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National Nuclear Security Administration
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NMED Hazardous
Waste Bureau

John Young
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John:

Attached is the letter from Tim DeLong to Rich Mayer, requesting the technical review on the well completion technique issues.

Also attached is most of the material relating to Bob Gilkeson's report, the DOE/UC response, other reviews, and subsequent comments by Mr. Gilkeson.

Please call me at 505-665-7203 if you have questions or concerns.

Ted

Theodore J. Taylor
Deputy Designated Federal Officer

13897

Memorandum

To: RACER Project Files

From: Pete Shanahan

Date: June 25, 2004

Re: Review of Robert Gilkeson Report

This memorandum provides a review of a draft report *Groundwater Contamination in the Regional Aquifer Beneath the Los Alamos National Laboratory* written by Robert Gilkeson and provided to the Northern New Mexico Citizen's Advisory Board (Gilkeson, 2004).

Gilkeson (2004) presents the conclusion that various drilling fluids used to construct the monitoring wells installed by the Los Alamos National Laboratory under their Hydrogeologic Workplan prevent the collection of representative samples of groundwater from these wells. The drilling fluids alter the chemistry of the aquifer near the wells such that radionuclides that should be detected cannot be detected. He also concludes that the wells, therefore, do not satisfy the requirements for monitoring wells under the Resources Conservation and Recovery Act.

I found that Mr. Gilkeson's report raises concerns that merit consideration. The following provides some background on the issues raised by Mr. Gilkeson, a technical review of the issues he raises, and an evaluation of the regulatory consequences of those issues.

Background

The Hydrogeologic Workplan was prepared by LANL in March 1998 and lays out a program to develop a more complete understanding of the complex hydrogeology on the LANL site and its vicinity (LANL, 1998). The centerpiece of the Workplan is a program to install 32 boreholes into the regional aquifer and to complete those boreholes as monitoring wells in the intermediate perched aquifer and the regional aquifer. Well installation commenced in 1997 and has been continuing since.

LANL installed the first of the wells (R-9 in September–December, 1997; R-12 in March-June 1998) without the use of drilling fluids. Later wells installed by LANL were drilled using various proprietary drilling fluids including TORKease polymer, EZ-MUD (polyacrylamide-polyacrylate copolymer), QUIK-FOAM, Ben-seal Bentonite, Bentonite Gel, Aqua-Guard Bentonite, Pel-Plug Bentonite, Cellophane, Mag Fiber, and Nylon. A list of drilling fluids used based on the LANL well completion reports is provided as Table 1. Short descriptions of the additives are provided in Table 2.

Table 1. Summary of Information on Reported Use of Drilling Additives in LANL Wells

Well ID	Additives used	Quantities reported?
R-5	EZ-MUD, QUIK-FOAM	No
R-7	EZ-MUD, foam polymer	No
R-8	EZ-MUD, QUIK-FOAM	No
R-9	none	
R-9i	none reported	No
R-12	none	
R-13	"Polymer additives," QUIK-FOAM, EZ-MUD	No
R-14	Bentonite, LIQUI-TROL, QUIK-FOAM, soda ash, N-Seal, Magma Fiber	Yes
R-15	TORKease polymer, EZ-MUD	No
R-16	QUIK-GEL, LIQUI-TROL, foam, soda ash, EZ-MUD, Magma Fiber, Pac-L, N-Seal	Yes
R-19	TORKease polymer, EZ-MUD, QUIK-FOAM	No
R-20	QUIK-GEL, LIQUI-TROL, QUIK-FOAM, soda ash, EZ-MUD, Magma Fiber, Pac-L, N-Seal	Yes
R-22	QUIK-FOAM, EZ-MUD	No
R-23	Bentonite, LIQUI-TROL, QUIK-FOAM, soda ash, Pac-L, N-Seal, Magma Fiber	Yes
R-25	QUIK-FOAM, EZ-MUD, MF-1, Ben-seal Bentonite, Bentonite Gel, Aqua-Guard Bentonite, Pel-Plug Bentonite, Cellophane, Magma Fiber, Nylon, TORKease	Yes
R-31	TORKease polymer, EZ-MUD	No
R-32	QUIK-GEL, LIQUI-TROL, QUIK-FOAM, soda ash, EZ-MUD, Magma Fiber, Pac-L, N-Seal	Yes
CdV-R-15-3	QUIK-FOAM, EZ-MUD	No
CdV-R-37-2	QUIK-FOAM, EZ-MUD	No
MCOBT-4.4	EZ-MUD, foam polymer	No

Table 2. Description of Drilling Additives Used in LANL Wells

Product Name	Purpose	Description
AQUAGUARD®	Subsurface grouting material	One-sack sodium bentonite grout (granular-30 mesh)
BENSEAL®	Sealing and plugging agent	Coarse ground, granular sodium bentonite (8-mesh)
Bentonite/Bentonite Gel	Sealing and plugging agent	Bentonite clay
Cellophane	Control of lost circulation	Cellophane - form not specified
EZ-MUD®	Borehole stabilizer/Viscosifier	PHPA liquid polymer emulsion
LIQUI-TROL™	Filtration control/viscosifier	Modified natural cellulosic polymer suspension
Magma Fiber	Circulation control	Extrusion spun mineral fiber
MF-1	Well-bore stablizer	Polyacrylamide
N-SEAL™	Control of lost circulation	Acid soluble extrusion spun mineral fiber
Nylon	Control of lost circulation	Nylon - form not specified
PAC™-L	Filtration Control Agent	Polyanionic cellulose
PEL-PLUG	Sealant	High swelling western sodium bentonite pellet
QUIK-FOAM®	Foaming agent	High expansion, biodegradable liquid surfactant blend
QUIK-GEL®	High-yield gelant / viscosifier	High yield treated sodium bentonite
Soda ash	pH and hardness control	Sodium carbonate
TORKease	Lubrication	Polymer

The LANL well-completion reports vary in the degree of detail provided regarding the types and amounts of drilling fluids used. There are four general styles of presentation:

- A highly detailed tabulation of the types and quantities of drilling fluids used by depth interval: R-25 (Broxton et al. 2002)

- A summary table showing the types and total quantities of drilling fluids used in completing the well over large depth intervals: R-14 (LANL 2003d), R-16 (LANL 2003e), R-20 (LANL 2003f), R-23 (LANL 2003g), R-32 (LANL 2003h)

- A tabulation of the depth intervals over which drilling fluids were used, but not a complete record of the types and quantities of fluids: R-15 (Longmire et al. 2001), R-19 (Broxton et al. 2001b), R-31 (Vaniman et al. 2002)

- Acknowledgement that drilling fluids were used, but no detailed information on drilling fluid use: R-5 (LANL 2003a), R-7 (Stone et al. 2002), R-8 (LANL 2003b), R-9i (Broxton et al. 2001a), R-13 (LANL 2003c), R-22 (Ball et al. 2002), CdV-R-15-3 (Kopp et al. 2002), CdV-R-37-2 (Kopp et al. 2003), and MCOBT-4.4 (Broxton et al. 2002).

There are some seeming contradictions in the information available. For example, Dr. Patrick Longmire has reported the water quality of well R-9i to be compromised by drilling additives (Longmire and Counce 2003), but the well completion reports do not indicate the use of additives in this well.

Impact of Drilling Fluids

The drilling fluids used during well installation contain two potentially problematic classes of constituents: organic materials and clay minerals. Organic materials biodegrade over time, consuming oxygen in the process. There results anaerobic conditions in the well and adjacent groundwater and a chemically reduced state. The creation of reducing conditions in turn alters the chemical state of some metals and radionuclides. Some chemicals transition from essentially immobile species that precipitate as solids or adsorb strongly to aquifer solids to highly mobile dissolved species. Thus, the apparent chemical makeup of the groundwater as found in collected samples may be significantly altered from natural conditions.

Bentonite drilling muds and other additives containing clay alter the chemistry in a different way. Many clay minerals have high ion exchange capacity and thus the capability to adsorb some metal and radionuclide ions. As a result, clay minerals may make contaminants that are mobile in the natural groundwater immobile in the well and nearby aquifer invaded by clay drilling muds.

LANL has recognized and acknowledged that the use of drilling fluids compromises the characterization of water quality. The well completion reports include numerous references to water-quality samples compromised by drilling fluids. In addition, LANL has described the problems in public meetings. For example, at the October 2003 LANL Quarterly Groundwater Meeting, Dr. Patrick Longmire of LANL discussed the water chemistry compromises associated with EZ-MUD. He said that several of the wells showed anaerobic conditions and other indications that the EZ-MUD was undergoing biodegradation and changing the water chemistry in the process. It appeared this effect was diminishing over time as the EZ-MUD was being degraded, but that it could persist for years. The implication is that water-quality samples from these wells were not currently indicative of actual groundwater conditions. Longmire said that residual drilling fluids compromised water-quality data from R-7, R-9i, R-19, R-22, and R-32. The reported results for uranium in R-9i were specifically cited as compromised. Dr. Longmire presented compelling data to illustrate the alteration of the redox state and water chemistry in at least some of the monitoring wells.

Geochemistry reports have been issued for several of the characterization wells and further discuss the compromises to water quality due to drilling fluids. We have reviewed reports for R-7 (Longmire and Goff 2002), R-9 and R-9i (Longmire 2002b), R-12 (Longmire 2002c), R-15 (Longmire 2002a), R-19 (Longmire 2002d), and R-22 (Longmire 2000c). The compromises to water chemistry associated with degradation of the organic EZ-MUD additive are discussed in all reports except for R-15, which appears to not have been significantly affected by drilling fluids. The effects of EZ-MUD are observable in elevated alkalinity, a reduction in oxidized species (for example, nitrate and sulfate), an increase in reduced species (ammonia and sulfide), and an increase in dissolved (reduced)

iron and manganese. The effects of the EZ-MUD appear to be decreasing over time in some wells, such as Screen 4 at Well R-22, as evidenced by slow decreases in the concentration of dissolved iron, manganese, and ammonium (Longmire 2002d). In other wells, such as Screen 1 at Well R-22, there is no apparent change over time (Longmire 2002d).

In its reports and presentations, LANL has focused on the effects of organic drilling fluids and has not discussed the potential effects of clay drilling muds (bentonite) in compromising well water quality. Longmire (2002c) mentions ion exchange from drilling muds as a possible source of elevated ammonium in Well R-12, but does not address the potential for drilling muds to remove radionuclides, metals, and other ions. In his report, Mr. Gilkeson places great emphasis on the potential effects of bentonite in adsorbing radionuclides that would otherwise be detected in the monitoring wells. The following examines the potential effect of bentonite clay mud on water chemistry.

Bentonite is a clay with a high percentage of sodium montmorillonite. It has a high cation exchange capacity and, as such, can influence the chemistry of water in contact with it (Fetter 1993). The potential for bentonite-based drilling fluids and well cements to compromise monitoring wells has been recognized by various authors including Claassen (1982), Walker (1983, as cited by Driscoll 1986), Ericson et al. (1985), Brobst and Buszka (1986), Gibb and Jennings (1987), Puls and Barcelona (1989), ASTM (1990), and Hix (1993). The consensus of these authors is clear: where possible, drilling fluids should not be introduced into the borehole during drilling. That said, the authors recognize that drilling in some geologic formations requires drilling fluids if a well is to be successfully installed. One of those situations is in drilling deep wells or in unstable formations. Both situations are encountered in drilling at LANL. For these situations, the authors recommend that the completed well be thoroughly developed to purge residual drilling fluids from the well. Significantly, even guidance documentation from the EPA recognizes that drilling fluids may be necessary. For example, Puls and Barcelona (1989) give the following advice:

> If no alternative to the use of drilling muds or fluids exists, these materials must be removed from the well bore and adjacent formations by careful well development.

Similarly, mud-rotary drilling methods are included among the methods presented in EPA guidance documents for the RCRA (EPA 1986) and Superfund (EPA 1987 and 1993) programs.

Hix (1993) presents a useful summary of mud-drilling techniques for monitoring wells. He stresses that a key requirement is the use of appropriate equipment. The mud system should include a mud mixer and appropriately sized mud pump among other equipment. The use of proper components ensures that the mud will be used appropriately during the drilling process and that the drilling will proceed faster, with less opportunity for mud to invade the geologic formation. The mud system employed during the LANL drilling was a complete and appropriate system as described in the well completion report for Well R-14 (LANL 2003d):

> The system included a mixing tank and pump assembly, a generator to power the mixing unit, a de-sander unit for removing solids from the discharged drilling fluids, and a large auxiliary pump.

Use of drilling fluids was an unavoidable or pragmatic option for the LANL wells given their considerable depth and the character of the geologic formations penetrated. As such, these wells then have a need for thorough well development and cleaning after completion The LANL well-completion reports include detailed descriptions of the well development process at each well. The process was generally extensive; for example, development of well R-14 began on July 19, 2002, and continued through October 10, 2002. Altogether, over 200,000 gallons were removed from the well during the development process. The extensive development effort is no guarantee that the well is

free of contaminants, but certainly illustrates a good-faith effort to develop it properly. LANL has also continued to monitor the wells with specific attention to the effects of drilling fluids. The Laboratory continues to label some wells as compromised by drilling fluids and not representative of actual groundwater chemistry.

Review of Gilkeson Analysis

Gilkeson (2004) draws upon detailed analyses of the chemistry at wells R-7 and R-22 to conclude that the aquifer is contaminated by radionuclides but that the contamination is masked in the monitoring wells by the altered geochemistry. While his overall conclusion is clearly stated, I found his arguments difficult to follow in detail. He completes a review of the levels of strontium and strontium-90 in Well R-7, showing over four quarterly sampling rounds that concentrations decrease consistently. He then writes, "The trend analyses presented in Figure 5 of the analytical results for well R-7 confirm that the radionuclide contaminant strontium-90 is present in the regional aquifer below Los Alamos Canyon." The chemical mechanism to support this conclusion is not clearly stated. I presume that Gilkeson takes the decrease in concentration over time to be the result of progressive removal of strontium-90 from the groundwater by ion exchange with the clay minerals in the drilling mud and the earliest and higher concentrations are more representative of the aquifer. I am not convinced that this explanation is valid. Ion exchange ought to be much more rapid than the quarterly time scale of these samples, and I see no reason for its effects to become increasingly more pronounced over time. An alternative explanation is that the initially rapid biodegradation of the organic drilling muds created reducing conditions, increased alkalinity, and caused more dissolution of natural ions from the formation in response to the altered chemical equilibrium. As the chemical conditions in and near the well gradually return to normal after drilling, there is a decrease in concentrations of dissolved ions, total dissolved solids (as indicated by specific conductance), and alkalinity. Under this hypothesis, the wells are not progressively deviating from equilibrium conditions in the aquifer, but progressively returning to equilibrium conditions. This trend analysis points to the end point, with low concentrations, as chemistry representative of natural aquifer conditions. Another problem in Gilkeson's analysis is that the concentrations of strontium-90 are all below detection limits and thus of uncertain reliability.

Gilkeson (2004) concludes that the geochemistry at Well R-22 is compromised by drilling fluids and prevents an accurate understanding of the aquifer at that location. I concur in that conclusion, at least with respect to the current conditions in the well. For the same reasons as discussed above, I am not persuaded that his time-trend analysis proves the presence of radionuclides at Well R-22. This possibility clearly needs to be evaluated over time, but it is premature to draw conclusions while the well chemistry is compromised.

Gilkeson (2004) and LANL differ in that Gilkeson implicitly portrays the consequences of drilling mud as permanent whereas LANL in its various well completion and geochemistry reports implies it is temporary (although on a scale of years). There is no doubt that at least some wells are compromised and do not yield useful information as yet. This is disappointing for all who wish to understand as soon as possible the nature and extent of contamination in the aquifers beneath LANL. Nonetheless, the consensus of the literature is that wells drilled using drilling muds and other additives are far from irreparably damaged. Indeed, EPA guidance documents and many literature references indicate that such wells can be useful after proper well development. In light of the consensus of the literature, it appears premature to write off all LANL wells in which drilling fluids were used as unsuitable for groundwater monitoring.

Gilkeson (2004) further argues that the wells are a violation of the RCRA. I found his arguments here unconvincing in that EPA guidance for the RCRA and CERCLA programs recommends mud-rotary well drilling when required. Further, it is not clear that these wells will serve as RCRA monitoring wells, per se. The hydrogeologic workplan sought to install wells to provide a general

characterization of the aquifer systems, particularly in areas not previously explored. Many of these wells could be characterized as "fishing expeditions" trying to find out whether conditions were problematic and warranted further investigation. With this investigatory aspect of the work plan as context, I do not foresee that all, or perhaps even many, of these wells will see use as RCRA monitoring wells. That said, wells in which the chemistry is compromised by drilling fluids need close evaluation before conversion to RCRA groundwater monitoring wells.

Gilkeson (2004) also criticizes the fact that a number of wells have very long screen lengths and that screen lengths should be no longer than 10 feet. This general rule is appropriate at most sites in which contamination is shallow and localized, and in which aquifer units are relatively thin. This is less of a concern at the LANL site because the vertical length scales associated with the groundwater system are relatively long. Longer screen lengths are appropriate in the regional aquifer because the thick and non-uniform vadose zone can be expected to act as a relatively diffuse source of contamination to the regional aquifer, and because the regional aquifer is itself so thick and non-uniform. Furthermore, for the relatively broad characterization sought in the Hydrogeologic Workplan, longer screen lengths are desirable and are more likely to detect the presence of contamination. Eventually, wells with shorter screens may be necessary at particular locations where contaminant plumes are identified and better quantification for contaminants is needed.

Gilkeson (2004) similarly criticized the geologic formations selected for certain wells, saying that zones of high hydraulic conductivity were missed. The uncertain nature of the subsurface makes all hydrogeologists "Monday-morning quarterbacks" to some extent, even for their own work. The type of second-guessing indicated by Gilkeson is not unusual and certainly not unexpected for the Hydrogeologic Work Plan, which was intended as a fairly generalized characterization effort. All hydrogeologic investigations raise questions and suggest additional locations to be explored in the future; obviously, future wells will need to be installed to fill the information gaps identified in this characterization.

Gilkeson (2004) criticizes the analysis of hydraulic conductivity completed by LANL. I found this section of the report to be too incomplete to evaluate. For example, he states that LANL used "wrong analytical methods to interpret the test data" without indicating the test methods used, why they are wrong, and what test methods should have been used instead. He also seemingly criticizes the tests for not recording high hydraulic conductivity values as observed in prior tests. This reflects LANL's choice of screened intervals to some extent, but may also simply be a reflection of natural variability of aquifer materials. It is common to find wide ranges in the results of aquifer field tests in a single simple formation, let alone in one of the complexity of the regional aquifer at LANL.

Conclusions and Recommendations

There is little doubt that the use of drilling fluids has compromised the water quality in many of the LANL wells. This compromise is unfortunate but not necessarily avoidable in the first place or permanent in its effect. The conclusion by Gilkeson (2004) that the damage is irreparable is contrary to EPA guidance and the seeming consensus in the technical literature. The current approach by LANL appears prudent: that is, to monitor the wells over time, recognize that water chemistry in some wells is not currently representative of the actual aquifer, and observe trends to evaluate whether the wells are approaching an equilibrium representative of the aquifer. LANL's effort in this regard has focused on the effects of degradation of organic drilling muds and has been carefully documented in the well geochemistry reports by Longmire. This effort should be expanded to include an evaluation of potential effects of bentonite additives on chemical species and radionuclides subject to ion exchange.

My review has indicated uneven documentation of the drilling techniques and fluids used during the LANL well installations. Those information deficiencies should be corrected. A complete tabulation

of the types and quantities of drilling fluids use by depth interval is essential. This tabulation should be compared with the screened intervals in the installed wells to identify which drilling fluids have the potential to affect which well screens.

Gilkeson's (2004) conclusion that radionuclides are present in the aquifer at some wells (and specifically R-7) but masked by altered water chemistry appears to be premature at best. He does not state his hypothesized mechanism behind this conclusion with great clarity, but it is clear that the available data are subject to alternative explanations that would lead to the conclusion that radionuclides are, in fact, not present. Those alternative mechanisms of water chemistry are presented with considerable clarity in the multiple reports by Longmire and are more persuasive in my opinion. Nonetheless, as recommended above, additional consideration should be given to Gilkeson's (2004) hypothesis as the well data continue to be evaluated over time.

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Review Comments
Geochemistry Reports for Characterizations Wells
R-7, R-9, R-9i, R-15, and R-22
June 13, 2004

Objective:

This review was conducted to evaluate the discussion in the geochemistry reports of the impacts of the drilling methods on the representativeness of groundwater sampling results for the subject wells. This review resulted from the discussions regarding the construction methods employed for the regional groundwater monitoring wells for Los Alamos National Laboratory at the June 9,2004 meeting of the Environmental Monitoring, Surveillance, and Remediation Subcommittee of the Northern New Mexico Citizens Advisory Board.

Comments:

1. Drilling muds and polymers were used in the completion of all four of the characterization wells; however, the impact(s) of the use of drilling fluids on the representativeness of the water quality samples is not highlighted in any of the reports. In fact, most readers would easily think that the water quality results are representative of the aquifer, when, for various analytes, they are not.

2. The texts of the reports indicate that all of the wells are still equilibrating to the groundwater regime due to the use of various drilling fluids, but only the abstracts for R-7 and R-22 recognize that those wells are not yet in equilibrium with the groundwater. There is no apparent reason for the failure to include a statement in the abstract that R-9/R9i and R-15 are also not yet in equilibrium due to the drilling fluids.

3. Characterization Well R-9i was screened at two elevations, but it was left open allowing contamination of the lower aquifer by inflow from the upper aquifer. This is recognized in the text of the report (pg. 17), but indicated as "probably short-term" in terms of impact. Nevertheless, knowing that the data was not representative, there was no discussion as to the overall impacts of the cross-contamination on analyte concentrations in the deeper zone.

4. There were significant differences in the construction/completion methods for the wells:

    - R-7 – Used TORKease, QUICKFOAM, and EZ-MUD
    - R-9 – Section 2.0 do not mention any use of drilling fluid additives, but the text on pg. 13, preceding Figure 5.1-2 indicates that EZ-MUD was used. (See also comment No. 5 following)
    - R-9i – Used TORKease, EZ-MUD
    - R-15 – Used TORKease, EZ-MUD

- R-22 – Used TORKease, QUICKFOAM, and EZ-MUD.

While it appears that drilling fluids were used for every well, the reports did not indicate the amounts of drilling fluids used for each separate well. Further, the R-22 report compared the groundwater data from R-22 to data from R-9 and R-15 without any discussion of the possible impacts of the different well construction/completion methods on the data being compared.

5. In the R-9 report, the presence of higher than expected concentrations of iron and manganese was noted but attributed to natural phenomena. In the R-22 report, Section 5.2 **Comparison to Wells R-9, R-12, and R-15,** the high levels of iron and manganese are attributed to the affect of residual drilling fluids. An interesting difference.

Conclusion:

Since each of the reports indicate that the water quality samples taken from the associated wells are not in equilibrium with the regional aquifer due to the residual impacts of the drilling fluids, this reports should not be considered to truly represent the regional groundwater quality. At best, they show the pace at which the individual wells may be equilibrating with the natural or undisturbed groundwater quality.

Recommendation:

Future regional groundwater characterization reports should include a specific section that addresses in more detail the impact of the drilling methods on the representativeness of the resultant water quality samples and provides a summary of the overall state of equilibrium of each well by group of analytes. Further, if there are any factors included in the evaluations to mitigate the impacts of the drilling fluids, they should be identified and discussed..

GROUNDWATER CONTAMINATION IN THE REGIONAL AQUIFER

BENEATH

THE LOS ALAMOS NATIONAL LABORATORY

Version of July 13, 2004

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ABSTRACT

In the past several years, the Los Alamos National Laboratory (LANL) has installed an extensive network of monitoring wells for detection of chemical and radioactive contaminants in the regional aquifer. Unfortunately, misinterpretation of the sampling data and inadequate installation of the monitoring wells have concealed the fact that radionuclide and chemical contaminants are present in the regional aquifer beneath canyon and mesa settings. Although the current levels of these contaminants are probably below any harmful level, it is the apparent inability to acquire reliable data and to interpret it properly that generate concern. This report documents the installed features of the monitoring wells that distort the data and particular trends in the data that reveal a failure to recognize the situation. There is an immediate need for installation of additional monitoring wells at critical locations.

LANL's investigation of the regional aquifer is intended to comply with the Resource Conservation and Recovery Act (RCRA). However, many of the LANL monitoring wells do not meet RCRA requirements. One requirement of RCRA is that monitoring wells shall provide groundwater samples that are representative of the groundwater in the aquifer strata. The LANL monitoring wells were drilled using polymer-based drilling fluids and foams, and/or bentonite clay muds that may prevent the detection of contamination and/or introduce false indications of contamination.

The drilling fluids and foams caused the groundwater chemistry at the immediate location of many monitoring wells to change from oxidizing to strongly reducing. The new, unnatural chemistry that surrounds the monitoring wells will remove many contaminants including radionuclides from groundwater entering the wells by chemical processes that include adsorption, precipitation, coprecipitation, and reductive precipitation. Uranium is an important radionuclide contaminant at LANL that is removed from groundwater entering many monitoring wells by reductive precipitation and adsorption. Perchlorate is an important chemical contaminant at LANL that is removed from groundwater by the unnatural reducing chemistry that surrounds many monitoring wells

The bentonite clay in drilling muds is a strong adsorbent to remove many radionuclide contaminants from the groundwater. Furthermore, the bentonite clay muds and drilling fluids also reduce the permeability of the aquifer strata near the wells, with the result that water samples are collected from the stagnant zone that surrounds the wells and do not represent the chemistry of the groundwater in the aquifer. LANL is aware of the unnatural chemistry that surrounds the screened intervals in many monitoring wells, and predicts that the altered chemistry will be present for the next three to ten years. However, LANL reports to the public do not adequately represent this uncertainty.

This report presents findings from the trend analyses of LANL contaminant data for groundwater samples collected from the recently installed set of monitoring wells. The trend analyses confirm that the radionuclide contaminants strontium-90 and technetium-99 are present in groundwater in the regional aquifer and illustrate the action that would be expected by the injection of drilling fluids and bentonite clay muds into the aquifer strata. The trend analyses prove the presence of the radionuclide contaminants in the regional aquifer beneath the Laboratory facility but do not reveal the level of contamination actually present in the groundwater.

This report presents findings that technetium-99 and chemical contaminants are present in groundwater beneath the LANL low-level radioactive waste disposal landill, MDA G. It is possible that other radionuclide contaminants are present in the regional aquifer beneath MDA G.

This report presents a review of the design of LANL monitoring wells and an evaluation of selected data, showing that at many monitoring well locations, screens were not installed in the aquifer strata having the highest hydraulic conductivity (i.e.,permeability). The strata with the highest hydraulic conductivity are expected to have the highest levels of contamination and are the fast pathways for travel of contaminated groundwater. One example of LANL's inability to install well screens in aquifer strata that have high hydraulic conductivity is the monitoring well that is installed for monitoring the impact of MDA G on the regional aquifer. At this well the screens were not installed in the high hydraulic conductivity strata present in the basalt and in gravels of the channel of the ancestral river that are present below MDA G.

The poor understanding of groundwater contamination beneath MDA G creates concerns for the continued operation of the RCRA disposal facility and for DOE's strategy to leave the large volume of legacy wastes "buried in place" at many locations on the Laboratory facility.

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1.0 Executive Summary

The regional aquifer beneath the Los Alamos National Laboratory (LANL) is a valuable groundwater resource. Beneath canyon and mesa settings, groundwater in the regional aquifer is contaminated with radionuclide and chemical contaminants. Presently, the nature and extent of the groundwater contamination is poorly understood. There is also insufficient knowledge of the physical setting of the regional aquifer with a special need for the study of aquifer strata that are fast pathways for contaminated groundwater.

LANL's investigation of the regional aquifer is intended to comply with RCRA. However, many of the LANL monitoring wells do not meet RCRA requirements. The monitoring wells were installed in boreholes drilled with drilling fluids and bentonite clay muds. The fluids and bentonite clay capture many radionuclide and chemical contaminants and remove them from groundwater entering the wells. In addition, many LANL monitoring wells have the well screens installed in inappropriate aquifer strata; water samples do not come from strata most likely to be contaminated.

LANL reports to the public claim the only radionuclide contaminant in the regional aquifer to be low levels of tritium. Trend analyses in this report confirm that the radionuclide contaminants technetium-99 and strontium-90 are present in the regional aquifer. Other radionuclide contaminants may be present. The improper installation of monitoring wells prevents an accurate understanding of the type and levels of radioactive and chemical contaminats that are present.

The principal source for radionuclide and chemical contamination in the canyon settings are the large volumes of liquid wastes from Laboratory operations that were discharged to the canyons over the past 60 years. The data in LANL reports show that strontium-90 contamination is present in the regional aquifer beneath Los Alamos and Mortandad Canyons. Other radionuclide contaminants may be present. The chemical contaminants include perchlorate, semivolatiles and volatiles (solvents).

The principal sources of contamination for mesa settings are the many landfill disposal sites (LANL MDA's) that contain large volumes of radioactive and chemical wastes. Landfill disposal of chemical and radioactive wastes has been a disposal practice since the early years of Laboratory operations.

MDA G is a 65-acre landfill that has been in operation since 1957. Large volumes of chemical and radioactive wastes are disposed of in trenches and shafts at MDA G. Presently, MDA G is the Laboratory's active facility for landfill disposal of low-level radioactive waste. Trend analyses confirm the presence of the radionuclide contaminant technetium-99 in the regional aquifer beneath MDA G. Other radionuclide contaminants

that may be present include iodine-129 and uranium. The chemical contaminants in the regional aquifer beneath MDA G include semivolatiles and volatiles (solvents).

The poor understanding of groundwater contamination beneath MDA G creates concerns for the continued operation of the RCRA disposal facility and for DOEs strategy to leave the large volume of legacy wastes "buried in place" at many locations on the Laboratory facility.

2.0 Introduction

LANL, the United States Department of Energy (DOE), and the New Mexico Environment Department (NMED) are performing an investigation across the 43-square mile Laboratory facility to characterize the physical setting of the regional aquifer and to determine the presence or absence of radionuclide and chemical contaminants in groundwater.

The Laboratory facility is underlain by a thick interval of unsaturated strata. The depth to the top of the regional aquifer is commonly greater than 500 feet (ranging up to greater than 900 feet) for canyon settings and greater than 800 ft (ranging up to greater than 1200 feet) for mesa landscapes. Perched zones of saturation may occur within the thick section of unsaturated strata.

The strategy and schedule for the investigation of the regional aquifer are described in the LANL Hydrogeologic Workplan document.[1] An important mission of the Hydrogeologic Workplan is to characterize the regional aquifer sufficiently to satisfy the Hazardous and Solid Waste Amendments (HSWA) portion of the Laboratory's United States Environmental Protection Agency (EPA) Resource Conservation and Recovery Act (RCRA) operating permit.[2] A requirement of RCRA is for the Laboratory facility to have a network of monitoing wells that are installed in aquifer strata where contaminants may be present. The Hydrogeologic Workplan includes a schedule for installation of 32 monitoring wells in the regional aquifer below the RCRA facility.

Through year 2003, LANL has installed more than 20 monitoring wells in the regional aquifer. Figures 1 and 2 are maps for the locations of 18 of the LANL monitoring wells. The wells are R-5, R-7, R-9, R-12, R-13, R-14, R-15, R-16, R-19, R-20, R-21, R-22, R-23, R-25, R-31, R-32, CDV-R-15, and CDV-R-37. The majority of the wells are multiple-screened with Westbay* sampling apparatus for collection of groundwater samples from discrete screened intervals installed at different depths in the regional aquifer.

Many of the LANL monitoring wells do not meet RCRA requirements. This report documents the non-compliance with RCRA for LANL monitoring wells R-7, R-9i, R-15, R-16, and R-22. The findings presented in this report are from information in the LANL well completion and well geochemistry reports for the five wells.

3.0 RCRA Requirements for Monitoring Wells

The United States Environment Protection Agency (EPA) has published a document that describes RCRA requirements for the installation of monitoring wells on RCRA facilities. The document is titled "RCRA Groundwater Monitoring: Draft Technical Guidance"[3] (referred to in this report as "the EPA RCRA document").

The following list presents RCRA requirements for the installation of monitoring wells at LANL.

1. A RCRA requirement under 40 CFR Part 264 Subpart F Sect. 264.97 is for LANL to install a groundwater monitoring system that yields representative groundwater samples from the uppermost aquifer beneath the Laboratory facility.

Many of the LANL monitoring wells do not produce representative groundwater samples because of 1. the use of drilling fluids and bentonite clay muds in the boreholes for the wells, and 2. the installation of long well screens that cause mixing and dilution of contamination present in discrete intervals of aquifer strata. This report describes the nonrepresentative groundwater samples that are collected from LANL monitoring wells R-7, R-9i, R-15, R-16, and R-22.

EPA has identified the "uppermost aquifer" as the geologic strata nearest the ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected within the facility's property boundary. "Aquifer" is defined as the geologic strata that are capable of yielding a significant amount of groundwater to wells or springs (40 CFR Sect. 260.10). Many groundwater supply wells in the region of LANL are installed at a depth of greater than 1800 feet below the water table into the regional aquifer. Therefore, at LANL a minimum requirement of RCRA is to characterize the upper several hundred feet of the regional aquifer to identify and install monitoring wells in the aquifer strata that are capable of yielding a significant amount of water; the aquifer strata that have a high hydraulic conductivity and are fast pathways for groundwater travel.

LANL monitoring well R-22 is located close to MDA G, the Laboratory's active landfill for disposal of low-level radioactive waste. Well R-22 is a example of LANL's failure to identify, characterize, and install well screens in the discrete aquifer strata that are capable of significant yields of groundwater. See the findings for well R-22 in section 7.0 of this report. LANL monitoring wells R- 7 and R-15 are also examples of LANL's failure to characterize and install well screens in the uppermost aquifer. The boreholes for these wells were drilled into the top of productive aquifer strata. However, LANL did not characterize the aquifer strata or install a monitoring well in the strata. The boreholes were sealed back and a screen was installed at a shallow depth in the regional aquifer. See the findings for wells R-7 and R-15 in sections 5.0 and 6.0 of this report.

2. Groundwater monitoring shall include measurement, sampling, and analytical methods that accurately assess groundwater quality, and that provide early detection of hazardous constituents released to groundwater – A requirement of RCRA 40 CFR Sections 264.97(d) and 264.97(e).

The performance of groundwater monitoring at LANL are a violation of this RCRA requirement for several factors: the use of drilling fluids and bentonite clay muds in the boreholes that cause changes to the chemistry of the groundwater samples; the installation of long well screens that cause dilution of contamination; the failure to install well screens in the aquifer strata that have high hydraulic conductivity; the failure to successfully develop the well screens to establish efficient hydraulic communication with the aquifer strata; and the collection of groundwater samples from the stagnant zone with altered chemistry that surrounds the screened intervals. All of these factors prevent accurate assessment of groundwater quality and early detection of contaminants in groundwater.

3. Install monitoring wells close to the down-gradient side of hazardous waste management units (LANL MDAs), and locate screened intervals in all transmissive zones that may act as contaminant transport pathways – a RCRA requirement under 40 CFR Sections 264.95(a) and 264.97(a)(3).

The transmissive zones are the aquifer strata that have high hydraulic conductivity and are the fast pathways for travel of contaminated groundwater. LANL has not installed screened intervals in the transmissive zones in the regional aquifer beneath MDA G, the Laboratory's active landfill for disposal of low-level radioactive waste. LANL has installed monitoring wells at locations that are in close proximity to only a few of the 26 MDAs that are present on the RCRA facility.

4. As a general rule, monitoring well screens shall not have a length greater than 10 ft because long well screens may cause dilution of contamination - the LANL HSWA Permit[2] limits well screens in monitoring wells to a length of not greater than 10 feet.

Many of the LANL monitoring wells have screened lengths greater than 10 feet; screen lengths of 40 feet are common and LANL well R-15 has a screen length of 60 feet. See the discussion of LANL well R-15 in section 6.0 of this report.

The EPA RCRA document[3] contains basic guidance to assist in the selection of drilling procedures, the design and installation of monitoring wells, and the characterization of the uppermost aquifer pursuant to 40CFR Part 264, Subpart F, as follows:

A. Drilling should be performed in a manner that preserves the natural properties of the subsurface materials.

LANL's use of polymer-based drilling fluids and bentonite clay drilling muds has resulted in a great change to the physical and chemical properties of the aquifer strata that surround the monitoring wells.

B. The drilling method should allow for the collection of representative samples of rock, unconsolidated materials, and soil.

The use of the mud rotary drilling method at LANL has resulted in long intervals in boreholes in the regional aquifer where no samples are recovered of the aquifer strata

C. The drilling method should allow for the collection of representative groundwater samples. Drilling fluids (including air) should be used only when minimal impact to the surrounding formation and groundwater can be ensured.

The use of polymer-based drilling fluids and bentonite clay drilling muds in the boreholes for many LANL monitoring wells are preventing the collection of representative groundwater samples.

D. All monitoring wells should be developed to create an effective filter pack around the well screen, to rectify damage to the formation caused by drilling, to remove fine particles from the formation near the borehole, to remove any foreign materials (drilling fluids, bentonite clay muds, etc.) that may have been introduced into the borehole during drilling and well installation, and to assist in restoring the formation around the screen as well as the filter pack, so that mobile fines, silts, and clays are pulled into the well and removed.

The successful development of a well is extremely important to ensuring the collection of representative groundwater samples – a requirement of 40 CFR Part 264, Subpart F Sect. 264.97 (see requirement 1 above). A failure at LANL is the incorrect belief that drilling fluids and bentonite clay drilling muds can effectively be removed from the invaded strata that surround the screened intervals. Ensuring the collection of representative groundwater samples precludes the use of drilling fluids and bentonite clay drilling muds for drilling the boreholes for monitoring wells. Well development may accomplish an adequate flow of groundwater into the monitoring well for collection of samples. However, the chemistry of the groundwater samples are still affected by a long residence time in the aquifer strata that are invaded by the fluids and bentonite clay muds.

E. The design and installation of monitoring wells should determine groundwater flow directions and hydraulic gradient - a RCRA requirement under 40 CFR Sect. 264.97(f).

The network of LANL monitoring wells have greatly improved the contour map of the water table on the regional aquifer. However, RCRA requires that the groundwater flow directions and hydraulic gradients are determined for the discrete aquifer strata that have high hydraulic conductivity and are fast pathways for groundwater travel. For the regional aquifer beneath MDA G, RCRA requires that the groundwater flow directions and hydraulic gradients are determined for the aquifer strata in the basalt and in the Puye sediments (the river gravel strata) that have high hydraulic conductivity. The hydrogeologic setting beneath MDA G is described in section 7.0 of this report. LANL has not installed monitoring wells in the important aquifer strata beneath MDA G.

F. The hydraulic conductivities of the discrete aquifer strata that comprise the uppermost aquifer and its confining units should be measured, preferably with appropriate field methods.

The regional aquifer beneath LANL is heterogeneous and anisotropic. For this hydrostratigraphic setting, knowledge of the variation in hydraulic conductivity as a function of vertical position in the discrete aquifer strata is essential to understanding the potential migration of contaminants. LANL well R-22 is a god example of LANL's failure to measure the hydraulic conductivities of the discrete strata below MDA G that have high hydraulic conductivity Section 8.0 of this report describes LANL's failure to gain knowledge of aquifer strata that have high hydraulic conductivity.

G. The vertical position of monitoring well screens are functions of:

a. hydrogeologic factors that determine the distribution of, and fluid/vapor phase transport within, potential pathways of contaminant migration to and within the uppermost aquifer, and

b. the chemical and physical characteristics of contaminants that control their distribution in the subsurface.

At LANL, factors a and b require that screened intervals in monitoring wells are installed in 1. appropriate strata at a shallow depth in the regional aquifer to ensure early detection of hazardous constituents that are released to the unsaturated zone and travel down to the top of the regional aquifer and 2. at depth intervals within the regional aquifer in aquifer strata with high hydraulic conductivity. Concerning factor a, LANL has installed long screens at the top of the regional aquifer. The long well screens are not focused on the water quality at a shallow depth in the regional aquifer.

Concerning factor b. LANL has failed to install screened intervals in the upper several hundred feet of the regional aquifer in the discrete strata that have high hydraulic conductivity. Examples of this failure are in sections of this report for wells R-7, R-15, and R-22.

4.0 Issues Concerning the use of Bentonite Clay Muds and Drilling Fluids in the Boreholes of LANL Monitoring Wells

Drilling fluids and/or bentonite clay drilling muds were used during drilling of the boreholes in the regional aquifer for all of the LANL monitoring wells.

4.1 Concerns for Mud Rotary Drilling Methods

Presently, LANL is using the mud rotary drilling method for installation of monitoring wells. The LANL wells on Figures 1 and 2 that were installed in boreholes drilled with mud rotary methods that used bentonite clay drilling muds include R-14, R-16, R-20, R-21, R-23, and R-32.

The EPA RCRA document[3] for the construction of RCRA monitoring wells states the following concern for boreholes drilled with bentonite clay muds:

"Bentonite muds may adsorb metals, potentially reducing contaminant concentrations and affecting the reliability of sampling results."
"Drilling fluid invasion of permeable zones may compromise validity of subsequent monitoring well samples."

LANL established a team of experts as the External Advisory Group (EAG) to review activities conducted by the Hydrogeologic Workplan. The EAG Semi-Annual Report dated Dec. 23, 1999[4] lists 17 disadvantages for installing monitoring wells in boreholes that were drilled with the mud rotary method. The EAG report contains the following summary statements concerning use of the mud rotary drilling method:

" The use of mud rotary drilling techniques is largely inappropriate for the goal of the LANL Hydrogeologic Workplan. Drilling with mud carries the risk of adsorbing contaminants onto the bentonite that permeates into the pore space around the well screen and is not removed by well development. Should this occur, it could result in reduced concentrations or non-detects on contaminants that are actually present in the vicinity of the well."

"The artificial entrainment of bentonite clay drilling muds in the pore space around a monitoring well is clearly not desirable. This is because these materials can remove from solution the very constituents that need to be monitored by the well. This is a significant concern for LANL since radionuclides are known to be adsorbed by these clays. That the drilling mud, i.e., bentonite, penetrates into the aquifer strata is not disputed. It is reasonable to assume that fairly extensive intrusion of the bentonite into the aquifer strata can be expected. It is argued that well development, via high-flow pumping, using surge blocks, etc. is sufficient to remove blockage and create adequate flow through the well screen when a well has been drilled with mud. This is generally true. However, sufficient water flow is not the only consideration here. It is extremely unlikely that such well development techniques can remove the extruded bentonite sufficiently to assure that residual clay materials are not present in the pore space around the wells and serving as an adsorptive barrier to contaminant detection and quantification. Unfortunately, if no contamination is detected then there is simply no way (without drilling another well by a different technique) to determine whether the contaminant is truly absent at this point or whether it is being adsorbed by residual drilling fluids."

"The EAG would therefore caution LANL about using mud drilling techniques for the installation of the deep regional monitoring wells. If bentonite clay drilling mud is to be used, it should be used sparingly (e.g., as a lubricant only) and it would be best to avoid it altogether when drilling zones where the well screens will be located."

Large quantities of bentonite muds were introduced into the permeable strata in the regional aquifer in the LANL boreholes that were drilled with the mud rotary method. A large percentage of the introduced bentonite clay drilling mud can not be recovered from the aquifer by well development methods.

The LANL wells on Figures 1 and 2 that were installed in boreholes drilled with mud rotary methods that used bentonite clay drilling muds include R-14, R-16, R-20, R-21, R-23, and R-32. Figure 2 shows that all of the monitoring wells surrounding MDA's G and L were installed in boreholes drilled with the mud rotary method using bentonite clay muds. The exception is well R-22 that is installed in a borehole drilled with polymer-based drilling fluids. The unreliable contaminant data from well R-22 is discussed in section 7.0 of this report. All of the monitoring wells that surround MDAs G and L are unreliable for detection of many contaminants of concern for the wastes disposed of in the two MDAs.

Figures 1 and 2 show that the three LANL monitoring wells that are located between MDA G and the Santa Fe Buckman well field are wells R-22, R-23, and R-16. The improper construction of the three wells makes them unreliable for the detection of many radionuclide and chemical contaminants in groundwater.

The next section of this report describes the mud rotary drilling of LANL monitoring well R-16. The discussion of LANL well R-16 is based on the LANL Well R-16 Completion Report.[5]

4.1.1. LANL Monitoring Well R-16 Located Between MDA G and the Santa Fe Buckman Well Field

Figures 1 and 2 show that LANL well R-16 is located between the Laboratory's low-level radioactive waste disposal facility (MDA G) and the Santa Fe Buckman well field. The monitoring well is a multiple-screen completion with three screened intervals located at different depths in the regional aquifer. A Westbay* groundwater sampling system is installed in the well. The Westbay* system produces a small volume of groundwater at a slow rate which prevents collection of groundwater from aquifer strata outside of the zone of the invaded drilling muds and fluids. The use of bentonite clay drilling muds and polymer drilling fluids in the borehole for LANL well R-16, the use of chemical additives for development of the well screens, and the collection of groundwater samples with the Westbay* system have a combined effect of making the well unreliable for the detection of many radionuclide and chemical contaminants in groundwater.

During the mud rotary drilling of the borehole for LANL well R-16 the mud rotary drilling lost circulation of drilling fluids for the depth interval of 867 ft to 1047 ft within the regional aquifer.[5] The lost circulation indicates a depth interval of aquifer strata with high permeability. The lost circulation shows that there was a great invasion of bentonite clay drilling muds into the highly permeable strata. The total amount of drilling fluid used for drilling the borehole in the regional aquifer at well R-16 was greater that 38,350 gallons of water to which greater than 31,100 lb of bentonite clay drilling mud was added.[5] In addition, organic polymer drilling fluids were used during drilling the borehole in the regional aquifer.[5] The RCRA concerns for the use of polymer-based drilling fluids are discussed in section 4.2 of this report.

LANL used chemical additives during the development of the monitoring wells that were installed in the mud rotary boreholes. The additives increased the dispersion of the bentonite clays in the aquifer strata, increasing the total surface area of bentonite clays for adsorption (removal from groundwater) of dissolved metal and radioactive contaminants.

The EPA RCRA document[3] contains the following statement concerning boreholes drilled with bentonite muds, and use of chemical additives for well development:

"Bentonite muds form a filter cake on the sides of the borehole, thus reducing the effective porosity of formations in the borehole, and compromising the design of the well. Bentonite may also affect local ground-water pH. Additives to modulate viscosity and density may also introduce contaminants to the system or force large, unrecoverable quantities of mud into the formation."

The issues that are presented in this report show the poor reliability of contaminant analyses for groundwater samples collected from LANL monitoring wells that are installed in boreholes drilled with the mud rotary method.

4.2 Concerns for Boreholes Drilled With Drilling Fluids and Foams

The majority of the LANL monitoring wells displayed on Figure 1 were installed in boreholes drilled with polymer-based drilling fluids and drilling foams. Changes in the chemistry of the groundwater and in the chemistry of the aquifer strata were initiated at the time of introduction of the drilling fluids and foams into the strata as the borehole was drilled. In general, well development activities were several months after the drilling fluids were injected into the aquifer strata. A large change in the chemistry of groundwater and chemistry of the aquifer strata occurred before the first groundwater samples were collected from the monitoring wells for contaminant analyses. The unnatural chemistry in the zone surrounding the screened interval in many LANL monitoring wells is depicted in Figure 3. The altered chemistry results in removal of contaminants from groundwater that enters the well by the set of chemical processes that are shown on Figure 3.

The EPA RCRA document[3] for monitoring well construction contains the following guidance against the use of drilling fluids in boreholes for RCRA monitoring wells:

"Drilling fluids, drilling fluid additives, or lubricants that impact the analysis of hazardous constituents in groundwater samples should not be used. Some organic polymers and compounds provide an environment for bacterial growth, which reduces the reliability of sampling results."

The drilling fluids and foams used in the boreholes of the LANL monitoring wells provided an environment for bacterial growth.[9,10,14] The bacterial growth caused the development of a zone of strong reducing chemistry in groundwater and in aquifer strata for an unknown radius around the borehole.

The development methods that were used in many of the LANL monitoring wells were insufficient to establish efficient mixing of groundwater in the zone of unnatural chemistry with groundwater in the regional aquifer. The poor mixing is shown on Figure 4. The result for LANL multiple-screened monitoring wells equipped with Westbay* sampling apparatus is that groundwater samples are collected from the zone of stagnant groundwater in the aquifer strata that surrounds the screened intervals. The Westbay* sampling system does not purge large volumes of groundwater before collection of groundwater samples for contaminant analyses. LANL is aware of the altered zone of

chemistry that surrounds the screened intervals in many LANL monitoring wells and predicts that the altered chemistry will be present for a period of the next 3 to 10 years.[6]

The nonrepresentative groundwater samples collected from many LANL monitoring wells are a violation of RCRA.

The October 2002 Semi-Annual Report of the EAG[7] contains the following discussion of the use of drilling fluids in the boreholes of monitoring wells:

"Give careful consideration to the geochemical DQOs for each monitor well to be drilled; consider using drilling methods that would have fewer detrimental impacts on aqueous/contaminant geochemistry when appropriate, even though this approach might be much more expensive during the drilling process."

"The EAG realizes that drilling conditions on the Pajarito Plateau are extremely difficult, time-consuming and expensive. It must be argued, however, that drilling wells inexpensively and quickly that

1. *require increasingly energetic/time-consuming/expensive development procedures to remove entrained drilling materials,*

2. *alter aqueous chemistry for two to 10 years (based on estimates of drilling fluid degradation rate*

3. *might alter aquifer material surface chemistry for an unknown radius around the well bore for an unknown time (e.g., potentially resulting in the reductive precipitation of uranium and other radionuclides, much like an in situ remediation around the monitoring well), and*

4. *continue to require expensive periodic analytical suites during the re-equilibration period that might result in data of questionable quality and errors in interpretation,*

should perhaps not be considered so inexpensive after all."

"For certain canyons, it might be less expensive overall to drill in a more expensive manner and have increased confidence in the chemistry data sooner, rather than having to wait several additional years to attain the needed level of confidence."

The impact of the zone of unnatural chemistry to cause the collection of nonrepresentative samples of groundwater from LANL monitoring wells R-7, R-9i, R-15, and R-22 are discussed in the following sections of this report.

5.0 Groundwater Contamination in the Regional Aquifer Beneath Los Alamos Canyon at LANL Well R-7

The information presented in this section is from the LANL Well R-7 Completion Report[8] and the LANL Well R-7 Geochemistry Report.[9] LANL monitoring well R-7 is a multiple-screen well with three screened intervals that is located in upper Los Alamos Canyon. Screen no. 3 has a length of 42 feet and is installed at the top of the regional aquifer. Information in the LANL reports[8,9] show that the filter pack sediments and aquifer strata that surround screen no. 3 are not well developed. The Westbay* sampling system in well R-7 collects groundwater samples from the stagnant zone of groundwater that surrounds screen no. 3.

Figure 5 shows the consistent decline in levels of strontium-90 and strontium that has occurred for screen no. 3 in well R-7 for groundwater samples collected over a one-year period because of the zone of altered chemistry that is caused by the use of drilling fluids. The unnatural chemical processes that lower the levels of strontium and strontium-90 in groundwater were introduced in the drilling fluids several months before the first groundwater samples were collected for contaminant analyses. The actual activity of strontium-90 in the regional aquifer is not known and may be much greater than the low instrument recorded values that are reported in the LANL geochemistry report.[9]

Strontium is a chemical that is commonly present in groundwater. The source of strontium in groundwater is the natural occurrence of strontium in the aquifer strata. Groundwater samples from properly installed monitoring wells will show little change in strontium levels between quarterly sampling events. For example, residual drilling fluids have little impact on the chemistry of groundwater samples collected from LANL monitoring well R-9. For this well, strontium levels in four succeeding quarterly groundwater samples show little change and are 160, 160, 150, and 160 parts per billion (ppb), respectively.[10]

Strontium and strontium-90 have identical chemical properties. The pronounced decline in strontium and strontium-90 levels shown in Figure 5 is because of the removal of these constituents from groundwater in the zone of unnatural chemistry that surrounds well R-7. The trend analyses presented in Figure 5 of the analytical results for well R-7 indicate that the radionuclide contaminant strontium-90 is present in the regional aquifer beneath Los Alamos Canyon.

Other radionuclide contaminants that were measured at low levels in groundwater samples collected from well R-7 include americium-241; cesium-137; plutonium-238; plutonium-239,240; technetium-99; and uranium-235.[9] Some of the measured low levels of contamination may be because of analytical error; the contaminants may not be present

in groundwater. However, the use of drilling fluids in the R-7 borehole, the poor development of the well screen and the possible dilution effects of the 42-foot long well screen prevent an accurate understanding of the presence or absence of the radionuclide contaminants in the regional aquifer beneath Los Alamos Canyon.

LANL Well R-7 is located in upper Los Alamos Canyon where Laboratory effluent has been released, including radionuclides and inorganic chemicals. Known groundwater contaminants in the shallow alluvial sediments in upper Los Alamos Canyon include americium-241; cesium-137; plutonium-238; plutonium-239,240; strontium-90; tritium; uranium-235; and uranium-238.[11] Note the close comparison of this list of known contaminants in Los Alamos Canyon to the list of radionuclide contaminants recorded at low levels in the regional aquifer at LANL monitoring well R-7.

The strong reducing chemistry at LANL well R-7 causes the uranium analyses in groundwater samples from well R-7 to be anomalously low. The uranium analyses on groundwater samples from monitoring well R-7 are not valid for knowledge of uranium levels in groundwater in the regional aquifer beneath Los Alamos Canyon. The effect of the reducing chemistry on uranium in groundwater is discussed in section 9.0 of this report.

6.0 Groundwater Contamination in the Regional Aquifer Beneath Mortandad Canyon at LANL Well R-15

The information presented in this section is from the LANL Well R-15 Completion Report[11] and the LANL Well R-15[12] Geochemistry Report. Groundwater samples collected from LANL monitoring well R-15 show that radionuclide and chemical contamination is present in the regional aquifer beneath Mortandad Canyon. A validated (>3 sigma) strontium-90 activity of 1.51 pCi/L was measured in the third quarter round of groundwater samples.[12] The radionuclide contamination recorded at low levels include americium-241; cesium-137; plutonium-238; and plutonium-239,240.[12] Some of the measured low levels may be due to analytical error; some of the recorded contaminants may not be in groundwater.

LANL records show that known groundwater contaminants in the shallow, saturated alluvial sediments in Mortandad Canyon include americium-241; cesium-137; plutonium-238; plutonium-239,240; strontium-90; tritium; uranium-235; uranium-238; nitrate; chloride; sulfate; and other inorganic solutes.[11] Note the close comparison of this list of known radionuclide contaminants in the shallow groundwater to the list of radionuclide contaminants that are recorded in groundwater samples from the regional aquifer at LANL well R-15.

Perchlorate levels in groundwater samples collected from monitoring well R-15 range from <2.80 to 4.19 ppb.[12] A proposed drinking water standard for perchlorate is 1 ppb. Perchlorate levels as high as 200 parts per billion have been measured in the groundwater in the alluvial sediments in Mortandad Canyon and a perchlorate level of 20 parts per billion was measured in perched groundwater present in the borehole for well R-15.[11]

Radionuclides that were detected in the perched groundwater present in the R-15 borehole include americium-241 and tritium; the measured tritium level in the perched groundwater was 3,770 pCi/L.[11]

Issues for the construction of LANL well R-15 that impact the reliability of analytical results are the use of drilling fluids in the borehole and the installation of a 60-ft long screen that straddles the top of the water table and spans intervals of aquifer strata with differing values of hydraulic conductivity. Figure 6 shows that the 60-ft screen crosses a layer of clayey fine-grained sediments that is present at a depth of 1007 to 1009 feet below land surface. Figure 6 shows the large change in static water level that has occurred since construction of the monitoring well. The installation of the long well screen across the fine-grained sediments is allowing groundwater from above the fine-grained layer to drain down inside the well and mix with groundwater present below the fine-grained layer. The mixing will dilute contaminant levels that are present at the top of the regional aquifer. LANL monitoring well R-15 does not meet RCRA requirements for representative groundwater samples.

For the location of LANL well R-15 it is very important to have early detection of contaminants that travel beneath Mortandad Canyon and enter the coarse sediments with high hydraulic conductivity that are present at the top of the regional aquifer. Accurate information on the presence of contamination at the top of the regional aquifer below Mortandad Canyon requires that monitoring wells are installed at the top of the aquifer with a screen length that does not cross confining layers and that allows for collection of groundwater samples from the appropriate strata at the top of the regional aquifer. It is also important that drilling fluids and bentonite clay muds are not used in the borehole interval that is drilled into the regional aquifer.

An immediate activity that should be performed at LANL monitoring well R- 15 are remedial measures to stop the downward flow of groundwater in the well The successful performance of remedial measures should restore the original water table on the regional aquifer at a depth of 964 feet. After restoration of the original water table a low-flow sampling system should be installed in well R-15 to collect groundwater samples from the top of the regional aquifer. Replacement of well R-15 with a RCRA-compliant monitoring well will be necessary if the remedial measures are unsuccessful.

The RCRA requirement to install monitoring wells in Mortandad Canyon to a depth of several hundred feet in the regional aquifer is described in section 3.0 of this report. The

borehole log in the LANL Well R-15 Completion Report[11] shows that Totavi Lentil sediments are present in the depth interval of 1100 to 1107 feet, the total depth of the borehole. These sediments are known to have very high hydraulic conductivity. For well R-15, the top of the regional aquifer is at a depth of 964 feet and the top of the Totavi Lentil sediments is at a depth of 136 feet in the regional aquifer.

The LANL Well R-15 Completion Report[11] predicts that the Totavi Lentil sediments at the location of well R-15 have a total thickness of 65 feet. It is unfortunate that the R-15 borehole did not drill through the total thickness of the Totavi Lentil sediments and install a monitoring well in this interval of important aquifer strata. Presently, groundwater contamination and groundwater hydrology are poorly understood for the regional aquifer beneath Mortandad Canyon.

7.0 Groundwater Contamination in the Regional Aquifer Beneath MDA G at LANL Well R-22

The information presented in this section is from the LANL Well R-22 Completion Report[13] and the LANL Well R-22 Geochemistry Report.[14] LANL monitoring well R-22 is located atop Mesita del Buey immediately east of Material Disposal Area G (MDA G), the Laboratory's active landfill for disposal of low-level radioactive waste. The location of MDA G is shown on Figure 2. Well R-22 is a multiple-screen completion with five screened intervals installed at depths ranging from the top of the regional aquifer to a depth of 500 feet in the aquifer. The drilling fluids that were used in the borehole for this monitoring well have caused the development of a strong reducing chemistry in the groundwater that enters the well at screen no. 1, 2, and 4. Information in the LANL well R-22 Completion Report[13] shows that screens no. 1 and 2 are poorly developed. The Westbay* sampling system collects water samples from the stagnant zone of groundwater that surrounds the screened intervals.

Screen no. 1 was installed to straddle the water table of the regional aquifer. A comparison of the tritium activity in a groundwater sample collected at the top of the regional aquifer from the borehole for well R-22 to the tritium values in water samples collected from screen no. 1 are evidence of the stagnant zone of groundwater that surrounds the well screen. The tritium activity in the groundwater sample collected from the borehole was 109 pCi/L[13] compared to values of 2.01, 2.87, 2.30, and 2.33 pCi/L, respectively, in the four quarterly samples collected from screen no.1.[14] The low tritium values are evidence that groundwater samples collected from screen no. 1 are not representative of groundwater at the top of the regional aquifer beneath MDA G. The markedly higher tritium value in the groundwater sample collected at the top of the regional aquifer in the borehole for well R-22 creates a concern that other contaminants are present in groundwater and the improper construction of well R-22 is preventing an accurate understanding of the impact of MDA G on water quality in the regional aquifer.

Trend analyses show that the radionuclide contaminant technetium-99 is present in groundwater in the regional aquifer beneath MDA G. Technetium-99 activities in groundwater samples from screen no.3 and no.4 were validated levels (>3sigma) of 4.9 and 4.3 pCi/L, respectively.[14] The trend analyses in figure 7 show the declining levels of technetium-99 that occur over four quarterly sampling events for three of the screened intervals in well R-22. The declining levels of technetium-99 were shown in all five screened intervals in the well. The declining levels illustrate the action that is expected because of the use of drilling fluids in the borehole.

Other radionuclide contaminants that were recorded at low levels in the groundwater samples collected from monitoring well R-22 include americium-241; cesium-137; iodine-129; plutonium-238; plutonium-239,240; and strontium-90.[14] Some of the measured low levels of contamination may be because of analytical error; some of the contaminants that were recorded at low levels may not be present in the regional aquifer. However, the unnatural chemistry that surrounds well R-22 prevents an accurate understanding of the presence of contamination in the regional aquifer beneath MDA G.

The strong reducing chemistry in the zone that surrounds well R-22 is responsible for the anomalously low values of uranium in groundwater samples. The uranium analyses on groundwater samples from well R-22 are not valid for understanding the presence of uranium contamination in the regional aquifer beneath MDA G. Uranium chemistry is discussed in section 9.0 of this report.

A large quantity of the radionuclide contaminant iodine-129 was disposed of at MDA G.[15] Iodine-129 is mobile for transport through the unsaturated zone beneath MDA G,[15] and it is possible that this radionuclide is present in the regional aquifer. Iodine-129 was recorded at a value of 18 pCi/L in the first quarter of groundwater samples collected from screen no. 3.[14]

Volatile and semivolatile chemical contaminants are present in groundwater samples collected from well R-22.[14] The volatile contaminants are commonly known as solvents. In the past, a large volume of solvents were disposed of in trenches at MDA G. The LANL geochemistry report for well R-22 assigns the degradation of the drilling fluids as being the source of the chemical contaminants detected in groundwater from well R-22.[14] The drilling fluids used in the borehole for well R-22 prevent an accurate understanding of the chemical and radionuclide contamination in the regional aquifer beneath MDA G.

An important issue for LANL well R-22 (and many other LANL monitoring wells) is the failure to install screened intervals in aquifer strata that are fast pathways for groundwater travel. The fast pathway strata also have the greatest potential for the presence of contamination, and the highest levels of contamination.[16] Figure 8 displays the depth intervals for screened intervals in LANL well R-22. The figure shows that the screened intervals are installed in aquifer strata with low hydraulic conductivity and that screens were not installed in aquifer strata within the Cerros del Rio basalt and coarse gravels in

the Puye sediments that have very high hydraulic conductivity. Because of MDA G, there is a special need to characterize chemical and radionuclide contamination in the fast groundwater pathways. The measured values of hydraulic conductivity that are posted on Figure 8 are from the LANL Hydrologic Tests Report.[17]

There is a need to understand the direction and rate of groundwater travel in the fast groundwater pathways that are present below MDA G. The thick interval of river gravels in the R-22 borehole shows that an ancestral channel of the Rio Grande River is located below MDA G. The hydrostratigraphic setting of the ancestral channel is shown on Figure 9. The direction of groundwater flow in the coarse gravels that are in the ancestral channel may be southward; a markedly different flow direction from the easterly direction shown by the contour map of the water table on the regional aquifer in Figure 1. Similarly, the directions of groundwater flow in the fast pathways in the basalt strata beneath MDA G are not known. Presently, groundwater contamination and groundwater hydrology are poorly understood for the regional aquifer beneath MDA G

8.0 Failure of LANL to Acquire Accurate Knowledge of Aquifer Properties

Activities that have been performed for the LANL Hydrogeologic Workplan[1] are not developing an accurate understanding of the physical properties of the regional aquifer. The physical property that has received the greatest study in LANL monitoring wells is hydraulic conductivity. Unfortunately, many measured values of hydraulic conductivity are anomalously low because of 1. the incomplete development of the screened intervals in the monitoring wells, 2. the failure to install screened intervals in aquifer strata that have high hydraulic conductivity (see Figure 8), 3. the failure of pumping tests to discharge groundwater at a high enough rate to stress the aquifer, 4. the use of the wrong analytical methods to calculate aquifer properties from injection test data, and 5. most pumping tests are in monitoring wells (and supply wells) with long screen intervals that span aquifer strata with differing values for hydraulic conductivity (see Figure 6); the pumping tests determine an average value for hydraulic conductivity that greatly underestimates the hydraulic conductivity of the highly permeable strata that are fast pathways for travel of groundwater.

The information presented in this report for monitoring wells R-7. R-15 and R-22 shows the failure of LANL to gain knowledge of aquifer strata that have high hydraulic conductivity. Additional information on the poor knowledge that LANL has of fast pathways in the regional aquifer is shown by Table 4.3.2. – "Hydraulic Conductivity Estimates" in the LANL Report, "Groundwater Annual Status Report for Fiscal Year 2002".[18] The table shows the hydraulic conductivity of basalt to range from 0.04 ft/day to 14.87 ft/day. The table does not capture the high hydraulic conductivity that is present in the basalt strata in the regional aquifer beneath MDA G where estimated values of 200 and 400 ft/day are based on the borehole log in the LANL Well R-22 Completion Report,[13] a conversation with the driller,[19] and a review of aquifer properties.[16,20,21]

During 1995 to 1996, a field study measured the hydraulic properties of the unsaturated strata beneath MDA G and MDA L. The locations of the two MDA's are shown on Figure 2. The findings from the study are published in a journal article by Neeper.[23] The field study determined the unsaturated Cerros Del Rio Basalt beneath MDA G and MDA L to have a hydraulic conductivity greater than 1,000 Darcies (greater than 2,400 feet/day). The stratigraphy beneath MDA G is shown in Figure 8. Hydraulic conductivity is a physical property of aquifer strata that is independent of the fluid in the strata being either water or air. The measured value of hydraulic conductivity in the unsaturated basalt strata show that the estimated values posted on Figure 8 for hydraulic conductivity values of the basalt strata in the regional aquifer are conservative.

Table 4.3.2 in the LANL Annual Status Report[18] lists the hydraulic conductivity values for the Totavi Lentil sediments to range from 0.54 ft/day to 32.29 ft/day. The table does not capture the high hydraulic conductivities of the Totavi Lentil sediments that are present in the regional aquifer beneath Los Alamos and Mortandad Canyons, and beneath MDA G. An estimated value of 500 ft/day for the Totavi Lentil sediments in the regional aquifer beneath MDA G is based on the borehole log in the LANL well R-22 Completion Report, a conversation with the driller,[19] and a review of aquifer properties.[16,20,21]

Two of the hydraulic conductivity values listed in Table 4.3.2[18] are for injection tests in Totavi Lentil sediments present in LANL monitoring well R-31.[22] The listed values of 1.23 and 0.75 ft/day are incorrect because of the use of wrong analytical methods to interpret the test data and because the two screened intervals are surrounded by a thick interval of sloughed sediments that flowed around the well screens as the drill casing was retracted.[22] The injection test measured the hydraulic conductivity of the sloughed sediments. A review of information in the LANL Well R-31 Completion Report[22] of the description of drilling activities in the Totavi Lentil sediments in the borehole of well R-31 and a review of the borehole log establish an estimated hydraulic conductivity for the thick section of Totavi Lentil Sediments in the regional aquifer at LANL monitoring well R-31 to range from 250 to 500 ft/day.

9.0 Reductive Precipitation of Uranium From Groundwater

Over the past 60 years, research at LANL has used large quantities of uranium. There is a need for accurate knowledge of the levels of uranium in the regional aquifer.

A review of uranium analyses for groundwater samples collected from LANL monitoring wells where drilling fluids were used shows that the drilling fluids are causing removal of uranium from groundwater by the chemical process known as reductive precipitation. The drilling fluids were used in a large number of the monitoring wells. Uranium is a natural constituent in the regional aquifer and is generally present at levels of approximately 1 part per billion.[24] Groundwater samples collected from many of the LANL monitoring wells show anomalously low values for dissolved uranium. The

validity of uranium analyses in all of the wells where drilling fluids were used is questionable.

The review of chemical analyses for the LANL monitoring wells included in this report shows that reductive precipitation is removing uranium from groundwater at wells R-7, R-9i, and R-22. The values of dissolved uranium in groundwater samples from these wells are not representative of levels in the aquifer.

9.1 Anomalous Uranium Levels in LANL Well R-7

At LANL well R-7, the polymer-based drilling fluids caused the development of a strong reducing chemistry in the zone surrounding screen no. 3 at the top of the regional aquifer. The strong reducing chemistry is shown by the very low values for dissolved sulfate and the presence of a hydrogen sulfide odor at the well site during the collection of groundwater samples.[9] Because of the strong reducing chemistry, groundwater in the regional aquifer has very high levels for dissolved iron (17mg/L) and manganese (3.4 mg/L).[9] Because of reductive precipitation, dissolved uranium is at an anomalously low value of 0.051 ppb in groundwater samples collected from screen no. 3.[9] For comparison, a groundwater sample collected at the top of the regional aquifer in the borehole for well R-7 had a uranium level of 2.1 ppb.[8]

9.2 Anomalous Uranium Levels in LANL Well R-9i

LANL monitoring wells R-9 and R-9i are located in Los Alamos Canyon near the eastern boundary of the Laboratory facility. Drilling fluids were not used in the borehole for well R-9. Groundwater was present in two perched zones during the drilling of the borehole. Chemical analyses on groundwater samples collected from the two perched zones measured uranium values of 1.22 parts per billion (ppb) for the upper zone and 48.4 ppb for the lower zone, respectively.[25] The proposed EPA maximum contaminant level for uranium in drinking water is 7 ppb. In addition, plutonium-238 was detected at a validated level of 0.76 pCi/L in a groundwater sample collected from the lower perched zone in the borehole for well R-9.[25] At well R-9 the two perched zones were sealed off and the well has a single screen at the top of the regional aquifer.

Because of the presence of plutonium-238 and the high level of uranium in the lower perched zone, monitoring well R-9i was installed at a location close to well R-9 with screened intervals installed in the two perched zones.[26] Drilling fluids were used in the borehole for well R-9i. Groundwater samples for contaminant analyses were collected on a quarterly schedule from well R-9i for a one-year period. For the lower perched zone, the measured levels of uranium for successive quarters were 0.068, 0.04, 0.02, and <0.003 ppb, respectively.[10] The declining trend of the very low values is because of the removal of uranium from groundwater samples entering the well by reductive precipitation. For comparison, note that a uranium value of 48.4 ppb was measured in the groundwater sample collected from the lower perched zone in the well R-9 borehole.[25]

For the lower perched zone in well R-9i, analyses of the quarterly groundwater samples recorded very low values of plutonium-238 ranging from <0.006 pCi/L to -0.001 pCi/L.[10] Note that a much higher plutonium-238 value of 0.76 pCi/L was measured in a groundwater sample collected from the lower perched zone in the well R-9 borehole.[25]

For the upper perched zone in well R-9i, a trend analysis shows declining levels of dissolved uranium from a value of 0.588 ppb for the first quarterly groundwater sample to a value of 0.194 ppb for the groundwater sample collected in the fourth quarter.[10] Note that the groundwater sample collected from the upper perched zone in the R-9 borehole had a measured value for dissolved uranium of 1.22 ppb.[25]

Comparison of the analytical data from the R-9 borehole to the R-9i monitoring well is instructive in showing the large decline in contaminant analyses for plutonium and uranium that occurred because of the use of drilling fluids. It is important to note that a very large decline in contaminant levels for plutonium and uranium occurred at monitoring well R-9i before the first groundwater samples were collected for contaminant analyses. A similar large decline in contaminants may have occurred at many of the LANL monitoring wells that were installed in boreholes where drilling fluids were used.

9.3 Anomalous Uranium Levels in LANL Well R-22

At LANL well R-22, the polymer-based drilling fluids caused the development of a strong reducing chemistry in the zone surrounding well screens no. 1, 2, and 4. For screen no. 1, located at the top of the regional aquifer, the strong reducing chemistry is shown by the very low values for dissolved sulfate and the presence of hydrogen sulfide odors at the well site when groundwater samples are collected from screen no.1[14]. Because of the reducing chemistry very high values for dissolved iron (14.9 mg/L) and manganese (4.4 mg/L) are present in groundwater samples from screen no.1.[14] Dissolved uranium values are very low and show a declining trend to 0.02 ppb. The anomalously low values of dissolved uranium in groundwater samples from well R-22 are because of reductive precipitation that is caused by the use of drilling fluids in the R-22 borehole. The levels of total dissolved uranium and isotopic uranium in groundwater below MDA G are not accurately known.

10.0 Affect of High Levels of Dissolved Iron and Manganese on Contaminant Chemistry in LANL Monitoring Wells and on Well Development

The very high levels of dissolved iron and manganese in LANL monitoring wells are because the strong reducing chemistry dissolves these constituents from the aquifer strata. The natural dissolved iron and manganese levels in groundwater are very low (0.05 mg/L or less) in the oxidizing chemistry that is naturally present in the regional aquifer.

Presently, the high levels of dissolved iron and manganese are causing the precipitation of iron and manganese oxide/hydroxide coatings on the surfaces of the aquifer strata , on the filter pack sediments that surround the well screen, and also on the well screen. The coatings are a "slimy" gelatinous substance that obstructs the flow of groundwater through the aquifer strata, the filter pack sediments, and the well screen. The coatings increase the difficulty to develop the screened intervals and the coatings continue to be deposited after the well development activities were terminated.

The precipitation of the iron and manganese from groundwater also has potential to remove dissolved contaminants from groundwater by the chemical process coprecipitation[27]. In addition, the pervasive presence of the iron and manganese oxide/hydroxide coatings in the zone surrounding the monitoring wells are a serious issue for removing metal and radionuclide contaminants from groundwater because the coatings have strong adsorption properties for many of these dissolved contaminants.[27] The coatings are stable in the normal oxidizing groundwater environment which means that the coatings may be present for decades and will lower the validity of contaminant analyses of groundwater samples collected from the monitoring wells.

11.0 Concerns for Groundwater Samples Collected from the LANL Multiple-Screen Monitoring Wells

A large number of the LANL monitoring wells are constructed with multiple-screened intervals at different depths in the aquifer strata. Figure 8 displays the five screened intervals in LANL monitoring well R-22. The LANL monitoring wells in this report that are constructed with multiple screens include R-7, R-9i, R-16, and R-22. Westbay* multiple-port groundwater sampling systems are installed in all of the LANL multiple-screen monitoring wells. The Westbay* sampling system collects small volume groundwater samples from the immediate environment of the screened intervals. Large volumes of groundwater are not purged from the multiple-screen wells before groundwater samples are collected for contaminant analyses.

11.1 Concerns for Well Development Practices in the LANL Multiple-Screen Monitoring Wells

The record shows that the development of the discrete screened intervals in many of the LANL multiple-screen monitoring wells was insufficient to establish open hydraulic communication of the well screen with groundwater in the regional aquifer. Screen no. 1 in LANL monitoring well R-22 is a example of the poor development. Because of the strong downward hydraulic gradient in the regional aquifer at the location of this monitoring well, the static water level in the open multiple-screen well was below screen no. 1. Development activity in screen no.1 and no. 2 of well R-22 was limited to scrubbing with a wire brush.[13] Pumping development was not performed in the two screens because screen no. 1 was above the water table and attempted pumping at screen

no.2 yielded no water.[13] The static water level was restored in screen no.1 after installation of the Westbay* multiple-port groundwater sampling system. LANL monitoring well R-22 is located immediately down-gradient of MDA G where it is important to collect representative samples of groundwater at the top of the regional aquifer. The information in the LANL reports[13,14] shows that groundwater samples from screen no. 1 in monitoring well R-22 are collected from the stagnant pool of groundwater that surrounds the well screen. The nonrepresentative chemistry in groundwater samples collected from monitoring well R-22 is discussed in section 7.0 of this report.

Many of the LANL monitoring wells were installed in mud rotary boreholes with invasion of the aquifer strata with a large volume of bentonite clay drilling mud. Development activities in these monitoring wells included the use of chemicals to disperse and spread the bentonite clay over a large surface area of the aquifer strata. The development activity may have improved the hydraulic communication of the well screen with the aquifer. However, because of the slow groundwater flow in the regional aquifer, the Westbay* low volume groundwater sampling system collects groundwater samples that have had a long residence time in aquifer strata that are coated with bentonite clay. The bentonite clay has strong sorption properties to remove from groundwater many chemical and radionuclide contaminants.

11.2 Concern for Cross-Flow of Groundwater in the LANL Multiple-Screen Monitoring Wells

For a variable and often long period of time after construction, the LANL multiple-screen monitoring wells allowed cross-communication of groundwater between the screened intervals. Groundwater flowed downward from the upper screened intervals and out into the aquifer through the lower screened intervals. The downward flow of a large volume of groundwater that ocurred in many of the multiple-screened wells before installation of the Westbay* low volume groundwater sampling system is an additional factor that prevents accurate knowledge of water quality.

For LANL monitoring well R-9i, the low levels of uranium and plutonium-238 in the groundwater samples collected from the lower screen may in part be due to dilution of contaminant levels by the downward flow of groundwater during the time that the well was open for cross-flow of groundwater between the upper and lower screened intervals. The nonrepresentative chemistry of groundwater samples collected from LANL monitoring well R-9i is discussed in section 9.2 of this report.

For LANL monitoring well R-22, the levels of technetium-99 that are reported in the LANL Geochemistry Report[14] for screen no. 4 and no. 5 may be due to cross-contamination of groundwater from the upper screens to the lower screens during the time that the multiple-screened well was open for cross-communication of groundwater flow. However, it is also possible that the technetium-99 contamination is present deep in the regional aquifer beneath MDA G and the declining levels measured in all of the

screened intervals in well R-22 are because of the use of polymer-based drilling fluids in the borehole of this well. The improper construction of LANL monitoring well R-22 prevents accurate knowledge of the nature and extent of chemical and radionuclide contamination in the regional aquifer beneath MDA G.

12.0 Misleading Information in LANL Reports and Meetings with the Public

The analytical data presented in this report are from the LANL geochemistry reports for the R-series monitoring wells. The analytical data show that nonrepresentative groundwater samples are collected from many of the LANL monitoring wells where the drilling methods used drilling fluids and foams. For many of the monitoring wells, the LANL geochemistry reports describe the unnatural chemistry in groundwater that is caused by the drilling fluids. However, the LANL reports do not acknowledge that the analyses on groundwater samples collected from these monitoring wells are unreliable to provide accurate knowledge of the levels of many radionuclide and chemical contaminants. For example, the LANL Well R-22 Geochemistry Report[14] contains the following statement:

"Activities of technetium-99 were less than detection in groundwater samples collected from screens #1 and #2. Based on these findings, it is not likely that the isotope migrated from TA-54 (MDA G) because it was not observed at the regional water table at well R-22."

The trend analyses in Figure 7 of this report are evidence that technetium-99 is present in groundwater samples collected from screen #1 in well R-22. The radionuclide was observed at a low activity. The low values of technetium-99 in groundwater collected from screen #1 may be the result of the unnatural chemistry that is caused by the use of drilling fluids in the borehole for well R-22 The actual level of technetium-99 in groundwater at the top of the regional aquifer beneath MDA G is not known.

Another example of the misleading information that is present in the LANL reports is the following statement from the LANL Well R-7 Geochemistry Report:[9]

"Americium-241; cesium-137; plutonium-238; plutonium-239,240; strontium-90; technetium-99; and uranium-235 were not detected in the groundwater samples collected from well R-7."

The term "not detected" is commonly used in the LANL geochemistry reports and will lead many readers to believe that the contaminants are not present in groundwater. In reality, the term "not detected" means that the contaminant was detected by the analytical method at a low level; a low level that is possibly an error of the analytical method. However, the low levels may be a result of the unnatural chemistry that surrounds many of the monitoring wells. The trend analyses in Figure 5 of this report

are evidence that strontium-90 is present in the regional aquifer at well R-7. All of the radionuclide contaminants that are listed as "not detected" in the LANL Well R-7 Geochemistry Report will be removed from groundwater by the unnatural chemistry that surrounds the monitoring well.

A further example of the misleading information that is presented in the LANL geochemistry reports is the following statement from the LANL Well R-22 Geochemistry Report:[14]

"Activities of uranium-238, uranium-235, and uranium-234 were generally less than 0,5 pCi/L in groundwater samples collected from well R-22. Similar activities of uranium were measured in supply wells during 2000."

In reality, the uranium levels in groundwater samples collected from well R-22 (and many other LANL monitoring wells) are not similar to the uranium activities in groundwater samples from the supply wells. For screen #1, #2, and #4, the uranium values are anomalously low because of the strong reducing chemistry that surrounds the well screens (see section 9.0 of this report). The anomalous uranium values show that the groundwater samples are not reliable for understanding the level of uranium and the presence or absence of many other radionuclides.

At a public meeting held on January 7, 2004, LANL and DOE presented a proposed strategy for an accelerated schedule for completion of the investigation of environmental contamination at the Laboratory facility. A claim by LANL and DOE is that radionuclide contamination in the regional aquifer is limited to low levels of tritium. The presence of strontium-90 and technetium-99 in the regional aquifer beneath the Laboratory facility was not mentioned at the public meeting.

Concerning MDA G, DOE and LANL assured the people at the public meeting that an "intensive study" had not found releases of contamination. A LANL study of MDA G identified technetium-99 as one of the most mobile contaminants disposed of in trenches

at MDA G.[15] However, the LANL study concluded that releases of technetium-99 from MDA G would not reach the top of the regional aquifer for a period of 600 years.[15] The measurement in groundwater samples from well R-22 of technetium-99 and chemical contamination in the regional aquifer beneath MDA G was not mentioned at the public meeting. Figure 7 shows the presence of technetium-99 in the regional aquifer beneath MDA G.

A document delivered to the public that attended the DOE and LANL meeting displayed the LANL monitoring wells as monitoring wells for contamination in the regional aquifer.[28] The document did not explain that improper well construction practices make many of the wells unreliable for detection of contamination in the regional aquifer. The LANL estimate that many of the wells will not provide groundwater samples with an

unaltered chemistry for a period as great as 10 years[6] was not mentioned at the public meeting.

The DOE and LANL accelerated cleanup strategy proposes to leave the large volume of legacy wastes disposed of in trenches and shafts at many locations across the Laboratory facility "buried in place" with little additional investigation. DOE and LANL claim that this is a correct strategy because a careful study shows that contamination has not been released from MDA G to the regional aquifer and therefore, by analogy contamination is being contained at the other MDA's where radioactive and chemical wastes are disposed of in trenches and shafts. The validity of the accelerated cleanup strategy is now in question because of the presence of radionuclide and chemical contamination in the regional aquifer beneath MDA G. There is a need to install monitoring wells in the regional aquifer in the immediate vicinity of the other LANL MDAs that contain large volumes of legacy radioactive and chemical wastes. Presently, monitoring wells in the regional aquifer are not installed at locations that are close to many of the LANL MDAs that contain legacy wastes.

The presence of radionuclide and chemical contamination in the regional aquifer below MDA G raises a serious concern for the continued use of MDA G as a licensed disposal facility for low-level radioactive waste. An immediate investigation is needed to characterize the nature and extent of contamination in the regional aquifer below MDA G. This investigation will require the installation of several RCRA-compliant monitoring wells to characterize the radionuclide and chemical contamination present at the top of the regional aquifer and in the fast groundwater pathways in the aquifer strata beneath the landfill disposal facility. The fast pathways are shown on Figure 8. It is also important to determine the direction and rate of travel for groundwater in the fast pathways.

LANL operations are regulated by RCRA. The RCRA facility does not have a network of monitoring wells that meet RCRA requirements. There is a poor understanding of the nature and extent of radionuclide and chemical contamination in the regional aquifer beneath the Laboratory facility. There is also a poor understanding of the fast pathways for groundwater travel in the regional aquifer.

A technical review of activities conducted for the Hydrogeologic Workplan is necessary. A study of each of the LANL monitoring wells is required to determine their future value. This review should be conducted by a panel of experts in the following disciplines:

- Hydrogeology (with emphasis in measurement of aquifer properties and contaminant hydrology),
- Geochemistry (with emphasis in monitoring well installation requirements to acquire reliable information on contaminant chemistry),
- Geophysics (with emphasis in groundwater borehole geophysics), and
- Groundwater modeling of regional groundwater flow in aquifer strata that are anisotropic and heterogeneous.

13.0 Sentry Monitoring Wells for the Protection of Groundwater Supply Wells

The poor understanding at LANL of groundwater contamination and groundwater hydrology requires the installation of early warning monitoring wells (sentry wells) to protect the groundwater resources of San Ildefonso Pueblo and Pueblo de Cochiti. Sentry wells are also needed for the Santa Fe Buckman well field, and the supply wells that provide water to the Laboratory facility, to the communities of Los Alamos, White Rock, and to Bandelier National Monument. It is very important that drilling fluids, foams, and muds are not used during drilling of the boreholes into the regional aquifer. The sentry wells shall collect groundwater samples that are representative of the fast pathways within the regional aquifer. The groundwater samples shall be suitable for the detection of low levels of chemical and radionuclide contamination.

13.0 References

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7. LANL Report – "Semi-Annual Report to the Groundwater Integration Team (GIT) of the Los Alamos National Laboratory by the External Advisory Group", Oct., 2002

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28. LANL Report – "The Proposed Risk-Based End-State Vision for Completion of the EM Cleanup Mission at Los Alamos National Laboratory." LANL Report LA-UR-03-8254, 2003.

Novak, Lorelei

From: Dorothy Hoard [dorothyh@swcp.com]
Sent: Thursday, October 14, 2004 9:12 AM
To: Novak, Lorelei
Subject: Yanicek on Gilkeson

Hi, Lorelei. Here is what I have of Yanicek's comments. I cleaned out some of the junk addressing stuff. You are doing a wonderful job!!! djh

From - Sat Jul 24 13:06:22 2004
From: "Novak, Lorelei" <lnovak@doeal.gov>
To: "'fberting@losalamos.com'" <fberting@losalamos.com>,
"'jd@campy.com'" <jd@campy.com>,
"'dchurch@sde.state.nm.us'" <dchurch@sde.state.nm.us>,
"'dporterfield@nnsa.net'" <dporterfield@nnsa.net>,
"'rjfries@mindspring.com'" <rjfries@mindspring.com>,
"'dorothyh@swcp.com'" <dorothyh@swcp.com>,
"'cmtimmpe@aol.com'" <cmtimmpe@aol.com>, "',tdelong@lanl.gov'" <>,
tdelong@lanl.gov
Subject: FW: DOE REQUEST: DOE OB Comments - Mr. Gilkeson's "GROUNDWATER CO NTAMINATION IN THE REGIONAL AQUIFER BENEATH THE LOS ALAMOS NATIONAL LABOR ATORY, July 13, 2004, section 5.0, Well R-7 (and other sections pertinent to R-7)
Date: Fri, 23 Jul 2004 08:29:13 -0600

-----Original Message-----
From: Taylor, Theodore
Sent: Friday, July 23, 2004 6:47 AM
To: Novak, Lorelei
Cc: 'DeLong'
Subject: FW: DOE REQUEST: DOE OB Comments - Mr. Gilkeson's "GROUNDWATER CONTAMINATION IN THE REGIONAL AQUIFER BENEATH THE LOS ALAMOS NATIONAL LABORATORY, July 13, 2004, section 5.0, Well R-7 (and other sections pertinent to R-7)
Importance: High

Lorelei:

Please forward this analysis by NMED's DOE Oversight Bureau to the EMSR Committee members.

Ted
-----Original Message-----
From: Stephen Yanicak [mailto:syanicak@lanl.gov]
Sent: Thursday, July 22, 2004 12:03 PM
To: Turner, Gene E.
Cc: ecimino@cybermesa.com; PShanahan@hydroanalysisinc.com; Novak, Lorelei; john_young@nmenv.state.nm.us; darlene_goering@nmenv.state.nm.us; courte_voorhees@nmenv.state.nm.us; tim_michael@nmenv.state.nm.us; Johansen, Mathew; Taylor, Theodore; Whitacre, Thomas; jarends@nuclearactive.org; mayer.richard@epa.gov; stavert@lanl.gov
Subject: DOE REQUEST: DOE OB Comments - Mr. Gilkeson's "GROUNDWATER CONTAMINATION IN THE REGIONAL AQUIFER BENEATH THE LOS ALAMOS NATIONAL LABORATORY, July 13, 2004, section 5.0, Well R-7 (and other sections pertinent to R-7)
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Yanicak

Gene and Ted -

(please forward this to your LANL and CAB representatives... and all else that have interest)

We set aside some time this week so as to evaluate the referenced section from Bob's report, and offer the following.

* Based on the major ion chemistry at screen #1 (perched at 378'), it appears that true or representative hydrochemical conditions exist.

* Samples derived from screen #3 do not represent natural hydrochemical conditions (i.e., lack of sulfate, high TOC and high Alk).

* Based on all available data, strontium-90 (90Sr) was not detected in the 10 ground-water samples collected from screens #1 and 3# at R-7. The LANL WQH database (http://wqdbworld.lanl.gov/ <http://wqdbworld.lanl.gov/>) shows a 90Sr activity value of 1.4 pCi/L (0.95 1 sigma?) but does not provide a detection limit; however, the R-7 geochemistry report shows that 90Sr was not detected above 1.4 pCi/L. Please note that 90Sr was detected in the solids portion of the screen #1-perched sample collect during drilling: the result was 0.65 pCi/g, 1 sigma at 0.155 with a detection limit of 0.44 pCi/g. In sum, the 90Sr notations on Figure 5 from the Gilkeson report are not valid detections, one could consider them to be detection limits, not results.

* Elemental or total Sr was detected in the borehole water sample from screen 3# at 45 ug/L (first sample collected).

* As noted on Figure 5 from the Gilkeson report, total Sr was detected at 160, 140 117 and 90 ug/L through time. These data and presentation are correct.

* We contend that the concentration of total Sr (not Sr90) in ground water at screen 3# is gradually moving back to "background" conditions, and not because of precipitation or the removal of total Sr from the natural ground-water environment - see next bullet for justification.

* Natural or background levels of total Sr in upper Puye Formation ground water runs from about 40 to 70 ug/L (see historical Sr data from TW-2, TW-3, and TW-8); note that TW-3 is completed in the same zone as R-7 and is located approximately 1.2 miles downgradient of R-7, hence, a fairly good hydrochemical comparison point. The mean concentration for total Sr at TW-3 for period 1995 through 2003 is 78 ug/L (n = 11), nearing that of what was detected in the fourth-quarter sampling round at R-7, screen 3#.

* The high total Sr levels detected during the early quarterly-sampling period may be attributed to the residual drilling fluids that contain soluble mineral phase(s) such as calcium carbonate which in turn may contain trace levels of strontium.

* One would suspect to find tritium at R-7 (which we don't) if indeed 90Sr or any other contaminants associated with releases from TAs-1, 2 or 41 were present in ground water. Of course, one could argue that the associated tritium had already passed the monitoring point and that the less mobile constituents were showing up now.

Let us know if you have any questions concerning this material - the contact person on this is Michael Dale. Thanks --S Yanicak

Steve Yanicak, Natural Sciences Manager-2
email: syanicak@lanl.gov
(505) 672-0448

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(505) 428-2567 -FAX: Santa Fe DOE OB Office

http://www.nmenv.state.nm.us/ <http://www.nmenv.state.nm.us/> NMED web site http://www.nmenv.state.nm.us/DOE_Oversight/ <http://www.nmenv.state.nm.us/DOE_Oversight/> NMED DOE OB web site

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Novak, Lorelei

From: Donivan Porterfield [dporterfield@nnsa.net]
Sent: Wednesday, July 14, 2004 10:30 PM
To: dorothyh@swcp.com; Novak, Lorelei
Cc: tdelong@lanl.gov
Subject: NNMCAB EMS&R: Gilkerson

Dorothy and Lorelei,

In reading through the copy of the July 13, 2004 version of Gilkerson's report on "Groundwater Contamination in the Regional Aquifer Beneath the Los Alamos National Laboratory" there are references to figures but none are present. I wasn't sure if these are references to figures in other documents or weren't included in the electronic file he sent to the CAB office?

I think his citations from EPA guidance and EAG reports does raise the presence of drilling fluids as an issue worthy of a formal response as to its potential impact on completed wells and its continued use. Also, Timm's comments also point out a lack of consistency in how well reports address the issue of equilibrium, i.e. how do we know when its in equilibrium.

However, their are aspects of his data analysis that leave me quite unconvinced of an impact to the analytical data. For example in Section 5.0, 2nd paragraph:

"Figure 5 shows the consistent decline in levels of strontium-90 and strontium that has occurred for screen no. 3 in well R-7 for groundwater samples collected of a one-year period because of the zone of altered chemistry that is caused by the use of drilling fluids. The unnatural chemical process that lower the levels of strontium and strontium-90 in groundwater were introduced in the drilling fluids several months before the first groundwater samples were collected for contaminant analyses. The actual activity of strontium-90 in the regional aquifer is not known and may be much greater than the low instrument recorded values that are reported in the LANL geochemistry report."

If the cited drilling fluids were indeed capable of removing strontium, including strontium-90, then I would expect the kinetics of that reaction would be pretty quick, i.e. there would be no consistent decline but it just wouldn't be there, unless there is some very limiting aspect to this. For example, is the removal limited by very slow diffusion of water in the well zone?

I could hypothesize that the consistent decline he observes is the result of mixing of water in that particular well zone with water from a higher zone, which was more contaminated, as the well was drilled. As water is drawn out of that well zone by sampling it is replaced by less contaminated water that is more representative of that well zone.

I think an important aspect would be the presence of tritium. I wouldn't expect the drilling fluids would have significant impact on tritium levels, i.e. it would not be removed by the drilling fluids. So if it is not present that suggests that other possible radionuclides are also not present and not just being masked by drilling fluid impact as Gilkerson suggests. Generically, it is thought that tritium would be the lead contaminant and only be followed by others. This since it is effectively part of the water carrying any contaminant and is less likely to be impeded as it travels through the ground.

If yall only have the figures in hard copy, you can fax to me at 240-358-1192.

At 01:20 PM 7/13/2004, Novak, Lorelei wrote:
>Members and Guests,
>
>...
>
>Also, attached please find the attached DRAFT Minutes from the 6-9-04 EMS&R
>Committee Meeting. Please note the Mr. Gilkeson has agreed to send an
>electronic copy of his full-revised report, '"Groundwater Contamination in
>the Regional Aquifer beneath the Los Alamos National Laboratory" to be
>available at tomorrow's meeting. Also, Mr. Timm's (NNMCAB Nominee) Review
>Comments on Geochemistry Reports for Characterization Wells R-7, R-9, R-9i,
>R-15, and R-22 will also be available for review.
>
>Thank you,
>Lorelei Novak
>Community Outreach Specialist
>Northern New Mexico Citizens' Advisory Board
>A U.S. Department of Energy Site-Specific Advisory Board
>1660 Old Pecos Trail, Suite B, Santa Fe, NM 87505
>Phone: (505) 988-1749 or 1-800-218-5942
>Fax: (505) 989-1752
>Check us out on the WEB at: www.nnmcab.org
>

Mr. Donivan Porterfield
PO Box 1417
Los Alamos, NM 87544
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Novak, Lorelei

From: Donivan Porterfield [dporterfield@nnsa.net]
Sent: Tuesday, August 17, 2004 10:56 PM
To: tdelong@lanl.gov
Cc: dorothyh@swcp.com; Novak, Lorelei; Taylor, Theodore
Subject: Fwd: NNMCAB EMS&R: Gilkerson

Some additional comments on the Gilkeson report:

Section 7.0, 2nd paragraph
I guess I'm simply missing the point in perceiving a problem in that different tritium levels are being observed at two different levels in this well. Is it being postulated that there should be more uniformity over significantly different depth intervals?

Section 7.0, 3rd paragraph
I'm troubled by Figure 7 associated with this paragraph. This figure is plotting negative values without any suggestion of uncertainty or that some of these plotted values are likely below the associated detection limit. I'm little convinced of the argument being made.

Section 7.0, 6th paragraph
I'm missing the point of the mention of iodine-129. This information doesn't seem to be used to support any real point of view.

I believe Gilkeson raises a valid question as to the impact of drilling fluid impact on analytical results. However, I'm more persuaded of that point of view by the content of Pete Shanahan's review of Gilkeson's report in which he cites LANL reports admitting such impact. I think the Committee, in order to best address this issue, should focus on broader issues. Toward this end I would ask the following questions that may help illustrate some of the possible broader issues.

1. Is the possible impact of drilling fluids on sample analytical results consistent with the Data Quality Objectives for the project? In other words is it accepted that there will be a delay, due to drilling fluid use, before analytical results are truly representative of the sampled aquifer level?

2. Do the project Data Quality Objectives recognize two different types of analytical data, i.e. that before and after the analytical data is truly representative of the sampled aquifer depth?

3. Does the project have objective criteria for determining when the analytical results are no longer impacted by drilling fluids? In what manner is the application of these criteria to reported data documented and reported to the public?

4. When reporting analytical results how does the project describe the possible influence of drilling fluids on the reported data? This to ensure that the limitations of the data are clearly indicated.

5. Does the project have any clear guidance for reporting the use and amount of drilling fluids in each well completion report?

Not really addressing the above but the data cited in the Gilkeson report drives me to ask if the project reports are clearly reporting radionuclide results, the associated uncertainty (based on stated confidence levels), and detection limits (based on a consistent project statistical basis).

>Date: Wed, 14 Jul 2004 21:29:46 -0700
>To: "dorothyh@swcp.com" <dorothyh@swcp.com>, "Novak, Lorelei"
><lnovak@doeal.gov>
>From: Donivan Porterfield <dporterfield@nnsa.net>
>Subject: NNMCAB EMS&R: Gilkerson
>Cc: "tdelong@lanl.gov" <tdelong@lanl.gov>
>
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