Reply to the Review by Mr. Shanahan of the Report *"Groundwater Contamination in the Regional Aquifer Beneath the Los Alamos National Laboratory"*, version June 26, 2004 by Robert H. Gilkeson

Reply by Robert H. Gilkeson (Version January 3, 2005)

Executive Summary

Mr. Shanahan is a consultant who is employed by the RACER project; a risk assessment project that is evaluating all existing data on radionuclides and chemicals originating from the Laboratory facility. An important source of information to the Racer Project is the analytical data on water samples collected from the LANL monitoring wells that were installed for the Hydrogeologic Workplan. Mr. Shanahan's review of Gilkeson (2004) is presented in a memorandum dated June 25, 2004.

Mr. Shanahan concurs with the conclusion in Gilkeson (2004) that the groundwater samples from many LANL monitoring wells are not representative of the aquifer chemistry and are unreliable for accurate knowledge of the presence or absence of many chemical and radionuclide contaminants. Mr. Shanahan's claim (and also LANL's claim) that the impacted LANL monitoring wells will provide representative groundwater samples at an unknown date in the future (from a few years to possibly greater than ten years) can not be proven. In addition, a delay of even six months for monitoring wells to provide representative groundwater samples is unacceptable. In fact, there is consensus in the technical literature that the majority of the LANL monitoring wells installed in aquifer strata impacted by biodegradable drilling fluid, biodegradable foam, and bentonite clay muds are irreparably damaged, will never provide representative groundwater samples for contaminants of concern. Many of the wells require replacement. The technical literature is summarized in the Appendices to this reply.

Mr. Shanahan's assertion that the geology beneath LANL requires the use of the conventional mud rotary drilling method with bentonite clay drilling mud is <u>wrong</u>! The majority of LANL monitoring wells that are installed in mud rotary boreholes require replacement because of irreparable damage to the aquifer strata that are important for monitoring by the invasion of thousands of pounds of bentonite clay that can not be recovered by well development activities. The design features of the LANL monitoring wells that prevent recovery of drilling fluids are described in Article A-5 in Appendix A. The properties of bentonite clay for removal of many radionuclide contaminants from groundwater are described in Appendix D.

An irony in Mr. Shanahan's memorandum is the citation of LANL monitoring well R-14 as an example of the successful application of the mud rotary drilling method. In reality, the mud rotary drilling method was <u>unsuccessful</u> for drilling the borehole for well R-14 because of lost circulation of the bentonite clay drilling mud and inability to stabilize the borehole from collapse. The drilling method that was used for the installation of monitoring well R-14 is air rotary under-reamer casing advance. Many of the LANL monitoring wells are installed in boreholes drilled with the air rotary method.

Unfortunately, it is necessary to replace LANL monitoring well R-14 because the initial drilling with the mud rotary method caused the invasion of thousands of pounds of bentonite clay into the aquifer strata that are important to monitoring for radionuclide contaminants. An important concern at the location of monitoring well R-14 is monitoring for the presence of radionuclides in the regional aquifer from the LANL radioactive liquid waste treatment plant.

Mr. Shanahan's assertion that the United States Environmental Protection Agency (EPA) recommends the mud rotary drilling method with bentonite clay drilling muds for the installation of monitoring wells is wrong! It is important to note that as a general practice EPA advises against the use of the mud rotary drilling method and strongly advises against the use of this drilling method when trace radionuclides and metals are contaminants of concern. The concerns of EPA for the mud rotary drilling method are summarized in Appendix C. Appendix D summarizes the properties of bentonite clay to remove radionuclide and metal contaminants from groundwater.

Mr. Shanahan's assertion that as a general rule it is appropriate to install long well screens in the LANL monitoring wells is wrong! The length of each well screen should be determined by the physical properties of the aquifer strata where the well screen is installed. Most well screens should not have a length greater than 20 feet. Many of the LANL monitoring wells have screen lengths of approximately 10 feet. The installation of a 60-ft well screen at the top of the regional aquifer in LANL monitoring well R-15 is a serious mistake because the screen is causing dilution that prevents accurate knowledge of the type and levels of chemical and radionuclide contaminants that are present in the regional aquifer. Perchlorate and strontium-90 contamination is present in the diluted groundwater samples collected from the well. Well R-15 is located a. within a region of Mortandad Canyon that has received liquid wastes over periods of decades, and b. within a region of large groundwater withdrawal by Los Alamos County supply wells. At the location of LANL monitoring well R-14 there is a critical need for accurate knowledge of contamination at the top of the regional aquifer.

Mr. Shanahan's arguments with the validity of the trend analyses in Gilkeson (2004) are a distraction from the important fact that all of the contaminant analyses on groundwater samples collected from LANL monitoring wells R-7 and R-22 are spurious. The trend analyses in Gilkeson (2004) were an appropriate technique for study of the compromised data. The trend analyses confirm that strontium-90 contamination in present in the regional aquifer beneath landscapes in Los Alamos Canyon where liquid wastes bearing high levels of strontium-90 were discharged and technetium-99 contamination is present at the top of the regional aquifer beneath MDA G, a landfill where high volumes of wastes bearing technetium-99 were disposed of. LANL cannot dispute these conclusions.

Mr. Shanahan's defense of the failure of LANL to install monitoring wells to meet the requirements of RCRA is unconscionable because of the high cost of each well and the intrusion of boreholes into the regional aquifer should be held to a minimum. The RCRA

requirements (e.g., collect representative groundwater samples from the discrete strata where contamination is most likely to be present, and install screens in the highly permeable aquifer strata; the very strata where the greatest contamination is expected) are not unique: they are minimum requirements to assure that monitoring wells provide the necessary knowledge of the impact of the Laboratory facility on the regional aquifer.

The large amount of incorrect information that is presented in the Shanahan memorandum is further support of the recommendation in Gilkeson (2004) that all activities of the LANL Hydrogeologic Workplan be reviewed by an external panel of experts. 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,
- Groundwater modeling of groundwater flow in aquifer strata that are anisotropic and heterogeneous. and
- Risk Assessment with expertise to evaluate the impact of past and present LANL waste management on the groundwater resource.

It is important for this expert panel to be managed by an agency that is independent of the University of California, the Department of Energy, and the New Mexico Environment Department.

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biodegradable, polymer-based drilling fluid, biodegradable drilling foam, and bentonite clay drilling muds) should be avoided. In addition, the literature cited by Mr. Shanahan recognizes the special importance of avoiding the drilling additives where there is a concern for trace levels of radionuclide and metal contamination. The articles cited in the Shanahan Memorandum are summarized in Appendix A of this reply document. Additional articles against the use of biodegradable drilling additives and bentonite clay muds for the construction of monitoring wells are summarized in Appendix B.

The statement in the Shanahan Memorandum that "EPA guidance for the RCRA and CERCLA programs recommends mud-rotary well drilling when required" is a wrong interpretation of the EPA guidance for the installation of monitoring wells at LANL. It is important to understand that the use of the mud rotary drilling method is not required or appropriate for the hydrogeologic setting beneath the Laboratory facility (See topic 3). In addition, the EPA RCRA MANUAL (1992) contains much discussion of why the mud rotary drilling method is inappropriate for the installation of monitoring wells. The specific guidance by EPA to avoid the invasion of aquifer strata with biodegradable drilling fluids, Biodegradable foams, and bentonite clay drilling muds are summarized in Appendix C of this document. The properties of bentonite clay for preferential removal of trace radionuclide and metal contaminants from groundwater are described in Appendix D. The changes to the geochemistry of aquifer strata that result from the presence of biodegradable, polymer-based drilling fluids and biodegradable drilling foams are described in Appendix E. The chemical changes to the aquifer strata cause enhanced capability for removal of many radionuclide contaminants from groundwater.

Topic 3:
Discussion of drilling methods in the Shanahan Memorandum

The reader of the Shanahan Memorandum is left with the impression that the hydrogeologic setting beneath LANL requires the use of the mud rotary drilling method with bentonite clay muds for the installation of monitoring wells. This assertion in the Shanahan Memorandum is wrong! Drilling activities for the LANL Hydrogeologic Workplan have installed many monitoring wells in the regional aquifer with the air rotary under-reamer casing-advance drilling method. The following is an incomplete list that contains examples of monitoring wells, the total depth drilled, TD, and the depth drilled into the regional aquifer, RA, with the casing-advance method: well R-9, TD – 771 ft, RA – 82 ft: well R-12, TD – 886 ft, RA – 81 ft; well R-14, TD – 1327 ft, RA – 145 ft; well R-15, TD – 1107 ft, RA – 143 ft; well R-22, TD – 1489 ft, RA – 559 ft; well R-25, TD – 1942 ft, RA – 656 ft; and well R-31, TD – 1103 ft, RA – 569 ft. The well installation record of the Hydrogeologic Workplan activities is proof that the air rotary casing-advance drilling method has installed monitoring wells deep into the regional aquifer at locations distributed across the Laboratory facility.

- **LANL monitoring well R-14, an example of the failure of the mud-rotary drilling method**

The Shanahan Memorandum cites LANL monitoring well R-14 as an example of a well that was installed in a borehole that was drilled with a correct application of the mud-rotary drilling method using bentonite clay drilling muds. Mr. Shanahan points out that the mud-rotary drilling equipment used for the R-14 borehole compares closely to the recommended equipment in an article by Hix (1993). The Shanahan Memorandum contains the following statement:

> "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, 2003)."

The use of the optimal mud rotary equipment for the well R-14 borehole identifies the performance record for that borehole as "state of the art" for the installation of monitoring wells beneath the LANL facility in boreholes drilled with the conventional mud rotary method using bentonite clay drilling muds. Therefore, it is very important to understand that the LANL Well Completion Report for Monitoring Well R-14 (LANL, 2003) shows that the mud rotary drilling method was unsuccessful for the installation of monitoring well R-14. The LANL report describes the mud rotary drilling of the R-14 borehole in the regional aquifer as follows:

> "The borehole then was drilled open-hole with a 12.25 in. tricone bit into the top of the regional aquifer, stopping at 1225 ft bgs (below ground surface) on June 26, 2002, to obtain a static water level, which was measured at 1180.9 ft bgs. On June 27, 2002, Dynatech (the drilling contractor) switched to the conventional mud-rotary system and continued open-hole drilling with the 12.25-in. bit from 1225 ft bgs to 1285 ft bgs. From June 29 to June 30, 2002, recurring problems with lost fluid circulation around 1285 ft bgs stalled progress. WGII (the field services contractor) and the Laboratory made the decision to install an 11.75-in. casing, to seal the zones where fluid loss was occurring. On July 2, 2002, Dynatech completed casing installation and reamed through 14 ft of slough back down to 1285 ft bgs. Air-rotary drilling resumed using casing-advance with a 12.75-in. under-reaming down-the-hole (UR-DTH) hammer bit and the 11.75-in drill casing to 1327 ft." (the total depth of the borehole)

After the failure of the mud rotary drilling method, LANL monitoring well R-14 was installed in a borehole drilled to total depth with ***the air rotary under-reamer casing-advance drilling method.*** **The drilling history at LANL monitoring well R-14 attests to the fact that the mud rotary drilling method was inappropriate, unsuccessful, and unnecessary.**

The LANL Report for Well R-14 lists the following drilling additives for the borehole depth interval of 848 to 1315 ft: 28,250 lb of bentonite clay, 175 gal of Quick-Foam*, 22 gal of Liqui-Trol*, 700 lb of Pac-L*, 1830 lb of N-Seal* and 2160 lb of Magma Fiber*. The majority of materials on this list were used during drilling in the regional aquifer with the mud rotary method. The drilling additives Pac-L*, N-Seal* and Magma Fiber* were used in the unsuccess-ful attempt to stabilize the mud rotary borehole in the regional aquifer.

LANL monitoring well R-14 has two screened intervals installed in the regional aquifer below the static water level of 1182 ft bgs. Screen #1 is 33 ft long and is installed in the depth interval of 1200.6 – 1233.2 ft bgs. Screen #2 is 6.6 ft long and is installed in the depth interval of 1286.5 – 1293.1 ft bgs. The screens have an internal dimension of 4.5 in. and are a perforated pipe-based design with a wrap of stainless steel wire over the perforations. The wire wraps have a very close spacing of 0.010 in. The filter pack sediments have a texture of medium-grained 20/40 sand. Given the restrictive design of the monitoring well, it is not possible for the development activities in well R-14 to have removed more than a small amount of the bentonite clay drilling mud that invaded the aquifer strata. From the Shanahan report:

> "If no alternative to the use of drilling muds or fluids exists, these materials must be removed from the well bore and adjacent formations (aquifer strata) by careful well development." (From Puls and Barcelona, 1989)

The fact that the physical design of the LANL monitoring wells prevents the removal of a large volume of bentonite clay mud from the aquifer strata is described in article A-5 in Appendix A. The LANL Report for Well R-14 shows that well development activities were performed over the four month period from July 19, 2002 to November 18, 2002. The well development activities included the use of chemical additives to disaggregate the bentonite clay mud cake and further disperse the bentonite clay outward in the aquifer strata. The EPA RCRA Manual (1992) contains the following caution for the use of chemical additives as an aid in the development of monitoring wells:

> "Additives to modulate the viscosity and density of the bentonite muds may also introduce contaminants in the groundwater or force large, unrecoverable quantities of mud into the formation."

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 (EAG, Dec. 23, 1999) 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."

The LANL Monitoring Well R-14 Completion Report describes the objective of the monitoring well as follows:"

"The potential sources of groundwater contamination of most concern at R-14 are the present-day radioactive liquid-waste treatment plant at TA-50 and the former radioactive liquid waste treatment plant at TA-35. R-14 primarily is designed to determine the potential impacts of TA-50 effluent discharges on groundwater quality in the regional zone of saturation just south of Mortandad Canyon. The R-14 site in Ten Site Canyon also provides information about potential contaminants in the regional zone of saturation that could be drawn towards water supply well PM-5, located approximately one mile east-southeast."

LANL Monitoring Well R-14 is surrounded by aquifer strata that are invaded with a large volume of bentonite clay. The groundwater samples collected from the two screened

intervals in this well were in contact with bentonite clay for a long period of time. The improper methods that are used for the collection of groundwater samples from the LANL multiple-screen monitoring wells are described in Appendix F. Groundwater samples collected from LANL monitoring well R-14 are not valid for the detection of many of the radionuclide contaminants that are a concern for the location of the well. The monitoring objectives require replacement of this well with a properly constructed monitoring well in a borehole that is drilled without invading the aquifer strata with bentonite clay muds, biodegradable polymer-based drilling fluids, or biodegradable drilling foams.

Topic 4:
The statistics of detection of radionuclide contamination in groundwater

Mr. Shanahan questions the detection of strontium-90 contamination in groundwater samples from the regional aquifer at LANL monitoring well R-7 and the detection of technetium-99 in groundwater samples from the regional aquifer at LANL monitoring well R-22 because the recorded levels listed in the LANL geochemistry reports do not meet the arbitrary 3-standard deviation requirement. EPA and NMED disagree with the 3-standard deviation requirement of LANL as follows:

> "With respect to the interpretation of analytical results of radionuclide monitoring under the Safe Drinking Water Act, EPA has stated that "the analytical result is the number that the laboratory reports, not including (i.e. not adding or subtracting) the standard deviation." 65 Fed. Reg. 76,727 Dec. 7, 2000). LANL routinely applies standard deviations to its analytical results of groundwater monitoring. In its groundwater monitoring reports, LANL defines detections as "values exceeding both the analytical method detection limit (where available) and three times the individual measurement uncertainty." – the Environment Department disagrees with this restrictive definition of "detection", -" (NMED, November 26, 2002).

The text book *Applications of Environmental Chemistry* by Weiner (2000) has the following discussion of "not detected" values reported by analytical laboratories:

> "When a laboratory reports that a target contaminant was "not detected", it does not mean that the contaminant was not present. It always means that the contaminant was not present in a concentration above a certain lowest reporting limit. There always is the possibility that the contaminant was present at a concentration below the reporting limit."

Gilkeson (2004) presents trend analyses as evidence of the presence of strontium-90 contamination in groundwater samples collected from LANL monitoring well R-7 and of technetium-99 contamination in groundwater samples collected from LANL monitoring well R-22. The consistent trend displayed by the trend analyses confirms the presence of the radionuclide contamination. Furthermore, the technetium-99 levels for some of the first

quarter samples from well R-22 meet the arbitrary 3-standard deviation requirement. The trend analyses in Gilkeson (2004) were an appropriate technique for study of the compromised contaminant data for water samples collected from wells R-7 and R-22.

Topic 5:
The irreparable damage to many LANL monitoring wells because of the biodegradable, polymer-based drilling fluids, the biodegradable foams, and the bentonite clay muds.

Shanahan posits that the impacted wells can be useful after proper well development with the following statements:

> "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."
>
> "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 is 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."

The above statements in the Shanahan memorandum are an acknowledgment of the damage that the drilling fluids have caused to the groundwater chemistry. However, it is important to recognize the dichotomy in the statements. Mr. Shanahan recognizes the need to perform well development activities to remove the entrained drilling fluids. However, for many of the monitoring wells, there is irrefutable evidence that these materials were not removed by the LANL well development activities and no further well development activities are being performed. It is important to note that for the majority of the impacted monitoring wells, the performance of additional well development would be futile as the drilling fluids have caused irreparable damage. The large change in groundwater chemistry that was caused by the biodegradable drilling fluids and bentonite clay muds is proof of damage to the chemistry of the aquifer strata that surrounds the screened intervals. The monitoring by LANL of the return of the groundwater chemistry to an oxidized condition with low levels of dissolved organic carbon and a "representative chemistry" for major ions is not proof that the groundwater samples collected from the monitoring well are providing accurate knowledge for trace radionuclide and metal contaminants.

There is consensus in the articles referenced in the Shanahan memorandum of the requirement for thorough well development to remove the drilling fluids as soon as

possible after the borehole was drilled. For the LANL multiple-screen monitoring wells, there was a long delay between when the drilling fluids invaded the aquifer strata and the performance of well development to remove the fluids. In fact, no well development activities were performed in the screened intervals of some LANL multiple-screen monitoring wells (e.g., Screen #1 in LANL monitoring wells R-7 and R-22). The articles referenced in the Shanahan memorandum are summarized in Appendix A of this reply document. Article A-5 in Appendix A describes why the physical design of the LANL monitoring wells prevents the removal of large volumes of drilling fluids and drilling muds from the impacted aquifer strata.

The large volume of bentonite clay muds that have invaded the aquifer strata at many LANL monitoring wells and the use of chemical additives to disperse the clays a greater distance into the aquifer strata are irrefutable evidence of irreparable damage to the monitoring wells for detection of many radionuclide and metal contaminants. The properties of bentonite clay to remove these contaminants from groundwater are described in Appendix D.

In addition, it is essential that the biodegradable drilling fluids and foams are removed from the impacted aquifer strata before the fluids cause a large change in the aquifer chemistry. The LANL reports document that the required thorough development was not performed and that large changes have occurred to the geochemistry of the impacted aquifer strata. The changes to the geochemistry of the impacted aquifer strata that result in enhanced properties for the removal of many radionuclide contaminants from groundwater are described in Appendix E.

Furthermore, it is important to note that LANL has not performed any activities to further develop the screened intervals in the impacted wells. LANL is only monitoring the progression of the chemical reactions that are causing irreparable damage to the screened intervals. LANL is misrepresenting the chemical reactions as showing that the wells are "cleaning up". However, articles A-2 and B-1 in the appendixes of this reply identify the need to replace monitoring wells that display the unnatural groundwater chemistry present at many LANL monitoring wells.

Topic 6:
Misplacement of screened intervals in LANL monitoring wells

Statement in the Shanahan Memorandum

> "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 Workplan,"

Reply by Mr. Gilkeson
I disagree with the above statement by Mr. Shanahan. The EPA guidance and the technical literature have consensus on the importance for the installation of monitoring wells in the aquifer strata that have high permeability (e.g., high hydraulic conductivity). My finding that LANL has not installed screened intervals in the appropriate aquifer strata is not a 'Monday-morning quarterback' activity or 'second guessing'. My analysis is from the primary information from the drilling record and the borehole log descriptions of aquifer strata that are presented in the LANL well completion reports. My review of this primary information for LANL monitoring well R-22 shows that screened intervals were not installed in the important aquifer strata that have high hydraulic conductivity. This monitoring well is at an important location for the investigation of groundwater contamination beneath the Laboratory's active landfill for disposal of low-level radioactive waste.

A few examples from EPA Guidance and the technical literature of the importance to install monitoring wells in the aquifer strata with high hydraulic conductivity follow:

> "RCRA regulations for permitted facilities require point of compliance wells to be designed and installed to detect releases of hazardous waste or hazardous waste constituents to ground water. To meet regulatory requirements (Section 264.95(a) and Section 264.979(a)(3)), point of compliance monitoring wells should be installed adjacent to a hazardous waste management unit along its downgradient limit -. In a practical sense, this means that point of compliance monitoring wells should be as close as physically possible to the edge of hazardous waste management unit(s), and screened in all transmissive zones (aquifer strata with high hydraulic conductivity) that may act as contaminant migration pathways." - From US EPA RCRA Ground-Water Monitoring: Draft Technical Guidance, November 1992. (US EPA, Nov. 1992)

> "Maintenance of the hydraulic performance of monitoring wells and the connection of wells to the zones of greatest hydraulic conductivity, where contaminant transport is most probable, should take equal importance to the collection of representative water quality data." - From "Ground Water Sampling for Metals Analyses" by Puls and Barcelona (1989)

> "Heterogeneities in the aquifer can cause the pattern of the solute movement to vary from what one might expect in homogeneous beds. Because flowing groundwater always follows the most permeable pathways, those pathways will also have the most contaminant." - From Applied Hydrogeology by Fetter (1994).

The failure of LANL to install screened intervals in the aquifer strata with high hydraulic conductivity that are present in the regional aquifer beneath MDA G is a serious problem that requires explanation. For monitoring well R-22, why was screen #3 installed in aquifer strata with low hydraulic conductivity that are described in the well R-22

Completion Report as "silty very fine sand to pebble gravel"? Introductory courses in Geology teach that poorly sorted sediments with this description have a low permeability. What was the role of the suite of Schlumberger* borehole geophysics logs for the identification of the aquifer strata in well R-22 where screened intervals were installed? A review is needed for the location of screened intervals in all of the LANL monitoring wells.

Topic 7:
Length of well screens in LANL monitoring wells

Statement in the Shanahan memorandum

> "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 strata 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 contamination is needed."

Reply by Mr. Gilkeson

I disagree with the above statement by Mr. Shanahan for several reasons. The philosophy expressed by Mr. Shanahan's defense of long well screens reminds me of the adage "dilution is the solution to pollution". For the heterogeneous aquifer strata beneath the Laboratory facility, long well screens would assure dilution of contamination. The majority of screened intervals in LANL monitoring wells are short; on the order of 10 feet. Mr. Shanahan should have reviewed the LANL well completion reports that he references in his memorandum before he wrote his defense of long well screens.

The concern in Gilkeson (2004) is for the long well screens that are installed across the top of the regional aquifer where it is important to investigate the presence of contamination at the very top of the regional aquifer. The example in Gilkeson (2004) is LANL monitoring well R-15, a single screen well installed across the top of the water table to detect contamination in the regional aquifer beneath Mortandad Canyon. This well has a 60-ft screen that has breached a confining layer allowing the in situ groundwater at the top of the regional aquifer to drain downward into deeper strata in the regional aquifer. The contaminants strontium-90 and perchlorate are detected at validated levels in groundwater

samples collected from this well. The dilution caused by the improper construction of well R-15 prevents accurate knowledge of the level of contamination that is present. The location of LANL monitoring well R-15 qualifies for construction of a new monitoring well with a short screen as described above in the "phased approach" of Mr. Shanahan –

> "Eventually, wells with shorter screens may be necessary at particular locations where contaminant plumes are identified and bettcontamination is needed."

LANL monitoring well R-15 is installed within a region of large groundwater withdrawal by four Los Alamos County supply wells. There is a critical need for accurate knowledge of the type and level of chemical and radionuclide contaminants that are in the regional aquifer at the location of well R-15. The dilution caused by the 60-ft screen prevents the required knowledge of the contamination that is present at the top of the aquifer. LANL installed the 60-ft screen to guarantee a 50-year life for the monitoring well. WHAT IS THE VALUE OF 50 YEARS OF BAD DATA?

The LANL EAG advised LANL that the installation of long well screens that straddle the water table was inappropriate as follows:

> "The problems with long well screens have become fairly well known in recent years, In effect, such screens
>
> - Tend to average contaminant concentrations by mixing waters from truly high concentration zones and low concentration zones
> - Yield little, if any, information about the zone of contaminant transport or the location and thickness of a plume
> - Serve as a conduit for contaminants to move from contaminated to uncontaminated regions of the aquifer
> - Confound hydrogeologic understanding due to variable stratigraphy and flow across the screened interval ("short-circuiting")

Topic 8:
The failure of LANL to acquire accurate knowledge of aquifer properties

The Shanahan Memorandum has misunderstood the concern in Gilkeson (2004) for the failure of LANL to gather accurate knowledge of aquifer properties. This failure by LANL prevents knowledge of the speed with which contaminants travel in the groundwater flow system, prevents the identification of "fast pathways" for travel of contaminated groundwater, and also prevents an understanding of the valuable groundwater resource that is available across the Laboratory facility to supply wells.

There are several reasons for why LANL has failed to acquire accurate knowledge of aquifer properties and include the following:

1. The failure to install screened intervals in the aquifer strata with high hydraulic conductivity (e.g., well R-15 located within a region of large groundwater withdrawal by Los Alamos County supply wells and well R-22 located downgradient of MDA G).

2. The failure to properly develop the screened intervals to establish an open hydraulic connection to the aquifer strata.

3. The failure to recognize that screened intervals are surrounded by an envelope of slough sediments; the injection tests measured the permeability of the slough sediments (e.g., screen #3 in well R-22 and screen #4 and #5 in well R-31).

4. The installation of long screened intervals across aquifer strata with great differences in hydraulic conductivity. Injection and pumping tests in the long screened intervals determined an average hydraulic conductivity that greatly underestimated the hydraulic conductivity in the "fast pathway" strata. Examples are the 60 ft screens in LANL monitoring wells R-13 and R-15, and screen lengths of several hundred feet in many Los Alamos County supply wells.

5. The group of external consultants (the EAG) that advised LANL on activities of the Hydrogeologic Workplan reviewed the data gathered in the injection tests performed in the LANL monitoring wells. The EAG advised LANL that it was inappropriate to use slug-test analytical methods to calculate the hydraulic conductivity for the injection test data from many screened intervals (LANL EAG, 2002-b). Nevertheless, LANL published the markedly low hydraulic conductivity values that were calculated from the slug-test methods (LANL, 2003).

6. The EAG advised LANL of inaccurate data for injection and pumping tests (LANL EAG, 2002-b). However, LANL failed to correct all of the data inaccuracies in the published LANL hydrologic tests report (LANL, 2003).

7. The failure to include in LANL reports the published large-scale aquifer test by Neeper (2003) that determined the basalt strata below the region of MDA L and MDA G to have a hydraulic conductivity greater than 2,400 ft/day.

The significance of the failure of LANL to acquire accurate knowledge of aquifer properties is shown by the LANL injection tests in three screened intervals in monitoring well R-31 (LANL, 2003). An interesting feature in the LANL hydrologic tests report (LANL, 2003) is the performance of injection tests before and after all development activities were performed in screen # 3 in LANL monitoring well R-31. The higher hydraulic conductivity of 1.95 ft/day measured in the first injection test compared to the significantly lower value of 0.41 ft/day for the second test after "full development" of the screened interval is evidence that the development activities increased the "plugging" of

the filter pack sediments and the aquifer strata in the impacted zone that surrounds the screened interval.

For the development of screened intervals in monitoring well R-31 (and many other monitoring wells), LANL operated the surge block on a wire line. The surge block caused flow of water into the well but did not have a back-flushing action. The EPA RCRA Manual (1992) advises against the operation of a surge block on a wire line as follows:

> "Inducing movement of groundwater into the well (i.e., in one direction) generally results in bridging the particles. A means of inducing flow reversal is necessary to break down bridges and produce a stable filter."

In addition, the hydraulic conductivity value of 0.41 ft/day published in the LANL hydrologic tests report (2003) is unreasonably low for the aquifer strata based on the description in the LANL Well R-31 Completion Report of the drilling activities in the basalt strata where screen #3 is installed. The LANL Well R-31 Completion Report describes the aquifer strata as clay-free, columnar jointed basalt that yielded enhanced groundwater flow during the drilling. The aquifer strata where screen #3 is installed may have a hydraulic conductivity greater than 100 ft/day.

Unfortunately, the LANL reports present the much lower value of 0.41 ft/day as representative of aquifer properties for the regional aquifer. (See Table 4.3-2, "Hydraulic Conductivity Estimates" in the LANL Groundwater Annual Status Report for Fiscal Year 2002, LA-UR-03-0244.) Table 4.3-2 also lists unreasonably low hydraulic conductivity values of 1.23 and 0.75 ft/day, respectively, for the aquifer strata at screen #4 and #5 in well R-31.

The EAG advised LANL that incorrect methods were used to calculate the hydraulic conductivity for screen #4 and #5 in well R-31 (LANL EAG, 2002-b). The EAG used the correct analytical methods to calculate significantly higher hydraulic conductivity values for screen #4 and #5 of 36.2 ft/day and 16.7 ft/day, respectively (EAG, 2002-b). Nevertheless, LANL published the unreasonably low hydraulic conductivity values of 1.23 and 0.75 ft/day for the two screened intervals.

In addition, it is important to be aware that the LANL Well R-31 Completion Report shows that screen #4 and #5 are surrounded by slough sediments that flowed into the borehole as the drill casing was retracted during the construction of the monitoring well. The injection tests measured the hydraulic conductivity of the slough sediments. The description in the LANL Well R-31 Completion Report of the drilling activities in the thick interval of coarse sediments where screen #4 and #5 are installed and the large production of groundwater while drilling through the greater than 393-ft thick interval are evidence that supports a hydraulic conductivity for the aquifer strata at screen #4 and #5 of greater than 250 ft/day.

The failure of LANL to properly gather knowledge of the hydraulic conductivity of aquifer strata in the regional aquifer is a serious problem. The anomalously low values cause an underestimation of the speed of groundwater travel and an underestimation of the valuable groundwater resource that is available to supply wells.

Topic 9:
The Shanahan Memorandum comparison of the findings in Gilkeson (2004) to the LANL Geochemistry Reports

The Shanahan Memorandum compares Gilkeson (2004) to the LANL Geochemistry Reports with the following statement:

> "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 hypothetical 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. These alternative mechanisms of water chemistry are presented with considerable clarity in the multiple reports by Longmire and are more persuasive in my opinion."

Reply by Mr. Gilkeson:
The analytical data in the LANL Monitoring Well R-7 Geochemistry Report are unreliable for the presence or absence of many chemical or radioactive contaminants. The great chemical change caused by the biodegradable drilling fluids requires a careful, conservative analysis of the compromised analytical data. This is the reason for the trend analyses that are presented in Gilkeson (2004).

I wrote the report "Groundwater Contamination in the Regional Aquifer Beneath the Los Alamos National Laboratory", (Gilkeson, 2004) to call attention to the serious problems because of LANL's failure to correctly perform activities of the Hydrogeologic Workplan. It was not premature to write the report. Furthermore, the contaminant data collected from monitoring wells should not be subject to "alternative explanations". The data should be of sufficient quality to accurately define the presence or absence of contamination and the level of contamination that is present. In addition, my review of the LANL Geochemistry Reports does not find the "considerable clarity" that is claimed by Mr. Shanahan.

The improper construction of many LANL monitoring wells is preventing knowledge of the presence or absence of many contaminants. The best interpretation of the available data is that strontium-90 and technetium-99 contamination is present in the regional aquifer; in fact, the measured levels exceed the LANL arbitrary 3-standard deviation requirement for groundwater samples from LANL monitoring wells R-15 and R-22. The levels of strontium-90 that are recorded at monitoring well R-7 do not meet the LANL 3-standard

deviation requirement. However, US EPA and NMED disagree with the restrictive 3-standard deviation requirement. See topic 4.

Many of the LANL Geochemistry Reports acknowledge the altered chemistry of groundwater samples because of the biodegradable drilling fluids and biodegradable foams. The same reports do not acknowledge that the contaminant data for the impacted groundwater samples are unreliable.

Many of the LANL Geochemistry Reports acknowledge that the biodegradable drilling fluids and biodegradable foams are responsible for very high levels of dissolved iron in groundwater. However, the reports do not describe the well-known geochemical processes that are causing the precipitation of "fresh" blanket coatings of iron precipitates on the aquifer strata and filter pack sediments in the impacted zone that surrounds the screened intervals. The "fresh" precipitates greatly reduce the aquifer permeability and have significant sorption properties for many contaminants of concern. The geochemical processes in the impacted strata and the properties of the iron precipitates are described in Appendix E.

The dissolved uranium concentrations are at anomalously low levels for many screened intervals in LANL monitoring wells that are impacted by the biodegradable drilling fluids and foams. In general, the LANL geochemistry reports fail to recognize that the unnatural chemistry due to the drilling fluids has removed uranium from groundwater. The removal of uranium is evidence of the presence of a chemical environment that may remove other contaminants of concern. The geochemical processes that are responsible for the very low levels of uranium are described in Appendix E.

The LANL geochemistry report for monitoring well R-22 acknowledges that significant dilution has occurred for the tritium level measured in groundwater samples collected from the screened interval installed in aquifer strata at the top of the regional aquifer. Slightly greater than 2 pCi/L of tritium were measured in the samples from the screened interval compared to the much higher value of 109 pCi/L that was measured in the groundwater sample collected from the borehole when drilling reached the top of the regional aquifer. The dilution of tritium values will also cause dilution of other contaminants such as technetium-99. However, the LANL geochemistry report contains the unsupported conclusion that technetium-99 was not present in groundwater at the top of the regional aquifer. Monitoring well R-22 is at a location that is very important for knowledge of the impact of the Laboratory's active landfill for low-level radioactive waste on the regional aquifer. There is an immediate need to replace this monitoring well.

There is considerable uncertainty in the knowledge that LANL has for the chemistry of groundwater samples that are collected from the LANL monitoring wells because of the inappropriate methods that are used to collect the water samples. The LANL EAG has advised LANL to change the methods that are used for the collection of groundwater samples (EAG, 2002-a). The necessary changes to LANL sampling methods are described in Appendix F.

References:

ASTM (American Society for Testing and Materials) 2004. *Stamdard Practice for Design and Installation of Ground Water Monitoring Wells.* ASTM Standard D 5092-04. Philadelphia, Pennsylvania.

ASTM (American Society for Testing and Materials) 1990. *Stamdard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers*. ASTM Standard D 5092-90. Philadelphia, Pennsylvania.

Australian Drilling Committee, 1997. DRILLING – *The Manual of Methods, Applications, and Management.* Australian Drilling Industry Training Committee Industry. CRC Press LLC.

Brobst, R.P. and P.M. Buszka. 1986. "The Effect of Three Drilling Fluids on Ground-Water Sample Chemistry." *Ground Water Monitoring Review* 6(1): p. 62-70.

Claassen, H.C. 1982. *Guidelines and Techniques for Obtaining Water Samples that Accurately Represent the Water chemistry of an Aquifer.* Open-File Report 82-1024, U.S. Geological Survey, Lakewood, Colorado.

Driscoll, F. G., 1986. *Groundwater and Wells.* Johnson Division, St. Paul, Minnesota.

EAG, 2002-b. "Review of Hydrologic Test Report of Los Alamos National Laboratory." Review of draft version by David Schafer, member of the LANL External Advisory Group, October, 2002.

EAG, 2002-a. "Semi-Annual Report to the Groundwater Integration Team (GIT) of the Los Alamos National Laboratory.

EAG, 2001. "Semi-Annual Report to the Groundwater Integration Team (GIT) of the Los Alamos National Laboratory.

EAG, 1999. "Semi-Annual Report to the Groundwater Integration Team (GIT) of the Los Alamos National Laboratory.

Fetter, C.W. 1999. *Contaminant Hydrogeology.* Second Edition. Upper Saddle River, New Jersey: Prentice Hall.

Gibb, J.P., and K.V.B. Jennings. 1987. "How Drilling Fluids and Grouting Materials Affect the integrity of Ground Water Samples from Monitoring Wells. *Ground Water monitoring Review* 7(1): 33.

Gilkeson, Robert. 2004. *Groundwater Contamination in the Regional Aquifer Beneath the Los Alamos National Laboratory,* version July 13, 2004.

Jennings, K.V.B. 1986. "The Effects of Grouts, Sealants, and Drilling Fluids on the Quality of Ground Water Samples" In: *Proceedings of the Sixth National Symposium and Exposition on Aquifer Restoration and Ground Water Monitoring,* Columbus, Ohio, May 19-22, 1986.

Langmuir, D., 1997. *Aqueous Environmental Geochemistry.* Prentice-Hall, Inc., Upper Saddle River, New Jersey.

LANL. 2003. "Hydrologic Tests at Characterization Wells R-9i, R-13, R-19, R-22, and R-31. LA-13987-MS. Los Alamos National Laboratory, Los Alamos, New Mexico.

LANL. 2003. "Groundwater Annual Status Report for Fiscal Year 2002." LA-UR-03-244, Los Alamos National Laboratory, Los Alamos, New Mexico.

LANL. 2003. *Characterization Well R-16 Completion Report,* LA-UR-03-1841. Los Alamos National Laboratory, Los Alamos, New Mexico.

LANL. 2003. *Characterization Well R-14 Completion Report, LA-UR-03-1664.* Los Alamos National Laboratory, Los Alamos, New Mexico.

LANL. 2002. *Characterization Well R-15 Completion Report*, LA-13749-MS. Los Alamos National Laboratory, Los Alamos, New Mexico.

LANL. 2002. *Characterization Well R-15 Geochemistry Report*, LA-13896-MS. Los Alamos National Laboratory, Los Alamos, New Mexico.

LANL. 2002. *Characterization Well R-22 Completion Report,* LA-13893-MS. Los Alamos National Laboratory, Los Alamos, New Mexico.

LANL. 2002. *Characterization Well R-22 Geochemistry Report,* LA-13986-MS. Los Alamos National Laboratory, Los Alamos, New Mexico.

LANL. 2002. *Characterization Well R-7 Completion Report,* LA-13932-MS. Los Alamos National Laboratory, Los Alamos , New Mexico.

LANL. 2002. *Characterization Well R-7 Geochemistry Report,* LA-14004-MS. Los Alamos National Laboratory, Los Alamos , New Mexico.

LANL. 2001. *Characterization Well R-31 Completion Report,* LA-13910-MS. Los Alamos National Laboratory, Los Alamos , New Mexico.

LANL, 2000. Hydrogeologic Characterization Program Quarterly Meeting / EAG Semi-Annual Meeting, October 3-5, 2000.

LANL. 1998. Hydrogeologic Workplan. Los Alamos National Laboratory, Los Alamos, New Mexico.

New Mexico Environment Department, November 26, 2002. The NMED Response to LANL Legal Comments Concerning the NMED LANL Draft Order.

Puls, R.W., and M. J. Barcelona, 1989. *Groundwater Sampling for Metals Analyses.* Report Number EPA/540/4-89/001. U.S. Environmental Protection Agency, Ada, Oklahoma.

Stumm, W., and J. J. Morgan, 1996. *Aquatic Chemistry. 3rd Edition.* John Wiley and Sons, Inc., New York.

US EPA. 1992. "RCRA Groundwater Monitoring: Draft Technical Guidance," November 1992. EPA 530-R93-001.

Walker, S.E. 1983. "Background Ground-Water Quality Monitoring: Well Installation Trauma." In: *Proceedings of the Third national Symposium of Aquifer Restoration and Ground-Water Monitoring,* May 25-27, 1983, Columbus, Ohio.

Weiner, E. R., 2000. *Applications of Environmental Chemistry. Lewis Publishers, New York.*

APPENDICES

Appendix A: Summary of articles referenced in the Shanahan memorandum

Article A-1:

The article by Claassen (1982) presents guidelines and techniques for obtaining water samples that accurately represent the water chemistry of an aquifer. The article has no discussion of the mud rotary drilling method as uniquely suited to drilling in unstable geologic formations or for drilling deep boreholes. The article describes mud rotary drilling as follows:

> "Drilling with cable tool produces some fine rock chips that fill some native pore spaces; rotary drilling produces a similar effect, but also contributes additional plugging material in the form of additives to the circulating fluid. The most common of these is "mud", a mixture of water, bentonite clay and other additives. Mechanical requirements for efficiently producing a hole to be used for collecting hydrologic data are counterproductive to obtaining the data. – If a significant part of the drilled hole is plugged by drilling fluids, well development will be difficult or inadequate. This may result in a water sample that does not represent the entire thickness of aquifer, and also results in incorrect hydrologic data being obtained from the aquifer. It may be argued that permeable intervals will be under sufficient hydraulic head to remove mud caked on the borehole wall when the hole is jetted, but this is not a foregone conclusion."

> "There is some evidence both from onsite experience and laboratory experimentation that significant changes in water quality are effected by the presence of drilling mud in a well. Most of the changes can only be qualitatively inferred from estimates of mud composition; however, very significant affects on both major- and minor-constituent concentrations are caused by mud contamination."

Article A-2:

The article by Walker (1983) reviews the installation and chemical analysis data from 20 background water quality monitoring wells at six locations in northern New England. Eighteen of the wells are not installed at a depth greater than 70 ft. The deepest well is installed at a depth of 135 ft. The article has no discussion of the mud-rotary drilling method as uniquely suited for drilling in unstable geologic formations or for drilling deep boreholes. Concerning drilling methods the article has the following recommendations:

> "Minimize or eliminate the introduction of water in installing the well: do not use bentonite or other drilling fluids unless absolutely needed."

> "Replace wells that display extreme or slowly dissipating trauma."

The term "trauma" describes monitoring wells where groundwater samples have a non-representative water chemistry. The screened intervals in many LANL monitoring wells such as R-7, R-9i, and R-22 display "extreme trauma" and "slowly dissipating trauma"

Article A-3:
The article by Ericson et al (1985) describes the impact of drilling fluids on the installation of monitoring wells in boreholes that were drilled with conventional rotary methods. The wells were installed on uranium mill tailings sites to investigate radionuclide and metals contamination in groundwater. Bentonite clay muds were not used in any of the boreholes because of the sorption properties of bentonite clay for the contaminants. The authors do not claim that the drilling environment uniquely required the mud rotary drilling method. They also used temporary casing to stabilize the boreholes at some well sites. The maximum depth for boreholes was not greater than 200 feet.

The Ericson et al article has the following recommendation:

> "Bentonite clay drilling muds, anionic polymer emulsion products (i.e., Baroid EZ-MUD), and synthetic, biodegradable surfactant drilling media (i.e., Baroid QUIK FOAM) should not be used in or near the aquifer strata to be screened or sampled for radionuclide and metal contaminants".

<u>The LANL monitoring wells have screened intervals installed in aquifer strata that are invaded by bentonite clay drilling muds, Baroid EZ-MUD, and Baroid QUIK FOAM.</u>

I am familiar with the findings of the Ericson et al article as I was the Corporate Technical Director for the Earth Sciences at WESTON*, an environmental consulting company that was part of the "team" of companies doing investigations on the uranium mill tailings sites. I would not have used the conventional fluid rotary drilling method for the installation of any of the monitoring wells for the geologic conditions described in the Ericson et al article. The wells could have been installed in boreholes drilled without the use of any fluids by using either the air rotary top-head casing driver method (Driscoll, 1986) or the Becker* reverse air percussion method to drive temporary casing to stabilize the boreholes.

Article A-4:
The article by Brobst and Buszka (1986) describes their research of the effect of three drilling fluids on groundwater sample chemistry. One of the drilling fluids was bentonite clay mud. The groundwater analytes that were studied include only chemical oxygen demand, chloride, and sulfate. The effect of bentonite clay muds on the trace constituents including radionuclides and heavy metals was not studied. The article has the following discussion of the mud-rotary drilling method:

> "In many environments similar to those in the study area, mud rotary drilling represents the most practical method of borehole construction. However, the parties responsible for well installation, groundwater sampling and interpretation of

analytical results must be aware of the changes that mud rotary drilling imposes on the subsurface environment."

"The principal disadvantages of conventional mud rotary drilling are the damage the method causes to formation permeability and the changes the method effects to hydrochemistry".

"The invasion of mud filtrate may alter the geochemical equilibrium between groundwater and formation solids. Therefore, a successfully installed well is one in which both wall cake and mud filtrate are fully removed from the formation during well development. Even in well development procedures employing either borehole flushing prior to well installation, surging with a pump or surge block or bailing, substantial quantities of drilling fluid residue may still remain in the borehole and the formation."

"Because of the thixotropic behavior of bentonite drilling fluids, vigorous well development and purging efforts may be the only means of reducing the amount of drilling mud left downhole. The addition of dispersing agents such as barium phosphate or organic polymers may possibly reduce mud viscosity and enhance mud recovery. However, the geochemical changes imparted to groundwater and the geologic matrix by the dispersing agents may render the well unfit for water quality monitoring."

<u>Dispersing agents were routinely used for the development of the LANL monitoring wells that were installed in mud rotary boreholes drilled with bentonite clay muds.</u>

I disagree with the authors' analysis that the mud rotary drilling method represents the most practical method of borehole construction for the geologic formations in the study area. The study installed three monitoring wells in glacial deposits to a maximum depth of 105 ft. I gained much experience in the installation of monitoring wells in glacial tills and outwash sediments during my 17 years of employment as a Research Scientist in the Hydrogeology and Geophysics Sections of the Illinois Geological Survey. Three drilling methods that are suitable for the glacial deposits described in this article are the air-rotary casing-advance with a surface operated air hammer (Driscoll, 1986), the Becker* reverse air percussion to drive casing, and the Rotasonic* (Australian Drilling Committee, 1997). These methods do not use water, drilling fluids, or bentonite clay muds.

Article A-5:
The article by Gibb and Jennings (1987) describes how drilling fluids and grouting materials affect the integrity of groundwater samples from monitoring wells. The article has no discussion of the mud-rotary drilling method as uniquely suited for drilling in deep, unstable geologic formations. The article has the following discussion concerning the drilling of boreholes for monitoring wells with the rotary method using drilling fluids and/or bentonite clay muds:

"In geologic environments where drilling fluids are a necessity, inorganic clay muds are preferred over those containing organic materials. The introduction of substrates for microbial activity can seriously impact the integrity of water samples."

"Rotary drilling methods using bentonite or organic based drilling fluids present serious problems in the construction of monitoring wells. Wells constructed with these drilling methods are seldom capable of providing accurate hydrologic or chemical data for a wide variety of inorganic and organic constituents. - - The amount of drilling fluids lost into formations or deposits (aquifer strata) is directly proportional to their hydraulic conductivity."

"In addition to the migration of drilling fluids into the subsurface materials, monitoring wells normally are constructed in the borehole while it is still filled with the drilling fluid. The casing, screen, and gravel pack materials are placed directly into the drilling fluid. The gravel pack materials often become suspended in the drilling fluid making it extremely difficult to determine where the gravel pack materials terminate and the overlying well seal begins. It is almost impossible to document the "as built condition" of monitoring wells constructed using rotary drilling methods and drilling fluids."

"Breaking down the mud cake and removal of all drilling fluids introduced during the drilling and construction process is extremely difficult. Groundwater velocities required to remove drilling fluids, and the colloidal size particles associated with them from the aquifer materials usually cannot be created during development of small diameter monitoring wells."

"Experience has shown that drilling muds not effectively removed from the well bore opposite the screen and gravel pack will interfere with the chemical and biological quality of samples from those wells."

"The potential consequences of using drilling fluids (fluids and muds) should be obvious. The use of drilling fluids and muds should be curtailed whenever possible. Migration of bentonite or even "clean water" into the aquifer materials disturbs the subsurface environment and creates chemical and biological conditions that have the potential for altering water quality in the immediate vicinity of the well and the area impregnated. Due to the limited area of influence experienced during the development of monitoring wells, drilling fluids seldom are removed to the extent that they will not cause "well trauma". ("well trauma" means the monitoring well provides groundwater samples with a chemistry that is not representative of the aquifer.)

"Similarly, the improper placement of well sealing materials often results in these materials being in the flow path to the well or in such close proximity that they also chemically interfere with the quality of water collected from the well". (See the

above discussion on the difficulty of installing monitoring wells in boreholes that are filled with drilling fluids. The well sealing materials for the LANL monitoring wells are bentonite clay that has properties to remove radionuclide contaminants from groundwater.) The inability to measure in situ groundwater quality conditions prevents field documentation or measurement of these types of chemical interferences. The sparsity of field documentation or evidence should not be used as an excuse to overshadow common sense and laboratory evidence that clearly indicates the potential for chemical interference from drilling fluids and grout materials."

The features of LANL monitoring wells that prevent the recovery of most of the drilling fluids that have invaded the aquifer strata where screens are installed include 1. the great depth of the monitoring wells limits the pumping energy for development, 2. the small inside diameter for well casing of 4.5 inches limits the power of submersible pumps, 3. the short length of the well screens, the small spacing of 0.01 inch for the slots on the well screens, and the medium-grained sand in the filter pack that surrounds the well screens restricts the energy for recovering the drilling fluids, 4. the long delay before the performance of well development allowed much damage to the aquifer strata by the chemical processes that result from the use of biodegradable drilling fluids, and 5. the mud rotary drilling method caused the invasion of thousands of pounds of bentonite clay into the aquifer strata that are important for monitoring. For well development, LANL used chemical dispersing agents that spread the bentonite clay further outward in the aquifer strata beyond recovery.

Article A-6:
The article by Puls and Barcelona (1989) is titled "Ground Water Sampling for Metals Analyses". The article has the following recommendations for the construction and development of monitoring wells:

"The disturbance of the subsurface environment as a result of well construction and sampling procedures presents serious obstacles to the interpretation of ground-water quality results. The impact of improper well construction and sampling techniques can permanently bias the usefulness and integrity of wells as sampling points."

"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."

The Puls and Barcelona article and the ASTM Standard (Article 7) do not describe the mud rotary drilling method as uniquely suited to drilling in unstable aquifer strata or for drilling deep boreholes. One drilling environment that may be appropriate for the mud rotary drilling method is the presence of very high levels of contamination because the mud rotary method provides safe containment of the contaminated drill cuttings that are produced from the borehole.

> "It should be recognized, however, that the well must first provide a representative hydraulic connection to the geologic formation of interest. Without the assurance of this hydraulic integrity, the water chemistry information cannot be interpreted in relation to the dynamics of the flow system or the transport of chemical constituents."

Many of the screened intervals in the LANL monitoring wells are not developed sufficiently to provide an open hydraulic connection to the aquifer strata.

> "Maintenance of the hydraulic performance of monitoring wells and the connection of wells to the zones of greatest hydraulic conductivity, where contaminant transport is most probable, should take equal importance to the collection of representative water quality data."

An example of a LANL monitoring well that does not meet this guidance is well R-22. This well is installed at a location for monitoring the impact of the Laboratory's active radioactive waste landfill on the regional aquifer.

Article A-7:
The ASTM (1990) article is ASTM Standard D 5092 – Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. The ASTM article does not identify any unique aquifer environments that require the use of the mud rotary drilling method for the successful installation of monitoring wells. The ASTM article presents the following guidance for drilling methods and well development:

> "Whenever feasible, drilling procedures should be utilized that do not require the introduction of water or liquid fluid into the borehole. When the use of drilling fluids is unavoidable, the selected fluid should have as little impact as possible on the water samples for the constituents of interest. In addition, care should be taken to remove as much drilling fluid as possible from the well and the aquifer during the well development process."

> "Well development should be continued until representative water, free of the drilling fluids, cuttings, or other materials introduced during well construction is obtained. Representative water is <u>assumed</u> to have been obtained when pH, temperature, and specific conductivity readings stabilize and the water is visually clear of suspended solids."

The above guidance for successful well development does not guarantee that all or even most of the drilling fluids are removed from the aquifer strata that are in contact with groundwater samples that are collected from the monitoring wells for contaminant analyses. The small diameter of the LANL monitoring wells, the great depth of the wells, the short screen length, the small slot size of the screen openings, and the small size of the filter pack sediments that surround the well screen are factors that prevent removal of most

of the bentonite clay muds and drilling fluids that are entrained into the aquifer strata. The well development may eventually produce groundwater samples that meet the ASTM guidance. Nevertheless, groundwater samples collected from the monitoring wells are not representative of groundwater in the aquifer outside of the strata that is invaded by the bentonite clay muds or drilling fluids. Also, see the discussion in article 5 by Gibb and Jennings (1987) concerning the difficulty of construction and development of monitoring wells installed in boreholes drilled with the mud rotary method.

Article A-8:
The article by Hix (1993) describes the use of the conventional mud rotary drilling method with bentonite clay muds for drilling boreholes for monitoring wells and remediation wells. Mr. Hix describes the use of the mud rotary drilling method for drilling deep boreholes in difficult formations as follows:

> "There are those who maintain it is the best way to drill monitoring wells, especially deeper wells in difficult formations. Some regulators, however, are concerned that the drilling fluid can invade some formations, making it difficult to remove through well screens and gravel packs. Manufacturers and suppliers of these products claim their products are environmentally safe and easy to remove, noting that they are NSF- and EPA-approved."

The approvals by NSF and EPA are for the use of the bentonite clay products for the construction of groundwater supply wells. The approvals do not address the issues concerning the use of these products for the construction of monitoring wells. It is possible to develop water supply wells and remediation wells adequately for production of the required groundwater supply. Most supply wells and remediation wells are constructed with long screens, large screen openings and a gravel pack surrounding the screen. This construction is very different from the restrictive design of the LANL monitoring wells. The great difficulty in removing drilling additives from screened intervals in monitoring wells installed in boreholes drilled with fluid rotary methods is described in Article 5.

Appendix B: Other articles with guidance against the use of drilling fluids in the boreholes of monitoring wells

Article B-1:
The article by Jennings (1989) is titled "The Effect of Grouts, Sealants, and Drilling Fluids on the Quality of Ground-Water Samples". The conclusion of the Jennings article includes the following statement:

> "Drilling fluids and additives may introduce contamination to the well which may persist even after repeated cleanings (repeated well development activities). The inability to properly clean the formation and borehole may necessitate the construction of a new well. Where possible, hollow stem auger, cable tool, or air rotary should be used to install (monitoring) wells."

Article B-2:
"DRILLING – The Manual of Methods, Applications and Management" by The Australian Drilling Industry Training Committee Linited (1996).

From page 480 of the Drilling Manual:
"Drilling fluids, if used, must be carefully chosen to avoid contamination or alteration of final water (chemistry of groundwater produced from monitoring wells) or soil chemistry (chemistry of aquifer strata),"

"When metals or radionuclides are the target compounds, bentonite muds must be avoided. They have cation-exchange properties, and bind up these constituents. In this case, synthetic polymers may be a better choice. Biodegradable muds may also be used; but they must be completely removed to the trace level; otherwise they promote biofouling, which also alters groundwater quality."

From page 472 of the Drilling Manual:
"Causes of Biofouling plugging of well screens: Microbial oxidation and precipitation of Fe, Mn, and S, with associated growth and slime production. Usually associated with simultaneous chemical encrustation and corrosion. Associated problem: water quality degradation. Includes, but not always, "iron bacteria". Biofouling plugging causes reduced specific capacity and efficiency, reduced yield, and even complete well production loss."

Article B-3:
"Handbook of Ground Water Development" by Roscoe Moss Company (1990).

From page 211 of the Handbook:
"Because iron and sulfur bacteria are ubiquitous, - care should be taken in drilling and casing and screen installation so as not to introduce gross organic contamination into the aquifer." (The biodegradable drilling additives are a form of gross organic contamination).

From page 371 of the Handbook:
"Excessive growth of filamentous iron bacteria results in gelatinous slimes that may seriously reduce water yield from wells. This problem is more likely to occur in a well that is inactive or intermittently operated. (The LANL multiple-screen monitoring wells are essentially "inactive" as no volume of water is purged from the screened intervals before water samples are collected for the analytical suite.)

Article B-4:
"Groundwater and Wells, Second Edition" by Fletcher Driscoll (1986), published by Johnson Screens, St. Paul, Minnesota.

From page 455:
"If the iron content of the groundwater exceeds 0.5 mg/l. precipitation of iron is likely, although some precipitation may begin at concentrations as low as 0.25 mg/l. (The concentration of dissolved iron in LANL monitoring wells that are impacted by biodegradable drilling fluids are commonly greater than several mg/l, and even greater than 10 mg/l (e.g., screen #3 in monitoring well R-7 and screen #1 in monitoring well R-22).

From page 456:
"The most common bacteria affecting the condition of a well are iron bacteria. Iron bacteria are nuisance organisms that cause plugging of pores in water-bearing formations and openings in well screens. Iron bacteria produce accumulations of slimy material of gel-like consistency, and oxidize and precipitate dissolved iron and manganese. The combined effect of growing organisms and the precipitating minerals can plug a well almost completely within a short time. Cases have been reported where a 75-percent reduction in well yield has occurred in three months to a year."

Appendix C: USEPA RCRA Guidance for Installation of Monitoring Wells

The Shanahan Memorandum makes the following statement concerning the guidance in EPA RCRA documents for the construction of monitoring wells in boreholes drilled using the mud rotary methods with bentonite clay muds, biodegradable drilling fluids, and/or biodegradable foams:

> "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."

Reply by Mr. Gilkeson
I disagree with the above statement by Mr. Shanahan that implies a recommendation by RCRA for installing monitoring wells in aquifer strata invaded with bentonite clay muds, biodegradable polymer-based drilling foams, and/or biodegradable foams when the groundwater contaminants include trace levels of radionuclide or metal contaminants.

Many of the LANL monitoring well reports include a statement that the design and construction of the monitoring wells meet the requirements of a RCRA – compliant monitoring well as described in the US Environmental Protection Agency (EPA) document "RCRA Groundwater Monitoring: Draft Technical Guidance," November, 1992, EPA/530-R-93-001.

This EPA RCRA document (known as the EPA RCRA MANUAL, 1992) has the following concerns for installation of monitoring wells in boreholes drilled with the mud rotary method:

Concern 1:

> "While there are hydrogeologic conditions where mud rotary drilling is the best option (e.g., where it is extremely difficult to maintain a stable borehole), mud rotary creates a high potential for affecting aquifer characteristics and ground-water quality. If the mud rotary method is used, the drilling mud(s) should not affect the chemistry of ground-water samples." (page 6-12)

The biodegradable, polymer-based drilling fluids, biodegradable foams, and bentonite clay drilling muds that were used in the boreholes for the LANL monitoring wells have a large affect on the chemistry of groundwater samples for many radionuclide and chemical contaminants of concern for monitoring at LANL.

Concern 2:

> "The ability of a well development method to remove clays from the sides of the borehole should be considered, because clays retained in the borehole may alter the chemical composition of groundwater in the well." (page 6-50)

The physical design of the LANL monitoring wells is an obstacle to the removal of the large volume of bentonite clay that has invaded the aquifer strata.

Concern 3:

> "Additives to modulate the viscosity and density of the bentonite muds may also introduce contaminants in the groundwater or force large, unrecoverable quantities of mud into the formation." (page 6-12)

LANL has used additives to develop the screened intervals in monitoring wells installed in boreholes drilled with the mud rotary method using bentonite clay muds.

Concern 4:

> "Some organic polymers and compounds provide an environment for bacterial growth, which reduces the reliability of sampling results." (page 6-12)

Many of the LANL monitoring wells are installed in boreholes that were drilled with fluids and foams that are biodegradable. The result was bacterial growth that caused irreparable damage to the aquifer strata that surround the screened intervals. The groundwater samples

collected from many of the impacted wells are not representative of groundwater quality in the regional aquifer.

Concern 5:

> "Drilling should be performed in a manner that preserves the natural properties of the subsurface materials." (page 6-2)

The invasion of the aquifer strata with biodegradable drilling fluids and bentonite clay muds has caused a great change to the natural properties of the aquifer strata; a lowering of the permeability and an increase of the chemical properties for removing contaminants from groundwater.

Concern 6:

> "Drilling fluids, drilling fluid additives, or lubricants that impact the analysis of hazardous constituents in groundwater samples should not be used." (page 6-2)

LANL has used drilling methods that have entrained the aquifer strata with drilling fluids that impact the analysis of hazardous and radioactive constituents in groundwater samples collected from the wells. The drilling fluids include biodegradable polymer-based EZ-MUD*, biodegradable Quick-FOAM* surfactant, and bentonite clay drilling muds.

Appendix D: Removal of trace radionuclide and metal contaminants from groundwater by bentonite clay

Many of the LANL monitoring wells are installed in boreholes that were drilled with the mud rotary drilling method using bentonite clay drilling muds. The aquifer strata that surround the screened intervals in these monitoring wells are invaded with a very large volume of bentonite clay. The Shanahan Memorandum recommends a study of the potential effects of the bentonite clay drilling muds on chemical and radionuclide contaminants that are subject to ion exchange. The recommended study is not necessary as the properties of bentonite clay for preferential removal from groundwater of the LANL radionuclide contaminants of concern are well known. It was improper for LANL to use the mud rotary method for the installation of monitoring wells. Many of the wells require replacement.

It is important to understand the properties of bentonite clay for removal of the trace metal and radionuclide contaminants from groundwater. The term "trace contaminants" refers to contaminants that are present in groundwater at very low or extremely low levels compared to the major constituents like calcium, magnesium, and bicarbonate that are dissolved in the groundwater. For the groundwater beneath LANL, it is necessary for monitoring wells

to provide groundwater samples that are valid for knowledge of extremely low levels of radionuclide contaminants. Examples of trace radionuclide contaminants that are preferentially removed from groundwater by bentonite clay include americium-241, cesium-137, plutonium-238, plutonium-239,-240, and strontium-90.

The text book *Environmental Chemistry* by Langmuir (1997) describes the preferential adsorption of trace contaminants as follows:

> "Adsorption (onto bentonite clay) of a dissolved ionic species is always part of an (ion) exchange reaction that involves a competing ionic species. The desorbing species creates the vacant site to be occupied by the adsorbing one. As the trace metal (or radioactive contaminant) level drops relative to that of a competing major ion, adsorption of the trace species is increasingly favored relative to competing major species."

The text book *Aquatic Chemistry* by Stumm and Morgan (1996) describes the preferential adsorption of trace contaminants by bentonite clay as follows:

> "The sorption of alkaline and earth-alkaline cations (e.g., strontium-90) on expandable three-layer clays (e.g., bentonite clays) can usually be interpreted as stoichiometric exchange of interlayer ions (ion exchange). To understand binding of trace heavy metals (e.g., also the trace radioactive contaminants such as plutonium and americium) on clays, one needs to consider – in addition to ion exchange – the surface complex formation on end–standing functional OH groups. Three layer silicates (e.g., bentonite clays) contain on the crystal edges (broken bonds) end-standing OH groups which can interact with (remove from groundwater) metal ions (and many radionuclide contaminants)."

It is important to understand that the radioactive contaminants of concern in groundwater beneath LANL that are removed by adsorption on clay minerals are present at extremely low levels compared to the major ions in groundwater. The radioactive contaminants are preferentially removed from groundwater by adsorption on bentonite clay and are retained by the essentially infinite number of sorption sites in the large quantity of bentonite clay that is entrained into the aquifer strata surrounding the monitoring wells that are installed in mud rotary boreholes. If an individual radionuclide ion is desorbed from a sorption site, it will be immediately recaptured by another site. The large volume of bentonite clay that is entrained into the aquifer strata surrounding the screened intervals in the LANL monitoring wells is there permanently. It will not be removed by natural groundwater flow. The preferential sorption capacity of the bentonite clay for trace radionuclide and metal contaminants will not become exhausted. There is a very high probability that the bentonite clays that have invaded the aquifer strata may cause groundwater samples collected from the impacted monitoring wells to be invalid for knowledge of many

radionuclide contaminants in the regional aquifer for a period of time that is longer than the scheduled 50 year life for the LANL monitoring wells.

Appendix E: The chemistry of the biodegradable, polymer-based drilling fluids and biodegradable foams that are used for LANL monitoring wells

A LANL document (LANL, OCT. 2000) describes the sorption properties of the BAROID EZ-MUD* biodegradable polymer-based drilling fluid that was used in the boreholes for many LANL monitoring wells as follows:

> "The EZ-MUD* drilling fluid has a negative charge density of 30% which may enhance the polymers ability to adsorb the cations Sr^{2+}, PuO_2^{1+}, UO_2^{2+}, and $AmCO_3^{1+}$."

> "EZ-MUD* is strongly hydrophobic (high molecular weight polymer), which probably has the ability to adsorb organic compounds such as RDX, HMX, and TNT."

It is important to note that the drilling of the boreholes for many LANL monitoring wells with the use of EZ-MUD* began after LANL released the information on the adsorption properties of the drilling fluid for contaminants of concern. It was inappropriate for LANL to use drilling fluids that have sorption properties for many contaminants of concern in groundwater beneath the Laboratory facility.

An important ingredient in the EZ-MUD* and Quick-FOAM* drilling additives is the organic carbon that resulted in a "bloom" of bacteria in the impacted aquifer strata. The enhanced respiration of the bacteria greatly increased the level of carbonic acid in groundwater with a corresponding dissolution of the alkaline earth metals from the aquifer strata. The alkaline earth metals include strontium, calcium, magnesium, and barium.

The enhanced bacterial respiration also created an anaerobic environment that resulted in high levels of dissolved iron and manganese in groundwater while causing the precipitation of dissolved uranium and some other radionuclide contaminants (if present in the groundwater). The natural level of dissolved iron in the regional aquifer is less than 0.05 mg/L. The high and increasing concentrations of dissolved iron listed in the LANL Well R-22 Geochemistry Report for the four quarterly samples from screen #1 of 5.0, 9.1, 9.46, and 14.9 mg/L, respectively, show that the anaerobic bacterial respiration is active, and causing dissolution of iron from the aquifer strata. For comparison, the declining levels of dissolved iron in the LANL Well R-7 Geochemistry Report for the four quarterly samples from screen #3 of 17.0, 14.0, 12.4, and 8.75 mg/L, respectively, are an indication that the bacterial respiration is declining and the groundwater is changing back to an oxidizing chemistry. The high dissolved iron levels at wells R-7 and R-22 are direct evidence of the formation of iron precipitates as hydrous ferric oxides (HFO) and ferric oxyhydroxides on

the aquifer strata that surrounds the screened intervals. (Langmuir, 1997, Roscoe Moss Company, 1990, and Driscoll, 1986).

The precipitation of HFO and ferric oxyhydroxides is important as these "fresh coatings" on the aquifer strata and even on the well screen and the filter pack sediments have strong sorption properties for many radionuclide contaminants including the actinides and uranium (Langmuir, 1997).

The sorption properties of the ferric oxyhydroxide precipitates is illustrated by comparing their cation exchange capacity (CEC) of 100 to 740 meq/100 gm to the CEC of 80 to 150 meq/100 gm for bentonite clay (Langmuir, 1997). The HFO and the ferric oxyhydroxide precipitates, and also the bentonite clays have strong sorption properties for many radionuclide and metal contaminants of concern for monitoring in groundwater beneath the Laboratory facility (Langmuir, 1997, Stumm and Morgan, 1996).

The high concentrations of dissolved iron that are present in the altered chemistry at many LANL monitoring wells because of the biodegradable drilling fluids will also cause the presence of high concentrations of suspended ferrihydrite as colloids in groundwater. The suspended ferrihydrites have strong sorption properties for many dissolved metal and radionuclide contaminants, including uranium (Langmuir, 1997).

The anomalously low concentrations of dissolved uranium in groundwater samples from many LANL monitoring wells that are impacted by the use of biodegradable drilling fluids and biodegradable foams is important evidence that chemical processes are removing constituents from groundwater. Uranium is a natural constituent in groundwater. However, uranium is also a contaminant of concern in groundwater because of its extensive use in LANL activities. There is a need for valid knowledge of the level of dissolved uranium in the regional aquifer for groundwater samples collected from the LANL monitoring wells.

The LANL well R-7 reports show that a uranium concentration of 0.0021 mg/L was measured in a groundwater sample collected at the top of the regional aquifer from the borehole for well R-7 and significantly lower dissolved uranium concentrations of 0.000084 and 0.000051 mg/L were measured in the first two quarterly samples collected from the top of the regional aquifer in well R-7. Uranium was "not detected" in the groundwater samples collected in the third and fourth quarter from well R-7. LANL does not have accurate knowledge of the levels of dissolved uranium in the regional aquifer beneath Los Alamos Canyon at the location of LANL monitoring well R-7 at the present time, and for an unknown period of time into the future.

The LANL well R-22 reports show that a dissolved uranium-238 level of 1.41 pCi/L was measured in a groundwater sample collected at the top of the regional aquifer from the borehole for well R-22, and significantly lower dissolved uranium-238 levels of 0.046, 0.062, 0.0156, and 0.0099 pCi/L, respectively, were recorded in the four quarterly samples

collected from screen #1 installed in aquifer strata at the top of the regional aquifer immediately downgradient of MDA G.

For screen #1 in well R-22, the removal of dissolved uranium from groundwater samples by the unnatural, anoxic chemistry is evidence that the analytical data for many other radionuclides including technetium-99 are not reliable (Langmuir, 1997).

It is essential to understand that the pervasive presence of the HFO and the ferric oxyhydroxide precipitates as coatings on the well screen, the filter pack sediments and the aquifer strata for an unknown distance away from the monitoring well are a permanent change as the iron coatings are stable in the natural oxidizing groundwater chemistry that will eventually be restored to the groundwater within the impacted strata. A location where the precipitation of HFO is enhanced by iron bacteria is where the anaerobic groundwater in the impacted strata transitions to the normal aerobic groundwater in the aquifer (Langmuir, 1997). The microbially mediated precipitation of the HFO as blanket deposits on the aquifer strata will result in the impacted screened intervals being surrounded by aquifer strata with enhanced properties for removal of trace metals and radionuclides from groundwater. There is a very high probability that the biodegradable, polymer-based drilling fluids and the biodegradable drilling foams that have invaded the aquifer strata may cause groundwater samples collected from the impacted monitoring wells to be invalid for knowledge of many radionuclide contaminants in the regional aquifer for a period of time that is longer than the scheduled 50 year life for the LANL monitoring wells.

Appendix F: Concerns for the methods that are used to collect groundwater samples from the LANL monitoring wells

The methods that LANL presently uses for collection of groundwater samples from the monitoring wells may be inappropriate for either sample quality or the measurement of sensitive parameters such as temperature, pH, Eh, bicarbonate concentration, and dissolved gases. LANL does not use a flow-through cell for the measurement of the sensitive parameters.

Presently, LANL does not use a low-flow pump system to collect groundwater samples from the multiple-screen monitoring wells. Instead, an evacuated container (the Westbay* MOSDAX tool) is deployed to collect water samples from the discrete sampling ports in the Westbay* sampling systems. Many trips with the container may be necessary to collect the volume of groundwater required for the analytical suite. At LANL, no volume of groundwater is purged from the screened intervals prior to the measurement of groundwater parameters and the collection of groundwater samples. In addition, the field-measured parameters including temperature, specific conductance, dissolved oxygen, and turbidity were measured when the groundwater was in contact with the atmosphere (LANL Well R-7 Geochemistry Report, 2002). The inappropriate methods used at LANL for

measurement of important field parameters and collection of analytical samples compromise data quality and prevent accurate knowledge of aquifer chemistry.

The failure of LANL to a. use a flow-through cell for the measurement of sensitive parameters, and to b. purge an appropriate volume of water before the collection of water samples for the analytical suite does not meet the following requirements in the NMED LANL Order:

A.1.a.i **IX.B.2.i.i Well Purging**

> "All zones in each monitoring well shall be purged by removing groundwater prior to sampling in order to ensure that formation water is being sampled. Purge volumes shall be determined by monitoring, at a minimum, groundwater pH, specific conductance, dissolved oxygen concentrations, turbidity, redox potential, and temperature during purging of volumes and at measurement intervals approved by the Department. The groundwater quality parameters shall be measured using a flow-through cell and instruments approved by the Department. The volume of groundwater purged, the instruments used, and the readings obtained at each interval shall be recorded on the field monitoring log. Water samples may be obtained from the well after the measured parameters of the purge water have stabilized to within ten percent for three consecutive measurements." (NMED LANL Order, Nov. 26, 2002)

The EAG (2001) recognized the need to use a low-flow pumping system for the collection of groundwater samples from the LANL multiple-screen monitoring wells as follows:

> "The presence of residual drilling additives is disappointing, but not surprising; it is both difficult (perhaps impossible) and expensive to develop wells at this depth sufficiently to completely remove such materials. The Westbay* tool (MOSDAX) currently being used for sampling provides no capability for avoiding sample contamination with the residual drilling additives; in fact, it probably maximizes it. This is because the tool almost passively collets the groundwater from the immediately adjacent zone of the sand pack/borehole wall/formation. In the absence of drilling additive contamination, this would be a desirable outcome, but not when it is present. Since the additives are impacting the samples and their subsequent evaluation, the EAG has one recommendation for altering the manner in which samples are being collected until the additives are no longer an issue.
>
> RECOMMENDATION:
> **Temporarily discontinue use of the measurement port and MOSDAX probe in the Westbay* wells. Instead, collect samples with the pump and the Westbay* pumping port via low-flow sampling techniques with equilibration of indicator parameters using a flow-through cell.**
>
> This sampling approach would increase the likelihood that groundwater from outside the borehole zone contaminated with drilling additives could be acquired.

Observation of the stabilization of purging indicator parameters, such as dissolved oxygen, Eh, and conductivity, during the low-flow purging process can be used to detect this continuity with the aquifer water. Although the acquired water would still have to travel through the additive contaminated zones (the zones of altered chemistry that are contaminated with residual drilling fluids), the amount of contamination imparted to the samples during this brief contact should be minimal relative to the MOSDAX samples that have set in this zone for some time."

LANL has not followed the advice of the EAG for using a low-flow pumping system for collection of groundwater samples. Concerning the present practice at LANL of not purging a volume of groundwater for monitoring of field parameters before the collection of groundwater samples for contaminant analyses, an EPA Superfund Forum Guidance document by Puls and Barcelona (1989) contains the following guidance:

- Use a positive displacement pump to pump groundwater from the screened interval.
- Groundwater samples should be collected in such manner to eliminate O_2 and CO_2 exchange with the atmosphere.
- Use a flow-through type cell to monitor the pumped groundwater. Monitoring for dissolved oxygen, temperature, conductivity and pH (also monitoring Eh and turbidity) aids in the interpretation that representative groundwater samples are collected for contaminant analyses.
- Before collection of groundwater samples for the analytical suite, continue low-flow pumping and monitoring of groundwater parameters for a sufficient period of time to ascertain that the groundwater parameters have stabilized. The time of pumping necessary to collect representative water from the aquifer strata is around two times the time required to get plateau values for the above parameters.
- For analysis of metals (and radionuclides), routinely collect both filtered and unfiltered samples. Filtration should be performed in the field with no air contact. In-line pressure filtration is best with as small a filter pore size as practically possible (e.g., 0.05, 0.10 micron). The prevention of air contact during the filtration process is very important for anoxic ground-water (e.g., well R-7, R-22, and many other LANL monitoring wells.) Air contact of anoxic groundwater during filtration will result in iron oxidation and colloid formation and a removal during filtration of previously dissolved species in the anoxic groundwater.

The use of a low-flow pumping system is an important remedial activity to determine the future value of many of the impacted screened intervals in LANL monitoring wells. Unfortunately, the collection of groundwater samples with a low-flow pumping system will not provide a remedy for the need to replace many of the monitoring wells that are irreparably damaged.