16-Jun-2011	8	0.8	15	3.5	3.2	1.4	0.10	0.26	0.25	58	125	<1	66	7.9
R-25	MP6A	1406.3	15-Sep-2011	8	0.9	15	3.5	2.9	1.3	0.08	0.30	0.25	56	127	<0.6	62	8.0
R-25	MP6A	1406.3	13-Jan-2012	8	1.1	15	3.6	3.0	1.3	0.12	0.40	0.25	58	140	0.7	63	8.0
R-25	MP7A	1606	8-Apr-2010	9	1.5	10	3.0	1.5	1.4	0.15	0.35	0.22	64	106	0.5	54	8.0
R-25	MP7A	1606	23-Sep-2010	9	1.6	10	3.0	2.0	1.4	0.15	0.31	0.26	61	127	0.6	53	7.8
R-25	MP7A	1606	16-Jun-2011	9	1.3	10	2.7	1.6	1.5	0.17	0.28	0.26	58	110	<1	54	8.0
R-25	MP7A	1606	14-Sep-2011	9	1.5	10	2.9	1.5	1.5	0.16	0.30	0.27	60	111	<0.5	53	7.9
R-25	MP7A	1606	17-Jan-2012	10	1.8	11	3.0	1.6	1.5	0.19	0.38	0.25	65	114	0.4	52	7.9

Table B-2.0-2 (continued)

Location	Port Name	Depth (ft bgs)	Date	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	SO_4 (mg/L)	Cl (mg/L)	F (mg/L)	NO_3+NO_2-N (mg/L)	ClO_4 (µg/L)	SiO_2 (mg/L)	TDS (mg/L)	TOC (mg/L)	Alkalinity[a] (mg/L as $CaCO_3$)	Lab pH[a]
R-25	MP8A	1796	9-Apr-2010	10	1.5	12	3.0	1.7	1.5	0.15	0.40	0.24	62	137	0.4	56	8.3
R-25	MP8A	1796	24-Sep-2010	9	1.7	12	3.1	1.8	1.5	0.16	0.33	0.26	60	120	0.5	58	8.3
R-25	MP8A	1796	17-Jun-2011	10	1.7	12	3.2	1.6	1.5	0.14	0.41	0.28	62	117	<0.4	61	8.2
R-25	MP8A	1796	14-Sep-2011	10	1.8	13	3.3	1.8	1.4	0.18	0.34	0.27	65	116	0.6	58	8.2
R-25	MP8A	1796	17-Jan-2012														
R-25b	Single	750	21-Apr-2010	19	1.4	10	3.4	6.1	2.1	0.16	<0.72	0.29	54	155	0.7	67	7.6
R-25b	Single	750	8-Sep-2010	17	1.6	12	3.9	5.5	2.2	0.19	0.74	0.31	55	142	1.0	65	7.6
R-25b	Single	750	7-Apr-2011	14	1.4	11	3.7	5.1	2.3	0.17	0.93	0.29	51	126	0.9	67	7.6
R-25b	Single	750	15-Sep-2011	13	1.5	12	3.8	4.1	2.1	0.14	0.69	0.30	54	119	<0.6	62	7.6
R-25b	Single	750	23-Jan-2012	12	1.3	12	3.9	3.8	2.0	0.15	0.46	0.29	56	123	0.8	64	7.7
R-26	MP1A	659.3	13-Aug-2010	9	2.3	7	2.9	1.3	1.2	0.13	0.38	0.23	55	104	0.5	48	7.9
R-26	MP1A	659.3	1-Jun-2011	8	2.4	8	3.0	1.4	1.3	0.14	0.42	0.24	59	123	0.6	49	7.8
R-26	MP1A	659.3	16-Sep-2011	9	2.3	8	3.0	1.3	1.2	0.14	0.36	0.22	59	86	<1.3	48	7.7
R-26	MP1A	659.3	9-Dec-2011	9	2.2	8	3.0	1.3	1.2	0.11	0.08	0.22	61	99	0.7	46	7.6
R-26	MP1A	659.3	26-Jan-2012	9	2.3	8	3.0	1.2	1.2	0.13	0.37	0.25	59	106	0.4	49	7.7
R-26 PZ-2	R-26 PZ-2	150	12-Jan-2010	10	2.8	23	5.7										
R-26 PZ-2	R-26 PZ-2	150	5-Apr-2010	10	2.9	25	6.4	3.7	7.5	0.12	0.90	0.19	35	142	1.3	90	7.6
R-26 PZ-2	R-26 PZ-2	150	10-Sep-2010	10	3.0	23	6.0										
R-26 PZ-2	R-26 PZ-2	150	5-Apr-2011														
R-26 PZ-2	R-26 PZ-2	150	19-Sep-2011	11	3.3	27	6.9										
R-26 PZ-2	R-26 PZ-2	150	26-Jan-2012														
R-27	Single	852	7-Oct-2009	10	1.4	10	3.1	1.4	1.4	0.36	<0.18	0.22	65	112	0.6	58	7.9
R-27	Single	852	9-Apr-2010	11	1.3	11	3.1	1.5	1.5	0.20	0.41	0.21	70	139	0.4	54	8.1
R-27	Single	852	14-Sep-2010	10	1.4	11	3.1	1.5	1.5	0.21	0.29	0.23	71	120	0.4	56	7.8

Table B-2.0-2 (continued)

Location	Port Name	Depth (ft bgs)	Date	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	SO_4 (mg/L)	Cl (mg/L)	F (mg/L)	NO_3+NO_2-N (mg/L)	ClO_4 (µg/L)	SiO_2 (mg/L)	TDS (mg/L)	TOC (mg/L)	Alkalinity[a] (mg/L as $CaCO_3$)	Lab pH[a]
R-27	Single	852	4-Apr-2011	10	1.3	10	3.0	1.6	1.6	0.24	<0.03	0.24	67	122	0.4	55	7.9
R-47i	Single	840	2-Dec-2010	18	0.6	10	2.4	8.9	2.9	0.15	0.25	0.23	56	142	2.9	60	8.0
R-47i	Single	840	7-Apr-2011	16	0.6	10	2.4	7.1	2.7	0.18	0.38	0.24	58	127	1.2	60	7.5
R-47i	Single	840	21-Jun-2011	17	0.5	11	2.6	6.6	2.7	0.15	0.32	0.25	59	130	<1.6	60	7.5
R-47i	Single	840	8-Sep-2011	18	<0.6	11	2.5	7.1	2.6	0.20	0.30	0.23	60	129	2.1	60	7.6
R-47i	Single	840	24-Jan-2012	16	0.4	10	2.4	6.8	2.6	0.17	0.13	0.24	59	136	2.3	59	7.5
R-48	Single	1500	6-Jan-2011	14	1.3	10	3.2	5.2	2.3	0.17	0.26	0.30	51	117	0.5	60	8.1
R-48	Single	1500	28-Mar-2011	14	1.4	10	3.3	4.9	2.5	0.19	0.26	0.31	54	114	0.4	58	8.0
R-48	Single	1500	22-Jun-2011	13	1.3	11	3.5	4.2	2.4	0.16	0.79	0.31	56	110	<1	59	8.2
R-48	Single	1500	13-Sep-2011	13	1.3	10	3.3	3.8	2.3	0.18	0.28	0.34	52	124	0.3	57	8.1
R-48	Single	1500	18-Jan-2012	13	1.5	10	3.3	3.4	2.4	0.20	0.48	0.31	55	109	0.4	57	8.1
R-63	Single	1325	12-Apr-2011	9	1.0	9	2.8	2.6	<1.2	0.13	0.43	0.22	55	114	0.5	53	7.6
R-63	Single	1325	22-Jun-2011	9	0.8	10	3.0	2.5	1.1	0.11	0.81	0.23	59	104	<0.3	50	7.7
R-63	Single	1325	8-Sep-2011	9	0.8	10	3.1	2.4	1.1	0.14	0.42	0.22	62	103	<1	48	7.7
R-63	Single	1325	16-Dec-2011	8	0.8	9	2.9	2.3	1.2	0.11	0.30	0.22	59	121	0.5	48	7.7
R-63	Single	1325	20-Jan-2012	9	0.8	10	3.1	2.4	1.2	0.14	0.35	0.23	62	110	0.6	56	7.6

Source: Attachment B-1.

[a] Alkalinity and pH measured at off-site analytical laboratory unless otherwise indicated.

[b] Gray-shaded cells indicate the well was not sampled for this analyte.

[c] Italicized values indicate sample analyses by Earth and Environmental Sciences 14.

Table B-2.0-3
Trace Metals

Location	Port Name	Depth (ft bgs)	Date	Filtered (µg/L)												Unfiltered (µg/L)	
				Al	Ba	B	Cr	Fe	Mn	Mo	Ni	Sr	U	V	Zn	Al	Fe
			MDL	**68**	**1**	**15**	**2**	**30**	**2**	**0.1**	**0.5**	**1**	**0.067**	**1**	**3.3**	**68**	**30**
			PQL	**200**	**5**	**50**	**10**	**100**	**10**	**0.5**	**2**	**5**	**0.2**	**5**	**10**	**200**	**100**
16-26644	Single	130	22-Jul-2010	162	90	<50	2.9	78	4	1	5	89	0.3	3	7	896	597
16-26644	Single	130	2-Nov-2010	418	51	<50	3.5	176	<10	1	6	94	0.6	4	9	603	305
16-26644	Single	130	2-Mar-2011	113	51	<50	<10	69	<10	1	6	103	0.7	4	<10	140	80
16-26644	Single	130	19-Sep-2011	114	108	<50	<10	69	<10	1	2	115	0.6	3	6	160	112
16-26644	Single	130	13-Jan-2012	<200	50	<50	<10	<100	<10	1	2	110	0.8	4	4	[a]	
CdV-16-1(i)	Single	624	16-Apr-2010	<200	17	56	<10	<100	3	1	7	95	0.6	3	<5	<200	39
CdV-16-1(i)	Single	624	13-Sep-2010	<200	17	58	4	<100	3	1	10	94	0.5	3	5	<200	<100
CdV-16-1(i)	Single	624	8-Apr-2011	<200	16	58	<10	<100	6	1	12	92	0.4	3	31	<200	49
CdV-16-1(i)	Single	624	22-Sep-2011	<200	18	65	<10	<100	5	1	8	95	0.6	3	26	<200	<100
CdV-16-2(i)r	Single	850	1-Apr-2010	<200	2	<50	<10	<100	2	1	1	56	0.2	1	14	229	176
CdV-16-2(i)r	Single	850	7-Sep-2010	<200	3	19	<10	<100	<10	1	<2	56	<0.3	1	16	536	423
CdV-16-2(i)r	Single	850	30-Mar-2011	<200	2	22	3	<100	<10	1	1	63	0.3	2	14	<200	156
CdV-16-2(i)r	Single	850	6-Sep-2011	<200	3	18	<10	<100	<10	1	<1	63	<0.4	<5	9	<79	50
CdV-16-2(i)r	Single	850	18-Jan-2012	<200	2	25	<10	<100	<10	1	<2	63	0.3	<5	13		
CdV-16-4ip	P1A	815.6	31-Aug-2010	<200	5	115	<10	<100	7	1	1	70	0.6	2.9	<5	639	359
CdV-16-4ip	P1A	815.6	7-Mar-2011	<200	5	82	<10	<100	7	1	1	61	0.5	2.5	5	221	122
CdV-16-4ip	P2A	1110	18-Sep-2010	<200	7	90	<10	<100	14	1	<1.2	62	0.4	2.4	<10	335	211
CdV-16-4ip	P2A	1110	2-Nov-2010	<200	9	15	2.5	<100	2	1	0.6	56	<0.41	2.3	<10	<200	<59
CdV-16-4ip	P2A	1110	31-Mar-2011	<200	8	<50	<10	<100	15	1	1	57	0.4	1.6	10	<200	33
CdV-37-1(i)	Single	632	21-Sep-2010	<200	13	17	<10	36	23	2	2	50	<0.2	1	10	<227	262
CdV-37-1(i)	Single	632	1-Dec-2010	116	11	<50	<10	63	15	2	2	51	0.6	1	13	247	157
CdV-37-1(i)	Single	632	31-Mar-2011	<200	11	<50	<10	<100	9	1	2	50	0.5	1	10	199	169

Table B-2.0-3 (continued)

Location	Port Name	Depth (ft bgs)	Date	Filtered (µg/L)												Unfiltered (µg/L)	
				Al	Ba	B	Cr	Fe	Mn	Mo	Ni	Sr	U	V	Zn	Al	Fe
			MDL	**68**	**1**	**15**	**2**	**30**	**2**	**0.1**	**0.5**	**1**	**0.067**	**1**	**3.3**	**68**	**30**
			PQL	**200**	**5**	**50**	**10**	**100**	**10**	**0.5**	**2**	**5**	**0.2**	**5**	**10**	**200**	**100**
CdV-37-1(i)	Single	632	20-Jun-2011	<200	11	<50	<10	<98	8	1	1	49	0.5	<5	15	117	213
CdV-37-1(i)	Single	632	24-Jan-2012	<200	9	<50	<10	<100	7	1	1	47	0.4	< 5	10		
CdV-R-15-3	MP4A	1254	5-Aug-2010	<200	22	<50	5	<100	<10	<1	1	54	0.5	4	<10	<200	<100
CdV-R-15-3	MP4A	1254	11-May-2011	70	23	<50	<10	<100	2	<1	1	51	0.5	4	5	<200	173
CdV-R-15-3	MP5A	1350	4-Aug-2010	<200	83	<50	<10	133	313	1	1	315	<0.2	<5	<10	<200	148
CdV-R-15-3	MP5A	1350	4-May-2011	<200	58	<50	<10	<100	149	2	1	352	1.0	4	<10	<200	42
CdV-R-15-3	MP6A	1640	5-Aug-2010	<200	21	<50	<10	56	54	2	1	58	0.2	<5	7	<200	77
CdV-R-15-3	MP6A	1640	3-May-2011	92	39	<50	<10	43	206	1	2	52	0.7	6	7	154	63
CdV-R-37-2	MP2A	1200	11-Aug-2010	<200	85	18	3	13100	967	11	8	36	<0.2	<5	14	<200	12800
CdV-R-37-2	MP2A	1200	24-Apr-2011	<200	20	<50	<10	44	201	1	2	53	0.7	9	7	90	92
CdV-R-37-2	MP3A	1359	10-Aug-2010	<200	11	<50	5	<100	<10	<1	1	59	0.5	9	<10	<200	<100
CdV-R-37-2	MP3A	1359	12-Apr-2011	<200	9	<50	<10	<100	3	1	<1	48	0.5	9	<10	<200	<100
CdV-R-37-2	MP4A	1551	10-Aug-2010	<200	12	<50	3	<100	3	1	<2	53	0.3	4	<10	<200	30
CdV-R-37-2	MP4A	1551	16-Apr-2011	<200	8	<50	<10	<100	<10	1	<2	47	0.4	9	<10	<200	<100
R-18	Single	1358	11-Mar-2010	<200	20	<50	<10	<100	<10	<1	<2	50	0.5	3	<10	<200	<100
R-18	Single	1358	21-Oct-2010	<200	20	<50	<10	<100	<10	<1	<2	51	0.4	3	<10	<200	<100
R-18	Single	1358	22-Apr-2011	92	19	<50	<10	<100	<10	<1	1	49	0.4	3	3	104	<100
R-18	Single	1358	7-Sep-2011	<200	23	<50	<10	<100	<10	<1	1	52	0.4	3	<10	<200	<100
R-18	Single	1358	17-Jan-2012	<200	20	<50	<10	47	<10	<1	<2	51	0.4	3	<10		
R-25	MP1A	754.8	31-Mar-2009	<200	9	103	9	30	140	1	731	94	0.5	<5	11	<200	782
R-25	MP1A	754.8	21-Sep-2010	<200	7	91	9	92	84	1	454	97	0.7	1	6	<200	214
R-25	MP1A	754.8	14-Jun-2011	<200	11	105	6	35	93	1	623	103	0.5	<5	<10	<200	378
R-25	MP1A	754.8	9-Sep-2011	<200	7	109	9	35	76	1	493	108	1.0	<5	6	<200	482
R-25	MP1A	754.8	11-Jan-2012														

Table B-2.0-3 (continued)

Location	Port Name	Depth (ft bgs)	Date	Filtered (µg/L)												Unfiltered (µg/L)	
				Al	Ba	B	Cr	Fe	Mn	Mo	Ni	Sr	U	V	Zn	Al	Fe
			MDL	**68**	**1**	**15**	**2**	**30**	**2**	**0.1**	**0.5**	**1**	**0.067**	**1**	**3.3**	**68**	**30**
			PQL	**200**	**5**	**50**	**10**	**100**	**10**	**0.5**	**2**	**5**	**0.2**	**5**	**10**	**200**	**100**
R-25	MP2A	891.8	6-Apr-2010	*9*[b]	*2*	*217*	*27*	*29700*	*984*	*10*	*6079*	*26*	*< 0.2*	*<1*	*21*	*169*	*41720*
R-25	MP2A	891.8	21-Sep-2010	*< 1*	*< 1*	*222*	*12*	*23736*	*872*	*7*	*3709*	*26*	*< 0.2*	*<1*	*14*	*88*	*21615*
R-25	MP2A	891.8	15-Jun-2011	*2*	*5*	*238*	*24*	*34048*	*1074*	*9*	*9174*	*20*	*< 0.2*	*<1*	*31*	*43*	*30291*
R-25	MP2A	891.8	12-Sep-2011	*2*	*2*	*216*	*13*	*27520*	*930*	*8*	*3053*	*28*	*< 0.2*	*<1*	*26*	*36*	*35268*
R-25	MP2A	891.8	12-Jan-2012	<200	<5	167	19	20900	686	6	3730	36	<0.2	<5	9		
R-25	MP4A	1192.4	7-Apr-2010	<200	21	29	<10	79	40	<1	4	136	0.4	<5	15	<200	32
R-25	MP4A	1192.4	21-Sep-2010	<200	20	27	<10	<100	<10	<1	1	115	0.8	<5	<10	<200	<100
R-25	MP4A	1192.4	15-Jun-2011	<200	21	30	3	289	44	<1	2	136	0.1	<5	9	<200	56
R-25	MP4A	1192.4	12-Sep-2011	<200	20	31	<10	<100	9	<1	3	123	0.7	<5	5	<200	66
R-25	MP4A	1192.4	12-Jan-2012	<200	20	27	<10	<100	<10	<1	1	119	0.7	<5	4		
R-25	MP5A	1303.4	7-Apr-2010	<200	11	50	<10	<100	6	4	2	176	0.3	<5	16	<200	<100
R-25	MP5A	1303.4	23-Sep-2010	221	10	43	<10	<100	3	4	1	174	<0.4	<5	<10	<200	<100
R-25	MP5A	1303.4	15-Jun-2011	<200	12	41	2	<100	7	4	3	172	0.4	<5	6	<200	<100
R-25	MP5A	1303.4	19-Sep-2011	<200	15	40	<10	<100	6	3	2	177	0.7	<5	4	<200	<100
R-25	MP5A	1303.4	13-Jan-2012	<200	13	39	<10	<100	6	3	3	173	0.5	<5	10		
R-25	MP6A	1406.3	8-Apr-2010	<200	44	16	<10	<100	<10	<1	1	82	0.6	2	<10	<200	<100
R-25	MP6A	1406.3	22-Sep-2010	<200	45	<50	3	<100	<10	<1	1	79	0.7	2	<10	<200	107
R-25	MP6A	1406.3	16-Jun-2011	<200	46	16	<10	35	<10	<1	1	80	0.6	2	4	<200	<100
R-25	MP6A	1406.3	15-Sep-2011	<200	47	19	<10	<100	<10	<1	1	76	0.6	1	7	<200	35
R-25	MP6A	1406.3	13-Jan-2012	<200	48	<50	<10	<100	<10	<1	1	79	0.5	3	7		
R-25	MP7A	1606	8-Apr-2010	<200	35	<50	<10	<100	<10	<1	1	58	0.4	5	5	<200	<100
R-25	MP7A	1606	23-Sep-2010	<200	35	<50	<3	<100	<10	<1	1	57	<0.6	5	4	<200	<133
R-25	MP7A	1606	16-Jun-2011	<200	31	<50	<10	35	<10	<1	1	54	0.4	4	5	<200	103
R-25	MP7A	1606	14-Sep-2011	<200	34	<50	<10	<100	<10	<1	<2	54	0.4	5	6	<200	50

Table B-2.0-3 (continued)

Location	Port Name	Depth (ft bgs)	Date	Filtered (µg/L)												Unfiltered (µg/L)	
				Al	Ba	B	Cr	Fe	Mn	Mo	Ni	Sr	U	V	Zn	Al	Fe
			MDL	**68**	**1**	**15**	**2**	**30**	**2**	**0.1**	**0.5**	**1**	**0.067**	**1**	**3.3**	**68**	**30**
			PQL	**200**	**5**	**50**	**10**	**100**	**10**	**0.5**	**2**	**5**	**0.2**	**5**	**10**	**200**	**100**
R-25	MP7A	1606	17-Jan-2012	<200	34	<50	<10	<100	<10	<1	<2	57	0.4	5	5		
R-25	MP8A	1796	9-Apr-2010	<200	32	<50	<10	<100	<10	<1	1	84	<0.4	5	<10	<200	57
R-25	MP8A	1796	24-Sep-2010	<200	40	<50	<3	<100	<10	<1	1	87	<0.6	5	<10	<200	<135
R-25	MP8A	1796	17-Jun-2011	<200	39	17	<10	<39	<10	<1	1	87	0.4	5	6	<200	<125
R-25	MP8A	1796	14-Sep-2011	<200	42	<50	<10	<100	2	<1	<2	91	0.4	5	4	<200	41
R-25	MP8A	1796	17-Jan-2012														
R-25b	Single	750	21-Apr-2010	<200	13	27	5	<100	9	12	1	70	2.1	4	24	483	258
R-25b	Single	750	8-Sep-2010	172	15	24	3	90	13	10	2	75	1.9	3	47	1250	583
R-25b	Single	750	7-Apr-2011	<200	14	19	<10	117	4	5	2	67	1.3	3	40	861	484
R-25b	Single	750	15-Sep-2011	<200	12	23	<10	<100	<10	4	1	57	1.4	2	35	649	329
R-25b	Single	750	23-Jan-2012	<200	11	16	<10	33	<10	3	1	72	1.1	3	14		
R-26	MP1A	659.3	1-Jun-2011	<200	9	<50	<10	<100	5	1	1	46	<0.4	9	<10	<200	85
R-26	MP1A	659.3	16-Sep-2011	<200	8	<50	2	<100	5	1	2	47	0.4	9	13	<200	201
R-26	MP1A	659.3	9-Dec-2011	<200	8	<50	<10	<100	3	1	2	47	0.3	9	13		
R-26	MP1A	659.3	26-Jan-2012	<200	6	<50	5	<100	<10	1	1	47	0.3	8	14		
R-26 PZ-2	R-26 PZ-2	150	12-Jan-2010	<200	28	<50	<10	<96	<13	3	7	144	0.3	<5	<10		
R-26 PZ-2	R-26 PZ-2	150	5-Apr-2010	<200	31	<50	<10	<100	12	2	4	156	0.3	<5	<10	8210	10500
R-26 PZ-2	R-26 PZ-2	150	10-Sep-2010	<200	32	<50	3	55	22	3	6	146	0.4	<5	5	2700	2870
R-26 PZ-2	R-26 PZ-2	150	5-Apr-2011														
R-26 PZ-2	R-26 PZ-2	150	19-Sep-2011	<200	34	<50	<10	34	51	2	3	168	0.4	<5	32	14500	16900
R-26 PZ-2	R-26 PZ-2	150	26-Jan-2012														
R-27	Single	852	7-Oct-2009	<200	26	<50	5	<100	<10	1	1	47	0.5	5	<10	<200	<100
R-27	Single	852	9-Apr-2010	<200	27	17	<10	<100	<10	<1	<2	50	<0.5	6	<10	<200	<100
R-27	Single	852	14-Sep-2010	<200	28	<50	5	<100	<10	<1	<2	50	0.5	6	<10	<200	<100

Table B-2.0-3 (continued)

Location	Port Name	Depth (ft bgs)	Date	Filtered (µg/L)												Unfiltered (µg/L)	
				Al	Ba	B	Cr	Fe	Mn	Mo	Ni	Sr	U	V	Zn	Al	Fe
			MDL	**68**	**1**	**15**	**2**	**30**	**2**	**0.1**	**0.5**	**1**	**0.067**	**1**	**3.3**	**68**	**30**
			PQL	**200**	**5**	**50**	**10**	**100**	**10**	**0.5**	**2**	**5**	**0.2**	**5**	**10**	**200**	**100**
R-27	Single	852	4-Apr-2011	<200	27	<50	3	<100	<10	<1	<2	48	0.5	5	<10	<200	<100
R-47i	Single	840	2-Dec-2010	143	8	16	<10	42	13	5	3	58	0.8	<5	9	214	359
R-47i	Single	840	7-Apr-2011	<200	7	<50	4	<100	3	2	2	54	0.3	1	<10	88	63
R-47i	Single	840	21-Jun-2011	<200	8	16	3	<100	<10	3	1	56	0.5	1	<10	<200	83
R-47i	Single	840	8-Sep-2011	<200	8	16	<10	<100	<10	3	1	58	0.7	1	<10	101	71
R-47i	Single	840	24-Jan-2012	<200	7	<50	<10	<100	<10	3	1	55	0.5	<5	<10		
R-48	Single	1500	6-Jan-2011	<200	11	<50	<3	<100	5	3	2	53	0.6	11	<10	346	425
R-48	Single	1500	28-Mar-2011	<200	11	<50	<10	<60	4	3	2	55	0.6	11	<10	<200	<93
R-48	Single	1500	22-Jun-2011	<200	11	<50	<4	33	<10	3	1	54	0.5	11	6	124	119
R-48	Single	1500	13-Sep-2011	<200	9	<50	<10	<100	<10	3	1	54	0.6	10	<10	452	203
R-48	Single	1500	18-Jan-2012	<200	9	<50	<10	<100	<10	2	1	51	0.5	11	<10		
R-63	Single	1325	12-Apr-2011	<200	15	<50	<10	<100	6	1	1	50	0.4	2	<10	267	132
R-63	Single	1325	22-Jun-2011	<200	15	<50	<10	<100	4	1	1	50	0.4	2	<10	141	147
R-63	Single	1325	8-Sep-2011	<200	15	<50	<10	<100	<10	1	1	52	0.4	1	<10	158	75
R-63	Single	1325	16-Dec-2011	<200	13	<50	<10	<100	<10	<1	1	49	0.4	2	<10	<200	<100
R-63	Single	1325	20-Jan-2012	<200	15	<50	<10	<100	<10	<1	<2	50	0.4	1	<10		

Source: Attachment B-1.

[a] Gray-shaded cells indicate the well was not sampled for this analyte.

[b] Italicized values indicate sample analyses by Earth and Environmental Sciences 14.

Table B-2.0-4
Detected VOCs and SVOCs

Location	Port Name	Depth (ft bgs)	Date	VOCs (µg/L)									SVOCs (µg/L)			
				Acetone	Butanol[1-]	Chloromethane	Isopropylbenzene	Isopropyltoluene[4-]	Methyl tert- Butyl Ether	Tetrachloroethene	Toluene	Trichloroethene	Benzoic Acid	Bis(2-ethylhexyl) phthalate	Diethylphthalate	Indeno (1,2,3-cd) pyrene
			MDL	**3.5**	**15**	**0.3**	**0.25**	**0.25**	**0.25**	**0.3**	**0.25**	**0.25**	**6**	**2**	**2**	**0.2**
			PQL	**10**	**50**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**20**	**10**	**10**	**1**
16-26644	Single	130	22-Jul-2010	—[a]	—	—	—	—	—	3.3	—	2.8	—	—	—	—
16-26644	Single	130	2-Nov-2010	—	—	—	—	—	—	1.4	—	0.9	—	—	3	—
16-26644	Single	130	2-Mar-2011	—	—	—	—	—	—	3.3	—	2.4	—	—	—	—
16-26644	Single	130	19-Sep-2011	—	—	—	—	—	—	5.0	—	4.1	[b]			
16-26644	Single	130	13-Jan-2012	—	—	—	—	—	—	2.9	—	2.1				
CdV-16-1(i)	Single	624	16-Apr-2010	—	—	—	—	—	1.0	1.4	0.3	—				
CdV-16-1(i)	Single	624	13-Sep-2010	—	—	—	—	—	1.3	1.1	0.3	—	—	—	—	—
CdV-16-1(i)	Single	624	8-Apr-2011	—	—	—	—	—	1.4	1.2	119	—				
CdV-16-1(i)	Single	624	22-Sep-2011	—	—	—	—	—	1.6	1.5	49	—	—	—	—	—
CdV-16-2(i)r	Single	850	1-Apr-2010	—	—	—	—	—	—	0.4	1.5	—				
CdV-16-2(i)r	Single	850	7-Sep-2010	—	—	—	—	—	—	0.3	9.9	—	—	—	—	—
CdV-16-2(i)r	Single	850	30-Mar-2011	—	—	—	—	—	0.4	0.4	—	—				
CdV-16-2(i)r	Single	850	6-Sep-2011	—	—	—	—	—	0.4	0.5	0.4	0.2	—	—	—	—
CdV-16-2(i)r	Single	850	18-Jan-2012	—	—	—	—	—	0.4	0.6	2.3	0.4				
CdV-16-4ip	P1A	815.6	31-Aug-2010	—	—	—	—	—	0.8	1.2	1.1	0.8	—	—	—	—
CdV-16-4ip	P1A	815.6	7-Mar-2011	—	—	—	—	—	0.7	0.9	—	0.6	—	—	—	—
CdV-16-4ip	P2A	1110	18-Sep-2010	—	—	—	—	—	0.8	1.1	1.8	0.8	—	—	12	—

Table B-2.0-4 (continued)

Location	Port Name	Depth (ft bgs)	Date	VOCs (µg/L)									SVOCs (µg/L)			
				Acetone	Butanol[1-]	Chloromethane	Isopropylbenzene	Isopropyltoluene[4-]	Methyl tert- Butyl Ether	Tetrachloroethene	Toluene	Trichloroethene	Benzoic Acid	Bis(2-ethylhexyl) phthalate	Diethylphthalate	Indeno (1,2,3-cd) pyrene
			MDL	**3.5**	**15**	**0.3**	**0.25**	**0.25**	**0.25**	**0.3**	**0.25**	**0.25**	**6**	**2**	**2**	**0.2**
			PQL	**10**	**50**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**20**	**10**	**10**	**1**
CdV-16-4ip	P2A	1110	2-Nov-2010	—	—	—	—	—	—	—	0.3	—	—	—	—	—
CdV-16-4ip	P2A	1110	31-Mar-2011	—	—	—	—	—	0.3	—	0.5	—	—	—	—	—
CdV-37-1(i)	Single	632	21-Sep-2010	5	—	—	—	—	—	—	2.7	—	—	3	—	—
CdV-37-1(i)	Single	632	1-Dec-2010	—	—	—	—	—	—	—	1.3	—	—	4	—	—
CdV-37-1(i)	Single	632	31-Mar-2011	—	—	—	—	—	—	—	1.4	—	—	—	—	—
CdV-37-1(i)	Single	632	20-Jun-2011	—	—	—	—	—	—	—	0.7	—	—	—	—	—
CdV-37-1(i)	Single	632	24-Jan-2012	4	—	—	—	—	—	—	—	—				
CdV-R-15-3	MP4A	1254	5-Aug-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-15-3	MP4A	1254	11-May-2011	—	—	—	—	—	—	—	10.8	—	—	—	—	—
CdV-R-15-3	MP5A	1350	4-Aug-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-15-3	MP5A	1350	4-May-2011	—	—	—	—	—	—	—	3.0	—	—	—	—	—
CdV-R-15-3	MP6A	1640	4-Aug-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-15-3	MP6A	1640	3-May-2011	—	—	—	—	—	—	—	0.5	—	—	—	—	—
CdV-R-37-2	MP2A	1200	11-Aug-2010	—	—	—	0.3	0.4	—	—	—	—	—	—	—	—
CdV-R-37-2	MP2A	1200	24-Apr-2011	8	—	—	—	—	—	—	6.5	—	—	3	—	—
CdV-R-37-2	MP3A	1359	10-Aug-2010	—	—	—	—	—	—	—	—	—	—	—	13	—
CdV-R-37-2	MP3A	1359	12-Apr-2011	—	—	—	—	—	—	—	4.2	—	—	—	4	—
CdV-R-37-2	MP4A	1551	10-Aug-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-37-2	MP4A	1551	16-Apr-2011	—	—	—	—	—	—	—	0.5	—	—	—	—	—

Table B-2.0-4 (continued)

Location	Port Name	Depth (ft bgs)	Date	VOCs (µg/L)									SVOCs (µg/L)			
				Acetone	Butanol[1-]	Chloromethane	Isopropylbenzene	Isopropyltoluene[4-]	Methyl tert- Butyl Ether	Tetrachloroethene	Toluene	Trichloroethene	Benzoic Acid	Bis(2-ethylhexyl) phthalate	Diethylphthalate	Indeno (1,2,3-cd) pyrene
			MDL	**3.5**	**15**	**0.3**	**0.25**	**0.25**	**0.25**	**0.3**	**0.25**	**0.25**	**6**	**2**	**2**	**0.2**
			PQL	**10**	**50**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**20**	**10**	**10**	**1**
R-18	Single	1358	11-Mar-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-18	Single	1358	21-Oct-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-18	Single	1358	22-Apr-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-18	Single	1358	7-Sep-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-18	Single	1358	17-Jan-2012	—	—	—	—	—	—	—	—	—				
R-25	MP1A	754.8	31-Mar-2009	—	—	—	—	—	0.3	—	—	0.4	—	—	—	—
R-25	MP1A	754.8	21-Sep-2010	—	157	—	—	—	0.4	0.7	—	0.6	—	—	—	—
R-25	MP1A	754.8	14-Jun-2011	—	—	—	—	—	0.3	0.7	—	0.8	—	—	—	—
R-25	MP1A	754.8	9-Sep-2011	—	—	—	—	—	0.3	0.7	—	0.8	—	—	—	—
R-25	MP1A	754.8	11-Jan-2012	—	—	0.4	—	—	0.3	0.5	—	0.5				
R-25	MP2A	891.8	6-Apr-2010	—	—	—	—	—	0.7	0.6	—	0.7	—	—	—	—
R-25	MP2A	891.8	21-Sep-2010	—	—	—	—	—	0.7	0.4	—	0.4	—	—	—	—
R-25	MP2A	891.8	15-Jun-2011	—	—	—	—	—	0.8	—	—	0.4	—	—	—	—
R-25	MP2A	891.8	12-Sep-2011	—	—	—	—	—	0.6	0.9	—	1.2	—	—	—	—
R-25	MP2A	891.8	12-Jan-2012	—	—	—	—	—	0.6	—	—	0.4				
R-25	MP4A	1192.4	7-Apr-2010	—	—	—	—	—	1.1	0.5	—	0.3	—	—	—	—
R-25	MP4A	1192.4	21-Sep-2010	—	—	—	—	—	1.1	—	—	—	—	—	—	—
R-25	MP4A	1192.4	15-Jun-2011	—	—	—	—	—	1.3	0.6	—	0.5	—	—	—	—
R-25	MP4A	1192.4	12-Sep-2011	—	—	—	—	—	1.2	1.0	—	0.7	—	—	—	—

Table B-2.0-4 (continued)

Location	Port Name	Depth (ft bgs)	Date	VOCs (µg/L)									SVOCs (µg/L)			
				Acetone	Butanol[1-]	Chloromethane	Isopropylbenzene	Isopropyltoluene[4-]	Methyl tert- Butyl Ether	Tetrachloroethene	Toluene	Trichloroethene	Benzoic Acid	Bis(2-ethylhexyl) phthalate	Diethylphthalate	Indeno (1,2,3-cd) pyrene
MDL				**3.5**	**15**	**0.3**	**0.25**	**0.25**	**0.25**	**0.3**	**0.25**	**0.25**	**6**	**2**	**2**	**0.2**
PQL				**10**	**50**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**20**	**10**	**10**	**1**
R-25	MP4A	1192.4	12-Jan-2012	—	—	—	—	—	1.0	0.3	—	—				
R-25	MP5A	1303.4	7-Apr-2010	—	—	—	—	—	—	0.4	—	—	—	—	—	—
R-25	MP5A	1303.4	23-Sep-2010	—	—	—	—	—	—	—	—	—	20	—	—	—
R-25	MP5A	1303.4	15-Jun-2011	—	—	—	—	—	0.4	—	—	—	—	—	—	—
R-25	MP5A	1303.4	19-Sep-2011	—	—	—	—	—	0.4	0.3	—	—	—	—	—	—
R-25	MP5A	1303.4	13-Jan-2012	—	—	—	—	—	0.3	—	—	—				
R-25	MP6A	1406.3	8-Apr-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP6A	1406.3	22-Sep-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP6A	1406.3	16-Jun-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP6A	1406.3	15-Sep-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP6A	1406.3	13-Jan-2012	—	—	—	—	—	—	—	—	—				
R-25	MP7A	1606	8-Apr-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP7A	1606	23-Sep-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP7A	1606	16-Jun-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP7A	1606	14-Sep-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP7A	1606	17-Jan-2012	—	—	—	—	—	—	—	—	—				
R-25	MP8A	1796	9-Apr-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP8A	1796	24-Sep-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP8A	1796	17-Jun-2011	—	—	—	—	—	—	—	—	—	—	—	—	—

Table B-2.0-4 (continued)

Location	Port Name	Depth (ft bgs)	Date	VOCs (µg/L)									SVOCs (µg/L)			
				Acetone	Butanol[1-]	Chloromethane	Isopropylbenzene	Isopropyltoluene[4-]	Methyl tert- Butyl Ether	Tetrachloroethene	Toluene	Trichloroethene	Benzoic Acid	Bis(2-ethylhexyl) phthalate	Diethylphthalate	Indeno (1,2,3-cd) pyrene
			MDL	**3.5**	**15**	**0.3**	**0.25**	**0.25**	**0.25**	**0.3**	**0.25**	**0.25**	**6**	**2**	**2**	**0.2**
			PQL	**10**	**50**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**20**	**10**	**10**	**1**
R-25	MP8A	1796	14-Sep-2011	—	—	—	—	—	—	—	—	—	—	—	9	—
R-25	MP8A	1796	17-Jan-2012	—	—	—	—	—	—	—	—	—				
R-25b	Single	750	21-Apr-2010	—	—	—	—	—	—	0.4	—	—	—	—	—	—
R-25b	Single	750	8-Sep-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25b	Single	750	7-Apr-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25b	Single	750	15-Sep-2011	—	—	—	—	—	—	0.3	—	—	—	—	—	—
R-25b	Single	750	23-Jan-2012	—	—	—	—	—	—	—	—	—				
R-26	MP1A	659.3	1-Jun-2011	—	—	—	—	—	—	—	2.5	—	—	—	—	—
R-26	MP1A	659.3	16-Sep-2011	61	—	—	—	—	—	—	1.2	—	—	—	—	—
R-26	MP1A	659.3	9-Dec-2011	14	—	0.4	—	—	—	—	0.9	—				
R-26	MP1A	659.3	26-Jan-2012	5	—	—	—	—	—	—	0.9	—	—	—	—	—
R-26 PZ-2	R-26 PZ-2	150	5-Apr-2010	—	—	—	—	—	—	1.2	—	—				
R-26 PZ-2	R-26 PZ-2	150	10-Sep-2010	—	—	—	—	—	—	1.6	—	—				
R-26 PZ-2	R-26 PZ-2	150	5-Apr-2011	—	—	—	—	—	—	1.8	—	—				
R-26 PZ-2	R-26 PZ-2	150	19-Sep-2011	—	—	—	—	—	—	1.3	—	—				
R-26 PZ-2	R-26 PZ-2	150	26-Jan-2012	—	—	—	—	—	—	1.5	—	—				
R-27	Single	852	7-Oct-2009	—	—	—	—	—	—	—	—	—	—	4	—	—
R-27	Single	852	9-Apr-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-27	Single	852	14-Sep-2010	—	—	—	—	—	—	—	—	—	—	—	4	0.4

Table B-2.0-4 (continued)

Location	Port Name	Depth (ft bgs)	Date	VOCs (µg/L)									SVOCs (µg/L)			
				Acetone	Butanol[1-]	Chloromethane	Isopropylbenzene	Isopropyltoluene[4-]	Methyl tert- Butyl Ether	Tetrachloroethene	Toluene	Trichloroethene	Benzoic Acid	Bis(2-ethylhexyl) phthalate	Diethylphthalate	Indeno (1,2,3-cd) pyrene
			MDL	**3.5**	**15**	**0.3**	**0.25**	**0.25**	**0.25**	**0.3**	**0.25**	**0.25**	**6**	**2**	**2**	**0.2**
			PQL	**10**	**50**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**20**	**10**	**10**	**1**
R-27	Single	852	4-Apr-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-47i	Single	840	2-Dec-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-47i	Single	840	7-Apr-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-47i	Single	840	21-Jun-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-47i	Single	840	8-Sep-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-47i	Single	840	24-Jan-2012	—	—	—	—	—	—	—	—	—				
R-48	Single	1500	6-Jan-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-48	Single	1500	28-Mar-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-48	Single	1500	22-Jun-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-48	Single	1500	13-Sep-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-48	Single	1500	18-Jan-2012	—	—	—	—	—	—	—	—	—	—	—	—	—
R-63	Single	1325	12-Apr-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-63	Single	1325	22-Jun-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-63	Single	1325	8-Sep-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-63	Single	1325	16-Dec-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-63	Single	1325	20-Jan-2012	—	—	—	—	—	—	—	—	—	—	—	—	—

Source: Attachment B-1.

[a] Not detected.

[b] Gray-shaded cells indicate the well was not sampled for this analyte.

Table B-2.0-5
Detected HE Compounds

Location	Port Name	Depth (ft bgs)	Date	HE Analytical Suite (µg/L)										Extended HE Suite (µg/L)		
				Amino-2,6-dinitrotoluene[4-]	Amino-4,6-dinitrotoluene[2-]	Dinitrotolune[2,4-]	Dinitrotolune[2,6-]	HMX	Nitrotoluene[2-]	RDX	Trinitrobenzene[1,3,5-]	Trinitrotoluene[2,4,6-]	2,4-Diamino-6-nitrotoluene	DNX[a]	MNX[b]	TNX[c]
			MDL	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.39**	**0.091**	**0.091**	**0.082**
			PQL	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**1.3**	**0.5**	**0.5**	**0.5**
16-26644	Single	130	22-Jul-2010	0.2	0.3	—[d]	—	2.3	—	16.	2.3	—	—	0.52	0.62	0.94
16-26644	Single	130	2-Nov-2010	—	—	—	—	0.2	—	3.7	0.4	—	—	—	—	—
16-26644	Single	130	2-Mar-2011	—	—	—	—	0.1	—	2.9	0.3	—	—	—	—	—
16-26644	Single	130	19-Sep-2011	0.4	0.5	—	—	4.4	—	35	6.7	—	—	0.79	1.1	1.6
16-26644	Single	130	13-Jan-2012	—	—	—	—	0.1	—	2.8	0.3	—	—	—	—	—
CdV-16-1(i)	Single	624	16-Apr-2010	0.2	0.1	—	—	1.4	—	28	—	—	—	—	—	—
CdV-16-1(i)	Single	624	13-Sep-2010	0.2	0.1	—	—	1.6	—	32	—	—	—	—	0.27	0.17
CdV-16-1(i)	Single	624	8-Apr-2011	0.2	—	—	—	1.3	—	24	—	—	—	0.15	0.29	0.20
CdV-16-1(i)	Single	624	22-Sep-2011	0.2	0.1	—	—	1.6	—	29	—	—	—	0.14	0.25	0.17
CdV-16-2(i)r	Single	850	1-Apr-2010	—	—	—	—	0.3	—	57	0.2	—	—	—	—	—
CdV-16-2(i)r	Single	850	7-Sep-2010	—	—	—	—	0.4	—	52	0.2	—	—	—	0.20	—
CdV-16-2(i)r	Single	850	30-Mar-2011	—	—	—	—	0.4	—	80	0.2	—	—	—	0.25	—
CdV-16-2(i)r	Single	850	6-Sep-2011	—	—	—	—	0.4	—	82	0.1	—	—	—	0.65	—
CdV-16-2(i)r	Single	850	18-Jan-2012	—	—	—	—	0.5	—	80	—	—	—	—	0.31	—
CdV-16-4ip	P1A	815.6	31-Aug-2010	2.6	—	—	0.1	10.4	1.2	265	0.2	—	—	—	0.84	0.38
CdV-16-4ip	P1A	815.6	7-Mar-2011	1.7	—	—	0.1	4.7	0.3	186	0.3	—	—	—	0.71	0.51
CdV-16-4ip	P2A	1110	18-Sep-2010	1.5	—	—	0.1	6.8	0.8	167	0.3	—	—	—	0.75	0.34

Table B-2.0-5 (continued)

Location	Port Name	Depth (ft bgs)	Date	HE Analytical Suite (µg/L)										Extended HE Suite (µg/L)		
				Amino-2,6-dinitrotoluene[4-]	Amino-4,6-dinitrotoluene[2-]	Dinitrotolune[2,4-]	Dinitrotolune[2,6-]	HMX	Nitrotoluene[2-]	RDX	Trinitrobenzene[1,3,5-]	Trinitrotoluene[2,4,6-]	2,4-Diamino-6-nitrotoluene	DNX[a]	MNX[b]	TNX[c]
			MDL	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.39**	**0.091**	**0.091**	**0.082**
			PQL	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**1.3**	**0.5**	**0.5**	**0.5**
CdV-16-4ip	P2A	1110	2-Nov-2010	0.1	—	—	—	0.6	—	22	—	—	—	—	—	—
CdV-16-4ip	P2A	1110	31-Mar-2011	0.1	—	—	—	0.5	—	20	—	—	—	—	—	—
CdV-37-1(i)	Single	632	21-Sep-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-37-1(i)	Single	632	1-Dec-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-37-1(i)	Single	632	31-Mar-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-37-1(i)	Single	632	20-Jun-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-37-1(i)	Single	632	24-Jan-2012	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-15-3	MP4A	1254	5-Aug-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-15-3	MP4A	1254	11-May-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-15-3	MP5A	1350	4-Aug-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-15-3	MP5A	1350	4-May-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-15-3	MP6A	1640	4-Aug-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-15-3	MP6A	1640	3-May-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-37-2	MP2A	1200	11-Aug-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-37-2	MP2A	1200	24-Apr-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-37-2	MP3A	1359	10-Aug-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-37-2	MP3A	1359	12-Apr-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
CdV-R-37-2	MP4A	1551	10-Aug-2010	—	—	—	—	—	—	—	—	—	—	—	—	—

Table B-2.0-5 (continued)

Location	Port Name	Depth (ft bgs)	Date	HE Analytical Suite (µg/L)										Extended HE Suite (µg/L)		
				Amino-2,6-dinitrotoluene[4-]	Amino-4,6-dinitrotoluene[2-]	Dinitrotolune[2,4-]	Dinitrotolune[2,6-]	HMX	Nitrotoluene[2-]	RDX	Trinitrobenzene[1,3,5-]	Trinitrotoluene[2,4,6-]	2,4-Diamino-6-nitrotoluene	DNX[a]	MNX[b]	TNX[c]
			MDL	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.39**	**0.091**	**0.091**	**0.082**
			PQL	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**1.3**	**0.5**	**0.5**	**0.5**
CdV-R-37-2	MP4A	1551	16-Apr-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-18	Single	1358	11-Mar-2010	—	—	—	—	—	—	0.9	0.1	—	—	—	—	—
R-18	Single	1358	21-Oct-2010	—	—	—	—	—	—	0.8	—	—	—	—	—	—
R-18	Single	1358	22-Apr-2011	—	—	—	—	—	—	1.2	0.1	—	—	—	—	—
R-18	Single	1358	7-Sep-2011	—	—	—	—	—	—	1.0	—	—	—	—	—	—
R-18	Single	1358	17-Jan-2012	—	—	—	—	—	—	1.0	—	—	—	—	—	—
R-25	MP1A	754.8	31-Mar-2009	2.6	2.8	0.8	—	8.0	0.2	42	0.8	6.3	—	—	—	—
R-25	MP1A	754.8	21-Sep-2010	2.3	2.4	0.7	—	4.4	—	26	0.9	8.1	—	—	0.17	0.47
R-25	MP1A	754.8	14-Jun-2011	2.8	3.0	0.6	—	4.2	—	38	1.0	7.8	—	—	0.24	0.68
R-25	MP1A	754.8	9-Sep-2011	2.7	2.6	0.7	—	3.7	—	28	1.0	8.6	—	—	0.17	0.49
R-25	MP1A	754.8	11-Jan-2012	2.2	1.7	0.5	—	2.9	—	31	1.0	8.6	—	—	0.18	0.58
R-25	MP2A	891.8	6-Apr-2010	0.3	0.1	—	—	3.2	—	8.8	—	—	0.6	—	—	—
R-25	MP2A	891.8	21-Sep-2010	1.1	0.5	—	—	5.0	—	18	0.2	0.2	—	—	—	0.19
R-25	MP2A	891.8	15-Jun-2011	0.3	0.2	—	—	3.2	—	12	—	—	—	—	—	—
R-25	MP2A	891.8	12-Sep-2011	1.4	0.8	—	—	4.8	—	19	—	0.2	—	—	0.25	0.15
R-25	MP2A	891.8	12-Jan-2012	0.6	0.3	—	—	4.4	—	18	—	—	—	—	0.27	0.11
R-25	MP4A	1192.4	7-Apr-2010	—	—	—	—	—	—	16	—	—	—	—	—	—
R-25	MP4A	1192.4	21-Sep-2010	—	—	—	—	—	—	21	—	—	—	0.18	0.20	0.13

Table B-2.0-5 (continued)

Location	Port Name	Depth (ft bgs)	Date	HE Analytical Suite (µg/L)										Extended HE Suite (µg/L)		
				Amino-2,6-dinitrotoluene[4-]	Amino-4,6-dinitrotoluene[2-]	Dinitrotolune[2,4-]	Dinitrotolune[2,6-]	HMX	Nitrotoluene[2-]	RDX	Trinitrobenzene[1,3,5-]	Trinitrotoluene[2,4,6-]	2,4-Diamino-6-nitrotoluene	DNX[a]	MNX[b]	TNX[c]
MDL				**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.39**	**0.091**	**0.091**	**0.082**
PQL				**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**1.3**	**0.5**	**0.5**	**0.5**
R-25	MP4A	1192.4	15-Jun-2011	—	—	—	—	0.13	—	27	—	—	—	0.16	0.34	0.13
R-25	MP4A	1192.4	12-Sep-2011	—	—	—	—	—	—	18	—	—	—	0.20	0.13	0.16
R-25	MP4A	1192.4	12-Jan-2012	—	—	—	—	0.12	—	21	—	—	—	—	0.17	0.20
R-25	MP5A	1303.4	7-Apr-2010	—	—	—	—	0.15	—	0.13	—	—	—	[e]		
R-25	MP5A	1303.4	23-Sep-2010	—	—	—	—	0.24	—	0.25	—	—	—	—	—	—
R-25	MP5A	1303.4	15-Jun-2011	—	—	—	—	0.25	—	0.38	—	—	—	—	—	—
R-25	MP5A	1303.4	19-Sep-2011	—	—	—	—	0.18	—	0.26	—	—	—	—	—	—
R-25	MP5A	1303.4	13-Jan-2012	—	—	—	—	0.17	—	0.21	—	—	—	—	—	—
R-25	MP6A	1406.3	8-Apr-2010	0.1	—	—	—	—	—	0.37	—	—	—	—	—	—
R-25	MP6A	1406.3	22-Sep-2010	—	—	—	—	0.11	—	0.35	—	—	—	—	—	—
R-25	MP6A	1406.3	16-Jun-2011	—	—	—	—	0.12	—	0.47	—	—	—	—	—	—
R-25	MP6A	1406.3	15-Sep-2011	—	—	—	—	—	—	0.36	—	—	—	—	—	—
R-25	MP6A	1406.3	13-Jan-2012	—	—	—	—	—	—	0.38	—	—	—	—	—	—
R-25	MP7A	1606	8-Apr-2010	—	—	—	—	—	—	—	—	0.2	—	—	—	—
R-25	MP7A	1606	23-Sep-2010	—	—	—	—	—	—	—	—	0.2	—	—	—	—
R-25	MP7A	1606	16-Jun-2011	—	—	—	—	—	—	—	—	0.2	—	—	—	—
R-25	MP7A	1606	14-Sep-2011	—	—	—	—	—	—	—	—	0.2	—	—	—	—
R-25	MP7A	1606	17-Jan-2012	—	—	—	—	—	—	—	—	0.1	—	—	—	—

Table B-2.0-5 (continued)

Location	Port Name	Depth (ft bgs)	Date	HE Analytical Suite (µg/L)										Extended HE Suite (µg/L)		
				Amino-2,6-dinitrotoluene[4-]	Amino-4,6-dinitrotoluene[2-]	Dinitrotolune[2,4-]	Dinitrotolune[2,6-]	HMX	Nitrotoluene[2-]	RDX	Trinitrobenzene[1,3,5-]	Trinitrotoluene[2,4,6-]	2,4-Diamino-6-nitrotoluene	DNX[a]	MNX[b]	TNX[c]
			MDL	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.39**	**0.091**	**0.091**	**0.082**
			PQL	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**1.3**	**0.5**	**0.5**	**0.5**
R-25	MP8A	1796	9-Apr-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP8A	1796	24-Sep-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP8A	1796	17-Jun-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP8A	1796	14-Sep-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-25	MP8A	1796	17-Jan-2012	—	—	—	—	—	—	—	—	—	—	—	0.18	—
R-25b	Single	750	21-Apr-2010	—	—	—	—	0.46	—	6.2	—	—	—	—	—	—
R-25b	Single	750	8-Sep-2010	—	—	—	—	0.68	—	6.4	—	—	—	—	—	—
R-25b	Single	750	7-Apr-2011	0.1	—	—	—	0.66	—	8.5	—	—	—	—	—	—
R-25b	Single	750	15-Sep-2011	—	—	—	—	0.63	—	8.2	—	—	—	—	—	—
R-25b	Single	750	23-Jan-2012	0.2	—	—	—	0.57	—	7.2	—	—	—	—	—	—
R-26	MP1A	659.3	1-Jun-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-26	MP1A	659.3	16-Sep-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-26	MP1A	659.3	9-Dec-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-26	MP1A	659.3	26-Jan-2012	—	—	—	—	—	—	—	—	—	—	—	—	—
R-26 PZ-2	R-26 PZ-2	150	5-Apr-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-26 PZ-2	R-26 PZ-2	150	10-Sep-2010											—	—	—
R-26 PZ-2	R-26 PZ-2	150	5-Apr-2011													
R-26 PZ-2	R-26 PZ-2	150	19-Sep-2011	—	—	—	—	—	—	—	—	—	—			

Table B-2.0-5 (continued)

Location	Port Name	Depth (ft bgs)	Date	HE Analytical Suite (µg/L)										Extended HE Suite (µg/L)		
				Amino-2,6-dinitrotoluene[4-]	Amino-4,6-dinitrotoluene[2-]	Dinitrotolune[2,4-]	Dinitrotolune[2,6-]	HMX	Nitrotoluene[2-]	RDX	Trinitrobenzene[1,3,5-]	Trinitrotoluene[2,4,6-]	2,4-Diamino-6-nitrotoluene	DNX[a]	MNX[b]	TNX[c]
			MDL	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.39**	**0.091**	**0.091**	**0.082**
			PQL	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**1.3**	**0.5**	**0.5**	**0.5**
R-26 PZ-2	R-26 PZ-2	150	26-Jan-2012													
R-27	Single	852	7-Oct-2009	—	—	—	—	—	—	—	—	—	—	—	—	—
R-27	Single	852	9-Apr-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-27	Single	852	14-Sep-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-27	Single	852	4-Apr-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-47i	Single	840	2-Dec-2010	—	—	—	—	—	—	—	—	—	—	—	—	—
R-47i	Single	840	7-Apr-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-47i	Single	840	21-Jun-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-47i	Single	840	8-Sep-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-47i	Single	840	24-Jan-2012	—	—	—	—	—	—	—	—	—	—	—	—	—
R-48	Single	1500	6-Jan-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-48	Single	1500	28-Mar-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-48	Single	1500	22-Jun-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-48	Single	1500	13-Sep-2011	—	—	—	—	—	—	—	—	—	—	—	—	—
R-48	Single	1500	18-Jan-2012	—	—	—	—	—	—	—	—	—	—	—	—	—
R-63	Single	1325	12-Apr-2011	—	—	—	—	—	—	1.2	—	—	—	—	—	—
R-63	Single	1325	22-Jun-2011	—	—	—	—	—	—	1.4	—	—	—	—	—	—
R-63	Single	1325	8-Sep-2011	—	—	—	—	—	—	1.3	—	—	—	—	—	—

Table B-2.0-5 (continued)

Location	Port Name	Depth (ft bgs)	Date	HE Analytical Suite (µg/L)										Extended HE Suite (µg/L)		
				Amino-2,6-dinitrotoluene[4-]	Amino-4,6-dinitrotoluene[2-]	Dinitrotolune[2,4-]	Dinitrotolune[2,6-]	HMX	Nitrotoluene[2-]	RDX	Trinitrobenzene[1,3,5-]	Trinitrotoluene[2,4,6-]	2,4-Diamino-6-nitrotoluene	DNX[a]	MNX[b]	TNX[c]
MDL				**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.39**	**0.091**	**0.091**	**0.082**
PQL				**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**0.325**	**1.3**	**0.5**	**0.5**	**0.5**
R-63	Single	1325	16-Dec-2011	—	—	—	—	—	—	1.4	—	—	—	—	—	—
R-63	Single	1325	20-Jan-2012	—	—	—	—	—	—	1.4	—	—	—	—	—	—

Source: Attachment B-1.

[a] DNX = Hexahydro-1,3,5-trinitro-1,3,5 triazine.

[b] MNX = Mononitrosodimethylamine.

[c] TNX = Hexahydro-1,3,5-trinitroso-1,3,5-triazine.

[d] — = Not detected..

[e] Gray-shaded cells indicate the well was not sampled for this analyte.

Table B-2.0-6
Low-Level Tritium Activities, 2008–2011

Location	Port Name	Depth (ft bgs)	Date	Analytical Lab	Activity (pCi/L)	Lab Qualifier	Validation Flag
16-26644	Single	130	20-Apr-2010	ARSL	32	—*	—
16-26644	Single	130	22-Jul-2010	ARSL	14	—	—
16-26644	Single	130	2-Nov-2010	ARSL	24	—	—
16-26644	Single	130	2-Mar-2011	ARSL	17	—	—
CdV-16-1(i)	Single	624	20-Oct-2008	UMTL	55	—	—
CdV-16-1(i)	Single	624	14-Oct-2009	UMTL	51	—	—
CdV-16-1(i)	Single	624	13-Sep-2010	ARSL	0.9	U	U
CdV-16-1(i)	Single	624	22-Sep-2011	ARSL	32	—	—
CdV-16-2(i)r	Single	850	10-Apr-2008	UMTL	6.4	—	—
CdV-16-2(i)r	Single	850	21-Oct-2008	UMTL	6.1	—	—
CdV-16-2(i)r	Single	850	8-Oct-2009	UMTL	5.7	—	—
CdV-16-2(i)r	Single	850	7-Sep-2010	ARSL	6.7	—	—
CdV-16-2(i)r	Single	850	6-Sep-2011	ARSL	6.2	—	—
CdV-16-4ip	P1A	815.6	31-Aug-2010	ARSL	16	—	—
CdV-16-4ip	P1A	815.6	7-Mar-2011	ARSL	15	—	—
CdV-16-4ip	P2A	1110	18-Sep-2010	ARSL	19	—	—
CdV-16-4ip	P2A	1110	2-Nov-2010	ARSL	7.0	—	—
CdV-16-4ip	P2A	1110	31-Mar-2011	ARSL	3.4	—	—
CDV-37-1(i)	Single	632	8-Feb-2010	UMTL	0.03	U	U
CDV-37-1(i)	Single	632	1-Apr-2010	ARSL	0.2	U	U
CDV-37-1(i)	Single	632	21-Sep-2010	ARSL	1.4	U	U
CDV-37-1(i)	Single	632	1-Dec-2010	ARSL	0.3	U	U
CDV-37-1(i)	Single	632	31-Mar-2011	ARSL	1.2	U	U
CDV-37-1(i)	Single	632	20-Jun-2011	ARSL	0.2	U	U
CdV-R-15-3	MP4A	1254	9-Oct-2008	ARSL	-5.8	U	U
CdV-R-15-3	MP4A	1254	7-Oct-2009	UMTL	0	U	U
CdV-R-15-3	MP4A	1254	5-Aug-2010	ARSL	-1.6	U	U
CdV-R-15-3	MP5A	1350	3-Apr-2008	UMTL	0.1	U	U
CdV-R-15-3	MP5A	1350	14-Oct-2008	ARSL	-1.4	U	U
CdV-R-15-3	MP5A	1350	7-Oct-2009	UMTL	-0.1	U	U
CdV-R-15-3	MP6A	1640	10-Oct-2008	ARSL	-6.4	U	U
CdV-R-15-3	MP6A	1640	7-Oct-2009	UMTL	-0.4	U	U
CdV-R-37-2	MP2A	1200	9-Apr-2008	UMTL	0.2	U	U
CdV-R-37-2	MP2A	1200	10-Oct-2008	ARSL	-5.4	U	U
CdV-R-37-2	MP2A	1200	15-Oct-2009	UMTL	0.03	U	U
CdV-R-37-2	MP3A	1359	8-Oct-2008	ARSL	-5.8	U	U
CdV-R-37-2	MP3A	1359	15-Oct-2009	UMTL	0.03	U	U
CdV-R-37-2	MP3A	1359	10-Aug-2010	ARSL	-2.0	U	U

Table B-2.0-6 (continued)

Location	Port Name	Depth (ft bgs)	Date	Analytical Lab	Activity (pCi/L)	Lab Qualifier	Validation Flag
CdV-R-37-2	MP4A	1551	8-Apr-2008	UMTL	-0.06	U	U
CdV-R-37-2	MP4A	1551	9-Oct-2008	ARSL	-5.9	U	U
CdV-R-37-2	MP4A	1551	14-Oct-2009	UMTL	-0.2	U	U
CdV-R-37-2	MP4A	1551	10-Aug-2010	ARSL	-1.6	U	U
R-18	Single	1358	7-Mar-2008	ARSL	5.6	—	—
R-18	Single	1358	25-Jun-2008	UMTL	0.6	—	U
R-18	Single	1358	17-Sep-2008	UMTL	0.4	—	U
R-18	Single	1358	12-Mar-2009	UMTL	0.3	U	U
R-18	Single	1358	28-May-2009	UMTL	1.0	—	—
R-18	Single	1358	14-Sep-2009	UMTL	0.2	U	U
R-18	Single	1358	11-Mar-2010	UMTL	0.2	U	U
R-18	Single	1358	21-Oct-2010	ARSL	1.0	U	U
R-18	Single	1358	7-Sep-2011	ARSL	2.6	—	—
R-25	MP1A	754.8	22-Oct-2008	UMTL	26	—	—
R-25	MP1A	754.8	21-Sep-2010	ARSL	29	—	—
R-25	MP1A	754.8	9-Sep-2011	ARSL	21	—	—
R-25	MP2A	891.8	22-Oct-2008	UMTL	34	—	—
R-25	MP2A	891.8	16-Oct-2009	UMTL	31	—	—
R-25	MP2A	891.8	21-Sep-2010	ARSL	34	—	—
R-25	MP2A	891.8	12-Sep-2011	ARSL	27	—	—
R-25	MP4A	1192.4	31-Mar-2008	UMTL	33	—	—
R-25	MP4A	1192.4	20-Oct-2008	UMTL	29	—	—
R-25	MP4A	1192.4	19-Oct-2009	UMTL	26	—	—
R-25	MP4A	1192.4	21-Sep-2010	ARSL	28	—	—
R-25	MP4A	1192.4	12-Sep-2011	ARSL	12	—	—
R-25	MP5A	1303.4	7-Apr-2009	UMTL	14	—	—
R-25	MP5A	1303.4	23-Sep-2010	ARSL	16	—	—
R-25	MP6A	1406.3	17-Oct-2008	UMTL	1.5	—	—
R-25	MP6A	1406.3	19-Oct-2009	UMTL	1.9	—	—
R-25	MP6A	1406.3	22-Sep-2010	ARSL	3.6	—	—
R-25	MP6A	1406.3	15-Sep-2011	ARSL	0.8	U	U
R-25	MP7A	1606	16-Oct-2008	UMTL	0.06	U	U
R-25	MP7A	1606	20-Oct-2009	UMTL	0.4	—	U
R-25	MP7A	1606	23-Sep-2010	ARSL	1.1	U	U
R-25	MP7A	1606	14-Sep-2011	ARSL	-1.4	U	U
R-25	MP8A	1796	15-Oct-2008	UMTL	0.1	U	U
R-25	MP8A	1796	20-Oct-2009	UMTL	0.1	U	U
R-25	MP8A	1796	24-Sep-2010	ARSL	1.3	U	U
R-25	MP8A	1796	14-Sep-2011	ARSL	-0.8	U	U

Table B-2.0-6 (continued)

Location	Port Name	Depth (ft bgs)	Date	Analytical Lab	Activity (pCi/L)	Lab Qualifier	Validation Flag
R-25b	Single	750	5-Jan-2008	UMTL	3.6	—	—
R-25b	Single	750	8-Jun-2009	UMTL	6.3	—	—
R-25b	Single	750	9-Oct-2009	UMTL	6.0	—	—
R-25b	Single	750	21-Apr-2010	ARSL	3.3	—	—
R-25b	Single	750	8-Sep-2010	ARSL	4.4	—	—
R-25b	Single	750	15-Sep-2011	ARSL	2.2	U	U
R-26	MP1A	659.3	7-Oct-2008	ARSL	-6.6	U	U
R-26	MP1A	659.3	19-Oct-2009	UMTL	-0.03	U	U
R-26	MP1A	659.3	13-Aug-2010	ARSL	-1.5	U	U
R-26	MP1A	659.3	16-Sep-2011	ARSL	-0.3	U	U
R-26	MP1A	659.3	9-Dec-2011	ARSL	1.4	U	U
R-26	MP1A	659.3	26-Jan-2012	ARSL	1.0	U	U
R-27	Single	852	10-Oct-2008	ARSL	-6.5	U	U
R-27	Single	852	7-Oct-2009	UMTL	-0.2	U	U
R-27	Single	852	14-Sep-2010	ARSL	1.1	U	U
R-47i	Single	840	21-Dec-2009	UMTL	0.7	—	U
R-47i	Single	840	8-Apr-2010	ARSL	-1.5	U	U
R-47i	Single	840	23-Sep-2010	ARSL	3.2	—	—
R-47i	Single	840	2-Dec-2010	ARSL	0.5	U	U
R-47i	Single	840	7-Apr-2011	ARSL	-0.4	U	U
R-47i	Single	840	21-Jun-2011	ARSL	0.2	U	U
R-47i	Single	840	8-Sep-2011	ARSL	1.3	U	U
R-48	Single	1500	23-Nov-2009	UMTL	0.06	U	U
R-48	Single	1500	17-Feb-2010	UMTL	0.4	—	U
R-48	Single	1500	7-Apr-2010	ARSL	-1.0	U	U
R-48	Single	1500	22-Sep-2010	ARSL	0.9	U	U
R-48	Single	1500	2-Dec-2010	ARSL	5.4	—	—
R-48	Single	1500	6-Jan-2011	ARSL	1.0	U	U
R-48	Single	1500	28-Mar-2011	ARSL	-0.3	U	U
R-48	Single	1500	22-Jun-2011	ARSL	-0.5	U	U
R-48	Single	1500	13-Sep-2011	ARSL	3.1	—	—
R-63	Single	1325	12-Apr-2011	ARSL	-1.8	U	U
R-63	Single	1325	22-Jun-2011	ARSL	0.03	U	U
R-63	Single	1325	8-Sep-2011	ARSL	0.4	U	U
R-63	Single	1325	16-Dec-2011	ARSL	1.65	U	U
R-63	Single	1325	20-Jan-2012	ARSL	-0.2	U	U

Source: Attachment B-1.

Notes: ARSL = American Radiation Services International; UMTL = University of Miami Tritium Laboratory; U = the analyte was analyzed for but was not detected.

*— = No qualifier code applied to this result.

Table B-2.0-7
Stable Isotopes

Location	Port Name	Depth (ft bgs)	Date	$\delta^{18}O$ (permil)	$\delta^{2}H$ (permil)	$\delta^{15}N\text{-}NO_3$ (permil)	$\delta^{18}O\text{-}NO_3$ (permil)
16-26644	Single	130	20-Apr-2010	-12.0	-86.4	6.56	1.68
16-26644	Single	130	22-Jul-2010	-11.9	-85.7	5.67	-0.72
16-26644	Single	130	2-Nov-2010	-11.6	-81.9	5.49	-1.80
16-26644	Single	130	2-Mar-2011	-11.7	-84.6	5.21	-2.87
CdV-16-1(i)	Single	624	20-Oct-2008	-12.0	-83.7	6.23	—*
CdV-16-1(i)	Single	624	14-Oct-2009	-12.0	-85.6	5.19	-1.06
CdV-16-1(i)	Single	624	13-Sep-2010	-11.7	-84.0	5.41	3.81
CdV-16-1(i)	Single	624	22-Sep-2011	-11.7	-82.0	6.30	-0.59
CdV-16-2(i)r	Single	850	21-Oct-2008	-12.0	-85.1	5.57	—
CdV-16-2(i)r	Single	850	8-Oct-2009	-12.3	-85.2	5.09	2.77
CdV-16-2(i)r	Single	850	7-Sep-2010	-11.9	-83.4	4.98	1.39
CdV-16-2(i)r	Single	850	6-Sep-2011	-11.9	-83.1	4.99	2.32
CdV-16-4ip	P1A	815.6	31-Aug-2010	-11.5	-83.0	5.60	9.32
CdV-16-4ip	P1A	815.6	7-Mar-2011	-12.0	-85.4	5.05	7.87
CdV-16-4ip	P2A	1110	18-Sep-2010	-11.9	-83.1	5.34	9.60
CdV-16-4ip	P2A	1110	26-Oct-2010	-12.0	-83.6	4.58	3.79
CdV-16-4ip	P2A	1110	2-Nov-2010	-12.1	-85.9	4.44	2.44
CdV-16-4ip	P2A	1110	31-Mar-2011	-12.2	-83.9	4.52	-0.01
CDV-37-1(i)	Single	632	8-Feb-2010	-11.2	-79.0	10.43	3.55
CDV-37-1(i)	Single	632	1-Apr-2010	-11.3	-79.9	4.45	-3.41
CDV-37-1(i)	Single	632	21-Sep-2010	-11.3	-81.8	4.97	-8.73
CDV-37-1(i)	Single	632	1-Dec-2010	-11.4	-81.1	2.22	-4.46
CDV-37-1(i)	Single	632	31-Mar-2011	-11.5	-80.0	4.00	-5.23
CdV-R-15-3	MP4A	1254	3-Apr-2008	—	-82.5	4.51	—
CdV-R-15-3	MP4A	1254	9-Oct-2008	-11.6	-82.8	5.23	—
CdV-R-15-3	MP4A	1254	7-Oct-2009	-12.0	-84.4	4.20	-3.29
CdV-R-15-3	MP4A	1254	5-Aug-2010	-11.4	-82.9	3.26	-4.47
CdV-R-15-3	MP4A	1254	11-May-2011	-11.7	-82.8	3.22	-1.49
CdV-R-15-3	MP5A	1350	7-Oct-2009	-11.8	-83.0	—	—
CdV-R-15-3	MP5A	1350	4-May-2011	-11.4	-80.9	4.41	-5.79
CdV-R-15-3	MP6A	1640	7-Oct-2009	-11.6	-83.3	—	—
CdV-R-15-3	MP6A	1640	3-May-2011	-11.4	-80.3	5.04	—
CdV-R-37-2	MP2A	1200	15-Oct-2009	-11.2	-81.2	—	—
CdV-R-37-2	MP2A	1200	24-Apr-2011	-11.6	-81.4	7.50	—
CdV-R-37-2	MP3A	1359	8-Oct-2008	-11.2	-82.2	5.13	—
CdV-R-37-2	MP3A	1359	15-Oct-2009	-11.5	-82.2	4.53	-3.91

Table B-2.0-7 (continued)

Location	Port Name	Depth (ft bgs)	Date	$\delta^{18}O$ (permil)	$\delta^{2}H$ (permil)	$\delta^{15}N\text{-}NO_3$ (permil)	$\delta^{18}O\text{-}NO_3$ (permil)
CdV-R-37-2	MP3A	1359	10-Aug-2010	-11.5	-82.0	3.78	-5.28
CdV-R-37-2	MP3A	1359	12-Apr-2011	-11.3	-79.5	4.40	-6.37
CdV-R-37-2	MP4A	1551	14-Oct-2009	-11.5	-81.5	—	—
CdV-R-37-2	MP4A	1551	10-Aug-2010	-11.7	-81.8	—	—
CdV-R-37-2	MP4A	1551	16-Apr-2011	-11.6	-81.2	4.10	-6.38
R-18	Single	1358	17-Sep-2008	-12.0	-86.0	4.98	9.60
R-18	Single	1358	12-Mar-2009	-11.5	-84.8	4.80	8.95
R-18	Single	1358	28-May-2009	-11.9	-85.7	4.84	—
R-18	Single	1358	14-Sep-2009	-12.0	-85.3	5.13	7.95
R-18	Single	1358	21-Oct-2010	-12.0	-82.7	4.68	7.61
R-18	Single	1358	7-Sep-2011	-12.1	-84.4	4.44	8.22
R-25	MP1A	754.8	22-Oct-2008	-12.0	-83.5	6.14	—
R-25	MP1A	754.8	21-Sep-2010	-11.8	-81.5	6.66	1.22
R-25	MP1A	754.8	9-Sep-2011	-11.8	-82.9	5.21	-2.33
R-25	MP2A	891.8	16-Oct-2009	-12.1	-83.5	—	—
R-25	MP2A	891.8	21-Sep-2010	-11.9	-82.2	—	—
R-25	MP2A	891.8	12-Sep-2011	-11.7	-82.3	—	—
R-25	MP4A	1192.4	20-Oct-2008	-11.7	-84.8	5.67	—
R-25	MP4A	1192.4	19-Oct-2009	-12.0	-83.9	—	—
R-25	MP4A	1192.4	21-Sep-2010	-11.6	-83.6	5.95	1.25
R-25	MP4A	1192.4	12-Sep-2011	-11.8	-84.1	6.96	-1.09
R-25	MP5A	1303.4	7-Apr-2009	-11.8	-86.1	—	—
R-25	MP5A	1303.4	23-Sep-2010	-11.9	-84.8	—	—
R-25	MP6A	1406.3	17-Oct-2008	-12.0	-84.9	4.49	-3.94
R-25	MP6A	1406.3	19-Oct-2009	-12.1	-85.8	5.50	-3.88
R-25	MP6A	1406.3	22-Sep-2010	-11.8	-84.1	4.23	-5.52
R-25	MP6A	1406.3	15-Sep-2011	-11.8	-85.0	5.59	-3.70
R-25	MP7A	1606	16-Oct-2008	-11.8	-83.8	4.66	-5.93
R-25	MP7A	1606	20-Oct-2009	-11.3	-85.0	4.35	-4.92
R-25	MP7A	1606	23-Sep-2010	-11.5	-82.3	3.71	-7.92
R-25	MP7A	1606	14-Sep-2011	-11.5	-83.1	4.74	-5.65
R-25	MP8A	1796	15-Oct-2008	-11.6	—	2.65	-8.32
R-25	MP8A	1796	20-Oct-2009	-11.3	-82.8	3.99	-5.07
R-25	MP8A	1796	24-Sep-2010	-11.6	-83.4	3.89	-7.17
R-25	MP8A	1796	14-Sep-2011	-12.0	-81.8	3.83	-6.92
R-25b	Single	750	8-Jun-2009	-11.6	-84.5	4.39	-1.66
R-25b	Single	750	9-Oct-2009	-11.7	-85.0	6.17	-0.46
R-25b	Single	750	21-Apr-2010	-11.9	-85.7	8.82	-1.23

Table B-2.0-7 (continued)

Location	Port Name	Depth (ft bgs)	Date	$\delta^{18}O$ (permil)	$\delta^{2}H$ (permil)	$\delta^{15}N\text{-}NO_3$ (permil)	$\delta^{18}O\text{-}NO_3$ (permil)
R-25b	Single	750	8-Sep-2010	-11.8	-83.7	5.48	-3.23
R-25b	Single	750	15-Sep-2011	-11.7	-83.5	6.08	-2.09
R-26	MP1A	659.3	7-Oct-2008	-11.7	-85.5	4.61	—
R-26	MP1A	659.3	19-Oct-2009	-12.2	-83.8	3.75	-5.83
R-26	MP1A	659.3	13-Aug-2010	-12.2	-82.9	3.91	-4.80
R-26	MP1A	659.3	1-Jun-2011	-11.9	-83.9	4.43	-3.88
R-26	MP1A	659.3	16-Sep-2011	-11.8	-83.9	3.83	-5.87
R-26 PZ-2	R-26 PZ-2	150	15-Apr-2009	-11.1	-82.0	—	—
R-26 PZ-2	R-26 PZ-2	150	11-Jun-2009	-11.3	-81.9	—	—
R-26 PZ-2	R-26 PZ-2	150	5-Apr-2010	-11.3	-79.7	5.48	-0.02
R-27	Single	852	10-Oct-2008	-11.0	-82.8	4.69	—
R-27	Single	852	7-Oct-2009	-11.4	-82.7	4.02	-4.09
R-27	Single	852	14-Sep-2010	-11.2	-80.1	4.74	-4.54
R-47i	Single	840	21-Dec-2009	-11.8	-84.0	2.98	-3.78
R-47i	Single	840	8-Apr-2010	-11.7	-80.4	-0.77	-7.77
R-47i	Single	840	23-Sep-2010	-11.7	-83.7	3.04	-4.35
R-47i	Single	840	2-Dec-2010	-11.9	-81.9	2.30	-3.50
R-47i	Single	840	7-Apr-2011	-11.8	-82.7	2.96	-4.63
R-47i	Single	840	8-Sep-2011	-12.0	-83.2	—	—
R-48	Single	1500	23-Nov-2009	-11.5	-81.3	4.55	-4.05
R-48	Single	1500	17-Feb-2010	-11.0	-78.5	4.67	-4.22
R-48	Single	1500	7-Apr-2010	-11.3	-79.4	5.34	-3.50
R-48	Single	1500	22-Sep-2010	-11.4	-77.9	5.05	-5.08
R-48	Single	1500	2-Dec-2010	-11.4	-79.8	5.82	-2.36
R-48	Single	1500	6-Jan-2011	-11.4	-79.7	4.70	-3.80
R-48	Single	1500	28-Mar-2011	-11.2	-79.4	4.52	-5.66
R-48	Single	1500	13-Sep-2011	-11.5	-80.2	4.38	-5.76
R-63	Single	1325	12-Apr-2011	-11.8	-84.8	4.14	0.66
R-63	Single	1325	22-Jun-2011	-12.2	-84.8	4.64	3.39
R-63	Single	1325	8-Sep-2011	-12.2	-84.3	3.91	1.94

Source: Attachment B-1.

*— = No data.

Table B-3.0-1
Data Excluded from Summary Statistics of Area-Specific Groundwater Background Water Quality

Parameter	Location	Sampling Date	Value	Units	Rationale for Exclusion
Turbidity	Water Canyon Gallery	12-Apr-10	24.4	NTU	All data for this sample were excluded because such high turbidity is not characteristic of other samples from this location. The high turbidity is associated with the presence of colloidal material that heavily biases data for filtered constituents, particularly trace metals. Extreme examples of biased trace-metal concentrations for this sample are filtered aluminum (3700 μg/L) and filtered iron (1500 μg/L).
Field pH	Water Canyon Gallery	19-Oct-09	4.25	SU*	Outlier; suspect data. Not representative of other field pH values for this location.
Arsenic	CdV-R-15-3 screen 4	12-Apr-10	<6.29	µg/L	Reported as detected by analytical laboratory; categorized as nondetect during validation. Suspect data due to contamination in method blank. Also not representative of other arsenic concentrations for these locations.
Arsenic	CdV-R-37-2 screen 3	14-Apr-10	<5.03	µg/L	
Arsenic	R-25 screen 7	8-Apr-10	<5.63	µg/L	
Arsenic	R-27i	20-Jun-11	<7.72	µg/L	
Sulfate	CdV-R-37-2 screen 3	25-Mar-09	9.05	mg/L	Outlier. Not representative of other sulfate concentrations for this location which are all ≤2.0 mg/L (22 samples, 2002 to 2010).
Total Organic Carbon	R-26 screen 1	16-Sep-11	<1.28	mg/L	Reported as detected by analytical laboratory; categorized as nondetect during validation. Suspect data due to contamination in method blank. Also not representative of other TOC concentrations for this location.
Total Phosphate as Phosphorus	R-25 screen 7	08-Apr-10 23-Sep-10 16-Jun-11 14-Sep-11	0.156 0.153 0.114 0.269	mg/L	Downhole chemical. These phosphate concentrations are not representative of groundwater background at this location but reflect the presence of residual SAPP used to scrub the screen after well construction.
Total Phosphate as Phosphorus	R-25 screen 8	09-Apr-10 24-Sep-10 17-Jun-11 14-Sep-11	0.191 0.165 0.122 0.182	mg/L	

Data source: Attachment B-1.
*SU = Standard unit.

Table B-3.0-2
Descriptive Statistical Data for
Geochemical Parameters in Area-Specific Background Groundwater

Parameter	Units	MDL[a]	PQL[a]	Number of Observations	Number of Detects[b]	Min Value	Max Detected Value	Average	Std Dev
Alkalinity-CO_3+HCO_3	mg/L	0.73	1	56	56	36	76	53	6
Aluminum	µg/L	68	200	50	5	68	624	81	79
Arsenic	µg/L	1.5	5	46	9	1.5	3.8	1.8	0.6
Barium	µg/L	1	5	50	50	4.3	42	21	12
Boron	µg/L	15	50	50	3	12.6	17.4	15.1	0.6
Calcium	mg/L	0.05	0.2	50	50	6.8	12.8	9.5	1.3
Chloride	mg/L	0.05	0.2	55	54	0.80	2.29	1.53	0.26
Chromium	µg/L	2.5	10	50	19	2.1	5.2	3.0	0.9
Cobalt	µg/L	1	5	50	2	1	2.0	1.0	0.1
Copper	µg/L	3	10	50	1	3	3.7	3.0	0.1
DO	mg/L	—[c]	—	57	57	4.3	14.9	7.2	1.6
Fluoride	mg/L	0.03	0.1	55	55	0.097	0.363	0.188	0.054
Iron	µg/L	30	100	50	9	30	239	40	33
Magnesium	mg/L	0.085	0.3	50	50	2.09	3.46	2.92	0.32
Manganese	µg/L	2	10	50	10	2	5.4	2.3	0.7
Molybdenum	µg/L	0.1	0.5	50	34	0.34	1.65	1.0	0.3
Nickel	µg/L	0.5	2	50	28	0.5	2.11	0.75	0.37
Nitrate + Nitrite (as N)	mg/L	0.05	0.25	54	46	0.03	0.66	0.27	0.13
Oxidation-reduction potential	mV[d]	—	—	37	37	-74	433	162	125
Perchlorate	mg/L	0.05	0.2	55	55	0.117	0.297	0.232	0.041
pH—field	SU[e]	—	—	54	54	6.4	8.3	7.7	0.4
Potassium	mg/L	0.05	0.15	50	50	0.30	2.48	1.45	0.53
Silicon dioxide	mg/L	0.015	0.1	55	55	43	80	66	8
Sodium	mg/L	0.1	0.2	50	50	5.6	12.3	9.9	1.5
Specific conductance	µS/cm	—	—	57	57	69	132	112	14
Strontium	µg/L	1	5	50	50	41	91	52	11
Sulfate	mg/L	0.1	0.4	54	52	1.26	3.40	1.82	0.37
TDS	mg/L	—	—	55	55	76	146	120	14
TOC	mg/L	0.33	1	54	34	0.33	1.48	0.51	0.22
Total phosphorus (as P)	mg/L	0.015	0.05	47	10	0.015	0.204	0.058	0.044
Turbidity	NTU	—	—	55	54	0	4.5	1.0	0.8
Uranium	µg/L	0.05	0.2	50	41	0.13	0.63	0.42	0.12

Table B-3.0-2 (continued)

Parameter	Units	MDL[a]	PQL[a]	Number of Observations	Number of Detects	Min Value	Max Detected Value	Average	Std Dev
Vanadium	µg/L	1	5	50	50	1.2	10.0	5.5	2.4
Zinc	µg/L	3.3	10	50	15	3.2	13.1	4.2	2.1

Source of values: Statistics calculated from groundwater data set in Attachment B-1.

[a] MDLs and PQLs from section C-4.1-1 in 2011 IFGMP R1 (LANL 2011, 208811).

[b] Categorized as detected following validation

[c] — = Not applicable.

[d] mV = Millivolts.

[e] SU = Standard unit.

Table B-3.0-3
Statistical Data for Deep Groundwater (Area-Specific and Plateau-Scale)

Parameter	Units	Area-Specific Groundwater Background[a]			Plateau-Scale Perched-Intermediate Groundwater Background[b]			Plateau-Scale Regional Groundwater Background[b]		
		% Detects	5th Percentile	95th Percentile	% Detects	25th Percentile	95th Percentile	% Detects	25th Percentile	95th Percentile
Alkalinity-CO_3+HCO_3	mg/L	100	41	58	100	36	126	100	57	91
Aluminum	µg/L	10	68	82	56	50	713	3	68	200
Arsenic	µg/L	20	1.5	3.3	50	1.5	5	62	1.8	6
Barium	µg/L	100	5	39	98	12	89	100	21	68
Boron	µg/L	6	15	15	60	10	50	87	13	50
Calcium	mg/L	100	7.2	11.7	100	6.8	35.8	100	10.3	20.6
Chloride	mg/L	98	1.1	1.9	99	1.1	3.3	100	1.9	3.2
Chromium	µg/L	38	2.4	4.9	57	2.2	6.2	85	3	6.9
Cobalt	µg/L	4	1	1	6	1	5	6	1	5
Copper	µg/L	2	3	3	12	3	10	5	3	10
DO	mg/L	100	5.4	9.5	100	6.5	9.8	100	4.3	7.1
Fluoride	mg/L	100	0.12	0.27	97	0.10	0.58	96	0.27	0.48
Iron	µg/L	18	30	77	61	21	254	22	18	100
Magnesium	mg/L	100	2.3	3.3	100	1.4	3.5	100	2.8	4.3
Manganese	µg/L	20	2	3.8	54	2	174	47	2	14
Molybdenum	µg/L	68	0.5	1.6	68	0.9	3.0	69	1.1	3.3
Nickel	µg/L	56	0.5	1.4	48	0.6	1.1	66	0.6	2.6
Nitrate + Nitrite (as N)	mg/L	85	0.05	0.42	89	0.12	0.48	94	0.28	0.57
Oxidation-reduction potential	mV[c]	100	-9	395	100	239	450	100	105	369
Perchlorate	mg/L	100	0.13	0.28	87	0.20	0.50	100	0.27	0.52
pH—field	SU[d]	100	7.0	8.2	100	6.9	8.4	100	7.7	8.4
Potassium	mg/L	100	0.35	2.4	100	1.8	5.2	100	1.5	2.8

Table B-3.0-3 (continued)

Parameter	Units	Area-Specific Groundwater Background[a]			Plateau-Scale Perched-Intermediate Groundwater Background[b]			Plateau-Scale Regional Groundwater Background[b]		
		% Detects	5th Percentile	95th Percentile	% Detects	25th Percentile	95th Percentile	% Detects	25th Percentile	95th Percentile
Silicon dioxide	mg/L	100	53	78	97	36	70	100	66	83
Sodium	mg/L	100	6.0	12	100	5.4	31	100	11	17
Specific conductance	µS/cm	100	85	129	100	79	246	100	126	193
Strontium	µg/L	100	43	86	100	52	446	100	46	189
Sulfate	mg/L	96	1.3	2.5	99	2.6	8.4	100	2.1	5.0
TDS	mg/L	100	90	139	100	97	191	100	133	176
TOC	mg/L	63	0.3	0.9	83	1	3.9	78	0.4	1.1
Total phosphorus (as P)	mg/L	21	0.015	0.17	43	0.03	0.09	29	0.03	0.10
Turbidity	NTU	98	0.3	2.2	100	2	37	100	0.2	4.8
Uranium	µg/L	82	0.2	0.6	81	0.2	2.3	95	0.41	1.50
Vanadium	µg/L	100	1.5	9.3	85	2	16	98	6.3	14
Zinc	µg/L	30	3.3	7.3	32	2	9.1	63	2.7	15

[a] Calculated from groundwater data set in Attachment B-1.

[b] Tables 4.2-1 and 4.2-2 in GBIR R4 Update (LANL 2011, 207447); MDLs and PQLs from section C-4.1-1 in 2011 IFGMP R1 (LANL 2011, 208811).

[c] mV = Millivolts.

[d] SU = Standard unit.

Attachment B-1

Water-Quality Data for the
Technical Area 16 Well Network Evaluation
(on CD included with this document)

Appendix C

Analysis of Technical Area 16
Regional Aquifer Monitoring Network Based on
Numerical Simulations of Potential Contaminant Transport

The objective of the numerical simulations presented in this appendix is to analyze potential flow directions in the regional aquifer to determine the likely migration direction for contaminants released in the area of Technical Area 16 (TA-16), including the 260 Outfall. Uncertainties in the flow directions are also addressed in this analysis. Through this analysis, monitoring wells that are important for detecting potential plume migration in the regional aquifer are identified. This analysis includes the areas described in section 3.1 and Appendix D that represent the arrival locations of the medium- to high-priority sources at TA-16, including some spreading along canyon floors. The simulations, however, do not account for flow and transport in the deep perched-intermediate zones of saturation. Contaminant transport through the vadose zone is assumed to be predominantly vertical other than the initial spreading of the sources (Figure 3.2-1).

C-1.0 MODEL DESCRIPTION

Various basin-scale and site-scale numerical models of three-dimensional (3-D) groundwater flow and transport in the aquifer beneath Los Alamos National Laboratory (the Laboratory or LANL) have been developed. The site-scale models represent a portion of the regional basin-scale aquifer in the vicinity of the Laboratory (Keating et al. 1999, 088746; Keating et al. 2000, 090188; Keating et al. 2001, 095399; Vesselinov et al. 2002, 201607; LANL 2006, 094431; LANL 2006, 093798; LANL 2007, 095787). Previous modeling work has targeted issues related to sustainability of groundwater resources in the region, potential impacts of previous and current Laboratory activities on the subsurface environment, and quality and quantity of groundwater resources (LANL 1998, 059599). During previous model developments, a series of site-scale models was generated. Differences between the models are associated with different input information used in the model development (e.g., using latest updates in the geological model and the hydraulic-head database). More importantly, there are differences related to alternative conceptualizations of groundwater flow and transport in the models. For example, there are steady-state models that assume temporal changes are negligible (Keating et al. 1999, 088746) versus transient models that incorporate them (Keating et al. 2001, 095399). There are also models that focus on the processes in the phreatic zone of the regional aquifer (within 100–200 ft below the regional water-table), and models that incorporate the whole thickness of the regional aquifer (the thickness of the regional aquifer is unknown and spatially variable; overall, it is more than 1500 ft).

An assumption based on the conceptual model discussions in section 3 is that the regional aquifer at TA-16 is at steady state (the model ignores the water-level fluctuations; the flow directions are assumed to temporally be constant). As a result, a steady-state flow model in the phreatic zone is applied in this work. Similar conclusions for the regional aquifer have been made previously for other locations across the Pajarito Plateau (Vesselinov 2004, 089753; Vesselinov 2004, 090040; Vesselinov 2004, 090117). The water-table gradients are also assumed to be known and defined by the two alternative water-table maps presented in Figures C-1.0-1 and C-1.0-2 for the area near TA-16; the modeling results discussed below use similar water-table maps that extend outside the TA-16 area and cover the entire Pajarito Plateau. Another assumption is limited vertical mixing of contaminants occurs below the phreatic zone, and therefore, the model is reduced to a relatively thin zone with thickness of 50 m (~164 ft) below the water-table. As a result, the model is pseudo-3-D with a uniform vertical thickness that is negligible compared with the lateral model extent (several kilometers).

The first water-table map, presented in Figure C-1.0-1, takes into account the existing water-level data. The second water-table map, presented in Figure C-1.0-2, is based on an assumption that a regional recharge mound occurs beneath Cañon de Valle, and the shape of the mound is symmetric north and the south of the canyon axis. In this case, water levels to the north of the mound are assumed to be similar to

the water levels near R-48. This causes a northern component of the groundwater flow on the north side of the recharge mound.

The model domain is shown in Figure C-1.0-3. Laterally, the grid extends from the flanks of the Sierra de los Valles on the west to the Rio Grande on the east. The entire Laboratory lies within the boundaries of this domain, as do most of the Los Alamos County water-supply wells. The top of the grid is defined by the shape of the regional water table (Figures C-1.0-1, C-1.0-2, and C-1.0-3). The computational grid is uniform (structured), and the size of the grid cells is uniform and equal to 25 m × 25 m × 50 m.

Flow directions and magnitudes that control contaminant transport in the aquifer are generally dictated by the shape of the regional water table. Transport velocities are a function of the hydraulic gradients and the permeability and porosity of the hydrostratigraphic units. The hydrostratigraphic units are assumed to have spatially uniform hydrogeologic properties. The uniform hydrogeologic properties are uncertain and represented as random variables within predefined uncertainty bounds. The permeability ranges of hydrostratigraphic units are based on site-specific field hydraulic tests (McLin 2006, 093670) and literature data (Freeze and Cherry 1979, 088742). The ranges of porosity values for the regional aquifer units are defined based on data from the literature (Freeze and Cherry 1979, 088742). Site-specific porosity data are available only for the Cerros del Rio basalt (Tb4) and Puye Formation (Tpf), and these data were considered in developing the distributions for those two units (Keating et al. 2001, 095399). Note that for contaminant transport near TA-16, only flow properties (permeability, porosity) of the Puye Formation (Tpf) and Tschicoma Formation (Tvt2) are directly relevant; statistical properties of these uncertain model parameters are listed in Table C-1.0-1. The flow properties of the other hydrostratigraphic units are not expected to influence this analysis because the potentiometric surface intersects these two units only in the vicinity of TA-16.

To represent the dispersion of the contaminant plumes, an axisymmetric form of the dispersion tensor was used (Lichtner et al. 2002, 095397); longitudinal and transverse dispersivities were defined to characterize the tensor. The longitudinal and transverse dispersivities are assumed to be random variables with the statistical parameters discussed in Table C-1.0-2. Site-specific data supporting these values are not available; additional information about the longitudinal and transverse dispersivities, as well as effective transport velocity, will be obtained by the planned tracer tests in the TA-16 area. Based on literature data (Neuman 1990, 090184), and given the properties of the flow medium, the selected range of values is reasonable for the spatial scale of simulated contaminant transport (~500 m).

A set of 1000 uncorrelated random variables of permeability, porosity, and longitudinal and transverse dispersivities was generated with a Latin hypercube sampling technique using the Model Analysis & Decision Support (MADS) software (http://mads.lanl.gov). In this case, there is a relatively limited set of hydrogeological parameters that affect contaminant transport near TA-16. These are permeability and porosity of Tpf and Tvt2, as well as longitudinal and transverse dispersivities; six parameters in total. Therefore, the use of 1000 realizations to characterize uncertainties numerically is reasonable.

The analysis considers six potential contaminant breakthrough windows along the regional water table. These breakthrough windows are identified to have high and medium potential to impact groundwater (section 3). The windows are labeled as Cañon de Valle, 260 pond, S-Site Canyon, 90s Line pond, 30s Line ponds, and Fishladder Canyon. The assumed spatial extent of the potential sources at the top of the regional aquifer is presented in Figures C-1.0-1 and C-1.0-2, which are based on Figure 3.1-1. In each realization, 2860 particles are released in the numerical model to represent the spatial extent of the six potential contaminant breakthrough windows. The particle movement is tracked through the model domain. The model predicts potential transient contaminant plumes in the aquifer and contaminant breakthrough curves at the monitoring wells. The plumes and breakthrough curves are computed using

particle-tracking capabilities of the Finite Element Heat and Mass Transfer Code (FEHM) (Zyvoloski et al. 1996, 054421) and a specially developed code for numerical convolution, CONVOLUTE. The model analyses are computationally intensive and produce a large output data set. The analyses are achieved efficiently through parallelization using the Laboratory's supercomputers. The MADS software efficiently executes a series of Monte Carlo runs in a parallel environment. Because of the independent nature of the individual Monte Carlo runs, the parallelization efficiency scales well with the number of applied processors.

The model incorporates all the existing regional monitoring wells. In addition, the model includes 68 hypothetical monitoring well locations in the area near TA-16. The wells are distributed downgradient of potential contamination sources and located in areas where it is feasible to drill, given topographic and logistics constraints. The existing and hypothetical monitoring wells are presented in Figures C-1.0-1 and C-1.0-2.

The hydraulic gradients in the model are constrained by two alternative water-table maps (Figures C-1.0-1 and C-1.0-2). As a result, permeability variations in the 1000 stochastic runs might produce groundwater flow (Darcy) velocities that exceed ranges expected based on previous information about the total amount of water flowing through the regional aquifer. Groundwater velocity is equal to hydraulic gradient multiplied by hydraulic conductivity but can also be computed by dividing the total groundwater flow rate by the flow area. The groundwater velocities through the phreatic zone at TA-16 are expected to be on the order of 100 m/yr. However, the transport velocities simulated in the model are considered to be characteristic for only the fraction of the groundwater flow medium where a dominant portion of contaminant transport occurs. As a result, the total amount of groundwater flowing through the aquifer will be still consistent with existing hydrogeological information. Therefore, the simulations target estimation of potential uncertainties associated with contaminant transport velocities rather than groundwater flow velocities.

The monitoring metric set for this network evaluation is that the regional-aquifer monitoring network must detect potential contaminant plumes in the regional aquifer with detection efficiency higher than 95%. In the model, successful detections are plumes detected by any of the existing or hypothetical monitoring wells near TA-16. The detection efficiency is the number of successfully detected plumes divided by the number of simulated plumes (1000 plumes).

C-2.0 RESULTS AND DISCUSSION

The simulation analyses used two alternative water-table maps in order to estimate (1) uncertainties in the flow directions in the regional aquifer and (2) efficiency of the existing monitoring network for detecting TA-16 contaminants,

Tables C-2.0-1 and C-2.0-2 present the efficiencies of the existing TA-16 regional monitoring wells for detecting contaminants from high to medium potential sources. The analyses are based on the regional water tables presented in Figures C-1.0-1 and C-1.0-2, respectively. Regardless of uncertainties in the shape of the regional water table, the existing monitoring network, which includes R-25, R-63, R-18, R-48 and CdV-R-15-3, is sufficient to detect TA-16 contaminants with efficiency above 95% for most of the high to medium potential contamination sources; these sources include Cañon de Valle, 260 pond, 90s Line pond, and 30s Line ponds. The detection efficiency is below 95% for S-Site and Fishladder Canyon.

Based on existing hydrogeological information about the groundwater flow in the regional aquifer, the modeling analyses indicate that CdV-R-37-2 may not be an important regional monitoring well for

detecting contaminants originating in the TA-16 area. However, the CdV-R-37-2 water-level data provide important information about the structure of the regional groundwater table.

Tables C-2.0-3 and C-2.0-4 present the efficiencies of the 68 hypothetical TA-16 regional monitoring wells for detecting contaminants from high to medium potential sources. The analyses are based on the regional water tables presented in Figures C-1.0-1 and C-1.0-2, respectively. The analyses of the hypothetical regional monitoring wells were performed because the current monitoring network is not sufficient to detect potential contaminants from two of the potential TA-16 contamination sources, S-Site and Fishladder Canyon. Well location W-38 (see Figures C-1.0-1 and C-1.0-2 and Tables C-2.0-3 and C-2.0-4) would be a good candidate for improving the monitoring network efficiency for these two source locations.

The analyses of the 68 hypothetical TA-16 regional monitoring wells also demonstrate that based on the current hydrogeological information, the locations labeled as W-20 and W-21 in Figures C-1.0-1 and C-1.0-2 will not provide additional monitoring network efficiency (Tables C-2.0-3 and C-2.0-4). These locations are close to the proposed location for regional well R-47 near intermediate well R-47i. Therefore, the site for well R-47 is not necessary for detecting potential TA-16 contaminants; in fact, R-63, which was placed west of the proposed location of R-47, is providing better monitoring efficiency than will the proposed R-47 location.

C-3.0 DISCUSSION AND CONCLUSIONS

The numerical model simulations presented in this appendix address various aspects of existing hydrogeological uncertainties. The analyses of these simulations led to the conclusion that the existing regional monitoring network, which includes wells R-25, R-63, R-18, R-48 and CdV-R-15-3, serves an important function in detecting contaminants released at TA-16.

The existing monitoring network is sufficient for detecting TA-16 contaminants with efficiency above 95% for most of the potential contamination sources with high and medium importance, including Cañon de Valle, 260 pond, 90s Line pond and 30s Line ponds. The detection efficiency is below 95% for S-Site Canyon and Fishladder Canyon (Tables C-2.0-1 and C-2.0-2).

The analyses also demonstrated that CdV-R-37-2 is most likely not an important regional monitoring well for detecting contaminants originating at TA-16. However, the CdV-R-37-2 water-level data provide important information about the structure of regional groundwater table (Tables C-2.0-1 and C-2.0-2).

Furthermore, the analyses also demonstrated that the proposed location for regional well R-47, near intermediate well R-47i, does not improve the detection of TA-16 contaminants. Newly installed well R-63, which was placed west of the proposed R-47 location, is providing better monitoring efficiency than will the proposed R-47 location.

Therefore, it is proposed to move well R-47 to a location north of Cañon de Valle between R-18 and R-63. The well will address uncertainties associated with regional aquifer flow directions and contaminant concentrations north-northeast of Cañon de Valle. Because of current uncertainties in the flow directions, the location labeled as W-11 in Figures C-1.0-1 and C-1.0-2 (and Tables C-2.0-3 and C-2.0-4) would be the most optimal for the proposed well. The W-11 well location will provide very good detection efficiency (above 95%; see Tables C-2.0-3 and C-2.0-4), regardless of uncertainties in the regional flow directions north of Cañon de Valle represented by the alternative shapes of the regional water table in Figures C-1.0-1 and C-1.0-2.

The detection efficiency of the existing monitoring network is below 95% for two of the high to medium potential sources: S-Site and Fishladder Canyon. Well location W-38 in Figures C-1.0-1 and C-1.0-2 provides detection efficiency above 95% for potential contaminants originating from both S-Site and Fishladder Canyon (Tables C-2.0-3 and C-2.0-4). Therefore, well location W-38 is proposed as the best site for drilling an additional regional monitoring well that will provide supplementary monitoring network efficiency for these two source locations.

These conclusions regarding efficiency of the current monitoring network are confirmed by existing monitoring data; R-25, R-18, and R-63 detect contaminants that potentially originate from TA-16 sources. The other wells in the current monitoring network (R-48, CdV-R-15-3 and CdV-R-37-2) do not detect TA-16 contaminants at the moment. The lack of contamination detected at CdV-R-37-2 is consistent with the analyses presented here because based on existing hydrogeological information, the groundwater flow in the regional aquifer near TA-16 is not expected to have substantial southern component.

C-4.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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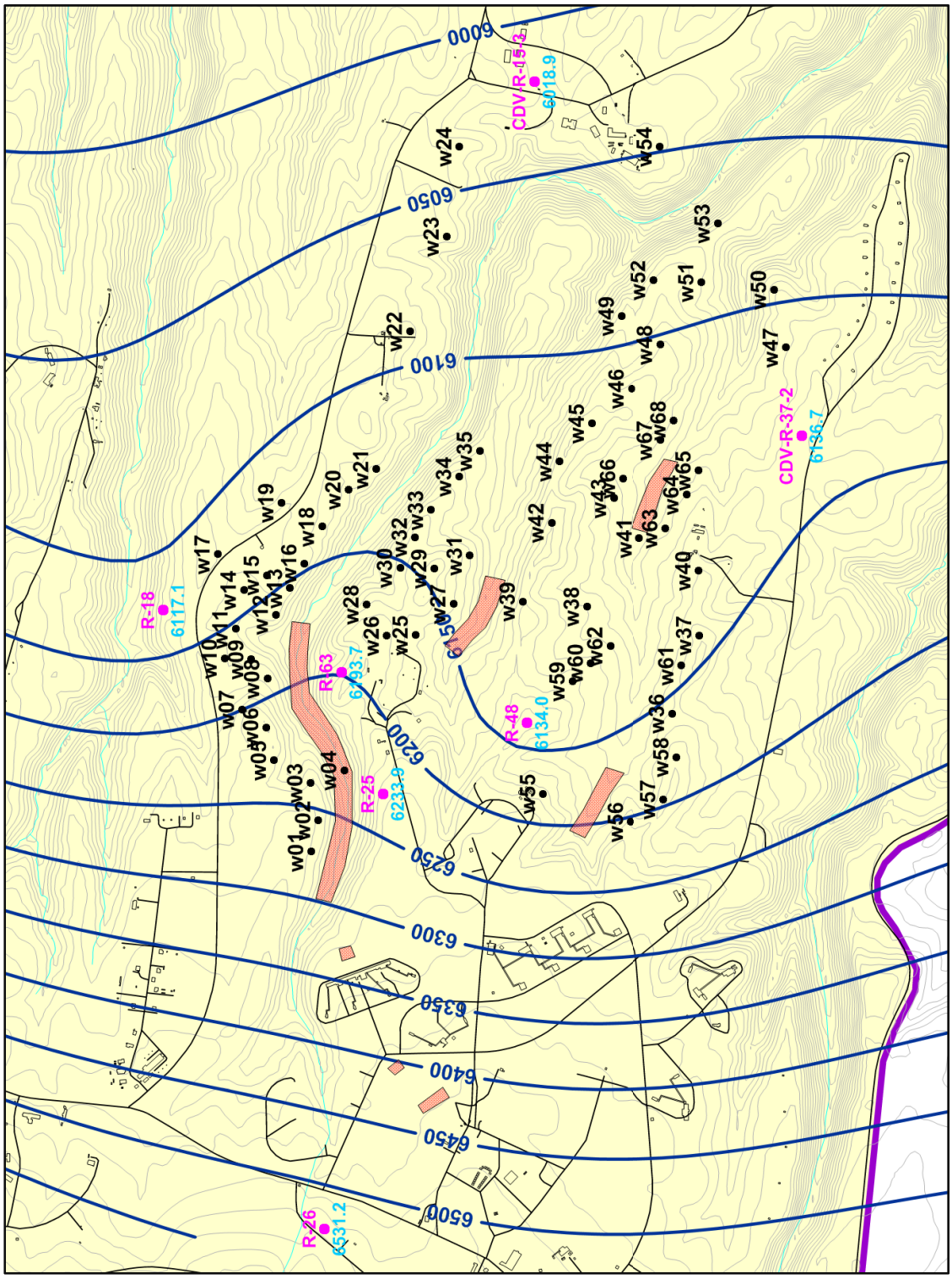

Figure C-1.0-1 Water-table map near TA-16 based on existing water-level data (circa February 2011). The map also shows the potential contaminant breakthrough windows (red shaded polygons) along the top of the regional aquifer, and locations of a series of hypothetical monitoring wells (68).

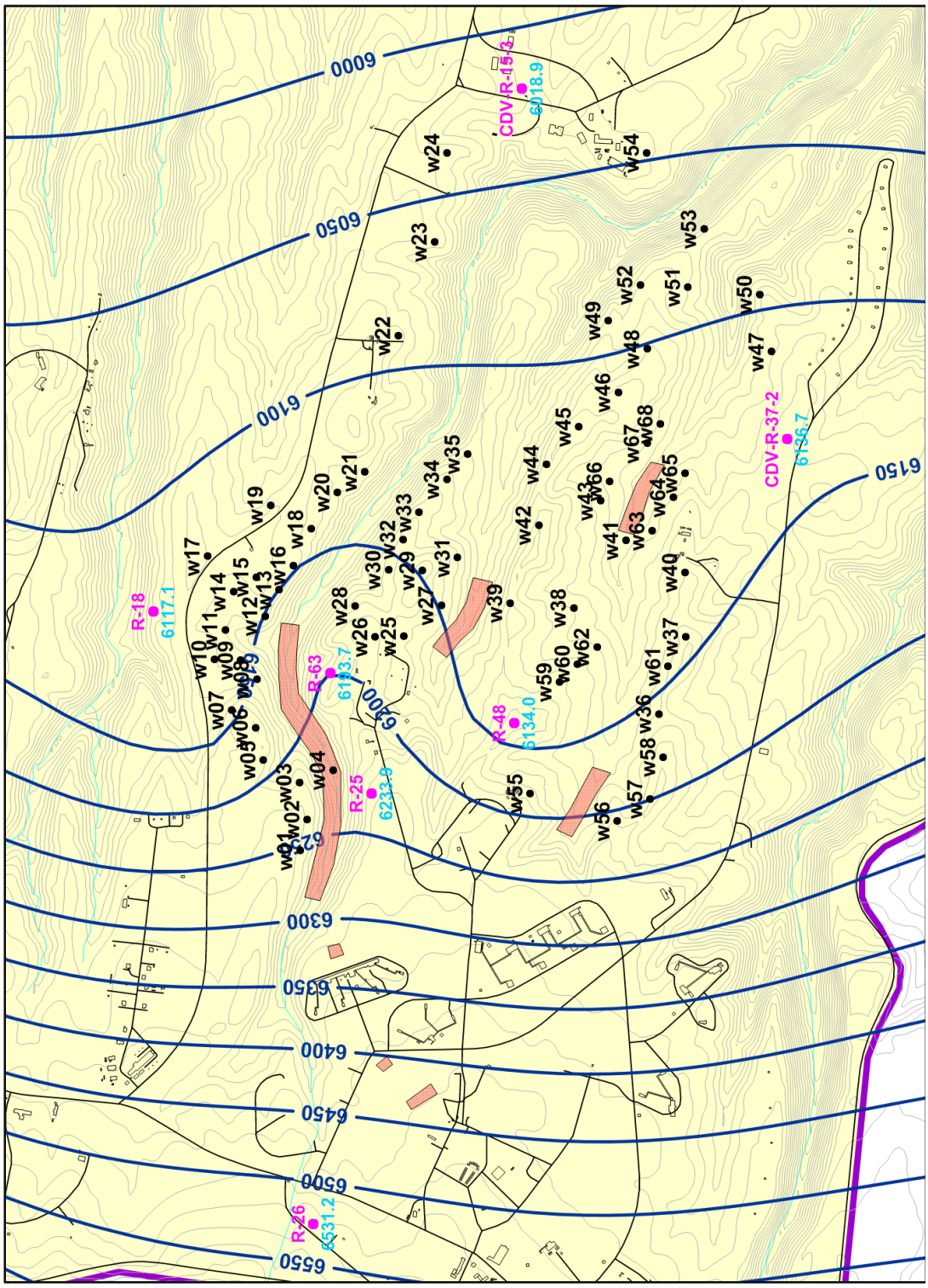

Figure C-1.0-2 Alternative water-table map near TA-16 assuming that the shape of the regional recharge mound is symmetric north and south of Cañon de Valle. In this case, water levels to the north of the mound are assumed to be similar to the water levels near R-48. This causes a more pronounced northern component of the groundwater flow to the north of the groundwater recharge mound.

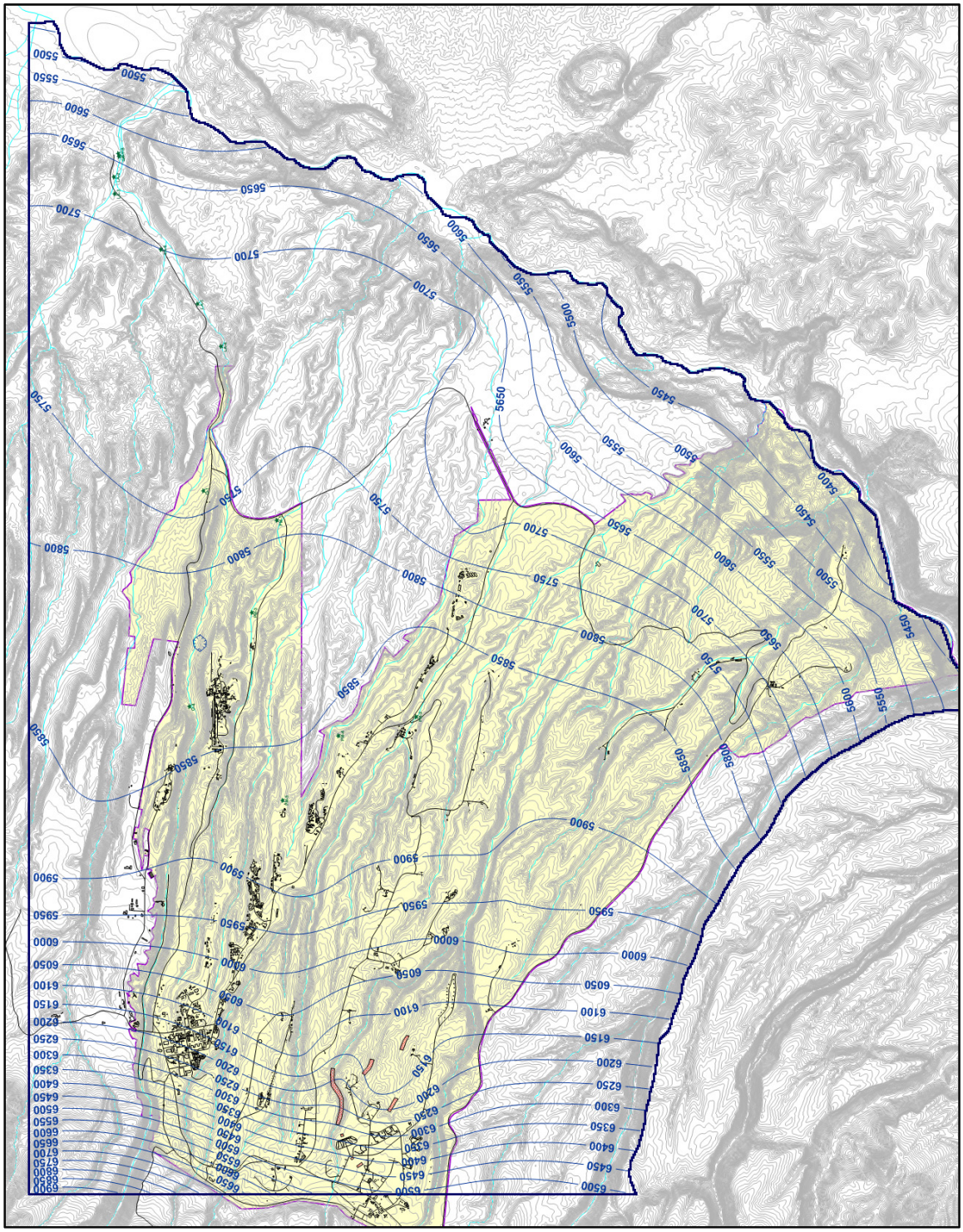

Figure C-1.0-3 Model domain (blue solid line); the figure also shows the regional water-table map based on existing water-level data (circa February 2011).

Table C-1.0-1
Characteristics of Hydrostratigraphic Units Represented in the Model

Unit	Name	Hydraulic Conductivity (m/d)			Porosity (−)		
		Distribution Type	Min	Max	Distribution Type	Min	Max
Tschicoma	Tvt2	Uniform	0.06	4.00	Uniform	0.1	0.2
Puye Fanglomerate	Tpf	Uniform	0.02	0.30	Uniform	0.001	0.01

Table C-1.0-2
Statistical Properties of Dispersivities

Dispersivity	Distribution Type	Min	Max
Longitudinal	Uniform	5	50
Transverse	Uniform	0.5	5

Table C-2.0-1
Detection Efficiency of Current
TA-16 Well Monitoring Network Based on Water-Table Map Alternative 1

Well	Sources					
	Cañon de Valle	260 Pond	S-Site Canyon	90s Line Pond	30s Line Ponds	Fishladder Canyon
R-25	100%	95%	0%	0%	0%	0%
R-48	49%	74%	34%	100%	100%	10%
R-18	1%	0%	0%	0%	0%	0%
R-63	41%	0%	0%	0%	0%	0%
CdV-R-15-3	47%	40%	46%	41%	40%	59%
CdV-R-37-2	0%	0%	0%	0%	0%	0%
Total	**100%**	**98%**	**62%**	**100%**	**100%**	**61%**

Notes: Detection efficiencies are in percent (%). This analysis is based on the regional water table presented in Figure C-1.0-1.

Table C-2.0-2
Detection Efficiency of Current
TA-16 Well Monitoring Network Based on Water-Table Map Alternative 2

Well	Sources					
	Cañon de Valle	260 Pond	S-Site Canyon	90s Line Pond	30s Line Ponds	Fishladder Canyon
R-25	5%	53%	0%	0%	25%	0%
R-48	3%	15%	32%	100%	100%	8%
R-18	100%	92%	0%	0%	5%	0%
R-63	23%	1%	0%	0%	0%	0%
CdV-R-15-3	12%	14%	45%	40%	41%	59%
CdV-R-37-2	0%	0%	0%	0%	0%	0%
Total	**100%**	**96%**	**60%**	**100%**	**100%**	**60%**

Notes: Detection efficiencies are in percent (%). This analysis is based on the regional water table presented in Figure C-1.0-1.

Table C-2.0-3
Detection Efficiency of Hypothetical
TA-16 Well Monitoring Network Based on Water-Table Map Alternative 1

Well	Sources					
	Cañon de Valle	260 Pond	S-Site Canyon	90s Line Pond	30s Line Ponds	Fishladder Canyon
W-1	80%	6%	0%	0%	0%	0%
W-2	74%	6%	0%	0%	0%	0%
W-3	39%	2%	0%	0%	0%	0%
W-4	100%	6%	0%	0%	0%	0%
W-5	2%	0%	0%	0%	0%	0%
W-6	2%	0%	0%	0%	0%	0%
W-7	4%	0%	0%	0%	0%	0%
W-8	98%	0%	0%	0%	0%	0%
W-9	82%	0%	0%	0%	0%	0%
W-10	36%	0%	0%	0%	0%	0%
W-11	94%	0%	0%	0%	0%	0%
W-12	100%	0%	0%	0%	0%	0%
W-13	100%	0%	0%	0%	0%	0%
W-14	100%	0%	0%	0%	0%	0%
W-15	100%	0%	0%	0%	0%	0%
W-16	70%	0%	0%	0%	0%	0%
W-17	100%	0%	0%	0%	0%	0%
W-18	15%	0%	0%	0%	0%	0%
W-19	35%	0%	0%	0%	0%	0%
W-20	8%	0%	0%	0%	0%	0%
W-21	4%	0%	0%	0%	0%	0%
W-22	2%	0%	0%	0%	0%	0%
W-23	1%	0%	0%	0%	0%	0%
W-24	2%	0%	1%	0%	1%	1%
W-25	65%	3%	6%	3%	2%	10%
W-26	44%	0%	0%	0%	0%	0%
W-27	60%	21%	34%	22%	21%	45%
W-28	19%	0%	0%	0%	0%	0%
W-29	18%	2%	5%	2%	3%	5%
W-30	11%	0%	0%	0%	0%	0%
W-31	24%	8%	14%	7%	8%	17%
W-32	7%	0%	0%	0%	0%	0%
W-33	5%	0%	0%	0%	0%	0%
W-34	3%	0%	0%	0%	0%	0%

Table C-2.0-3 (continued)

Well	Sources					
	Cañon de Valle	260 Pond	S-Site Canyon	90s Line Pond	30s Line Ponds	Fishladder Canyon
W-35	2%	0%	0%	0%	0%	0%
W-36	1%	1%	2%	1%	1%	1%
W-37	3%	1%	2%	1%	1%	3%
W-38	31%	43%	96%	70%	68%	98%
W-39	78%	58%	86%	58%	58%	100%
W-40	0%	0%	0%	0%	0%	1%
W-41	8%	5%	8%	4%	4%	11%
W-42	25%	11%	20%	12%	13%	28%
W-43	26%	20%	25%	19%	19%	35%
W-44	17%	8%	14%	8%	7%	18%
W-45	53%	45%	50%	46%	45%	69%
W-46	1%	0%	1%	0%	0%	1%
W-47	0%	0%	0%	0%	0%	0%
W-48	0%	0%	0%	0%	0%	0%
W-49	6%	4%	5%	2%	4%	8%
W-50	0%	0%	0%	0%	0%	0%
W-51	0%	0%	0%	0%	0%	0%
W-52	0%	0%	0%	0%	0%	0%
W-53	0%	0%	0%	0%	0%	0%
W-54	0%	0%	0%	0%	0%	0%
W-55	1%	1%	27%	44%	4%	0%
W-56	0%	0%	2%	0%	0%	0%
W-57	0%	0%	0%	0%	0%	0%
W-58	0%	0%	0%	0%	0%	0%
W-59	52%	49%	100%	50%	50%	40%
W-60	51%	46%	83%	47%	47%	43%
W-61	5%	2%	5%	2%	2%	4%
W-62	54%	48%	58%	49%	49%	59%
W-63	1%	0%	1%	0%	0%	1%
W-64	0%	0%	0%	0%	0%	0%
W-65	0%	0%	0%	0%	0%	0%
W-66	3%	2%	4%	2%	2%	6%
W-67	0%	0%	0%	0%	0%	0%
W-68	80%	6%	0%	0%	0%	0%

Notes: Detection efficiencies are in percent (%). This analysis is based on the regional water table presented in Figure C-1.0-1.

Table C-2.0-4
Detection Efficiency of Hypothetical
TA-16 Well Monitoring Network Based on Water-Table Map Alternative 2

Well	Sources					
	Cañon de Valle	260 Pond	S-Site Canyon	90s Line Pond	30s Line Ponds	Fishladder Canyon
W-1	99%	86%	0%	0%	0%	0%
W-2	97%	100%	0%	0%	3%	0%
W-3	100%	98%	0%	0%	4%	0%
W-4	99%	88%	0%	0%	5%	0%
W-5	100%	99%	0%	0%	4%	0%
W-6	100%	100%	0%	0%	7%	0%
W-7	100%	100%	0%	0%	9%	0%
W-8	100%	13%	0%	0%	1%	0%
W-9	99%	11%	0%	0%	0%	0%
W-10	99%	24%	0%	0%	1%	0%
W-11	100%	3%	0%	0%	0%	0%
W-12	100%	0%	0%	0%	0%	0%
W-13	17%	0%	0%	0%	0%	0%
W-14	100%	0%	0%	0%	0%	0%
W-15	33%	0%	0%	0%	0%	0%
W-16	3%	1%	0%	0%	0%	0%
W-17	48%	0%	0%	0%	0%	0%
W-18	4%	1%	0%	0%	0%	0%
W-19	3%	0%	0%	0%	0%	0%
W-20	7%	1%	0%	0%	0%	0%
W-21	2%	0%	0%	0%	0%	0%
W-22	1%	0%	0%	0%	0%	0%
W-23	0%	0%	0%	0%	0%	0%
W-24	1%	1%	1%	0%	0%	1%
W-25	14%	5%	6%	2%	3%	8%
W-26	18%	6%	0%	0%	1%	0%
W-27	12%	6%	31%	22%	21%	40%
W-28	16%	3%	0%	0%	0%	0%
W-29	6%	3%	3%	2%	2%	4%
W-30	4%	2%	0%	0%	0%	0%
W-31	5%	3%	11%	7%	6%	17%
W-32	3%	0%	0%	0%	0%	0%
W-33	1%	1%	0%	0%	0%	0%
W-34	1%	1%	0%	0%	0%	0%

Table C-2.0-4 (continued)

Well	Sources					
	Cañon de Valle	260 Pond	S-Site Canyon	90s Line Pond	30s Line Ponds	Fishladder Canyon
W-35	1%	1%	0%	0%	0%	0%
W-36	0%	0%	2%	1%	1%	2%
W-37	0%	0%	1%	1%	1%	2%
W-38	31%	43%	96%	70%	68%	98%
W-39	23%	25%	84%	56%	57%	100%
W-40	0%	0%	0%	0%	0%	1%
W-41	0%	1%	8%	5%	6%	13%
W-42	4%	2%	19%	10%	10%	27%
W-43	4%	5%	31%	24%	23%	40%
W-44	3%	2%	13%	8%	7%	19%
W-45	20%	26%	49%	45%	46%	73%
W-46	0%	0%	1%	1%	1%	1%
W-47	0%	0%	0%	0%	0%	0%
W-48	0%	0%	0%	0%	0%	0%
W-49	0%	1%	6%	4%	4%	9%
W-50	0%	0%	0%	0%	0%	0%
W-51	0%	0%	0%	0%	0%	0%
W-52	0%	0%	0%	0%	0%	0%
W-53	0%	0%	0%	0%	0%	0%
W-54	0%	0%	0%	0%	0%	0%
W-55	0%	0%	24%	29%	2%	0%
W-56	0%	0%	3%	0%	0%	0%
W-57	0%	0%	0%	0%	0%	0%
W-58	0%	0%	0%	0%	0%	0%
W-59	8%	16%	100%	54%	51%	40%
W-60	11%	19%	82%	51%	49%	48%
W-61	0%	0%	5%	2%	3%	3%
W-62	17%	22%	59%	49%	50%	61%
W-63	0%	0%	0%	0%	0%	0%
W-64	0%	0%	0%	0%	0%	0%
W-65	0%	0%	0%	0%	0%	0%
W-66	0%	1%	5%	2%	2%	6%
W-67	0%	0%	0%	0%	0%	0%
W-68	99%	86%	0%	0%	0%	0%

Notes: Detection efficiencies are in percent (%). This analysis is based on the regional water table presented in Figure C-1.0-1.

Appendix D

Contaminant Sources at Technical Area 16

D-1.0 INTRODUCTION

This appendix discusses in detail the sources with high, medium, and low potential for groundwater impacts that are briefly listed in section 3.1 of the well network evaluation report for Technical Area 16 (TA-16) at Los Alamos National Laboratory (the Laboratory).

D-2.0 SOURCES WITH HIGH POTENTIAL FOR GROUNDWATER IMPACT

TA-16-260 Outfall/Pond: The TA-16 260 Outfall/pond (Figure 3.1-1) has high potential for groundwater impacts because historically it had a very large contaminant source (LANL 1998, 059891). Every year during operations, it received millions of gallons of water discharge from the outfall, and the water from the outfall ponded within the area directly downgradient of the outfall. The 260 Outfall, which consists of Solid Waste Management Units (SWMUs) 16-003(k) and 16-021(c), is considered the major source of contaminants in the Cañon de Valle watershed (LANL 1996, 055077; LANL 2011, 207069). Building 16-260, in operation since 1951, is a high explosives– (HE-) machining facility that processes large quantities of HE. Machine turnings and HE wash water are routed as waste to 13 sumps associated with the building. Historically, discharge from the sumps was routed to the outfall; in the early 1990s, discharge was several million gallons per year (LANL 1994, 076858). In the late 1970s, the 260 Outfall was permitted under the Laboratory's National Pollutant Discharge Elimination System (NPDES) permit (05A-056). The 260 Outfall was last permitted in 1994, was deactivated in November 1996, and was removed from the Laboratory's NPDES permit in January 1998. The outfall discharged to a well-defined upper drainage channel, a former settling pond (excavated and removed in 2000), and a lower drainage channel leading to Cañon de Valle. The channel runs approximately 183 m (600 ft) from the outfall to the bottom of Cañon de Valle (LANL 2003, 077965, p. 1-8).

The outfall pond contained extremely high concentrations of HE in soil, over 20 weight by percent (wt%), for almost 50 yr (LANL 1996, 055077; LANL 1998, 059891; LANL 2002, 073706; LANL 2003, 077965). Barium levels were also highly elevated because of the historical use of the explosive Baratol, a mixture of barium nitrate and TNT (2,4,6-trinitrotoluene). Coupled with the entrapment of water in the outfall pond behind a rock dam, this source almost certainly has contaminated deeper groundwater bodies at TA-16 (LANL 1998, 059891; LANL 2003, 077965). Further evidence for migration of HE-contaminated water from the pond area include (1) the presence of low levels of HE (<5 ppm) in fracture zones and surge beds surrounding the 260 Outfall area (LANL 1998, 059891); (2) the presence of high levels of HE (1000s of ppm) in a surge bed underlying the pond at a depth of ~17 ft (LANL 2003, 077965; LANL 2007, 098192); (3) the observation of bromide tracer breakthrough in nearby springs, less than 6 mo after deployment of 400 lb of KBr tracer in the pond (LANL 1998, 059891); and (4) the observation that grout injection in the highly contaminated surge bed beneath the 260 Outfall pond accepted over 80 yd^3. of grout in the vadose zone, suggesting large open fractures beneath the pond (LANL 2010, 108868).

The majority of near-surface contaminants in the 260 Outfall and pond were cleaned up in an interim measure in 2000–2001. This cleanup removed over 1300 yd^3. of environmental media and an estimated 8500 kg of HE (LANL 2002, 073706). Residual contamination in the outfall and pond was removed during the 2009 corrective measures implementation (CMI), when an additional ~100 yd^3 of soil and debris was removed from the outfall ponds and drainage (LANL 2010, 108868). Following this effort, soils in the pond and outfall met risk-based cleanup goals (LANL 2010, 108868).

Cleanup of residual contamination from the 260 Outfall is addressed in two corrective measures evaluations, one for surface contamination and alluvial groundwater (LANL 2005, 091140) and the other for intermediate and regional groundwater (LANL 2007, 098734). The Laboratory prepared a CMI plan for

surface contamination and alluvial groundwater (LANL 2007, 098192) and has implemented much of this plan. Additional investigations of intermediate and regional groundwater are ongoing.

Cañon de Valle: Cañon de Valle has high potential for groundwater impacts because it has a large contaminant inventory in both water and sediment, it has a perennially saturated reach that provides hydrologic head to drive contaminants into the vadose zone, and it exhibits a significant losing reach downgradient of the 260 Outfall and other TA-16 HE sources.

Cañon de Valle received contaminants, particularly barium, RDX (hexahydro-1,3,5-trinitro-1,3,5 triazine), and other HE, from the 260 Outfall (see above) via surface drainage and through the vadose zone with discharge at SWSC Spring, Burning Ground Spring, and possibly blind seeps (LANL 1998, 059891; LANL 2003, 077965; LANL 2011, 207069) (Figure 3.1-1). Cañon de Valle also received contaminants via surface runoff from Material Disposal Area (MDA) R (SWMU 16-019), MDA P (SWMU 16-018), the TA-16 Burning Ground, the 90s Line (Consolidated Unit 16-008(a)-99), the silver outfall (SWMU 16-020) (LANL 2006, 091698), and other SWMUs and areas of concern (AOCs) (LANL 2011, 207069). MDA R, MDA P, the Burning Ground, and the 90s Line are described further below. The 260 Outfall and drainage are the largest source of contamination to the canyon (LANL 2011, 207069). The principal contaminants are RDX and barium; levels of these constituents in surface water and alluvial groundwater are consistently above the regulatory criteria of 6.11 µg/L for RDX and 1000 mg/L for barium (LANL 1998, 059891; LANL 2003, 077965; LANL 2011, 207069).

Cañon de Valle is a moderately wet canyon (LANL 2011, 207069) that contains a perennial reach between Burning Ground Spring and a location a few hundred meters downgradient of MDA P (Figure 3.1-1) (LANL 2011, 207069). Surface flows range up to 5 L/s, with more typical flows below 1 L/s (LANL 2003, 077965). Much of the surface and alluvial groundwater is hypothesized to infiltrate the vadose zone between Burning Ground Spring and a few hundred meters east of MDA P. Evidence of this reach being a primary infiltration zone include die-out of the alluvial system (bare tuff) a few hundred meters east of MDA P, geophysical resistivity anomalies suggesting water infiltration in that zone, and water balance evaluations (LANL 2003, 077965, LANL 2011, 207069).

Cañon de Valle is hypothesized to be the principal recharge zone for the contaminated deep-perched aquifer located in the northern portion of TA-16 (LANL 1998, 059891; LANL 2003, 077965; LANL 2011, 207069). RDX and other constituents are detected in deep intermediate-perched zone wells R-25, R-25b, CdV-16-1i, CdV-16-2ir, and CdV-16-4ip (Figure 3.1-1). Low-levels of constituents are also detected in regional well screens in R-25, R-63, and R-18 (Figure 3.1-1). RDX is the principal contaminant in this zone, but it is accompanied by other mobile constituents such as low-levels of chlorinated solvents, tritium, other HE, and HE impurities and breakdown products (LANL 1998, 059891; LANL 2003, 077965; LANL 2011, 207069). Less mobile contaminants, such as barium, are retained in sediment and potentially in clays within the vadose zone.

In sediment, several key contaminants, including barium, RDX, and other HE, have their highest concentrations in the Water Canyon and Cañon de Valle watershed in Cañon de Valle downstream from the 260 Outfall (LANL 2011, 207069). RDX has been measured at up to 36.8 mg/kg in the sediment investigation reach closest to the outfall (CDV-2W; Figure D-1). The 1.3-km-long part of the canyon downstream from the outfall, which includes the losing reach, contains an estimated 35% of the barium inventory present in canyon-bottom sediment deposits in the watershed, and an estimated 17% of the RDX inventory. These sediment deposits constitute a potential source for contaminants that could impact groundwater, particularly for the more mobile constituents such as RDX.

D-3.0 SOURCES WITH MEDIUM POTENTIAL FOR GROUNDWATER IMPACTS

Fishladder Canyon: Fishladder Canyon (Figure 3.1-1) has medium potential for groundwater impacts because it contains an intermediate-sized contaminant source with tetrachloroethane (PCE) at levels greater than the water regulatory criteria in one alluvial well and in Fishladder Seep (LANL 2011, 207069) and elevated RDX that is occasionally present at levels greater than regulatory criteria. It is intermittently wet, containing saturated alluvium primarily during spring snowmelt runoff and summer monsoonal rainfall. Thus far, the PCE detected in Fishladder Canyon has not been detected in deeper downgradient wells at high concentrations.

Fishladder Canyon (Figure 3.1-1) received contaminants primarily from the TA-16-340 Complex (LANL 2009, 105061.17) and the TA-16 Burning Ground (LANL 2006, 091698, and description below).

The 340 Complex consists of SWMUs 13-003(a,b), 16-003(n,o), 16-026(j2), and 16-029(f,i). These sites include an inactive septic system, HE sumps, and associated drainlines and outfalls located near the eastern end of the TA-16 mesa, close to the head of Fishladder Canyon. The complex operated from 1953 to 1999 and processed and produced large quantities of plastic-bonded explosives, manufactured by slurrying HE and solvents together with inert binders. HE and solvent-contaminated wash water were routed as waste to sumps and outfalls. During the mid-1990s, the discharge to the building 16-340 outfall measured over 3.5 million gal./yr (LANL 1994, 076858). Investigation and cleanup of the 340 Complex SWMUs were completed in 2008 (LANL 2009, 105061.17), and no further actions are needed.

In Fishladder Canyon sediment, some solvents, including PCE and trichlorethene (TCE), have their highest concentrations in the Water Canyon and Cañon de Valle watershed downstream from the Burning Ground (reach FL-2; Figure D-1) (LANL 2011, 207069). These sediment deposits constitute a potential source for contaminants that could impact groundwater. HE, including RDX, is also present in sediment deposits in Fishladder Canyon but at much lower concentrations than in Cañon de Valle. The maximum measured RDX concentration in Fishladder Canyon sediment samples is only 1.01 mg/kg, in reach FL-1 (Figure D-1) or 3% of the maximum concentration measured in Cañon de Valle.

S-Site Canyon: S-Site Canyon (Figure 3.1-1) has medium potential for groundwater impacts because it contains an intermediate-sized source of RDX and boron, with levels in water consistently greater than regulatory standards in Martin Spring, and it contains a short perennial reach downgradient of Martin Spring that provides a hydrologic driving force for infiltration of contaminant-laden waters into the vadose zone.

S-Site Canyon received contaminants from the 300s Line (LANL 2011, 111810.32; LANL 2011, 207069); the TA-16 Sanitary Wastewater Treatment Plant (LANL 2011, 111810.32); Martin Spring (LANL 2011, 207069); and K-Site (LANL 2011, 111810.32, and below). RDX in water is at levels much greater than the regulatory criteria in Martin Spring and below the regulatory criteria in three alluvial wells (LANL 2011, 207069) downgradient of the spring. Boron is also present at levels greater than the regulatory criteria in Martin Spring and is elevated in concentration, but below the regulatory criteria, in the three alluvial wells (LANL 2011, 207069). A short perennial reach is present directly downgradient of Martin Spring, and a second perennial reach is present north of K-Site (LANL 2011, 207069 and see below), so a persistent hydrologic head may drive contaminant migration to deeper groundwaters. The second of these perennial reaches has low levels of contamination (RDX consistently much less that regulatory criteria) and thus has low potential for groundwater impacts. Thus far, the boron detected in Martin Spring and the S-Site Canyon alluvium has not been detected in deeper downgradient wells at high levels.

In S-Site canyon sediment, some contaminants, including boron, polychlorinated biphenyls (PCBs), and TNT, have their highest concentrations in the Water Canyon and Cañon de Valle watershed (LANL 2011,

207069). Boron has its highest measured concentration in the reach immediately downstream from Martin Spring (MS-1) (Figure D-1), and TNT and the PCB mixture Aroclor-1260 have their highest concentrations in the reach immediately downstream from the 300s Line Complex (SS-1W) (Figure D-1). However, RDX is present at relatively low concentrations, with a maximum measured concentration of 0.92 mg/kg in reach MS-1, or 3% of the maximum concentration measured in Cañon de Valle.

30s Line and 90s Line Ponds: The 30s Line and 90s Line Ponds (Figure 3.1-1) have medium potential for groundwater impact because they historically represented a large HE source and they contained standing water during their years of operation.

These ponds received HE wastewater discharge from two 1940s/1950s-vintage HE-machining lines, referred to as the 30s Line [Consolidated unit 16-007(a)-99] and 90s Line [Consolidated Unit 16-008(a)-99] (LANL 2010, 108279). The 30s Line ponds were cleaned up and filled in during the mid-1960s (LANL 2010, 108279), limiting the source and eliminating a perennial hydrologic driving force. The 90s Line, except for the pond, was initially cleaned up during a 1996 voluntary corrective action (VCA) (LANL 1996, 062537). Further soil cleanups, which achieved risk-based standards for soils, were completed during the late 2000s (LANL 2010, 108279). The 90s Line Pond itself continues to be saturated during wet seasons. The 90s Line pond water contains RDX at levels infrequently greater than regulatory screening criteria (LANL 2011, 207069). Barium in the 90s Line pond is consistently present at levels greater than the regulatory screening criteria (LANL 2011, 207069). RDX is occasionally present at levels above the regulatory screening criteria in borehole 16-26644 (Figure 3.1-1), located within 100 ft of the pond; this indicates migration of constituents into the vadose zone, most likely from the 90s Line Pond (LANL 2011, 207069). Similarly, intermittent contaminated perched water in well 16-2669 (LANL 1998, 059891), located within 100 ft of the pond, also suggests migration of constituents from the 90s Line pond.

D-4.0 SOURCES WITH LOW POTENTIAL FOR GROUNDWATER IMPACTS

TA-16-430 Drainage: The TA-16-430 drainage [Consolidated Unit 16-003(l)-99; see Figure 3.1-1] has low potential for groundwater impact because the contaminant inventory is small (LANL 2011, 111602.33), and historically flow from the outfall was only moderate (e.g., 36,000 gal./yr in 1994; LANL 1994, 076858). The TA-16-430 drainage received HE-contaminated wastewater associated with building 16-430, an HE-pressing building that operated from the early 1950s to the mid 2000s; the NPDES outfall (05A-071) was deactivated in 1998. The highest RDX value detected in soils in the drainage was 2.5 mg/kg (LANL 2010, 110410; LANL 2011, 111602.33) in a sample collected in 1995 when the outfall was still active. This drainage is part of the Upper Water Canyon Aggregate Area investigation (LANL 2011, 111602.33)

TA-16-460 Drainage: The TA-16-460 drainage [Consolidated Unit 16-003(c)-99; see Figure 3.1-1] has low potential for groundwater impact because the contaminant inventory is small (LANL 2011, 111602.33); however, flows from the outfall were large (3,859,000 gal./yr in 1994; LANL 1994, 076858). The TA-16-460 drainage received water contaminated with HE and other Laboratory constituents associated with building 16-460, an HE analytical chemistry building that operated from the early 1950s to early 2000s; the NPDES outfall (05A-072) was deactivated in 1997. RDX was not detected in soils in this drainage when it was sampled in 1995 (LANL 2011, 111602.33; LANL 2011, 110410) when the outfall was still active. The principal HE detected was triaminotrinitrobenzene (TATB). Other constituents in sediment in this drainage were also at low levels during the 1995 sampling (LANL 2011, 111602.33; LANL 2011, 110410). This drainage is part of the Upper Water Canyon Aggregate Area investigation (LANL 2011, 111602.33)

V-Site Pond: The V-Site pond [Consolidated Unit 16-029(x)-99] has low potential for groundwater impact because the contaminant inventory is small (LANL 2011, 111810.32), and currently minimal ponding occurs (no ponding has been observed since Laboratory personnel began field reconnaissance at the site in 1993) to provide hydrologic head to promote infiltration into the vadose zone. However, the pond would have contained intermittent standing water during HE-processing operations during the 1940s through 1960s (LANL 2011, 111810.32).The V-Site pond received water contaminated with HE and other constituents associated with building 16-515, an HE-processing building used for multiple HE operations, most notably casting of Boracitol, an explosive consisting of a mixture of TNT and boric acid (LANL 2011, 111810.32). The V-Site pond was part of the S-Site Aggregate Area investigations (LANL 2011, 111810.32). The highest RDX value detected in soils in the pond was <1 mg/kg (LANL 2011, 111810.32).

MDA P and the TA-16 Burning Ground: MDA P (SWMU 16-018) and the TA-16 Burning Ground [Consolidated Unit 16-010(h)-99] (Figure 3.1-1) have low potential for groundwater impact because although both sites had moderately large contaminant inventories (LANL 2005, 092251; LANL 2006, 091698), the sites are located on the TA-16 mesa top and mesa edge and had minimal surface water ponding that could provide a hydrologic driving force to enable infiltration into the vadose zone. Contaminant transport that may have occurred with runoff from MDA P and the TA-16 Burning Ground before cleanup or corrective actions at these sites is covered within the Cañon de Valle or Fishladder Canyon sources, respectively, described above.

MDA P is an approximately 9.25-acre site located along the southern slope of Cañon de Valle (Figure 3.1-1). MDA P contained wastes from the synthesis, processing, and testing of HE; residues from the burning of HE-contaminated equipment; and construction debris. HE waste-disposal activities at this site began in the early 1950s and ceased in 1984. MDA P underwent clean closure under the Resource Conservation and Recovery Act (RCRA) in which approximately 55,000 yd^3 of soil and debris was removed (LANL 2005, 092251). The New Mexico Environment Department (NMED) approved the closure (NMED 2005, 093247), and no further actions are needed. Large amounts of HE, including over 50 lb of solid HE, were present in MDA P during cleanup (LANL 2005, 092251). Drilling beneath the disposal area revealed minimal migration of constituents from the area into the vadose zone (LANL 2005, 092251).

The TA-16 Burning Ground includes SWMUs 16-005(g), 16-006(e), 16-010(a), 16-016(c), and 16-028(a), which are located on the mesa in the northeast corner of TA-16 within the Fishladder Canyon watershed (Figure 3.1-1). The Burning Ground was constructed in 1951 for HE waste treatment and disposal, including the treatment of solvents contaminated with HE. SWMU 16-010(b) underwent RCRA clean closure, and SWMUs 16-006(e), 16-010(a), 16-016(c) underwent a VCA concurrently with the MDA P clean closure. Additional investigations are being conducted as part of the Cañon de Valle Aggregate Area investigation (LANL 2006, 091698). The maximum concentration of RDX detected at the Burning Ground was 10,700 mg/kg (LANL 2006, 091697), one of several high (>100 mg/kg) RDX values detected during 1995 sampling

MDA R: MDA R (SWMU 16-019) (Figure 3.1-1) is ranked as low priority because although it had a moderate contaminant source (LANL 2006, 091698), it is located on the TA-16 mesa top and mesa edge and had minimal surface water that could produce a hydrologic driving force to allow migration of contaminants into the vadose zone.

MDA R is an approximately 2.25-acre site located north of the 260 Outfall area along the mesa top and edge and extends onto the southern slope of Cañon de Valle. MDA R was constructed in the mid-1940s and used as a burning ground and disposal area for waste explosives and other debris. Use of this site was discontinued in the early 1950s (LANL 2003, 077965). Removal of 1500 yd^3 of contaminated soil and debris and associated site investigations was conducted at MDA R following the Cerro Grande fire (LANL 2001, 069971). Additional investigations are being conducted as part of the Cañon de Valle Aggregate

Area investigation (LANL 2006, 091698). The maximum concentration of RDX detected during the post–Cerro Grande fire cleanup and associated sampling was 1500 mg/kg (LANL 2006, 091697). Additional investigations are being conducted as part of the Cañon de Valle Aggregate Area investigation (LANL 2006, 091698). Runoff from MDA R that may have occurred before the cleanup is discussed within the Cañon de Valle source described above.

K-Site: K-Site [Consolidated Unit 11-004(a)-99 and associated SWMUs] (Figure 3.1-1) has low potential for groundwater impact because although it has a moderate contaminant source (LANL 2011, 111810.32), it is located on the mesa top and had minimal surface water that could produce a hydrologic driving force to allow migration of contaminants into the vadose zone.

The TA-11 Firing Site aggregate consists of SWMUs 11-001(a), 11-002, 11-004(a–e), 11-006(a–d), and 11-011(b) and AOCs 11-003(b), 11-004(f), and C-11-001. These sites comprise components of firing site and other operations at TA-11 and include a firing pit, burn area, former drop tower facility, mortar impact area, sump, catch basins, outfall, and drainline. Investigation of most of these sites under the Compliance Order on Consent has been deferred because of potential impacts from active firing site activities. The other sites were investigated as part of the S-Site Aggregate Area investigation (LANL 2011, 111810.32).

TA-11 was constructed in 1944 and originally contained a Betatron Facility and Cloud Chamber. It later housed facilities for testing explosives components and systems under a variety of extreme physical environments. The maximum RDX concentration detected during environmental sampling at K-Site was ~5 mg/kg (LANL 2011, 111810.32); however, chunks of HE from low-order detonations at the drop tower were routinely observed during field visits during the 1990s. This “chunk” HE was thoroughly removed during 2000s-vintage cleanups.

World War II S-Site Drainage: The TA-16 World War II (WWII) S-Site drainage (also referred to as the Mother Ditch) (Figure 3.1-1) has low potential for groundwater impact because it likely had low levels of contamination (LANL 2011, 111602.33), and currently surface water is rarely present (no persistent surface water has been observed since Laboratory personnel began field reconnaissance at the site in 1993) to provide a source for infiltration into the vadose zone. However, the drainage would likely have contained surface water during HE-processing operations from the 1940s to the 1950s (LANL 2011, 111602.33). The drainage received HE-contaminated waste water from numerous small HE production facilities in the WWII TA-16 HE-processing area, most notably the 20s Line [Consolidated Unit 16-026(q)-99].

Consolidated Unit 16-026(q)-99 comprises the former 20s Line facility, an experimental and production casting facility. Consolidated Unit 16-026(q)-99 consists of SWMUs 16-005(d), 16-017(h)-99, 16-017(x)-99, 16-025(k,l), 16-026(q), 16-029(f2,r), 16-031(d), 16-032(c), and 16-034(a) and AOCs C-16-006 and C-16-065. These sites include a septic system and sumps and outfalls associated with HE-processing buildings, an analytical laboratory, and a cooling tower. The 20s Line housed an HE powder-inspection facility, HE-casting buildings, an analytical laboratory, and a solvent storage building. Most 20s Line facilities were constructed in 1944 and 1945, and HE casting was conducted until the 1950s. Liquid effluents were discharged to a pond and to drainage ditches that ultimately discharged into the main WWII–era S-Site drainage. The 20s Line sites are part of the Upper Water Canyon Aggregate Area investigation (LANL 2011, 111602.33).The maximum RDX concentration detected in the 20s Line or its drainage is 14 mg/kg (LANL 2011, 110410).

Zia Shops: The Zia shops area drum storage rack [SWMU 16-034(j)] has low potential for groundwater impact. Although it has unknown levels of contamination, currently surface water is rarely present (no persistent surface water has been observed since Laboratory personnel began field reconnaissance at the site in 1993) to provide a source for infiltration into the vadose zone.

The Zia shops area drum storage rack [SWMU 16-034(j)] was used for drum storage from the mid-1940s to the mid-1950s. The Zia shops area was used for non-HE maintenance and support activities for TA-16 from 1944/45 to the mid-1950s; it included a fire station, paint shop, plumbing and electrical shops, storage buildings, and the drum storage area. Concern about these sites has increased during the past 2 yr since PCE was detected at low levels in the vadose zone in the piezometer at well R-26. The drum storage rack observed at the Zia shops is the probable source for this PCE in the vadose zone. No environmental sampling has been conducted at the Zia shops. The Zia shops are part of the Cañon de Valle Aggregate Area investigation (LANL 2006, 091698).

Water Canyon Alluvial Aquifer and Other Canyon Reaches: The Water Canyon alluvial aquifer has low potential for groundwater impact because it has low-levels of contamination in sediment (LANL 2011, 207069), although it has persistent water to provide a source for infiltration and contaminant migration into the vadose zone.

Water Canyon received surface discharges from the SWMU 16-430 drainage, the SWMU 16-460 drainage, and the main WWII S-Site drainage, all of which are low-priority sites described above. It also received discharge from smaller potential sources such as the barium nitrate–grinding facility (16-370) drainages [Consolidated Unit 16-006(c)-00], HE powder inspection building (16-380) drainage [Consolidated Unit 16-003(m)-99], and device assembly building (16-410) drainage [Consolidated Unit 16-003(a)-99]. All these sites are smaller potential sources of water and contaminants than those described above (LANL 2011, 111602.33). Most of these drainages were sampled in 1995, and the maximum RDX concentration detected was <1 mg/kg) (LANL 2011, 110410). These sites are all are part of the Upper Water Canyon Aggregate Area investigation (LANL 2011, 111602.33).

Sediment data from the Water Canyon and Cañon de Valle watershed investigation indicate although contaminants were released from many SWMUs, only a few of the sites discussed above as low-priority sources released mobile contaminants, such as RDX and PCE, that reached the canyon bottom and could potentially have impacted groundwater (LANL 2011, 207069). Excluding Cañon de Valle and Water Canyon downstream from the 260 Outfall, Fishladder Canyon, and S-Site Canyon (discussed above), RDX was detected only in two reaches, CDV-1E and CDVS-1, and PCE was only detected in one reach, CDV-1C (Figure D-1). Reach CDV-1E is in Cañon de Valle immediately downstream from MDA R and immediately upstream from the 260 Outfall drainage has measured RDX up to 9.8 mg/kg, indicating a source at MDA R. However, because this is a dry part of Cañon de Valle, the potential for the RDX in this reach to constitute a direct source for groundwater contamination is small. Reach CDVS-1 is located upstream in a tributary drainage to Cañon de Valle, below the 90s Line Complex and has much lower measured concentrations of RDX, up to 0.201 mg/kg. CDVS-1 is also a dry reach with little potential to be a direct source for groundwater contamination. Reach CDV-1C is located between reaches CDVS-1 and CDV-1E, and the PCE detected here may have had a source at the Zia shops area drum storage rack. Because CDV-1C is also a dry reach, the potential for the PCE in this reach to constitute a direct source for groundwater contamination is small. Notably, Water Canyon above Cañon de Valle, with persistent surface water and alluvial groundwater, has minimal contamination in sediment deposits and no PCE or RDX detects.

D-5.0 REFERENCES

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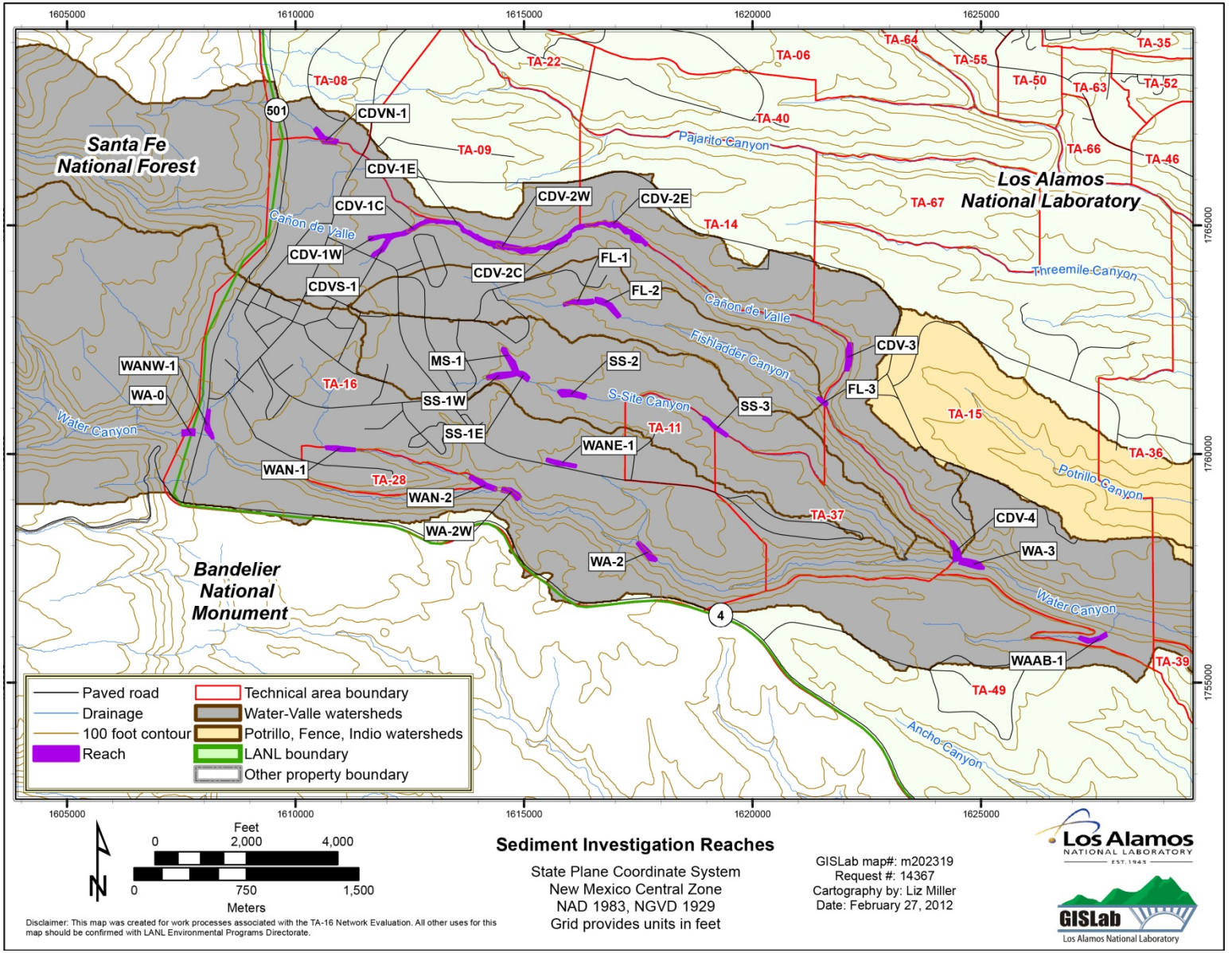

Figure D-1 Locations of sediment reaches in the TA-16 area

Appendix E

Analysis of Temporal Fluctuations of the Intermediate and Regional Water Levels Near Technical Area 16

Koch and Schmeer (2011, 201566) provide a recent summary of the intermediate and regional water levels near Technical Area 16 (TA-16) at Los Alamos National Laboratory. Further analyses are performed by Reid et al. (2008, 213290). The available water-level data observed in the intermediate and regional monitoring wells in the TA-16 area provide information about the long-term temporal trends in the water-level behavior. Table E-1 summarizes available water-level information for wells near TA-16.

Analysis of the available water-level temporal trends shows a general trend of water-level decline in all the intermediate and regional well screens except R-26 screen 1 (Table E-1). R-26 screen 1 shows a trend of water-level increase, but the cause for this increase is currently not well understood.

In general, the water-level decline is smaller in the regional aquifer than in the intermediate zones, and it is on the order of about 0.2 ft/yr (Table E-1). The greatest water-level declines in the regional aquifer are observed in R-26 screen 2 (~2 ft/yr) and R-25 screen 7 (~0.8 ft/yr).

The water-level decline in the intermediate zones is about 1 ft/yr (Table E-1). The greatest water-level decline in the intermediate zone is measured at CdV-16-1(i) (~2 ft/yr). The well is located north of R-25 close to Cañon de Valle. Water levels in R-25b and R-25 screens 1 and 2 show declines of about 1 ft/yr. The decline of the intermediate water levels diminishes to the east of R-25: at CdV-16-2(i)r the decline is 0.2 ft/yr; at R-47i the decline is 0.1 ft/yr. This suggests that the water-level decline in the vicinity of CdV-16-1(i) and R-25 is a result of diminishing water-level recharge along Cañon de Valle.

Further analyses demonstrate that the groundwater levels at CdV-16-1(i), R-25b, and R-25 screens 1 and 2 show an apparent response to snowmelt runoff along Cañon de Valle. R-25 screen 4 may have shown a slight response to runoff, although there was an abrupt rise at screen 4 in November 2010, which may have been a response to drilling nearby well CdV-16-4ip. Overall, there is no apparent response to snowmelt runoff at CdV-16-2(i)r. After dry well CdV-16-2(i) was plugged and abandoned in 2009, the groundwater level at CdV-16-2(i)r showed a recovery of greater than 1 ft.

The water-level declines may be caused by several hydrogeologic factors, but most likely they are not related to well construction problems because many wells and screens are showing the water-level declines. The water-level declines are observed not only near TA-16 but also throughout the Pajarito Plateau. The water-level declines might be related to (1) shutting off the TA-16 outfalls in the late 1990s, (2) long-term decline of aquifer recharge because of drought conditions, and (3) water-supply pumping of the regional aquifer.

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Table E-1
Temporal Behavior of Intermediate and
Regional Water Levels Observed in the Monitoring Wells Near TA-16

Monitoring Wells (Intermediate/ Regional)	Water-Level Decline (+)/ Increase(−) in ft/yr	Comments
R-26 screen 1 (intermediate)	**−0.2**	Since 2005, steady water-level increase of about 0.2 ft/yr; no apparent water-level fluctuations from recharge.
R-26 screen 2 (regional)	2	Since 2005, steady water-level decline of about 2 ft/yr; some water-level rebounds of about 5 ft potentially from recharge.
CdV-16-1(i) (intermediate)	2	Long-term decline of 2 ft/yr; periodic water-level rebounds of several feet from snowmelt recharge.
R-25b (intermediate)	1	Short record since 2010; steady water-level decline of about 1 ft/yr; no apparent recharge water-level fluctuations, but this is probably from short water-level record.
R-25 screen 1 (intermediate)	1	Steady water-level decline of about 1 ft/yr; some water-level fluctuations of about 0.5 ft potentially from recharge.
R-25 screen 2 (intermediate)	1	Steady water-level decline of about 1 ft/yr; some water-level fluctuations of about 0.5 ft potentially from recharge.
R-25 screen 4 (intermediate)	0.2	Since 2006, steady water-level decline of about 0.2 ft/yr; some water-level fluctuations of about 0.3 ft potentially from recharge; abrupt rise at screen 4 water levels in November 2010, which may have been a response to drilling nearby well CdV-16-4ip.
R-25 screen 5 (regional)	0.1	Steady water-level decline of about 0.1 ft/yr; no apparent water-level fluctuations from recharge or water-supply pumping.
R-25 screen 6 (regional)	0.1	Steady water-level decline of about 0.1 ft/yr; no apparent water-level fluctuations from recharge or water-supply pumping.
R-25 screen 7 (regional)	0.8	Since 2005, steady water-level decline of about 0.8 ft/yr; no apparent water-level fluctuations from recharge or water-supply pumping.
R-25 screen 8 (regional)	0.5	Steady water-level decline of about 0.5 ft/yr; no apparent water-level fluctuations from recharge or water-supply pumping.
CdV-16-2(i)r (intermediate)	0.2	Long-term decline of about 0.2 ft/yr; since July 9, 2009, CdV-16-2(i) plugging, the water level rebounded more than 3 ft.
CdV-16-4ip screen 1 (intermediate)	ND*	Very short record; water level seems to be steady but conclusions cannot be made because of the short water-level record.
R-47i (intermediate)	0.1	Short record since 2010; the water levels are relatively steady with long-term decline of about 0.1 ft/yr; periodic rebounds of about 0.5 ft from snowmelt recharge.
R-18 (regional)	0.25	Steady water-level decline of about 0.25 ft/yr; seasonal fluctuations in the water levels from water-supply pumping or aquifer recharge; there is no apparent response to supply-well pumping.
R-48 (regional) (formerly CdV-16-3i)	0.25	Steady water-level decline of about 0.25 ft/yr; seasonal fluctuations in the water levels; there is no apparent response to supply-well pumping.
CdV-R-37-2 screen 2 (regional)	0.15	Steady water-level decline of about 0.15 ft/yr; seasonal fluctuations in the water levels of about 0.2 ft; there is no apparent response to supply-well pumping.
CdV-R-37-2 screen 3 (regional)	0.15	Steady water-level decline of about 0.15 ft/yr; seasonal fluctuations in the water levels; there is no apparent response to supply-well pumping.

Table E-1 (continued)

Monitoring Wells (Intermediate/ Regional)	Water-Level Decline (+)/ Increase(−) in ft/yr	Comments
CdV-R-37-2 screen 4 (regional)	0.15	Steady water-level decline of about 0.15 ft/yr; seasonal fluctuations in the water levels; there is no apparent response to supply- well pumping.
CdV-R-15-3 screen 4 (regional)	0.15	Steady water-level decline of about 0.15 ft/yr; seasonal fluctuations in the water levels of about 0.2 ft; there is no apparent response to supply-well pumping.
CdV-R-15-3 screen 5 (regional)	0.15	Steady water-level decline of about 0.15 ft/yr; seasonal fluctuations in the water levels of about 0.2 ft; there is no apparent response to supply-well pumping.
CdV-R-15-3 screen 6 (regional)	0.1	Since 2002, steady water-level decline of about 0.2 ft/yr; seasonal fluctuations in the water levels of about 0.1 ft; there is no apparent response to supply-well pumping.

Notes: Wells are ordered from west to east. Bold text indicates water-level increase.

*ND = No sufficient data to estimate water-level decline/increase