LANL Single-Screen Characterization Well R-34 requires replacement, version 07-22-08

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Introduction. Figure 1 shows the location of the Los Alamos National Laboratory (LANL) characterization well R-34 in Cedro Canyon on the property of the San Ildefonso Pueblo. Figure 2 shows the plume pathway in the regional aquifer for travel of the contaminated groundwater below Mortandad Canyon across the property of the San Ildefonso Pueblo to the Rio Grande and to the Buckman well field, an important groundwater resource for Santa Fe. Well R-34 is located along the plume pathway but is not a reliable monitoring well.

The LANL contaminants of potential concern (COPC) for groundwater below Mortandad Canyon and along the plume pathway on Figure 2 include strontium-89, -90; cesium-137; plutonium-239, -240; americium-241; lanthanum-140; barium-140; yttrium-90; ruthenium-106; uranium-234, -235, and -238; tritium; hexavalent chromium; perchlorate; nitrate; chloride; fluoride; and 1,4-dioxane.

The groundwater in the regional aquifer along the plume pathway on Figure 2 is contaminated with hexavalent chromium at levels more than eight (8) times above the drinking water standard of the New Mexico Environment Department (NMED). The highest known hexavalent chromium contamination is at a location that is close to the property of the San Ildefonso Pueblo. LANL has no reliable monitoring wells for the investigation of groundwater contamination on the property of the San Ildefonso Pueblo and along the plume pathway in Figure 2.

The factors that require the replacement of LANL characterization well R-34 with two new reliable monitoring wells are as follows:

- 1). The screened interval was invaded with organic drilling additives that have well known properties to prevent the detection of many LANL contaminants.
- 2). The organic drilling additives formed a new mineralogy in the screened interval with well known properties to prevent the detection of many LANL contaminants, and especially the trace metal radionuclides listed above.
- 3). The well development methods were not able to remove the new mineralogy (i.e., precipitates of iron and manganese) from the screened interval.
- 4). The new stainless steel screen has well known properties for preventing the detection and accurate measurement of the strongly adsorbing LANL contaminants including isotopes of plutonium, cesium, americium, etc.
- 5). Over time the stainless steel screen will corrode and the corrosion process
- a). releases chromium and nickel to groundwater and
- b). forms rust on the screen with well known properties to prevent the detection and accurate measurement of many LANL contaminants.
- 6). The trend analysis of dissolved zinc and barium shows that water samples from well R-34 are not able to detect and accurately measure many LANL COPC including RCRA trace metals and the DOE trace metal radionuclides.

- 7). The well screen was not installed in the highly permeable aquifer strata where contamination is most expected to be present at highest concentrations. The information in this exhibit are from the following sources –

- LANL *Well R-34 Completion Report* (Kleinfelder Project No. 37151/17.12, Feb 2005
- LANL *Well R-10/10a Completion Report* (Kleinfelder Project No. 49436, Jan 2006
- LANL *Characterization Well R-13 Completion Report,* LA-UR-03-1373, June 2003
- LANL Hydrogeologic Synthesis Report, (ER 2005-0679, December 2005)
- LANL *Well Screen Analysis Report - Revision 2* (WSAR-2) (LA-UR-07-2852, May 2007)
- LANL water quality data base website
- NMED (New Mexico Environment Department) LANL Consent Order signed into Law on March 1, 2005
- NAS (National Academy of Sciences) *Plans and Practices for Groundwater Protection at the Los Alamos National Laboratory: Final Report,* The National Academies Press, 2007
- EPA (Environmental Protection Agency) Report titled *Impacts of Hydrogeologic Characterization Well Construction Practices at the Los Alamos National Laboratory*, EPA Memorandum (05RC06-001), February 10, 2006
- Gilkeson, Robert H., Presentation to the March 14, 2007 Meeting of the EMSR Committee of the Northern New Mexico Citizens' Advisory Board (CAB) on the need for LANL to use air-rotary casing advance drilling methods for the installation of monitoring wells.
- Gilkeson, Robert H., *Properties of the Stainless Steel Screens in the LANL Characterization Wells to Prevent the Detection of Radionuclide and Hazardous Waste Contamination in Groundwater* - Revision 1, May 6, 2008.
- Gilkeson, Robert H., *Groundwater Contamination in the Regional Aquifer Below the Los Alamos National Laboratory,* a paper presented to the June 9, 2004 meeting of the EMSR Committee of the CAB.

<u>Discussion of the mistakes in drilling and construction of LANL well R-34</u>. The borehole for well R-34 was drilled with the conventional circulation fluid-assisted air-rotary drilling method to drill an open bore hole to a total depth of 1165 ft bgs. The quantities of drilling fluids used were

- 36,204 gallons of water,
- 446 gallons of the organic surfactant Quik-FOAM^R and
- 37 gallons of the organic polymer EZ-MUD^R.

The single screen in well R-34 is Type 304 stainless steel with a rod-based design and 0.02 in spacing on the wire wrap. The screen has a length of 22.9 ft and is installed in the depth interval of 883.7 to 906.6 ft below ground surface (bgs). The water table is at a depth of 796 ft bgs and the top of the screen is 88 feet below the water table.

The conventional circulation pumping action of the drill rig and the weight of the 796-ft high column of water-based organic drilling fluids in the open borehole produced a hydraulic energy of greater than 300 pounds per square inch (psi) for invasion of the drilling additives a great lateral distance away from the borehole into the aquifer zones that are important to monitor for contamination. The maximum hydraulic energy that is possible with the well development methods for extraction of the organic drilling fluids and foams was much less than 10% and perhaps less than 1% of the hydraulic energy of the water-based fluid-assisted drilling method.

Another reason that well development was not feasible is that the organic foam greatly reduced the permeability of the invaded zone and blocked the ability for surging and pumping to remove the organic drilling additives. Furthermore, the well development methods were unable to restore the invaded zone to the predrilling chemistry because the organic drilling additives did not remain in solution. Instead, the additives formed precipitates of iron and manganese minerals that strongly adhered onto the aquifer matrix. The high-volume iron and manganese coatings and the residual organic drilling foam also lowered the permeability (Ksat) in the impacted zone surrounding the well screen compared to the *in situ* Ksat in the aquifer away from the impacted zone. The impacted zone is displayed on Figure 3. The fresh precipitates of iron and manganese minerals have strong properties for adsorption of many LANL COPC from groundwater.

<u>LANL did not follow the requirements in the NMED Consent Order to use chemicals to breakdown and destroy the organic drilling fluids</u>. The borehole for well R-34 was drilled before the NMED Consent Order was signed on March 1, 2005. However, the draft version of the Consent Order that was written in 2002 required LANL to use chemical agents to breakdown and destroy the organic drilling additives that were allowed to invade the screened intervals in practically all of the LANL characterization wells including well R-34. Well R-34 was drilled and developed over the period from June 28 to September 14 of 2004. The drilling method used in the borehole for R-34 caused the invasion of a large amount of organic drilling fluids and -foam into the zone surrounding the well screen. However, LANL did not comply with the requirements in the draft Consent Order that was signed into law for the use of chemical agents to destroy the organic additives. The requirements in Section X of the Consent Order are pasted below:

> "The drilling method shall allow for the collection of representative groundwater samples. Drilling fluids (which includes air) shall be used only when minimal impact to the surrounding formation and groundwater can be ensured." (p. 190)
>
> "There are several types of mud presently available, including bentonite, barium sulfate, organic polymers, cellulose polymers, and polyacrylamides. While drilling muds enhance the stability of the borehole and allow for drilling in formations not appropriate to other methods, <u>they can adversely affect the hydrologic properties and geochemistry of the aquifer</u> [emphasis supplied]. For example, drilling fluid invasion and the buildup of borehole filter cake may reduce the effective porosity of the aquifer in the vicinity of the borehole.
>
> "In addition, bentonite drilling muds may affect the pH of groundwater and <u>organic polymer drilling muds have been observed to facilitate bacterial growth, which reduces the reliability of sampling results. If polymer emulsions are to be used in the drilling program at the Facility, polymer dispersion agents shall be used at the completion of the drilling program to remove the polymers from the</u>

> _______ [emphasis supplied]. For example, if EZ Mud® is used as a drilling additive, a dispersant (e.g., BARAFOS® or five percent sodium hypochlorite) shall be used to disperse and chemically breakdown the polymer prior to developing and sampling the well." (p. 191)

The National Academy of Sciences (NAS) 2007 final report described the importance to use chemicals to disperse and breakdown the organic drilling additives:

> "The Consent Order allows mud rotary drilling while providing cautions about changes in the near-borehole environment that can be caused by bentonite and ionic or organic polymer fluids. In addition, the Consent Order recognizes that a polyacrylamide mud, such as EZ-Mud®, can be used appropriately if it is followed with a dispersant, such as BARAFOS®, to facilitate the breakdown and removal of the polymer. If the appropriate dispersant is applied, there should be reasonable success in recovering the dispersed and degraded EZ-Mud.®." (p.56)

In fact, the use of chemicals to destroy the organic drilling additives in order to prevent the new mineralogy formed by bacterial growth is the <u>standard industry practice</u>. However, LANL allowed the organic drilling additives to invade the screened intervals in practically all of the characterization wells, but <u>never</u> used the chemical agents to destroy the additives. Instead, LANL allowed bacterial reactions to flourish and form a new mineralogy in the screened intervals with well known properties to prevent accurate detection and measurement of many LANL contaminants.

Figure 3 is a cartoon of the new mineralogy that was formed in the sampling zones of practically all of the LANL characterization wells (including wells R-34, R-10 and R-10a) by the organic drilling additives. The new mineralogy in the impacted zone surrounding the well screens are precipitates of iron and manganese that have very strong properties to prevent the detection of many of the LANL contaminants and especially the trace metal radionuclide contaminants that are listed above (i.e., isotopes of plutonium, americium, cesium, etc). These radionuclide contaminants are a special concern for reliable detection and accurate measurement in the regional aquifer at the locations of the LANL characterization well R-13 and LANL wells R-34, R-10 and R-10a on the property of the San Ildefonso Pueblo.

<u>Unreliable water quality data from Well R-34</u>. There is no basis for the claim in Table 6-4 in the LANL *Well Screen Analysis Report - Revision 2* (WSAR-2) that well R-34 produces water samples that are reliable and representative for the detection and accurate measurement of all of the LANL potential contaminants of concern including the RCRA trace metals and the LANL trace metal radionuclides that are listed on page 1 of this exhibit. The text of the WSAR-2 acknowledged that there are no natural analogs for the strongly sorbing trace metal radionuclides and this fact alone is proof that the WSAR-2 cannot determine if well R-34 or any of the LANL characterization wells produce reliable

and representative water samples for detection of the trace metal radionuclide contaminants.
Nevertheless, the WSAR-2 presents unsupported findings that well R-34 produces technically defensible water quality data for accurate measurement of the *in situ* dissolved concentrations of zinc and barium, and accordingly, the WSAR-2 *assumes* the well produces technically defensible data for the RCRA trace metals and the LANL trace metal radionuclide contaminants. However, the water quality data presented below in Table 34-1 are proof that well R-34 does not produce water samples that are reliable and representative for the natural concentrations of dissolved zinc and barium that occur in the aquifer formation away from the impacted zone of new mineralogy that surrounds the well screen.

Table 34-1. LANL Water Quality Data for LANL Characterization Well R-34

Well No.	Zinc ug/L	Ba ug/L	Sr ug/L	Cr ug/L	Fe ug/L	Mn ug/L	Cl mg/L	D.O. mg/L	ORP mV	T.S. ug/L	T NTU
R-34	F / T	F	F	F	F / T	F / T	F	T	T	T	T
09-02-04	108 / NA	24	67	4.6	80 / NA	24 / NA	2.74	NA	NA	NA	3.7
06-07-05	4 J / 7	41.8	65	< 3.8J	<18U / 419	42.6 / 56.8	2.22	2.84	- 60.2	31	10.8
09-07-05	<2.2J/<9.9J	42	66	3.4	<18U / 440	20 / 35	2.43	3.79	106.9	14	8.4
11-29-05	< 2 U / 5.1J	39.5	64.8	4 J	<18U / 524	9.8 / 21.6	2.42	4.07	125.7	13	9.26
11-29-05*	< 2 U / 41.7	39.4	65.5	4 J	<18U / 483	10.7 / 20.8	2.42				
01-31-06	2.8J / 25	38.7	65.7	< 4.6J	<18U / 138	6.8 / 12.2	2.28	4	204.2	14	10.2
01-31-06*	2.5J/12.6J	NA	65	< 4.6J	<18U / <11	5.5 / 12	2.28				
07-17-06	<3.6J/< 9.2J	38.4	67.7	5.2	<18U / 500	6.7 / 20	2.32	3.62	- 88.9	?	8.91
10-30-06	4.5 J / 7.3 J	37.8	65.6	6.4	<18U / 442	6.8 / 17	2.39	2.99	92.2	?	22.3
03-13-07	<5.5J/<7.7J	37.9	66.7	5	<18U / 227	3.6 / 10.5	2.32			?	?
06-20-07	< 2 U / < 2 U	36	64.2	3.4	<18U / 110	3.6 / 6.5	2.41	5.3	240	?	4.72
08-14-07	< 2 U / 3.2J	34.6	65	< 6.5	<25U / 30.7	< 2 U / 2.5J	2.29	4.6	240	?	2.92
08-14-07*	< 2 U / 2.7J	34.8	65.8	< 7.3	<25U / 54.8	< 2 U / 2.6J	2.25				
11-14-07	< 10 U / 2.3J	32.2	64.8	5.2	<100 / <173	< 10 U / 4J	2.27	4.6	286	?	2.48
02-19-08	? / ?	?	?	?	? / ?	? / ?	?	5.33	263	?	2.18

- Ba = barium, Sr = strontium, Total Cr = trivalent chromium plus hexavalent chromium, Fe = iron, Mn = manganese, Cl = chloride, D.O. = dissolved oxygen,
- ORP = oxidation reduction potential, T.S. = total suflides, T = turbidity
- ug/L = micrograms per liter or parts per billion
- mg/L = milligrams per liter or parts per million
- mV = millivolts
- NTU = nephelometric turbidity units
- F = filtered water sample T = unfiltered water sample
- 09-02-04 = the date water samples were collected on the day well development was completed
- 10-30-06 = the date for the water quality data that were used in the "snapshot" statistical assessment in the WSAR-2.
- < indicates the actual value is less than the listed value
- NA identifies that analyses were not performed
- J = the listed concentration is an estimated value
- U = (Inorganic) -The material was analyzed for, but was not detected above the level of the associated numeric value. The associated numerical value is either the sample quantitation limit or the sample detection limit.

- * Asterisks identify duplicate sample of above sample

The statistical assessment scheme in the WSAR-2 was only a study of "snapshots" of the water quality data and an inferior study compared to a trend analysis of selected constituents from the first to the most recent water samples. The "snapshot statistical assessment" in the WSAR-2 was for the water sample collected from well R-34 on October 30, 2006.

From the "snapshot" statistical study of only the most recent water samples as of 2006 collected from 80 discrete screened intervals in the network of LANL characterization wells, including well R-34, the WSAR-2 made the following conclusion:

> "One hundred percent of the well screens provide reliable detections of those metals for which zinc can be considered a suitable indicator." (p. 34)

Specifically, Table 6-4 in the WSAR-2 identifies well R-34 as capable of producing reliable and representative water samples for all of the LANL contaminants of potential concern including the trace metal radionuclides. The table in the WSAR-2 also lists well R-34 as producing reliable and representative water samples for the natural dissolved constituents zinc and barium but this is not true as shown by a trend analysis of the dissolved zinc and barium data presented above in Table 34-1.

The dissolved concentrations of the natural constituents in groundwater in the regional aquifer should show little change over long periods of time on the order of decades (and possibly centuries) and also between successive sampling events and this is the case in Table 34-1 for the dissolved concentrations of the constituents strontium, chromium and chloride. For these constituents, the measured values are relatively constant and generally show a change of less than a few percent between sampling events. In addition, the large amount of change observed in the chromium data for some of the successive sampling events are because of the poor accuracy of the analytical method, and accordingly, many of the measured concentrations for dissolved chromium in Table 34-1 are marked as estimated values.

Trend analysis of dissolved zinc, barium and other constituents. In Table 34-1 the dissolved concentrations for zinc and barium show a consistent decline over time that indicates the naturally occurring trace metals are being removed from the groundwater because of the new mineralogy in the screened interval that was introduced by the organic drilling fluids:

- Zinc shows a large decline by > 99% from 108 ug/L to not detected (< 2 ug/L).
- Barium shows a moderate decline by ~25% from 42 ug/L to 32 ug/L.

The elevated levels of dissolved iron, manganese and total sulfides that are present in the first one to three years of sampling events are evidence of microbial mediated chemical processes to form a new mineralogy in the zone surrounding the screened interval as displayed in Figure 3. The high levels of total iron in the water samples collected over a period of the first two years may indicate high concentrations of suspensions of iron colloids that were formed by the microbial processes.

The WSAR-2 assessment did not identify the high turbidity in water produced from well R-34. Table 34-1 shows a great range in the turbidity values in the collected water samples. The water sample collected on 10-30-06 for the "snapshot" assessment in the WSAR-2 had a very high turbidity of 22.3 NTUs. The high turbidity alone is reason to identify the water sample as not reliable and representative, and to require that a new sample be collected after the well is properly purged to produce a water sample with turbidity less than 5 NTUs. Purging wells until the produced water has a turbidity of less than 5 NTUs is the standard industry practice and the EPA protocol.

The purging requirements in the NMED Consent Order are pasted below:

> "IX.B.2.i.ii Groundwater Sample Collection
> Groundwater samples shall be obtained from each well after a sufficient amount of water has been removed from the well casing to ensure that the sample is representative of formation water." (p. 177)

The *in situ* formation water in the regional aquifer has very low turbidity and the data in Table 34-1 demonstrate that on many sampling events, the turbidity of the collected water samples was less than the EPA protocol of 5 NTUs and often less than 3 NTUs. The fact that the LANL WSAR-2 does not recognize the importance for the LANL characterization wells to produce water with low turbidity is a disappointment. The WSAR-2 assigned a score of 97 out of 100 to the water sample with a high turbidity of 22.3 NTUs that was collected from Well R-34 on October 30, 2006.

Dissolved zinc was not detected in the recent water samples collected from Well R-34. The data in Table 34-1 show that the "snapshot" assessment in the WSAR-2 was based on a measured concentration of dissolved zinc of ~ 4.6 ug/L in the water sample collected on October 30, 2006. However, for the more recent water samples collected on June 20, 2007, August 14, 2007 and November 14, 2007, dissolved zinc was not detected at a detection limit of 2 ug/L. The disappearance of dissolved zinc from the water samples is proof that well R-34 does not produce water samples that are able to detect and accurately measure many of the LANL contaminants that are a concern along the plume pathway in Figure 2.

The EPA and NAS reports are highly critical of the assessment scheme used in the LANL WSAR-2. The reports in 2006 by the EPA Kerr Lab and in 2007 by the NAS concluded that the statistical scheme in the LANL WSAR-2 to only study "snapshots" of the water quality data could not determine that any of the screened intervals in the LANL characterization wells produce water samples that are reliable for detection and accurate measurement of the LANL COPC. The EPA Kerr Lab recommended that the water quality data from all of the LANL characterization wells be studied with the trend analysis that is presented in this exhibit for the water quality data collected over time from well R-34 but LANL has never performed the trend analysis.

The long delay in collecting the first sequential water samples from well R-34 was a mistake. Table 34-1 shows that a water sample was collected from well R-34 on the date that well development was completed but the next water sample was collected after a period of 275 days (> 9 months). The long delay in collecting a sequence of water samples on a quarterly schedule prevented accurate analysis of the effects of the organic drilling additives to form a new mineralogy in the screened interval.

The standard industry practice is to develop monitoring wells immediately after they are installed, collect water samples for the complete analytical suite within a few days of when well development was completed, and then collect water samples from the new monitoring wells on a quarterly schedule to evaluate if the wells produce reliable and representative water samples. This sampling schedule is mandatory when any drilling additives have been allowed to invade the screened intervals.

LANL did not collect water samples from well R-34 on the schedule that is the standard industry practice or on the schedule that was required in the NMED Consent Order. The sampling schedule required in the Consent Order is pasted below:

> "IX.B.2.i Groundwater Sampling
> Groundwater samples shall initially be obtained from newly installed intermediate zone and regional aquifer monitoring wells between ten (10) and sixty (60) days after completion of well development" [emphasis supplied]. (p. 176)

The NMED does not recommend that water samples be collected for the complete analytical suite immediately after well development but after a minimum period of ten days after completion of the activities to develop the well.

The failure of LANL to meet the water sampling schedule required in the Consent Order is not unique to well R-34 but was a common practice for the majority of the LANL characterization wells. The delay between well development and the collection of the first water sample was generally a period of around four to six months and often a delay of longer than one year. The failure to acquire water quality data soon after well development and then on a quarterly schedule is a serious mistake that prevents accurate knowledge of the effects of the organic drilling additives to form a new mineralogy in the screened intervals.

LANL hasn't performed the field studies recommended by the NAS and the EPA. Both the NAS and the EPA Kerr Lab identified the need for field studies in the impacted LANL characterization wells. Specifically, the Kerr Lab recommended for LANL to perform "push-pull tests" in the impacted wells but LANL has not performed the tests. The push-pull tests (i.e., injection-withdrawal tracer tests that use a "cocktail" of dissolved constituents with a range of sorption properties) should be performed in the screened interval in well R-34 if LANL continues to adhere to the scientifically unsound finding in the WSAR-2 that well R-34 produces reliable and representative water samples.

Misplaced well screen in well R-34. The conventional circulation drilling method did not produce reliable information for selection of the screened interval in well R-34. For example, the well R-34 completion report shows that the open borehole drilling method did not produce any drill cuttings over the borehole depth interval of 845 to 1000 ft bgs encompassing the zone of the screened interval from 877 to 935 ft bgs.

The best information for selection of the screened interval was from the Schlumberger[R] borehole geophysics. However, the Schlumberger[R] geophysics report in Appendix C of the well R-34 completion report shows that the screened interval in well R-34 was misplaced. Excerpts from the geophysics report are pasted below in quotations:

- **Note: 72-ft thick productive groundwater zone from 796 to 868 ft bgs**
- The regional aquifer water table is at a depth of 796 ft below ground surface (bgs)
- 794 to 805 ft bgs: "Heterogeneous fanglomerate - characterized by highly variable, very high total porosity (50 to 80%) ... severe washouts ... and no evidence of clays"
- 805 to 817 ft bgs: Heterogeneous fanglomerate - characterized by much lower total porosity (25 to 50%) than the surrounding severely washed-out zones .... and the presence of varying, relatively small amounts of clay"
- 817 to 828 ft bgs: "Heterogeneous fanglomerate - characterized by highly variable, very high total porosity (42 to 80%) ... severe washouts ... and no evidence of clays"
- 828 to 834 ft bgs: "Heterogeneous fanglomerate - characterized by much lower total porosity (25 to 30%) than the surrounding severely washed-out zones .... and the presence of varying, relatively small amounts of clay"
- 834 to 846 ft bgs: "Heterogeneous fanglomerate - characterized by highly variable, generally very high total porosity (35 to 70%) .... severe washouts .... and no evidence of clays" [emphasis added]
- 846 to 868 ft bgs: characterized by high total porosity (32 to 58%, highest values likely caused by the effect of washouts on porosity logs); ... and only variable, minor amounts of clay"
- **Note:** The "washouts" are zones of enlarged borehole diameter because of poorly cemented sediments that flow into the boreholes. The zones of washouts and no presence of clays are zones of sediments that are highly productive of groundwater.
- **22-ft thick confining bed from 868 to 890 ft bgs**
- 868 to 890 ft bgs: "Heterogeneous fanglomerate containing clay - characterized by ... the presence of relatively significant amounts of clay" (emphasis supplied)

- **Note:** The well R-34 screened interval is from 877 to 935 ft bgs. The upper 13 ft (22%) of the screened interval was mistakenly installed in the poorly productive confining bed.
- 890 to 898 ft bgs: "Heterogeneous fanglomerate - characterized by moderate total porosity (32 to 42%, highest values at bottom) .... and only variable, minor amounts of clay"
- 898 to 901 ft bgs: "Extremely porous <u>pumice bed</u> [emphasis supplied] - characterized by very high total porosity (58% in an interval that is not washed out) .... and only variable, minor amount of clay"
- **Note:** It was a mistake to install the well screen across the pumice bed because the pumice bed is expected to be poorly productive for lateral flow of groundwater into the screened interval.
- 901 to 933 ft bgs: "(bottom of log interval): Porous fanglomerate - characterized by consistent, high total porosity (31 - 40%), and high silica mineral/glass content (other minerals undeterminable [including presence and amount of clay] due to lack of available logs)"
- **Note:** The collapse of the bottom section of the open borehole during the geophysical logging prevented Schlumberger[R] from collecting a complete suite of geophysics logs for the screened interval in well R-34. Because of the incomplete suite of logs, Schlumberger[R] could not estimate the amount of clay present in the screened interval or estimate the permeability (i.e., saturated hydraulic conductivity (Ksat)) of the screened interval.

The Schlumberger[R] geophysics report provides evidence that the screen in well R-34 is misplaced. The screened interval should have been installed above the 22-ft thick confining bed in the 34-ft thick zone of highly permeable sediments in the depth interval of 834 to 868 ft bgs. The 34-ft thick zone of sediments with high permeability that are located above the confining bed may stratigraphically correlate with the highly permeable zone in Well R-28 where the groundwater is contaminated with hexavalent chromium at a level eight times greater than the NMED drinking water standard. Both well R-28 and R-34 are along the plume pathway in Figure 2 with well R-34 located approximately 6,000 feet southeast of well R-28.

<u>The unreasonable low permeability value measured by the pumping tests in well R-34</u>. The organic drilling foam trapped a large amount of air in the screened interval of well R-34 which 1). plugged the permeability of the zone surrounding the screened interval, 2). lowered the effectiveness of the well development, and 3). prevented the pumping tests from measuring an accurate value for the *in situ* hydraulic conductivity (Ksat) of the formation outside the impacted zone.

The presence of a very large quantity of drilling foam in the screened interval *<u>after</u>* the well development was terminated is illustrated by excerpts from Appendix E in the well R-34 completion report. Appendix E describes the results from the pumping tests that were performed to measure the hydraulic properties of the screened interval in well R-34. Excerpts from the appendix are pasted below:

> "During the drilling of R-34, it was noted that substantial quantities of air were injected into the subsurface sediments. As evidence of this, following completion of the drilling and prior to running casing, on two separate occasions, the well spontaneously ejected large quantities of air and foam at the surface." (p. E-2)
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> "Prior to [the aquifer] testing, it is probable that, under ambient pressure, portions of the aquifer were at saturated or near-saturated conditions, with respect to air. Under these conditions, the pressure reduction caused by drawing down the water level in the well would cause de-gassing of the water, forming small air bubbles analogous to what occurs when popping the top of a canned beverage. Also, it appears that, during background monitoring, sufficient gas built up in the casing around the pump, beneath the inflated packer, to prevent the pump from working altogether." (p. E-2)
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> "The most likely explanation for the reduced specific capacity [observed during the 24-hr pumping test] is that the entrained air in the formation pores near the screen reduced the hydraulic conductivity. It is well known that partial saturation reduces sediment hydraulic conductivity significantly. Trapped air in the formation pores blocks the flow of water, thereby, reducing the overall ease with which water moves through the sediments" (p. E-12)
>
> "Buildup of air [i.e., residual drill foam] in the formation pores reduced the hydraulic conductivity of the sediments around the well, causing a reduction in the specific capacity of the well, from 0.70 gpm/ft initially, to 0.27 gpm/ft during the 24-hr pumping test." (p. E-12)
>
> "The presence of air in the formation water interfered with pump operation, resulting in either erratic discharge rate fluctuations or no flow at all." (p. E-12)
>
> "Furthermore, the presence of the gas phase would be expected to significantly reduce the formation hydraulic conductivity" [emphasis supplied]. (p. E-3)

The above excerpts from Appendix E in the Well R-34 completion report are proof that the pumping tests in well R-34 measured an incorrect and unreasonable low value for the permeability (i.e., hydraulic conductivity) of the screened interval in well R-34. In addition, the Schlumberger[R] geophysics report shows that ~30% of the screened interval was installed in sediments that were expected to have very low values for permeability.

The Schlumberger[R] geophysics report identified thick zones in the borehole for well R-34 that had markedly higher permeability than the zone where the well screen was installed. The low permeability of 3.5 feet/day measured by the pumping tests in well R-34 is an unreasonably low value that should not be used as an accurate value in LANL reports. For comparison, the pumping test in well R-28 measured a permeability value of 149 ft/day and a similar high permeability value may be present at well R-34 in the 34-ft thick zone in the depth interval of 834 to 868 ft bgs that is located above the screened interval in well R-34.

Although the pumping tests in well R-34 and also in wells R-10 and R-10a produced spurious data that resulted in the calculation of an unreasonably slow speed of groundwater travel in the plume pathway displayed on Figure 2, LANL reports now present the unreasonably slow groundwater travel speed as accurate.

<u>LANL reports do not identify the highly productive groundwater resource on the San Ildefonso Pueblo</u>. The LANL *Hydrogeologic Synthesis Report* published in 2005 has made the mistake to use the incorrect and unreasonably low permeability value of 3.5 feet/day measured by the failed pumping tests in well R-34 to show that zones with high permeability are not present in the regional aquifer east of LANL on the property of the San Ildefonso Pueblo.

Figure 4 is a map from the Hydrogeologic Synthesis Report that shows two landscape areas in the central part of LANL where the regional aquifer has high permeability. The northern area covers 6.5 square miles and the southern area covers 4 square miles. The two areas are identified as having aquifer strata near the top of the regional aquifer with permeability (i.e., saturated hydraulic conductivity (Ksat)) greater than 3 meters/day (>10 feet/day). On the map, well R-34 is displayed as a red symbol at a location immediately south of the northern area with high permeability.

The LANL *Hydrogeologic Synthesis Report* describes the northern and southern areas on Figure 4 as follows:

> "As shown in Figure 2-26 [Figure 4 in this exhibit], there appear to be two zones near the top of the aquifer that are particularly conductive (>3 m/day). These zones are not correlated with hydrostratigraphy, suggesting that structure or alteration may be the controlling factor. No high permeability zones occur east of [characterization well] R-13." (p. 2-73)

The conclusion in the LANL *Hydrogeologic Synthesis Report* that there are no high permeability zones (i.e., Ksat > 10 feet/day) east of LANL on the property of the San Ildefonso Pueblo is a serious mistake. The Schlumberger**R** geophysics report for well R-34 identified a 72-ft thick section of saturated sediments at the top of the regional aquifer with a permeability much greater than 10 feet/day. Discrete layers within the 72-ft thick section may have Ksats greater than 50 and even greater than 100 ft/day. The description of the highly permeable sediments in the Schlumberger**R** report are on page 9 of this exhibit.

LANL monitoring wells R-10 and R-10a were installed at locations on the property of San Ildefonso Pueblo after the LANL *Hydrogeologic Synthesis Report* was published. The pumping tests in the two screened intervals in well R-10 measured Ksats of 27 ft/day and 13 ft/day for the upper and lower screens, respectively. The measured permeability's in the two screened intervals in well R-10 are lower bound estimates of the actual permeability in the formations away from the well because the screened intervals were invaded with drilling muds that were a mixture of bentonite clay with organic drilling additives. The drilling muds lowered the permeability of the screened intervals. In addition, the Schlumberger geophysics performed in the borehole for well R-10 identified thick sections of sediments near the water table with higher permeability than the two screened intervals in well R-10.

The measured permeability values in well R-10 and the geophysics logs for wells R-10 and R-34 are proof that the "high permeability zones" displayed on Figure 4 are also present over a large area on the property of the San Ildefonso Pueblo. Furthermore, the zones with high permeability are along the plume pathway on Figure 2. It is a serious mistake that LANL reports do not recognize the high permeability of the regional aquifer over a large area on the property of the San Ildefonso Pueblo.

<u>LANL used inappropriate drilling methods for the LANL characterization wells</u>. The recent success of the air-rotary casing advance drilling methods to prevent the invasion of <u>any</u> organic fluids and -foams or bentonite clay drilling muds into the screened intervals of three LANL monitoring wells installed into the regional aquifer (wells R-35a, R-35b and R-36) is proof that the LANL practice of allowing the organic drilling additives and bentonite muds to invade the screened intervals of the LANL characterization wells was never necessary. The air-rotary casing advance drilling methods used for drilling the boreholes for the three wells are not new drilling technology and were in common use for the past twenty years and long before any of the LANL characterization wells were installed.

I recommended the air-rotary reverse circulation casing advance drilling method with only air as the drilling fluid when I was the lead consultant in 1997 for installing the LANL characterization wells. I repeated that recommendation in a report I presented to the June 9, 2004 meeting of the EMSR Committee of the Northern New Mexico Citizens' Advisory Board (CAB). However, LANL began to use the correct application of casing advance drilling methods only after I repeated the recommendation at the March 2007 meeting of the EMSR Committee of the CAB.

The NAS described the importance to use the air-rotary casing advance drilling methods for installation of the LANL monitoring wells. The pertinent excerpt from the 2007 NAS final report is pasted below:

> "For [LANL] monitoring wells, given the uncertainties about effects of drilling muds and additives and the importance of minimizing alterations in the groundwater environment around screened intervals, the portion of the borehole to be sampled should be drilled to the extent possible with air or water as the

circulating fluid. Advancing an outer casing to keep the borehole open can reduce or prevent the need for more complex drilling fluids." (p. 56)

Recommended Activities at LANL Characterization Well R-34.

- The only long-term use of well R-34 is for measurement of water levels.
- Rehabilitation of well R-34 is not possible.
- The "push-pull tests" recommended by the EPA Kerr Research Laboratory should be performed in the screened interval in well R-34 if LANL adheres to the position that the well produces technically defensible water quality data.
- There is an immediate need to install two new monitoring wells at the location of well R-34 with one well installed in the zone with high Ksat in the depth interval of 834-868 ft bgs. The second well should be installed in an appropriate zone located below the clay-rich confining bed.
- Drill the boreholes for the new wells with the air-rotary reverse circulation casing advance method using only air as a drilling fluid to investigate perched zones of saturation and to profile *in situ* water produced from the borehole in “real time" for a chemical suite including hexavalent chromium, molybdenum, zinc, tritium, nitrate, chloride, perchlorate, etc. The water quality data collected from the boreholes will provide important information for placement of the well screens.
- Install nonmetallic screens in the new monitoring wells because stainless steel screens have properties to prevent the detection of the LANL trace metal radionuclides and the highly oxidizing groundwater will corrode the stainless steel screens.

Please contact Robert H. Gilkeson with questions or comments.

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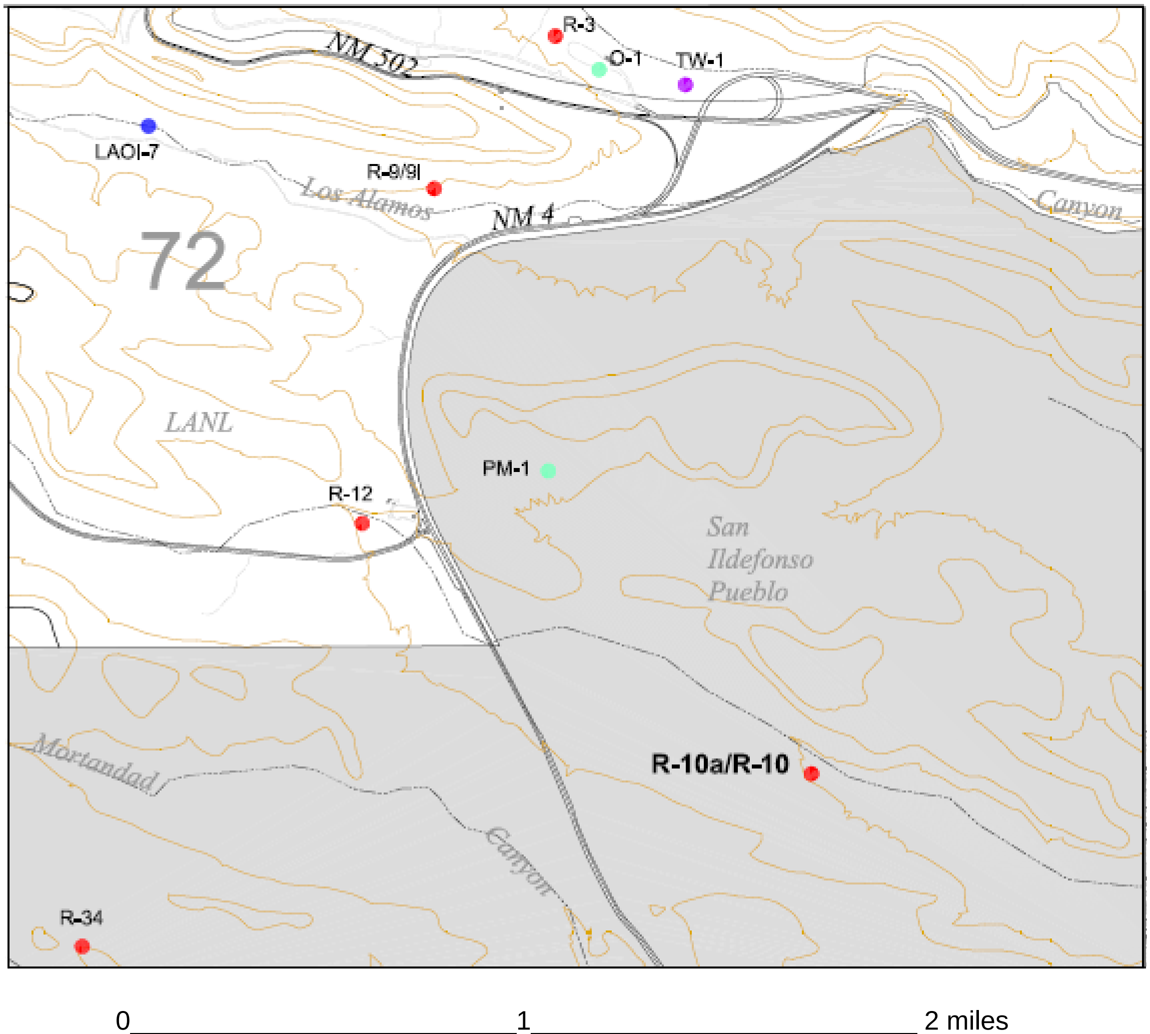
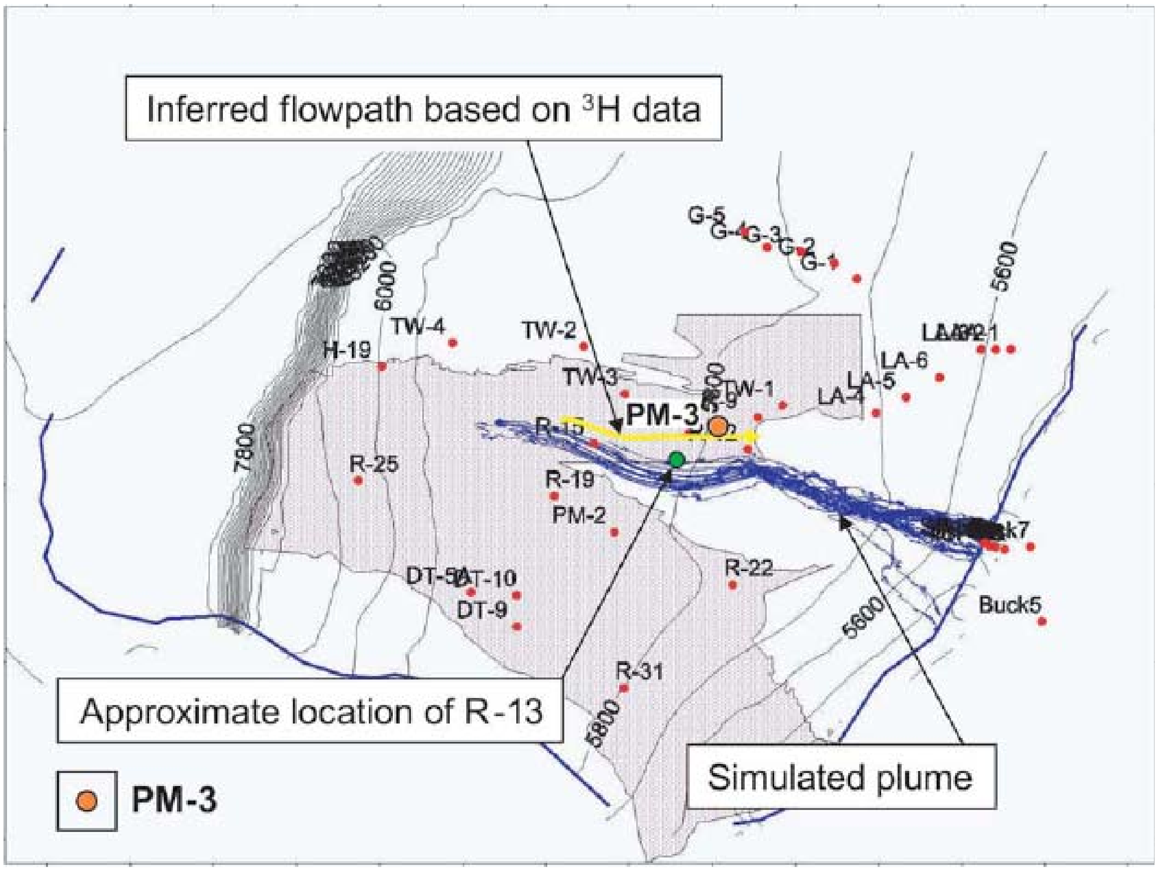
Figure 1. The location of LANL characterization wells R-34, R-10 and R-10a on the property of the San Ildefonso Pueblo.



- On the map the direction of north is up.
- Wells R-34 is located along the plume pathway displayed on Figure 2.
- The map does not show the correct location for Los Alamos County Supply Well PM-1. The correct location of Well PM-1 is immediately northwest of well R-12 and west of highway NM4.
- The well displayed on the map as regional aquifer well R-3 is actually well R-3i installed in a perched zone of saturation.

Source: Figure 1.0-1 in *FINAL COMPLETION REPORT CHARACTERIZATION WELLS R-10a/R-10 LOS ALAMOS NATIONAL LABORATORY,* Kleinfelder Project No. 49436, January 2006.

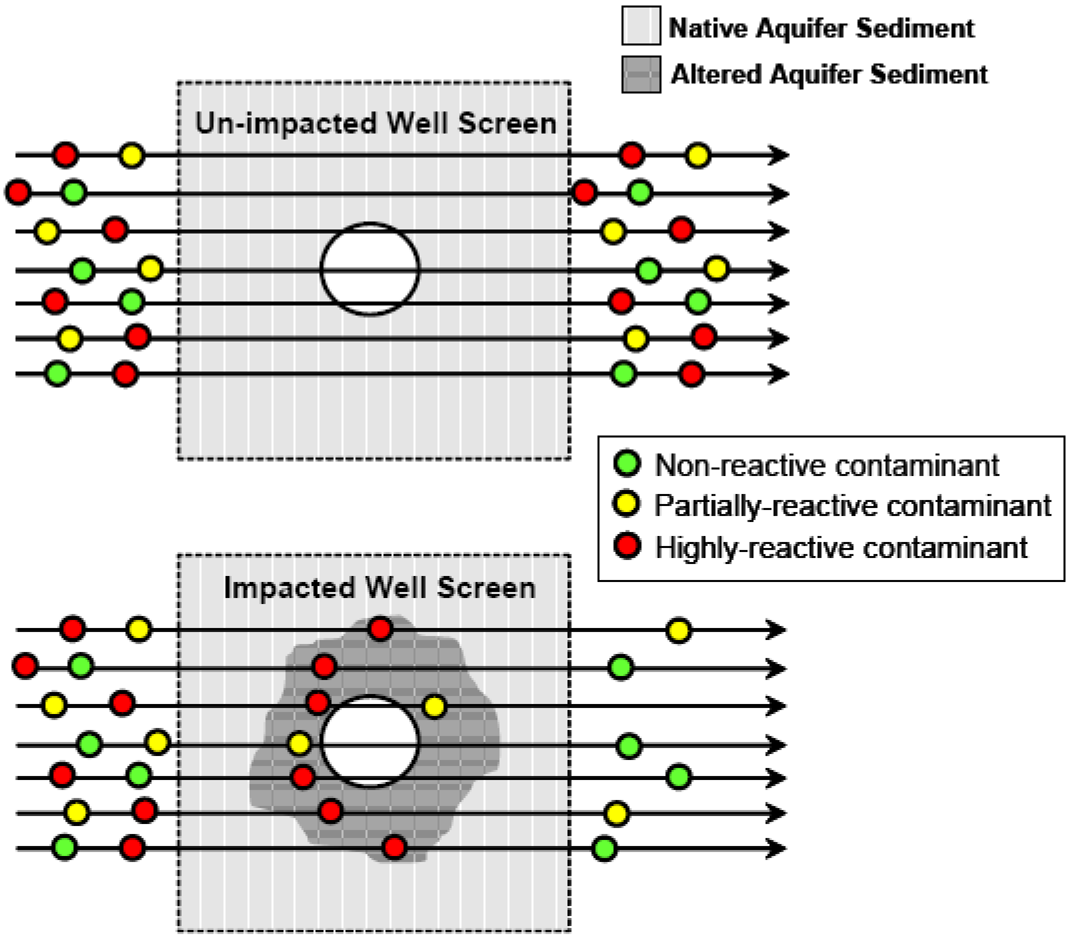
Figure 2. Predicted plume migration for sources released at the water table below Mortandad Canyon, based on a steady-state, with pumping, flow field.



- On the map the direction of north is up.
- Well R-34 is located approximately due south of well PM-3 along the southern side of the simulated plume.
- The Rio Grande is marked by the solid blue line trending northeast to southwest on the eastern side of the map at the eastern termination of the simulated plume.
- On the map the distance from R-13 to the Rio Grande is approximately 5 miles.
- The Buckman well field is located at the eastern end of the simulated plume immediately east of the Rio Grande.

Source: Figure 4-33 in LANL *Hydrogeologic Synthesis Report,* December 2005

Figure 3. Effect of organic drilling fluids to form a new mineralogy in a zone surrounding the screened intervals that prevents detection and accurate measurement of LANL contaminants in water produced from the LANL characterization wells. The cartoon is an overhead view of the wells.

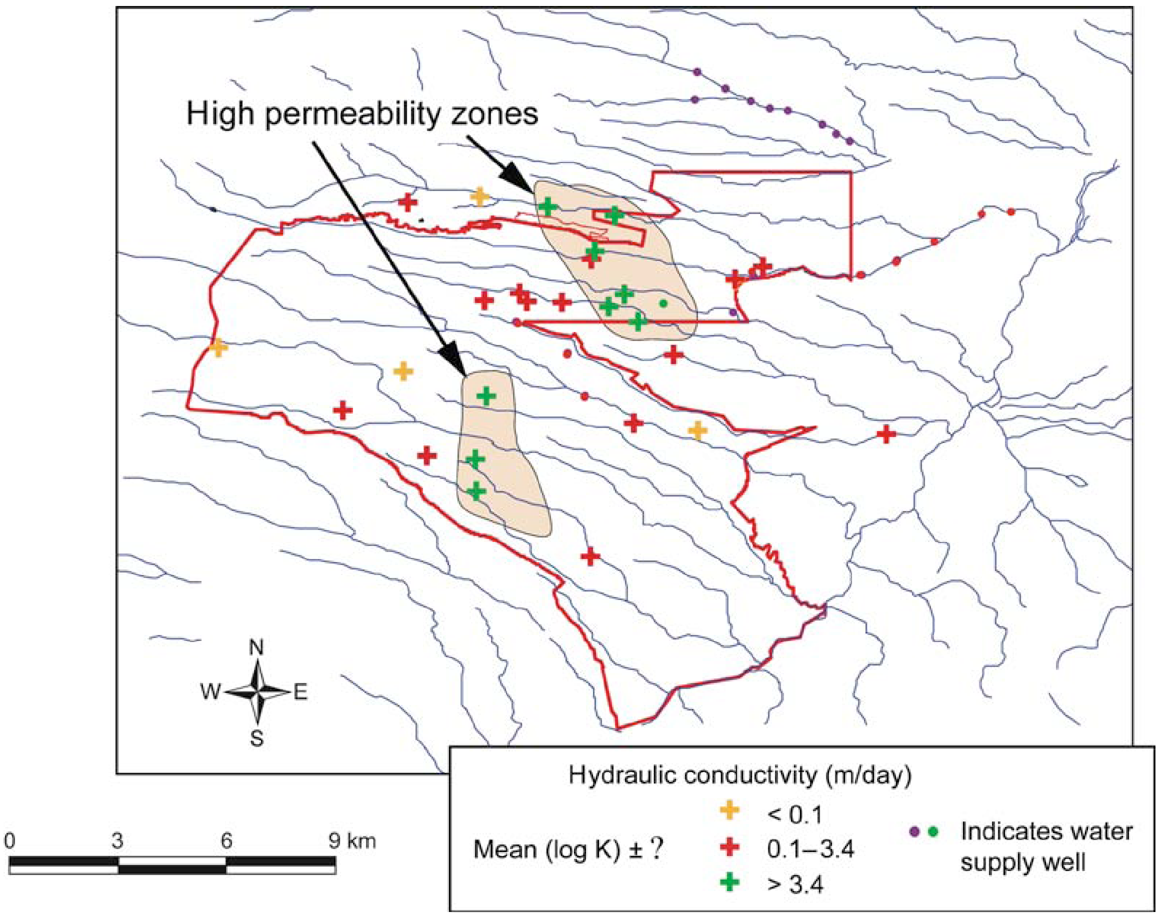


- The gray zone surrounding the impacted well screen represents the zone of the new mineralogy formed by the biodegradation of the organic drilling fluids.
- Examples of non-reactive contaminants are chloride and tritium.
- Examples of partially reactive contaminants are high explosives and uranium.
- Examples of highly reactive contaminants are plutonium, americium and cesium.

Source: A figure in EPA Report titled Impacts of Hydrogeologic Characterization Well Construction Practices at the Los Alamos National Laboratory, EPA Memorandum (05RC06-001), February 10, 2006

Figure 4. Hydraulic conductivity estimates in the regional aquifer. If multiple screens have been tested at a single location, the uppermost result is shown. Red line is the outline of the Laboratory.

The "High permeability zones" have hydraulic conductivity >3 m/day (>10 ft/day)



Hydraulic conductivity -	meters/day	versus	feet/day
	< 0.1		< 0.33
	0.1 - 3.4		0.33 - 11.2
	> 3.4 m/day		> 11.2 ft/day

Source. Figure 2-26 in LANL Hydrogeologic Synthesis Report, LA-14263-MS, December 2005.