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Status of Inflatable Packer Systems and Assessment of Cross Flow in Monitoring Wells at Los Alamos National Laboratory

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CONTENTS

1.0 INTRODUCTION 1

2.0 ASSESSMENT 1

3.0 CORRECTIVE ACTIONS 2

4.0 ASSESSMENT OF GEOCHEMICAL IMPACTS FROM CROSS FLOW 3

5.0 ADDITIONAL CORRECTIVE ACTIONS PLANNED 4

6.0 REFERENCES 5

Figure

Figure 2.0-1 Monitoring wells with inflatable packer systems 7

Tables

Table 2.0-1 Monitoring Wells with Inflatable Packers and Estimated Cross-Flow Volumes that Occurred in 2009 9

Table 2.0-2 Summary of Packer Pressure Problems and Their Causes, Corrective Actions Taken, and Additional Maintenance Recommendations 10

Appendixes

Appendix A Groundwater-Level Data for Monitoring Wells with Baski Sampling Systems

Appendix B Cross-Flow Volume Analysis

Appendix C Geochemical Evaluation for Cross-Flow Effects in Monitoring Network Wells

Acronyms and Abbreviations

APV	access port valve
bgs	below ground surface
DOE	Department of Energy (U.S.)
Elev	elevation
EP	Environmental Programs Directorate
EPA	Environmental Protection Agency (U.S.)
F	filtered sample
FLD	field parameters
GELC	General Engineering Laboratories, Inc.
gpm	gallons per minute
GIS	Geographical Information System

HWB	Hazardous Waste Bureau
LANL	Los Alamos National Laboratory
LASO	Los Alamos Site Office
meq	milliequivalents
N/A	not applicable
NMED	New Mexico Environment Department
psi	pounds per square inch
PVC	polyvinyl chloride
RACER	Risk Analysis, Communication, Evaluation, and Reduction
SOP	standard operating procedure
STSL	Severn Trent Laboratories, Inc.
TA	technical area
TKN	total Kiedahl nitrogen
TOC	total organic carbon
UF	unfiltered sample
UMTL	University of Miami Tritium Laboratory

1.0 INTRODUCTION

This report summarizes the status of inflatable packers associated with the Baski multilevel sampling systems and temporary packer systems in Los Alamos National Laboratory (the Laboratory) monitoring wells, and the impacts related to the loss of pressure and resultant underinflation of packers in these systems. The report includes an assessment of the identified causes for the pressure losses, estimates of the volumes of cross flow that may have occurred, identification of groundwater samples impacted by cross-flow, corrective actions taken to date, and recommendations for additional actions related to the issues associated with the packer systems.

This report was developed as a follow-up to the November 20, 2009, letter from the Laboratory to the New Mexico Environment Department (NMED) regarding recently identified issues related to loss of pressure in packer systems in monitoring wells at the Laboratory (LANL 2009, 107503). This report also provides documentation and corrective actions relating to the packer underinflation incident at well R-16, in response to the letter from NMED on December 23, 2009, regarding its approval with modifications of the well R-16 rehabilitation and conversion summary report (NMED 2009, 108209, item 7).

2.0 ASSESSMENT

Following identification of the packer issues described in the November 20, 2009, letter to NMED, a review of packer systems in the Laboratory's monitoring wells was conducted to evaluate the performance of the systems and to identify potential causes for the problems. Currently, packer systems are installed in 14 monitoring wells with multiple screens at the Laboratory. Thirteen packer systems are integral parts of Baski multilevel sampling systems, and one is an inflatable packer system installed as a temporary measure in R-22 following well rehabilitation. The locations of monitoring wells with packer systems are shown in Figure 2.0-1.

The current status of all packer systems in Laboratory monitoring wells was evaluated to better understand the causes of the pressure losses responsible for packer underinflation. Performance of the packer systems was evaluated using field notes from personnel responsible for monitoring the pressures within the systems. In addition, water-level data from pressure transducers were evaluated to identify the specific periods for which packers may have been underinflated. Water-level data provide useful indications of proper performance of packers in monitoring wells as well as indications of periods when potential cross flow and commingling of groundwater between monitored zones in a well may have occurred. In general, for a given well, water levels tend to decline with increasing depth in the regional aquifer. These differences in water level will persist as long as hydraulic isolation is maintained between the screened intervals. However, if a packer is underinflated and no longer isolates the two adjacent screens, a composite water level is observed in both screens. Thus, water-level data from pressure transducers provide valuable information regarding the performance of packer systems in monitoring wells.

Groundwater-level data for the inflatable packers associated with the thirteen Baski sampling systems in Laboratory monitoring wells are presented in Appendix A. These water-level data indicate that cross flow between screened intervals potentially occurred in monitoring wells R-16, R-20, and R-23i at various times over the past year because of underinflated packers in these sampling systems. The pressure data in Appendix A also show the specific time periods during which the packers in these wells were underinflated to the extent that cross flow occurred between zones.

Packer underinflation resulting in potential cross flow also occurred with the temporary packer systems installed in wells R-16 and R-22 in 2009 following well rehabilitation. The temporary packer system installed in R-16 was replaced in October 2009 with the packer system that is part of the Baski multilevel sampling system. The temporary packer system installed in R-22 remains in place pending a decision on the final disposition of this well.

An analysis of the estimated volumes of cross flow that may have occurred as a result of loss of pressure in packer systems is provided in Appendix B. These estimates were calculated based on the duration of cross-flow events (Appendix A), head differences between screened intervals, and hydraulic conductivity or specific-capacity data for each screened interval.

Table 2.0-1 summarizes the status of packer systems installed in Laboratory monitoring wells. This table identifies systems where problems maintaining packer pressure have been documented, whether cross flow may have occurred, and how much cross flow occurred based on the analysis presented in Appendix B. Note that several Baski sampling systems in recently installed monitoring wells R-40, R-44, and R-45 have had problems maintaining packer pressure but have shown no evidence of cross flow based on water-level data.

Table 2.0-2 summarizes the pressure problems identified and the primary causes for these problems, the corrective actions taken to date, and recommendations for additional corrective actions. Table 2.0-2 also summarizes the current status for each packer system where pressure problems have been encountered.

3.0 CORRECTIVE ACTIONS

The Laboratory has implemented a two-part corrective-action process to address the issues related to loss of pressure in packer systems. Several corrective actions were implemented immediately to stop any further cross flow from occurring. Several longer-term corrective-action steps have also been taken to reduce the potential for pressure losses in the future.

- A new formal procedure addresses pressure monitoring of packer systems. The procedure lists well-specific minimum and maximum packer pressure ranges for each packer system, and identifies target pressures (for inflation purposes), and action-level pressures (pressures that require additional pressurization).
- The frequency of field pressure checks for packer systems was increased from approximately once or twice per month to frequencies based on the performance of the individual systems. A monitoring schedule was developed based on the performance and reliability of each system. Packers with no history of leakage problems are monitored less frequently than packers with a history of leakage problems. This schedule is revised on an as-needed basis to incorporate modifications to the systems, including repairs or modifications to the packer systems.
- Data and field observations were compiled for each well to identify any trends in packer performance indicating the need for repairs to the packer system. Where appropriate, dedicated nitrogen tanks were deployed to wells with packers to ensure adequate packer pressures are maintained.
- Immediate corrective actions were taken to resolve the problems with the inflatable packers that had been installed temporarily in R-16 and R-22. The packer in R-16 was removed and replaced with a permanent packer system that is part of the Baski dual-valve sampling system, as planned under the well rehabilitation activities (LANL 2009, 106945). The damaged packers in R-22 were

replaced. The packer system in R-22 will be removed once a final decision has been made regarding the final reconfiguration of this well.

- A drilling work-over rig was mobilized to repair the Baski multilevel sampling systems in R-20 and R-23i. The Baski system at R-20 was repaired without requiring its removal from the well; the Baski system at R-23i was pulled and repaired and is scheduled for reinstallation at the end of February 2010.
- Nitrogen tanks have been installed at monitoring wells where packer systems were found to be leaking. The tanks serve as a pressure reservoir, maintaining operational pressures within the packers in spite of any leaks.
- Monitoring well R-16 is more vulnerable to tampering and vandalism than other monitoring wells with packer systems, because it is located in an area easily accessible to the public. The well had previously been surrounded by an unlocked fence. Access to R-16 is now locked, and the fence has been moved away from the wellhead to further protect the system from tampering or unauthorized access.
- Security measures are being implemented to protect wells with packer systems installed from tampering and vandalism. Metal lockable gas cabinets have been ordered for systems with nitrogen tanks at the wellheads. The safety manifolds that mount directly on the packer-pressure regulators will be locked within the gas cabinets, minimizing the potential for unauthorized access and tampering. In addition, the nylon high-pressure lines between the nitrogen tanks and the packer system are being replaced with ruggedized high-pressure metal tubing.
- Samples found to be affected by cross flow have been flagged and identified as such in the Laboratory groundwater quality database (e.g., as indicated in Table C-6.0-1).
- Additional improvements in the design for the Baski sampling systems are being considered for new systems. Potential modifications being considered include replacement of the packer inflation valves with a more-reliable valve design, replacement of the Swagelok fittings with more reliable fittings, and replacement of the PVC inflation lines with stainless-steel lines.
- Should packer pressures drop below the minimum pressure ranges identified in the new field procedure, a notification process has been put in place that will require an immediate assessment of whether cross flow may have occurred based on water-level data for the monitoring well. If water-level data indicate cross flow may have occurred, and if there is a potential for contaminant migration from a shallower screen to a deeper screen, the NMED Hazardous Waste and Water Quality Control Bureaus will be notified in a timely manner.

4.0 ASSESSMENT OF GEOCHEMICAL IMPACTS FROM CROSS FLOW

Packer systems in monitoring wells R-16, R-20, and R-23i potentially allowed cross flow to occur between monitoring horizons during periods of underinflation. Nine water-quality samples were collected from the lower screens of these wells between June and December 2009, during or after losses of pressure that led to packer underinflation. Geochemical indicators in these nine samples were evaluated for evidence of commingling with groundwater from an overlying interval, based primarily on visual examination of Piper (trilinear) plots and time-series plots. The geochemical evaluation of cross-flow impacts is presented in Appendix C, as summarized below and in Table C-6.0-1 of Appendix C.

There is no evidence for commingled water in the sample collected from R-20, screen 2, following losses of pressure, and evidence for commingled water is inconclusive for samples collected from R-16, screen 4. Although it is conceivable that some proportion of mixed groundwater may be present in one or more samples from the lower screened intervals in these two wells, the geochemical effects of such mixing appear to be minor.

In contrast, multiple lines of geochemical evidence indicate the presence of commingled water in the sample collected on June 10, 2009, from R-23i screen 3. This is consistent with the analysis of the pressure transducer data for R-23i (Appendix A), which indicate this sample was collected during a period when the packer was underinflated, and when cross flow from the upper screen to the lower screen was occurring. The water chemistry of the sample collected from the lower screen of R-23i on June 10, 2009 represents a mixture of water between the lower and upper screened intervals of R-23i. These data have been flagged in the Laboratory's water quality database, and a statement has been included in their comment fields indicating that the samples collected are believed to be commingled water from screens 2 and 3.

The geochemical review of the data demonstrates the transient nature of the cross flow that occurred in monitoring wells R-16, R-20, and R-23i. Of the nine groundwater samples collected from the lower screens of these wells between June and December 2009, during or after loss of packer pressure, the only sample that showed an impact was the sample collected from R-23i during the actual cross-flow event, while the packer was underinflated. In all other cases, the groundwater chemistry data indicate that although cross flow may have occurred during periods before the sampling event, natural dilution processes (e.g., hydrodynamic dispersion) in combination with standard purging protocols resulted in short-lived commingling. The data indicate the geochemical impacts from the cross flow at monitoring wells R-16, R-20, and R-23i were short-term, dissipating within a few months following packer reinflation. The actual time required for the geochemical effects to revert to the original chemistry is well-screen specific and a function of the heterogeneity of the formation, the hydraulic conductivity, and the hydraulic gradients in the vicinity of the well screen.

5.0 ADDITIONAL CORRECTIVE ACTIONS PLANNED

Groundwater chemistry data for samples collected from the lower screen of R-23i on June 10, 2009 have been flagged in the Laboratory's water quality database, and a statement has been included in its comment fields indicating that the samples collected may be commingled water from screens 2 and 3. In the future, if packer underinflation results in cross flow, groundwater samples that may have been potentially impacted by cross flow will be assessed geochemically to determine if geochemical effects from the cross flow were present in the samples. If these effects are observed, the data will be flagged in the Laboratory's water-quality database and a statement will be included in associated comment fields indicating the samples collected may be commingled water from multiple well screens.

Groundwater chemistry data from samples collected from wells R-20 and R-23i following packer deflation events in 2009 indicate that the cross-flow effects on chemistry were short-lived. The cross flow that occurred did not significantly impact the chemistry of samples collected from these wells after the packers had been reinflated. For this reason, the Laboratory proposes no additional actions (including no additional purging beyond that conducted during routine sampling) at R-20 and R-23i.

Because the lower screen in well R-16 did not provide representative water-quality data before well rehabilitation, there is uncertainty regarding the baseline water quality of groundwater from the lower screen in well R-16. However, the geochemical assessment of postrehabilitation data from this well show distinct water chemistry differences between samples collected from the two screens. Both screens of R-16 will continue to be sampled on a quarterly basis in accordance with the 2009 Interim Facility Wide Groundwater Monitoring Plan (LANL 2009, 106115), with a minimum of three casing volumes purged before sampling. These data will be evaluated to verify the preliminary findings that cross-flow effects have dissipated at R-16.

The current inflatable packer system installed as a temporary measure in well R-22 will be maintained until a decision is reached between the Laboratory and NMED on the final disposition of the well.

In response to the packer deflation problems documented in 2009, the Laboratory has increased the pressure-monitoring frequency and formalized the pressure-monitoring process to reduce the potential for these types of problems in the future and to reduce the duration if such an event should occur. Packer pressures in monitoring wells are monitored more frequently and on a schedule appropriate for each packer system. A formal standard operating procedure has been implemented for field personnel specifying minimum packer pressures, maximum packer pressures, and operational pressure ranges for each packer system. If packer pressures drop below the minimum required pressure, a process is implemented to allow a rapid assessment of whether cross flow has occurred based on water levels and the pressure monitoring history for the packer system. If cross flow was determined to have occurred, appropriate corrective action will be taken. This corrective action will depend on the volume of cross flow, the cause for the packer failure, and whether the cross flow event could potentially result in commingled waters that compromise data representativeness. The Laboratory will notify NMED Hazardous Waste Bureau and provide additional notifications to NMED as appropriate.

6.0 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.

LANL (Los Alamos National Laboratory), May 2009. "2009 Interim Facility-Wide Groundwater Monitoring Plan," Los Alamos National Laboratory document LA-UR-09-1340, Los Alamos, New Mexico. (LANL 2009, 106115)

LANL (Los Alamos National Laboratory), September 2009. "Rehabilitation and Conversion Summary Report for Well R-16," Los Alamos National Laboratory document LA-UR-09-5372, Los Alamos, New Mexico. (LANL 2009, 106945)

LANL (Los Alamos National Laboratory), November 20, 2009. "Recently Identified Issues with Inflatable Packers in Monitoring Wells," Los Alamos National Laboratory letter (EP2009-0624) to J.P. Bearzi (NMED-HWB) from M.J. Graham (LANL) and D.R. Gregory (DOE-LASO), Los Alamos, New Mexico. (LANL 2009, 107503)

NMED (New Mexico Environment Department), December 23, 2009. "Approval with Modifications, Rehabilitation and Conversion Summary Report for Well R-16," New Mexico Environment Department letter to D. Gregory (DOE-LASO) and D. McInroy (LANL) from J.P. Bearzi (NMED-HWB), Santa Fe, New Mexico. (NMED 2009, 108209)

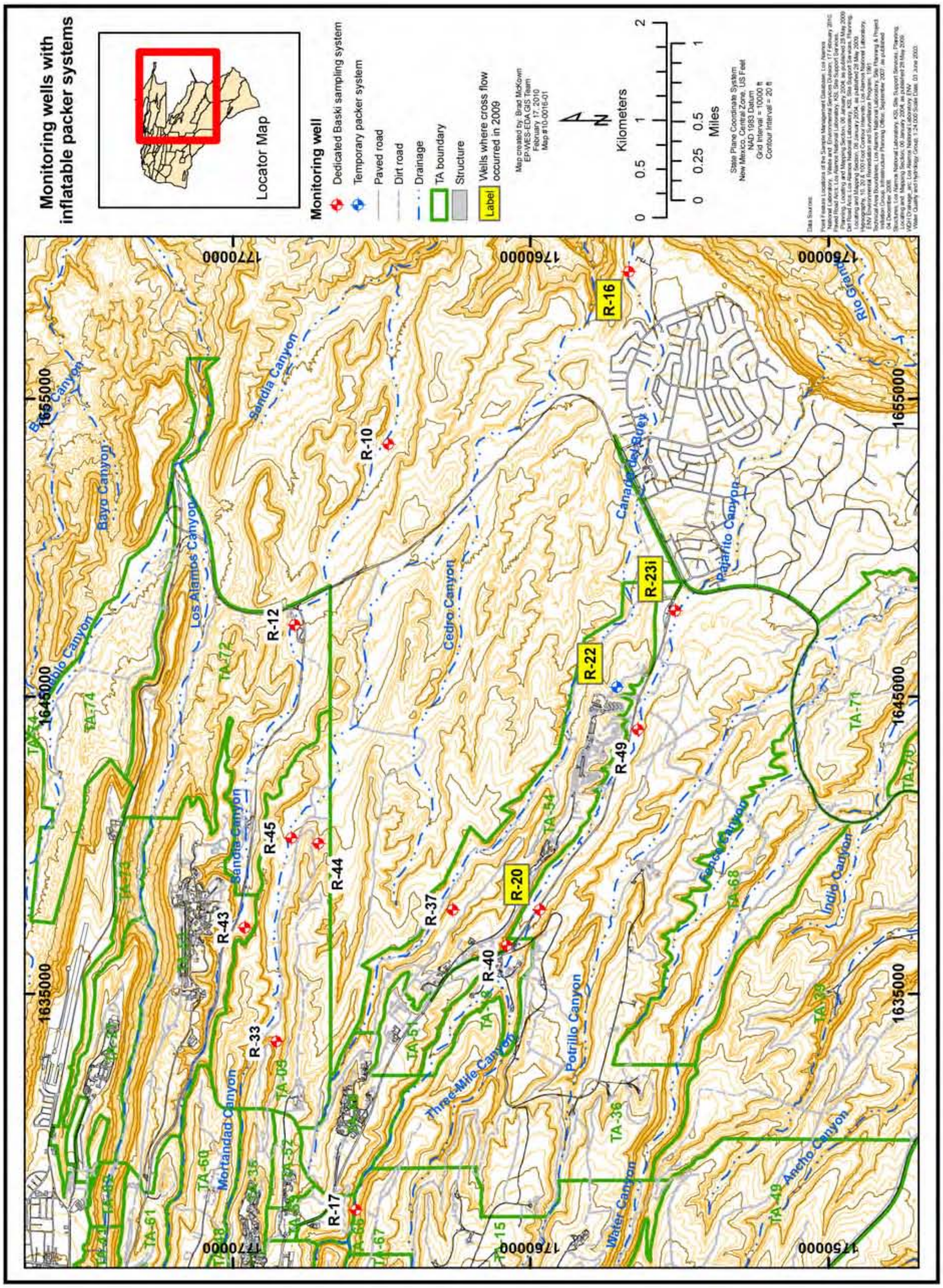

Figure 2.0-1 Monitoring wells with inflatable packer systems

Table 2.0-1
Monitoring Wells with Inflatable Packers and Estimated Cross-Flow Volumes that Occurred in 2009

Monitoring Well	Packer System	Packer Pressure Problems Identified?	Did Cross Flow Occur?	Total Estimated Cross Flow (gal.)
R-10	Baski Dual Valve	No	No	Not applicable
R-12	Baski Dual Pump	No	No	Not applicable
R-16	Temporary Packer / Baski Dual Valve	Yes	Yes	32,465 to 175,342 gal. to screen 4
R-17	Baski Dual Valve	No	No	Not applicable
R-20	Baski Dual Pump	Yes	Yes	2419 to 29,044 gal. to Screen 2
R-22	Temporary Packers	Yes	Yes	19,530 to 20,955 gal. to screen 4; 15,428 to 19,388 gal. to screen 5
R-23i	Baski Dual Pump	Yes	Yes	84,346 gal. to screen 3
R-33	Baski Dual Valve	No	No	Not applicable
R-37	Baski Dual Pump	No	No	Not applicable
R-40	Baski Dual Pump	Yes	No	Not applicable
R-43	Baski Dual Valve	No	No	Not applicable
R-44	Baski Dual Valve	Yes	No	Not applicable
R-45	Baski Dual Valve	Yes	No	Not applicable
R-49	Baski Dual Valve	No	No	Not applicable

Table 2.0-2
Summary of Packer Pressure Problems and Their Causes, Corrective Actions Taken, and Additional Maintenance Recommendations

Well	Packer Pressure Problems	Primary Causes for Pressure Problems	Actions Taken	Current Status	Corrective Actions
R-16	Temporary packer was installed between screens 3 and 4 after well rehabilitation and conversion on July 18, 2009. Packer found deflated on 10/8/2009. A new Baski sampling system was installed 10/14/2009; packer in the new system lost pressure over several days in November. Potential cross flow may have occurred from screens 2 and 3 to screen 4.	Cause of temporary packer failure unknown. Packer pressure was not monitored between July 18, 2009, and October 8, 2009, and the leak in the packer remained undetected during this period. In November, loss of pressure in the packer of the recently-installed Baski sampling system was due to inadvertent disturbance of a pressure fitting at the wellhead during field activities. The resulting loss of pressure was discovered several days later, and the pressure fitting was repaired.	Damaged temporary packer system was removed and replaced with Baski sampling system, as part of the well rehabilitation process. Pressure monitoring of the Baski system is conducted on a more frequent basis in accordance with the established operating procedure and schedule. A nitrogen tank has been installed at the wellhead to maintain operational pressure within the Baski system over longer periods of time. Protective fence around R-16 has been moved away from the well to reduce the potential for tampering.	Operational pressure is maintained within the Baski system using nitrogen tank at wellhead. However, the nitrogen tank loses pressure at a rate of approximately 100 psi/day, indicating a pressure leak in Baski sampling system. The leak is apparently downhole, as an assessment of pressure fittings at the wellhead show no evidence of nitrogen leakage. Recent water level data from R-16 show no further evidence of cross flow.	Remove the Baski sampling system in R-16 for repairs. Continue sampling both screens of R-16 on a quarterly basis in accordance with the Interim Facility-Wide Groundwater Monitoring Plan, and review the geochemical data to confirm that cross flow effects have dissipated. Continue pressure monitoring per established procedure and schedule.
R-20	R-20 Baski packer system lost pressure between June and September 2009 and intermittently between September and November 2009. Potential cross flow may have occurred from screen 1 to screen 2.	The R-20 Baski system was repaired on January 6, 2010. Three pressure leaks were identified. The primary and most significant pressure leak was determined to be from a damaged packer-inflation valve at the wellhead. A smaller pressure leak was also found at the connection between the inflation line to the bottom of the well cap. A very slow pressure leak remains from an unidentified component downhole.	The R-20 Baski system was repaired on January 6, 2010. The leaky packer-inflation valve at the wellhead was replaced, and the leak at the connection between the inflation line to the well cap was repaired. The small downhole pressure leak remains, but is slow enough that it does not affect system performance. A nitrogen tank has been installed at the wellhead to maintain operational pressure within the system over long periods of time.	Operational pressure is maintained within the Baski system using a nitrogen tank at the wellhead. Repairs conducted to the system in January 2010 were successful, and water level data from R-20 show no further evidence of cross flow.	Continue pressure monitoring per established procedure and schedule. No further corrective action is required.
R-22	Four temporary packers were installed in R-22 on May 30, 2009, upon completion of well rehabilitation and conversion activities. No abnormalities were observed with the packers during operations with the Bennett pump on 6/19/2009 and 6/20/2009. The two lower-most (3rd and 4th) packers were found deflated on 10/8/2009, and the temporary packer system was removed for repairs on 10/16/09. The 3rd and 4th packers were found damaged, and were replaced. The temporary packer system was reinstalled on 10/17/09. Cross flow occurred from screens 1, 2, and 3 to screens 4 and 5.	Packer pressure for the temporary packers in R-22 was not monitored between May 30, 2009, and October 8, 2009, and the leaks in the packer remained undetected during this period. Observations during removal and repairs of the temporary packers in R-22 on October 16, 2009 suggest abrasion damage to the lowermost (third and fourth) packers. This abrasion was not observed in the upper two packers, suggesting that damage to the lower packers may have been inflicted from something (perhaps well screens) deeper in R-22, that the upper packers did not contact.	All four temporary packers in R-22 were removed on 10/16/09 for evaluation. The two lowermost temporary packers were found damaged, and were replaced. The temporary packer string was reinstalled in R-22 on 10/17/2009. Pressure monitoring of the temporary packer system is conducted on a more frequent basis in accordance with the established operating procedure and schedule. A nitrogen tank has been installed at the wellhead to maintain operational pressures within the temporary packer system.	A recent nitrogen leak has been identified in at least one of the two uppermost packers; operational pressures within the packers in R-22 are maintained using a nitrogen tank at the wellhead. Due to the fairly significant rate of nitrogen leakage, the nitrogen tank needs to be replaced every 1.5 days.	The current temporary packer system in R-22 will be maintained until a decision is reached between the Laboratory and NMED on the final configuration of the well. Continue pressure monitoring of temporary packers in R-22 per established procedure and schedule.
R-23i	R-23i packer lost pressure between June and September, 2009, and intermittently between September and November, 2009 (see Appendix A). Cross flow occurred from screen 2 to screen 3.	The R-23i Baski system was removed for assessment and repairs on December 16, 2009, and replaced with a temporary packer system. Several pressure leaks were identified in the Baski system. The nitrogen tank and control system installed at the wellhead were found to have a leak, sufficient to drain a nitrogen bottle in 1.5 days. There was also evidence of over tightening of Swagelok fitting on 1/4" nylon packer inflation tubing just below to top of the well. Most significantly, a major nitrogen leak was identified at a bolt connection on top of the steel packer body. The bolt was loose, and had no Teflon tape or (apparent) sealant on it.	The R-23i Baski system was removed for repairs on December 16 2009, and replaced with a temporary packer. The packer element and pressure fittings were replaced, and the system was reconfigured with a liquid inflation chamber. The liquid inflation chamber will eliminate the potential for nitrogen diffusion through the rubber packer element, as the packer is inflated using water rather than nitrogen. (Liquid inflation chambers are a standard element of current Baski system design, but were not available when the R-23i packer was built). The reconfigured R-23i Baski system will be reinstalled in late February.	The R-23i Baski system is scheduled for installation in the last week of February. The current temporary packer in the well is holding pressure.	Continue pressure monitoring per established procedure and schedule. Geochemical impacts from cross flow have dissipated, and no further corrective action is required.
R-40	The R-40 Baski system has a moderate pressure leak, losing pressure at a rate of 5 psi/day. The R-40 system currently requires frequent monitoring to keep operational pressures within recommended guidelines. No inadvertent cross flow has occurred.	The R-40 packer inflation valve at the surface has a moderate pressure leak; there may also be a small pressure leak from an unknown component of the R-40 Baski system downhole.	Field personnel conducted an assessment of the Baski system at the wellhead to identify potential pressure leaks. Pressure monitoring of the Baski system is conducted in accordance with the established operating procedure and schedule. A nitrogen tank will be installed at the wellhead to maintain operational pressures within the system.	The Baski system in R-40 loses pressure at a rate of 5 psi/day. The system is actively managed to maintain operational pressures and prevent cross flow.	Install nitrogen tank at R-40 wellhead to maintain operational pressures within Baski system. Continue pressure monitoring per established procedure and schedule.
R-44	Operational pressures within the R-44 Baski system are maintained using a nitrogen tank at the wellhead. However, when disconnected from the tank, the packer inflation valve at the wellhead leaks significantly. No inadvertent cross flow has occurred.	The R-44 packer inflation valve at the surface has a significant leak. The valve does not leak when connected in series to a nitrogen tank at the wellhead.	Field personnel conducted an assessment of the Baski system at the wellhead to identify potential pressure leaks. Pressure monitoring of the Baski system is conducted in accordance with the established operating procedure and schedule. A nitrogen tank was installed at the wellhead to maintain operational pressures within the system.	Operational pressure is maintained within the Baski system using a nitrogen tank at the wellhead.	Replace the leaky packer-inflation valve at the wellhead will be replaced. Continue pressure monitoring per established procedure and schedule.
R-45	The R-45 Baski system has a relatively minor pressure leak, losing pressure at a rate of 2 psi/day. Operational pressures are maintained within recommended ranges, and no inadvertent cross flow has occurred.	The R-45 packer inflation valve at the surface has a small pressure leak; there may also be a small pressure leak from an unknown component of the R-45 Baski system downhole.	Field personnel conducted an assessment of the Baski system at the wellhead to identify potential pressure leaks. Pressure monitoring of the Baski system is conducted in accordance with the established operating procedure and schedule. A nitrogen tank was installed at the wellhead to maintain operational pressures within the system.	The Baski system in R-45 has a very slow pressure leak, but the operational pressure is maintained through routine pressure monitoring in accordance with the established procedure and schedule.	Continue pressure monitoring per established procedure and schedule.

Appendix A

Groundwater-Level Data for
Monitoring Wells with Baski Sampling Systems

A-1.0 INTRODUCTION

Baski sampling systems installed in regional aquifer monitoring wells at Los Alamos National Laboratory (LANL) utilize inflatable packers to isolate specific screens in the monitoring wells. The systems incorporate gage tubes that extend above and below the packer(s) to allow monitoring of the groundwater levels at each screen. Pressure transducers are installed in the gage tubes to monitor the groundwater levels. The resulting groundwater-level data are useful to monitor and diagnose the effectiveness of the packers in isolating the groundwater to each screen. This appendix summarizes the groundwater level data for each Baski packer system at LANL and provides evidence for packer effectiveness and failures.

Groundwater-level measurements for each screen in the Baski systems are accessed via two 1-in.-diameter polyvinyl chloride (PVC) gaging tubes. The bottom of the upper-screen gage tube is perforated to measure water levels at the upper screen. The lower screen gage tube connects to 1/4-in.- or 3/8-in.-diameter tubing that extends downward through the packer to measure the groundwater level at the lower screen.

A-2.0 R-10

Monitoring well R-10 is located on San Ildefonso land east of the Laboratory boundary. The Baski sampling system was originally installed in R-10 in May 2006, and transducers were installed in July 2006. Well-construction information, including the as-built diagram showing the Baski sampling system, is presented in the well completion report for R-10 (Kleinfelder 2006, 092491).

The R-10 Baski sampling system was removed for repair in February 2008 and was reinstalled on March 14, 2008. The reinstalled R-10 Baski system had a similar configuration, but slightly different depths for some components. The screen 2 gage tube functioned appropriately after the reinstallation of the system in 2008. However, the Baski access port valves (APVs) malfunctioned after the 2008 reinstallation, and the system was again removed from the well in July 2009 for repair of the APVs.

The R-10 Baski dual-valve submersible pump sampling system was reinstalled on August 27, 2009. Table A-2.0-1 shows the details of the R-10 well and sampling system components. After the sampling system was installed, the packer was inflated and the transducers were installed. The packer in R-10 is currently located from 918.4 ft below ground surface (bgs) to 923.3 ft bgs, about 21.4 ft below screen 1 and 119 ft above screen 2.

Figure A-2.0-1 shows the groundwater-level data for monitoring well R-10. Data are available only once the Baski system is in place. The groundwater-level data indicate the Baski packer has functioned appropriately in maintaining separation of the groundwater between screens when the Baski system has been in place.

A-3.0 R-12

The Baski packer and dual-pump sampling system was installed on December 13, 2007. Well construction information was provided in the well completion report for R-12 (Broxton et al. 2001, 071252). Table A-3.0-1 summarizes the R-12 construction information. The intermediate screens 1 and 2 have very similar heads, with screen 2 having about 0.2 ft higher head than screen 1. If the packer were to fail, a relatively small volume of water would flow upward from screen 2 to screen 1.

Figure A-3.0-1 shows the groundwater-level data from R-12 since the Baski sampling system was installed. The groundwater-level data indicate the packer has functioned appropriately in maintaining separation of the groundwater between screens.

A-4.0 R-16

A single submersible pump with dual valve Baski sampling system was installed in R-16 October 14, 2009 to monitor screens 2 and 4; screen 3 was sealed between packers and was no longer monitored after April 15, 2009 (LANL 2009, 106945). Table A-4.0-1 summarizes the construction information for R-16. The head separation between screens 2 and 4 is typically about 93 ft.

Figure A-4.0-1 shows the groundwater-level data from R-16 since the Baski sampling system was installed. Figure A-4.0-2 shows the water-level data for R-16 between November 12 and December 16, 2009. The groundwater-level data indicate the lower packer deflated three times between November 12 and December 1, 2009, for a total of 212 hr, allowing cross flow from screen 3 to screen 4 (Table A-4.0-2). The upper packer deflated one time on November 17, 2009 for 8 hr, allowing cross flow between screens 2, 3, and 4 (Table A-4.0-2). Except for the deflation times noted, the R-16 packers functioned appropriately in maintaining separation of the groundwater between screens.

A-5.0 R-17

The R-17 Baski system installation was completed on December 12, 2006. Well construction information was provided in the well completion report for R-17 (Kleinfelder 2006, 092493). Table A-5.0-1 summarizes the construction of R-17, which has one packer that separates screens that are 44 ft apart.

Figure A-5.0-1 shows the groundwater-level data from R-17 since the Baski sampling system was installed. The deeper screen responds more to supply-well pumping than the shallow screen. The groundwater-level data indicate the packer has functioned appropriately in maintaining separation of the groundwater between screens.

A-6.0 R-20

The R-20 dual pump/dual packer Baski sampling system was installed May 22, 2008. Table A-6.0-1 shows the summary of the recompleted R-20 well. Screen 3 was plugged and abandoned in December 2007, and the Baski sampling system was installed to monitor screens 1 and 2.

Figure A-6.0-1 shows the valid groundwater level data for R-20 screens 1 and 2 since the Baski system was installed. The head difference between screens is typically about 3.5 ft; however, because screen 3 responds more to supply-well pumping than screen 1, the head separation can be over 4 ft.

Figure A-6.0-2 shows the water-level data from R-20 from June to December 2009. The packers lost pressure several times during this period, causing cross flow from screen 1 to screen 2. Table A-6.0-2 summarizes the packer deflation times at R-20. The Baski system was removed from R-10 for repair of the packer system on January 5, 2010.

A-7.0 R-23I

The Baski packer and dual pump sampling system were installed December 15, 2006. Well construction information was provided in the well completion report for R-23i (Kleinfelder 2006, 092495). Table A-7.0-1 summarizes the R-23i construction information. The Baski system is installed in the 4.5-in.-diameter well casing. Figure A-7.0-1 shows the historical groundwater-level data for R-23i, screens 2 and 3. The head separation between these screens is about 8 ft.

Figure A-7.0-2 shows the water-level data from R-23i, screens 2 and 3, for June to December 2009. The packer initially deflated on June 5 and was reinflated numerous times; however, from mid-September to November 25, 2009, the packer could not be kept inflated on a continuous basis. The Baski system was removed from R-23i on December 08, 2009, for repair of packer system.

Table A-7.0-2 summarizes the periods of packer deflation at R-23i. From June 5 to December 7, 2009, the packer was deflated for over a total of 122 d.

A-8.0 R-33

A Barcad system with Tam packer was installed in R-33 in February 2005 (Kleinfelder 2005, 092385). Composite water levels were measured at R-33 until October 2006 when a dedicated compressed nitrogen gas tank and safety manifold were constructed and connected to the packer system (LANL 2007, 098688). All groundwater samples collected from R-33 before October 2006 were probably from the composite water in the well. Transducer equipment problems from 2005 to October 2006 prevented the collection of accurate groundwater-level data during this period. The Barcad sampling system was removed from R-33 January 2008. The Baski sampling system was installed in R-33 on July 1, 2008. Table A-8.0-1 lists the R-33 well completion information (Kleinfelder 2005, 092385) and a summary of the Baski sampling system (LANL 2008, 103171). The packer is located about 50 ft below screen 1 and 34 ft above screen 2.

Figure A-8.0-1 shows the R-33 groundwater-level data since October 2006. Screen 2 responds to pumping of nearby supply well PM-5, but screen 1 does not show a significant response. The head difference between screens is typically about 30 ft or greater. The groundwater-level data since July 2008 indicate that the Baski packer has functioned appropriately in maintaining separation of the groundwater between screens.

A-9.0 R-37

The R-37 Baski dual pump sampling system was initially installed November 11, 2009, but because of problems with the Bennett pump, the system was removed and reinstalled on December 16, 2009. Table A-9.0-1 summarizes the R-37 construction information, and Figure A-9.0-1 shows the available groundwater-level data for R-37. The groundwater-level data indicate the packer has functioned appropriately in maintaining separation of the groundwater between screens.

A-10.0 R-40

The dual pump Baski sampling system was installed in R-40 in June 2009 (LANL 2009, 106432). Table A-10.0-1 summarizes the R-40 construction. The Baski system is installed in the 5-in.-diameter well with screen 1 in a perched intermediate zone and screen 2 at the top of the regional aquifer.

Figure A-10.0-1 summarizes the available groundwater-level data for R-40. These data indicate the packer has functioned appropriately in maintaining separation of the groundwater between screens.

A-11.0 R-43

The R-43 Baski dual-valve submersible pump sampling system was installed on June 8, 2009. Table A-11.0-1 summarizes the details of the R-43 well construction and sampling system components. Figure A-11.0-1 summarizes the available groundwater level data for R-43. The screens are about 45 ft apart with a head difference of about 1 ft. The groundwater-level data indicate the packer has functioned appropriately in maintaining separation of the groundwater between screens.

A-12.0 R-44

The R-44 Baski dual-valve submersible pump sampling system was installed July 3, 2009. Table A-12.0-1 summarizes the details of the R-44 well construction and sampling system components. Figure A-12.0-1 summarizes the available groundwater level data for R-44. The screens are about 80 ft apart with a head difference of about 0.25 ft during the summer pumping stress period and about 0.15 ft during winter months. The groundwater-level data indicate the packer has functioned appropriately in maintaining separation of the groundwater between screens.

A-13.0 R-45

The R-45 Baski dual-valve submersible pump sampling system was installed on June 28, 2009. Table A-13.0-1 summarizes the details of the R-45 well construction and sampling system components. Figure A-13.0-1 summarizes the available groundwater-level data for R-45. The screens are about 85 ft apart with a head difference of about 0.08 ft during the summer pumping stress period and about 0.05 ft during winter months. The groundwater level data indicate that the packer has functioned appropriately in maintaining separation of the groundwater between screens.

A-14.0 R-49

The R-49 Baski dual-valve submersible pump sampling system was installed on August 20, 2009. Table A-14.0-1 summarizes the details of the R-49 well construction and sampling system components. Figure A-14.0-1 summarizes the available groundwater-level data for R-49. The screens are about 50 ft apart with a head difference of about 24 ft. The groundwater-level data indicate the packer has functioned appropriately in maintaining separation of the groundwater between screens.

A-15.0 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.*

Broxton, D., R. Warren, A. Crowder, M. Everett, R. Gilkeson, P. Longmire, and J. Marin, May 2001. "Characterization Well R-12 Completion Report," Los Alamos National Laboratory report LA-13822-MS, Los Alamos, New Mexico. (Broxton et al. 2001, 071252)

Kleinfelder, February 2005. "Final Completion Report, Characterization Well R-33," report prepared for Los Alamos National Laboratory, Project No. 37151, Albuquerque, New Mexico. (Kleinfelder 2005, 092385)

Kleinfelder, January 2006. "Final Completion Report, Characterization Wells R-10a/R-10," report prepared for Los Alamos National Laboratory, Project No. 49436, Albuquerque, New Mexico. (Kleinfelder 2006, 092491)

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LANL (Los Alamos National Laboratory), August 2007. "Evaluation of Sampling Systems for Multiple Completion, Regional Aquifer Wells at Los Alamos National Laboratory," Los Alamos National Laboratory document LA-UR-07-4034, Los Alamos, New Mexico. (LANL 2007, 098688)

LANL (Los Alamos National Laboratory), August 2008. "R-33 Well Conversion and Rehabilitation Summary Report," Los Alamos National Laboratory document LA-UR-08-4696, Los Alamos, New Mexico. (LANL 2008, 103171)

LANL (Los Alamos National Laboratory), June 2009. "Completion Report for Regional Aquifer Well R-40," Los Alamos National Laboratory document LA-UR-09-3067, Los Alamos, New Mexico. (LANL 2009, 106432)

LANL (Los Alamos National Laboratory), September 2009. "Rehabilitation and Conversion Summary Report for Well R-16," Los Alamos National Laboratory document LA-UR-09-5372, Los Alamos, New Mexico. (LANL 2009, 106945)

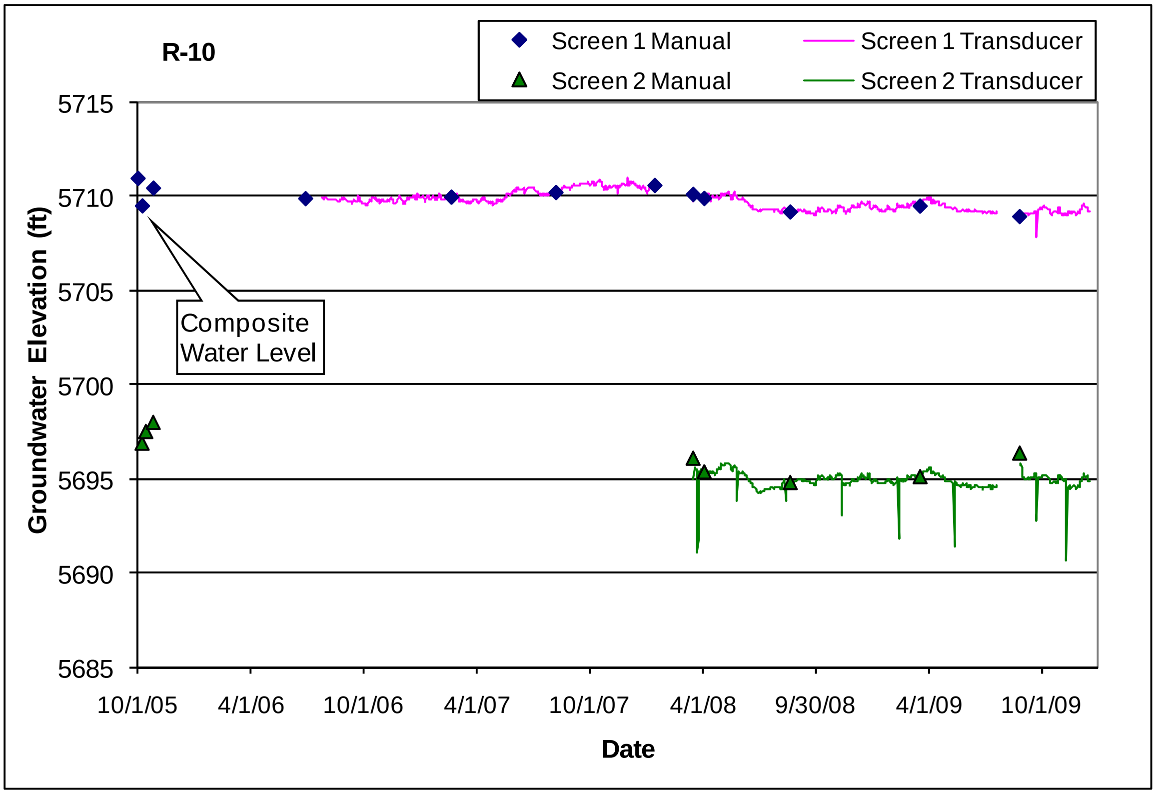

Figure A-2.0-1 R-10 groundwater-level summary

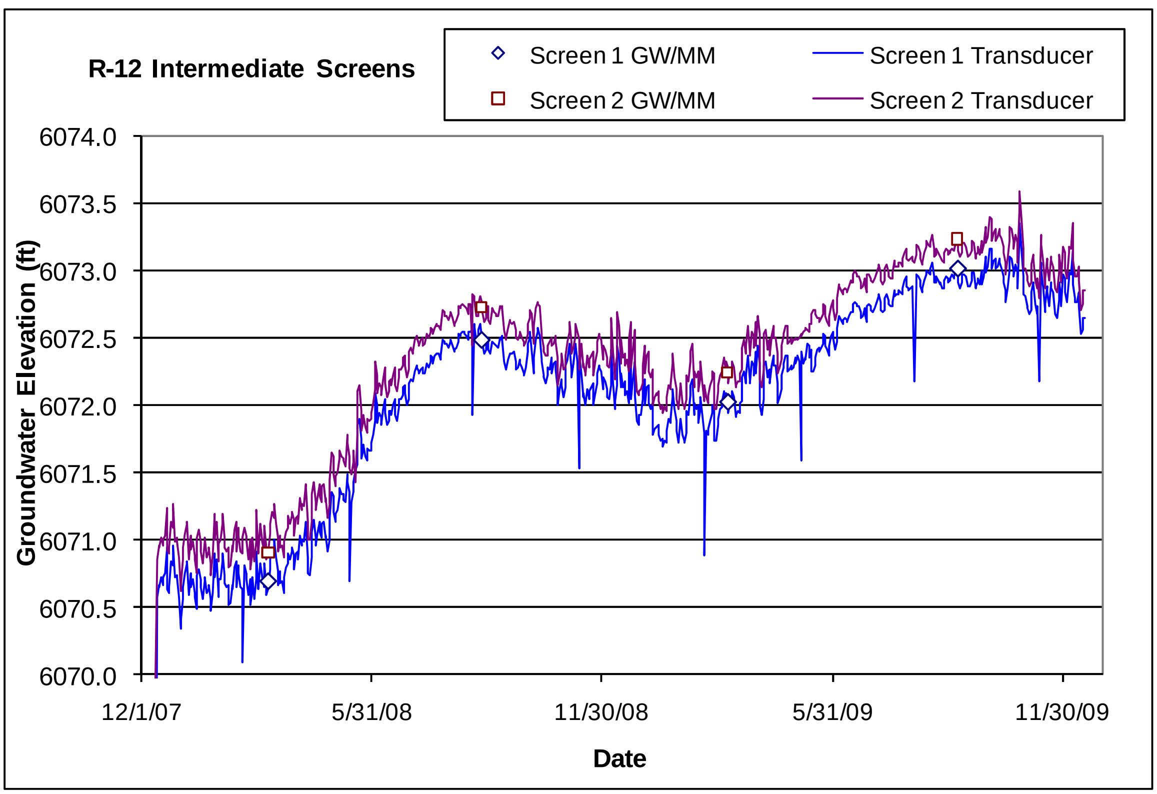

Figure A-3.0-1 R-12 groundwater-level data

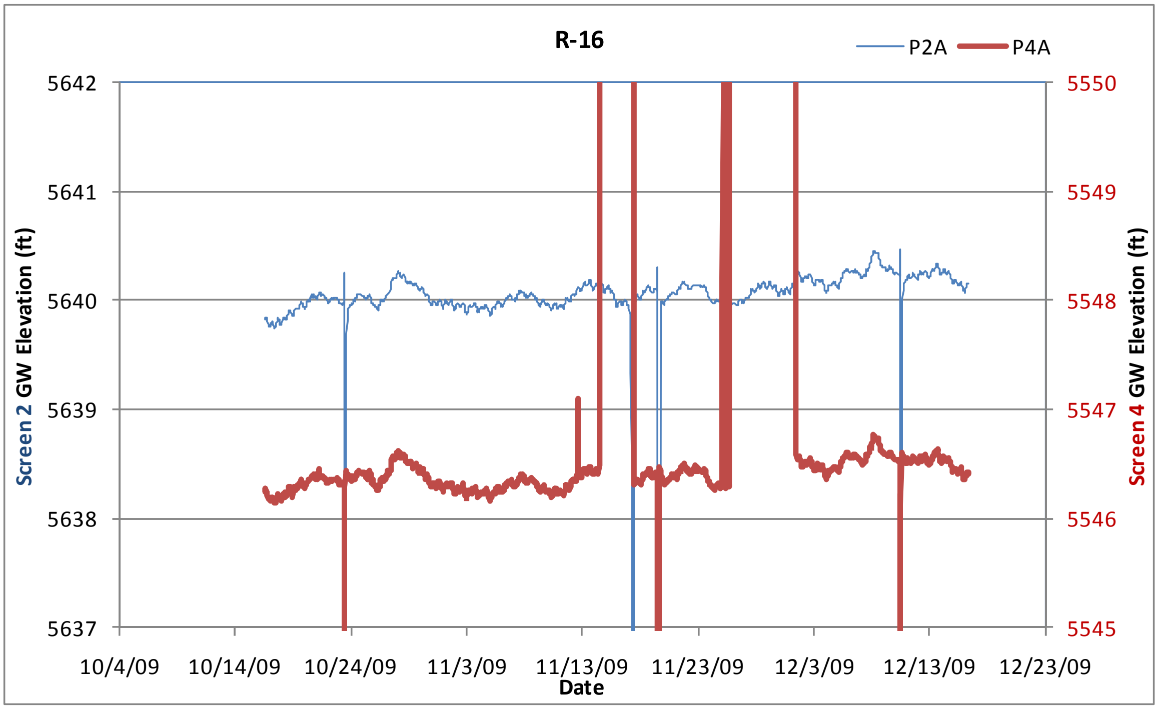

Figure A-4.0-1 R-16 groundwater-level data with Baski system in place

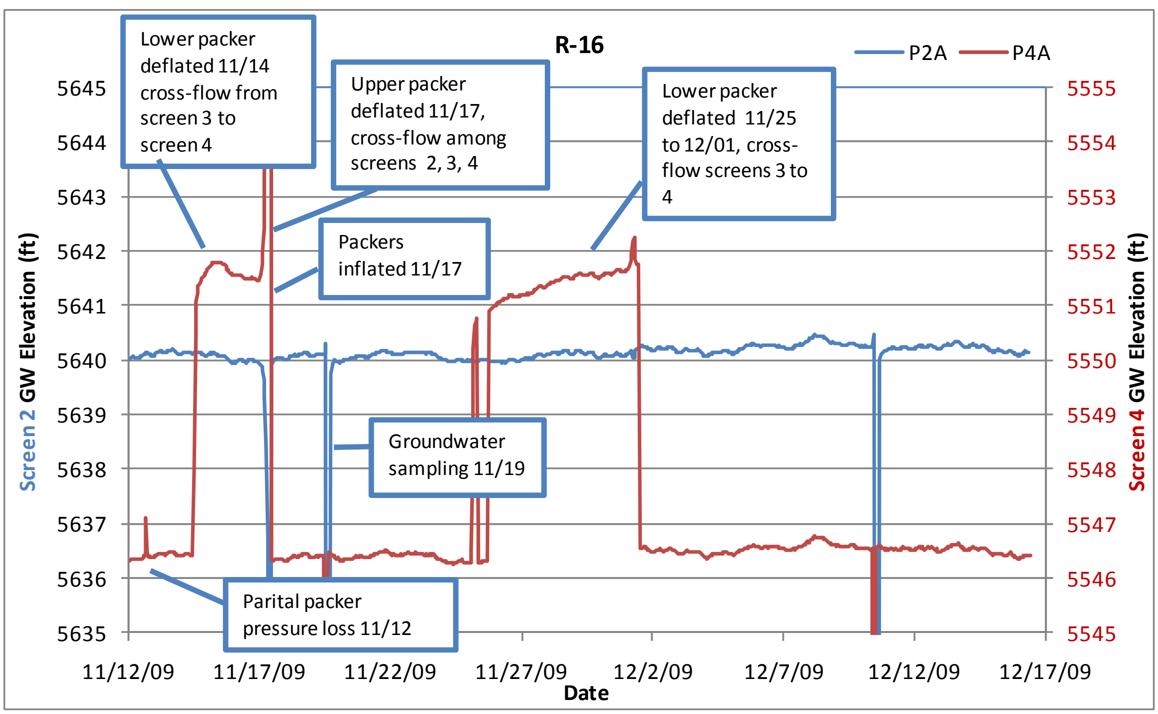

Figure A-4.0-2 R-16 Water-level data showing episodes of packer deflation

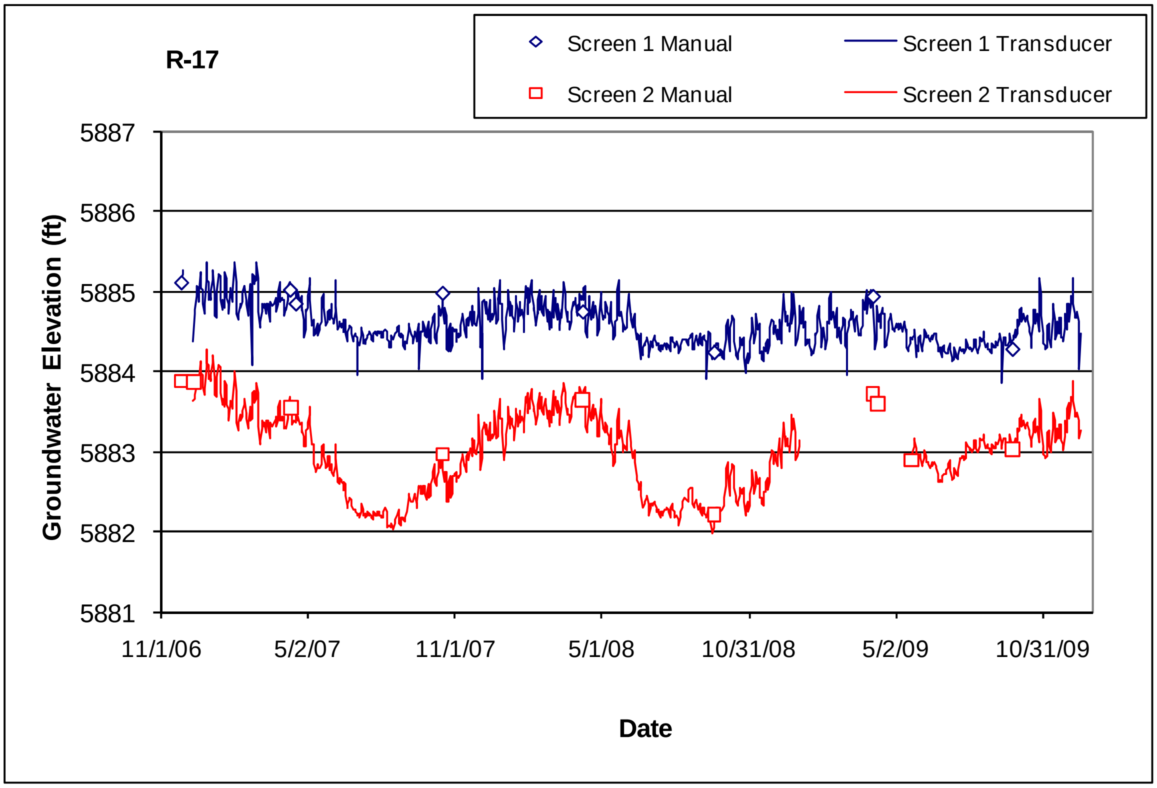

Figure A-5.0-1 R-17 groundwater-level data

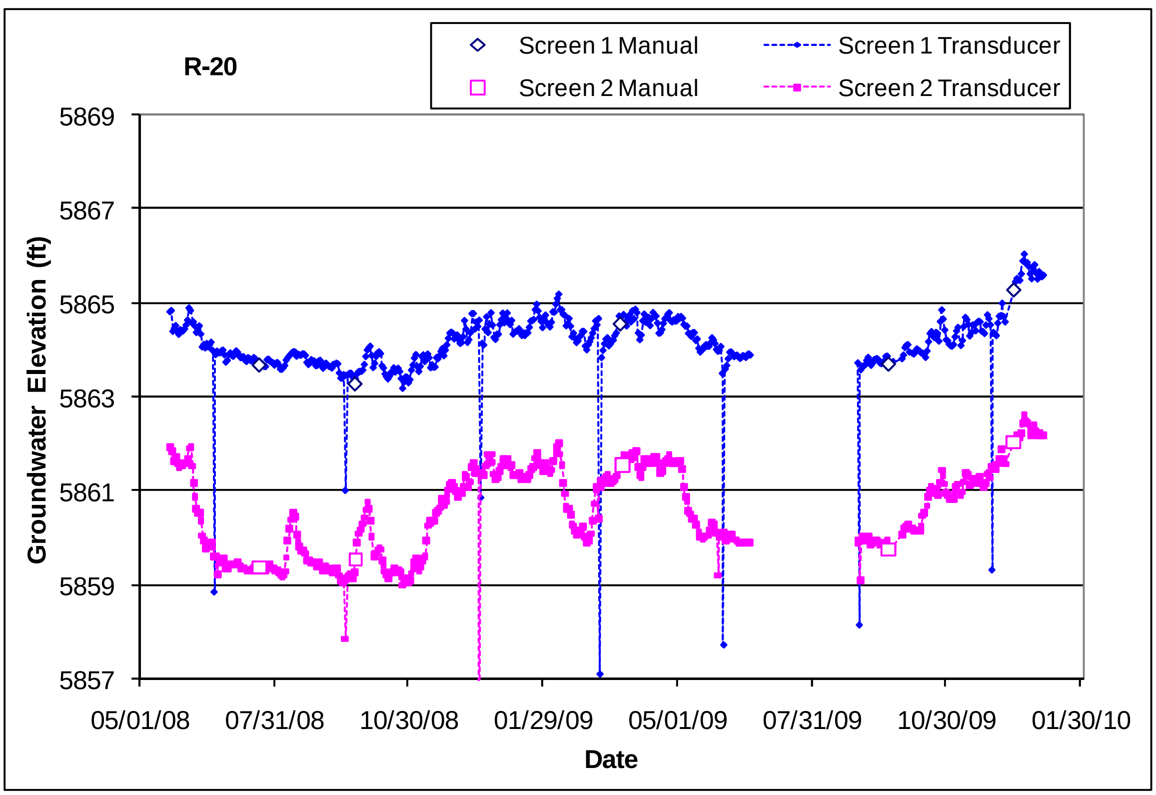

Figure A-6.0-1 R-20 groundwater-level data

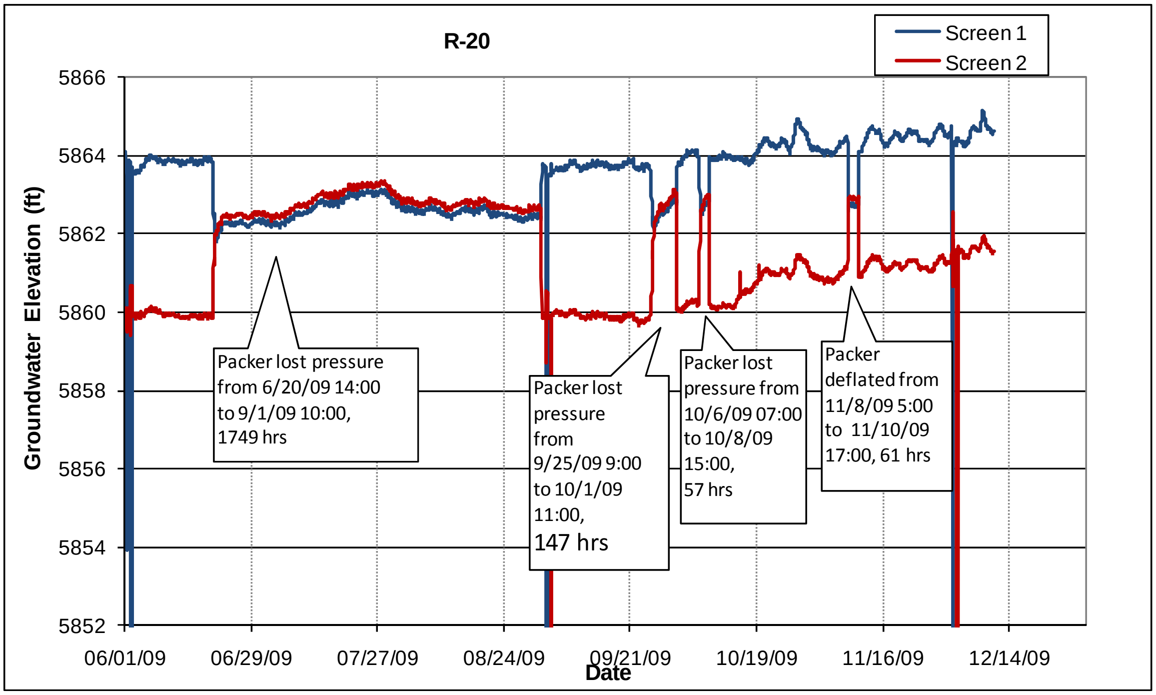

Figure A-6.0-2 R-20 water-level data June to December 2009

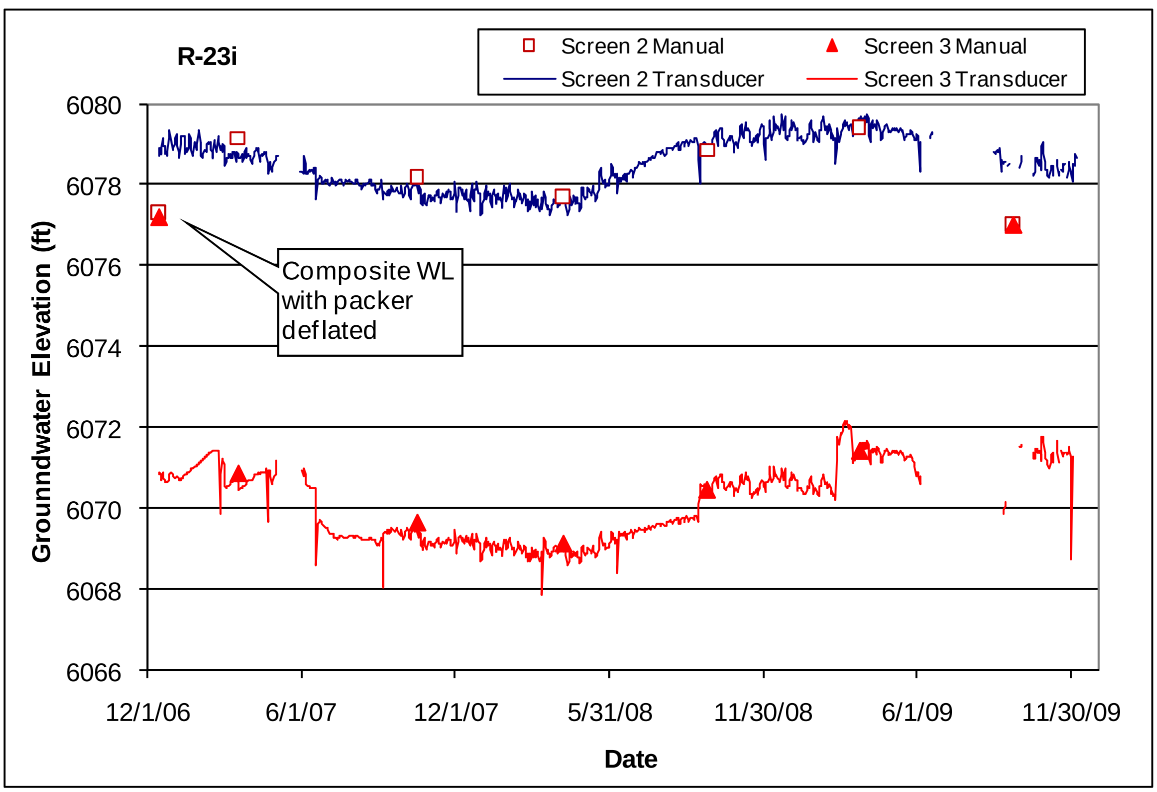

Figure A-7.0-1 R-23i historical groundwater-level data

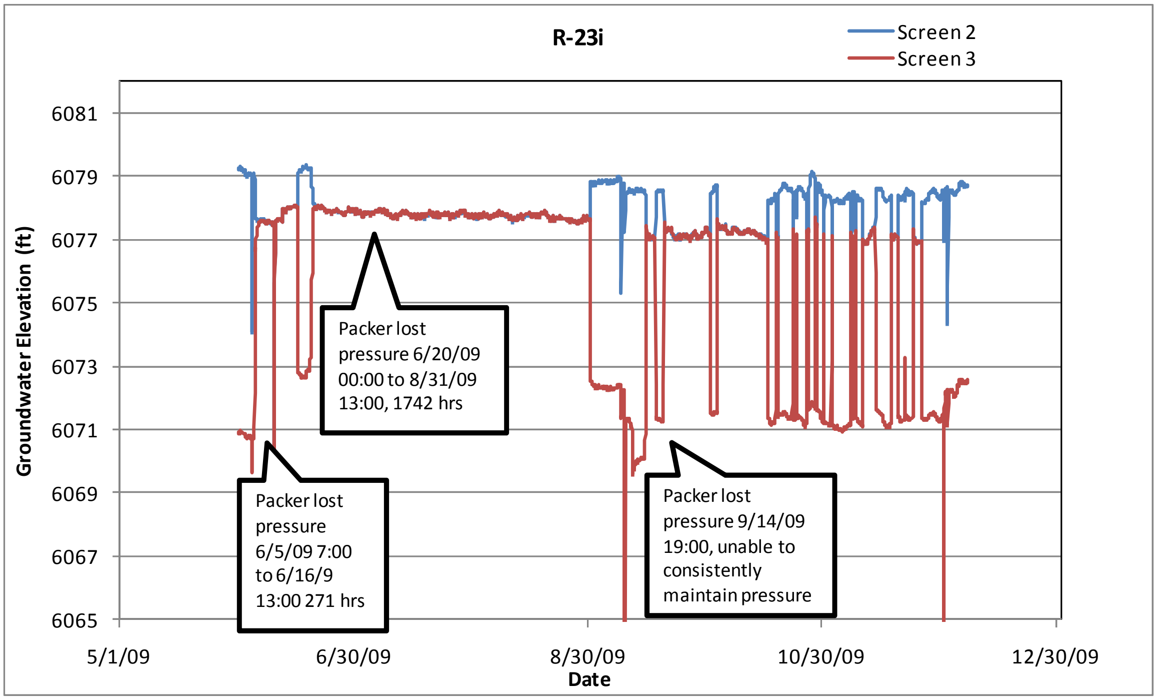

Figure A-7.0-2 R-23i water-level data showing packer deflation

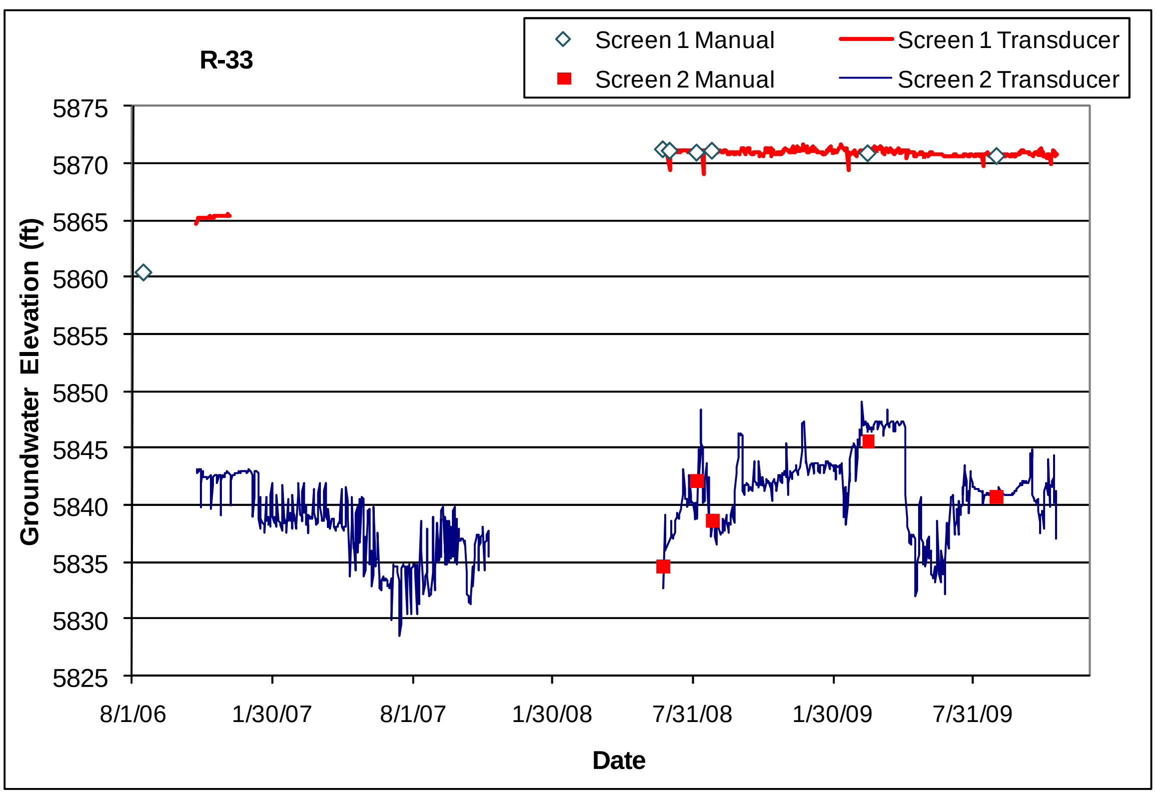

Figure A-8.0-1 R-33 groundwater-level data since Baski system installation

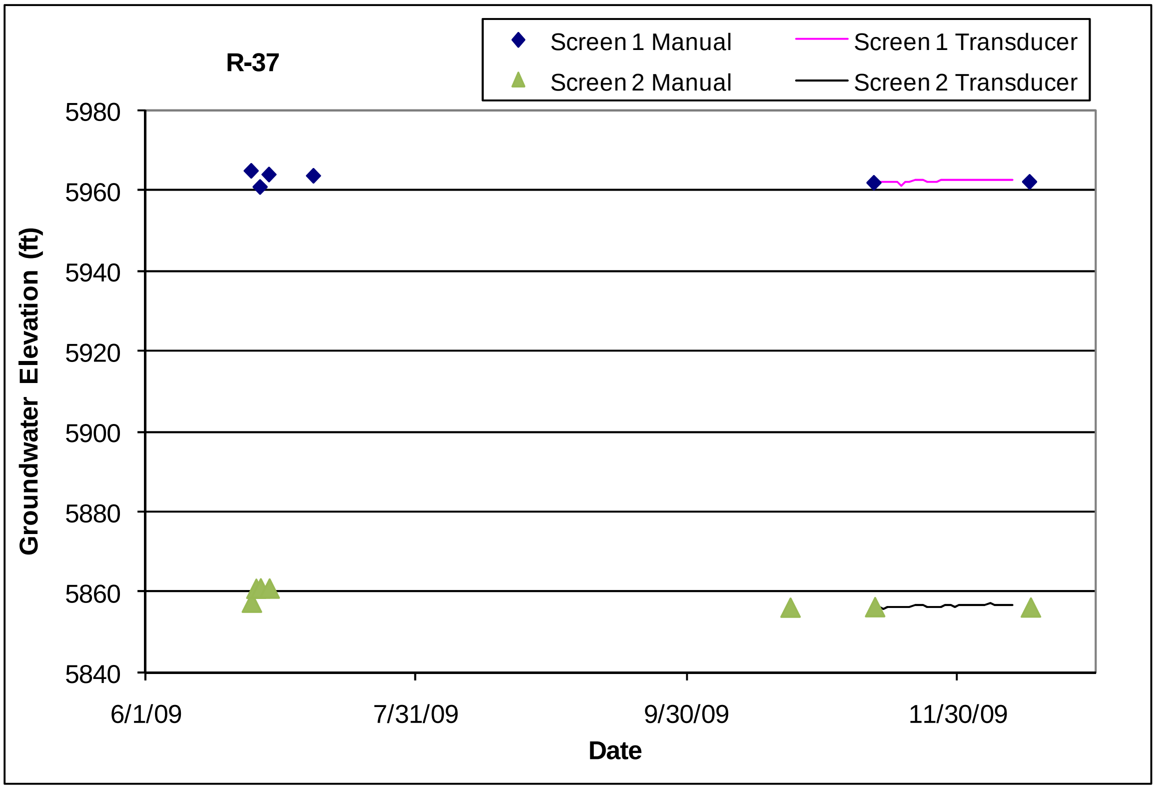

Figure A-9.0-1 R-33 groundwater-level data summary

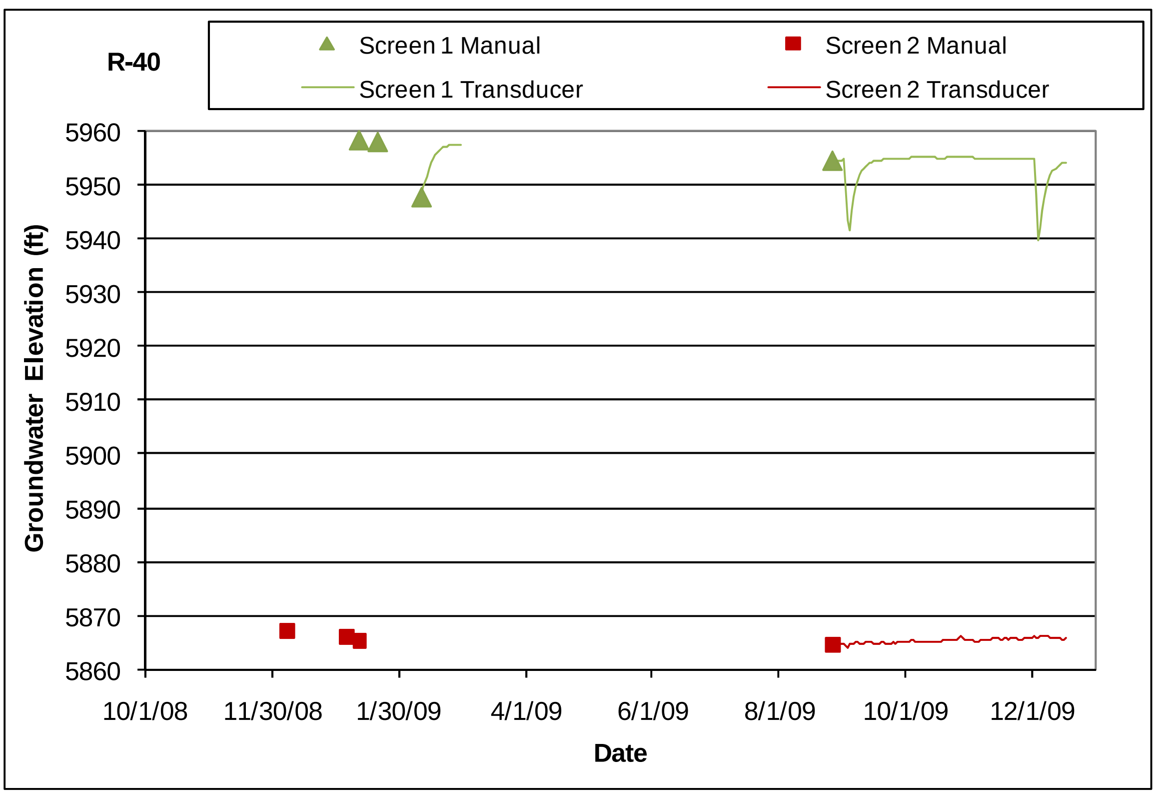

Figure A-10.0-1 R-40 groundwater-level data summary

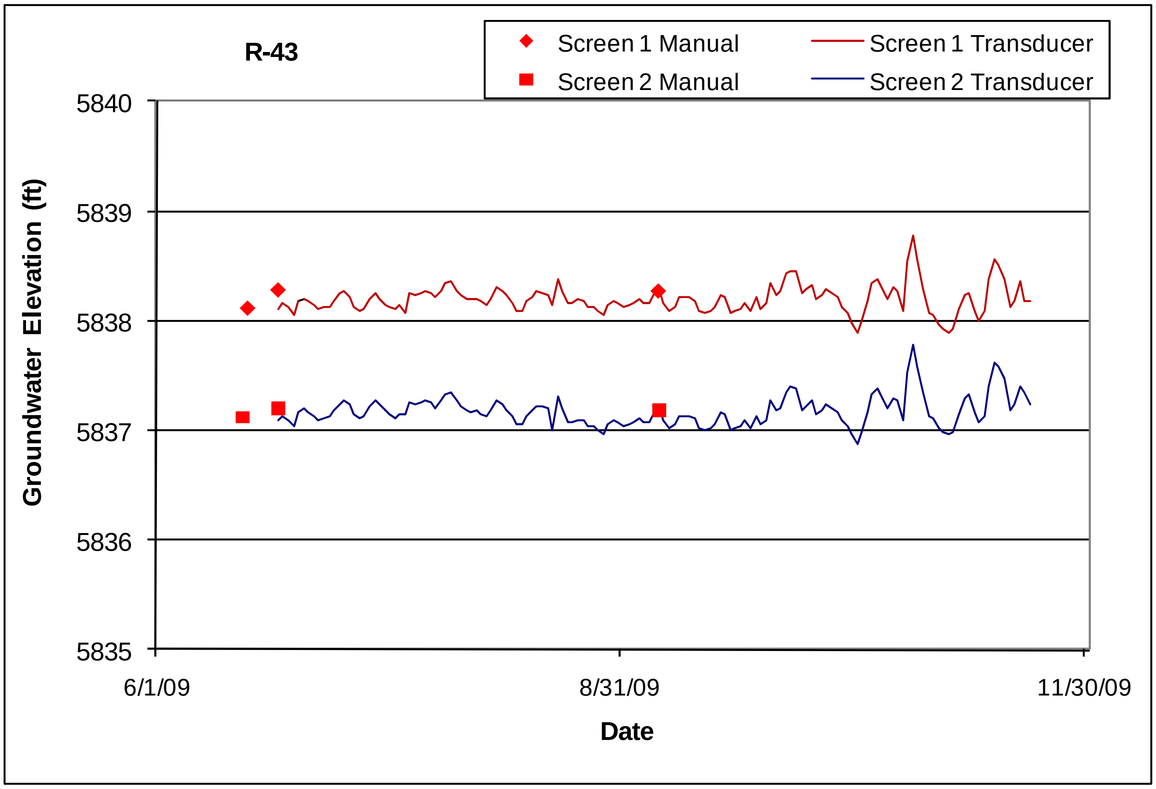

Figure A-11.0-1 R-43 groundwater-level summary

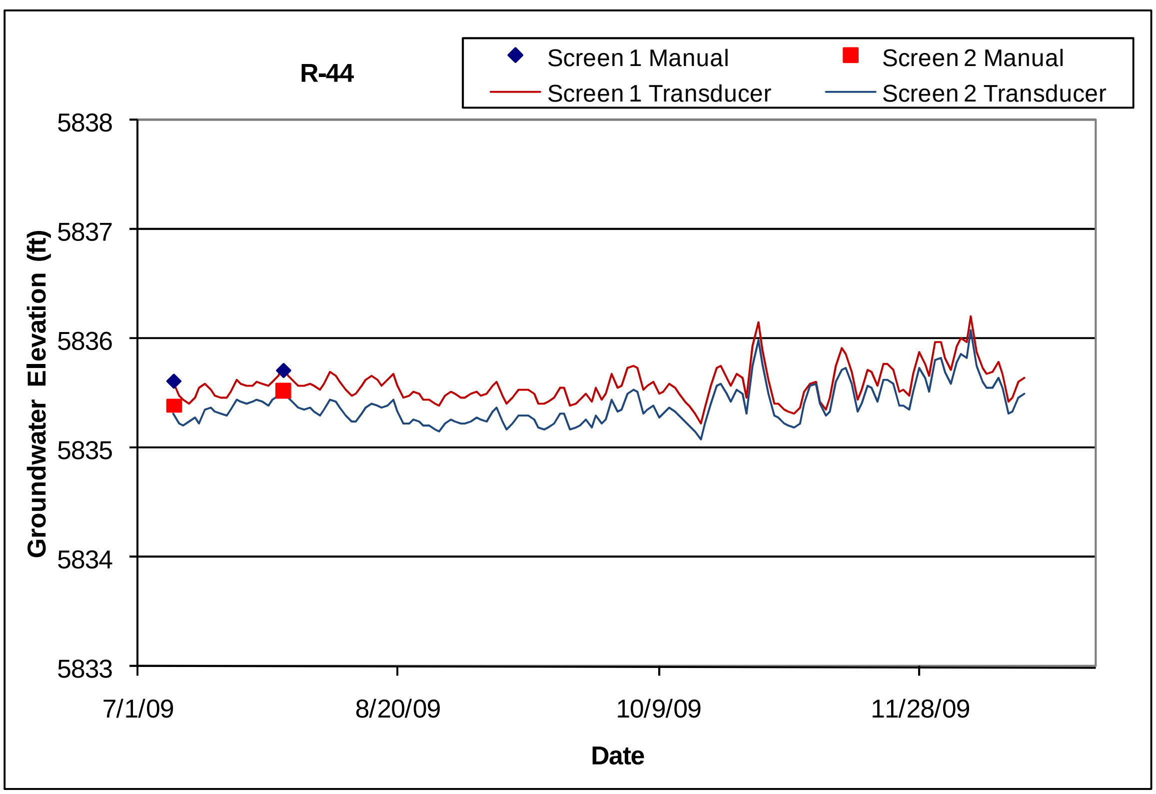

Figure A-12.0-1 R-44 groundwater-level summary

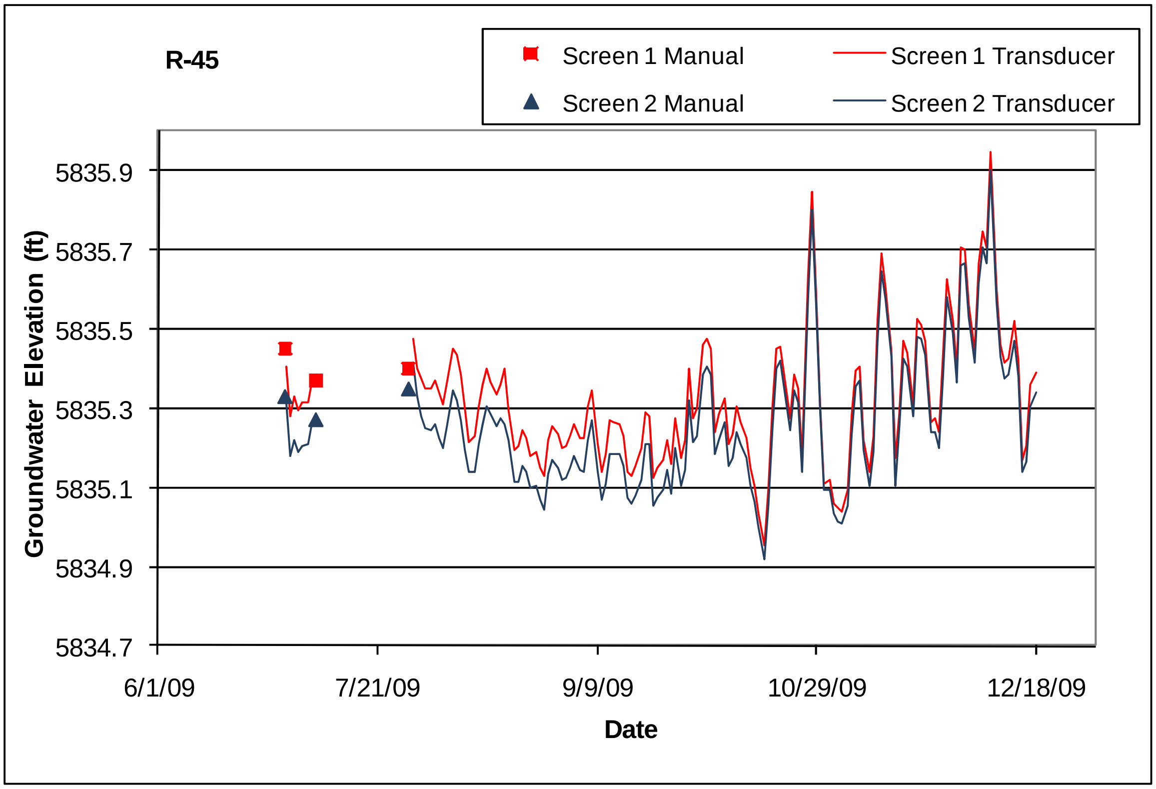

Figure A-13.0-1 R-45 groundwater-level summary

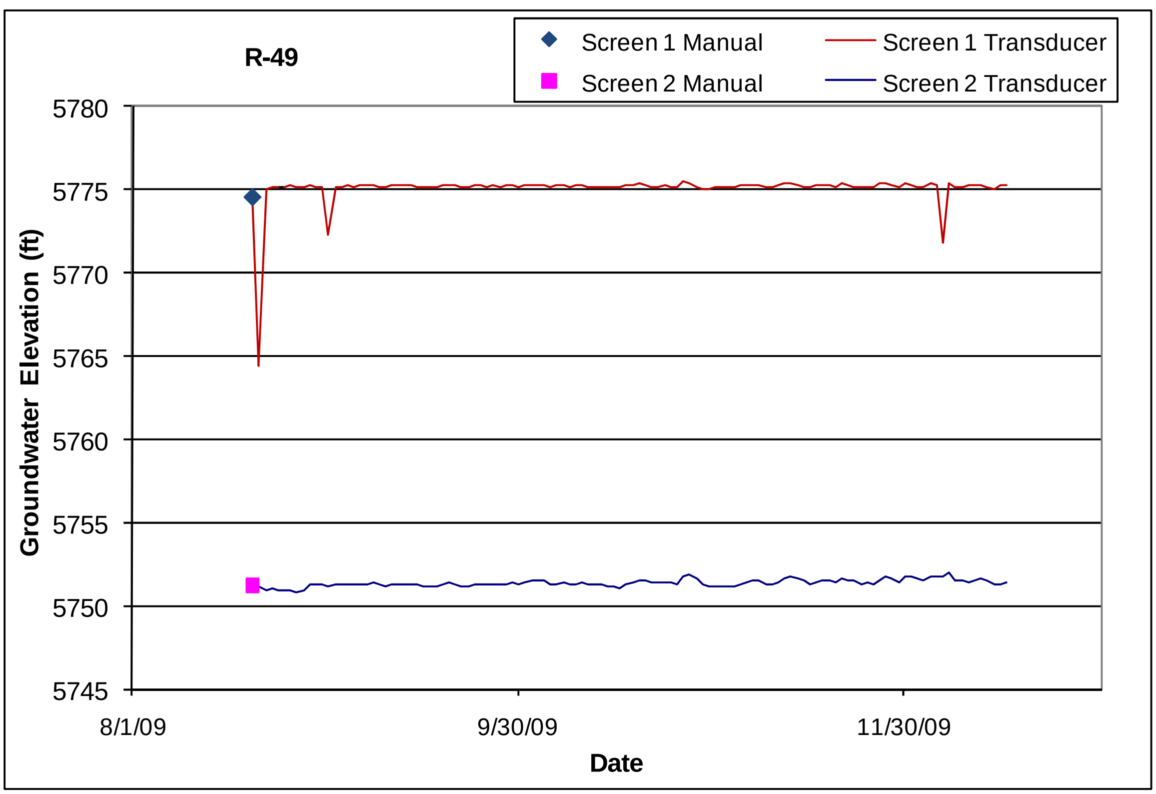

Figure A-14.0-1 R-49 groundwater-level summary

Table A-2.0-1
R-10 Construction Summary

R-10 Construction Information Updated August 2009

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Depth to Top/ Bottom of Packer (ft)	Top / Bottom of Packer Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	874.0	897.0	5488.3	5465.3	23.0	889.3	5473.0	918.4	5443.9	918.4	21.4	66.9	RD	Tsf
2	1042.0	1065.0	5320.3	5297.3	23.0	1045.2	5317.1	923.3	5439.0	1081.6	16.6	51.8	RD	Tsf

Note: R-10 Brass Cap Ground Elevation: 6362.31 ft; all measurements are from this elevation

APV = Access Port Valve

Table A-3.0-1
R-12 Construction Summary

R-12 Construction Infomration

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Packer/ Sump (ft)	Top of Packer/ Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	459.0	467.5	6040.6	6032.1	8.5	465.0	6034.6	470.7	6028.9	470.7	3.2	9.1	I	Tb4
2	504.5	508.0	5995.1	5991.6	3.5	501.0	5998.6	508.0	5991.6	540.8	32.8	93.7	I	Tp
3	801.0	839.0	5698.6	5660.6	38	**Screen 3 Plugged and Abandoned December 2007**							RT	Tsfb

Brass Cap Elevation: 6499.6 ft; all measurements are from this elevation

Table A-4.0-1
R-16 Construction Summary

R-16 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Packer/ Sump Bottom (ft)	Packer Bottom Depth (ft)	Bottom of Sump Elev (ft)	Sump Length (ft)	Hydro Zone Code	Geo Unit Code	Comment
1	641.0	648.6	5615.9	5608.3	7.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RT	Tp	Screen unusable
2	863.4	870.9	5393.5	5386.0	7.5	872.8	5384.1	870.9	5386.0	881.2	885.6	5375.6	10.3	RD	Tsf	Upper zone
3	1014.8	1022.4	5242.1	5234.5	7.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RD	Tsf	Screen sealed off
4	1237.0	1244.6	5019.9	5012.3	7.6	1234.6	5022.3	1244.6	5012.3	1276.7	1223.0	4980.2	32.1	RD	Tsf	Lower zone

Brass Cap Elevation: 6256.87 ft; all measurements are from this elevation

Table A-4.0-2
Summary of R-16 Packer Deflation

Upper Packer			
Packer Deflation	Packer Inflation	Days	Hours
11/17/2009 2:01	11/17/2009 10:01	0.33	8
	Total	0.33	8
Lower Packer			
Packer Deflation	Packer Inflation	Days	Hours
11/14/2009 11:01	11/17/2009 10:01	2.96	71
11/25/2009 3:01	11/25/2009 7:01	0.17	4
11/25/2009 18:01	12/1/2009 11:01	5.71	137
	Total	8.83	212

Table A-5.0-1
R-17 Construction Summary

R-17 Construction Information														
Screen	**Screen Top Depth (ft)**	**Screen Bottom Depth (ft)**	**Screen Top Elev (ft)**	**Screen Bottom Elev (ft)**	**Screen Length (ft)**	**Pump Intake Depth (ft)**	**Pump Intake Elev (ft)**	**Depth to Top of Packer/ Sump (ft)**	**Top of Packer/ Sump Elevation (ft)**	**Depth to Sump Bottom (ft)**	**Sump Length (ft)**	**Sump Volume (L)**	**Hydro Zone Code**	**Geo Unit Code**
1	1057.0	1080.0	5864.5	5841.5	23.0	1089.6	5831.9	1101.2	5820.4	1101.2	21.1	66.1	RT	Tpf
2	1124.0	1134.0	5797.5	5787.5	10.0	1128.6	5792.9	1134.0	5787.5	1140.9	6.9	21.6	RD	Tpf

Note: Brass Cap Ground Elevation: 6921.51 ft; all measurements are from this elevation

Table A-6.0-1
R-20 Construction Summary

R-20 Construction Information															
Screen	**Screen Top Depth (ft)**	**Screen Bottom Depth (ft)**	**Screen Top Elev (ft)**	**Screen Bottom Elev (ft)**	**Screen Length (ft)**	**Pump Intake Depth (ft)**	**Pump Intake Elev (ft)**	**Second Packer Bottom Depth (ft)**	**Depth to Top of Sump (ft)**	**Top of Sump Elev (ft)**	**Depth to Packer/ Sump Bottom (ft)**	**Sump Length (ft)**	**Sump Vol (gal)**	**Hydro Zone Code**	**Geo Unit Code**
1	904.6	912.2	5789.8	5782.2	7.6	908.43	5785.9		912.2	5782.2	918.7	6.5	5.3	RT	Tb4
2	1147.1	1154.7	5547.3	5539.7	7.6	1141.7	5552.6	1133.8	1154.7	5539.7	1183.5	28.8	23.8	RD	Tpp
3	1328.8	1336.5	5365.6	5357.9	7.7	**Screen 3 plugged and abandoned November 2007**								RD	Tsf

Note: R-20 Brass Cap Ground Elevation: 6694.35 ft; all measurements are from this elevation

Table A-6.0-2
Summary of R-20 Packer Deflation

Packer deflation	Packer Inflation	Days	Hours
6/20/2009 14:00	9/1/2009 10:00	72.83	1749
9/25/2009 9:00	10/1/2009 11:00	6.08	147
10/6/2009 7:00	10/8/2009 15:00	2.33	57
11/8/2009 5:00	11/10/2009 17:00	2.50	61
	Total	83.75	2014.00

Table A-7.0-1
R-23i Construction Summary

R-23i Construction Information																
Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Packer/ Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code	Comment
1	400.3	420.0	6127.6	6107.9	19.7	None	None	420.0	6107.9	425.3	5.3	16.6	I	Tb4	2.1 in. Piez
2	470.2	480.1	6057.7	6047.8	9.9	477.1	6050.8	495.3	6032.5	495.3	0.0	0.0	I	Tb4	4.5 in. well
3	524.0	547.0	6003.9	5980.9	23.0	516.7	6011.2	547.0	5980.9	550.7	3.7	11.6	I	Tb4	4.5 in. well

Note: Brass Cap Ground Elevation: 6527.88 ft; all measurements are from this elevation

Table A-7.0-2
Summary of R-23i Packer Deflation

Packer Deflated	Packer Inflated	Days	Hours
6/5/2009 7:00	6/16/2009 13:00	11.25	271
6/20/09 0:00	8/31/2009 13:00	72.54	1742
9/14/2009 19:00	9/17/2009 11:00	2.67	65
9/19/2009 16:01	10/1/2009 14:01	11.92	287
9/29/2009 14:00	10/1/2009 14:00	2.00	49
10/3/2009 13:01	10/16/2009 15:01	13.08	315
10/18/2009 18:01	10/19/2009 8:01	0.58	15
10/23/2009 4:01	10/23/2009 10:01	0.25	7
10/24/2009 7:01	10/24/2009 8:01	0.04	2
10/26/2009 22:01	10/27/2009 9:01	0.46	12
10/29/2009 2:01	10/29/2009 8:01	0.25	7
10/31/2009 5:01	10/31/2009 9:01	0.17	5
11/2/2009 6:01	11/2/2009 11:01	0.21	6
11/7/2009 5:01	11/7/2009 12:01	0.29	8
11/8/2009 9:01	11/8/2009 13:01	0.17	5
11/10/2009 11:01	11/13/2009 15:01	3.17	77
11/17/2009 21:01	11/19/2009 9:01	1.50	37
11/23/2009 10:01	11/25/2009 12:01	2.08	51
	Total	122.63	2961

Table A-8.0-1
R-33 Construction Summary

R-33 Construction Information															
Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Depth to Top of Packer/ Sump (ft)	Top of Packer/ Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	995.5	1018.5	5857.8	5834.8	23.0	1067.0	5786.3	1074.6	5778.8	1074.6	56.1	175.3	RT	Tpp
2	1112.4	1122.3	5740.9	5731.0	9.9	1110.8	5742.6	1122.3	5731.0	1126.0	3.7	11.6	RD	Tpp
Note: R-33 Brass Cap Ground Elevation: 6853.33 ft; all measurements are from this elevation; APV = access port valve														

Table A-9.0-1
R-37 Construction Summary

R-37 Construction Information													
Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Packer/ Sump Bottom (ft)	Depth to bottom of Packer	Sump Length (ft)	Bottom of Well Elev (ft)	Hydro Zone Code	Geo Unit Code
1	929.3	950.0	5941.3	5920.6	20.7	948.9	5921.7	959.3	NA	9.3	5911.3	I	Tpf
2	1026.0	1046.6	5844.6	5824.0	20.6	1055.9	5814.7	1068.8	964.1	22.2	5801.8	RT	Tpf
Note: Brass Cap Elevation: 6870.59 ft; all measurements are from this elevation													

Table A-10.0-1
R-40 Construction Summary

R-40 and R-40i Construction Information															
Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Packer / Sump Bottom (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code	Comment
R-40i	649.7	669.0	6069.5	6050.2	19.3	669.0	6050.2	669.0	6050.2	674.6	5.6	7.8	I	Tb4	3" ID PVC Casing
1	751.6	785.1	5967.6	5934.1	33.5	778.0	5941.2	785.1	5934.1	794.1	9.0	34.8	I	Tb4	5" ID SS Casing
2	849.3	870.0	5869.9	5849.2	20.7	871.0	5848.2	870.0	5849.2	895.0	25.0	96.5	RT	Tpf	5" ID SS Casing
Note: Brass Cap Ground Elevation: 6719.24 ft; all measurements are from this elevation															

Table A-11.0-1
R-43 Construction Summary

R-43 Construction Information															
Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Depth to Top of Packer/ Sump (ft)	Top of Packer/ Sump Elev (ft)	Bottom of Packer (ft)	Sump Length (ft)	Bottom of Sump/ Well Elev (ft)	Hydro Zone Code	Geo Unit Code
1	903.9	924.6	5828.8	5808.1	20.7	948.4	5784.3	960.7	5772.0	NA	36.1	5772.0	RT	Tsfu
2	969.1	979.1	5763.6	5753.6	10.0	967.5	5765.2	990.4	5742.3	965.4	11.3	5742.3	RD	Tsfu
Note: Brass Cap Ground Elevation: 6732.65 ft; all measurements are from this elevation														

Table A-12.0-1
R-44 Construction Summary

R-44 Construction Information															
Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Top/Bottom of Packer (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	895.0	905.0	5819.9	5809.9	10.0	921.9	5793.0	905.0	5809.9	936.3	936.3	31.3	120.9	RT	Tpf
2	985.3	995.2	5729.6	5719.7	9.9	983.2	5731.7	995.2	5719.7	941.1	1016.0	20.8	80.3	RD	Tpf
Note: Brass Cap Ground Elevation: 6714.91 ft; all measurements are from this elevation															

Table A-13.0-1
R-45 Construction Summary

R-45 Construction Information															
Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Top/ Bottom of Packer (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	880.0	890.0	5824.0	5814.0	10.0	905.5	5798.5	890.0	5814.0	921.3	921.26	31.26	120.7	RT	Tpf
2	974.9	994.9	5729.1	5709.1	20.0	973.2	5730.8	994.9	5709.1	926.0	1016.0	21.1	81.5	RD	Tsfu
Note: Brass Cap Ground Elevation: 6704.02 ft; all measurements are from this elevation															

Table A-14.0-1
R-49 Construction Summary

R-49 Construction Information															
Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Packer/ Sump (ft)	Top of Packer/ Sump Elev (ft)	Bottom of Packer (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	845.0	855.0	5739.5	5729.5	10.0	874.3	5710.3	887.6	5697.0	N/A	887.6	32.6	125.8	RT	Tb4
2	905.6	926.4	5678.9	5658.1	20.8	904.4	5680.1	926.4	5658.1	892.3	949.3	22.9	88.4	RD	Tpt
Note: Brass Cap Ground Elevation: 6584.54 ft; all measurements are from this elevation															

Appendix B

Cross-Flow Volume Analysis

B-1.0 INTRODUCTION

This appendix provides an analysis of the volumes of cross flow that occurred in 2009, in wells R-16, R-20, R-22, and R-23i. Cross flow occurred whenever multiple screens were in hydraulic communication, caused by either deliberate packer removal to perform work on the wells, or packer and/or packer line failure causing nitrogen leaks that eventually allowed deflation of the isolation packers.

Cross-flow volumes were calculated by estimating the cross-flow rate and identifying the time duration that screens were in hydraulic communication. The cross-flow rates were computed from known, specific capacities of the screens involved, and their relative heads.

B-2.0 CROSS-FLOW RATES

To estimate the cross-flow rate between two screen zones, the depth to water must be known for each zone (d_1 and d_2 for screens 1 and 2, respectively) as well as the specific capacity of each zone (c_1 and c_2, respectively). From this information, the composite depth to water (d_c) achieved when the screens are in hydraulic communication can be calculated as follows:

$$d_c = \frac{c_1 d_1 + c_2 d_2}{c_1 + c_2}$$

The parameter d_c can be computed in this fashion or, if water level data are available, observed directly from the hydrograph. From this, the cross-flow rate, Q, is computed by multiplying the specific capacity of either screen by the difference between its depth to water and the composite depth to water. This result can be calculated using the following formula:

$$Q = \frac{c_1 c_2}{c_1 + c_2}\left(d_2 - d_1\right)$$

Where Q = cross-flow rate, in gallons per minute (gpm)

c_1 = specific capacity of screen 1, in gpm/ft

c_2 = specific capacity of screen 2, in gpm/ft

d_1 = depth to water in screen 1, in ft

d_2 = depth to water in screen 2, in ft

B-3.0 WELL R-16

In well R-16, when screens 3 and 4 are in hydraulic communication there is a downward flux of 0.17 gpm from screen 3 to screen 4. When screens 2, 3, and 4 are all open there is a downward flux from screen 2 into screens 3 and 4, with 1.21 gpm flowing into screen 4.

Periods of cross flow in well R-16 included the following:

- From July 10 through July 18, 2009, well development/rehabilitation was performed. During this period, flow from screen 2 into screen 4 occurred for 5291 min at 1.21 gpm, and flow from screen 3 into screen 4 occurred for 1279 min at 0.17 gpm (cross-flow volume: 6620 gal.).

- Between July 18 and October 8, 2009, the temporary packer deflated, resulting in flow from screen 2 to screen 4 at 1.21 gpm for up to 82 d (up to 118,080 min) (cross-flow volume: up to 142,877 gal.).
- From October 8 through October 14, 2009, the Baski sampling system was installed resulting in flow from screen 2 to screen 4 for 6 d (8640 min) (cross-flow volume: 10,454 gal.).
- During November and December 2009, intermittent fitting/line failure resulted in packer deflation and cross flow from screen 2 to screen 4 at 1.21 gpm for 212 h (12,720 min) cross-flow volume: 15,391 gal.).

Summing the foregoing contributions, the total cross flow from all of these episodes was 32,465 to 175,342 gal.

B-4.0 WELL R-20

The hydraulic characteristics of the aquifer zones in well R-20 are not well defined because of contradictory data collected from the well. During numerous pumping events conducted in 2006 and 2007, the measured specific capacity of screen 1 ranged from 0.01 to 0.02 gpm/ft, while that of screen 2 ranged from 0.004 to 0.01 gpm/ft. The overall average specific capacity for the two zones was approximately 0.01 gpm/ft. Subsequently, during installation of the Baski system in 2008, brief test pumping of screen 1 showed a specific capacity of 0.12 gpm/ft. Potential explanations for this difference in specific capacity are discussed in the “Well R-20 Rehabilitation and Conversion Summary Report, Revision 1” (LANL 2008, 103100).

During cross flow in well R-20 from screen 1 to screen 2, the drawdown in screen 1 was roughly equal to the head buildup in screen 2 at about 2 ft. This implied similar specific capacities for the two zones. Because of the divergent results obtained from specific capacity testing on this well, analytical calculations were performed for a range of assumed specific capacities of 0.01 to 0.12 gpm/ft. Based on the observed head change in each zone of about 2 ft, this resulted in a cross-flow range of 0.02 to 0.24 gpm.

Periods of cross flow in well R-20 included the following:

- A leaky valve resulted in several packer deflation events from June through November 2009, totaling 2014 h (120,840 min) (cross-flow volume: 2417 to 29,002 gal.).
- During repair procedures to replace the valve, the packers were deflated for an additional 90 min on January 5 and 6, 2010 (cross-flow volume: 2 to 22 gal.).

Summing these contributions, the total cross flow from all of these episodes was 2419 to 29,044 gal.

B-5.0 WELL R-22

In well R-22, when screens 3, 4 and 5 were in hydraulic communication, there was a downward flux of 0.034 gpm from screen 3 to screens 4 and 5, with 0.009 gpm flowing into screen 4 and 0.025 gpm into screen 5. When all screens were open, there was a downward flux of 0.22 gpm from screen 1 and 3.56 gpm from screen 2 to screens 3, 4, and 5, with screens 3, 4, and 5 receiving about 1%, 27%, and 72% of the flow, respectively.

Periods of cross flow in well R-22 included the following:

- During West Bay sampling system removal in April and May 2009, water from screen 2 flowed downward to screens 3, 4, and 5 for 16,679 min (59,377 gal.), and water from screen 1 flowed downward into screens 3, 4, and 5 for 15,801 min (3476 gal.). Thus, the total flux volume was 62,853 gal. (cross-flow volume: 629 gal. into screen 3, 16,970 gal. into screen 4, and 45,254 gal. into screen 5.)
- Subsequent purging in May 2009 removed 437 gal. from screen 3, 3222 gal. from screen 4, and 83,441 gal. from screen 5. For screen 5, the volume purged was substantially greater than the original cross flow (cross-flow volume: -437 gal. from screen 3, -3222 gal. from screen 4, and -83,441 gal. from screen 5 [greater than the original contribution]).
- Following purging, the well was open during pump removal and packer installation from May 28 to May 30, 2009, for 3619 min, allowing a cross flow of 13,680 gal. (cross-flow volume: 137 gal. into screen 3, 3694 gal. into screen 4, and 9849 gal. into screen 5).
- The lower two packers failed sometime between June 20 and October 8, 2009, and allowed communication among screens 3, 4, and 5 until October 16, 2009. Thus, there was downward flux from screen 3 into screen 4 at 0.009 gpm and into screen 5 at 0.025 gpm for 8 to 118 d (cross-flow volume: -392 to -5777 gal. from screen 3, 104 to 1529 gal. into screen 4, and 288 to 4248 gal. into screen 5).
- The well was opened to remove, repair and replace the defective packers from October 16 to October 17, 2009, allowing downward flux of 3.78 gpm from screens 1 and 2 to screens 3, 4, and 5 for 1944 min (cross-flow volume: 73 gal. into screen 3, 1984 gal. into screen 4, and 5291 gal. into screen 5).

The cross-flow volumes described above for well R-22 are summarized in Table B-5.0-1.

The net effective cross-flow volume was negligible for screen 3 but significant for screens 4 and 5.

B-6.0 WELL R-23I

In well R-23i, the downward flux is estimated to be 0.47 gpm from screen 2 to screen 3 when the well is open.

Periods of cross flow included the following:

1. Numerous episodes of cross flow caused by a failed packer totaled 2961 h (177,660 min) during the period June through November 2009 (cross-flow volume: 83,500 gal.).
2. The well was open for an additional 30 h (1800 min) while the Baski sampling system was removed in December 2009 (cross-flow volume: 846 gal.).

Summing the foregoing contributions, the total cross flow was 84,346 gal.

B-7.0 SUMMARY

The estimated rates and volumes of cross flow for monitoring wells R-16, R-20, R-22 and R-23i are summarized in Table B-7.0-1.

B-8.0 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.

LANL (Los Alamos National Laboratory), July 2008. "Well R-20 Rehabilitation and Conversion Summary Report, Revision 1," Los Alamos National Laboratory document LA-UR-08-3828, Los Alamos, New Mexico. (LANL 2008, 103100)

Table B-5.0-1
R-22 Cross Flow

Task	Date	Cross Flow (gal.)		
		Screen 3	Screen 4	Screen 5
West Bay Removal	April/May 2009	629	16,970	45,254
Purging	May 2009	-437	-3222	-83,441
Packer Installation	5/28/09 to 5/30/09	137	3694	9849
Packer Failure	6/20/09 to 10/16/09	-392 to -5777	104 to 1529	288 to 4248
Packer Repair	10/16/09 to 10/17/09	73	1984	5291
Combined Effect		**73**	**19,530 to 20,955**	**15,428 to 19,388**

Table B-7.0-1
Cross-Flow Summary

Monitoring Well and Screen	Total Estimated Cross Flow (gal.)
R-16 Screen 4	32,465 to 175,342
R-20 Screen 2	2419 to 29,044
R-22 Screen 4	19,530 to 20,955
R-22 Screen 5	15,428 to 19,388
R-23i Screen 3	84,346

Appendix C

Geochemical Evaluation for
Cross-Flow Effects in Monitoring Network Wells

C-1.0 INTRODUCTION

This appendix presents an evaluation of water-quality data from well screens potentially impacted by cross flow during periods of pressure loss and resulting underinflation of packers used to separate discrete monitoring horizons. The objective of the evaluation is to determine whether compelling evidence exists to indicate that one or more water-quality samples collected from the lower screens of these wells may not be representative of groundwater in the screened interval due to cross flow from an overlying screened interval. An underlying assumption is that, if a water-quality sample contains commingled groundwater, then the effects of that mixing will be manifested by more than just one or two geochemical indicators.

Tables B-5.0-1 and B-7.0-1 in Appendix B of this report identified packer systems in wells R-16, R-20, R-22, and R-23i as potentially allowing cross flow to occur between monitoring horizons during periods of underinflation. Figure C-1.0-1 depicts the chronology of sampling events relative to periods of packer deflation for wells R-16, R-20, and R-23i, and shows that nine water-quality samples were collected from the lower screens between June and December 2009, during, or subsequent to, loss of packer pressure. These nine samples are listed in Table C-1.0-1 and are the focus of the evaluation in this appendix. Because no water-quality data were collected from the lower screen at well R-22 subsequent to pressure-loss events at that location, this well is not discussed in this appendix.

The evaluation examines water-quality data for evidence of commingling, based primarily on temporal trends of selected geochemical indicators. These indicators are selected based upon the availability of an adequate data set and consistent quantitative differences between concentrations in adjacent screened intervals. Mixing indicators used in this appendix include the following, as appropriate for a particular well:

- Major ions, including chloride, sulfate, alkalinity, sodium, potassium, calcium, and magnesium;
- Trace ions and metals, including nitrate, perchlorate, barium, manganese, molybdenum, nickel, strontium, and uranium; and
- Other indicators, including tritium.

C-2.0 OVERVIEW OF GRAPHICAL METHODS

Geochemical data relevant to identifying commingled groundwater are presented in this appendix using standard graphical methods. Each type of plot, the protocol used to select the data shown on the plots, and relevant caveats and limitations of these data are summarized below.

- Trilinear (Piper) plots are commonly used to identify waters with similar chemistries that plot in a distinct position on the Piper plot, or that appear to be evolving along similar paths. Relative percentages of major cations and major anions (expressed in milliequivalents [meq] per L) are plotted on separate ternary plots. Major cations are calcium, magnesium, and sodium + potassium; major anions are generally chloride, sulfate, and bicarbonate + carbonate. However, when nitrate comprises a significant proportion of the total anion charge, as is commonly the case in groundwater beneath the Pajarito Plateau, its contribution is included with that from chloride—i.e., the bottom axis is labeled "Cl +NO_3" on the anion ternary plot—analogous to the inclusion of the contribution from potassium with that from sodium (Na+K) on the cation ternary plot. Points plotted on the two ternary plots are then projected upwards where they intersect on the central diamond.

Another common application of this graphical tool is to identify potential mixing between end-members. 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. An underlying assumption is that the products remain in solution when two waters mix in some proportion. In addition, absolute concentrations in the mixture must be between the concentrations of the two end members.

- Time-series plots show temporal trends of geochemical indicators. These plots provide a quick visual means to classify a particular geochemical trend as stable, increasing, decreasing, or variable; and to identify possible correlated trends for other analytes as expected for commingled groundwater samples. The time-series plots in this appendix use grey shading to identify time periods during which cross flow may have occurred in a well.

Data from special sampling events such as indicator suites and other special studies are included in the plots to elucidate geochemical trends. An indicator suite is assigned to a well screen when water-quality data collected from that screen show that some or all data might not be adequately representative of undisturbed groundwater at that location. In the 2009 Interim Facility-Wide Groundwater Monitoring Plan (hereafter, the 2009 Interim Plan) (LANL 2009, 106115), indicator suites are generally assigned to screened intervals that are recovering from the effects of drilling or from well-rehabilitation or well-conversion activities. The indicator suite is a limited screening suite of key constituents that can be used to trend geochemical performance of a well, but these data generally do not undergo the same level of validation review as monitoring data because the data objectives are different. Indicator-suite data are used to guide the selection of monitoring suites for future sampling events, with regard to overall well performance for specific monitoring objectives.

The majority of the plotted data are for filtered samples; data from nonfiltered samples are used only if no filtered samples were collected or if data for nonfiltered samples are more appropriate. Plotting symbols used on the graphs do not distinguish between nonfiltered and filtered samples, nor is any distinction made between classification of a result as detected or not detected, or as validated or not validated. Such simplifications of the plotted data are justified in this case because the inclusion of such information on the figures generally would not affect the user's interpretation of the overall data trends.

C-3.0 EVALUATION OF R-16 SCREEN 4

Well R-16 underwent rehabilitation and conversion to a two-screen well in April and July 2009. In the converted well, lower and upper packers isolate screen 3 from screens 2 and 4 (LANL 2009, 106945). Screen 3 has not been available for sampling since the Westbay sampling system was pulled out of the well in July 2009. However, water-quality data from screen 3 are presented in this geochemical evaluation because of the potential for groundwater from this screened interval to flow into screen 4 when the lower packer loses pressure.

Water-quality samples used to evaluate geochemical effects of cross-flow from screens 2 and 3 to screen 4 are listed in Table C-3.0-1. The chronology of sampling events relative to pressure losses leading to packer underinflation are listed in Table C-3.0-2. The following geochemical data plots are used to support the cross-flow analysis:

- Piper plot of relative major-ion concentrations (Figure C-3.0-1),
- Time-series plots of major-ion concentrations (Figure C-3.0-2),
- Time-series plots showing concentrations of trace metals and dissolved oxygen (Figure C-3.0-3)

The evaluation of commingled groundwater focuses on samples collected from screen 4 during and after rehabilitation activities in July 2009. Post-rehabilitation groundwater samples from screens 2 and 4 plot in a single cluster on a Piper plot (Figure C-3.0-1a), but possible mixing lines between these screens emerge when these data are plotted on an expanded scale (Figure C-3.0-1b). In particular, the October 2009 sample from screen 2 and the November and December 2009 samples from screen 4 appear to be possible end-members of mixing lines in all three fields of the trilinear diagram; and samples collected from screen 4 in July and October 2009 plot on the straight lines connecting these two end-members.

However, time-series plots of geochemical trends do not support a conclusion that commingled groundwater is present in the July or October 2009 samples from screen 4. Among the major ions shown in Figure C-3.0-2, trends for calcium and sulfate in the two screens might suggest commingling in the July and October samples from screen 4, but this interpretation is inconsistent with chloride and sodium trends because concentrations of these two ions are relatively stable in screen 4 but variable in screen 2; counter to what would be expected for commingled groundwater. Time-series plots for trace metals lead to similarly ambiguous or inconclusive interpretations (Figure C-3.0-3).

In summary, although the geochemical assessment of post-rehabilitation data from well R-16 shows distinct water chemistry differences between samples collected from the different screened intervals, there is uncertainty regarding the baseline water quality of groundwater from the lowermost screen because it was not capable of providing representative water-quality data prior to well rehabilitation. Primarily for this reason, geochemical evidence is inconclusive concerning the presence of commingled water in screen 4 resulting from cross flow from screens 2 or 3. Although some proportion of mixed groundwater may be present in screen 4, the geochemical effects of cross flow appear to be minor relative to those associated with the reestablishment of equilibrium conditions in this screen following rehabilitation in July 2009.

These results should be considered preliminary and viewed with appropriate caution. Although concentrations of most inorganic analytes in post-rehabilitation samples fall within ranges observed in background regional groundwater, several indicators show definite increasing or decreasing trends over the six-month post-rehabilitation period, or show more variable concentrations than are typically observed for undisturbed groundwater. These trends suggest that not all geochemical parameters have attained stable conditions in screens 2 and 4, which may limit their applicability or reliability for identifying commingled groundwater in screen 4. As a general guideline, no firm conclusions should be made regarding the complete removal of commingled groundwater from screen 4 until additional data are gathered for a minimum of a 6-mo period following the most recent cross-flow event.

C-4.0 EVALUATION OF R-20 SCREEN 2

Well R-20 underwent rehabilitation and conversion to a two-screen well in 2008, retaining screens 1 and 2 for monitoring (LANL 2008, 103100). As part of the conversion process, screen 3 was plugged and abandoned in December 2007 and is not relevant to an assessment of cross-flow effects. A Baski dual-pump/dual-packer sampling system was installed in R-20 on May 22, 2008 ([LANL 2008, 103100]; this report, Appendix A).

Water-quality samples used to evaluate geochemical effects of cross-flow from screen 1 to screen 2 are listed in Table C-4.0-1. The chronology of sampling events relative to pressure losses leading to packer underinflation are listed in Table C-4.0-2. The following geochemical data plots are used to support this cross-flow analysis:

- Piper plot of relative major-ion concentrations (Figure C-4.0-1),
- Time-series plots of major-ion concentrations (Figure C-4.0-2), and
- Time-series plots showing concentrations of trace metals, perchlorate, and total dissolved carbon (Figure C-4.0-3).

The evaluation of commingled groundwater focuses on the two samples collected from screen 2 after the initial packer underinflation event on June 20, 2009. Groundwater samples from screens 1 and 2 plot in clearly separated tight clusters on a Piper plot (Figure C-4.0-1) with no indication of mixing between these screens.

Time-series plots of geochemical trends also do not support a conclusion that samples from screen 2 contain commingled groundwaters. Major-ion concentrations in screen 2 are either steady (e.g., chloride, magnesium, potassium) or follow trends opposite from those expected for commingled groundwater (e.g., sulfate, calcium) (Figure C-4.0-2). Time-series plots for trace metals and perchlorate (Figure C-4.0-3) show similar patterns; relatively stable concentrations for some metals (e.g., molybdenum) and trends opposite from those expected for commingled groundwater for other metals (e.g., barium, strontium).

The conclusion of this evaluation is that there is no compelling evidence for the presence of commingled water in screen 2 resulting from cross flow from screen 1. Although some proportion of mixed groundwater may be present in screen 2, its geochemical effects appear to be minor compared to those associated with the recovery from residual effects of drilling.

C-5.0 EVALUATION OF R-23i SCREEN 3

Water-quality samples used to evaluate geochemical effects of cross-flow from screen 2 to screen 3 in well R-23i are listed in Table C-5.0-1. The chronology of sampling events relative to pressure losses leading to packer underinflation are listed in Table C-5.0-2.

The following geochemical data plots are used to support this cross-flow analysis:

- Piper plot of relative major-ion concentrations (Figure C-5.0-1),
- Time-series plots of major-ion concentrations (Figure C-5.0-2), and
- Time-series plots showing tritium activities and concentrations of trace metals, perchlorate, and total organic carbon (Figure C-5.0-3).

The evaluation of commingled groundwater focuses on the three samples collected from screen 3 after the initial packer underinflation event on June 5, 2009. Groundwater samples from screens 2 and 3 generally plot in clearly separated tight clusters on a Piper plot (Figure C-5.0-1a), with a single obvious exception of the sample collected from screen 3 on June 10, 2009. When the data are plotted on an expanded scale (Figure C-5.0-1b), the June 10 sample is seen to be closely associated with the cluster defined by samples from screen 2.

Time-series plots of geochemical trends support a conclusion that the sample collected from screen 3 on June 10 consists of commingled groundwaters. Major-ion concentrations in screen 3 are nearly identical to those in screen 2 (e.g., chloride, sulfate, potassium, alkalinity) or otherwise follows trends expected for commingled groundwater (e.g., sodium) (Figure C-4.0-2). Time-series plots for concentrations of barium, strontium, uranium, molybdenum, and perchlorate likewise show trends that support a finding of commingled groundwater in the June 10 sample (Figure C-4.0-3).

Thus, a visual analysis of Piper plots and time-series plots indicate presence of commingled water in the sample collected on June 10, 2009, from screen 3, resulting from cross flow from screen 2. This finding is consistent with the review of water-level data for well R-23i, which showed that the packer between screens 2 and 3 was deflated at the time that the water-quality sample was collected from screen 3 (Appendix A).

C-6.0 SUMMARY OF EVALUATIONS

Packer systems in wells R-16, R-20, and R-23i potentially allowed cross flow to occur between monitoring horizons during periods of underinflation. Nine water-quality samples were collected from the lower screens of these wells between June and December 2009, during, or subsequent to, loss of packer pressure. Geochemical indicators in these nine samples were evaluated for evidence of commingling with groundwater from an overlying interval, based primarily on visual examination of Piper plots and time-series plots.

Although the geochemical assessment of post-rehabilitation data from well R-16 shows distinct water chemistry differences between samples collected from the different screened intervals, there is uncertainty regarding the baseline water quality of groundwater from the lowermost screen because it was not capable of providing representative water-quality data prior to well rehabilitation. Primarily for this reason, geochemical evidence is necessarily inconclusive concerning the presence of commingled water in screen 4 resulting from cross flow from screens 2 or 3. In the case of well R-20, there is no compelling geochemical evidence for the presence of commingled water in samples collected from screen 2 in this well following losses of packer pressure. Although it is conceivable that some proportion of mixed groundwater may be present in one or more samples from the lower screens in wells R-16 and R-20, the geochemical effects of such mixing appear to be minor relative to those associated with residual effects of drilling or of rehabilitation activities.

In contrast, multiple lines of geochemical evidence indicate the presence of commingled water in the sample collected on June 10, 2009 from R-23i screen 3. This is consistent with the analysis of the pressure transducer data for R-23i (Appendix A), which indicate that this sample was collected during a period when the Baski packer was underinflated, and when cross flow from the upper screen to the lower screen was occurring. Thus, the water chemistry of the sample collected from the lower screen of R-23i on June 10, 2009 represents a mixture of waters from the lower and upper screened intervals of R-23i.

These findings are summarized in Table C-6.0-1.

C-7.0 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 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 2008. “Well R-20 Rehabilitation and Conversion Summary Report, Revision 1,” Los Alamos National Laboratory document LA-UR-08-3828, Los Alamos, New Mexico. (LANL 2008, 103100)

LANL (Los Alamos National Laboratory), May 2009. “2009 Interim Facility-Wide Groundwater Monitoring Plan,” Los Alamos National Laboratory document LA-UR-09-1340, Los Alamos, New Mexico. (LANL 2009, 106115)

LANL (Los Alamos National Laboratory), September 2009. “Rehabilitation and Conversion Summary Report for Well R-16,” Los Alamos National Laboratory document LA-UR-09-5372, Los Alamos, New Mexico. (LANL 2009, 106945)

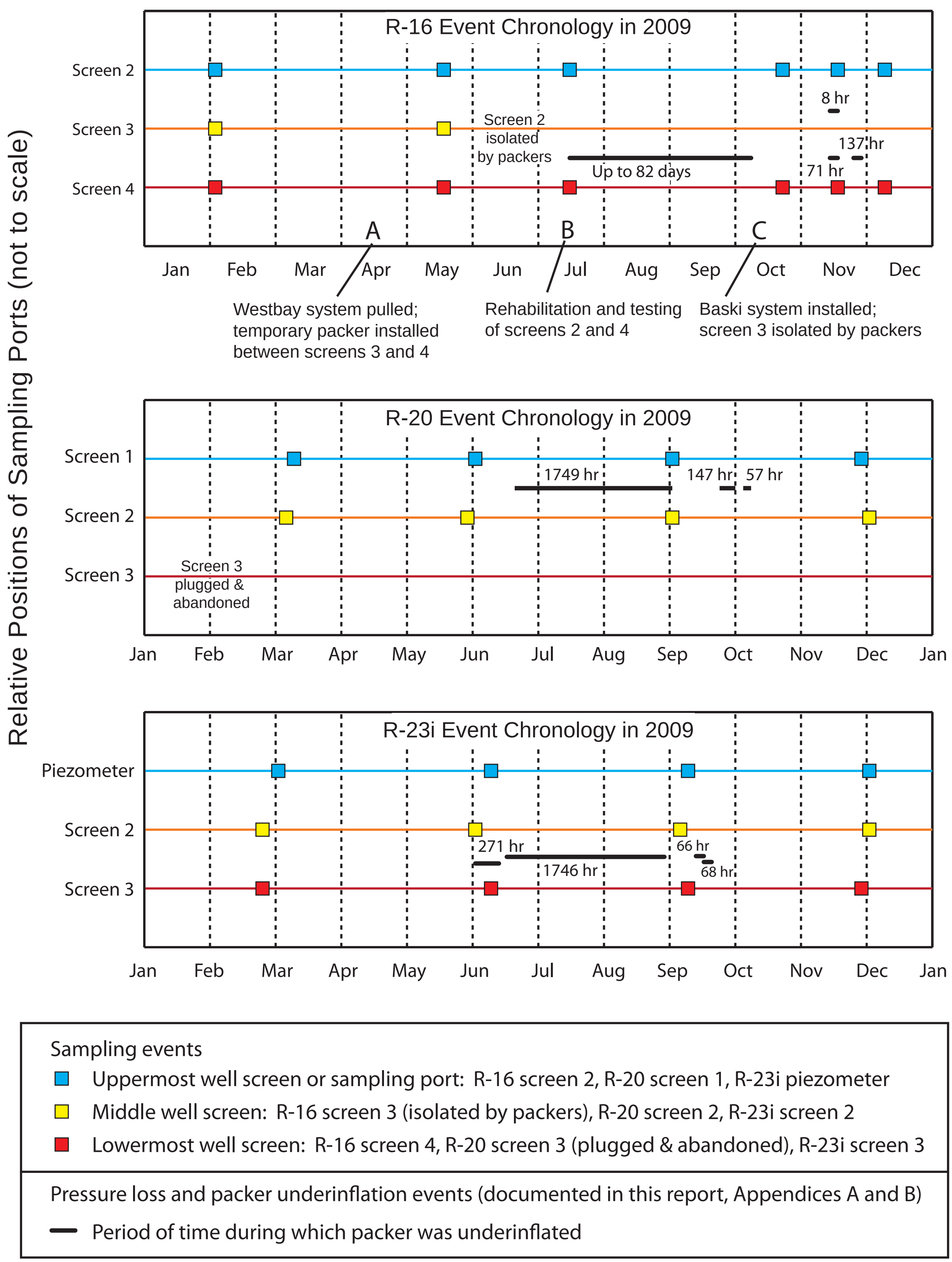

Figure C-1.0-1 Schematic showing relative chronology of packer leaks and sampling events at wells R-16, R-20, and R-23i, during calendar year 2009

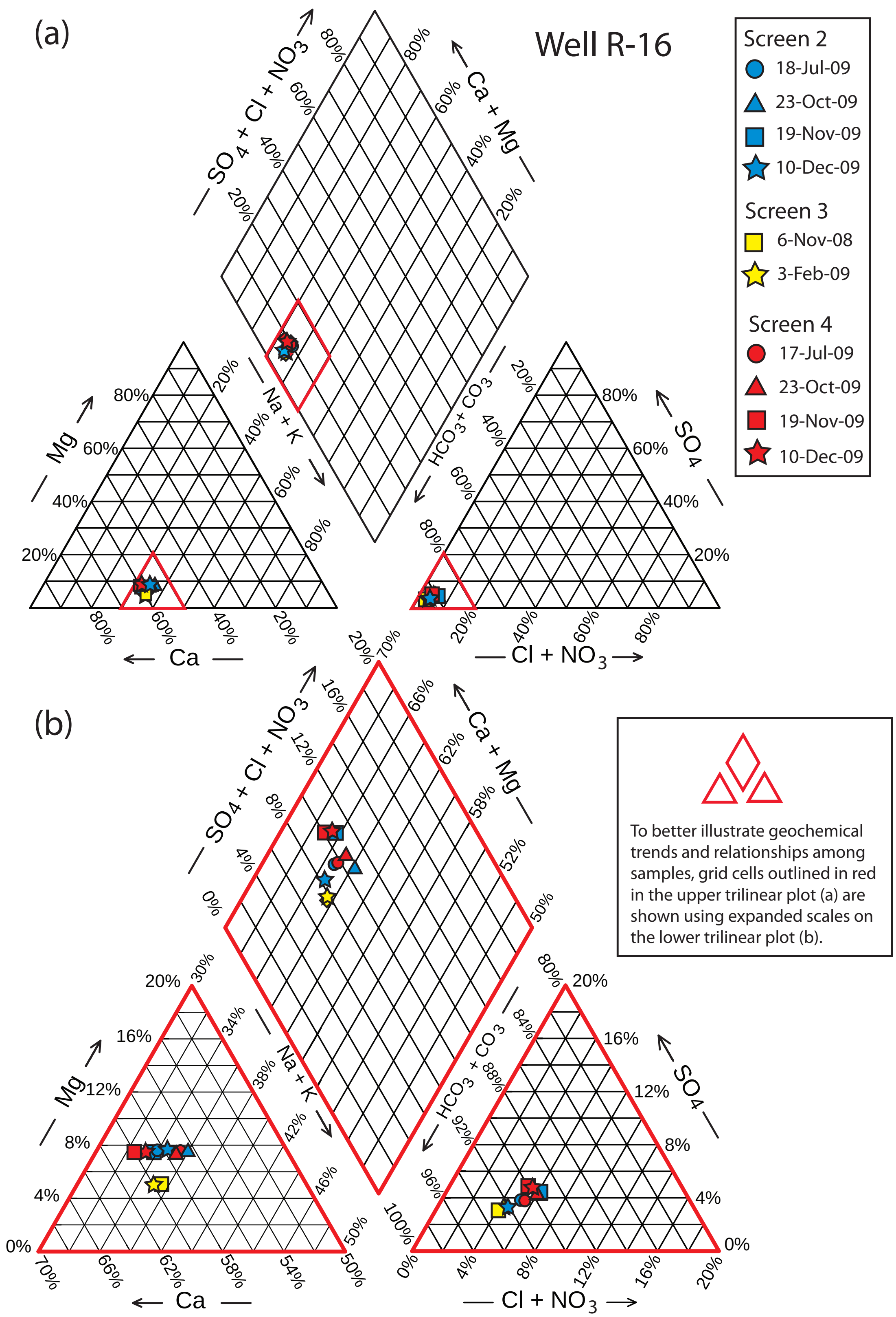

Figure C-3.0-1 Trilinear (Piper) plot depicting major-ion chemistry of groundwater samples collected at well R-16, screens 2, 3, and 4, between November 2008 and December 2009: (a) full scale and (b) expanded scale

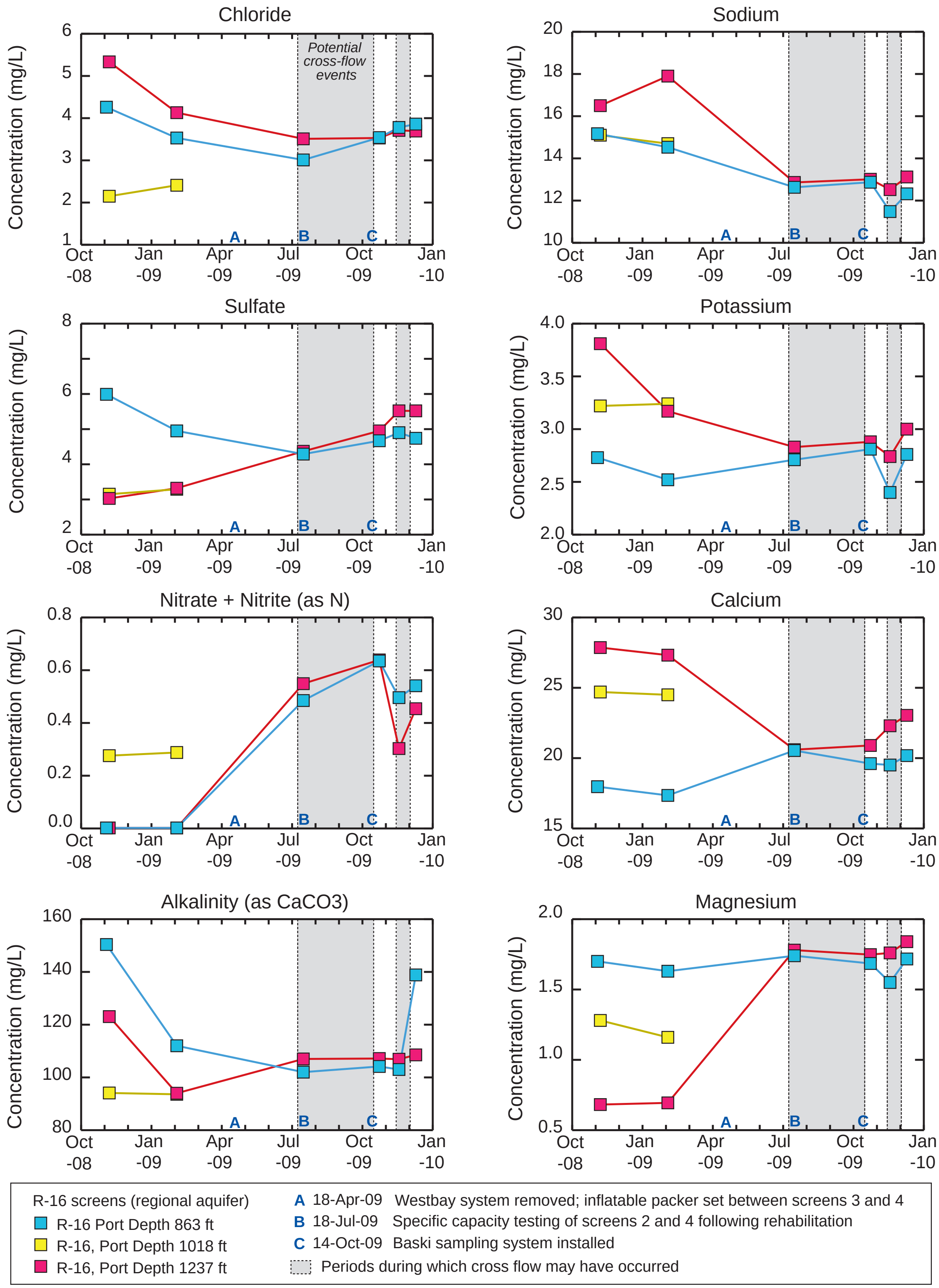

Figure C-3.0-2 Trends in major-ion concentrations in groundwater collected at Well R-16, screens 2, 3, and 4, between November 2008 and December 2009

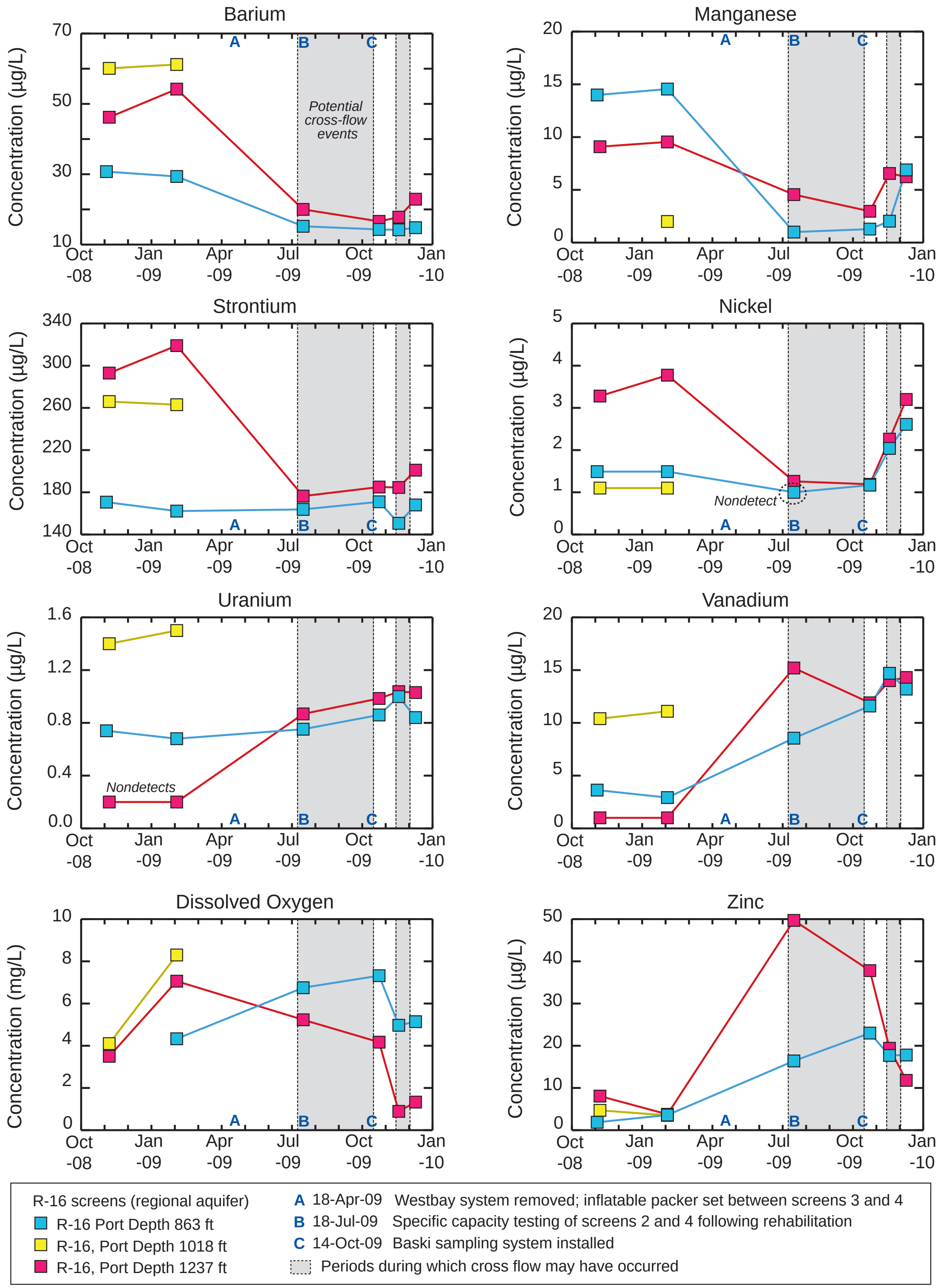

Figure C-3.0-3 Trends in trace-ion and total organic carbon concentrations in groundwater samples collected at well R-16, screens 2, 3, and 4, between November 2008 and December 2009

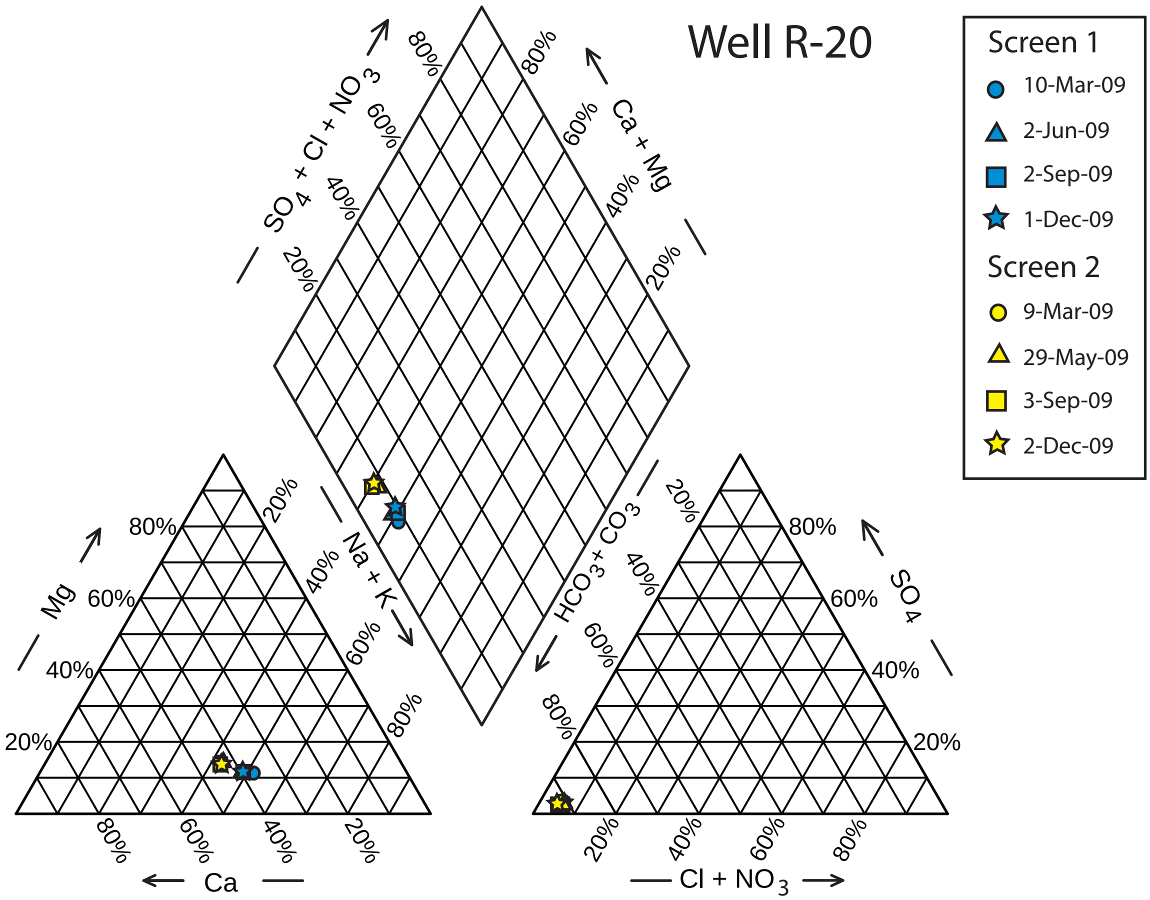

Figure C-4.0-1 Trilinear (Piper) plot depicting major-ion chemistry of groundwater samples collected at well R-20, screens 1 and 2, between December 2008 and December 2009

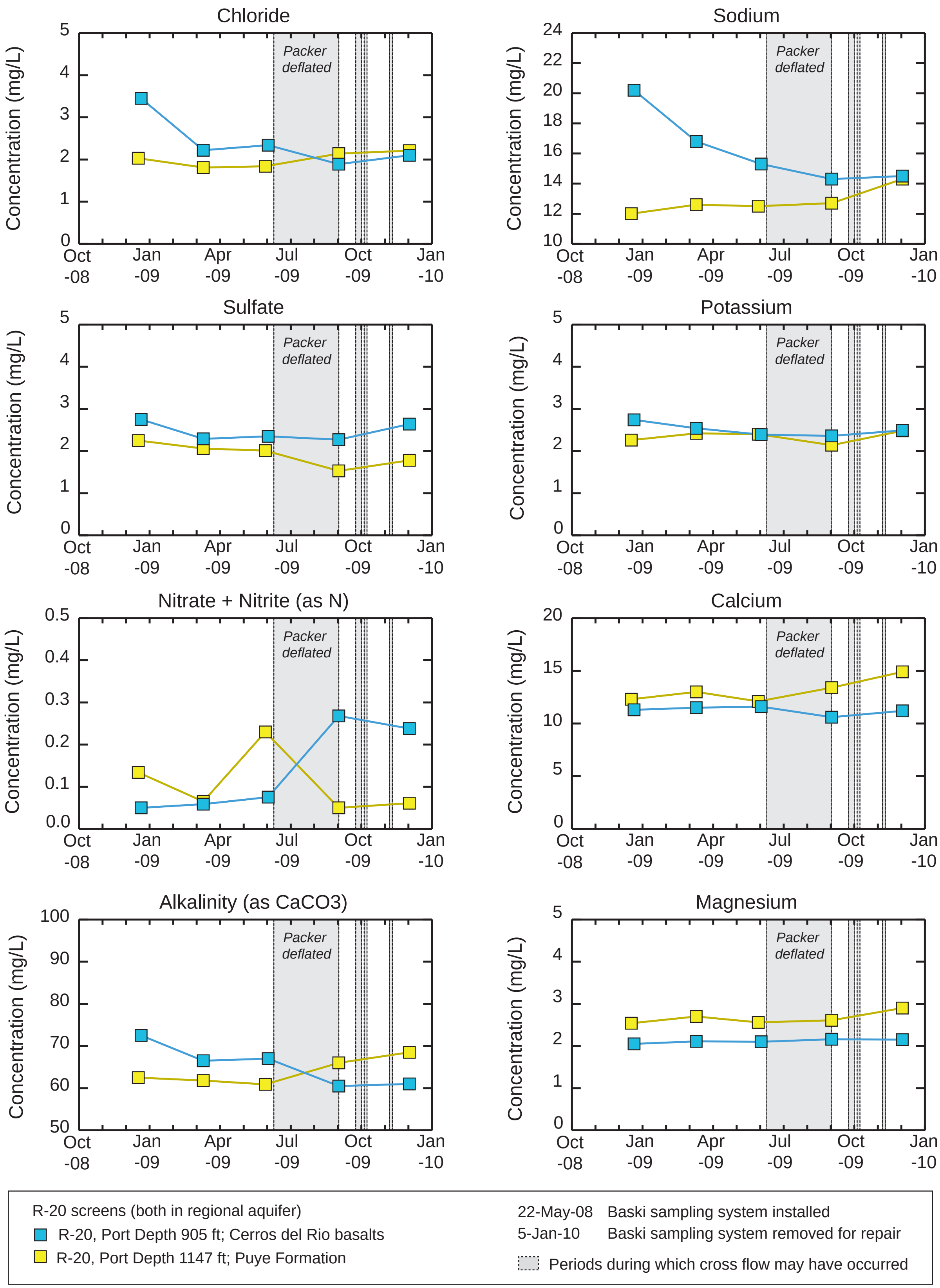

Figure C-4.0-2 Trends in major-ion concentrations in groundwater collected at Well R-20, screens 1 and 2, between December 2008 and December 2009

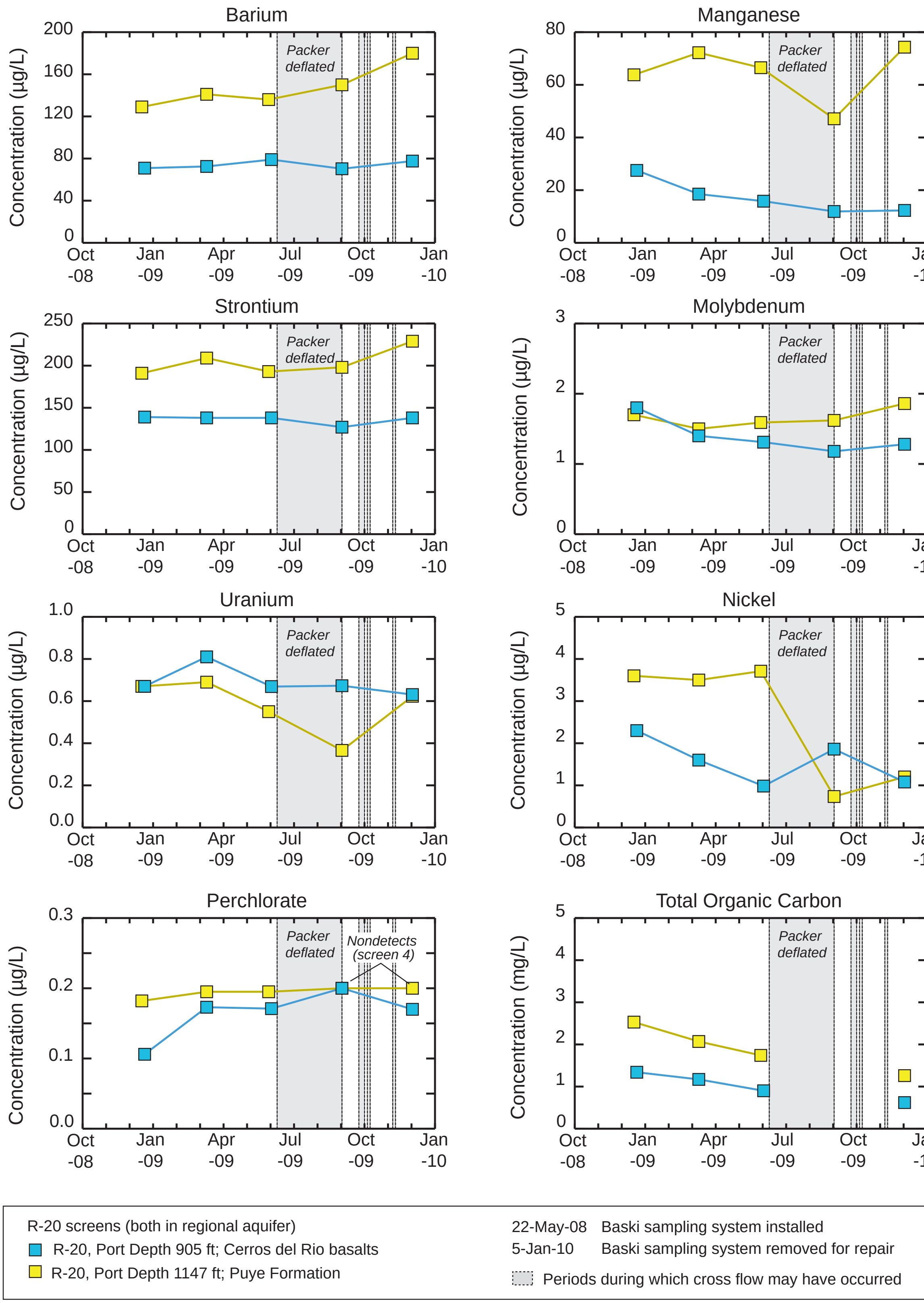

Figure C-4.0-3 Trends in trace-ion and total organic carbon concentrations in groundwater samples collected at well R-20, screens 1 and 2, between December 2008 and December 2009.

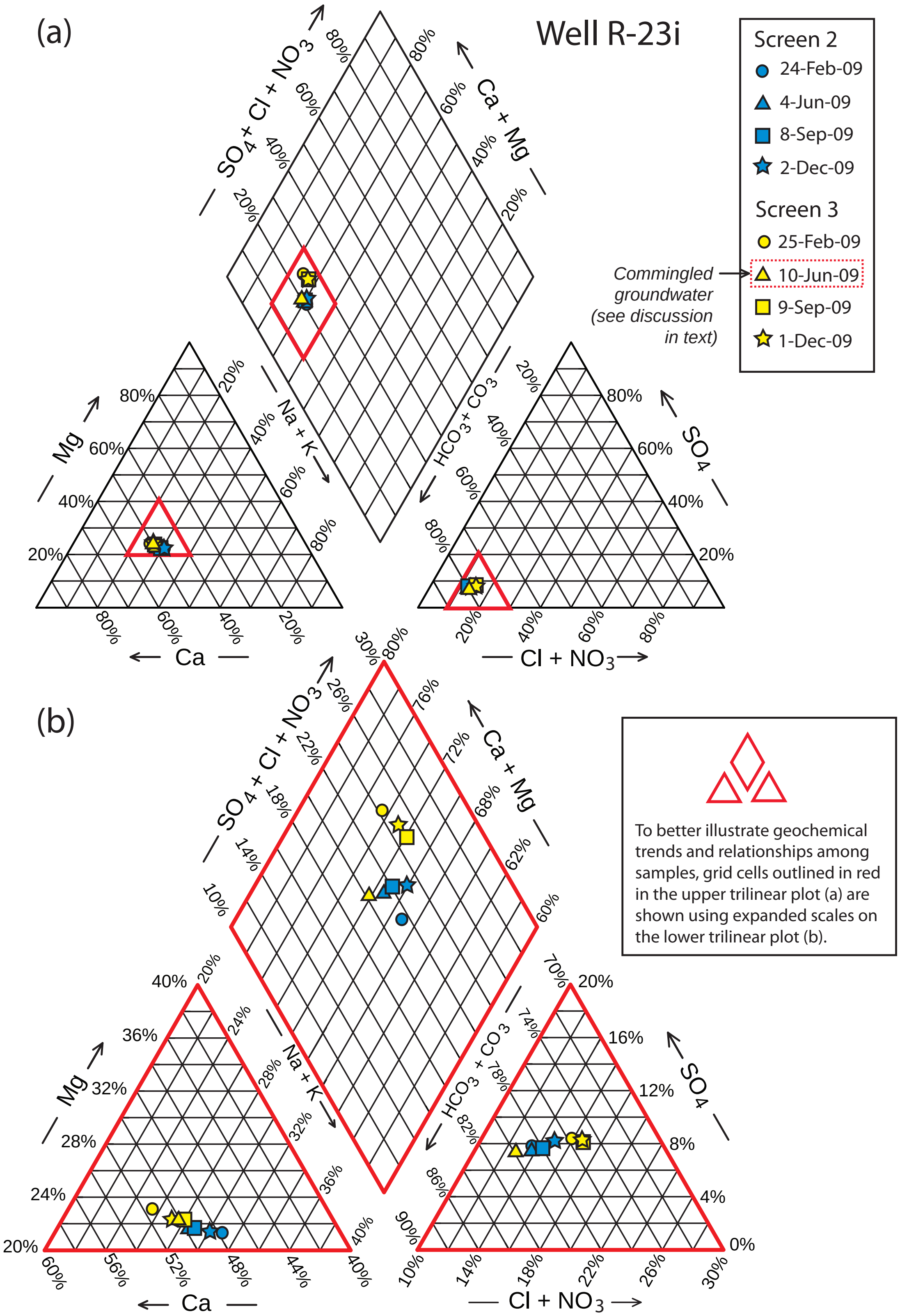

Figure C-5.0-1 Trilinear (Piper) plot depicting major-ion chemistry of groundwater samples collected at well R-23i, screens 2 and 3, between December 2008 and December 2009 (a) full scale and (b) expanded scale

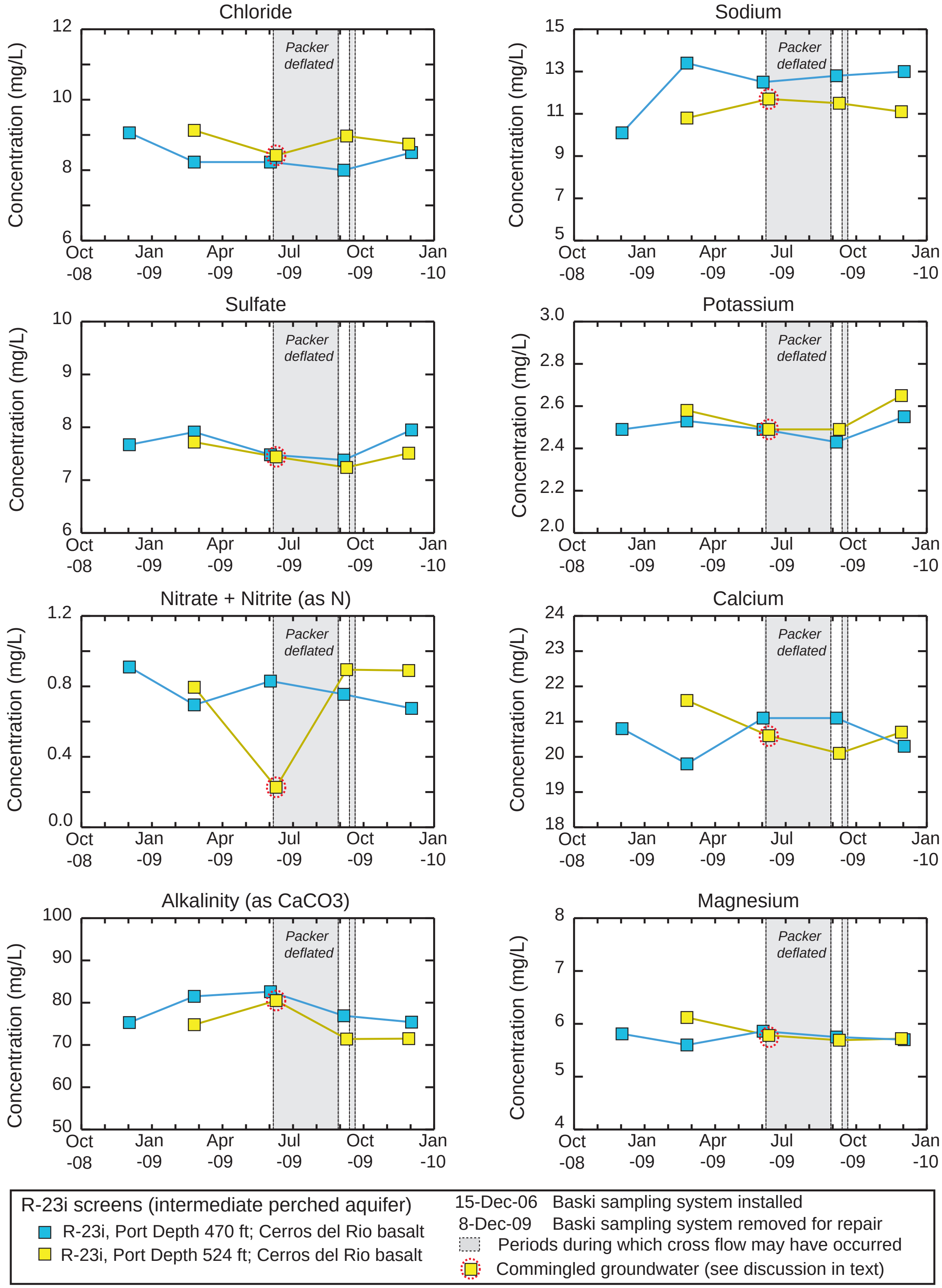

Figure C-5.0-2 Trends in major-ion concentrations in groundwater collected at well R-23i, screens 2 and 3, between December 2008 and December 2009

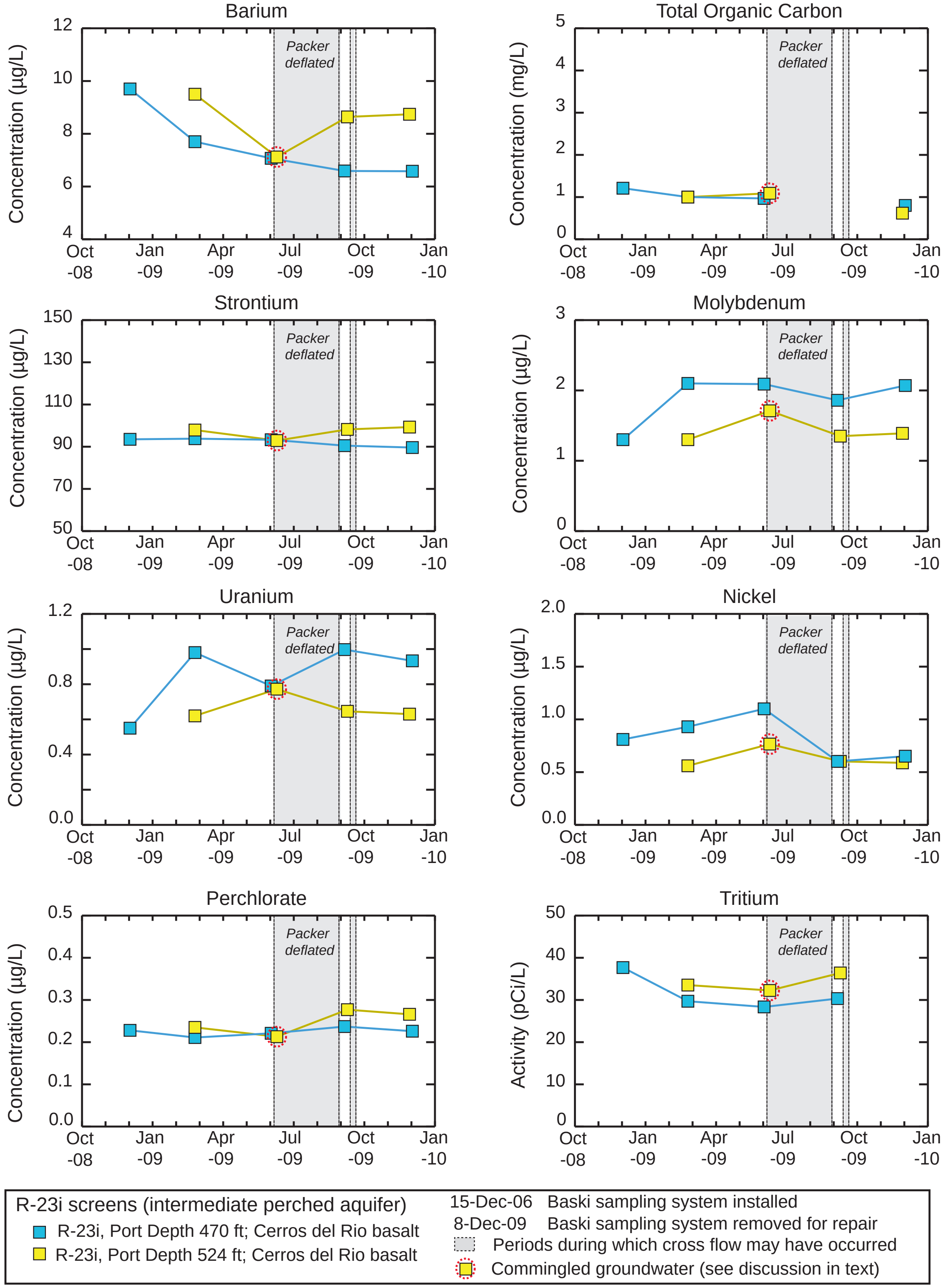

Figure C-5.0-3 Trends in trace-ion and total organic carbon concentrations and tritium activities in groundwater collected at well R-23i, screens 2 and 3, between December 2008 and December 2009

Table C-1.0-1
Water-Quality Samples Evaluated for Cross-Flow Effects

Well	Screen	Sampling Port Depth (ft bgs[a])	Collection Date	Sampling Objectives	Assigned Analytical Suites
R-16	Screen 4	1237	17-Jul-09	Special sampling event (rehabilitation activity)	Indicator suite[b]
R-16	Screen 4	1237	23-Oct-09	Special sampling event (post-rehabilitation monitoring)	Indicator suite
R-16	Screen 4	1237	19-Nov-09	Special sampling event (post-rehabilitation monitoring)	Extended indicator suite[c]
R-16	Screen 4	1237	10-Dec-09	Special sampling event (post-rehabilitation monitoring)	Indicator suite
R-20	Screen 2	1147.1	03-Sep-09	Monitoring per 2009 Interim Plan (LANL 2009, 106115)	Full characterization suite for TA-54 monitoring well network[d]
R-20	Screen 2	1147.1	02-Dec-09	Monitoring per 2009 Interim Plan (LANL 2009, 106115)	Full characterization suite for TA-54 monitoring well network
R-23i	Screen 3	524	10-Jun-09	Monitoring per 2009 Interim Plan (LANL 2009, 106115)	Watershed-specific monitoring suite, extended to provide baseline data[e]
R-23i	Screen 3	524	09-Sep-09	Monitoring per 2009 Interim Plan (LANL 2009, 106115)	Watershed-specific monitoring suite, extended to provide baseline data
R-23i	Screen 3	524	01-Dec-09	Monitoring per 2009 Interim Plan (LANL 2009, 106115)	Watershed-specific monitoring suite, extended to provide baseline data

[a] bgs = Below ground surface.

[b] The indicator suite includes major anions and cations (including metals), nitrate plus nitrite, alkalinity, pH, total organic carbon, and, as needed, sulfide, ammonia, total Kjeldahl nitrogen, and perchlorate (LANL 2009, 106115, Table 4.4-1, note g).

[c] The extended indicator suite includes the same analytes as the indicator suite, as well as one or more analytical suites targeting analytes of interest. For the sample collected at screen 4 of well R-16 in November 2009, the indicator suite was extended to include volatile organic compounds.

[d] Full characterization suite assigned to new wells that are part of the TA-54 monitoring well network for which suites and frequencies are defined in Table D-1.0-1 in the 2009 Interim Plan (LANL 2009, 106115). Although R-20 is not a “new” well, screens 1 and 2 were assigned to characterization sampling to reestablish baseline conditions following rehabilitation and conversion activities at well R-20.

[e] Watershed-specific monitoring suite for well R-23i is defined in Table D-1.0-5 of the 2009 Interim Plan (LANL 2009, 106115).

Table C-3.0-1
Samples Used to Evaluate Cross-Flow Effects in Samples Collected from Well R-16 Screen 4

Screen	Sampling Port Depth (ft bgs[a])	Collection Date	Sample ID and Field Preparation Code
Screen 2	866.1	03-Nov-08	CAMO-09-820 (UF)[b] CAMO-09-822 (F)[c]
Screen 2	866.1	03-Feb-09	CAMO-09-2637 (UF) CAMO-09-2639 (F)
Screen 2	866.1	18-Jul-09	CAMO-09-9305 (F) CAMO-09-9306 (UF)
Screen 2	863.4	23-Oct-09	GW16-10-2253 (UF) GW16-10-2254 (F)
Screen 2	863.4	19-Nov-09	CAMO-10-3149 (F) CAMO-10-3150 (UF)
Screen 2	863.4	10-Dec-09	GW16-10-2261 (UF) GW16-10-2262 (F)
Screen 3	1018.4	06-Nov-08	CAMO-09-805 (UF) CAMO-09-806 (F)
Screen 3	1018.4	03-Feb-09	CAMO-09-2622 (F) CAMO-09-2623 (UF)
Screen 4	1238	03-Nov-08	CAMO-09-823 (UF) CAMO-09-824 (F) CAMO-09-963 (F)
Screen 4	1238	03-Feb-09	CAMO-09-2640 (F) CAMO-09-2641 (UF)
Screen 4	1238	17-Jul-09	CAMO-09-9316 (F) CAMO-09-9317 (UF)
Screen 4	1237	23-Oct-09	GW16-10-2255 (UF) GW16-10-2256 (F)
Screen 4	1237	19-Nov-09	CAMO-10-3193 (UF) CAMO-10-3194 (F)
Screen 4	1237	10-Dec-09	GW16-10-2263 (F) GW16-10-2264 (UF)

[a] bgs = Below ground surface.

[b] UF = Unfiltered sample.

[c] F = Filtered sample.

Table C-3.0-2
Chronology of Sampling Events Relative to Rehabilitation Activities and Packer Pressure Losses in Well R-16

Date(s)	Activity or Event	Relevance to Cross-Flow Assessment
3-Nov-08 to 6-Nov-08	Sample collection from screens 2, 3, and 4	Samples included in analysis to establish geochemical trends.
03-Feb-09	Sample collection from screens 2, 3, and 4	Samples included in analysis to establish geochemical trends.
16-Apr-09 to 18-Apr-09	Removal of Westbay system; emplacement of temporary inflatable packer between screens 3 and 4	Potential cross flow of water from screens 2 and 3 to screen 4.
10-Jul-09 to 13-Jul-09	Rehabilitation of screens 2 and 4	Potential cross flow of water from screens 2 and 3 to screen 4.
17-Jul-09	Sample collection at end of screen 4 aquifer test. Screen 4 isolated by packer during test.	Samples included in analysis to establish geochemical trends.
18-Jul-09	Sample collection at end of screen 2 aquifer test. Screen 2 isolated by packers during test.	Samples included in analysis to establish geochemical trends.
8–Oct-09	Temporary packer between screens 3 and 4 observed to be deflated.	Effective start date of commingling is unknown but could have been as early as July 18.
14-Oct-09	Installation of Baski dual-valve sampling system. Screen 3 isolated from screens 2 and 4 by upper and lower packers.	Redesigned sampling system
23-Oct-09	Sample collection from screens 2 and 4	Screen 4 sample is evaluated for presence of commingled groundwater.
14-Nov-09 to 17-Nov-09	Lower packer deflated for about 3 days.	Potential cross flow of water from screen 3 to screen 4.
17-Nov-09	Upper packer deflated for about 8 hours.	Potential cross flow of water from screens 2 and 3 to screen 4.
19-Nov-09	Sample collection from screens 2 and 4	Screen 4 sample is evaluated for presence of commingled groundwater.
25-Nov-09 to 1-Dec-09	Lower packer deflated for about 6 days.	Potential cross flow of water from screen 3 to screen 4.
10-Dec-09	Sample collection from screens 2 and 4	Screen 4 sample is evaluated for presence of commingled groundwater.

Source: Appendix A of this report.

Table C-4.0-1
Samples Used Evaluate Cross-Flow Effects
in Samples Collected from Well R-20 Screen 2

Screen	Sampling Port Depth (ft bgs[a])	Collection Date	Sample ID and Field Preparation Code
Screen 1	904.6	19-Dec-08	CAPA-09-1223 (F)[b] CAPA-09-1224 (UF)[c]
Screen 1	904.6	10-Mar-09	CAPA-09-14363 (UF) CAPA-09-14364 (F) CAPA-09-5500 (UF) CAPA-09-5501 (F)
Screen 1	904.6	02-Jun-09	CAPA-09-9409 (F) CAPA-09-9410 (UF)
Screen 1	904.6	02-Sep-09	CAPA-09-12261 (F) CAPA-09-12263 (UF)
Screen 1	904.6	01-Dec-09	CAPA-10-6373 (UF) CAPA-10-6375 (F)
Screen 2	1147.1	18-Dec-08	CAPA-09-1226 (F) CAPA-09-1228 (UF)
Screen 2	1147.1	09-Mar-09	CAPA-09-4372 (UF) CAPA-09-4374 (F)
Screen 2	1147.1	29-May-09	CAPA-09-9412 (F) CAPA-09-9414 (UF)
Screen 2	1147.1	03-Sep-09	CAPA-09-12265 (UF) CAPA-09-12267 (F)
Screen 2	1147.1	02-Dec-09	CAPA-10-6855 (UF) CAPA-10-6856 (F) CAPA-10-6858 (F) CAPA-10-6859 (UF) CAPA-10-6860 (F) CAPA-10-6861 (UF)

[a] bgs = Below ground surface.

[b] F = Filtered sample.

[c] UF = Unfiltered sample.

Table C-4.0-2
Chronology of Sampling Events Relative to Packer Pressure Losses in Well R-20

Date(s)	Activity	Relevance to Cross-Flow Assessment
18-Dec-08 to 19-Dec-08	Sample collection from screens 1 and 2	Samples included in analysis to establish geochemical trends.
10-Mar-09	Sample collection from screens 1 and 2	Samples included in analysis to establish geochemical trends.
02-Jun-09	Sample collection from screens 1 and 2	Samples included in analysis to establish geochemical trends.
20-Jun-09 to 1-Sep-09	Packer lost pressure for approximately 73 days.	Potential cross flow of water from screen 1 to screen 2.
02-Sep-09	Sample collection from screens 1 and 2.	Screen 2 sample is evaluated for presence of commingled groundwater.
25-Sep-09 to 1-Oct-09	Packer lost pressure for approximately 6 days.	Potential cross flow of water from screen 1 to screen 2.
6-Oct-09 to 8-Oct-09	Packer lost pressure for approximately 2 days.	Potential cross flow of water from screen 1 to screen 2.
8-Nov-09 to 10-Nov-09	Packer deflated for approximately 2 1/2 days.	Potential cross flow of water from screen 1 to screen 2.
01-Dec-09	Sample collection from screens 1 and 2	Screen 2 sample is evaluated for presence of commingled groundwater.
5-Jan-10	Baski system removed for repair of the packer system.	No samples collected.

Source: Appendix A of this report.

Table C-5.0-1
Samples Used to Evaluate Cross-Flow Effects in Samples Collected from Well R-23i Screen 3

Screen	Sampling Port Depth (ft bgs[a])	Collection Date	Sample ID and Field Preparation Code
Screen 2	470.2	02-Dec-08	CAPA-09-1193 (F)[b] CAPA-09-1194 (UF)[c]
Screen 2	470.2	24-Feb-09	CAPA-09-4293 (F) CAPA-09-4295 (UF)
Screen 2	470.2	04-Jun-09	CAPA-09-9353 (F) CAPA-09-9354 (UF)
Screen 2	470.2	08-Sep-09	CAPA-09-12243 (F) CAPA-09-12244 (UF)
Screen 2	470.2	02-Dec-09	CAPA-10-6151 (UF) CAPA-10-6152 (F)
Screen 3	524	25-Feb-09	CAPA-09-4298 (UF) CAPA-09-4299 (F)
Screen 3	524	10-Jun-09	CAPA-09-9360 (F) CAPA-09-9361 (UF)
Screen 3	524	09-Sep-09	CAPA-09-12246 (UF) CAPA-09-12249 (F)
Screen 3	524	01-Dec-09	CAPA-10-6862 (F) CAPA-10-6863 (UF)

[a] bgs = Below ground surface.

[b] F = Filtered sample.

[c] UF = Unfiltered sample.

Table C-5.0-2
Chronology of Sampling Events Relative to Packer Pressure Losses in Well R-23i

Date(s)	Activity	Relevance to Cross-Flow Assessment
10-Mar-09	Sample collection from screens 2 and 3	Samples included in analysis to establish geochemical trends.
04-Jun-09	Sample collection from screen 2	Sample included in analysis to establish geochemical trends.
5-Jun-09 to 16-Jun-09	Packer lost pressure for approximately 11 days.	Potential cross flow of water from screen 2 to screen 3.
10-Jun-09	Sample collection from screen 3	Screen 3 sample is evaluated for presence of commingled groundwater.
20-Jun-09 to 31-Aug-09	Packer lost pressure for approximately 73 days.	Potential cross flow of water from screen 2 to screen 3.
08-Sep-09	Sample collection from screen 2	Sample included in analysis to establish geochemical trends.
09-Sep-09	Sample collection from screen 3	Screen 3 sample is evaluated for presence of commingled groundwater.
14-Sep-09 to 25-Nov-09	Packer intermittently lost pressure for 39 days (cumulative).	Potential cross flow of water from screen 2 to screen 3.
01-Dec-09	Sample collection from screen 3	Screen 3 sample is evaluated for presence of commingled groundwater.
02-Dec-09	Sample collection from screen 2	Sample included in analysis to establish geochemical trends.
8-Dec-09	Baski system removed for repair of the packer system.	No samples collected.

Source: Appendix A of this report.

Table C-6.0-1
Water-Quality Samples Impacted by Cross Flow from an Upper Screened Interval

Well	Port Name	Sampling Port Depth (ft bgs[a])	Collection Date	Sample ID and Field Preparation Code	Lab Code and Analytical Suites Associated with Samples Affected by Cross Flow
R-16	P4A	1237	17-Jul-09	CAMO-09-9316 (F)[b] CAMO-09-9317 (UF)[c]	Not applicable—No compelling evidence found for cross flow impacts
R-16	P4A	1237	23-Oct-09	GW16-10-2255 (UF) GW16-10-2256 (F)	Not applicable—No compelling evidence found for cross flow impacts
R-16	P4A	1237	19-Nov-09	CAMO-10-3193 (UF) CAMO-10-3194 (F)	Not applicable—No compelling evidence found for cross flow impacts
R-16	P4A	1237	10-Dec-09	GW16-10-2263 (F) GW16-10-2264 (UF)	Not applicable—No compelling evidence found for cross flow impacts
R-20	P2A	1147.1	03-Sep-09	CAPA-09-12265 (UF) CAPA-09-12267 (F)	Not applicable—No compelling evidence found for cross flow impacts
R-20	P2A	1147.1	02-Dec-09	CAPA-10-6855 (UF) CAPA-10-6856 (F) CAPA-10-6858 (F) CAPA-10-6859 (UF) CAPA-10-6860 (F) CAPA-10-6861 (UF)	Not applicable—No compelling evidence found for cross flow impacts
R-23i	P3A	524	10-Jun-09	CAPA-09-9360 (F)	GELC[d] • General Inorganics (GENINORG) • Metals (METALS) • Radionuclides (RAD)
				CAPA-09-9361 (UF)	GELC • General Inorganics (GENINORG) • High explosives (HEXP) • Metals (METALS) • Radionuclides (RAD) • Volatile organic compounds (VOA)
					FLD[e] • Field parameters
					STSL[f] • High explosives (HEXP)
					UMTL[g] • Tritium (RAD)

[a] bgs = Below ground surface.

[b] F = Filtered sample.

[c] UF = Unfiltered sample.

[d] GELC = General Engineering Laboratories, Inc.

[e] FLD = Field parameters.

[f] STSL = Severn Trent Laboratories, Inc.

[g] UMTL = University of Miami Tritium Laboratory.