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Reliability Assessment for Well R-47i



Prepared by the Environmental Programs Directorate

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Reliability Assessment for Well R-47i

March 2011

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1.0 INTRODUCTION

In a letter dated July 2, 2010, the New Mexico Environment Department (NMED) requested Los Alamos National Laboratory (LANL) perform a reliability assessment for well R-47i (LANL 2010, 109188; NMED 2010, 110438). This assessment was required to determine whether well R-47i is capable of producing representative groundwater samples and to identify any potential effects of well installation on sample quality. LANL submitted a letter work plan delineating the process to be used to perform the reliability assessment on August 9, 2010 (LANL 2010, 110512). The agreed-upon sampling of R-47i was completed between December 2009 and December 2010.

A principal purpose of well R-47i is to monitor the groundwater in the vicinity of Consolidated Unit 16-021(c)-99, which is also known as the 260 Outfall (Figure 1.0-1). This outfall discharged water contaminated with high explosives (HE), barium, and other constituents to a drainage channel and from there to Cañon de Valle. HE, barium, and other constituents from the 260 Outfall have migrated to downgradient water bodies, including springs, surface waters, alluvial groundwater, intermediate-depth groundwater, and the regional aquifer; at some locations, these constituents are at levels greater than cleanup and screening levels specified in the Compliance Order on Consent (hereafter the Consent Order). More details on contamination associated with the 260 Outfall and on previous cleanup activities associated with the site are provided in a series of plans and reports (LANL 2002, 073706; LANL 2003, 077965; LANL 2006, 093798; LANL 2007, 098192; LANL 2007, 098734; LANL 2007, 095787; LANL 2010, 109252 and references therein).

1.1 Purpose and Objectives of Reliability Assessment

The corrective measures evaluation (CME) for intermediate and regional groundwater associated with Consolidated Unit 16-021(c)-99 will evaluate remedial alternatives for HE present in the deep groundwater at LANL's Technical Area 16 (TA-16) (LANL 2006, 093798; LANL 2007, 098734). A key component of any remedial alternative for intermediate or regional groundwater is a comprehensive and effective groundwater monitoring network (LANL 2007, 095787; LANL 2007, 100113). Well R-47i is located east (down the hydrologic gradient) of the 260 Outfall and thus represents a potentially important location for monitoring groundwater associated with the 260 Outfall.

As part of any remedy or corrective action selected by the NMED, the Laboratory must demonstrate that groundwater wells along flow paths downgradient of the 260 Outfall (the monitoring network) are capable of reliably detecting contaminants for which the outfall may have been a source in a timely fashion (rapidly enough so that remedies may be implemented before any plume has widely dispersed or approached production wells). This document complements a previous reliability assessment of the TA-16 monitoring network (LANL 2007, 095787; LANL 2007, 100113) and provides a lead-in to an upcoming broader network evaluation to be produced in late 2011.

Thus, the principal objective of this document is to determine the reliability of well R-47i as a component of the TA-16 monitoring network. The key specific question to be resolved concerning well R-47i before it can be included within the TA-16 monitoring network is whether the well screen in R-47i is of adequate quality to reliably monitor for contaminants associated with the 260 Outfall, particularly those constituents present in intermediate or regional groundwater at levels above cleanup and screening levels. Specifically, are data for key contaminants present at the 260 Outfall reliable and representative of formation waters?

For this study, the representativeness of groundwater collected from well R-47i is evaluated using the methodology described in section 3. The methodology is applied to water-quality samples from the four

post-development sampling events conducted at this well between December 2009 and December 2010. Supporting information for the assessment is provided in three appendixes.

- Appendix A provides details of the assessment methodology and the data used in the assessment.
- Appendix B is on CD and contains the full set of data for each of the four sampling events at R-47i. Table B-1 provides time-series field parameters monitored during purging, and Table B-2 provides final field parameters and analytical data for the water-quality samples.
- Appendix C is on CD and contains field notes, groundwater sampling logs, and sample collection logs for each sampling event.

2.0 BACKGROUND

2.1 Well Description

Well R-47i was installed at TA-14 from September to November 2009 (LANL 2010, 109188) (Figure 1.0-1). The well was originally planned as a regional well to be called R-47 to augment the TA-16 monitoring well network. However, as a result of problems encountered during installation of the regional well, the regional target was abandoned and an intermediate-depth well (R-47i) was opportunistically installed in the borehole. R-47i was completed with a single 20-ft screen within a perched zone between 840.0 and 860.6 ft below ground surface (bgs) in sediments of the upper Puye Formation. The depth to intermediate perched water after well installation and well development (November 18, 2009) was 832.2 ft bgs, and the depth to the regional aquifer, as determined during the initial phase of drilling, was approximately 1242 ft bgs (Figure 2.1-1). Well development was completed November 24, 2009, and a dedicated sampling system was installed in well R-47i December 18, 2009.

Because the original target depth of well R-47 was 1350.5 ft bgs within the regional aquifer, drilling fluids including AQF-2 foaming agent and potable water were used in the depth interval of the screen in R-47i. In addition, bentonite sealant may have entered the formation near the screened interval because bentonite may have been present on the walls of the borehole in this zone due to the construction activities associated with the original regional well screen (LANL 2010, 109188; NMED 2010, 110438). The issues associated with drilling and the decision to complete a perched intermediate well within the R-47 borehole warrant an assessment of the reliability of data from R-47i.

2.2 Regulatory Context

Investigation and remediation actions at the Laboratory are subject to the Consent Order. Pursuant to the Consent Order, the reliability assessment supplements recent regulatory documents for the TA-16 260 Outfall, including the "Investigation Report for Intermediate and Regional Groundwater, Consolidated Unit 16-021(c)-99" (LANL 2006, 093798); the "Evaluation of the Suitability of Wells Near Technical Area 16 for Monitoring Contaminant Releases from Consolidated Unit 16-021(c)-99, Revision 1" (LANL 2007, 100113); and the "Corrective Measures Evaluation Report, Intermediate and Regional Groundwater, Consolidated Unit 16-021(c)-99" (LANL 2007, 098734).

3.0 CONDITIONS OF R-47i

To varying extents, geochemical evidence of perturbation (i.e., nonrepresentativeness) has been observed in early groundwater samples collected from nearly all perched intermediate and regional wells

(also called deep wells) following completion and development. In the case of well R-47i, effects from materials used downhole were of particular concern because of (a) the use of AQF-2 foaming agent in the screened interval, (b) suspended particulates in the screened interval following emplacement of the annular-seal bentonite and the overlying filter sand pack, and (c) potential diffusion of soluble constituents into the screened interval from the bentonite seal during its normal settling and compaction. Although not unique to well R-47i, the potential effects of these geochemical perturbations might be expected to be more prominent and persistent in this well as a consequence of the low hydraulic conductivity (0.21 ft/d) of the formation in the vicinity of the screened interval (LANL 2010, 109188, section 5.2). Such low hydraulic conductivities are also present in wells PCI-2 and R-21, which are also screened in the Puye Formation (Table A-3.0-1). Well PCI-2 was not able to attain the turbidity stabilization criterion of <5 nephelometric turbidity units (NTU) during well development, nor could this well sustain a recharge rate sufficient to conduct an aquifer test.

3.1 Assessment Methodology

Analytical data are presently available for R-47i for four post-development sampling events: December 21, 2009, April 8, 2010, September 23, 2010, and December 2, 2010. The September 23 event involved an extended purge of 6 casing volumes (CVs), with samples collected every 1 CV; the other three events followed the standard protocol of 3 CVs purge volumes before sampling. For each event, the assessment methodology involves examination of the following water-quality parameters as the most likely to detect geochemical effects of perturbation:

- time-series data for field parameters monitored during purging and final field parameter values for each sampling event (section 3.2);
- trends in concentrations of key indicators for the presence of the specific materials used in the screened interval (AQF-2 and annular-fill bentonite) (section 3.3);
- trends in relative concentrations of major ions, as plotted on a standard trilinear graph (section 3.3);
- comparison of concentrations with upper tolerance limits (UTLs) for background groundwater (section 3.3); and
- comparison of dissolved concentrations with those in groundwater from other deep wells screened in the Puye Formation (Tpf) or the Cerro Toledo interval of the Bandelier Tuff (Qct), and at which effects from downhole materials or local contaminants are absent (section 3.3).

Data used for the assessment are presented in tables and figures in Appendix A. For this analysis, additional insights are also obtained from examination of detected organics and time-series concentrations of area-specific chemicals of potential concern (COPCs) (section 3.4).

3.2 Field Parameters

Time-series data for field parameters monitored during purging before sample collection are examined for attainment of stable values by the end of purging. Stabilization criteria are prescribed in Standard Operating Procedure (SOP) 5232, Groundwater Sampling. Examination of tabulated data and time-series plots in Appendix A yields the following observations.

- Stabilization criteria are met for all four sampling events after purging 3 CVs.
- Field parameters for the first sampling event stabilized at higher values for specific conductance and turbidity, and at a lower dissolved oxygen concentration, than did those for the subsequent

three events (Figure A-1.0-1), suggesting that groundwater in the screened interval had re-equilibrated to predrilling conditions after April 8, 2010.

- Field parameters for the last three events stabilize at similar levels after 3 CVs purge volumes. The repeatability of these values supports the finding that they are representative of formation water at this location.
- Final field parameter values fall between the 25th and 75th percentiles for background perched intermediate groundwater (LANL 2010, 110535, Table 4.2-1), consistent with the conclusion that these field parameters are likely representative of formation water.
- Final field parameters are also comparable to those measured for other deep wells screened in the Tpf or Qct.

3.3 Analysis of Well-Screen Conditions

The presence of residual materials used in the screened interval is assessed by examining concentrations of key geochemical indicators for these materials. Concentrations of total organic carbon (TOC), sodium, and sulfate are used as indicators for the potential presence of AQF-2 foaming agent. Sulfate is a biodegradation product of sulfonate surfactants in the AQF-2 foaming agent, and sodium is present as a counterion for these anionic surfactants. Indicators for the potential presence of bentonite in the screen interval include turbidity, sodium, sulfate, and selected trace metals associated with bentonite, primarily aluminum, iron, manganese, and molybdenum. An important caveat to note is that geochemical effects of residual bentonite in the screened interval are difficult to distinguish from those arising from the effects of disturbing formation solids during drilling and development.

The following geochemical trends are observed in the data summarized and plotted in Appendix A (section A-2.0).

- Sodium and sulfate concentrations are highest in the first sampling event but decrease steadily for the subsequent two events. This trend suggests the possible presence of small amounts of inorganic ions associated with residual downhole products in the earliest samples.
- TOC is detected at low concentrations between 0.5 and 1.5 mg/L in the first three samples, suggesting the absence of residual organic product in the immediate vicinity of the screened interval.
- Major ion concentrations attain relatively stable values for the two most recent events. Furthermore, for the extended purge event September 23, 2010, major ion concentrations are within 10% of one another in samples collected at purge volumes of 3 CVs, 4 CVs, 5 CVs, and 6 CVs. This stability suggests that groundwater is relatively well mixed within the volume of the formation accessed during sampling, and hence little is to be gained by purging more than 3 CVs.
- Concentrations for the majority of trace metals remain fairly stable for all sampling events. Notable exceptions are total iron, total aluminum, and manganese. Concentrations for these three trace metals are highest in the first post-development samples (December 2009) and generally decrease in subsequent samples.
- Initially high concentrations of iron and manganese are not indicative of in-situ reducing conditions at this location because the persistent presence of perchlorate, nitrate, and dissolved oxygen indicate in-situ conditions are oxidizing, consistent with groundwater background. Other locations in or around TA-16 and in groundwaters in the Puye Formation are known to have high naturally occurring concentrations of iron and manganese; the source of these high concentrations is unknown, but they may be due to colloidal materials.

Representativeness is assessed with greater specificity by comparing dissolved major ion concentrations with those in groundwater from other deep wells screened in Tpf or Qct and at which effects from downhole materials or local contaminants are absent or negligible. Six screens in five wells meet these conditions: intermediate perched wells PCI-2 and R-26 screen 1 and regional wells R-17 screens 1 and 2, R-21, and R-27. With the single exception of well R-26, in which a Westbay sampling system is installed, these wells serve as background locations in the "Groundwater Background Investigation Report, Revision 4" (LANL 2010, 110535). The following trends are observed from such a comparison.

- Figure 3.3-1 shows that relative major ion concentrations in groundwater from the Tpf-Qct screens cluster in a distinct and well-defined field on a trilinear (Piper) plot, a common graphical tool used to identify waters with similar chemistries. Data points for well R-47i fall outside the cluster of points for the Tpf-Qct wells, but obviously trend toward it, consistent with the possible presence of a small, decreasing component of residual sodium and sulfate in the vicinity of the screened interval.
- Figure 3.3-2 compares major ion concentrations in groundwater from well R-47i with the ranges observed in groundwater from the six Tpf-Qct screens. Calcium and magnesium concentrations are relatively constant throughout the four sampling events. However, concentrations of sodium and sulfate (as well as chloride to a lesser extent) extend above the range observed for the Tpf-Qct screens, again consistent with the possible presence of a small component of residual downhole material in the vicinity of the screened interval.
- Figure 3.3-3 compares trace metal concentrations in filtered groundwater from well R-47i with the range in groundwater from the six Tpf-Qct screens. Figure 3.3-4 provides an analogous comparison for unfiltered samples. Other than for the first sampling event, these two figures show that total as well as dissolved concentrations of aluminum and iron fall within the range observed for groundwater collected from other intervals screened in Tpf-Qct. Following the extended-purge event at R-47i, manganese and molybdenum remain the only trace metals with concentrations above the range observed in the other Tpf-Qct screens.

The absence of residual organic product in the screened interval of R-47i is supported by the observation that toluene and diethylphthalate are the only volatile or semivolatile organics detected (once each). The detected concentrations are at or below the practical quantitation limit (PQL) and are thus validated as J (estimated values), indicating that the reported concentrations are regarded as uncertain. Toluene is detected at 0.504 µg/L (PQL = 1 µg/L) in the sample collected April 8, 2010, and is also detected in the field trip blank (0.386 µg/L) for that event. Diethylphthalate is reported at 10.1 µg/L (PQL = 10 µg/L) in the sample collected September 23, 2010. These analytes are not detected in any other post-development samples from R-47i.

3.4 COPCs for the 260 Outfall CME/Corrective Measures Implementation

The primary constituents associated with the 260 Outfall are HE and barium. The principal COPCs for intermediate and regional groundwater include RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), trinitrotoluene (TNT), other HE, and HE byproducts and degradation products. Organic solvents, particularly trichloroethene (TCE), are also detected in groundwater and springs downgradient of the 260 Outfall and other TA-16 sources.

Based upon the assessment summarized in sections 3.2 and 3.3, well R-47i appears fully capable of providing reliable and representative data for these COPCs. Water-quality data for HE compounds and volatile organic compounds (VOCs) such as TCE and other solvents are expected to be reliable and representative because conditions are oxic, residual organics are absent, and no compelling evidence

exists for the presence of large amounts of residual bentonite in the screened interval after the first post-development sampling event on December 21, 2009. Barium concentrations also appear to be reliable and representative; for the most recent two sampling events, dissolved concentrations of barium (8.5 µg/L and 7.9 µg/L, respectively) are similar to those measured at perched intermediate wells PCI-2 (average, 8.6 µg/L) and R-26 screen 1 (average, 7.9 µg/L).

3.5 Other Well Issues

The top of the filter sand and fine sand collar (832 ft bgs) extends above the well screen to within approximately 2 ft of the static water level (830 ft bgs), indicating at least partial dewatering of the filter pack is possible at any viable pumping rate (LANL 2010, 109188, p. E-12). During aquifer testing, pumping at 0.71 gpm for 40 min resulted in a drawdown of 4.5 ft and pumping at 0.91 gpm for 40 min resulted in a drawdown of 6.5 ft (LANL 2010, 109188, Table E-9.5-1). However, there is no obvious evidence that the groundwater data from R-47i are affected by this situation.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Geochemical effects arising from drilling and construction of well R-47i are apparent in the first water-quality sample collected following development. However, the geochemical trends from subsequent sampling show steady improvement. For the most recent two sampling events, residual effects appear to be limited to a few inorganic constituents: sodium, sulfate, chloride, manganese, and molybdenum.

Based on analyses presented herein, it appears that well R-47i is able to provide reliable and representative data for the key contaminants associated with the 260 Outfall, particularly RDX and other HE, barium, and VOCs.

It is recommended that the sampling program at R-47i be continued using the routine sampling protocol that involves purging of 3 CVs and stabilization of parameters per SOP 5232. Stabilization of field parameters and analytical results for the extended purge event September 23, 2010, indicate that no significant benefit is gained by purging more than 3 CVs.

5.0 REFERENCES AND MAP DATA SOURCES

5.1 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.

LANL (Los Alamos National Laboratory), July 2002. "Interim Measure Report for Potential Release Site 16-021(c)-99," Los Alamos National Laboratory document LA-UR-02-4229, Los Alamos, New Mexico. (LANL 2002, 073706)

- LANL (Los Alamos National Laboratory), September 2003. "Phase III RFI Report for Solid Waste Management Unit 16-021(c)-99," Los Alamos National Laboratory document LA-UR-03-5248, Los Alamos, New Mexico. (LANL 2003, 077965)
- LANL (Los Alamos National Laboratory), August 2006. "Investigation Report for Intermediate and Regional Groundwater, Consolidated Unit 16-021(c)-99," Los Alamos National Laboratory document LA-UR-06-5510, Los Alamos, New Mexico. (LANL 2006, 093798)
- LANL (Los Alamos National Laboratory), April 2007. "Evaluation of the Suitability of Wells Near Technical Area 16 for Monitoring Contaminant Releases from Consolidated Unit 16-021(c)-99," Los Alamos National Laboratory document LA-UR-07-2370, Los Alamos, New Mexico. (LANL 2007, 095787)
- LANL (Los Alamos National Laboratory), July 2007. "Corrective Measures Implementation Plan for Consolidated Unit 16-021(c)-99, Revision 1," Los Alamos National Laboratory document LA-UR-07-4715, Los Alamos, New Mexico. (LANL 2007, 098192)
- LANL (Los Alamos National Laboratory), August 2007. "Corrective Measures Evaluation Report, Intermediate and Regional Groundwater, Consolidated Unit 16-021(c)-99," Los Alamos National Laboratory document LA-UR-07-5426, Los Alamos, New Mexico. (LANL 2007, 098734)
- LANL (Los Alamos National Laboratory), September 2007. "Evaluation of the Suitability of Wells Near Technical Area 16 for Monitoring Contaminant Releases from Consolidated Unit 16-021(c)-99, Revision 1," Los Alamos National Laboratory document LA-UR-07-6433, Los Alamos, New Mexico. (LANL 2007, 100113)
- LANL (Los Alamos National Laboratory), April 2010. "Completion Report for Intermediate Aquifer Well R-47i," Los Alamos National Laboratory document LA-UR-10-2207, Los Alamos, New Mexico. (LANL 2010, 109188)
- LANL (Los Alamos National Laboratory), April 2010. "Long-Term Monitoring and Maintenance Plan for the Corrective Measures Implementation at Consolidated Unit 16-021(c)-99," Los Alamos National Laboratory document LA-UR-10-2196, Los Alamos, New Mexico. (LANL 2010, 109252)
- LANL (Los Alamos National Laboratory), August 2010. "Groundwater Background Investigation Report, Revision 4," Los Alamos National Laboratory document LA-UR-10-4827, Los Alamos, New Mexico. (LANL 2010, 110535)
- LANL (Los Alamos National Laboratory), August 9, 2010. "Submittal of the Response to the Approval with Direction for the Completion Report for Intermediate Aquifer R-47i," Los Alamos National Laboratory letter (EP2010-0355) to J.P. Bearzi (NMED-HWB) from M.J. Graham (LANL) and G.J. Rael (DOE-LASO), Los Alamos, New Mexico. (LANL 2010, 110512)
- NMED (New Mexico Environment Department), July 2, 2010. "Approval with Direction, Completion Report for Intermediate Aquifer Well R-47i," New Mexico Environment Department letter to G.J. Rael (DOE-LASO) and M. Graham (LANL) from J.P. Bearzi (NMED-HWB), Santa Fe, New Mexico. (NMED 2010, 110438)

5.2 Map Data Sources

Data sources for all figures are provided below unless otherwise indicated on the figures themselves.

Paved and Dirt Road Arcs, Existing and Former Structures, Security and Industrial Fences and Gates, Water and Gas Lines: Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating, and Mapping Section; 06 January 2004; Development Edition of 05 January 2005.

Potential Release Sites: Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program, ER2005-0748; 1:2,500 Scale Data; 22 November 2005.

Material Disposal Areas: Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program, ER2004-0221; 1:2,500 Scale Data; 23 April 2004.

Hypsography, 10, 20, and 100 Foot Contour Intervals: Los Alamos National Laboratory, Environmental Stewardship Remediation Services Project; 1991.

ER Location ID Points: Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program; 1:2,500 Scale Data; 10 November 2005.

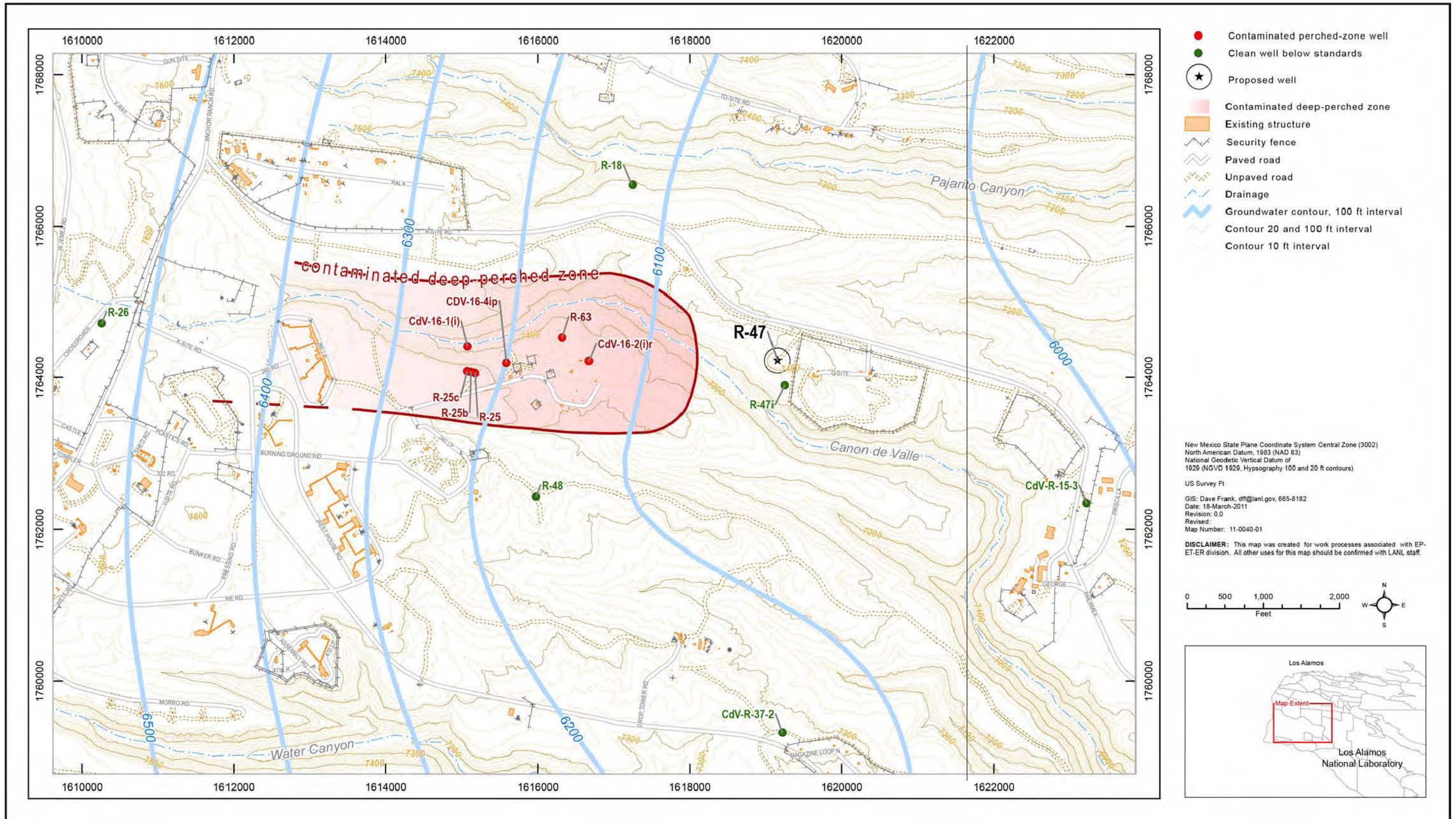
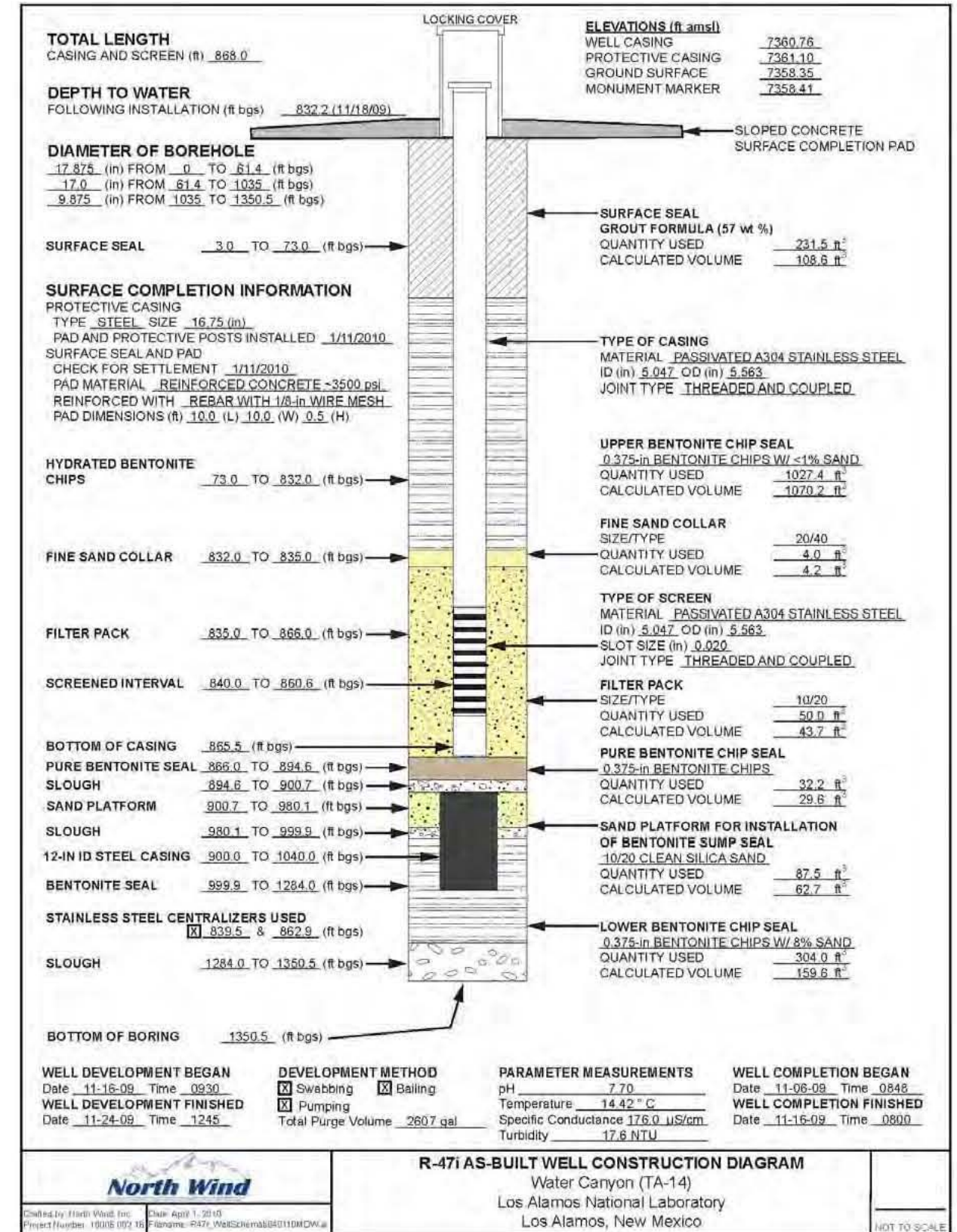
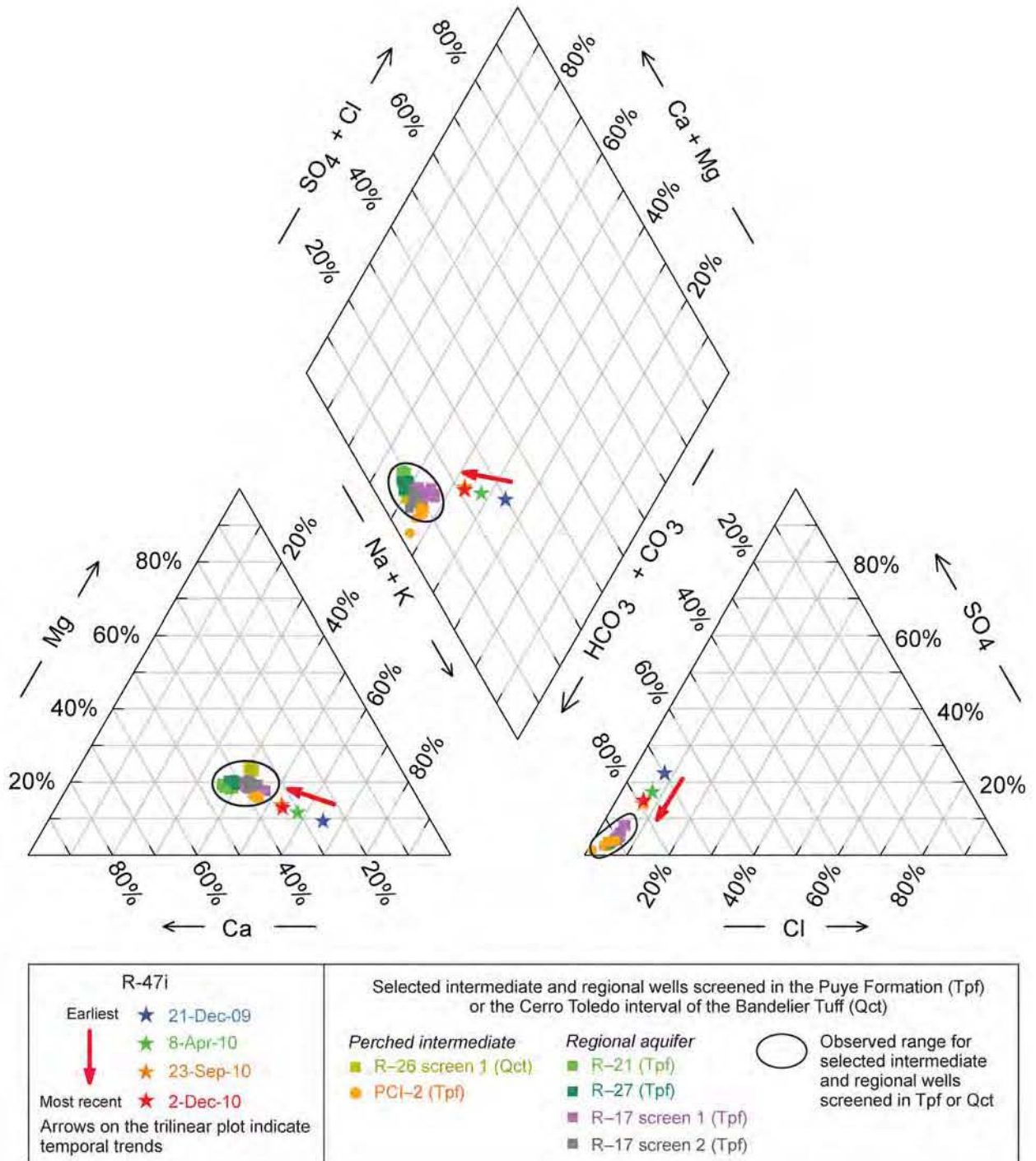


Figure 1.0-1 Locations of monitoring wells associated with the TA-16 260 Outfall monitoring network



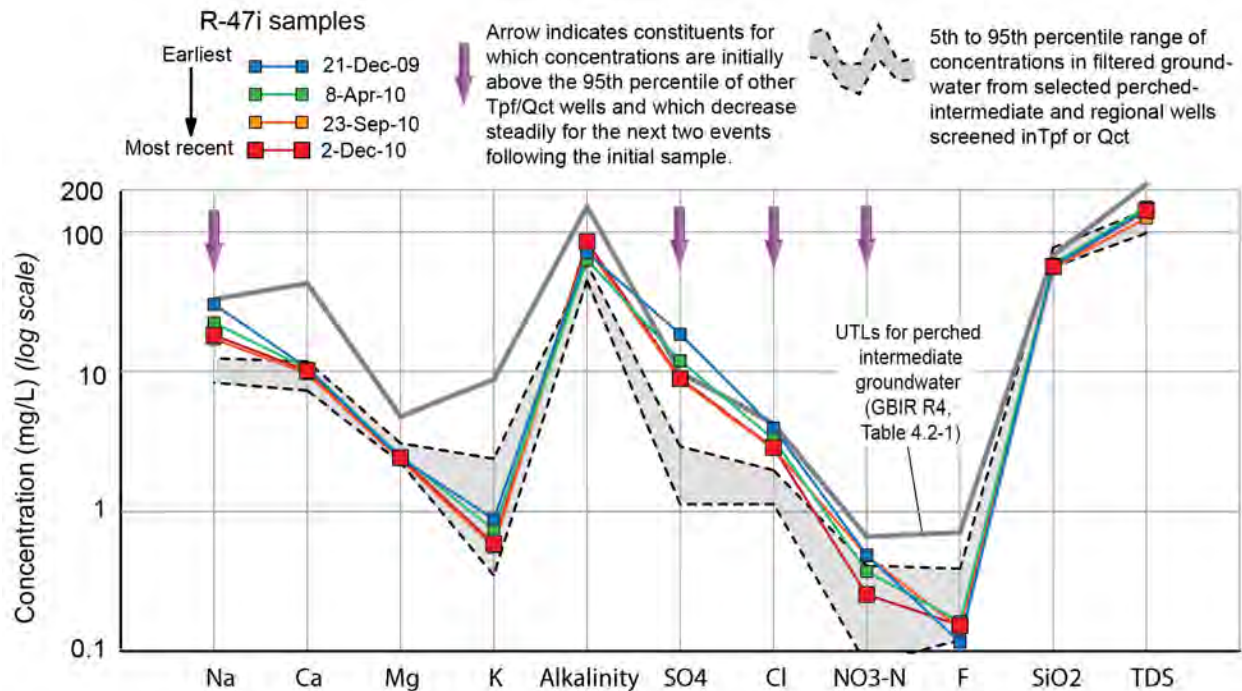
Source: LANL 2010, 109188, Figure 7.2-1.

Figure 2.1-1 Well construction diagram for well R-47i



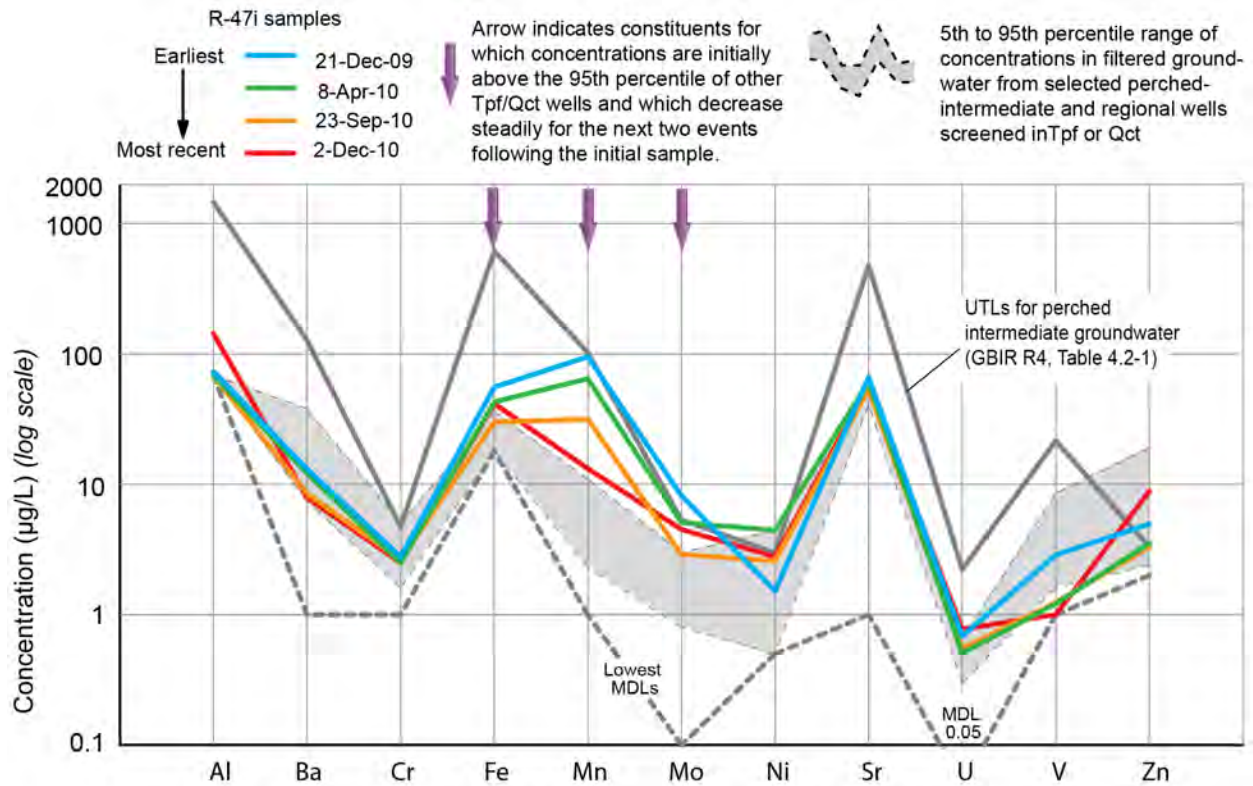
Source: Appendix A

Figure 3.3-1 Trilinear plot showing relative distribution of major ions in groundwater from well R-47i and selected intermediate and regional wells also screened in the Puye Formation or the Cerro Toledo interval of the Bandelier Tuff



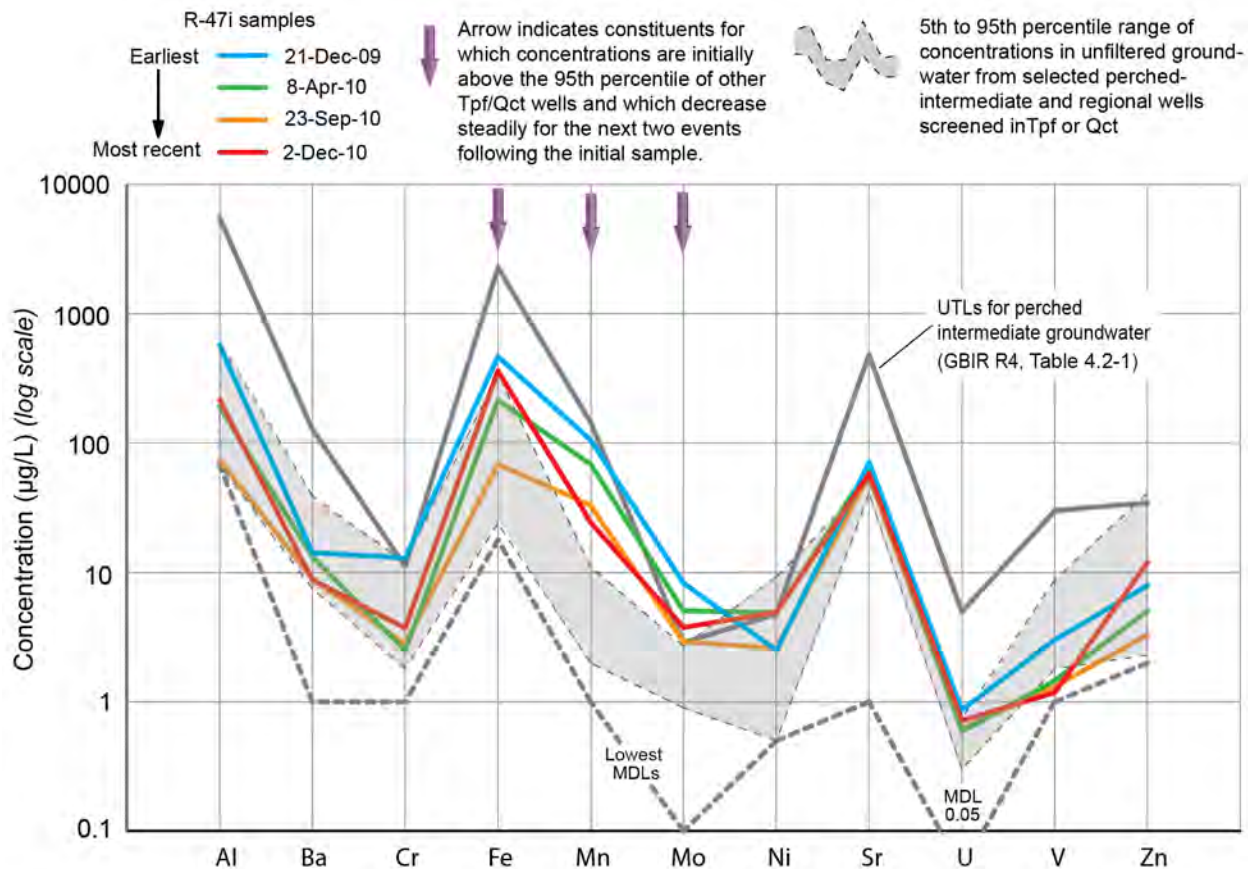
Source: Table A-2.0-1 (R-47i data) and Table A-3.0-2 (5th and 95th percentile concentrations for other wells)
 GBIR R4 = Groundwater Background Investigation Report, Revision 4 (LANL 2010, 110535)

Figure 3.3-2 Major ion and silica concentrations in filtered groundwater samples from R-47i compared with 5th to 95th percentile ranges for other wells screened in the Puye Formation or the Cerro Toledo interval of the Bandelier Tuff



Source: Table A-2.0-3 (R-47i data) and Table A-3.0-3 (5th and 95th percentile concentrations for other wells)
 GBIR R4 = Groundwater Background Investigation Report, Revision 4 (LANL 2010, 110535)

Figure 3.3-3 Trace metal concentrations in filtered groundwater samples from R-47i compared with the 5th to 95th percentile range for other wells screened in the Puye Formation or the Cerro Toledo interval of the Bandelier Tuff



Source: Table A-2.0-3 (R-47i data) and Table A-3.0-3 (5th and 95th percentile concentrations for other wells)
 GBIR R4 = Groundwater Background Investigation Report, Revision 4 (LANL 2010, 110535)

Figure 3.3-4 Trace metal concentrations in unfiltered groundwater samples from R-47i compared with the 5th to 95th percentile range for other wells screened in the Puye Formation or the Cerro Toledo interval of the Bandelier Tuff

Appendix A

Water-Quality Data Used in This Assessment

The purpose of this assessment is to identify water-quality data that may not be reliable and representative of predrilling groundwater conditions at this location if residual effects are present in the screened interval. The evaluation encompasses all post-development groundwater samples.

A-1.0 FIELD PARAMETERS

Time-series data for field parameters monitored during purging before sample collection are examined for attainment of stable values by the end of purging. Stabilization criteria are prescribed in Standard Operating Procedure 5232, Groundwater Sampling. The most sensitive indicator parameters are dissolved oxygen (DO) and turbidity. Other parameters such as water temperature, specific conductance, pH, and oxidation-reduction potential (ORP) are also monitored, but are considered less sensitive indicators of formation water. Water-quality indicator parameters are monitored at 5- to 30-min intervals until stability has been achieved for at least three consecutive measurements a minimum of 5 min apart. Stabilization is defined as the point at which measured values are within the criteria listed below for all parameters for three consecutive readings:

- <5 nephelometric turbidity units (NTU) if possible or, if turbidity remains, >5 NTU, $\pm 10\%$ of the reading;
- DO ± 0.3 mg/L;
- pH ± 0.1 pH unit;
- specific conductance $\pm 3\%$; and
- temperature $\pm 0.2^\circ\text{C}$.

Examination of time-series data collected during purging (Appendix B) shows that stabilization criteria are met for all four sampling events after purging three casing volumes (CVs). Field parameters for the first sampling event stabilized at higher values for specific conductance and turbidity, and at lower DO concentrations and ORP values than did those for the subsequent three events (Table A-1.0-1; Figure A-1.0-1). This indicates that groundwater in the screened interval had not fully re-equilibrated to predrilling conditions when the first sample was collected. In contrast, field parameters for the last two events stabilized at similar levels (Table A-1.0-1; Figure A-1.0-1); the repeatability of these values supports the expectation that they are largely representative of formation water at this location.

Table A-1.0-2 and Figure A-1.0-2 show that final field parameter values generally fall between the 25th and 75th percentiles for background perched intermediate groundwater (LANL 2010, 110535). This is consistent with the conclusion that these field parameters are likely representative of formation water. Additional insight concerning the representativeness of the final field parameters is provided by a comparison of these values with values measured for other wells in similar settings (Figure A-1.0-2). Data that provide the basis for this comparison are discussed in section A-3.0.

A-2.0 WATER-QUALITY DATA FOR R-47i

To evaluate general geochemical trends at R-47i, Figures A-2.0-1 and A-2.0-2 present geochemical trending plots that show the evolution of selected geochemical indicators used to identify possible residual effects from products and materials used downhole in R-47i, as compared with relevant guideline concentrations that are based on background groundwater statistics.

Major ion trends. Concentrations for most major ions remain fairly stable for all sampling events (Table A-2.0-1; Figure A-2.0-1). Notable exceptions are sodium and sulfate concentrations, which are

approximately twice as high in the first sample (December 21, 2009), as compared with the two most recent samples (September 23, 2010, and December 2, 2010). The decreasing trends for sodium and sulfate suggest the possible presence of small amounts of soluble inorganic ions associated with residual AQF-2 foaming agent or annular-fill bentonite in the earliest samples.

For the most recent two events, major ion concentrations are essentially constant (Table A-2.0-1; Figure A-2.0-1). For the extended purge event September 23, 2010, major ion concentrations are within 10% of one another in samples collected at 3CVs, 4CVs, 5CVs, and 6CVs (Table A-2.0-2). In concert with the low total organic carbon (TOC) concentrations (<1 mg/L) measured for samples throughout the extended-purge event, the stability of major ion concentrations suggests the water in the formation is relatively well mixed and homogeneous within the volume of the formation accessed by extended purging.

Trace metal trends. Concentrations for the majority of trace metals remain more or less stable for all sampling events (Tables A-2.0-3 and A-2.0-4). Notable exceptions are total iron, total aluminum, and manganese. Concentrations for these three trace metals are highest in the first sample (December 21, 2009) and generally decrease in subsequent samples (Figure A-2.0-2). Initially high concentrations of iron and manganese are not indicative of in situ reducing conditions at this location because the persistent presence of perchlorate, nitrate, and DO indicate in situ conditions are oxic, consistent with groundwater background. Dissolution of iron- or manganese-bearing minerals is judged to be unlikely because these minerals are generally stable under oxic conditions. Elevated concentrations of these particular trace metals (aluminum, iron, and manganese) most likely reflect potentially minor contributions from normal settling of formation fines dislodged during drilling or of residual bentonite from the emplacement of the annular bentonite seal below the filter-pack sand.

Organic analytes. In the four events, toluene and diethylphthalate are only two listed organics detected (once each) (Appendix B). The detected concentrations are at or below the practical quantitation limit (PQL) and are thus validated as J (estimated values), indicating that the reported concentrations are regarded as more uncertain than usual. Toluene is detected at 0.504 µg/L (PQL = 1 µg/L) in the sample collected April 8, 2010, and is also detected in the field trip blank (0.386 µg/L) for that event. Diethylphthalate is reported at 10.1 µg/L (PQL = 10 µg/L) in the sample collected September 23, 2010. These analytes are not detected in any other samples from R-47i.

A-3.0 WATER-QUALITY DATA FOR OTHER DEEP WELLS COMPLETED IN THE PUYE FORMATION OR CERRO TOLEDO INTERVAL OF THE BANDELIER TUFF

Representativeness is assessed with greater specificity by comparing concentrations of major ions and trace metals in R-47i samples with those in groundwater from other perched intermediate and regional wells completed in the Puye Formation (Tpf) or the Cerro Toledo interval of the Bandelier Tuff (Qct) and at which effects from downhole materials or local contaminants are absent. Six screens in five wells meet these conditions: intermediate perched wells PCI-2, R-26 screen 1, regional wells R-17 screens 1 and 2, R-21, and R-27 (Figure A-3.0-1). Information about these screened intervals is summarized in Table A-3.0-1. With the exception of well R-26, which has a Westbay sampling system, these wells serve as background locations in the "Groundwater Background Investigation Report, Revision 4" (LANL 2010, 110535).

The selection of these six screens as appropriate points of comparison for groundwater from R-47i is supported by examining trends in the relative major ion concentrations of the groundwater. These trends are shown on a trilinear (Piper) plot (Figure 3.3-1), which is commonly used to identify waters with similar chemistries that plot in a distinct position on the plot and to identify potential mixing between end members. Relative percentages of major cations and major anions (expressed in milliequivalents [meq]

per liter) are plotted on the two ternary plots in the lower corners of the Piper plot. Major cations are calcium, magnesium, and sodium + potassium; major anions are generally chloride, sulfate, and bicarbonate + carbonate. Points plotted on the two ternary plots are then projected upward where they intersect on the central diamond. This graphical presentation shows the major ion chemistries for the last two events are indistinguishable from one another. Samples that plot along straight lines formed between two end members in all three fields of the trilinear diagram potentially represent mixing between these end members. On Figure 3.3-1, the water chemistry of R-47i is observed to trend toward the field defined by other deep wells completed in Tpf or Qct, which is expected if a small component of residual sodium and sulfate is present in groundwater near the screened interval.

Figure A-3.0-2 presents a line graph showing the average major ion, silica, and total dissolved solids (TDS) concentrations in the six screened intervals as well as 5th and 95th percentiles of the concentrations for this group as a whole. The range of concentrations bounded by these percentiles calculated for screened intervals with lithology similar to that at R-47i is much more restricted than that bounded by upper tolerance limits (UTLs) calculated for the full set of background locations. Hence, this line graph provides a visual means of identifying major ion concentrations that may be nonrepresentative of groundwater at well R-47i (Figure 3.3-2). In Figure 3.3-2, it is observed that concentrations for most major ions, silica, and TDS fall within the range of the Tpf-Qct wells. However, concentrations for sodium, sulfate, and chloride, although greatly decreased from their initial concentrations and apparently stable for the most recent events, nonetheless still extend above the range observed for the other Tpf-Qct screened intervals. This observation is consistent with the finding in the preceding paragraph that a small component of residual sodium and sulfate—as well as an even smaller component of chloride—is present in groundwater near the screened interval.

Figure A-3.0-3 and Figure A-3.0-4 present analogous line graphs plotting average trace metal concentrations for groundwater from the set of six Tpf-Qct screens. Figure A-3.0-3 shows the 5th and 95th percentiles of the filtered concentrations for this group; Figure A-3.0-4 shows the 5th and 95th percentiles of trace metal concentrations in unfiltered samples. These two plots are used in Figures 3.3-3 and 3.3-4 to identify trace metal constituents that appear to be nonrepresentative of groundwater at well R-47i. These two figures show that total as well as dissolved concentrations of aluminum and iron for the most recent two samples fall within the range observed for groundwater collected from other intervals screened in Tpf-Qct. Following the extended-purge event at R-47i, manganese and molybdenum remain the only trace metals with concentrations (dissolved as well as total) significantly above the range observed in these other wells. Both trace metals are most likely present as negatively charged anions and, as such, are unaffected by adsorption onto reactive-mineral surfaces near the screen. This observation is consistent with the finding in section A-2.0 that elevated concentrations of these trace metals are minor contributions attributable to diffusion out of the bentonite seal or released from formation fines disturbed during drilling.

A-4.0 SUMMARY

In summary, geochemical effects arising from drilling and construction of well R-47i are apparent in the first water-quality sample collected following development. However, the geochemical trends from subsequent sampling show steady improvement. Extended purging accelerated flushing of these constituents from the screened interval. For the most recent two sampling events, residual effects appear to be limited to a few inorganic constituents: sodium, sulfate, chloride, manganese, and molybdenum. Continued flushing of these constituents from the screened interval by natural groundwater flow and purging is likely limited by the low hydraulic conductivity of the formation and by the slow rates at which these constituents diffuse out of low-permeability materials in the vicinity of the screen. Because of these

rate-limiting processes, it is unlikely that another extended purge would significantly reduce these residual effects of drilling and construction. However, none of the residual constituents impact the capability of well R-47i to provide reliable and representative water-quality data for chemicals of potential concern relevant to the 260 Outfall.

A-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 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.

Kleinfelder, June 6, 2003. "Characterization Well R-21 Completion Report," report prepared for Los Alamos National Laboratory, Project No. 22461, Albuquerque, New Mexico. (Kleinfelder 2003, 090047)

Kleinfelder, January 25, 2005. "Final Well R-26 Completion Report, Revision No. 1," report prepared for Los Alamos National Laboratory, Project No. 37151, Albuquerque, New Mexico. (Kleinfelder 2005, 087846)

Kleinfelder, May 2006. "Final Completion Report, Characterization Well R-17," report prepared for Los Alamos National Laboratory, Project No. 49436, Albuquerque, New Mexico. (Kleinfelder 2006, 092493)

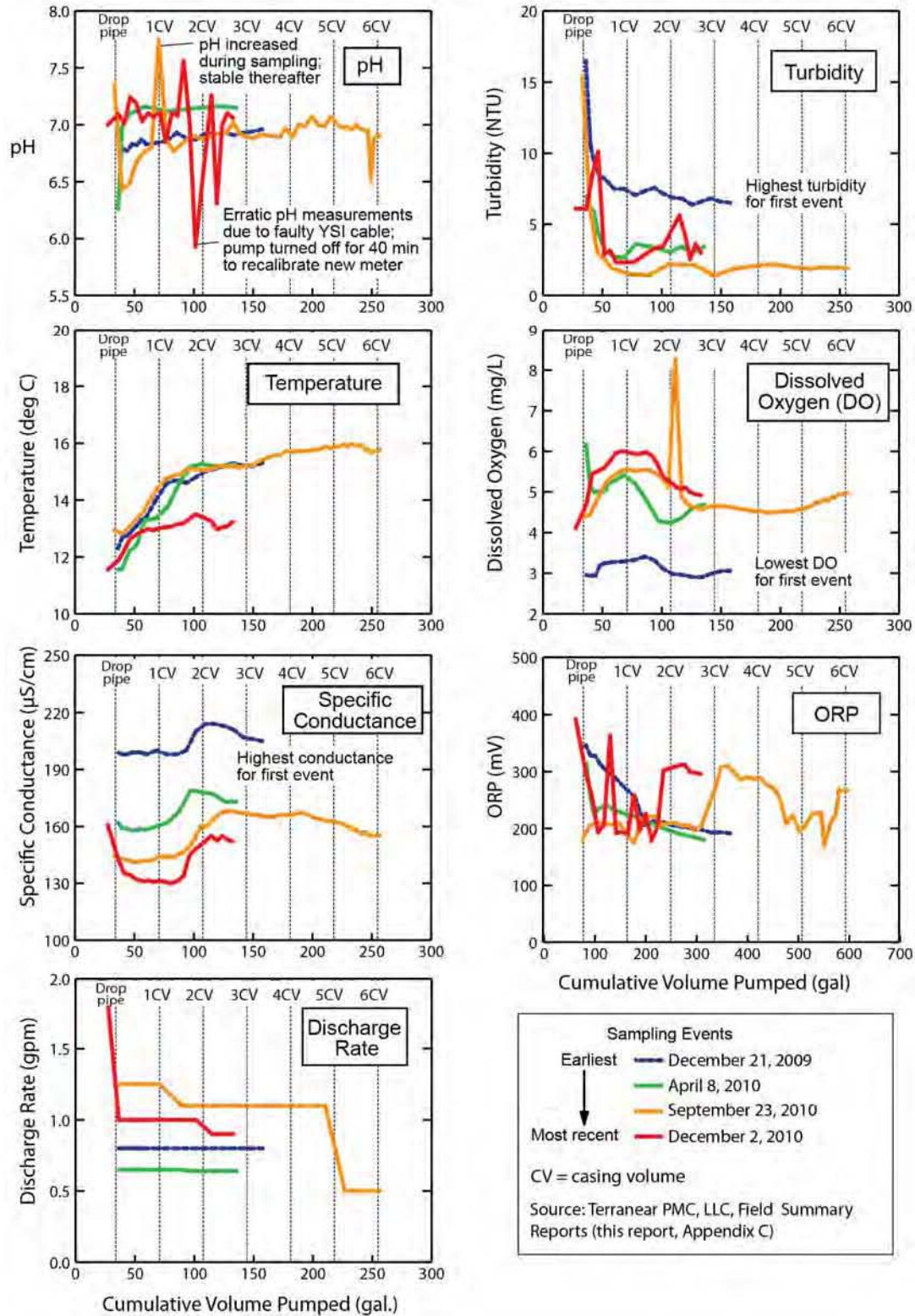
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LANL (Los Alamos National Laboratory), September 2009. "Completion Report for Intermediate Aquifer Well PCI-2," Los Alamos National Laboratory document LA-UR-09-5489, Los Alamos, New Mexico. (LANL 2009, 107342)

LANL (Los Alamos National Laboratory), April 2010. "Completion Report for Intermediate Aquifer Well R-47i," Los Alamos National Laboratory document LA-UR-10-2207, Los Alamos, New Mexico. (LANL 2010, 109188)

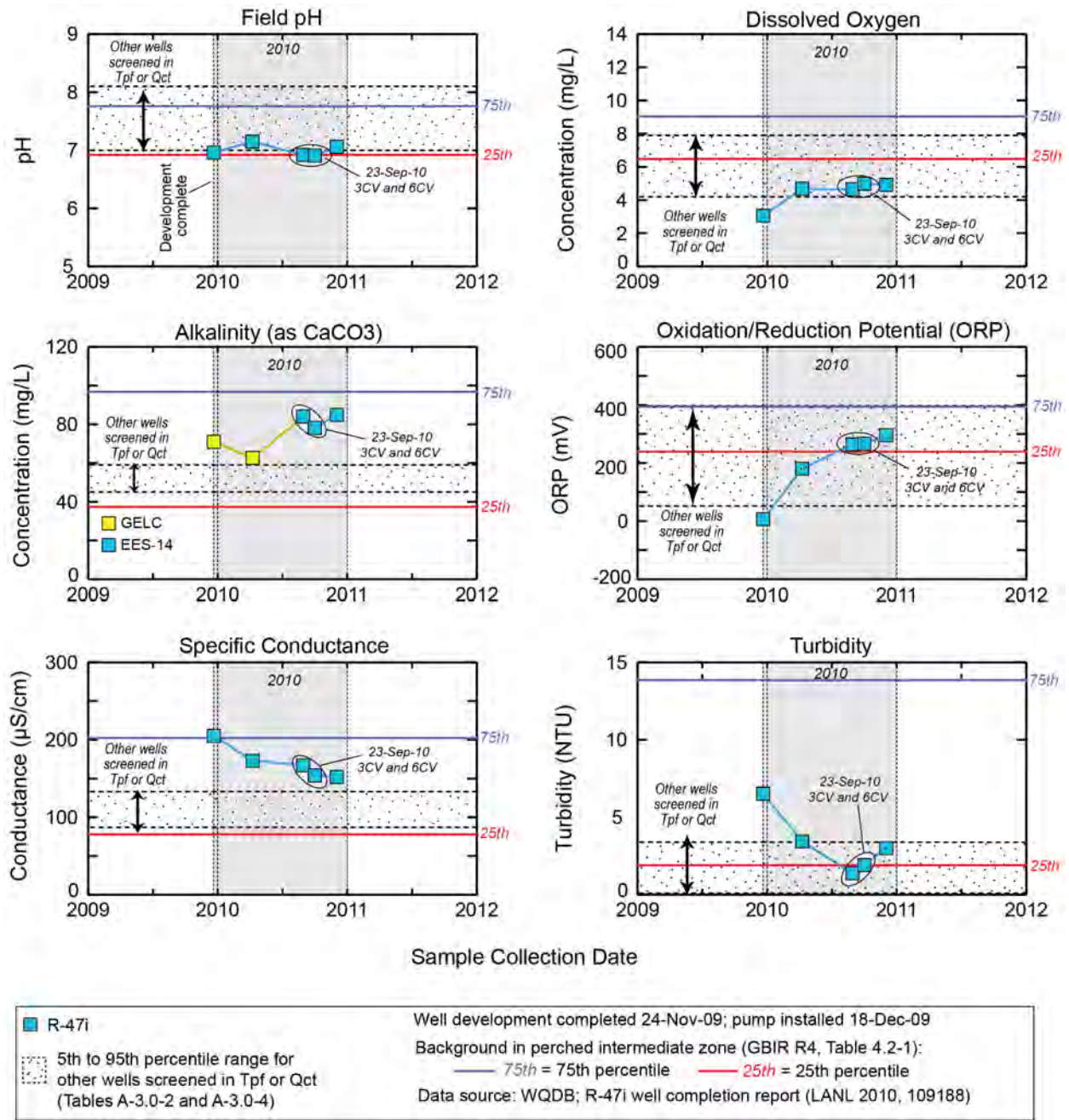
LANL (Los Alamos National Laboratory), June 2010. "2010 Interim Facility-Wide Groundwater Monitoring Plan," Los Alamos National Laboratory document LA-UR-10-1777, Los Alamos, New Mexico. (LANL 2010, 109830)

LANL (Los Alamos National Laboratory), August 2010. "Groundwater Background Investigation Report, Revision 4," Los Alamos National Laboratory document LA-UR-10-4827, Los Alamos, New Mexico. (LANL 2010, 110535)



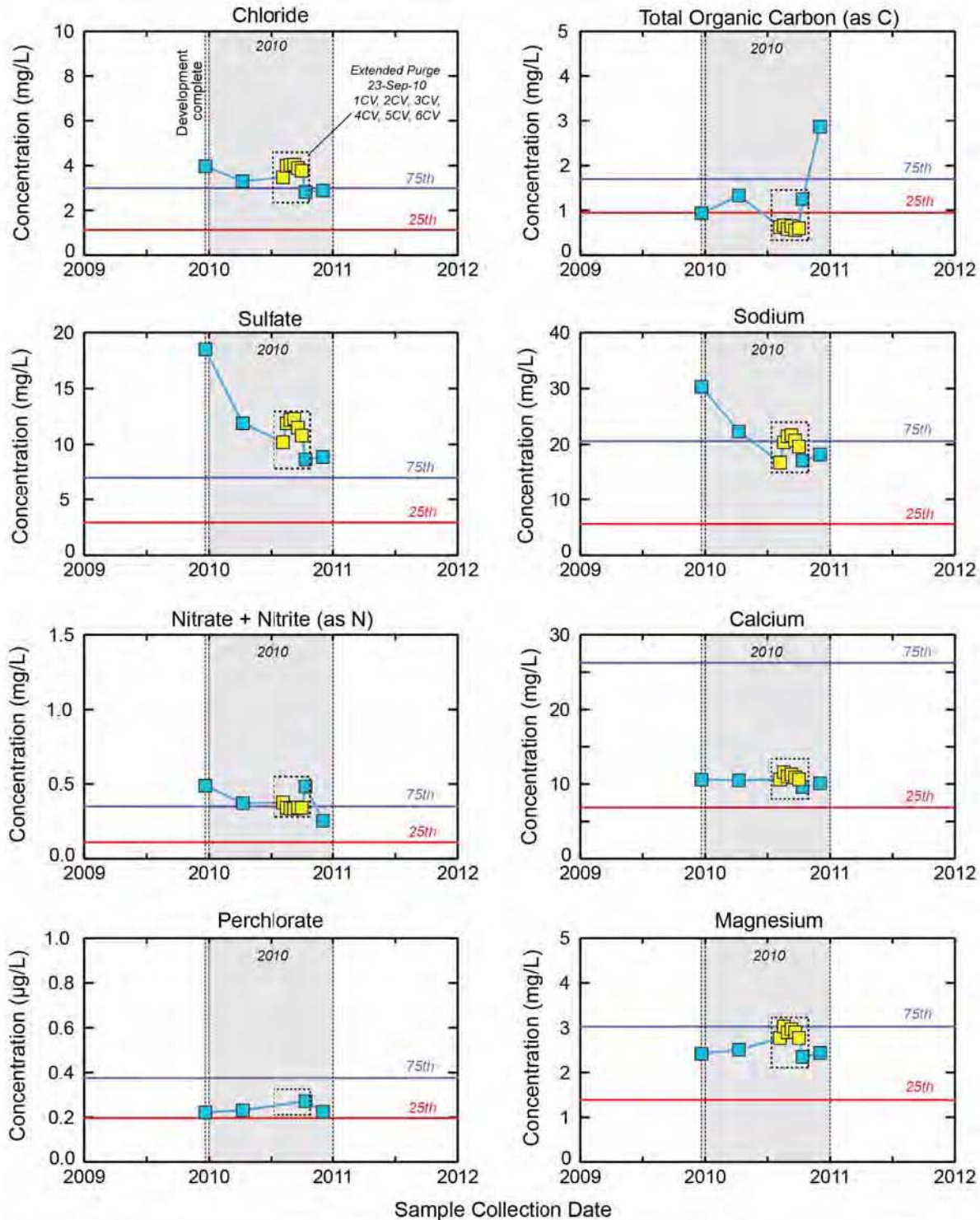
Notes: Cumulative purge volumes shown on these plots are estimated by multiplying the pump rate by the time elapsed between field parameter measurements (Appendix B). These volumes are not precise and may underestimate the actual purge volume.

Figure A-1.0-1 Time-series purge data for field parameters at well R-47i, December 2009 to December 2010



Tpf = Puye Formation; Qct = Cerro Toledo interval of the Bandelier Tuff; GBIR R4 = LANL 2010, 110535

Figure A-1.0-2 Final field parameters and carbonate alkalinity at well R-47i, December 2009 to December 2010



R-47i
 ■ Outside lab data (GELC)
 ■ EES-14 data
 ▭ Extended purge event (23-Sep-10)

Well completion dates: Drilling 4-Sep-09; construction 16-Nov-09; development 24-Nov-09
 75th = 75th percentile for background in perched intermediate zone (GBIR R4)
 25th = 25th percentile for background in perched intermediate zone (GBIR R4)
 GBIR R4 = Groundwater Background Investigation Report Revision 4 (LANL 2010, 110535)
 Data source: Appendix B (this report; R-47i well completion report (LANL 2010, 109188))

Figure A-2.0-1 Trends for concentrations of major ions and TOC in groundwater from well R-47i, December 2009 to December 2010

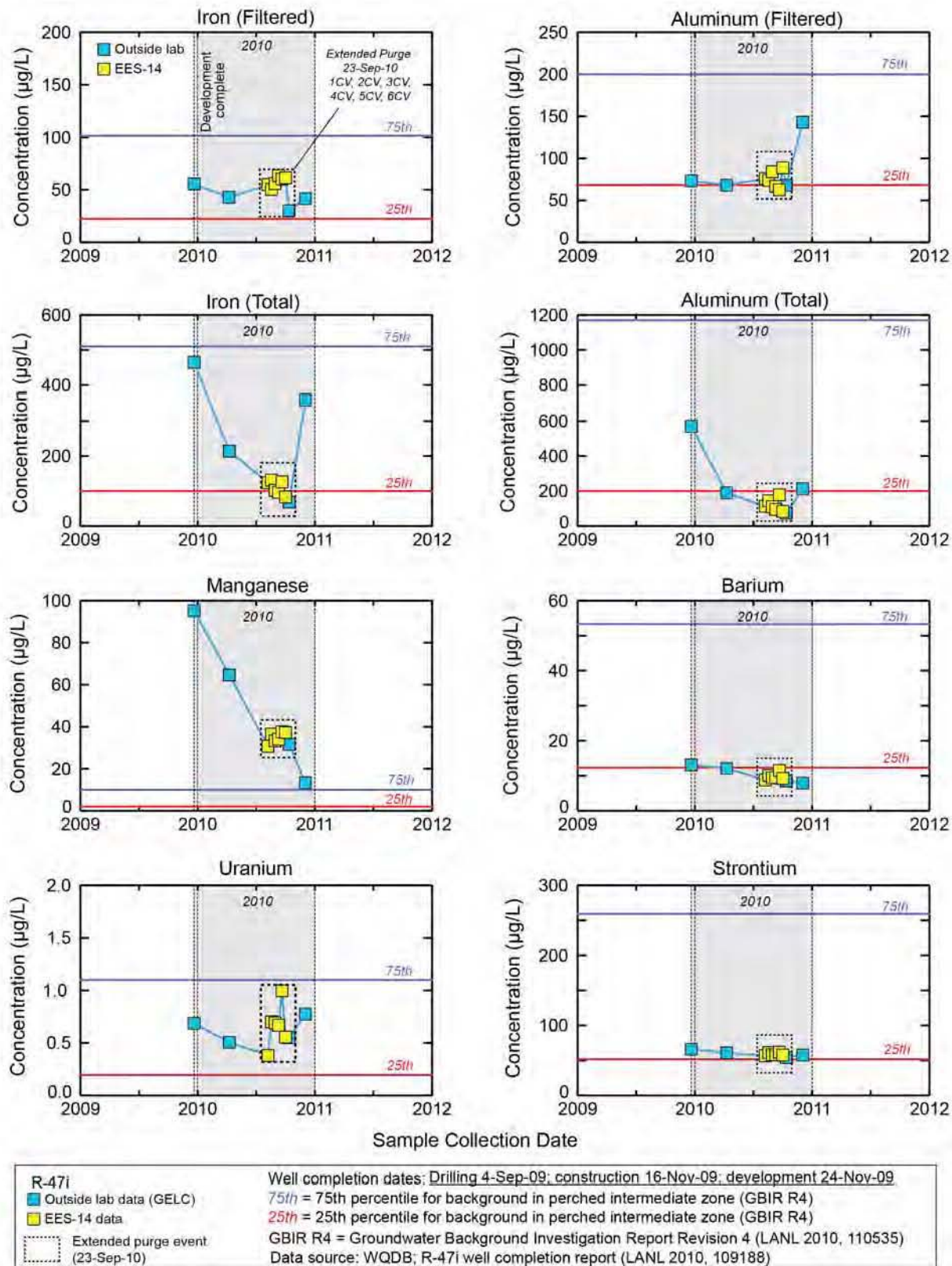


Figure A-2.0-2 Trends for trace metal concentrations in groundwater from well R-47i, December 2009 to December 2010

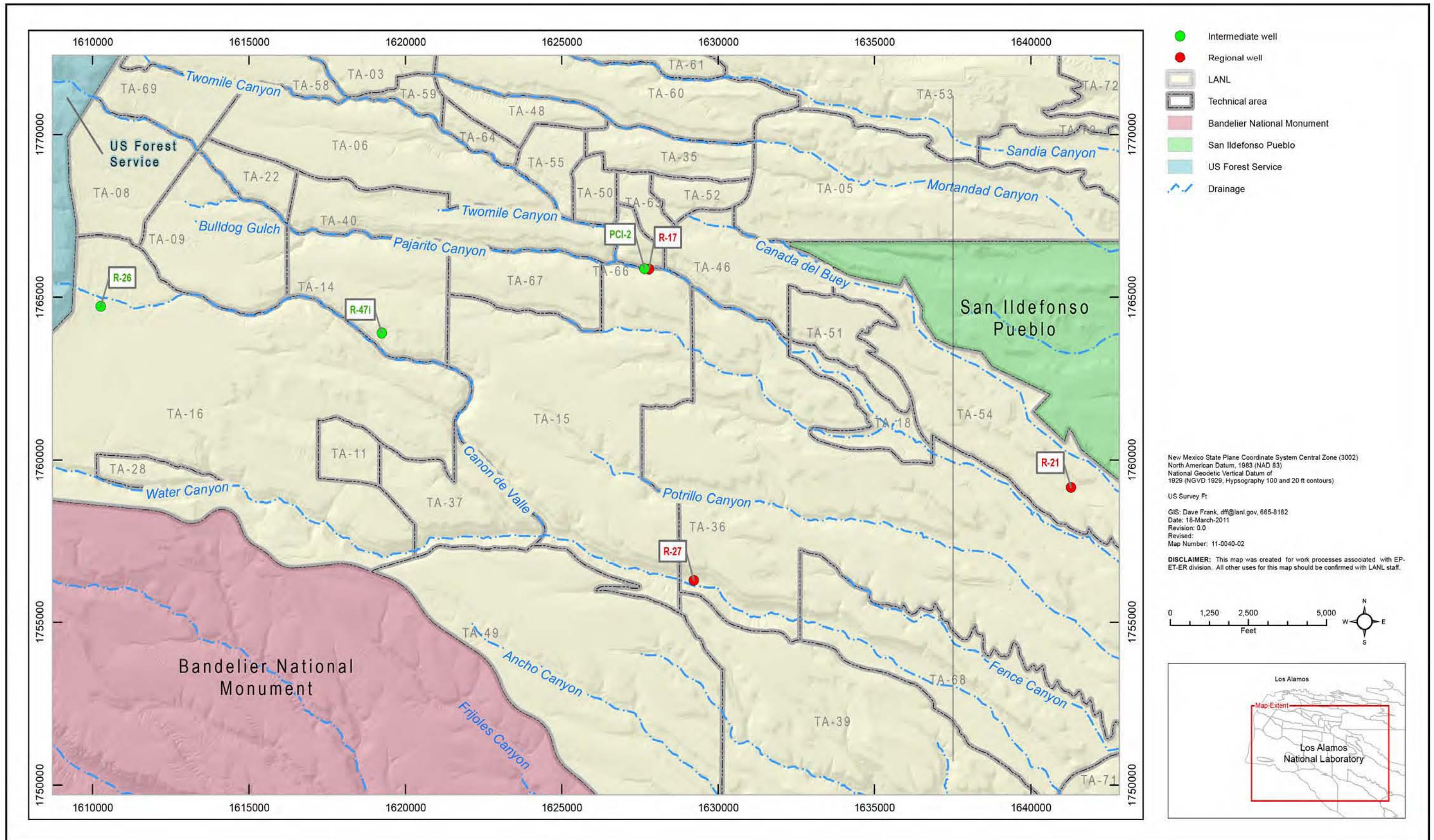


Figure A-3.0-1 Locations of well R-47i and selected perched intermediate and regional wells screened in the Puye Formation (Tpf) or the Cerro Toledo interval of the Bandelier Tuff (Qct)

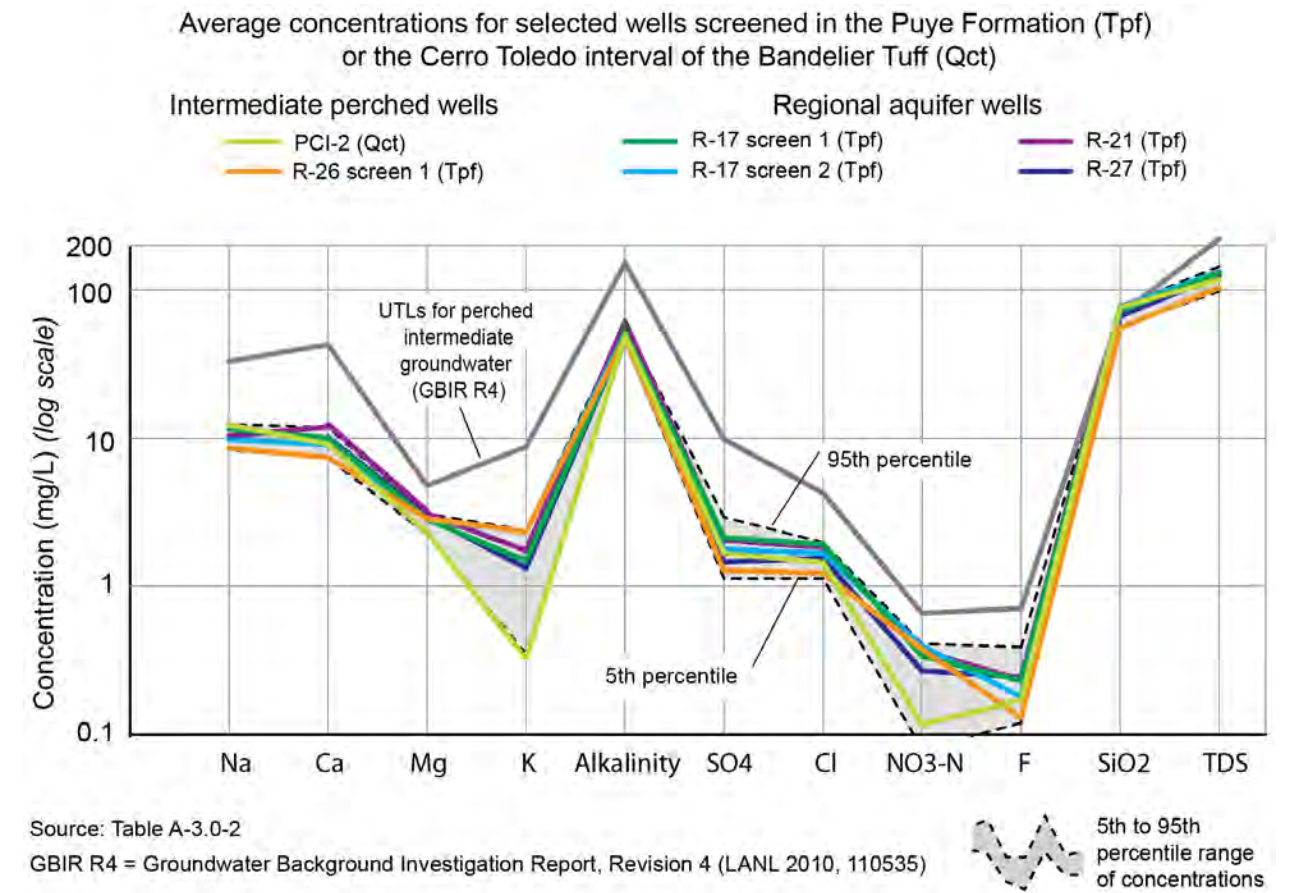
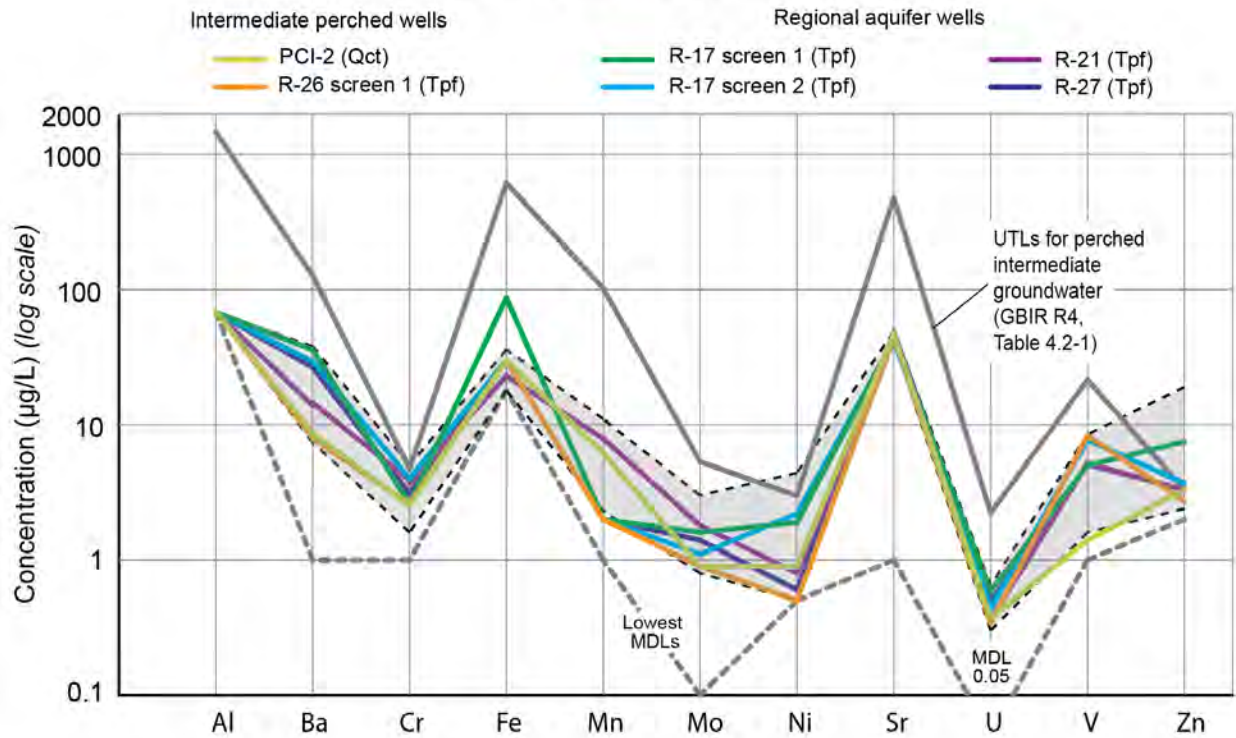


Figure A-3.0-2 Average major ion and silica concentrations in filtered groundwater from selected perched intermediate and regional wells screened in Tpf or Qct

Average concentrations for selected wells screened in the Puye Formation (Tpf) or the Cerro Toledo interval of the Bandelier Tuff (Qct)



Source: Table A-3.0-3

GBIR R4 = Groundwater Background Investigation Report, Revision 4 (LANL 2010, 110535)

5th to 95th percentile range of concentrations

Figure A-3.0-3 Average trace metal concentrations in filtered groundwater from selected perched intermediate and regional wells screened in Tpf or Qct

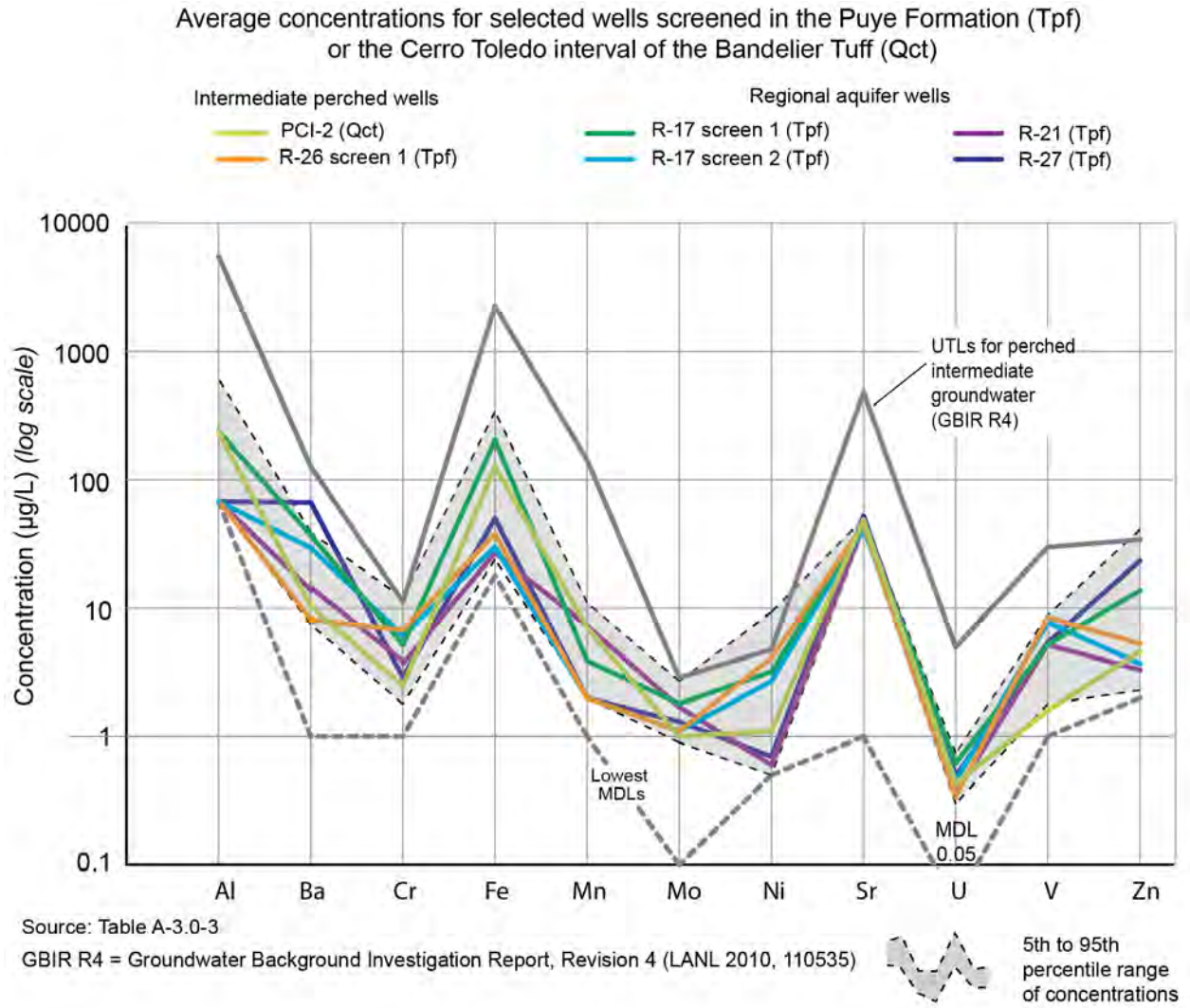


Figure A-3.0-4 Average trace metal concentrations in unfiltered groundwater from selected perched intermediate and regional wells screened in Tpf or Qct

Table A-1.0-1
Well Purging Volumes and Associated Final Field Water-Quality Parameters for R-47i

| Date | Purge Volume ^a (gal.) | Pump Rate (gpm) | Turbidity (NTU) | pH | ORP ^b (mV) | Dissolved Oxygen (mg/L) | Specific Conductance (μ S/cm) | Temperature ($^{\circ}$ C) |
|---|-------------------------------------|--------------------|--------------------|------|--------------------------|----------------------------|---------------------------------------|--------------------------------|
| Final Field Parameters at End of Well Development and Aquifer Testing (LANL 2010, 109188, section 5.2 and Table B-1.2-1) | | | | | | | | |
| 24-Nov-09 | 2607 | 1.5 | 17.6 | 7.7 | -26 | 3.08 | 176 | 14.4 |
| 5-Dec-09 | 1381 | 0.9 | 7.16 | 7.76 | -50 | 1.65 | 78 | 12.1 |
| Final Field Parameters during Post-Development Sampling Events (Water-Quality Database and Field Notes from Appendix C) | | | | | | | | |
| 21-Dec-09 | 166 | 0.8 | 6.52 | 6.96 | 6.5 | 3.06 | 205 | 15.3 |
| 8-Apr-10 | 150 | 0.65 | 3.44 | 7.15 | 180 | 4.69 | 173 | 15.2 |
| 23-Sep-10 | 112 (3 CVs) ^c | 1.1 | 1.38 | 6.92 | 264 | 4.65 | 167 | 15.2 |
| 23-Sep-10 | 223 (6 CVs) | 0.5 | 1.91 | 6.91 | 267 | 4.98 | 154 | 15.7 |
| 2-Dec-10 | 112 | 0.9 | 3.01 | 7.06 | 295 | 4.92 | 152 | 13.2 |

Source: Appendixes B (data) and C (purge volumes).

^a Purge volume = Formation water purged before sampling; excludes the volume of the pump drop pipe. In general, the target purge volume is 3 CVs (3 x 37.2 gal. = 112 gal.). For the extended purge event on 23-Sep-10, the target purge volume was 6 CVs (3 x 37.2 gal. = 223 gal.), with samples collected for every 1 CV.

^b ORP values can be converted to Eh (mV) by adding a temperature-sensitive correction factor, which is 208.9 mV for a temperature of 15 $^{\circ}$ C.

^c Field parameters at 3 CVs are shown for the 23-Sep-10 extended purge event to allow comparison with the 3 CVs parameter values for the other three sampling events.

Table A-1.0-2
Well Purging Volumes and Associated Final Field Water-Quality Parameters for Extended Purge Event at R-47i on September 23, 2010

| Start Time for Sample Collection | Last Field Measurement before Sample Collection | | | | | | | |
|----------------------------------|---|--------------------|--------------------|------|-------------|----------------------------|---------------------------------------|--------------------------------|
| | Purge Volume + Drop Pipe* (gal.) | Pump Rate (gpm) | Turbidity (NTU) | pH | ORP (mV) | Dissolved Oxygen (mg/L) | Specific Conductance (μ S/cm) | Temperature ($^{\circ}$ C) |
| 1 CV @ 12:00 | 71 | 1.25 | 1.52 | 7.75 | 189 | 5.57 | 144 | 14.5 |
| 2 CVs @ 12:32 | 111 | 1.1 | 2.19 | 6.88 | 210 | 8.36 | 160 | 15.1 |
| 3 CVs @ 13:06 | 150 | 1.1 | 1.38 | 6.88 | 307 | 4.65 | 166 | 15.2 |
| 4 CVs @ 13:40 | 188 | 1.1 | 2.05 | 7.00 | 277 | 4.49 | 167 | 15.7 |
| 5 CVs @ 14:14 | 221 | 1.1 | 1.98 | 7.00 | 207 | 4.60 | 162 | 15.9 |
| 6 CVs @ 15:22 | 257 | 0.5 | 1.91 | 6.90 | 267 | 4.97 | 155 | 15.8 |

Source: Appendixes B (data) and C (purge volumes)

*Drop pipe volume = 34 gal. for this event.

Table A-2.0-1
Concentrations of Major Ions, Silica, Selected Anions, TDS, and TOC for R-47i (Validated Data)

| 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) | ALK (mg/L as CaCO ₃) | pH ^b |
|-----------|-----------|----------|-----------|-----------|------------------------|-----------|----------|--|-------------------------|-------------------------|------------|------------|----------------------------------|-----------------|
| 21-Dec-09 | 30.3 | 0.882 | 10.6 | 2.42 | 18.5 | 3.97 | 0.12 | 0.489 | 0.222 | 56 | 145 | 0.94 | 71 | 7.0 |
| 8-Apr-10 | 22.3 | 0.739 | 10.5 | 2.51 | 11.9 | 3.3 | 0.16 | 0.372 | 0.231 | 59 | 151 | 1.33 | 63 | 7.2 |
| 23-Sep-10 | 17.1 | 0.56 | 9.61 | 2.35 | 8.65 | 2.82 | 0.15 | 0.483 | 0.272 | 55 | 126 | 1.25 | 78 | 7.2 |
| 2-Dec-10 | 18.2 | 0.588 | 10.1 | 2.44 | 8.89 | 2.88 | 0.15 | 0.254 | 0.225 | 56 | 142 | 2.87 | 85 | 7.2 |

Source: Appendix B

*ALK = Carbonate alkalinity. Alkalinity concentrations for the first two events (21-Dec-09 and 8-Apr-10) were measured by an outside analytical laboratory. Alkalinity concentrations for the events on 23-Sep-10 and 2-Dec-10 were measured by an on-site laboratory (Earth Systems Evaluation Group [EES-14]). The corresponding pH values shown are those measured in the field for the first two events, and those measured at the on-site laboratory (EES-14) for the last two events.

Table A-2.0-2
Concentrations of Major Ions, TDS, and TOC for
R-47i during Extended-Purge on September 23, 2010 (EES-14 Data)

| Sample | Na (mg/L) | K (mg/L) | Ca (mg/L) | Mg (mg/L) | SO ₄ (mg/L) | Cl (mg/L) | F (mg/L) | NO ₃ -N (mg/L) | SiO ₂ (mg/L) | TOC (mg/L) | Alkalinity - CO ₃ +HCO ₃ (mg/L as CaCO ₃) | pH |
|----------------|-----------|----------|-----------|-----------|------------------------|-----------|----------|---------------------------|-------------------------|------------|---|-----|
| R-47i @ 1 CV | 16.77 | 0.564 | 10.62 | 2.77 | 10.2 | 3.48 | 0.12 | 0.377 | 66 | 0.63 | 71 | 7.1 |
| R-47i @ 2 CVs | 20.37 | 0.615 | 11.58 | 3.03 | 11.9 | 3.99 | 0.22 | 0.342 | 64 | 0.66 | 84 | 7.3 |
| R-47i @ 3 CVs | 21.46 | 0.631 | 11.00 | 2.90 | 12.2 | 4.03 | 0.22 | 0.338 | 65 | 0.58 | 84 | 7.2 |
| R-47i @ 4 CVs | 21.66 | 0.689 | 11.31 | 2.97 | 12.3 | 4.04 | 0.23 | 0.336 | 65 | 0.65 | 84 | 7.2 |
| R-47i @ 5 CV s | 20.72 | 0.716 | 10.90 | 2.90 | 11.5 | 3.89 | 0.22 | 0.343 | 67 | 0.56 | 81 | 7.3 |
| R-47i @ 6 CVs | 19.65 | 0.689 | 10.64 | 2.77 | 10.8 | 3.77 | 0.23 | 0.341 | 66 | 0.60 | 78 | 7.1 |

Source: Appendix B.

**Table A-2.0-3
Concentrations of Selected Trace Metals for R-47i (Validated Data)**

| Sample | Al (µg/L) | Ba (µg/L) | Cr (µg/L) | Fe (µg/L) | Mn (µg/L) | Mo (µg/L) | Ni (µg/L) | Sr (µg/L) | U (µg/L) | V (µg/L) | Zn (µg/L) |
|---------------------------|-----------------|--------------|-----------------|--------------|--------------|--------------|--------------|--------------|-------------|-------------|--------------|
| MDL ^a | 68 | 1 | 2.5 | 30 | 2 | 0.1 | 0.5 | 1 | 0.05 | 1 | 3.3 |
| PQL ^a | 200 | 5 | 10 | 100 | 10 | 0.5 | 2 | 5 | 0.2 | 5 | 10 |
| Filtered Samples | | | | | | | | | | | |
| 21-Dec-09 | 73.1 | 13.1 | 2.78 | 55.6 | 95.2 | 8.16 | 1.52 | 66 | 0.686 | <2.88 | 4.95 |
| 8-Apr-10 | ND ^b | 12.1 | ND | 42.9 | 64.6 | 5.09 | 4.44 | 60.8 | 0.506 | 1.21 | 3.53 |
| 23-Sep-10 | ND | 8.48 | 2.64 | ND | 31.6 | 2.9 | 2.58 | 54 | 0.55 | 1.24 | ND |
| 2-Dec-10 | 143 | 7.88 | ND | 41.6 | 13.3 | 4.51 | 2.78 | 57.7 | 0.774 | ND | 8.87 |
| Unfiltered Samples | | | | | | | | | | | |
| 21-Dec-09 | 569 | 14.3 | ND ^c | 465 | 105 | 8.29 | ND | 70.7 | 0.864 | <3.01 | 7.96 |
| 8-Apr-10 | 190 | 13.3 | ND | 214 | 68.2 | 5.07 | 4.9 | 63.9 | 0.591 | 1.46 | 5.06 |
| 23-Sep-10 | 73.5 | 9.02 | 2.79 | 68.2 | 32.8 | 2.92 | 2.6 | 55.9 | 0.618 | 1.31 | ND |
| 2-Dec-10 | 214 | 8.79 | 3.73 | 359 | 24.4 | 3.77 | 4.93 | 57.4 | 0.716 | 1.18 | 12 |

Source: Appendix B.

^a Method detection limits (MDLs) and PQLs are from the 2010 Interim Facility-Wide Groundwater Monitoring Plan (LANL 2010, 109830, Appendix B) unless noted otherwise.

^b ND = Not detected.

^c Analytical limits reported for Cr for this sample are higher than usual: MDL = 13 µg/L and PQL = 50 µg/L.

Table A-2.0-4
Concentrations of Selected Trace Metals for
R-47i during Extended-Purge on September 23, 2010 (EES-14 Data)

| Sample | Al (µg/L) | Ba (µg/L) | Cr (µg/L) | Fe (µg/L) | Mn (µg/L) | Mo (µg/L) | Ni (µg/L) | Sr (µg/L) | U (µg/L) | V (µg/L) | Zn (µg/L) |
|---------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|-------------|-------------|--------------|
| MDL* | 1 | 1 | 1 | 10 | 1 | 1 | 1 | 1 | 0.2 | 1 | 1 |
| Filtered Samples | | | | | | | | | | | |
| R-47i @ 1 CV | 75.8 | 8.8 | 2.83 | 55.1 | 30.7 | 1.87 | 4.94 | 56.8 | 0.380 | 1.82 | 5.44 |
| R-47i @ 2 CVs | 73.7 | 10.1 | 3.00 | 50.6 | 36.5 | 3.82 | 3.39 | 61.3 | 0.701 | 1.88 | 5.94 |
| R-47i @ 3 CVs | 84.0 | 9.4 | 2.76 | 56.0 | 33.3 | 3.52 | 3.29 | 58.0 | 0.691 | 1.77 | 4.14 |
| R-47i @ 4 CVs | 66.7 | 9.5 | 2.76 | 63.4 | 34.1 | 3.75 | 3.12 | 58.2 | 0.668 | 1.71 | 8.48 |
| R-47i @ 5 CVs | 62.5 | 11.5 | 4.60 | 60.2 | 37.6 | 2.70 | 4.85 | 61.7 | 0.997 | 2.84 | 3.79 |
| R-47i @ 6 CVs | 88.7 | 9.2 | 2.49 | 61.4 | 37.3 | 2.55 | 4.04 | 57.7 | 0.555 | 1.71 | 6.35 |
| Unfiltered Samples | | | | | | | | | | | |
| R-47i @ 1 CV | 113.5 | 9.0 | 2.95 | 123.8 | 31.9 | 1.87 | 4.39 | 57.2 | 0.434 | 1.83 | 5.30 |
| R-47i @ 2 CVs | 144.2 | 10.4 | 3.61 | 131.1 | 38.0 | 3.97 | 5.61 | 63.8 | 0.790 | 2.02 | 7.32 |
| R-47i @ 3 CVs | 110.9 | 9.8 | 3.66 | 102.3 | 34.9 | 3.76 | 3.73 | 59.7 | 0.770 | 1.93 | 6.67 |
| R-47i @ 4 CVs | 95.4 | 12.0 | 4.35 | 96.6 | 43.1 | 3.19 | 3.69 | 70.0 | 0.828 | 2.39 | 6.70 |
| R-47i @ 5 CVs | 178.4 | 9.4 | 2.61 | 126.1 | 34.2 | 3.06 | 3.08 | 56.7 | 0.646 | 1.69 | 5.47 |
| R-47i @ 6 CVs | 84.05 | 8.5 | 1.95 | 83.2 | 31.9 | 2.56 | 3.47 | 53.5 | 0.529 | 1.51 | 5.58 |

Source: Appendix B.

*MDL = Method detection limit (EES-14).

**Table A-3.0-1
Selected Perched Intermediate and Regional Wells Completed in Tpf or Qct**

| Well | Screened Interval | | | | | Post-Completion Activities | | Sampling Events Used in this Report ^a | |
|-------------------|-------------------|-----------------|------|-----------------------|----------------------------|----------------------------|---------------------------|--|-----------------------------------|
| | Depth (ft bgs) | Completion Zone | Unit | k ^b (ft/d) | Specific Capacity (gpm/ft) | End of Development | Sampling System Installed | Earliest Sample | Most Recent Sample (as of Dec 10) |
| PCI-2 | 512 | Intermediate | Tpf | na ^{c,d} | na ^d | 20-Apr-09 | 9-Jun-09 | 11-Jun-09 | 11-Oct-10 |
| R-17 screen 1 | 1057 | Regional | Tpf | 1.7 | 0.3 | 24-Feb-06 | 12-Dec-06 | 22-Feb-07 | 22-Oct-10 |
| R-17 screen 2 | 1124 | Regional | Tpf | 147 | 8.3 | 24-Feb-06 | 12-Dec-06 | 22-Feb-07 | 22-Oct-10 |
| R-21 | 889 | Regional | Tpf | na | 0.2 | 5-Dec-02 | 14-Feb-03 | 6-Jun-05 | 11-Oct-10 |
| R-26 screen 1 | 659 | Intermediate | Qct | 2 | na | 16-Nov-03 | 16-Jul-04 | 13-Apr-05 | 13-Aug-10 |
| R-27 ^e | 852 | Regional | Tpf | 5 | na | 14-Nov-05 | 16-Sep-06 | 2-Feb-07 | 14-Sep-10 |
| R-47i | 840 | Intermediate | Tpf | 0.2 | 0.7 | 24-Nov-09 | 18-Dec-09 | 21-Dec-09 | 2-Dec-10 |

Sources: Well completion reports (LANL 2009, 107342; Kleinfelder 2006, 092493; Kleinfelder 2003, 090047; Kleinfelder 2005, 087846; Kleinfelder 2006, 092488; LANL 2010, 109188); LANL water-quality database.

^a Dates listed for wells PCI-2, R-17, R-26, and R-27 indicate the range of sampling events for which water-quality data are included in the statistical summaries presented in this appendix (Tables A-3.0-2 and A-3.0-4).

^b k = Hydraulic conductivity.

^c na = Not available.

^d Because of the low pumping and recharge rates observed during well development, no aquifer testing was conducted at PCI-2.

^e A dedicated pump was first installed in well R-27 on 3-Aug-06 but had to be pulled for repairs. The pump was reinstalled on 16-Sep-06.

Table A-3.0-2
Average Concentrations of Major Ions and Total Dissolved Solids for
Selected Perched Intermediate and Regional Wells Completed in Tpf or Qct, 2005–2010

| Location | No. of Events | Na (mg/L) | K (mg/L) | Ca (mg/L) | Mg (mg/L) | SO ₄ (mg/L) | Cl (mg/L) | F (mg/L) | NO ₃ -N (mg/L) | SiO ₂ (mg/L) | ALK ^a (mg/L as CaCO ₃) | TDS (mg/L) |
|--|------------------|-----------|----------|-----------|-----------|------------------------|-----------|----------|---------------------------|-------------------------|---|------------|
| Perched Intermediate Wells | | | | | | | | | | | | |
| PCI-2 | 7 | 11.9 | 0.33 | 8.7 | 2.21 | 1.48 | 1.30 | 0.20 | 0.10 | 70 | 49 | 122 |
| R-26 screen 1 | 13 | 8.5 | 2.20 | 7.4 | 2.91 | 1.18 | 1.17 | 0.14 | 0.35 | 57 | 46 | 104 |
| Regional Aquifer Wells | | | | | | | | | | | | |
| R-17 screen 1 | 17 | 12.0 | 1.55 | 9.8 | 2.85 | 2.60 | 1.92 | 0.27 | 0.24 | 72 | 56 | 130 |
| R-17 screen 2 | 17 | 10.1 | 2.36 | 8.8 | 2.85 | 1.73 | 1.64 | 0.22 | 0.34 | 76 | 54 | 129 |
| R-21 | 19 | 10.1 | 1.67 | 11.5 | 2.98 | 2.07 | 1.82 | 0.28 | 0.33 | 71 | 57 | 138 |
| R-27 | 10 | 10.1 | 1.33 | 10.1 | 2.98 | 1.45 | 1.55 | 0.24 | 0.27 | 67 | 51 | 125 |
| Summary Statistics, All Wells (Total = 81 events) | | | | | | | | | | | | |
| Average | n/a ^b | 10.4 | 1.71 | 9.6 | 2.85 | 1.85 | 1.63 | 0.23 | 0.28 | 69 | 53 | 127 |
| ±1 Std dev | n/a | ±1.2 | ±0.57 | ±1.4 | ±0.23 | ±0.60 | ±0.29 | ±0.08 | ±0.10 | ±6 | ±6 | ±20 |
| 5th Percentile | n/a | 8.3 | 0.35 | 7.3 | 2.25 | 1.13 | 1.13 | 0.12 | 0.08 | 56 | 45 | 98 |
| 95th Percentile | n/a | 12.4 | 2.39 | 11.8 | 3.09 | 2.93 | 1.98 | 0.39 | 0.41 | 77 | 59 | 144 |

Source: Calculated from data extracted from the LANL water-quality database.

^a ALK = Carbonate alkalinity.

^b n/a = Not applicable.

Table A-3.0-3
Average Concentrations of Trace Metals for Selected
Perched Intermediate and Regional Wells Completed in Tpf or Qct, 2005–2010

| Location | Al (µg/L) | Ba (µg/L) | Cr (µg/L) | Fe (µg/L) | Mn (µg/L) | Mo (µg/L) | Ni (µg/L) | Sr (µg/L) | U (µg/L) | V (µg/L) | Zn (µg/L) |
|--|------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|-------------|-------------|--------------|
| MDL ^a | 68 | 1 | 2.5 | 30 | 2 | 0.1 | 0.5 | 1 | 0.05 | 1 | 3.3 |
| PQL ^a | 200 | 5 | 10 | 100 | 10 | 0.5 | 2 | 5 | 0.2 | 5 | 10 |
| Filtered Samples | | | | | | | | | | | |
| PCI-2 | ND ^b | 8.7 | ND | ND | 6.2 | 0.9 | 0.9 | 47 | 0.37 | 1.4 | ND |
| R-17 screen 1 | ND | 35.9 | 2.6 | 87 | ND | 1.6 | 1.9 | 43 | 0.59 | 5.0 | 7.5 |
| R-17 screen 2 | ND | 29.3 | 4.0 | ND | ND | 1.1 | 2.2 | 42 | 0.44 | 7.7 | 3.7 |
| R-21 | ND | 13.9 | 3.7 | 23 | 7.9 | 1.8 | 0.8 | 45 | 0.36 | 5.2 | ND |
| R-26 screen 1 | ND | 7.9 | 2.6 | ND | ND | 0.9 | ND | 45 | 0.34 | 8.3 | 2.7 |
| R-27 | ND | 26.6 | 3.1 | ND | ND | 1.4 | 0.6 | 48 | 0.49 | 5.1 | ND |
| Statistics^c for Filtered Samples (All Wells) | | | | | | | | | | | |
| Total count | 82 | 82 | 81 | 82 | 82 | 82 | 81 | 82 | 82 | 82 | 82 |
| Detects | 1 | 82 | 53 | 11 | 33 | 53 | 50 | 82 | 74 | 78 | 29 |
| Detection rate | 1% | 100% | 65% | 13% | 40% | 65% | 62% | 100% | 90% | 95% | 35% |
| Average detect | ND | 22 | 3.3 | ND | 6.5 | 1.4 | 1.5 | 45 | 0.44 | 5.9 | 7.3 |
| ±1 Std dev | n/a ^c | ±11 | ±1.1 | n/a | ±3.6 | ±0.6 | ±1.8 | ±3 | ±0.11 | ±2.0 | ±12 |
| 5th Percentile | ND | 7.4 | 1.6 | ND | 2.3 | 0.8 | 0.5 | 41 | 0.30 | 1.6 | 2.4 |
| 95th Percentile | NC ^c | 38 | 5.0 | 36 | 11 | 3.0 | 4.4 | 49 | 0.65 | 8.5 | 19 |
| Maximum detect | 77 | 39 | 6.5 | 234 | 18 | 3.5 | 10 | 51 | 0.75 | 9.5 | 66 |
| Unfiltered Samples | | | | | | | | | | | |
| PCI-2 | 235 | 10.3 | ND | 127 | 7.1 | 1.0 | 1.1 | 49 | 0.43 | 1.6 | 4.6 |
| R-17 screen 1 | 238 | 37.2 | 5.2 | 204 | 3.9 | 1.8 | 3.2 | 44 | 0.62 | 5.2 | 13.7 |
| R-17 screen 2 | ND | 29.6 | 6.1 | ND | ND | 1.1 | 2.7 | 42 | 0.45 | 7.8 | 3.7 |
| R-21 | ND | 13.9 | 3.7 | 27 | 7.3 | 1.7 | 0.6 | 45 | 0.36 | 5.2 | ND |
| R-26 screen 1 | ND | 8.1 | 6.8 | 38 | 2.0 | 1.1 | 4.1 | 45 | 0.34 | 8.5 | 5.3 |
| R-27 | ND | 66.7 | 2.9 | 50 | ND | 1.3 | 0.7 | 52 | 0.49 | 5.4 | 23.4 |
| Statistics^c for Unfiltered Samples (All Wells) | | | | | | | | | | | |
| Total count | 81 | 81 | 80 | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 |
| Detects | 12 | 81 | 55 | 35 | 35 | 54 | 56 | 81 | 71 | 75 | 41 |
| Detection rate | 15% | 100% | 69% | 43% | 43% | 67% | 69% | 100% | 88% | 93% | 51% |
| Average detect | ND | 23 | 4.9 | 111 | 6.0 | 1.4 | 2.4 | 45 | 0.45 | 6.1 | 10 |
| ±1 Std dev | n/a | ±12 | ±3.8 | ±246 | ±3.3 | ±0.6 | ±3.5 | ±3 | ±0.13 | ±1.9 | ±16 |
| 5th Percentile | ND | 7.5 | 1.8 | 24 | 2.0 | 0.9 | 0.5 | 41 | 0.30 | 1.8 | 2.3 |
| 95th Percentile | 212 | 39 | 12 | 341 | 11 | 2.7 | 9.3 | 50 | 0.74 | 8.8 | 41 |
| Maximum detect | 641 | 42 | 25 | 1430 | 14 | 3.5 | 19 | 52 | 0.77 | 9.4 | 80 |

Source: Calculated from data extracted from the LANL water-quality database.

^a MDLs and PQLs are from the 2010 Interim Facility-Wide Groundwater Monitoring Plan (LANL 2010, 109830, Appendix B)

^b ND = Not detected. Note that an average detect of ND does not necessarily indicate ND for all data for that analyte.

^c n/a = Not applicable. Statistics are calculated for those analytes with detection rates ≥35% and when the number of samples ≥8. When these criteria are not met, the average detect and the 5th percentile are both presented as ND, and the std dev (standard deviation) is indicated as n/a (not applicable). When the number of detects is ≥8, 95th percentiles are calculated using the full data sets (detects and nondetects); if <8 detects, the 95th percentile is NC (not calculated)..

Table A-3.0-4
Average Final Field Parameters for Selected
Perched Intermediate and Regional Wells Screened in Tpf or Qct, 2005–2010

| Location | Start Date | End Date | No. of Events | Turbidity (NTU) | pH | ORP (mV) | Dissolved Oxygen (mg/L) | Sp Cond ^a (μS/cm) | Temp (°C) |
|---------------------------------------|------------------|-----------|---------------|-----------------|-----------|------------------|-------------------------|------------------------------|-----------|
| Perched Intermediate Wells | | | | | | | | | |
| PCI-2 | 11-Jun-09 | 11-Oct-10 | 7 | 3.6 | 7.0 | 211 | 7.6 | 100 | 13 |
| R-26 screen 1 | 27-Jul-05 | 13-Aug-10 | 11 | 0.5 | 7.9 | 173 ^b | 5.9 | 104 | 17 |
| Regional Aquifer Wells | | | | | | | | | |
| R-17 screen 1 | 22-Feb-07 | 22-Oct-10 | 16 | 1.9 | 7.8 | 254 | 6.3 | 118 | 21 |
| R-17 screen 2 | 22-Feb-07 | 22-Oct-10 | 16 | 0.4 | 7.8 | 253 | 5.8 | 111 | 21 |
| R-21 | 6-Jun-05 | 11-Oct-10 | 19 | 0.4 | 7.9 | 140 | 5.2 | 122 ^c | 21 |
| R-27 | 2-Feb-07 | 14-Sep-10 | 10 | 0.7 | 7.7 | 118 | 6.1 | 117 | 18 |
| Summary Statistics (All Wells) | | | | | | | | | |
| Count | n/a ^d | n/a | 79 | 79 | 79 | 61 | 74 | 77 | 78 |
| Average | n/a | n/a | n/a | 1.0 ± 1.8 | 7.8 ± 0.4 | 192 ± 109 | 6.0 ± 1.3 | 113 ± 15 | 20 ± 3 |
| 5th Percentile | n/a | n/a | n/a | 0.1 | 7.0 | 52 | 4.2 | 87 | 13 |
| 95th Percentile | n/a | n/a | n/a | 3.4 | 8.1 | 397 | 7.9 | 133 | 23 |
| Minimum | n/a | n/a | n/a | 0.1 | 6.6 | -111 | 0.5 | 77 | 11 |
| Maximum | n/a | n/a | n/a | 14.3 | 8.6 | 434 | 9.1 | 156 | 25 |

Source: Calculated from data extracted from the LANL water-quality database.

^a Sp Cond = Specific conductance.

^b ORP data are available only for one event for this location.

^c Two outliers are excluded from statistical summaries for this field parameter.

^d n/a = Not applicable.

Appendix B

*Groundwater Data for R-47i
(on CD included with this document)*

Appendix C

*Field Notes and Observations
(on CD included with this document)*

