Annotated Transcript of the Presentation by Robert H. Gilkeson to the June 9, 2004 Meeting of the Northern New Mexico Citizens Advisory Board (CAB), version November 8, 2004

The presentation was a summary of Mr. Gilkeson's report "*Groundwater Contamination in the Regional Aquifer Beneath the Los Alamos National Laboratory*", version July 13, 2004. The report is available from the CAB.

FOREWORD

The University of California staff (UC) and contractors who are responsible for activities of the Los Alamos National Laboratory (LANL) Hydrogeologic Workplan have recently published a report titled "*Response to Concerns About Selected Regional Aquifer Wells at Los Alamos National Laboratory*"(the Bitner et al. Report) by Kelly Bitner, David Broxton, Patrick Longmire, Steve Pearson, and David Vaniman. The Bitner et al. Report claims to be a response to the issues raised in Gilkeson (2004). Unfortunately, the Bitner et al. Report is non-responsive for many of the issues raised in Gilkeson (2004).

Gilkeson (2004) presents trend analyses for strontium-90 data and technetium-99 data for groundwater samples from LANL monitoring wells R-7 and R-22. The data are from LANL Geochemistry Reports wherein the data are described as "not-detected" values that were recorded by the analytical method at levels that do not meet the arbitrary three-standard deviation requirement for validated detection. The Bitner et al. Report claims that the trend analyses in Gilkeson (2004) are data that represent minimum detection limits for the analytical method. However, the LANL Geochemistry Reports do not present the data as minimum detection limits. Importantly, even discounting the trend analyses in Gilkeson (2004), the more important finding is that the groundwater samples from wells R-7 and R-22 (and many other LANL monitoring wells) do not provide knowledge of the presence of many radionuclide and chemical contaminants in the regional aquifer. Table 4 in the Bitner et al. Report acknowledges that groundwater samples collected from screen no.3 in well R-7 and screen no. 1, 3, 4, and 5 in well R-22 "are not yet representative of pre-drilling chemistry". Unfortunately, there is a naïve belief by the UC staff and contractors at LANL that the impacted well screens are capable of "self cleaning". In fact, the biodegradable drilling fluids caused chemical processes that resulted in irreparable damage to the screened intervals in the impacted monitoring wells. The chemical processes are well documented in the technical literature and are summarized on pages 19-23 of this annotated transcript.

Many LANL monitoring wells were installed in boreholes drilled using the mud-rotary drilling method with bentonite clay muds in spite of the extensive knowledge that the bentonite clay muds cannot be recovered from the aquifer strata because of the very large volume of bentonite clay drilling mud that has invaded the strata, the great depth and constrictive design of the monitoring wells, and the large amount of technical literature that documents the strong, preferential adsorption properties of bentonite clay for the radioactive contaminants of concern. The design features of the LANL monitoring wells

13900

that prevent removal of the bentonite clay are described on page 31 of this annotated transcript. The adsorption properties of bentonite clay are summarized on pages 5-6 of this annotated transcript.

Nevertheless, against the consensus in the literature, the Bitner et al. Report claims that development procedures have removed the bentonite clay from the aquifer strata and that the monitoring wells provide representative groundwater samples. However, the fact that the bentonite clay is affecting groundwater samples from the LANL monitoring wells is proven by Table 4 in the Bitner et al. Report. Table 4 acknowledges that the groundwater samples collected from monitoring well R-16 are affected by the presence of the large quantity of bentonite clay drilling mud in the aquifer strata. Well R-16 was identified in Gilkeson (2004) as a well that must be replaced. In addition, many of the LANL monitoring wells that are installed in strata invaded with bentonite clay drilling mud require replacement.

It is important to note that Table 4 in the Bitner et al. Report claims that groundwater samples collected from screen no. 1 in well R-7 are representative of pre-drilling water chemistry. I disagree with this finding. For screen #1, the trend analyses of the data in Table 5.1-1 in the LANL Well R-7 Geochemistry Report show a consistent and continuing decline in the dissolved concentrations of the alkaline earth metals calcium and strontium over the four quarters. The data do not show that the concentrations have stabilized. Also, even when the concentrations of the major ions stabilize, this will not be proof that the groundwater samples are representative of the contaminant chemistry in the regional aquifer.

The data in the LANL well R-7 reports show that a dissolved uranium concentration of 0.0014 mg/L was measured in a groundwater sample collected from the perched zone in the well R-7 borehole and significantly lower dissolved uranium concentrations of 0.000167 and 0.000252 mg/L were measured in the first two quarterly groundwater samples collected from screen #1 installed in the perched zone of saturation. Uranium was "not detected" in the groundwater samples collected in the third and fourth quarter from screen #1. <u>The uranium data are important evidence that groundwater samples collected from screen #1 in LANL monitoring well R-7 are not representative of the chemistry of groundwater in the perched aquifer</u>.

The Bitner et al. Report dismisses the finding in Gilkeson (2004) that the 60 ft screen in monitoring well R-15 was improperly installed across a confining layer with the result that groundwater at the top of the regional aquifer has drained downward across the confining layer to mix with deeper groundwater. Perchlorate and strontium-90 are present at validated levels in groundwater samples collected from this well. The dilution caused by the 60-ft screen prevents knowledge of the level of contamination that is present at the top of the aquifer. The Bitner et al. Report claims that the 60-ft screen is necessary to guarantee a 50-year life for the monitoring well. WHAT IS THE VALUE OF 50 YEARS OF BAD DATA?

A finding in Gilkeson (2004) is that screened intervals were not installed in the fast groundwater travel pathways that are present in the regional aquifer beneath MDA G. The Bitner et al. Report dismisses this finding and cites the Schlumberger geophysical logs as evidence that permeable river gravel strata were not present in the borehole for monitoring well R-22. However, the drilling record for this borehole shows that highly permeable strata are present in the regional aquifer over a distance of 46ft in the depth interval of 1191 to 1237 ft below ground surface. The drilling supervisor described the strata as river gravels. The reliability of the Schlumberger geophysical logs is further questioned as they were used to locate screen no. 3 in well R-22 "where the estimated permeability is the highest" (the Bitner et al. Report, p.16). The geologic log in the LANL Well R-22 Completion Report shows that screen no. 3 is installed in strata described as "very fine silty sand to pebble gravel". Introductory courses in geology teach that strata with this description have a low hydraulic conductivity. Apparently, the UC staff and contractors at LANL have placed undue reliance on the Schlumberger geophysics logs to provide knowledge of the water transmissive properties of the aquifer strata and for selecting the locations of screened intervals in the monitoring wells.

The Bitner et al. Report defends the methods used for development of screened intervals in the LANL monitoring wells by claiming that the methods meet industry standards. The Bitner et al. Report did not respond to the findings in Gilkeson (2004) that development methods were not performed in some screened intervals (e.g. screen no. 1 in wells R-7 and R-22) and that development activities were stopped in some screened intervals while groundwater contained unacceptably high turbidity (e.g. screen no. 3 in well R-7). In addition, the presence of anoxic groundwater in many monitoring wells is direct evidence that the well development activities did not remove the biodegradable drilling fluids (e.g. wells R-7, R-9i, R-12, R-13, R-19, and R-22).

Because of low values near the instrument detection limit, the Bitner et al. Report trivializes the validated detection of technetium-99 in groundwater samples collected for the 1st quarter sampling in screen no. 3 and 4 in well R-22. The low values are probably due to cross-contamination because of the improper construction of well R-22. A tritium value of 109 pCi/L was measured in a groundwater sample collected from the open borehole at the top of the regional aquifer. As drilling proceeded, a confining bed was penetrated and the groundwater at the top of the regional aquifer was flushed down the open borehole. Groundwater samples collected from screen no. 1 installed across the top of the regional aquifer have tritium levels of slightly greater than 2 pCi/L, a 50-fold dilution factor compared to the 109 pCi/L tritium activity that was measured in the sample collected from the borehole. The LANL Well R-22 Geochemistry Report acknowledges the large dilution of tritium that has occurred in groundwater samples collected from screen no. 1. However, the report does not acknowledge that this dilution also prevents valid knowledge concerning the presence of radionuclide contaminants at the top of the regional aquifer, and in particular, knowledge of the mobile contaminant technetium-99.

The 50-fold dilution factor for groundwater samples collected from screen no. 1 also prevents knowledge of the nature and extent of chemical contamination in groundwater at

the top of the regional aquifer beneath MDA G. The validated detection of volatile (VOC) and semivolatile (SVOC) contaminants in the diluted groundwater samples collected from screen no.1 is an indication of the presence of serious contamination in the regional aquifer with these chemical contaminants. In addition, the anaerobic chemistry that is present in the aquifer strata surrounding screen no.1 prevents accurate knowledge of the VOC and SVOC contaminants that are present at the top of the regional aquifer. The transformation and degradation of VOC and SVOC contaminants in the anaerobic groundwater that is present in the aquifer strata at screen no 1 is well documented in the technical literature. An excellent summary is presented in the book "*DENSE CHLORINATED SOLVENTS and other DNAPLs in Groundwater*" by James F. Pankow and John A. Cherry. Unfortunately, the Bitner et al. Report does not identify the serious groundwater contamination that is indicated because of the presence of VOC and SVOC contaminants in groundwater beneath MDA G. A very large volume of these chemical wastes were disposed of in trenches at MDA G. There is an immediate need to install properly constructed monitoring wells downgradient of MDA G to define the nature and extent of radionuclide and chemical contamination at the top the regional aquifer and in the fast groundwater pathways.

The misinformation presented in the Bitner et al. Report confirms the recommendation in Gilkeson (2004) for the establishment of an expert panel to review all of the activities of the LANL Hydrogeologic Workplan. A study of each of the LANL monitoring wells is required to determine their future value. This review should be conducted by a panel of experts in the following disciplines:

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

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.

Index to the Annotated Transcript

Page No.	Topic
5-6	Properties of bentonite clay for removal of the trace radionuclide and metal contaminants from groundwater
8-9	Presentation by Mr. Johansen on the importance of the "opinion of NMED" and the approval of NMED for the use of mud rotary drilling methods
9-12, 17	Requirement for LANL and DOE to install monitoring wells on the LANL facility that meet the requirements of DOE Orders 435.1 and 5400.5 and RCRA.
15	Presentation by Mr. Nylander on the "RCRA Guidance" and the need to use the mud rotary method for installing monitoring wells in the regional aquifer at LANL
15	Opinion of Mr. Gilkeson that the mud rotary method should not be used for the installation of LANL monitoring wells and a list of LANL monitoring wells installed in boreholes drilled with the air rotary casing advance drilling method
15-18	Opinion of Mr. Gilkeson concerning the requirements of RCRA and DOE Orders for the installation of monitoring wells at LANL
18	Consensus in the literature that fluid rotary drilling methods should be avoided for installing monitoring wells when trace metals and radionuclides are contaminants of concern.
19	The adsorption properties of the BAROID* EZ-MUD* drilling fluid that was used in the boreholes for many LANL monitoring wells.
19-23	The chemistry of the biodegradable polymer-based drilling fluids and the biodegradable drilling foams with emphasis on chemical reactions in the groundwater and the generation of hydrous ferric oxide and ferric oxyhydroxide blanket coatings on the aquifer strata.
19-22	The impact of the improper construction of monitoring well R-7 on knowledge of strontium-90 contamination in groundwater
19-20	The disagreement of USEPA and NMED for the LANL restrictive requirement of 3-standard deviations for the valid detection of radionuclide contaminants

23	The impact of the improper installation of well R-22 on knowledge of contamination in the regional aquifer beneath MDA G.
24-25	The requirement in DOE Order 435.1 for LANL to revise the Performance Assessment that is requird by DOE for authorization of MDA G for disposal of low-level radionuclide waste.
25-26 46-47	The misinterpretation of Dr. Longmire that the biodegradation of the drilling fluids and -foams is evidence that the drilling fluids are "breaking down" and the groundwater in the impacted aquifer strata is "cleaning up".
28-29 34-36	Discussion between Mrs. Hoard of the CAB and Dr. Longmire concerning removal of radionuclide contaminants from groundwater by the bentonite clay that is entrained into the aquifer strata surrounding the screened intervals in the LANL monitoring wells
29-34	Description by Mr. Nylander of the development procedures used by LANL to remove drilling fluids and muds from the monitoring wells and the opinion of Mr. Gilkeson that LANL has not removed the entrained fluids, foams, and bentonite clay muds from many screened intervals in LANL monitoring wells
31	The physical design of LANL monitoring wells that prevent the removal of the entrained drilling fluids, foams, and bentonite clay muds
31-33	The failure of LANL to gather knowledge of the hydraulic conductivity of the aquifer strata in the regional aquifer
33-34	The importance of developing screened intervals to establish open hydraulic communication with the surrounding aquifer
37-39	Recommendation of Mr. Gilkeson that the boreholes for LANL monitoring wells be drilled with the air rotary casing advance drilling method and the response by Mr. Nylander that this drilling method is too costly. Mr. Nylander defends the use of drilling fluids and bentonite clay muds.
39	Reply of Mr. Powell, the geochemist on the LANL External Advisory Group concerning the installation of monitoring wells in boreholes drilled with bentonite clay muds and biodegradable drilling fluids
40-42	Response by Mr. Gilkeson concerning the judgment by LANL and DOE that the high cost of LANL monitoring wells R-9, R-12, and R-25 was because of the air rotary casing advance drilling method

42-45 Defense by Mr. Whitacre of DOE of the use of mud rotary and fluids for the construction of LANL monitoring wells and the response of Mr. Gilkeson

48-50 Concerns of Mr. Gilkeson and the LANL EAG for the methods used by LANL for collection of water samples from the Westbay* sampling systems installed in the LANL multiple-screen monitoring wells

50-52 Finding of LANL that only three or four screened intervals in LANL monitoring wells are not providing representative groundwater samples compared to the analysis by Mr. Gilkeson that possibly more than twenty five screened intervals are not providing knowledge of the presence of contamination in groundwater.

53-55 Discussion between Mr. Taylor of DOE and Dr. Longmire concerning the presence and detection of radionuclide contamination for groundwater samples colleected from the LANL monitoring wells and response by Mr. Gilkeson

55-57 Summary statements by Mr. Johansen of DOE, Mr. Gilkeson, and Mr. Nylander of LANL

57-59 References

A.1-A.8 Appendix. Summary's of articles concerning the installation of monitoring wells in boreholes drilled with fluid rotary methods

Annotated Transcript of the Presentation by Robert H. Gilkeson to the June 9, 2004 Meeting of the Northern New Mexico Citizens Advisory Board (CAB) version September 19, 2004

The presentation was a summary of Mr. Gilkeson's report "*Groundwater Contamination in the Regional Aquifer Beneath the Los Alamos National Laboratory*", version July 13, 2004. The report is available from the CAB.

CAB/Dorothy Hoard: Okay, people, as most of you know, I worked on the ER Project for a number of years and we had a drilling project out on TA-33 that had more adventures than you'd really like. I'm sure everybody who's been in drilling knows about that. Anyhow, we had a parade of drilling people come through and Bob Gilkeson was one of them and quite frankly, I didn't remember him. But I got a call from him a few weeks ago and he said that he had written a report on concerns he had about the monitoring wells and to me, these concerns I found very serious. I read all the CCNS stuff and say, well, you guys are over flaky. But I found Bob's concerns valid and I felt that this committee should get into them so I contacted Tim and put it on the agenda so that's why I'd like to introduce Bob. I think some of you know him and he's here to present his concerns.

CAB/ Tim DeLong : All right, Bob, we're all ears.

Robert Gilkeson : I've already been introduced. You want to let the other folks introduce themselves?

CAB/DeLong: Yeah, why don't we do that so you know who everybody else is?

LANL/Pat Longmire: Pat Longmire, groundwater geochemist with Los Alamos.

Gilkeson: Oh, Pat, hello.

LANL/Longmire: Hello.

LANL/Tory George: I'm Tory George. I'm in environmental management services at the Lab corp.

DOE/Tom Whitacre: I'm Tom Whitacre. I'm project manager at DOE.

CAB/DeLong You're being recorded, you know. (Laughter)

DOE/Matt Johansen: My name is Matt Johansen and I am the groundwater program manager, NSSA at Los Alamos (DOE) Site Office.

Gilkeson: This is not the complete report. I'm having one copy of the complete report made now and that will go to you (Pat Longmire). It's being copied right now.

CAB/DeLong: And where did Charlie go? (Mr. Charles Nylander is the Project Manager at LANL for acitivities of the LANL Hydrogeologic Workplan.

DOE/Whitacre: Charlie is out on the phone.

CAB/DeLong: Okay. If you might just kind of introduce just how you came get involved in this and make this report and what it says and just...

Gilkeson: Oh, well, I had a long association with activities of the LANL Hydrogeologic Workplan and I left those activities in 1999 but I continued to watch the performance and this is a report I've written about that performance. This report is written on my own time. I have not been paid for generating this report. I wrote this report as a citizen of New Mexico. What's on the handout is an abstract of the report. I'm having a copy of the report made right now which I will deliver to Pat Longmire. Where I want to start at in the discussion is the use of bentonite clay muds in drilling the bore holes for the monitoring wells and also the use of drilling fluids in the boreholes.

CAB/DeLong: Bob, could you hold just one moment? I apologize. How long is your presentation going to be, do you think?

Gilkeson: I think it's going to run half an hour. If it's open for questioning, it might be longer than that.

CAB/DeLong: Sure, yeah, I just wanted to...we have a two hour meeting so I try, as the Chair, I try to watch the time so in about an half an hour, I will let you know, so we will try to wrap things up then. Thank you.

Gilkeson: Yeah, okay. It's important to keep in mind and keep separate the effect of the drilling fluids as compared to the effect of the betonite clay muds. In some ways, their behavior is similar. In other ways, it's different. I guess as it's laid out in this report, I will first talk about the mud rotary drilling. And that is the way a large set of monitoring wells have been constructed recently. And so, what I cite in here is the EPA RCRA document which gives guidance on the construction of monitoring wells on RCRA facilities. And, the quotation from that document is –

"Bentonite muds may adsorb metals, potentially reducing contaminant concentrations and affecting the reliability of sampling results".

And then the document states that-

"The invasion of the mud into the permeable zones may compromise the validity of subsequent monitoring well samples".

Activities of the (LANL) Hydrogeologic Workplan were guided and criticized by an external group of consultants which were named the External Advisory Group (EAG). The bottom of page 7 has comments by this External Advisory Group where they state -

"The use of mud rotary drilling techniques is largely inappropriate for the goal of the Hydrogeologic Workplan."

and they go on to state –

"The mud carries the risk of adsorbing contaminants of concern on to the bentonite that permeates out into the aquifer strata and is not removed by well development".

On the top of page 8 (the EAG report states) –

"The artificial entrainment of betonite clay drilling mud in the pore space surrounding the monitoring wells 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."

Then they have more discussion with their concerns for use of bentonite clay drilling muds and they finalized with the statement that –

"The EAG would therefore caution LANL about using mud drilling techniques for the installation of the deep regional monitoring wells."

The history (for LANL monitoring wells) shows that large volumes of bentonite clay were introduced into the aquifer strata in the boreholes that were drilled with the mud rotary method. At the back of this collection of pages, there are several figures. Figure one is the regional map and on this figure, what I want to point out here is MDA G which is located immediately west of well R-22 - if you can find R-22 (on the figure) and another thing that is significant to note on this figure is the Buckman well field location and Well R-16 which is between R-22, -MDA G is located immediately west of R-22 - and this figure also show the location of R-16 which was drilled with the mud rotary method. (MDA G is the active landfill at LANL for disposal of low-level radioactive waste. MDA G is a 65 acre site where disposal activities began in 1957.) On figure 2, next page, is a blow up which shows the location of MDA G, the well which we were talking about which was drilled with polymer-based drilling fluids which is R-22, immediately east of Area G.

Over on the right side of this figure is the location of well R-16. Okay, very brief discussion of well R-16. This well was drilled with the mud rotary method.

CAB/DeLong: Which page are you going back to, Sir?

Gilkeson: Page 9. LANL monitoring well R-16. This is a discussion of R-16 and on this page, there's an account of the lost circulation zones during the drilling. Lost circulation for the drilling method indicates drilling through strata that has high permeability, high hydraulic conductivity and ....

DOE/Whitacre: If it's saturated, right? It's only if it is saturated that you can say that. If it is in the vadose zone. How can you tell the permeability of the vadose zone?

Gilkeson: Well, the permeability...that's an interesting question ...permeability (or hydraulic conductivity) is the same physical property of aquifer strata, it isn't affected by the nature of the fluid. If it's in the vadose zone the fluid is air and in the regional aquifer the fluid is water.

DOE/Whitacre: Permeability or porosity, I guess.

Gilkeson: Of course,,,(interrupted) (permeability is different from porosity. A rock or sediment may a have a very high porosity with a low permeability.)

CAB/Timm: Anyway, that's on the second column.

Gilkeson: Okay, so all of this information (on the handout) is from the well R-16 and that's where the large volume of bentonite drilling mud was used. (The mud rotary drilling of the well R-16 borehole entrained over 31,000 pounds of bentonite clay into the strata of the regional aquifer.) So at the bottom of page 9 from the EPA RCRA document, there is a discussion about problems of drilling monitoring wells with bentonite muds. To develop well R-16 and many of the monitoring wells that were installed in boreholes drilled with bentonite clay mud, additives were used to help develop the well. And, these additives dispersed the bentonite clay muds and spread their presence out further and more widespread on the aquifer strata. And I think back here on page 8, I just want to go to a statement by the External Advisory Group-

"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 the 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 space around the wells and serving as an adsorption barrier to contaminant detection and quantifications. 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." (EAG, 1999)

Gilkeson: An additional concern for a monitoring well such as R-16, is that it's a multiple screen completion and it has a Westbay* system installed for the collection of groundwater samples. Turn back in the figures to figure 4; for many of these monitoring wells, the screened intervals are not properly developed. You do not have open hydraulic communication with groundwater in the regional aquifer. The result is that there is a "stagnant pool" of groundwater surrounding the screened intervals. The Westbay* sampling system doesn't remove large volumes of water before samples are collected for analysis. So the result is that the groundwater samples from many monitoring wells at Los Alamos Laboratory are collected from the (essentially) stagnant zone of groundwater that immediately surrounds the screened intervals.

Opinion of Mr. Gilkeson:
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 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.

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 exremely 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 "bumped off" 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 is not going to 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 contaminant chemistry in the regional aquifer for a period of time that is longer than the scheduled 50 year life for the LANL monitoring wells.

Gilkeson: Okay, any questions about the effect of the bentonite clay muds? They were used in many of the monitoring wells. I guess one of the things that I would want to point out to point out is on Figure 2. Figure 2 shows the site of monitoring wells that surround Area G and Area L. Everyone probably knows that Area G is the active landfill for the disposal of low-level radioactive waste. All of these monitoring wells (R-16, R-20, R-21, R-22, R-23, and R-32) save one, are installed in mud rotary boreholes drilled with bentonite clay muds. The exception is well R-22 which was installed in a borehole drilled with polymer-based drilling fluids. And, I will be talking more about well R-22. Right now, I'm going to talk about well R-7 which is located in the setting of Los Alamos Canyon and an unnumbered page in this document has a discussion of monitoring well R-7. If you can find that. It's a multiple-screen well.

CAB/Timm: Can I ask you a question?

Gilkeson: Okay.

CAB/Timm: Furthermore, I mean, I want to get back up in the perspective of just an understanding of how it fits together. When did they start putting in these wells?

Gilkeson: 1997

CAB/Timm: Okay so in 1999 a report to the Lab said that basically this is not the best way to do it. These wells you are talking about, R-7 and R-22, when were they put in?

Gilkeson: I am not sure.

LANL/Nylander: 2001, 2002.

CAB/Timm: So put in knowing this wasn't the best way to do it.

DOE/Whitacre: How about my take on this?

DOE/Johansen: Tim, Tim, we have a response to the mud issue. Is now a good time for a response?

CAB/Delong: Well, I don't know. You could ...Okay, you want to talk bentonite mud before you go into something else?

DOE/Whitacre: We want to talk about drilling a little bit.

CAB/Delong: Because I'm not even an amateur hydrogeologist, so some of this you know, mud and zones and you know, I think of a well as something drilled through a bunch of dirt and then a big open space with a bunch of water in it. Obviously, that's not true, you've got sand and you've got stuff going around.

DOE/Johansen: A little round thing with a little house top on it.

Woman: Yeah (Laughter)

CAB/DeLong: Exactly, you just...So some of us are not quite technically astute as others and ...

LANL/Nylander: Would you like some discourse at this time?

Gilkeson: My observation on the bentonite clay muds is from my experience as a technical consultant on contamination sites. I expressly have not looked at contaminanat data from any monitoring well that was drilled at Los Alamos Laboratories with bentonite clay muds. That information was not easily available to me when I wrote this report (Gilkeson, 2004). What I've used in this report are published documents. The LANL well completion reports and the LANL well geochemistry reports. I was not aware of any LANL geochemistry chemistry reports for wells installed in bentonite clay boreholes. So, what I have used for the present discussion of drilling and installing wells in boreholes drilled with bentonite clay muds is the information that's in the semi-annual reports from the External Advisory Group. And the advice in the RCRA Guidance Document concerning the use of bentonite clay muds in monitoring wells.

CAB/DeLong: Okay.

Gilkeson: So that is what the information is based on in this report (Gilkeson, 2004),

DOE/Johansen: We just have a just initial response today; we haven't had enough time to look at it to respond in any detail for the record. And, we will, we will look at this part. We take it seriously. I am going to start at about 5,000 feet and then Tom Whitacre, a driller, knows the well stuff. Pat's background is geochemistry and Charlie has better history than me but I want to start with the Regulator (The Regulator that Mr. Johansesn is referring to is the New Mexico Environment (NMED)). Because I think the person whose opinion really matters here is not mine, not Mr. Gilkeson, it's the Regulator and I want you all to know that each of the wells we have drilled, we have the method approved by the Regulator. Each of these mud - - each of these wells where mud was used, the Regulator knew ahead of time and there's been a history there. Some of them...

Gilkeson: Oh, excuse me, could I get your name down?

DOE/Johansen: Matt Johansen.

Gilkeson: Okay.

DOE/Johansen: There's been a history - a long history about the mud use. We've drilled all the wells under the Permit, uh, RCRA Permit and the wells have been in consistent, uh, the wells been put in consistent with the Permit and where we used mud, obviously that was the approach that we thought was best. Now there are downsides to mud and Mr. Gilkeson started that discussion and there's another side to that discussion. We'll have that when we get down there. But obviously, we didn't want to put in a lousy well, especially with all this money and so in the instances where we used mud, and I'll let Tom explain those, we thought it best. But still at the 5,000 foot level, it's been consistent with our Permit, and that is what really matters. Now the Permit is going away...

Gilkeson: Excuse me; I don't understand the 5000 foot level.

CAB/Timm: That's 2,000 foot below Los Alamos.

DOE/Johansen: OK. (Laughter)

DOE/Johansen: At the higher level of the Regulations and this is not the technical details, okay.

CAB/Hoard: Excuse us, what is the significance of 5,000 feet? I've never heard of that.

DOE/Johansen: Have you heard of 10,000 feet?

CAB/Hoard: If you're at 5,000 feet, you're below the level of the Rio Grande which is 5400.

DOE/Johansen: Okay, I'll do 10,000 feet.

CAB/DeLong: I say 50,000 feet.

CAB/Hoard: I see that you're saying that you're moving from an airplane at 5,000 feet.

CAB/Delong: He's out of the grass is what he's saying.

DOE/Johansen: Our Permit is going away. We are now going to be drilling wells under the NMED Order so let's ask the question. Does the Order allow the use of mud in drilling wells? Answer is, YES! You've seen the Final Draft Order that came out in November. We haven't seen the latest draft, we're still waiting for, but both of those allow the use of mud. So here's our Regulator allowing the use of mud; probably doesn't prefer it. There are probably situations where you don't want to use it but a Regulator is allowing it as an option.

Opinion of Mr. Gilkeson: I disagree with the following statements of Mr. Johansen.

"Because I think the person whose opinion really matters here is not mine, not Mr. Gilkeson, it's the Regulator-"- (the New Mexico Environment Department).

"But still at the '5,000 foot level' - at the higher level of the Regulations and this is not the technical details, okay.- it's been consistent with our Permit, and that is what really matters."

The "higher level of the Regulations" requires that managers are cognizant of the technical requirements to install monitoring wells that meet data quality objectives and are compliant with RCRA. Many of the LANL reports contain a statement to the effect that the design and construction of the monitoring wells meet RCRA requirements. As an example, the statement for LANL monitoring well R-22 is on page 16 of this annotated transcript.

The EPA RCRA Manual (1992) has the following instruction to the DOE and the prime contractor, the University of California (UC) concerning the installation of monitoring wells on the Laboratory facility:

"Inherent in the development of technical objectives is the determination of what quality of data is required or desired. Chapter One of SW-846 addresses Quality Assurance (QA) programs and Quality Control (QC) procedures that should be implemented by owners and operators who are conducting groundwater monitoring programs pursuant to

RCRA. Chapter One of SW-846 states that it is the goal of EPA's QA program to ensure that all data be scientifically valid, defensible, and of known precision and accuracy. Data should be of sufficient known quality to withstand scientific and legal challenges relative to the use for which the data are obtained." (page 3-2)

The RCRA Permit requires DOE and UC to install monitoring wells on the Laboratory facility that are compliant with RCRA requirements and that are scientifically sound. Obeying the opinion of the NMED "Regulator" does not diminish the requirement for DOE and UC to ensure that all data acquired by activities of the Hydrogeologic Workplan are scientifically valid and legally defensible.

Mr. Johansen is the Groundwater Program Manager, NSSA, in the Los Alamos DOE Site Office. The activities of the LANL Hydrogeologic Workplan are required to be in compliance with DOE ORDERS 435.1 and 5400.5. It is important to note that the DOE ORDERS also require the activities of the Hydrogeologic Workplan to be conducted in compliance with the technical requirements of RCRA.

- The objectives of DOE Order 435.1 are to ensure that all DOE radioactive waste is managed in a manner that is protective of worker and public health and safety, and the environment.

  - Mixed Transuranic Radioactive Waste. Mixed transuranic waste that is disposed of at LANL shall be managed in accordance with the requirements of RCRA and DOE Order 435.1.

  - Mixed Low-Level Radioactive Waste. Mixed low-level waste that is disposed of at LANL shall be managed in accordance with the requirements of RCRA and DOE Order 435.1.

  - Low-Level Radioactive Waste . At LANL, each operational or non-operational low-level radioactive waste treatment, storage, and disposal facility shall be monitored by an environmental monitoring program that conforms with DOE 5484.1 and, at a minimum, meet the requirements of paragraph 3K(2) through 3K(4) in DOE Order 435.1:

    - 3K(2) The environmental monitoring program shall be designed to include measuring and evaluating releases, migration of radionuclides, disposal unit subsidence, and changes in disposal facility and disposal site parameters which may affect long-term performance.

    - 3K(3) Based on the characteristics of the facility being monitored, the environmental program may include, but not necessarily be limited to, monitoring surface soil, air, surface water, and, in the subsurface, soil and water, both in the

saturated and the unsaturated zones. The site-specific "performance assessment and composite analysis shall be used to determine the media, locations, radionuclides, and other substances to be monitored.

- 3K(4) The monitoring program shall be capable of detecting changing trends in performance sufficiently in advance to allow application of any necessary corrective actions prior to exceeding performance objectives.

- Concerning MDA G, the active LANL low-level radioactive waste disposal facility, DOE Order 435.1 requires that the dispoal facilty be operated to "assure that external exposure to the waste and and concentrations of radioactive materials which may be released into suface water, groundwater, soil, plants, and animals results in an effective dose equivalent that does not exceed 25 mrem/yr to any member of the public.

- The Objectives of DOE ORDER 5400.5 are Radiation Protection of the Public and the Environment.

  - Protecting the Public. It is DOE's objective to operate its facilities and conduct its activities so that radiation exposures to membes of the public are maintained within the limits established in this Order and to control radioactive contamination through the management of real and personal property. It is also a DOE operative that potential exposures to members of the public be as far below the limits as is reasonably achievable (ALARA) and that DOE facilities have the capabilities, consistent with the types of operations conducted, consistent with the types of operations conducted, to monitoring routine and non-routine releases and to assess doses to members of the public.

  - Protecting the Environment. In addition to providing protection to members of the public, it is DOE's objective to protect the environment from radioactive contamination to the extent practical.

  From DOE Order 5400.5 Concerning Monitoring and Surveillance
  - <u>It is the intent of DOE that the monitoring and surveillance programs for the DOE activities, facilities, and locations be of high quality</u>.

  - Drinking Water Pathway Only. ALL DOE Sources of Radionuclides. It is the policy of DOE to provide a level of protection for persons consuming water from a public drinking water supply operated by the DOE, either directly of through a DOE contractor, that is equivalent to that provided to the public by the public community drinking water standards of 40 CFR Part 141. These systems shall not cause persons consuming the water to receive an effective dose equivalent greater than 4 mrem (0.04 mSv) in a year.

Opinion of Mr. Gilkeson:
The DOE Orders assign a responsibility to the Los Alamos Area Office of DOE and to the UC staff at LANL for the installation of monitoring wells on the Laboratory facility that meet the requirements of RCRA, DOE Order 435.1, and DOE Order 5400.5. It is the intent of DOE Order 5400.5 that the monitoring wells shall be of ***high quality****. The activities of the LANL Hydrogeologic Workplan have installed many monitoring wells on the Laboratory facility that do not meet either the requirements of RCRA or the DOE Orders. The "opinion" of the NMED Regulator does not eliminate the responsibility of DOE and UC to comply with RCRA and DOE Orders.*

DOE/Johansen: On the (NMED) Order all of these wells that were drilled, including the ones that were drilled by mud, the Order does not take exception to. So at this point and time in looking back, it does not take exception to any of these wells drilled with mud. It does take exception to one well, that's R-25. That well was not drilled with mud. That true?

Gilkeson: No, it's not true.

LANL/Nylander: It was drilled with drilling additives.

DOE/Johansen: Drilling additives ---

Gilkeson: It was drilled with mud. It was drilled with mud used as a lubricant. It was drilled with bentonite clay mud.

DOE/Whitacre: There was one well, as far as I know, was R-9.

Gilkeson: R-9 wasn't drilled with fluids in the vadose zone. (Well R-9 was drilled with air rotary casing advance without drilling fluids through the unsaturated zone. However, biodegradable drilling fluids were used for drilling in the regional aquifer.)

DOE/Johansen: You used mud when you drilled R-25?

Gilkeson: As a lubricant.

LANL/Nylander: On the backside of the casing

DOE/Johansen: On the backside of the casing?

CAB/Timm: In the Text R-22 was the only one drilled with polymers.

Gilkeson: On that figure 2.

CAB/Timm: Okay.

LANL/Nylander: When you use mud on the backside of the casing though, that's a whole different process than using it as a circulation fluid.

DOE/Johansen: I'm at 10,000 feet; I promised that I wouldn't dwell on details.

Gilkeson: Just for the …

DOE/Johansen: I have the floor. I do know that the Order takes exception to one well, out of all those wells, so that the wells that were drilled other than R-25, it does not take exception to. It does take exception to R-25.

CAB/Hoard: Because?

DOE/Johansen: Because of construction problems. Cross-contamination issues.

CAB/Timm: Which one is that?

Gilkeson: It's at a location where a concern was high explosives contamination.

CAB/Timm: Figure 1 or figure 2, probably figure 1.

CAB/DeLong: Was that fairly recent? Or was that one that's been there a long time?

DOE/Johansen: Mr. Gilkeson, did you finish R-25 before you left.

Gilkeson: No, it was finished after my departure.

DOE/Johansen: So it was finished after your departure?

Gilkeson: Right. The only other description I would put about R-25 is that the bentonite muds were used as lubricant because of the great depth of that casing-advance drill hole.

DOE/Johansen: Then let me ask you why you…

Gilkeson: And the bentonite clay muds, the concern there was high explosives.

DOE/Johansen: Okay.

Gilkeson: So the effect of the bentonite clay muds was seen to be minimal.

DOE/Johansen: So in this instance you chose to use the muds because in this instance, it wouldn't matter.

Gilkeson: It was less effect than drilling fluids and with the depth of the--.

DOE/Johansen: So it was the best option?

Gilkeson: It was the best option.

DOE/Johansen: In many cases, I agree.

Gilkeson: And there was not great concern about radionuclide contaminants for the location of that drill site.

DOE/Johansen: All right. The Order calls out exception to that well drilled by Mr. Gilkeson. R-25.

Gilkeson: I wouldn't say it was drilled by Mr. Gilkeson I was a member of a team.

DOE/Johansen: You weren't in charge of that well, the drilling of that well?

Gilkeson: I would not say I was in charge. I was a lead consultant placing advice.

CAB/DeLong: When you say the Order takes exception to that particular well, does that just mean that under the Order, we're not able to use data from that particular well?

DOE/Johansen In the Order that came out in November, 2002, they said to replace it. Now in negotiations we've offered to test the well through a tracer test to see if it works.

CAB/Timm: Let me ask you a silly question. If the RCRA guidance and other experts say don't use bentonite for regional aquifer monitoring wells but the NMED says it's okay to use it, obviously there's a reason why we do it that way or why the Lab does it that way. Is that a simple thing to explain to a fellow like me?

DOE/Johansen: Yeah, go ahead Charles.

CAB/Timm: And the fact that it is valid or invalid and we know it's an issue but we still do it.

LANL/Nylander EPA's technical guidance document is just that – guidance. They make recommendations, it's not Regulation or anything like that and in the national ground water picture, the RCRA picture, they do acknowledge that drilling additives - drilling muds are not that desirable as far as doing a pure monitoring well, but the realistic nature of drilling is that you have to use those materials to keep a hole open while you are drilling; otherwise you can't keep the hole open. So the regulators in New Mexico, as well as the other states in the country routinely allow mud drilling and the use of drilling additives, wells that were drilled in other spots in New Mexico, White Sands, NASA, South Valley of Albuquerque, those wells are drilling with drilling fluids, muds and it is routinely approved by the Regulator.

CAB/DeLong: How about other areas where they are doing similar type of sampling, similar type of contaminants, Hanford, Savannah river?

DOE/Johansen: And the Nevada test site.

DOE/Whitacre: Any place where there's a lot of alluvium; they're going to use it for sure.

LANL/Nylander: It's just that in a pure sort of chemistry sense, if all things were perfect, you would like to not use them just because you can't be sure you can purge them out of the well after you finish drilling and you develop the well.

CAB/Timm: And there's not an adjustment factor or multiplier or some way to – there's no way to really tell what the effect is.

LANL/Nylander: Eventually whatever residuals are left in the borehole, over time they will basically come back to equilibrium with the natural system.

Opinion of Mr. Gilkeson:
I disagree with Mr. Nylander's statement that it is necessary to use fluid rotary drilling methods with drilling fluids, -foams, and bentonite clay muds for the installation of monitoring wells in the aquifer strata beneath the Laboratory facility. The drilling activities of the LANL Hydrogeologic Workplan have installed many monitoring wells deep in the regional aquifer with the air rotary casing advance drilling method. The following is an incomplete list that contains examples of LANL 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 – 1330 ft, RA – 559 ft; well R-25, TD – 1942 ft, RA – 656 ft; and well R-31, TD – 1103 ft, RA – 569 ft.

The "pure sort of chemistry sense" mentioned by Mr. Nylander is a critical requirement for the drilling method that is used for many of the LANL monitoring wells because it is necessary to have knowledge of the presence of radionuclide contaminants in groundwater at extremely low levels. There is also a concern to have knowledge of chemical contaminants including metals and perchlorate at very low levels. The contaminants of concern at a given monitoring well location are the important factor that determines whether biodegradable drilling fluids or bentonite clay muds can be used in the drilling method. Where radionuclide, metal, and perchlorate contaminants are a concern, it is very important to prevent the drilling fluids or -foams and bentonite clay muds from entering the aquifer strata where well screens will be installed.

Mr. Nylander acknowledges that

"If all things were perfect, you would like to not use them (drilling fluids, foams, and muds) just because you can't be sure you can purge them out of the well after you finish drilling and you develop the well."

My reply to this statement is that you can be sure that the majority of LANL monitoring wells that are installed in boreholes drilled using the mud rotary method with bentonite clay muds are irreparably damaged by the bentonite clay that is permanently entrained into the aquifer strata. These monitoring wells must be replaced. DOE Order 5400.5 requires high quality monitoring wells.

Furthermore, many screened intervals in the monitoring wells installed in boreholes where the drilling method used biodegradable drilling fluids and -foams are irreparably damaged by the entrained fluids and foams and require replacement with new monitoring wells. Here the problem is greatest for the multiple-screen wells where the Westbay sampling system is used for collection of groundwater samples from the discrete screened intervals. At LANL, the Westbay* sampling procedure does not purge any volume of groundwater from the screened intervals before samples are collected for the analytical suite.*

I disagree with Mr. Nylander's description of the subject EPA RCRA Technical Guidance document for the installation of monitoring wells. This is the same document that is included in the introduction of many of the published LANL monitoring well completion reports and LANL monitoring well geochemistry reports. An example is the following statement in the LANL Monitoring Well R-22 Geochemistry Report:

> "Although well R-22 is primarily a characterization well, its design and construction also meet the requirements of a Resource Conservation and Recovery Act (RCRA)-complaint 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."

The EPA refers to this RCRA Guidance document as "the EPA RCRA Manual". LANL monitoring well R-22 does not meet many of the RCRA requirements that are spelled out in the EPA Manual.

From the EPA RCRA Manual:

"This Manual discusses the basic data necessary for meeting the performance standards for the design and implementation of a RCRA groundwater monitoring program. Performance standards, rather than specifications are set forth in Subpart F because of the diversity of the environmental settings in which regulated units exist, and because of the need to tailor monitoring systems to fit each setting." (page 3-1 to 3-2)

"Inherent in the development of technical objectives is the determination of what quality of data is required or desired. Chapter One of SW-846 addresses Quality Assurance (QA) programs and Quality Control (QC) procedures that should be implemented by owners and operators who are conducting groundwater monitoring programs pursuant to RCRA. Chapter One of SW-846 states that it is the goal of EPA's QA program to ensure that all data be scientifically valid, defensible, and of known precision and accuracy. Data should be of sufficient known quality to withstand scientific and legal challenges relative to the use for which the data are obtained." (page 3-2)

"All activities implemented pursuant to Subpart F (i.e., hydrogeologic site investigations, design and installation of groundwater monitoring wells, sampling, and sample analysis) should include a QA and QC program as required by Sect. 264.97(e)." (page 3-2)

"The procedures that an owner/operator uses to characterize the hydrogeology of a site, to design and construct a monitoring network, to collect and analyze environmental samples, and to evaluate analytical results should ensure that the data are of the type and quality necessary to allow for the detection of contaminants when hazardous waste or hazardous constituents have migrated from the waste management area to the uppermost aquifer (Sect. 264.97(a)(3)." (page 3-3)

The EPA RCRA Manual lists the following RCRA Regulations for monitoring wells on RCRA facilities. The RCRA regulations require that monitoring wells provide

1. representative groundwater samples for contaminants of concern at the location of the well (40 CFR Part 264 Subpart F Sect. 264.9)

2. early detection of contaminants in groundwater (40 CFR Sect. 264.97(d) and 264.87(e)), and

3. screened intervals installed in all of the discrete aquifer strata with high hydraulic conductivity that comprise the "uppermost aquifer"(40 CFR Sect. 264.95(a) and 264.97(a)(3)).

Many LANL monitoring wells do not comply with the RCRA Regulations. A major reason for the non-compliance is because biodegradable drilling fluids/foams and/or bentonite clay muds were used for drilling the boreholes for the monitoring wells.
In addition, some of the LANL monitoring wells do not have screened intervals installed in the aquifer strata that have high hydraulic conductivity; these are the strata that are expected to have the highest levels of contamination and are the fast pathways for travel of groundwater in the regional aquifer (Puls and Barcelona, 1989, Fetter, 1994). Gilkeson (2004) describes the failure of LANL and DOE to install well screens in the appropriate geologic strata for LANL monitoring wells R-7, R-15, and R-22.

Mr. Nylander defends the use of the drilling additives in the boreholes for LANL monitoring wells by claiming that drilling additives are used for installing monitoring wells on other sites in New Mexico and at those sites the Regulators have routinely approved the use of drilling fluids and muds. The practices that are used on other sites for the installation of monitoring wells do not obviate the requirement for LANL, DOE, and NMED to install monitoring wells on the Laboratory facility that are compliant with the DOE Orders and the RCRA Regulations that are listed above and are described in the EPA RCRA Manual.

When radionuclides and metals are contaminants of concern, there is consensus in the literature that biodegradable drilling fluids or foams and bentonite clay drilling fluids should not be used for drilling in the aquifer strata where the screened intervals of monitoring wells will be installed. This was also the advice of the LANL External Advisory Group (1999). This consensus includes journal articles by Claassen (1982), Walker (1983), Ericson et al (1985), Brobst and Buszka (1986), Jennings (1986), Gibb and Jennings (1987), Puls and Barcelona (1989), ASTM (1990), The EPA RCRA Manual (1992), and the Australian Drilling Manual (1997). Appendix a presents summary'sof the articles.

In addition, the consensus in the articles is that when drilling fluids and bentonite clay muds are used in boreholes for monitoring wells, these materials must be removed from the aquifer strata by careful well development. However, the article by Gibb and Jennings (1987) describes why the physical design of monitoring wells makes it very difficult to remove large amounts of the entrained driling fluids, -foams, and -muds from the aquifer strata. The Gibb and Jennings (1987) article is included in the discussion of LANL well development activities on pages 30 to 34 of this annotated transcript.

The air rotary casing advance drilling method can drill and advance casing without the use of any liquid drilling fluids, -foams, or - muds. For drilling efficiency, it is appropriate to use the fluids or muds to advance the drill casing through the unsaturated zone. However, the fluids and muds should not be used to advance the drill casing into the aquifer strata where a well screen will be installed. Unfortunately, LANL used biodegradable drilling fluids with this air rotary method for advancing the drill casing into the aquifer strata where the screened intervals of monitoring wells are installed.

For many of the LANL monitoring wells, the biodegradable drilling fluids, foams, and bentonite clay muds have invaded the aquifer strata where well screens are installed and have caused changes to the aquifer chemistry which prevent the collection of representative groundwater samples for many contaminants.

- *The chemistry of the biodegradable drilling fluids and 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.*

The borehole for LANL monitoring well R-7 was drilled into the regional aquifer using the EZ-MUD drilling fluid. The well development activities in the installed monitoring well left a large amount of the drilling fluid entrained in the aquifer strata. For screen #3, installed at the top of the regional aquifer, the LANL Well R-7 Geochemistry Report records strontium-90 levels in the four quarterly groundwater samples of 1.4, 0.9, 0.0329, and -0.00477 pCi/L, respectively.*

LANL's position is that strontium-90 was 'not detected' in the groundwater samples from screen #3 as the recorded values do not meet the 3-sigma requirement for valid detection. <u>However, the improper use of the biodegradable, polymer-based EZ-MUD drilling fluid and the biodegradable QUIK-FOAM* drilling surfactant in the well R-7 borehole does not afford LANL the privilege of using the 3-sigma requirement for the presence of contamination</u>*

Furthermore, NMED disagrees with the three- sigma requirement of LANL for radionuclide analyses with the following statement:

"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).

It is important to note that the trend of the Sr-90 values show a consistent pattern, indicating that strontium-90 is detected, even if not with the accuracy required by LANL. In addition, the declining trend is consistent with the observed alteration of the geochemistry that was caused by the use of drilling fluids and -foams in the borehole.

It is very important to gain knowledge of where strontium-90 recharge to the regional aquifer is occurring because of the detection of strontium-90 in groundwater samples collected from the public supply well Otowi-1. For groundwater samples collected in June and August of 2000, the measured activities with 3-sigma validation were 0.19 pCi/L and 0.23 pCi/L, respectively (NMED, 2002). This supply well is located downgradient of LANL monitoring well R-7. The NMED has expressed the following concern for strontium-90 contamination in the regional aquifer:

> "The extent of strontium-90 contamination at the LANL facility has not been fully investigated. Moreover, the levels of strontium-90 detected in the drinking water supply wells are likely to have been substantially diluted. The rate of groundwater withdrawal in municipal water supply wells often exceeds one thousand gallons per minute, and the screened interval is typically hundreds of vertical feet across multiple producing zones, resulting in a high degree of dilution."
>
> "The Environment Department believes that this evidence is sufficient to support its finding that there may be an imminent and substantial endangerment to health and the environment from strontium-90 contamination at the LANL facility." (NMED, November 26, 2002).

An important ingredient in the EZ-MUD and QUIK-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.
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 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 Compay 1990, and Driscoll 1986). The two screened intervals are located at the top of the regional aquifer where it is important to have knowledge of the presence of extremely low levels of radionuclide contaminants.

The precipitation of (HFO)and ferric oxyhydroxides is important as these "fresh coatings" on the aquifer strata and possibly 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).

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 sorption properties for trace metals and radionuclides.

Furthermore, the hydrous ferric oxide precipitates are a "slimy mass" that lowers the hydraulic conductivity of the aquifer strata and filter pack sediments (Driscoll, 1986). The impact of the biodegradable drilling fluids and –foams on the creation of a zone of "stagnant" groundwater that surrounds the screened intervals in many LANL monitoring wells is described on pages 30 to 34 of this annotated transcript.

The analytical data in the LANL Well R-7 Geochemistry Report for the four quarters show that the dissolved concentrations of calcium, strontium, strontium-90, and also iron, manganese, and uranium are declining with the primary reason for the decline being removal by precipitation, coprecipitation, and sorption (Langmuir, 1997). In addition, the presence of the iron precipitates enables the precipitation of the alkaline earth metals at dissolved concentrations lower than those calculated from the solubility product (Stumm and Morgan, 1996).

An important feature in the first three quarters of analyses in the LANL Well R-7 Geochemistry Report is the little change in dissolved concentrations of magnesium compared to the large decline in dissolved calcium. The decline in bacterial respiration that is occurring over the four quarters resulted in lower levels of dissolved carbon dioxide. The decline in dissolved carbon dioxide has little control on the concentration of dissolved magnesium but a large control on the concentration of dissolved calcium (Langmuir, 1997, Driscoll, 1986). This is important information as it indicates that the decline in concentrations of calcium, strontium, and strontium-90 (if present) is primarily because of precipitation, coprecipitation, and sorption, instead of dilution.

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 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 important to have knowledge of the presence of technetium-99 in groundwater at the top of the regional aquifer beneath MDA G because of the high mobility of this radionuclide contaminant and the large quantity of technetium-99 contaminated waste that is present in disposal pits at MDA G. Unfortunately, LANL did not analyze the groundwater sample collected at the top of the regional aquifer from the well R-22 borehole for technetium-99. <u>The improper dilution in the groundwater samples collected from screen #1 caused by the "flushing" of the native groundwater down the open borehole and the improper use of the biodegradable EZ-MUD and QUIK-FOAM* drilling additives in the well R-22 borehole would lower the levels of technetium-99 in groundwater samples collected from screen no. 1.</u>.*

The comparison of the tritium level of 109.2 pCi/L that was measured in the groundwater sample collected from the well R-22 borehole to the much lower tritium value of 2.01 pCi/L that was measured in the first quarterly sample collected from screen # 1 calculates a 50-fold dilution factor for the quarterly groundwater samples collected from screen no. 1. The LANL Well R-22 Geochemistry Report describes the reason for the large difference in the tritium values as due to dilution:

"Dilution of native groundwater during aquifer-performance (slug-injection) testing prior to well completion may account for decreased tritium activities observed near the regional water table during the (quarterly) characterization sampling."

The statement in the geochemistry report that the cause of the dilution is the performance of an injection test in screen #1 is contradicted by the LANL Hydrologic Tests Report (2003) which states that the injection tests were performed in screen #2, #3, #4, and #5 of well R-22. The dilution of the in situ native groundwater at the top of the regional aquifer downgradient of MDA G with 109.2 PCi/L tritium is because the borehole for well R-22 drilled through a confining layer and the native groundwater "flushed" down the open borehole (LANL Well R-22 Completion Report, 2002). Also, the LANL Geochemistry Report for Well R-22 does not acknowledge that the dilution caused by the injection tests in screen #2, #3, #4, and #5 may impair the detection of contamination in groundwater samples collected from the screened intervals.

Very importantly, the process that is responsible for the dilution of tritium will also cause dilution of technetium-99. Taking the dilution into account, the calculated level of technetium-99 that is present in groundwater at the top of the regional aquifer immediately downgradient of MDA G is 125 pCi/L. This is a serious level of contamination. The Performance Assessment of MDA G that was required by DOE predicted a period of 600 years for the travel time of technetium-99 from disposal pits at MDA G to groundwater at the top of the regional aquifer (LANL 1997). It is very important to install a single screen monitoring well immediately downgradient of MDA G for valid knowledge of the actual level of technetium-99 and other contaminants in groundwater at the top of the regional aquifer beneath MDA G.

The Performance Assessment and Composite Analysis of MDA G (LANL PA/CA) was based on many assumptions for the hydrogeologic setting in the unsaturated zone and in the regional aquifer beneath the disposal facility. The information from the borehole for monitoring well R-22 determined that the geologic environment beneath MDA G is less protective of the regional aquifer than the assumed geologic environment that was used in the Performance Assessment. In addition, the R-22 borehole determined that there are fast pathways for groundwater travel in the regional aquifer beneath MDA G. The fast pathways are in the basalt and also in river gravels that are present in an ancestral valley of the Rio Grande River. The flow direction of groundwater in the fast pathways may be very different from the flow direction predicted by the contour map of the top of the regional aquifer (ASTM, 2004).
The LANL PA/CA assumed that the regional aquifer was below the basalt strata in isotropic, homogeneous Puye sediments that were assumed to have a hydraulic conductivity of 13 ft/day. The hydraulic conductivity of the fast pathway aquifer strata that are present beneath MDA G may range from 250 ft/day to greater than 500 ft/ day.

The geologic knowledge from the well R-22 borehole requires LANL to update the PA/CA for authorization to operate MDA G as a landfill for low-level radioactive waste. The requirement for the update is described in DOE ORDER 435.1 as follows:

DOE G 435.1-1 IV-203
7-09-99
Chapter IV - Low-Level Waste Requireme

IV. P.(4) Performance Assessment and Composite Analysis Maintenance. The performance assessment and composite analysis shall be maintained to evaluate changes that could affect the performance, design, and operating bases for the facility. Performance assessment and composite analysis maintenance shall include the conduct of research, field studies, and monitoring needed to address uncertainties or gaps in existing data. The performance assessment shall be updated to support the final facility closure. Additional iterations of the performance assessment and composite analysis shall be conducted as necessary during the post-closure period.

(a) Performance assessments and composite analyses shall be reviewed and revised when changes in waste forms or containers, radionuclide inventories, facility design and operations, closure concepts, or the improved understanding of the performance of the waste disposal facility in combination with the features of the site on which it is located alter the conclusions or the conceptual model(s) of the existing performance assessment or composite analysis.

There is a clear need for a review and revision of the Performance Assessment for MDA G.

LANL/Longmire: If you know the type of drilling fluid, what it's made up, you can analyze for that in the groundwater. For example, with this EZ-MUD* which is an organic base fluid, you can analyze for total organic carbon, some other constituents and I would be a lot more concerned if I didn't see the breakdown of the drilling fluids, which in the case where we do have drilling fluids in some of the wells, we do see the breakdown and if I just saw uh, you know, just the indication of the drilling fluid without these breakdown products geochemically, I'd be a lot more concerned.

Opinion of Mr. Gilkeson:
The "breakdown of the drilling fluids" that Dr. Longmire is referring to is the consumption of the liquid organic carbon component of the drilling fluid by bacterial respiration. This respiration does not affect the polymer component of the drilling fluid; the component that has sorption properties to remove many contaminants from groundwater. The sorption properties of the EZ-MUD drilling fluid are described on page 19 of this annotated transcript.*

I disagree with Dr. Longmire's optimistic interpretation of the chemical data from screened intervals that are impacted by the presence of biodegradable drilling fluids entrained into the aquifer strata. Dr. Longmire refers to the observed "breakdown of the drilling fluids" as an indication that the groudwater is "cleaning up" and eventually, the groundwater samples collected from the screened interval will be representative of the chemistry of groundwater in the aquifer strata that are not impacted by the biodegradable drilling fluids. See comments by Dr. Longmire on page 46 to 47 of this annotated transcript.

The "cleaning up" that Dr. Longmire is describing is the decline over succeeding quarterly groundwater samples in the level of organic carbon and also that the groundwater is trending back to the natural oxidizing chemistry. The presence in groundwater samples of elevated levels of organic carbon and dissolved iron with an associated anoxic groundwater chemistry is proof that the biodegradable drilling fluids were not quickly removed from the aquifer strata – a quick and total removal of these fluids is essential to prevent the geochemical processes that alter and increase the properties of the aquifer strata for removal of trace metal and radionuclide contaminants. The chemical change to the aquifer strata that is caused by the

biodegradable drilling fluids and -foams is described on pages 19 to 22 of this annotated transcript.

The biodegradable drilling fluids and the bentonite clay muds that are entrained into the aquifer strata cause changes in the chemistry of the aquifer strata that will result in the removal of many contaminants of concern in groundwater samples collected from the impacted monitoring wells. The changed chemistry will prevent collection of representative groundwater samples for many radionuclide and chemical contaminants of concern from many LANL monitoring wells for very long periods of time on the scale of decades, and perhaps, permanently for the scheduled fifty year lifespan of an individual monitoring well.

CAB/Timm: Is it almost a worse issue the fact that you really don't have enough groundwater flow to get the purging you'd like?

LANL/Longmire: Well, it takes a long time. The multi-completed wells definitely take more time. The single completed wells clean up very rapidly because you can displace more water.

DOE/Whitacre: Because I remember development on these wells…

CAB/Delong: What do you mean multi-completed?

DOE/Whitacre: You have multiple screens within one well casing so you have blank casing, a screen zone, blank casing, a screen zone in one bore hole in one casing series.

LANL/Nylander: You're drawing water from different levels out the same well.

DOE/Whitacre: And you have sand and separation grout and concrete and you have a Westbay (sampling system) inside these screens and then the idea of a West bay, you could have…(machine cut out – no conversation)

DOE/Whitacre: Of course, that's a very widely used technology, Westbay is. Each state is involved in that and in that process. And I guess the issue on the development of these wells, uh, you know one of the keys is to get in there and move material quickly, water quickly and large volumes of water and in some of these wells, they are going to drill with mud methods. We can move anywhere from 10,000 to over 120,000 gallons of water.

Gilkeson: My comment on that is that (the quantity of water pumped from a screened interval) doesn't mean adequate removal of bentonite clay muds.

DOE/Whitacre: Then I'd say, yeah, that permeable of a zone, eventually the mud is not going to stick around the borehole forever and you're going to have a -- ? -- monitoring point.

***Opinion of Mr. Gilkeson**: The pumpage of a large volume of water during the development of a screened interval does not prove that a large percent of the drilling fluids or bentonite clay has been removed from the aquifer strata. In fact, it is <u>common sense</u> that the development activities in the LANL monitoring wells have only recovered a small part of the large quantity of bentonite clay that was entrained into the aquifer strata. The large amount of bentonite clay that has invaded the aquifer strata at monitoring wells R-14 and R-16 is there permanently with preferential sorption properties for many radionuclide contaminants of concern in groundwater at the location of the monitoring wells. My finding is that LANL monitoring wells R-14 and R-16 will never provide valid groundwater samples for the radionuclide contaminants of concern. It is necessary to replace the two wells and also replace most LANL monitoring wells that are installed in boreholes drilled with the mud rotary method.*

For many LANL monitoring wells, the presence of an anoxic environment with elevated levels of dissolved iron is direct evidence that LANL did not "get in there and move material quickly" to remove the biodegradable drilling fluids and –foams from the aquifer strata that surround the impacted screened intervals and that chemical processes are occurring that cause irreparable damage to the monitoring well. The chemical processes are described on pages 19 to 22 of this annotated transcript.

CAB/DeLong: Look, let me ask – rather than argue the point – I would like to ask a question. It's your contention then, Sir, that because these wells have been drilled in this manner, the data that we're getting is wrong or suspect or the Lab has contaminated at a higher level than what the ....

Gilkeson: You're making too many...

CAB/DeLong: I don't know, I'm just asking, I'm just trying to get to the bottom of the -- ? -- line.

Gilkeson: My concern remains that the monitoring wells constructed in bore holes drilled with bentonite clay muds are unreliable for detection of many contaminants of concern. Specifically, I would say that on figure 2 and figure 1, monitoring well R-16 does not serve as a reliable sentry well for the detection of radionuclide contaminants in the regional aquifer moving to the Buckman well field. (The Buckman well field is a location of many groundwater supply wells for the city of Santa Fe.)

CAB/Hoard: Tim?

CAB/DeLong: Oh, I'm sorry. Excuse me. Yeah, yes, mam.

CAB/Hoard: When I read Purtymun's papers in the '70s, it says that certain fine particle sizes strongly adsorbed plutonium, but since then I have had people tell me that pretty much any cation would be adsorbed on to these clays.

LANL/Longmire: Varying amounts, yeah, varying amounts, yeah-

CAB/Hoard; And if you have these clays around these wells and especially if the water is stagnant as Bob is saying, that they would adsorb onto the clays and be pulled out of the water- so that the concentration in the water would be low. And there is no way to quantify that.

LANL/Longmire: Yeah, I don't know if the water's completely stagnant because the wells are cleaning up. If you had stagnant water around well screens.....

Gilkeson: Pat, we are talking about bentonite clay muds now, we're not talking about drilling fluids.

LANL/Longmire: Well, I'm addressing if, you know, you had stagnant water.

CAB/Hoard: Well, even I would think even water that's in motion. I'm used to surface water so I'm --?-- wells, but if you have water that's even flowing very quickly, these fine clays are adsorbing enough that they would pull these cations.

LANL/Longmire: If you have where R-16 is, in White Rock, if you had plutonium or americium migrating that far, it could be an issue but out of all of this stuff, like R-16 is dead, there tritium is less than detections, less than a half a picocurie per litre. So what that means is that water is really old water; it hasn't seen any influence from water that was derived from the surface that could carry contaminates down to those depths.

***Opinion of Mr. Gilkeson**: The above statement by Dr. Longmire is an admission that the large volume of bentonite clay that is entrained into the aquifer strata surrounding the screened intervals in well R-16 may prevent valid knowledge of the presence of plutonium or americium contamination in groundwater. At the location of well R-16, Dr. Longmire is relying on the low level of tritium in groundwater as evidence that the radionuclide contaminants are not present. Very importantly, Dr. Longmire's admission that the bentonite clays at well R-14 are an" issue" for the detection of plutonium and americium means that the validity of groundwater analyses for many radionuclide contaminants is a <u>serious issue</u> for all LANL monitoring wells that are installed in boreholes drilled using the mud rotary method with bentonite clay drilling muds. It is necessary for these monitoring wells to be replaced.*

CAB/Hoard: But looking at all the wells, Pat, you're pulling this "dead" water out of the ground, you're sampling it all; these are public data and if you...from this it appears that you can't guarantee that the sampling was – was, uh...

Longmire: Well, R-16, I haven't looked at the data. I'm fairly knowledgeable on R-7 and I can address those points that Bob has brought up and I can give, you know, based on the geochemistry at that well and what my technical viewpoint is on how that well's behaving. R-16, we've done some sampling but I haven't had time to evaluate it.

Nylander: Can I interrupt that idea? I think the thing is that, I think there's a misconstruing here of this stagnant zone. When these screens are placed in the well - on the backside of the screen, outside the well, you have a sand filter pack. Beyond that, you have the natural earth materials of the bore hole wall and the geologic strata. When each of those screens is placed, you come back in and you develop that screen by pushing water out the screen, pulling it back in, surging water back and forth, you keep pumping water from the aquifer material through the sand, through the screen, into the well and up until you reduced its turbidity to less than five natural turbidity units (NTUs). Which means that you've pulled in most of the clay bentonite drilling materials that might have existed in that zone.

Gilkeson: I disagree. I disagree.

Nylander: And when water then is flowing naturally in the aquifer and you go to sample that zone that water will be moving toward the well and across the well through that screen and I think that this information about stagnation and a blockage conveniently on the upgradient side of the flow path is largely overstated. I think that we have chemical information from our sampling of the multiple screens. It shows changes in chemistry over time. It shows the natural equilibrium coming back into effect. And remember, any time you put a well in the ground; you're disturbing the natural environment. It's just like doing surgery on a human body; it takes a while for things to come back in a natural equilibrium. Every well goes through this; every RCRA type well in the country goes through this same process of trying to come back to natural equilibrium regardless of the drilling method that is used. So, I very much disagree with this stagnation theory.

Opinion of Mr. Gilkeson:
The LANL EAG shares the concern in Gilkeson (2004) for a "stagnant zone" surrounding the screened intervals in the multiple-screen monitoring wells because of the failure of well development activities to remove the drilling fluids. The concern of the EAG is on pages 3 to 4 and 48 to 49 of this annotated transcript. The LANL well completion and geochemistry reports are documentation that many screened intervals were not developed sufficiently to remove the entrained drilling fluids and foams.

LANL monitoring wells R-14 and R-16 are examples of where the development methods described above by Mr. Nylander have been used. The boreholes for the two wells were drilled using the mud rotary method with bentonite clay muds. The LANL Well R-14 and R-16 Completion Reports show that very large quantities of bentonite clay invaded the aquifer strata that surround the screened intervals in both wells; greater than 28,000 lbs. for well R-14 and greater than 31,000 lbs. for well R-16. The physical features of the LANL monitoring wells that prevent the removal of large volumes of entrained drilling fluids are described on page 31 of this annotated transcript.

LANL used chemical additives for development of the screened intervals in the two wells. The chemical additives disaggregated the bentonite clay mud cake and dispersed the bentonite clay further out into the aquifer strata. The development activities have improved the performance of the screened intervals for production of groundwater with low turbidity but this does not indicate that the bentonite clay has been removed from the aquifer strata. I strongly disagree with Mr. Nylander's claim that the low turbidity in groundwater samples is evidence that a large amount of the bentonite clay has been removed from the aquifer strata.

The contaminants of concern at the locations of monitoring wells R-14 and R-16 include radionuclides that must be monitored at extremely low levels in groundwater. The large volume of bentonite clay in the impacted zone surrounding the screened intervals in the two wells has an extremely large capacity to remove the contaminants of concern from groundwater. In fact, the bentonite clay has preferential sorption properties for the radionuclide contaminants at the present time and for decades of time into the future. These prefential sorption properties will still exist even though the major ion chemistry shows that the groundwater has returned to equilibrium. The sorption properties of bentonite clay are described on pages 5 and 6 of this annotated transcript.

When radionuclides and metals are contaminants of concern, there is consensus in the literature that biodegradable drilling fluids or foams and bentonite clay drilling fluids should not be used for drilling in the aquifer strata where the screened intervals of monitoring wells will be installed. This was my advice to LANL in 1997 and the advice of the LANL External Advisory Group (1999, 2002). This consensus includes journal articles by Claassen (1982), Walker (1983), Ericson et al (1985), Brobst and Buszka

(1986), Jennings (1986), Gibb and Jennings (1987), Puls and Barcelona (1989), ASTM (1990), The EPA RCRA Manual (1992), and the Australian Drilling Manual (1997).

In addition, the consensus in the articles is that when drilling fluids and bentonite clay muds are used in the boreholes for monitoring wells, these materials must be removed from the aquifer strata by careful well development. However, the article by Gibb and Jennings (1987) describes why the physical design of monitoring wells prevents the removal of large amounts of entrained fluids, foams, and muds from the aquifer strata:

> "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 degree or amount of drilling fluids lost into the aquifer strata is directly proportional to their hydraulic conductivity. Breaking down the mud cake and removal of all drilling fluids introduced during the drilling and construction process is extremely difficult. The groundwater velocities required to remove drilling fluids, and the colloidal size particles associated with them, from the aquifer strata, usually cannot be created during development of small diameter monitoring wells. 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" is a term used to describe the presence of an altered chemistry in the aquifer strata that is a result of the use of drilling fluids. Many of the LANL monitoring wells exhibit "well trauma".

The physical design of the LANL monitoring wells,

- *great depth below ground surface,*
- *small diameter casing,*
- *short well screens with small 0.01 inch openings, and*
- *medium-grained sand in the filter pack sediments that surround the well screens,*

presents great difficulty for removal of most of the drilling fluids and muds from the aquifer strata.

LANL routinely uses chemical additives to develop the screened intervals in monitoring wells that are installed in boreholes drilled using the mud rotary method with bentonite clay muds. The chemical additives improve the production of water from the screened interval by disaggregating the bentonite clay mud cake and spreading the bentonite clay further out into the aquifer strata.

Various LANL reports for activities performed by the LANL Hydrogeologic Workplan attest to the fact that a uniform practice has not been applied by LANL for the development of screened intervals in the LANL monitoring wells. For example, the LANL Monitoring Well R-22 Completion Report shows that no well development

activities were performed in screen #1 of that multiple-screen well. Screen #1 is located at the top of the regional aquifer where it is very important to have knowledge of the presence of extremely low levels of radionuclide contaminants in groundwater.

The LANL Monitoring Well R-22 Geochemistry Report lists turbidity values in the third and fourth quarter groundwater samples collected from screen #1 of 39.5 and 23.7 NTUs, respectively. A RCRA requirement for representative groundwater samples collected from monitoring wells is a measured turbidity of less than 5 NTUs,

An additional example of a LANL monitoring well where no or insufficient development activities were performed is LANL monitoring well R-7. The LANL monitoring well R-7 completion report shows that no development activities were performed in screen #1 of that well, and that the development activity in screen # 3 installed at the top of the regional aquifer was bailing that was terminated when the groundwater samples stabilized at a turbidity of 21 NTU.

LANL Report LA-13987-MS "Hydrologic Tests at Characterization Wells R-9i, R-13, R-19, R-22, and R-31" attests to the uneven application of development methods in LANL monitoring wells. Table 3 in the report shows that a surge block was only used to develop the screened intervals of two of the five subject monitoring wells, swabbing was only performed in one of the wells, and jetting was only performed in one of the wells.

An interesting feature in the LANL hydrologic tests report is the performance of injection tests before and after the full development of 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, LANL operated the surge block on a wireline. 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 wireline 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 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 LANL monitoring wells. The EAG advised LANL that incorrect methods were used to calculate the hydraulic conductivity for screen #4 and #5 in well R-31. 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). Nevertheless, LANL published the unreasonably low hydraulic conductivity values of 1.23 and 0.75 ft/day for the two screened intervals.

It is important to be aware that the LANL Well R-31 Completion Report shows that screen #4and #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.
In the LANL Well R-31 Completion Report, the description 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 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 groundwater resource available to supply wells.

The importance of careful development of screened intervals in monitoring wells to remove entrained drilling fluids and muds is described in an EPA Superfund Guidance document by Puls and Barcelona (1989). The EPA document has the following guidance 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."

"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."

"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."

The information in the LANL reports shows that many of the screened intervals in LANL monitoring wells are not providing a representative hydraulic connection to the aquifer strata. The degree of hydraulic connection varies from stagnation for some screened intervals to moderate production of groundwater for other screened intervals. The important fact is that many screened intervals are surrounded by impacted aquifer strata because of the biodegradable drilling fluids and bentonite clay drilling muds that were not removed by well development. The impacted zone has a lower hydraulic conductivity than the representative aquifer strata. Because of the impairment to groundwater flow in the zone of impacted strata, the groundwater samples that are collected from the Westbay sampling systems have had a long residence time in contact with the aquifer strata that have altered chemical properties that may remove contaminants of concern from groundwater. Groundwater samples are collected from the Westbay* sampling ports without purging the groundwater that has had a long residence time in the impacted zone that surrounds the screened interval. See the discussion of the concerns for the collection of "stagnant" groundwater samples from the Westbay* ports on pages 47 to 49 of this annotated transcript.*

CAB/Hoard: Well, discounting stagnation, all we can do is consider our own experiences. If you see clays in a stream and they'll settle on the rocks, to the rocks, and even flushing with regular stream later, those clays are still there. Do you understand what I'm trying to say?

LANL/Nylander: I understand what you're saying.

CAB/Hoard: That you drilled 31,000 pounds of clay and if you spread it out and you've got it on the sub-surface rocks and it's highly adsorbent; now can you prove to me unequivocally that you know that the clays are gone enough so that it's not sequestering the cations?

LANL/Longmire: Yes, cause we had this problem at R22, well not really a problem but when they developed the well…

Gilkeson: Pat, Pat, R-22…

LANL/Longmire: Let me finish. I'm trying to give an example for…

Gilkeson: It's the wrong example.

LANL/Longmire: No, you don't know what I'm going to talk about, Bob, let me finish.

Gilkeson: It's the wrong example.

LANL/Longmire: R-22, there was bentonite, bentonite was used as part of the well construction, as part of the seal, that bentonite is the same bentonite that they use during drilling. That water that was coming through had very high sodium, very high sulfate, very high natural uranium and so if you have say, you know, a well where they used bentonite mud, the chemistry is going to change where you can say, there's going to be higher sodium because a lot of these are sodium-based bentonites. And so there are chemical tests, if one understands the chemistry of you know, of the clays that are used and what the water chemistry is, Dorothy, and you can see there was a change. And this one screen or screen 3 in R-22 is cleaning up. The sodium levels are dropping off and your natural uranium levels are dropping off so there are ways to evaluate it.

CAB/Hoard: The natural uranium should be going up.

Gilkeson: I'm sorry.

LANL/Longmire: No.

Gilkeson: I'm sorry, Pat but I'm going to have to-

LANL/Longmire: No, it's in the drilling clay, Dorothy. It came from Wyoming that way.

CAB/Hoard: Okay, Okay.

LANL/Longmire: Yeah and I took that so seriously that I had this TIM's anaylsis done, the state of the art analysis where you're literally measuring atoms of uranium-235 to 238 and it came dead on with a natural uranium distribution and because the water was cleaning up in the concentrations over time, the sodium, the uranium, sulfate had decreased so in that case, we were able to evaluate how the clays can affect chemistry.

Opinion of Mr. Gilkeson:
It is very important to understand that the observed change in chemistry for the quarterly samples collected from screen no. 3 in well R-22 indicates that the well screen is contaminated with improper placement of backfill materials. The chemistry indicated a need for additional development activities. LANL did not perform any additional well development. I disagree with Dr. Longmires clain that the quarterly chemical data shows that the screen is "cleaning up". In addition, the TIMS analysis is not definite proof that the bentonite clay used for sealing the borehole is the source of the high levels of dissolved uranium in groundwater for the first quarterly sample collected from screen #3.

Gilkeson: Are you seeing that same chemistry in these wells that are completed with bentonite clay muds? There was a great --

LANL/Longmire: Well, R-16, I...

Gilkeson: --entrainment of muds out into the aquifer. Are you seeing the modified chemistry there, are you seeing the high sodium...?

LANL/Longmire: With the R-16, Bob, I haven't had a chance to look at those data. We just stated sampling.

Gilkeson: Okay. That's right so anyway, I'm sorry I interrupted you, but we need to keep very separate the discussion of wells installed in bentonite clay mud bore holes and the wells installed with the polymer-based drilling fluids and what Dorothy was talking about was the bentonite clay muds with the mud rotary drilling methods.

LANL/Longmire: Right. In my example was, you use the same mud for the sealant and that was used at R-22, they used it at all the wells that separate the screen and because I haven't had a chance to look at the R-16 chemistry, that chemistry would be identical to what Dorothy is talking about.

Opinion of Mr. Gilkeson:
Dr. Longmire's discussion of well R-22 has no relationship to the removal of trace levels of radionuclide contaminants from the groundwater samples collected from well R-16 where the aquifer strata is invaded by a large quantity of bentonite clay. Dr. Longmire did not answer Mrs. Hoard's question –

"now can you prove to me unequivocally that you know that the clays are gone enough so that it's not sequestering the cations?"

The properties of bentonite clay for preferential removal of trace radionuclide contaminants from groundwater are described on pages 5 to 6 of this annotated

transcript. The LANL monitoring wells installed in mud rotary boreholes where the aquifer strata are invaded with bentonite clay will not provide valid knowledge for many radionuclide contaminants. For these wells, LANL will be relying on very low levels of tritium as "proof" that the radionuclide contaminants are not present.

CAB/DeLong: Mr. Timm, do you have a comment or question?

CAB/Timm: Yeah, I'm being patient here. I have two, basically two questions, ones for Bob (Gilkeson) and ones for the LANL. Bob, you're saying that the wells shouldn't have been put in that way. How would you do it? That's yours. And, the second is to LANL, and LANL knows the limitations of what they did and sounds like they got a program to track it and maybe improve upon it so I might get that response. How would you do it differently, going forward? You said there are a lot of holes to put in and they're expensive and from LANL's perspective, what are they going to be doing differently.

Gilkeson: I would use casing advance and air rotary, dual reverse casing advance drilling method using lubricants on the outside of the casing to drill through the unsaturated zone and if you know that you're going to a specific depth in the regional aquifer, it would be possible to use those lubricants, the bentonite clay muds as a lubricant on the backside of the casing down to a depth that's probably not closer than a hundred feet to the depth where they're going to install screened intervals, something like that. I would not use drilling fluids or bentonite clay muds in the aquifer strata where I'm installing well screens. I simply would not do that for most locations at the Los Alamos National Laboratory where there is a concern for the detection of metals or radionuclides - radionuclide contaminants that have metal properties.

CAB/DeLong: Okay, we've got about...I want to keep this to about 10 more minutes, so I'm going to let you answer that question and then we're going to have final words from each side and then we've got some other business we have to tend to, so go ahead.

Gilkeson: This is going to require another meeting.

CAB/Delong: Possibly.

LANL/Nylander: Chris (Timm), my response is that Bob's answer is the same answer that he provided us back in 1996, 1997 timeframe when he was advising us on how to drill the characterization wells for this Hydrogeologic Workplan. That was his recommendation based on the very purist attempt to not alter the natural environment and that's how we started the program out with the first well, R9, and over the course of some twenty-three regional wells that we've installed, we continue to favor that method. In fact, early on, we even brainwashed, if I can use the expression...

***Opinion of Mr. Gilkeson**: None of the LANL monitoring wells have been installed with **"the very purist attempt not to alter the natural environment"** that is espoused by Mr. Nylander. For all of the LANL monitoring wells, including even well R-9. drilling into the aquifer strata was done with biodegradable drilling fluids or bentonite clay muds. The boreholes for LANL monitoring wells R-9 and R-12 were drilled from ground surface through the vadose zone to the top of the regional aquifer with the dry air rotary casing advance drilling method. However, LANL then used biodegradable drilling fluids for the drilling in the regional aquifer strata where the well screens were installed.*

CAB/Timm: the casing advance air rotary ....

LANL/Nylander: I had kind of brainwashed our own External Advisory Group by convincing them that we really wanted to take this purist approach and for the reasons that we stated, it was advantageous. They certainly concurred and some of the language that Bob has extracted from their reports follows along that line. Obviously, there are good technical reasons to avoid drilling fluids; however, as we progressed in the first two or three wells, we realized the casing advance was extremely time consuming, extremely expensive and our well costs were more than double what we had budgeted for and we began to work with the regulator to look for other drilling methods that could help us to get good data quality objectives and yet speed the process up and actually gain some efficiency on costs. Over time the program evolved to the point where the regulators agreed our program was too costly, too slow and they realized that they were approving mud drilling and fluid drilling and foam drilling in other parts of the State and that it was typical for RCRA permitted wells to use those kinds of drilling techniques. Regardless, of what the guidance document said.

CAB/Timm: Is there a difference in contaminants?

LANL/Nylander: No, it's not a difference in contaminants, it's just basically...

CAB/Timm: Is it okay to use it, maybe for a landfill as opposed to...?

Nylander: If you do the drilling with fluids and foams in the right technical manner and you do a thorough job on development, you will minimize the negative impacts on the aquifer and over a period of time and it can be very short, you will get back to an equilibrium with the natural system. Whatever drilling fluids are left in the ground that you can't recover, and you could never recover 100% of them. I mean they use these fluids for municipal well drilling all over the world and you never get back 100% but ultimately whatever little residual is left, is exhausted. It's basically whatever cation exchange capacity it has, it gets exhausted. And it does break down and it does flow and move eventually and so it's a matter of time and so that's why we negotiated with the regulator to actually delay some of our initial sampling events so that we gave the aquifer time to come back to some sort of equilibrium and we actually preferred a

lengthy delay after the well was drilled before we took the first samples. Again, trying to minimize the negative impacts on our result so the regulator came full circle and basically said, it's okay for you to use all these different methods and it was in compliance with RCRA and in compliance with our Permit and so that's where we are today.

Opinion of Mr. Powell, the geochemist on the LANL External Advisor Group.

"Charlie's defense in the (above) transcript was pretty much what we were told. I kept asking them how it would be less expensive to drill monitoring wells cheaper and faster if they might never give reliable information. Why bother to drill them at all then? Clearly they did not want to hear that. Maybe that's why we haven't been back for 2 years. I notice he compares the approach to drilling water supply wells which, of course, have a totally different purpose and absolutely nothing to do with monitoring wells."

Opinion of Mr. Gilkeson:

Response to the above presentation by Mr. Nylander: The nature of the contamination that must be monitored is an important factor in the decision of the drilling method that may be used for installing a monitoring well. The need to monitor for extremely low levels of radionuclides prohibits drilling procedures that cause the invasion of the aquifer strata with biodegradable polymer-based drilling fluids, biodegradable foams, and bentonite clay muds.

The cation exchange capacity of the invaded fluids does not become exhausted. The preferential removal of trace radionuclide contaminants from groundwater by bentonite clay is described on pages 5 to 6 of this annotated transcript. The polymer-based drilling fluids have sorption properties for many contaminants that will remain after the observed "breakdown" of the organic fluid component of the drilling fluids. The sorption properties are described on page 19 of this annotated transcript. In addition, the chemical processes that accompany the biodegradation of the organic component of the drilling fluids and foams result in the formation of "fresh coatings" of iron precipitates on the aquifer strata, and even on the filter pack sediments. The fresh coatings are stable in the natural oxidizing groundwater that will eventually return to the aquifer strata that surrounds the screened intervals. The "fresh coatings" have sorption properties to remove the trace radionuclide contaminants from groundwater.. The chemical processes that form the iron coatings on the aquifer strata are described on pages 20 to 22 of this annotated transcript.

Mr. Nylander acknowledges the importance of doing thorough well development to remove the drilling fluids from the aquifer strata that surrounds the screened intervals. However, the required removal of the drilling additives was often not performed. The fact that the physical design of the LANL monitoring wells prevents the removal of large volumes of drilling fluids is explained on page 31 of this annotated transcript. In addition, see the discussion concerning the poor development of LANL monitoring wells on pages 30 to34 of this annotated transcript. The drilling fluids and bentonite

clay muds that are not removed by well development do not appreciably move away from the impacted strata by the natural flow of groundwater. It is important to collect samples for the analytical suite immediately after the well development activities to assess the success of the well development for removing the drilling fluids.

THE HIGH COST OF AIR ROTARY CASING ADVANCE DRILLING FOR LANL MONITORING WELLS R-9, R-12, AND R-25

I was hired as a consultant to design the drilling methods for the data requirements of the LANL Hydrogeologic Workplan. The workplan required an in situ characterization of the thick vadose zone and the regional aquifer. The in situ characterization required the use of dry air rotary drilling methods. The objective of the Hydrogeologic Workplan was to characterize the in situ moisture content profile of the unsaturated sediments and rock strata in the vadose zone, and the identification of perched zones of saturation To do this characterization, the boreholes for the first two monitoring wells, R-9 and R-12 were drilled with dry air rotary methods through the entire thickness of the vadose zone into the top of the regional aquifer. The dry drilling through the vadose zone greatly increased the cost for the boreholes as compared to drilling through the vadose zone with the use of drilling fluids on the backside of the drill casing. An additional objective in the first two boreholes was to seal perched zones to prevent the downward flow of groundwater from any perched zone to the regional aquifer. The perched zones were sealed with the installation of telescoped drill casings at an additional cost.

- ***The Use of an Inefficient Air Rotary Drill Rig for Wells R-9 and R-12***

An additional problem with the drilling at R-9 and R-12 was the use of an air rotary drill rig with a short drill mast and single-rotation drill head that did not have the optimum power and design for the depth requirements to drill into the regional aquifer. This air rotary drill rig was part of an earlier contract for the LANL Environmental Restoration Project where the drilling was not to the depth required for the installation of monitoring wells in the regional aquifer. LANL had not established a new drilling contract with the optimum drilling equipment by the time that drilling activities for the Hydrogeologic Workplan had to begin. The drill rig used for wells R-9 and R-12 did not provide efficiency for drilling and management of the long strings of telescoped drill casings.

- ***The Use of an Inefficient Air Rotary Drill Rig for Wells R-9 and R-12***

An additional problem with the drilling at R-9 and R-12 was the use of an air rotary drill rig with a short drill mast and single-rotation drill head that did not have the optimum power and design for the depth requirements to drill into the regional aquifer. This air rotary drill rig was part of an earlier contract for the LANL Environmental Restoration Project where the drilling was not to the depth required for the installation of monitoring wells in the regional aquifer. LANL had not established a new drilling contract with the optimum drilling equipment by the time that drilling activities for the Hydrogeologic Workplan had to begin. The drill rig used for wells R-9 and R-12 did not provide efficiency for drilling and management of the long strings of telescoped drill casings.

- ***Air Rotary Casing Advance Drilling at LANL Monitoring Well R-25***

I worked with the drilling contractor, Dynatech, to design a custom-built dual rotation air rotary drill rig for drilling with telescoped casing advance for the installation of monitoring wells in the regional aquifer beneath LANL. Monitoring well R- 25 was the first well that was installed with the dual rotary drill rig. LANL and DOE are presenting incorrect information on the cost performance of the air rotary casing advance drilling method at well R-25. The dual rotary drill rig advanced telescoped drill casing to a total depth of 1942 ft below ground surface (bgs). The water table on the regional aquifer was at a depth of 1286 ft bgs; drill casing was advanced a distance of 656 ft into the regional aquifer. The three strings of telescoped drill casing were retracted from the borehole during the construction of a multiple-screen monitoring well with nine screened intervals.

- ***The high costs of monitoring well R- 25 were because:***

1. *The first string of drill casing was drilled from land surface to a depth of 588 ft without the use of lubricating agents in the annular space between the drill casing and the borehole wall. The dry drilling was performed to meet the requirements of the Hydrogeologic Workplan for in situ characterization of the vadose zone. The drill casing became bound up (stuck) in the dry borehole and a considerable cost was involved in activities to free the casing.*

2. *There was a large cost at well R-25 because there were incidents of the drilling contractor (Dynatech) dropping drilling materials in the R-25 borehole during the activities to install the backfill materials around the monitoring well. Long small diameter, hollow pipes (tremie lines) were used for the controlled injection of the backfill materials. Long lengths of tremie lines were dropped on two occasions. On one occasion Dynatech dropped a double string of tremie lines into the backfill materials. The retrieval of the dropped lines was at a high cost. All of the dropped tremie line was not recovered. The presence of unrecovered tremie line in the backfill materials is one reason for NMED's instruction for LANL to replace well R-25. On another occasion, Dyanatech dropped an L-shaped steel rod into the monitoring well. The rod lodged cross-wise above one of the screened intervals. The time required for retrieval of the steel rod was an additional cost.*

3. *During the installation of the individual sections of stainless steel casing and screen into the borehole, it was discovered that the threaded connectors did not easily screw together. The manufacturer had not welded the threaded connectors on the well casing and screen in true alignment. So, force was used to screw the casing and screen sections together. A long breaker bar was sleeved over the handle of a pipe wrench and three people operated the breaker bar to screw the damaged threaded connectors together. The force used to attach the threaded connections damaged the strength of the connection. I was away from LANL when the decision was made to use force to attach the threaded connections. After the placement of the backfill materials and retraction of the drill casing, a video log inside the monitoring well showed that the threaded connections had failed at the top of two of the screened intervals and there was collapse*

damage to the two screens. The remedial measures to repair the damage were at a high cost. The damage to the well screens is an additional reason for NMED's decision for LANL to replace well R-25.

I disagree with the finding of NMED for the replacement of LANL monitoring well R-25. The necessary study of this well has not been performed to determine whether the discrete screened intervals in the monitoring well will provide representative samples of groundwater for the contaminants of concern. An activity that may be required at well R-25 is properly performed well development for the discrete screened intervals to improve the hydraulic communication with the aquifer strata.

Besides wells R-9, R-12, and R-25, there are many other LANL monitoring wells that were installed in boreholes drilled with the air rotary casing advance drilling method. A partial list of the wells is on page 15 of this annotated transcript. The cost of the air rotary casing advance drilling method should be reviewed by a study of all monitoring wells where the drilling method was used.

CAB/DeLong: Did he answer your question?

CAB/Timm: Yeah

CAB/DeLong: Okay. About kind of what's going to ...?

CAB/Timm: Just _____ the last person that signed in.

DOE/Whitacre: Can I talk just a little bit on the drilling process and what we're doing up there and the approaches. We realized the idea on the drilling here is to try to minimize the effects on the aquifer to collect data, putting up a well, a monitoring well. What we hoped to use in the future for RCRA monitoring, it's our requirements. So we're very sensitive to the different effects of drilling, fluids and additives. The way we pretty much approach drilling now is a gradational approach. We have a driller and a contractor to do our requirements for the well. And generally the way it's been going in the past, the driller has been going strictly with air, air rotary. We drill with a tricone bit with air coming up, blow the cuttings. Got to introduce air, water, and fluid, something to move the cuttings out so you can drill down so we go that approach which also helps with the identification of perched zones. You know, you can tell when you're drilling dry but as we get deeper or hit the basalts or more consolidated zone, we'll go to an air hammer. It's a down hole hammer, they've got power that will chop through those hard basalts. But sometimes we break through the basalt and go back to a rotary because a hammer won't work good on clay. All the energy is dissipated in the clay. Now as you're drilling, you have material coming up above and starts to slough in, sticking the hammer or pipe or the tool, you may add water, potable water to help lubricate and move the cuttings away from the drill bit and then you may go a thin foam mixture. The foam is a bentonite-based fire fighting foam and the idea behind the foam is to allow enough

back pressure so that the cuttings can flow up inside the bore hole, the foam does not penetrate very far into the formation. And generally, we have been very successful in drilling to the top of the regional aquifer and maybe a 100 feet below for our single completion screens using that methodology. Now in certain situations when you are drilling and you have area full of fine-grained sand like a sandbox. If you've been to the beach and start dealing with sand, you hit the water, what happens? That sand just keeps coming in, no matter what you do. You want to go – you know casing advance is a great method when it works, I'd say that we've stuck 2 or 3,000 feet of casing up in those wells trying to drill with casing advance. The problem is you drill down, the casing is stuck and you can't complete a well. You can't perforate it cause you got to use dynamite or something to blow the casing and then the state is not going to buy that.

CAB/Timm: This is using solid pieces of casing?

DOE/Whitacre: Yeah, there are lots of methods out there. You read the (RCRA) technical enforcement guidance document and there are advantages and disadvantages to every method. US EPA doesn't say you can't use this or you have to use this. You leave it up to the experts and these are the requirements that we have.

CAB/Hoard: Do you have wells drilled that didn't use either the clay or the drilling fluid? My question is, do you have data with the top of the aquifer with contamination within so to compare with the data that you're pulling out of these monitoring wells now.

Opinion of Mr. Gilkeson:
The best comparison is between the water collected from the open borehole and the water collected from the same aquifer strata in the screened interval that is impacted by the biodegradable drilling additives. Gilkeson (2004) describes the validated detection of plutonium-238 and high levels of dissolved uranium in the borehole for monitoring well R-9 compared to the "not detected" values in groundwater samples collected from the screened interval in the same aquifer strata in monitoring well R-9i. In addition, there are many examples of anomalously low concentrations of dissolved uranium in the screened intervals that are impacted by the presence of the biodegradable drilling fluids and foams. The unreasonably low dissolved uranium concentrations in the impacted screen intervals in monitoring wells R-7 and R-22 are described on pages 22 to 23 of this annotated transcript.

LANL/Longmire: Well R-9 in Los Alamos Canyon. The first well we drilled…

Opinion of Mr. Gilkeson: *All of the LANL monitoring wells, including well R-9 were drilled in the aquifer strata where the sell screens are installed with biodegradable drilling fluids or bentonite clay muds.*

DOE/Whitacre: We got all our test wells and everything else in the ….

LANL/Longmire: The old test wells that were drilled (with the) cable tool drilling method), Dorothy, so there are wells that we can compare.

Opinion of Mr. Gilkeson:
Most of the old test wells were installed with long well screens (perforated iron and galvanized pipe) that have sorption properties for the radionuclide contaminants of concern. In addition, the long well screens result in dilution. The old test wells are of limited value for knowledge of many contaminants in groundwater, especially contaminants like strontium-90, the actinides, and perchlorate. The old test wells as described in LANL (1995) are not RCRA-compliant monitoring wells

CAB/Whitacre: And, I guess we're at the point where we want to make our point real quick, then you guys would have it, is so that there are different kinds of methods – you have to have different methods available to drill. it's a complex site. There's no silver bullet that's going to be perfect, you have trade offs. You know, you gotta drill the hole to collect the data to install the well. I think Pat has a good enough information as to what the background chemistry of the regional aquifer should be and we can use those as guidelines. I think the issue is the drilling method, I think you need to look at the quality of the water sample collected from the well. It's the proof of the pudding. You can poke holes in whatever method you want. R-25, you had casing advance, we had cross-contamination, I mean, it wasn't the silver bullet either. We stuck casing elsewhere. You have to use mud; you have to use foam, so that's what I want you to keep in mind. You know, there's no silver bullet. You use a gradational approach on the drilling and the driller, who is the expert saying, I have these problems, this is what we've got to do, you know. You can sit back here and say, do this and do that.

Opinion of Mr. Gilkeson:
It is important to understand that the air-rotary casing-advance drilling method was successful for drilling the borehole for monitoring well R-25 to a depth of 1942 ft bgs, and the casing advance drilling method is not responsible for the cross-contamination in the multiple-screened monitoring well. The cross-contamination in well R-25 is because of the decision by LANL to install a multiple-screen well in both the perched aquifer that is contaminated with high explosives and the regional aquifer. I advised LANL to install separate monitoring wells in the perched and regional aquifer. After the discovery of the thick perched zone with high explosive contamination, I advised LANL to complete the R-25 borehole as a monitoring well installed in the perched zone and to install cemented casing to seal off the perched zone in a new borehole that would be drilled into the regional aquifer. LANL did not follow my advice.

I agree with Mr. Whitacre's comment-

"I think the issue is the drilling method, I think you need to look at the quality of the water sample collected from the well. It's the proof of the pudding."

My analysis of the water quality data from many LANL monitoring wells installed in boreholes drilled with the biodegradable drilling fluids and foams shows that there is serious, possibly irreparable damage to many screened intervals, and the cause of the damage is the drilling method. Furthermore, the preferential sorption properties of bentonite clay for trace radionuclides is well understood and, therefore, the mud-rotary drilling method with bentonite clay muds is inappropriate for LANL monitoring wells. The driller is not the expert to be aware of the important effect of various drilling methods on the data quality requirements for the groundwater samples that are collected from the installed monitoring well.

CAB/Timm: So the future doesn't say you're going to use bentonite fluids in every well. You start with the best approach you can.

DOE/Whitacre: With the driest approach with least impact and as you're drilling and you're having problems....

LANL/Nylander: Things happen so you have to...

DOE/Whitacre: Right. And what we have on hand are different drilling methods, we have air, rotary, air casing. We have a stratex, which is a casing advance system. We have dual tube rotary. You know, we have a lot of different tools in the tool box and we have mud rotary. You know mud rotary's kind of the silver bullet. Sometimes, the holes collapsing on you and you've got material flowing in and you can't control it, you gotta stick your whole drill pipe ? off, you go to mud rotary, if you have to. I mean, that's kind of like last resort!

Opinion of Mr. Gilkeson:
I disagree with the drilling strategy described by Mr. Whitacre. It is important to note that the record in LANL reports attests to the fact that biodegradable drilling fluids or bentonite clay muds were used during drilling into the aquifer strata where screened intervals are installed for the entire population of LANL monitoring wells that have been installed for the LANL Hydrogeologic Workplan.

The mud-rotary method is not a "silver bullet" and does not belong in the "tool box". The LANL Well R-14 Completion Report describes a borehole where the mud rotary method was an expensive failure. Large volumes of bentonite mud and large volumes of borehole stabilization materials would not maintain an open borehole. As a last resort, the air-rotary casing-advance drilling method was used to install the multiple-screen monitoring well in the mud-rotary borehole.

The objective of monitoring well R-14 is to investigate the presence of contamination in the regional aquifer due to the history of liquid effluent released from the TA-35 and TA-50 radioactive liquid waste treatment plants, and to monitor for contamination in the future. The monitoring well does not provide valid knowledge of the presence of many

radionuclide contaminants in groundwater. The real costs on monitoring well R- 14 are not known as this well is irreparably damaged and requires replacement.

The drilling method that I recommend is air-rotary casing-advance with the use of an appropriate drilling fluid on the backside of the casing for lubrication. Dry air rotary drilling can be performed in advance of the drill casing to explore for perched zones and to collect information on the in situ moisture of the rock and sediments. It is important to avoid using drilling fluids, foams, and bentonite clay muds when drilling in the aquifer strata where screens are installed.

CAB/DeLong: Pat, are there a lot of differences between these bentonite drilled wells and some of these older wells?

LANL/Longmire: Well, my experience so far has been with the organic-based mud, what's called EZ-MUD*, in R-16 where we used the bentonite, I haven't had a chance to look at the data yet but I know enough of the chemistry of the drilling fluids and of the natural setting to sort out and say, Oh, you know, this is cleaning up. And each little screen is different depending on how much fluid was used and how well it was developed or cleaned up but on the whole, all these screens that are affected by residual drilling fluids, they are cleaning up. And, you know, it's really a trade off, you know, I hammered and I said, look, we can't use the drilling fluids if we want to get the best data. But, you know, when you have a budget and everybody beats up on you because you have exceeded the budget, you're taking all this time, everybody beat up on us on R-9. Uh, you know, you've got to realize that there are compromises for the technical data approach, hydrologic data or chemical data so designing these wells for 50 years, you're hoping that, okay, you can get the drilling fluids out and if you have a single screen that within six months or a year period for the single screen, the well, the water chemistry that's coming out of the well represents pre-drilling chemistry.

Opinion of Mr. Gilkeson:
I disagree with the interpretation of Dr. Longmire that the quarterly chemical data shows that screened intervals impacted by biodegradable drilling fluids and foams are "cleaning up". It is important to understand that LANL did not perform thorough well development activities to remove the entrained drilling fluids that are causing a large change to the chemistry of the impacted aquifer strata. The impacted screened intervals are not capable of "self-cleaning". Any screened interval that Dr. Longmire describes as "cleaning up" is probably irreparably damaged for the detection of trace radionuclide and metal contaminants. I describe the chemical processes that cause irreparable damage to aquifer strata that are invaded with biodegradable polymer-based drilling fluids and biodegradable foams on pages 19 to 22 of this annotated transcript.

I disagree that economic costs over-ride the DOE and RCRA requirements for the installation of monitoring wells with high quality on the Laboratory facility. The DOE

and RCRA requirements are described on pages 9 through 12 and page 17, respectively, of this annotated transcript.

CAB/DeLong: I want to wrap this up as much as I can. I'm going to help and give Dorothy a go ahead and then I want to offer a couple of alibis to folks.

CAB/Hoard : My real concern as a member of the CAB is, are you presenting data from these wells as clean data that's not compromised?

LANL/Longmire: The data, you read these reports, Dorothy, I spent a lot of time on the effects of the drilling fluids. Also that, like R-7, the tritium concentrations were very low. We know a lot of tritium was discharged in Los Alamos Canyon. My professional opinion is that the regional aquifer at R-7 is not contaminated because tritium moves so much faster than strontium or uranium or anything else that was discharged. So, you know, there are wells like R-15, R-9 that produce better data – the single screen wells. In the short term because they cleaned up faster. The data that I'm presenting in these reports that if there was contamination present in the case for strontium-90, the drilling fluids would increase the concentration of strontium-90. It wouldn't decrease it and so, if indeed there was strontium-90 contamination at the regional aquifer at R-7, the effects of the residual drilling fluids there - They're (strontium-90) not masked by the drilling fluids and that's because if Strontium was there, it would desorb because the part of absorbing minerals are dissolving because of the residual drilling fluid and there's not enough strontium in the water to precipitate out the strontium and I have done the calculations in these reports, so, you know, there are, on the whole, with looking at tritium and we have wells that have residual drilling fluid that we still see tritium. So, we know there is contamination and we're planning on monitoring these wells for 50 years and on the whole, the screens that have residual fluids are cleaning up.

Opinion of Mr. Gilkeson

I disagree with Dr. Longmire's interpretation of the chemical data for the quarterly samples collected from LANL monitoring well R-7. His statement that the polymer-based EZ-MUD drilling fluid would cause an increase in dissolved strontium-90 is contradicted by the LANL report that describes the drilling fluid as having sorption properties to remove strontium-90 from groundwater. I describe the impact of the chemistry of the drilling fluids on the aquifer strata at monitoring well R-7 on pages 19 to 22 of this annotated transcript. My analysis is that the altered chemistry of the aquifer strata that surround the screened intervals in LANL monitoring well R-7 are irreparable damage that prevents knowledge of the presence of contamination in the perched aquifer and the regional aquifer.*

In addition, my review of the LANL Geochemistry Reports has determined that the methods that are used to collect groundwater samples from the multiple-screened wells are inappropriate for measurement of unstable properties of the groundwater and for collection of samples for the analytical suite.

- ***LANL's procedures for collecting groundwater samples from the Westbay* sampling systems installed in the multiple-screen monitoring wells***

The methods that LANL presently uses for collection of groundwater samples from the multiple-screen 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.

Presently, LANL does not use a low-flow pump system to collect groundwater samples from the multiple-screen monitoring wells. Instead, a small 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 EAG (2001) recognized the need to use a low-flow pumping system for the collection of groundwater samples from the 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 sandpack/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 groundwater (e.g., well R-7 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.

Nylander: Pat, you did a survey on all the screens, there was something like 47 or 53 screens and out of that, there were only three or four that were still comprised in some way?

Pat: That's right, there was where we knew that say, in Sandia Canyon, nitrate was discharged there, that the nitrate was affected by the residual drilling fluid. I do agree generally with Bob on the uranium, that there are lower concentrations of uranium but we still have ways to test to see if that's laboratory derived uranium or natural, even at the levels that are...

Opinion of Mr. Gilkeson:
I disagree with the LANL analysis that only three or four screened intervals in the entire set of LANL monitoring wells are "compromised in some way".

- ***Impacted screened intervals in monitoring wells installed in mud rotary boreholes***

The use of the mud rotary method with bentonite clay drilling muds is unacceptable for the LANL monitoring wells installed at locations where radionuclides at extremely low levels are contaminants of concern. There is consensus in the technical literature that the mud rotary drilling method should not be used to install monitoring wells where the contaminants of concern include radionuclide contaminants and heavy metals (Classen 1982, Ericson et al 1985, Gibbs and Jennings 1987, RCRA Guidance 1992, The Australian Drilling Manual 1996, and the LANL EAG, 1999, 2002). The preferential sorption of radionuclide contaminants by bentonite clay is described in the chemistry text books by Stumm and Morgan (1996) and Langmuir (1997). The sorption properties of bentonite clay are summarized on pages 5 to 6 of this annotated transcript.

I have not reviewed all of the LANL well completion reports for wells installed in mud rotary boreholes. However, the reports for monitoring wells R-14 and R-16 document the invasion of a large amount of unrecovered bentonite clay into the aquifer strata where the well screens are installed; greater than 28,000 pounds of bentonite clay at well R-14 and greater than 31,000 pounds at well R-16. There are two irreparably damaged screened intervals in each of these wells. An incomplete list of LANL monitoring wells that are installed in mud rotary boreholes where there is a concern for radionuclide contaminants includes R-8, R-14, R-16, R-20, R-23, and R-32. I do not know the total number of impacted screened intervals in the monitoring wells but my preliminary analysis is that the number is greater than ten. All of these mud rotary wells may require replacement.

- ***Impacted screened intervals in monitoring wells installed in boreholes drilled with biodegradable drilling fluids and foams***

I disagree with the interpretation of Dr. Longmire that the screened intervals impacted by biodegradable polymer-based drilling fluids are "cleaning up" and will eventually provide groundwater samples that are valid for knowledge of the presence of many radionuclide contaminants. There is consensus in the literature that biodegradable drilling fluids should not be used in the boreholes for monitoring wells when there is a concern to monitor for the trace radionuclide and metal contaminants (Ericson et al 1985, Gibbs and Jennings 1987, and RCRA Guidance 1992).

There is also consensus in the literature that when biodegradable fluids are used, it is essential to carefully develop the screened interval to completely remove the drilling fluids from the aquifer strata (Classen 1982, Gibb and Jennings 1987, Puls and Barcelona 1989, and RCRA Guidance 1992). This is because of the sorption properties of the polymer-based drilling fluids for the trace radionuclide contaminants (LANL, 2000). In addition, this is because of the chemical reactions that result when the biodegradable drilling fluids are not removed. The chemical reactions increase the sorption properties of the aquifer strata for many of the radionuclide contaminants. I describe the chemical processes on page 19 to 22 of this annotated transcript. The change in chemistry in the groundwater samples that Dr. Longmire uses as evidence that the impacted screened intervals are "cleaning up" is actually evidence that the well development activities did not remove the biodegradable drilling fluids and that chemical processes that cause irreparable damage to the screened interval for collection of valid groundwater samples have occurred, and are still occurring for many screened intervals in the LANL monitoring wells.

It was improper for LANL to use biodegradable drilling fluids and foams in the boreholes for the monitoring wells. Furthermore, when the biodegradable fluids and foams were used, the proper procedure was to quickly and carefully develop the screened intervals and then immediately collect a groundwater sample for the analytical suite and for constituents that are sensitive to the presence of residual drilling fluids. Additional well development activities were required if the analyses determined that the drilling additives were still present. The impacted screened intervals do not "self clean". LANL has not performed the required well development activities for the impacted screened intervals. The observation for succeeding quarterly samples that the levels of dissolved iron, total organic carbon, hydrogen sulfide, and ammonium are declining and that an oxidizing chemistry is returning to the groundwater is not an indication that the aquifer strata in the impacted zone surrounding the screened interval are "cleaning up". Instead, the observed change in chemistry is evidence of irreparable damage to the screened interval for valid knowledge of many contaminants in groundwater.

I have not reviewed the LANL reports for all of the monitoring wells that are impacted by the residual biodegradable polymer-based drilling fluids and biodegradable foams.

However, my preliminary review has established that some screened intervals may be irreparably damaged in the following list of LANL monitoring wells: R-7, R-9i, R-12, R-13, R-19, R-21, R-22, R-31, CDV R-15-3, and CDV R-37-2. The total number of irreparably damaged screened intervals in this list of monitoring wells may be greater than 15.

- ***Impact of Long Well Screens on Collection of Representative Groundwater Samples***

An additional reason why some LANL monitoring wells are not providing representative groundwater samples is because of the installation of long well screens installed across the top of the regional aquifer. The long well screens may cause dilution and in addition, the installation across the top of the water table may cause changes to the chemistry of water samples due to aeration, especially since high-flow submersible pumps are installed in the monitoring wells (EAG, 1999). A finding in Gilkeson (2004) is that the long well screen in monitoring well R-15 is not providing representative groundwater samples because of dilution.

My preliminary analysis shows that the assertion by Mr. Nylander and Dr. Longmire that the total number of impacted screened intervals is only three or four is incorrect. My analysis is that the total number of irreparably damaged screened intervals may be greater than twenty five. In Gilkeson (2004) I recommend a review of all LANL monitoring wells by an external panel of experts. The assertion of Mr. Nylander and Dr. Longmire that only a few screened intervals are impacted by the drilling fluids and bentonite clay muds reinforces my recommendation.

CAB/Timm: Her question, I mean you've got all these different methods and you pick the one that's best for the situation and that's understandable.

DOE/Whitacre: We have multiple methods available.

CAB/Timm: Yes, Yes.

DOE/Whitacre: Depending on the borehole.

CAB/Timm: So the question is, do you have a document of protocol procedure, something within DOE/LANL that says, here's the pluses and minuses of each one (drilling method) with respect to the data (requirements) and here's how we can correlate one to another? Is there a report like that available? Because it would be a good thing to see, if it was.

LANL/Longmire: I think when we developed our tool box several years ago, we developed that method. We do have like a spreadsheet showing that.

DOE/Whitacre: The impacts and the advantages and the disadvantages--?-- which is based on the EPA--?--

CAB/Timm: Would you recognize, you know, you're looking at radionuclides and other stuff. I was just asking, I mean mud verses air verses water verses -?-

---?--- (Something about typical two, three – it is unintelligible)

CAB/DeLong: Okay, sir.

DOE/Taylor: Dorothy, I think, we don't want to leave an impression here with this forum that we have compromised data. We do have to make some compromises in the methods that we use, Tom's talking about that as well as Mr. Longmire. The concern I guess is whether we have representative data, whether we know the truth about what's going on in the aquifer.

CAB/Hoard: That's the one thing that we're concerned about.

DOE/Taylor: That's the essential thing. When we set up a well and we develop a well and whatever method we use, there's a finite amount of material that goes in there, correct? And you talk about there being a finite amount of what determines those sites that you'd have sites for adsorption that would have an affinity for contaminants that might somehow give you a jaded – some kind of jaded result. But at some point there, and I don't know what the history is, you know you guys can tell me when these wells were installed and when you first began sampling but at some point it would be a clear trend, right? If my thinking is off and that there's an infinite number of sites (adsorption sites) that contaminants have passed through the formation and (sorry about my hand) passed through the annulus there and around the screen, you know, a lot of that just makes sense to me that we start seeing an increased trend of contamination. Do we see that?

LANL/Longmire: Depends where you are. Uh, at R-12, it shows that the tritium concentrations are decreasing. R-15 in Mortandad Canyon shows perchlorate is increasing so it depends on where you drill the well relative to where the distribution of the contamination is.

DOE/Taylor: But for the rad, just speaking for rad --

LANL/Longmire: Well, see for the rad because of adsorption, what Dorothy's talked about, most of the – and we have thirty years of data showing this in the alluvial systems, most of the mass of the adsorbing radionuclides is still tied up in the shallow system –in the alluvium in Los Alamos Canyon and Mortandad Canyon. So, you know, it's very – and we do not see it because everytime we analyze for plutonium and

amerricium, even in the test wells, in the older wells that, you know, that they didn't use drilling fluids, we do not see a breakthrough of those adsorbing contaminants.

Opinion of Mr. Gilkeson: *The older test wells are not reliable for detection of the radionuclide contaminants. (See my comment on page 44 of this annotated transcript).*

DOE/Taylor: But on those that you did use the drilling fluids that are in question for this afternoon, do you see an increase over time in the radionuclides.

LANL/Longmire: Basically, because – no, we don't – and I don't believe they're there because the tritium concentrations are low and tritium is kinda running so fast, it's moving much faster than the radionuclide that …

DOE/Taylor: But on the other hand you were talking about that you guys delay this (sampling) as long as you can so as to allow the formation to equilibrate.

LANL/Longmire: From six months to a year.

DOE/Taylor: But if you didn't, would you expect to see some trend?

LANL/Longmire: Yeah.

DOE/Taylor: But over time, you're not seeing it long term? You plotted that on a graph, you say the change was either non-existent or very minimal?

LANL/Longmire: With the radionuclides, because most of them are non-detects.

DOE/Taylor: The answer already is a no. It just kinda reinforces --?—

Opinion of Mr. Gilkeson:
The above discussion between Mr. Taylor and Dr. Longmire concerning the "non-detection" of radionuclide contamination in groundwater samples from the impacted LANL monitoring wells and the trend in the contaminant data over time is a serious issue. The statement by the NMED on pages 19 to 20 of this annotated transcript show that NMED and the US EPA disagree with the arbitrary 3-standard deviation requirement of LANL for the validated detection of radionuclide contaminants. This issue is one of the reasons that I wrote Gilkeson (2004). The disagreement of NMED and US EPA for the LANL conservative 3-standard deviation requirement is the basis for the trend analysis in Gilkeson (2004) of the recorded strontium-90 data in the LANL well R-7 Geochemistry Report and of the recorded technetium-99 data in the LANL well R-22 Geochemistry Report. In addition, I maintain that LANL is disallowed the 3-standard

deviation requirement for "detection" because of the improper use of the biodegradable fluids and foams for drilling the R-7 and R-22 boreholes. An additional problem for screen #1 in well R-22 is that the improper drilling of the borehole allowed the in situ native groundwater at the top of the regional aquifer to drain down the open borehole. Nevertheless, the pattern of decline in the radionclide levels for the four quarterly samples from wells R-7 and R-22 is confirmation of the presence of the radionuclides in the collected water samples. In addition, the technetium-99 data for well R-22 include validated 3-standard deviation detection of the radinuclide in the first quarter samples.

A finding in Gilkeson (2004) is that strontium-90 contamination is present in the groundwater samples collected from the regional aquifer at LANL monitoring wells R-7 and R-15. The actual level of strontium-90 in groundwater beneath Los Alamos and Mortandad Canyons is not accurately known because of the improper installation of the two monitoring wells. The presence of strontium-90 contamination in the regional aquifer beneath the Laboratory facility is a serious issue because strontium-90 contamination is also detected in groundwater from Los Alamos County supply well Otowi-1 at a location downgradient of monitoring well R-7.

In addition, technetium-99 contamination is present in the regional aquifer beneath MDA G, the Laboratory's active landfill for low-level radioactive waste. Because of the improper installation of LANL monitoring well R-22, the level of technetium-99 at the top of the regional aquifer beneath MDA G is not known but a dilution calculation predicts that the level of dissolved technetium-99 is 125 pCi/L.

An additional important issue is the practice of LANL to delay the collection of groundwater samples from newly installed monitoring wells for a period as long as one year. This long period of time does not provide information on chemical processes that may be occurring to remove contaminants from groundwater because the monitoring well was not properly developed to remove entrained biodegradable drilling fluids and foams, and bentonite clays.. Of course, the improper construction of the monitoring well may also cause contamination to trend to lower values over time because of dilution. It is important to sample screened intervals for the chemical and radionuclide analytical suite immediately after well development activities are completed. If the analytical data show that the well is not sufficiently developed to remove entrained drilling fluids and foams, it is then essential to immediately perform additional activities to develop the impacted screened interval. Counter to the belief at LANL, the impacted screened intervals are not "self-cleaning".

CAB/DeLong: Okay, I really want to wrap this up. Matt?

DOE/Johansen: Briefly, the Regulator is very important. They've approved our path forward, our approach for drilling wells and they like it. --?-- In the past, for the wells that were drilled before this, there's one well (well R-25) they don't like. It was

drilled, using the approach that Mr. Gilkeson recommended so I'm not going to go back to that, it's not gonna work.

Opinion of Mr. Gilkeson: Mr. Johansen is wrong in his attitude toward the drilling method that was used for well R-25. Read my discussion of well R-25 on pages 41, 42, and 45 of this annotated transcript.

CAB/DeLong: You may have a quick couple of words and if you think you may want to come back and see us again. Oh sure.

Gilkeson: I'm not going to carry the responsibility for the problems at well R-25, so stop that story. And in addition, I am convinced that there is strontium-90 (and also perchlorate) contamination in the regional aquifer below Mortandad Canyon, at the location of well R-15 and the level of contamination there is not properly understood because of the improper construction of well R-15. It's a very large screened interval which is resulting in mixing with ground water over a great length of aquifer strata and what's important with the location of well R-15 is understanding contamination at the top of the aquifer.

I am convinced that there is strontium- 90 contamination below Los Alamos Canyon, at the location of LANL well R-7. I believe that the level of contamination is low because as Pat is saying, the tritium levels are low, so that's the good news. But, nonetheless, I am confident that a review of the analytical data shows the presence of low levels of strontium-90 contamination in the regional aquifer below Los Alamos Canyon and because of the improper construction of that monitoring well, an accurate understanding of the nature of contamination is not known.

In addition, I am convinced that there is technetium-99 contamination in the regional aquifer below the Laboratory's active radioactive waste landfill, Area G. A review of the analytical data in the well R-22 geochemistry report is evidence of the presence of technetium-99 contamination in the regional aquifer below Area G. The actual level to which contamination is present is not known because of the improper construction of LANL monitoring well R-22.

CAB/DeLong: We're going to have to wrap this up and I appreciate everybody's participation and Bob, we appreciate you coming by and talking to us, Thank You very much for initiating this discussion. I think we'll have to chew on this a little bit and decide if we want to know anything further. You know, have any further discussion or debate in a future meeting. Dorothy, is that accurate?

LANL/Nylander: I will say that since we haven't had ample time to review the full report (Gilkeson 2004), we will over the next few weeks, do a thorough job of reviewing and critiquing it. It's common to have professional differences of opinion. In my reading of the document, I think Bob has some inaccuracies and misunderstandings of a lot of

things - we hope to address those in a very professional and thorough manner and at some point when we have our analysis done, I'd be happy to share that with Bob. I would be happy to share it with the CAB.

CAB/DeLong: I don't think this is a done issue so we need to think about it and talk about it and try to ...

LANL/Nylander: I will say that I do believe that as a result of Bob's publication that it's behind a current on-going – (tape stopped)

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. "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. "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.

Los Alamos National Laboratory, 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.

LANL. 1995. Geologic and Hydrologic Records of Observation Wells, Test Holes, Test Wells, Supply Wells, Springs, and Surface Water Stations in the Los Alamos Area, LA-12883-MS. 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 Gound-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.

Appendix. Summary of articles concerning installation of monitoring wells in boreholes drilled with fluid rotary methods

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 QUICK 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 QUICK 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 limitd 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."

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 construction of most monitoring wells. See article 5 and the comment on construction of LANL monitoring wells that follows article 7.

Article A-9.

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 A-10.

"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."