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VALUE ENGINEERING STUDY

LOS ALAMOS NATIONAL LABORATORY

HYDROGEOLOGIC CHARACTERIZATION PROGRAM

OCTOBER 2001

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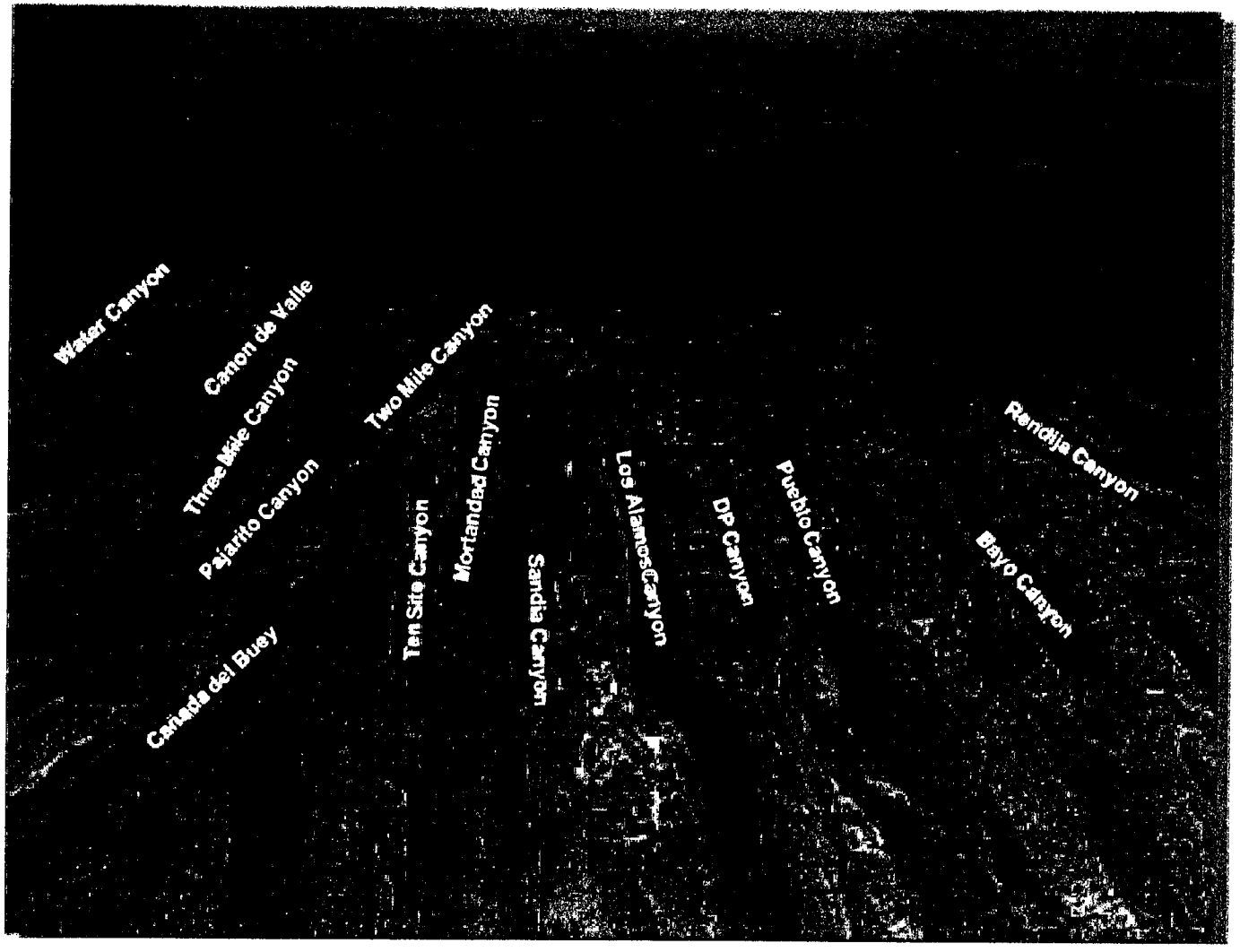

Aerial View of LANL with Primary Canyons Labeled

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CONCURRENCE:

Butt, Michael L.

James W. Mercer
Mercer, James W.

Russel W. Edge
Edge, Russel W.

Glenn Paulson
Paulson, Glenn

Tyler Gilmore 7/19/01
Gilmore, Tyler

Bob Ratzer
Ratzer, Erick R.

Stephen P. Hudson
Hudson, Stephen P.

Michael Space
Space, Michael

Dawn Kaback
Kaback, Dawn

APPROVED:

Neuscheler
Neuscheler, Philip E. - EM-6

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ACRONYMS

BCP	Baseline Change Proposal
CDM	Comprehensive Data Management
DOE	Department of Energy
DOE/AL	Department of Energy - Albuquerque Operations Office
DOE/EM	Department of Energy - Environmental Management
DOE/HQ	Department of Energy - Headquarters
DP-6	Defense Programs, Office of Project Management
DQO	Data Quality Objective
EAG	External Advisory Group
EM	Environmental Management
EM-6	Environmental Management, Office of Project Management
ER	Environmental Restoration
ERC	Environmental Restoration Contract
ERD	Environmental Restoration Division
FAST	Functional Analysis Systems Technique
FIMAD	Facility for Information Management, Analysis, and Display
GIS	Geographic Information System
GIT	Ground Water Integration Team
GW	Ground Water
GWPMP	Ground Water Protection and Management Plan
H&SP	Health & Safety Program
HE	High Explosives
INEEL	Idaho National Engineering and Environmental Laboratory
LANL	Los Alamos National Laboratory
LAAO	Los Alamos Area Office
NNSA	National Nuclear Security Administration
NMED	New Mexico Environment Department
O&M	Operations & Maintenance (a level of effort general contract)
PRS	Potential Release Site
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SOW	Statement of Work
SRS	Savannah River Site
TAs	Technical Areas
TQO	Total Quality Objective
UC	University of California
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VE	Value Engineering
Workplan	Hydrogeologic Workplan

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EXECUTIVE SUMMARY

At the request of the U.S. Department of Energy (DOE) Albuquerque Operations Office (AL), a Value Engineering (VE) Study was conducted for the Los Alamos National Laboratory's (LANL's) Hydrogeologic Characterization Program. The VE Study specifically focused on the hydrogeologic characterization of the Pajarito Plateau as performed by LANL.

The VE Study took place between April 30 and May 4, 2001. The VE Study Team was jointly sponsored by the following three DOE entities:

- The DOE/AL Environmental Restoration Division (ERD);
- The Office of Environmental Management (EM), Office of Project Management (EM-6); and
- The National Nuclear Security Administration (NNSA), Office of Defense Programs (DP), Office of Project Management (DP-6).

The VE Study's objective was to provide recommendations that could improve the Hydrogeologic Characterization Program. VE Study recommendations, if implemented, could result in over $10 million in savings, and avoid other significant costs. In recent years, increased costs and schedule slippage have resulted in significant impacts to the project, which is funded jointly by Environmental Management and Defense Programs. This fact, coupled with decreasing outyear budgets, makes a re-evaluation of remaining project activities prudent. This report presents both LANL and DOE with a realistic alternative to the most recent baseline change proposal. These recommendations can significantly improve the value of the Hydrogeologic Characterization Program, while maintaining the scientific integrity that has characterized LANL's efforts thus far.

Present activities within the LANL Hydrogeologic Characterization Program are based, in large part, on the Hydrogeologic Workplan (Workplan), which was approved by the New Mexico Environment Department (NMED) in 1998. A significant portion of the Workplan's characterization requirements are now finished. Based on this, the VE Study Team recommends that LANL prepare a comprehensive hydrogeologic report based on data collected to date. The VE Study Team is convinced that a complete analysis of the data collected to date, along with information obtained from other sources, may well demonstrate that characterization is sufficient to move the project from characterization to surveillance and allow planning and installation of a regional ground water monitoring network. While this is the VE Study Team's most significant recommendation, it will not require alteration of present regulatory mandates.

This VE Study Report is broken into five sections, along with several appendices. Section1.0 provides a brief summary of what Value Engineering is, the scope of this specific VE Study, and the methodology used to conduct the VE Study. Section 2.0 contains the VE Study Team's recommendation for installation of 10 strategically placed single screen monitoring wells for the regional ground water monitoring network. Simplification of well design and early installation of

the regional ground water monitoring network will result in cost savings and allow future resources to be redirected to other high priority Hydrogeologic Characterization Program activities, such as investigations of potential release sites (PRS).

The technical recommendations outlined in Section 3.0 concentrate on practical operations. These recommendations demonstrate means to decrease the cost of wells, reduce the cost of chemical analyses, minimize the time drilling rigs are on-site, and optimize the suite of geophysical logs used. The VE Study Team cites examples from similar programs.

Review of relationships with NMED and other stakeholders as recommended in Section 4.0 will improve chances of successful implementation of other recommendations. Specific recommendations describe methods to develop communications, collaborate on identifying deliverables, jointly prioritize data needs, and tailor communications for maximum impact.

Cost estimates are part of each recommendation in Sections 2.0 through 4.0. In Section 5.0, the VE Study Report describes the basic assumptions and strategies utilized to develop estimated cost savings figures. Overall savings per well were estimated by creating a standardized "model" well which was used in recommendations in other sections of the report. The potential savings and cost avoidance figures cited in this report are not meant to be precise, but to give order-of-magnitude approximations.

The final value of this VE Study depends on how it is used. The VE Study Team believes that the LANL staff seriously considered their preliminary recommendations during the open presentations at LANL, and will use their expertise to reconsider existing procedures. Staff questions were especially helpful in sharpening the VE Study Team's focus and increasing the report's information content. As a result of DOE/AL's decision to enlist VE as a pivotal management tool, initial discussions of new possibilities began before the VE Study Team left Los Alamos. This collegial approach has remained in place as study recommendations were formally considered and will result in further benefits for LANL.

1.0. VALUE ENGINEERING STUDY METHODOLOGY

1.1 VALUE ENGINEERING APPROACH

Value Engineering (VE) was developed to capture the informal methods Americans developed to radically improve their industrial base when faced with the huge demands of the Second World War. In the late 1940s, American industrial management looked back in wonder at the massive changes in the national industrial production structure. At that time, Larry Miles of the General Electric Company reviewed hundreds of successes that had overcome shortages. During his reviews, he saw that patterns existed in successful procedures and believed that concerned individuals could use these patterns to accelerate beneficial change. Mr. Miles began to train others in what became called "Value Engineering" and proved that a formalized procedure could replicate the amazing success that dedicated cooperation had produced earlier.

The basis of VE has always been to identify functions under study, then establish how much each function costs. Against this background, a team is asked to determine whether the greater value can be obtained by changing the function or using a lower cost alternative. VE is useful at many different levels of detail, from the smallest operation to large, complex organizational procedures. Essentially the same basic procedures are used, but the functions under consideration are defined in consonance with the level of the review. Most other management techniques can be used to alter the focus of a VE study, to develop its ideas, or to add precision to its recommendations. Refinements in VE have been introduced to modify its procedures so that consistent results can be obtained. These changes have not altered the basic approach, which has always been able to connect the imagination and capability of exceptional trained minds through a defined set of procedures to produce recommendations that improve value. This study has used VE techniques that capitalize on earlier successes of the method.

This VE Study followed the general study guidelines established by the Society of American Value Engineers (SAVE). It specifically defined functions, determined the costs of these functions based on the existing documented and approved Baseline for Fiscal Year 2000, and recommended alternative approaches that could decrease the funds required to complete budgeted functions. The phases of such a study are:

Information Collection Phase - The initial effort of the VE Study Team was to obtain as much information about the project as possible. LANL presentations, existing documentation, and personal contacts were used. Appendices A and B respectively identify the documents reviewed and personnel interviewed by the VE Study Team.

Functional Analysis Phase - The VE Study Team determined the functions involved to obtain project objectives. Basic and secondary functions were determined and Functional Analysis Systems Technique (FAST) diagrams were developed to establish the relationships among the functions involved. These diagrams took several hours to develop and helped shape the thinking and analysis of the VE Study Team. Their insights have been incorporated into this report.

Creative Phase - After studying the project, the VE Study Team used techniques such as brainstorming to identify a range of alternatives to the various functions. More than 60 potentially valid alternatives were suggested (see Appendix C). Some of these were developed.

Analytical Phase - Alternatives were analyzed to focus on the most cost-effective. Paired comparisons and other similar VE techniques were utilized. These techniques may be compared to longer, more detailed procedures normally used for program and project analysis. They develop 65 to 80 percent of the certainty that formal techniques produce, but accomplish this result in a few hours as opposed to the weeks normally devoted to such procedures.

Proposal Development Phase - The best alternatives were developed to assure achievement of the basic functions. These alternatives were prepared to present as recommendations. Wherever possible, the recommendations are quantified, often by the use of assumptions. The VE Study Team completed its proposals within four days of the start of its study. The intensity of proposal development forces concentration on only those key observations that will materially affect the object of study. VE proposals are meant to be illustrative, and normally need further development before they can be implemented. However, in every case, this VE Study Team has done its best to adequately define and clearly state its recommendations.

Presentation Phase - Two formal presentations were made. The first was given to Los Alamos Area Office (LAAO) and LANL senior management on Thursday, May 3; four days after the VE Study Team began its work. The second was given to all interested LAAO and LANL staff on May 4. Audience comments from both of these presentations have been incorporated into this report. This report diverges from traditional VE practice—it has required the VE Study Team to spend more than the normal amount of time to validate its recommendations. While this effort has produced a report that includes more recommendations and better integration than a standard VE Study, its estimates are still in the rough order-of-magnitude format. After the final report is delivered to LANL, one or more further teleconferences or video conferences are planned.

1.2 Value Engineering Study

At the request of DOE/AL, EM-6 conducted a VE Study of the LANL Hydrogeologic Characterization Program. The VE Study Team focused on the high cost, multi-year deep well drilling and hydrogeologic analysis designed to characterize the hydrogeology of the Pajarito Plateau and the regional aquifer. An Authorization Memorandum describing the VE mission and responsibilities is included as Appendix D. The VE Study Team's on-site review took place during the week of April 29, 2001, with a presentation of its preliminary recommendations late in the week.

The VE Study Team was drawn from DOE and the private sector. VE Study Team members include nationally-known experts with extensive experience who were specially selected by DOE/AL to provide sound technical advice. VE Study Team members viewed their VE involvement as a valuable opportunity to concentrate on a professionally interesting set of problems and participated with real dedication. They used their own resources as well as non-team experts from DOE to verify and amplify those ideas that would eventually be presented in this report as recommendations. Observers from DOE/HQ and DOE/AL were present to help guide the VE Study Team through organizational issues. VE Study Team members and observers of the VE Study are given below in Table 1-1. Biographical sketches of VE Study Team members are provided in Appendix E.

Table 1-1. Value Engineering Study Team Members and Observers

Name	Affiliation	Principal Focus Area
Neuscheler, Philip	DOE/EM-6	VE Study Team Lead
Butt, Michael	DOE/DP-6	Programs Funding and Integration
Edge, Russel	DOE/AL/ERD	Hydrogeology
Gilmore, Tyler	Pacific Northwest National Laboratory	Hydrogeology, Drilling Operations
Space, Michael	Terradigm, Inc.	Hydrogeology, Budget
Hudson, Stephen	Hudson Associates	Value Engineering Assistant
Kaback, Dawn	Concurrent Technologies Corporation	Technology, Geochemistry
Mercer, James	GeoTrans, Inc.	Modeling, Hydrogeology
Paulson, Glenn	Paulson & Cooper, Inc.	Regulatory Relationships
Ratzer, Eric R.	DOE/AL	Cost Engineering, LANL Baseline
Observers		
Longo, Thomas	DOE/EM-34	
Ordaz, John	DOE/DP-17	
Taylor, Theodore	DOE/AL/LAAO	

2.0 OVERALL PROJECT STRATEGY

2.1 LANL HYDROGEOLOGIC CHARACTERIZATION PROGRAM

Geographic Setting - LANL and the associated residential and commercial areas of Los Alamos and White Rock are located in Los Alamos County, in north-central New Mexico, approximately 60 miles north-northeast of Albuquerque and 25 miles northwest of Santa Fe. The 43-square-mile national laboratory is situated on the Pajarito Plateau. Most LANL facilities and community developments are confined to mesa tops. These mesa tops may be visualized as the spread-out fingers of a human hand. Maps contained in this report show the location of LANL (see Figure 2-1) and the photo that is the frontispiece shows an aerial view of LANL, with the primary canyons labeled.

LANL is divided into technical areas that are used for building sites, experimental areas, support facilities, roads, and utility rights-of-way. However, these uses account for only a small part of the total land area; much land provides buffer areas for security and safety or is held for future use.

Geology and Hydrology - Much is known about the subsurface underlying LANL. The Pajarito Plateau slopes from the Jemez Mountains at the western boundary of LANL to the east-southeast via a series of mesas and canyons to the Rio Grande River. If the ancient volcanic crater (Caldera) were at the palm of the hand, mesas would be the fingers, and the spaces between the fingers would be the canyons that lead to the Rio Grande River. Underlying LANL are the Bandelier Tuff, the Puye Formation (alluvial deposits) with inter-bedded basalts, the Santa Fe Formation (alluvial deposits) and, within the canyons, younger alluvial deposits.

Ground water in the Los Alamos area occurs in three modes: (1) Alluvial - water in shallow alluvium in canyons; (2) Intermediate - perched water (a body of ground water above a less permeable layer that is separated from the underlying main body of ground water by an unsaturated zone); and (3) Regional - the regional aquifer of the Los Alamos area.

The regional aquifer of the Los Alamos area is the only aquifer in the area capable of serving as a municipal water supply. Regional ground water beneath the Plateau flows toward the east-southeast, discharging to the Rio Grande. The source of most recharge to the aquifer appears to be infiltration of precipitation that falls on the Jemez Mountains to the west of LANL.

The vadose zone is between 600 and 1,200 feet thick; the regional water table is in the Puye Formation or the Santa Fe Group. Within LANL boundaries, recharge mainly occurs within canyons, especially the wetter canyons. Perched water occurs beneath major canyons, especially the wetter canyons. Very low recharge occurs on the mesas. Because of low-recharge conditions and a thick vadose zone, environmental impacts to the regional aquifer are anticipated to be small.

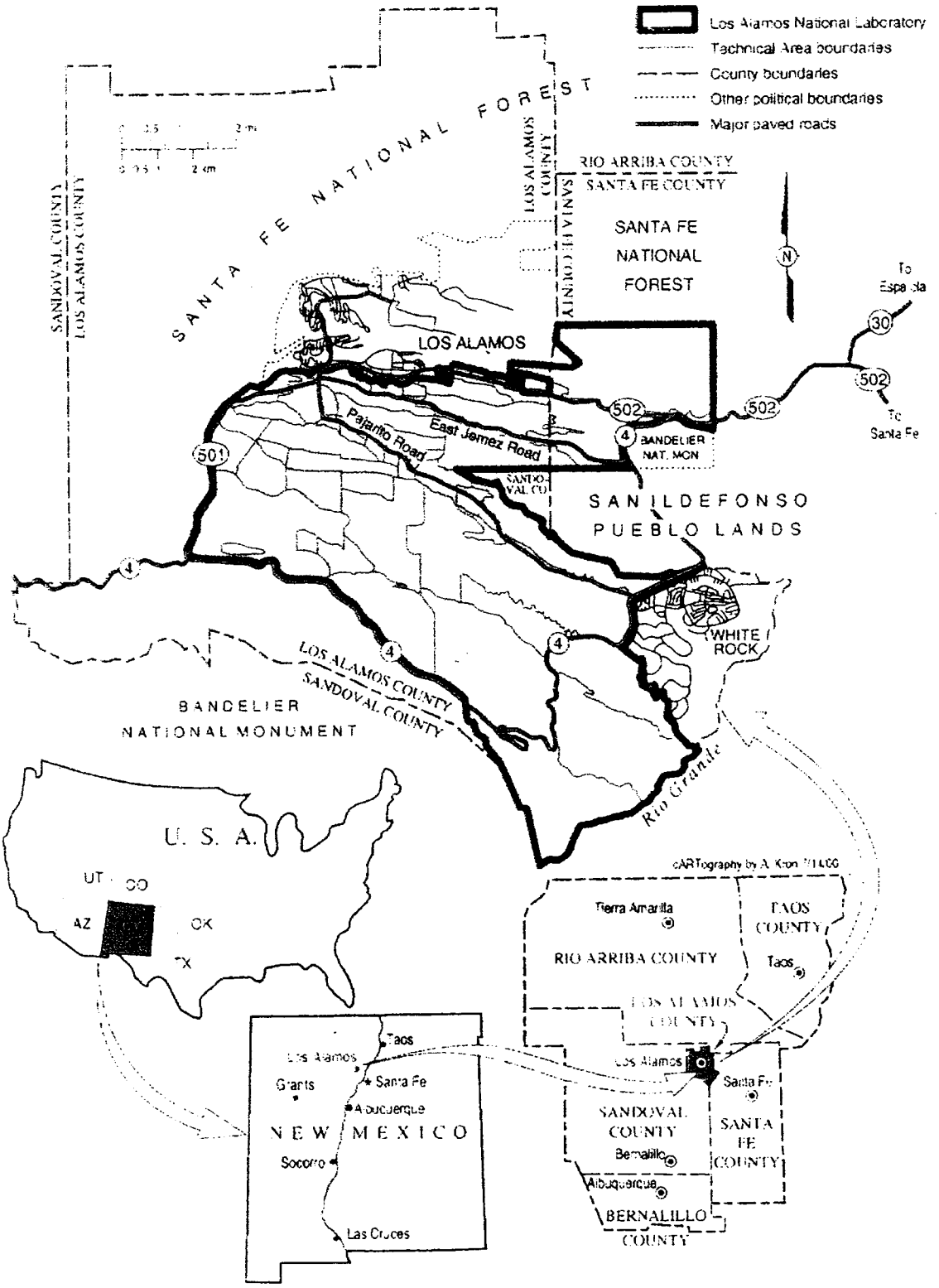

Figure 2-1. LANL Geographic Setting

Ground Water Investigations - In order to address issues raised by NMED in letter dated May 30 and August 17, 1995, consistent with DOE Order 5400.1, and to meet the mission and objectives of the LANL Ground Water Protection and Management Plan (GWPMP), the laboratory prepared a Hydrogeologic Workplan. In March 1998, NMED approved the Workplan, which committed LANL to performing a hydrogeologic investigation to characterize the hydrogeology below the LANL site. The main purposes of the Workplan were to "characterize the hydrogeologic setting beneath LANL, and to enhance LANL's ground water monitoring program"[1]. One ultimate goal of the Workplan is to characterize the regional aquifer system to the extent necessary to establish an effective long-term monitoring network[2].

The 1998 Workplan proposed a multi-year drilling and hydrogeologic analysis to characterize the Pajarito Plateau and assess the potential for ground water contamination from waste disposal operations. The project develops greater understanding of the geology, ground water flow, and geochemistry beneath the 43-square mile laboratory area and assesses potential impacts that LANL activities may have had on ground water quality. Workplan activities were planned to enhance understanding of LANL's ground water setting and improve its ability to plan adequate ground water monitoring.

Completion of the Workplan was anticipated in 2005. The VE Study Team could not identify the critical path or completion milestones associated with the Workplan in the ER Baseline (recognizing that some of the funding comes from DP). The DP-funded activities were difficult to evaluate due to a lack of project controls documentation. Therefore, to allow estimates and comparisons to be uniform within this report, a program duration of 10 years was assumed, and this assumption is referenced throughout as a common estimated end date.

Hydrogeologic characterization at LANL is one component of LANL's overall environmental strategy, which is risk-based, and addresses concerns expressed by NMED, DOE, stakeholders, and the public over threats to ground water. Hydrogeologic characterization is driven in large part by a need to identify potential risks to human health and the environment. However, LANL managers stressed that the "Hydrogeologic Workplan is not a risk-based plan." The VE Study Team believes that incorporating risk-based decision making into the Workplan will help specific characterization activities.

The ten wells completed and one in progress at the time of this VE Study are detailed in Table 2-1. Thirty-two deep wells were originally planned as part of the seven-year ground water study (see Figure 2-2). The deep wells penetrate to the regional aquifer. To date, most wells have included sampling ports and multiple screens to facilitate taking samples of intermediate ground water. These ports were positioned to sample intermediate aquifers or different levels of the regional aquifer.

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[1]Hydrogeologic Workplan (March 1998), ES-1
[2]Ibid, 4-1

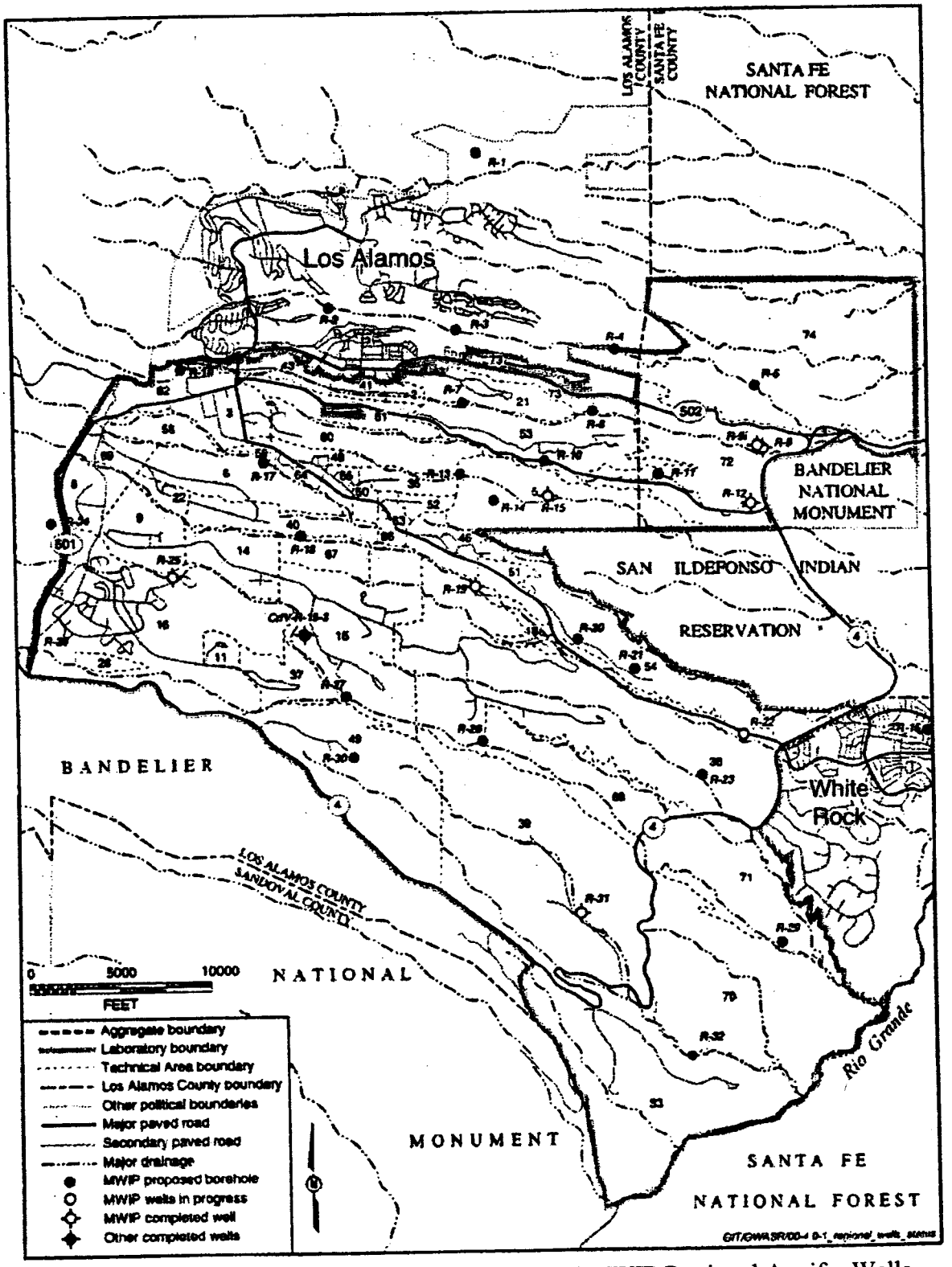

Figure 2-2. Completed, In-Progress, And Proposed MWIP Regional Aquifer Wells As Of The End Of FY00

Table 2-1. Well Status Table

Well	Date Drilled	Status	Watershed	Depth (feet)	Screens Intermediate/ Regional
R-15	Sep-99	c	Mortandad	1,170	0/1
R-9	Sep-99	c	LA/Pueblo	771	0/1
R-25	Feb-99	c	Water/Valle	1,941	3/6
R-12	Jan-00	c	Sandia	886	2/1
R-31	Feb-00	c	Ancho	1,103	2/3
R-9i	Mar-00	c	LA/Pueblo	323	2/0
R-19	Mar-00	c	Pajarito	1,903	2/5
CdV-15-3 Plume Chase HE	Apr-00	c	Water/Valle	1,722	3/3
R-22	Oct-00	c	Pajarito	1,489	0/5
R-7	Jan-01	c	LA/Pueblo	1,097	1/ 2
R-5	May-01	IP	LA/Pueblo	Incomplete	Incomplete

Key: IP - In Progress; c - Well Completion Report Done

Geologic core and water samples collected during the drilling operations were analyzed for chemical and radioactive constituents at defined intervals. Geologic core samples were analyzed to understand how water moves throughout the rocks. LANL is planning additional investigation wells to better understand the nature and extent of possible ground water contamination. These wells include deep, intermediate, and alluvial wells.

Table 2-2. Restrictions to Drilling

Cause	Time of Effect
Spotted Owl	March - May (can continue to September)
Peregrine Falcon	All Summer Months
Run-Off In Canyons	June - September
Security Lock-Outs	As Required
Lightning Season	July - September (afternoon stand downs)

LANL ground water drilling efforts have extensive scheduling and budgetary constraints placed on them. Scheduling is limited by several restrictions ranging from endangered species protection to normal security requirements. These schedule limitations may restrict active drilling operations to two quarters of the year or less. Table 2-2 lists these schedule restrictions and the times of the year when they affect operations.

A major, and increasingly important, restriction on drilling operations is the tightening budget. Compensating for potential budget restrictions are critical to the continued success of LANL's overall subsurface investigation in general, and hydrogeologic characterization in particular. Baseline budgets approved for 2000 and prior years were approximately $11 million, but annual funding is currently (May 2001) projected to decrease to approximately $9.5 million in 2002 and beyond (see Table 2-3). Projected funding decreases necessitate that LANL seek to improve

performance and more sharply define project scope. Increases in funding could occur in the future, but were not expected during the VE Study Team's review period.

While general funding is expected to decrease, LANL Hydrogeologic Characterization Program managers have been concerned that their project requires additional funds beyond those found in the approved FY 2000 Baseline (dated December 16, 1999). This VE Study was primarily targeted to review functions and costs of the project to develop alternative approaches that could mitigate the restrictions caused by decreasing funding.

Table 2-3. Funding of LANL Hydrogeologic Characterization Program ($ expressed in millions)

Year	EM	DP	Total
2001	$8.0	$3.0	$11.0
2002	$6.5	$3.0	$ 9.5
2003	$6.5	$3.0	$ 9.5

EM -Environmental Management
DP - Defense Programs

2.2 RECOMMENDATIONS

The VE Study Team believes that a redefinition of strategy under present regulatory mandates is possible and would greatly benefit the project. In recent years, increased costs and schedule slippage have resulted in significant impacts to the ER baseline and the Hydrogeologic Characterization Program as a whole. This fact, coupled with the current trend of decreasing outyear budgets, makes a re-evaluation of the remaining project activities prudent. LANL has begun this process and has made significant improvements in terms of drilling methods, drilling contracting approach, well completion techniques and in the analytical program. The VE Study Team believes that the following recommendations might further enhance the project. If implemented, these recommendations can significantly improve project value by achieving project goals in less time for less money, while maintaining the scientific integrity that has characterized LANL's efforts thus far.

Readers should bear in mind that the VE Study Team's intent is to suggest possible new approaches. Cost and schedule impacts presented here are intended solely to show order-of-magnitude potentials. Full development of the impacts will be an important part of implementation decision-making, and will require far more time than was available to the VE Study Team.

1. Recommendation: Prepare a comprehensive hydrogeologic report on the regional aquifer and initiate installation of a regional aquifer monitoring well network.

Current State: The current project, as embodied in the Workplan, includes plans for characterization of not only the regional aquifer, but also the intermediate-zone perched ground water. The attempt to address all characterization efforts simultaneously has greatly increased scope and costs. For example, some characterization wells have been relocated based on motivation to refine plume definition rather than stick to their intended purpose — to characterize ground water sufficiently to establish a compliant monitoring program. This approach has also delayed prompt installation of a long-term monitoring network to specifically address off-site regional aquifer risks. At the same time, investigation of contaminant impacts related to PRSs is impacted due to funding constraints.

The current Workplan specifies the number of wells, types, and locations. However, the VE Study Team observed that imprecise technical and regulatory requirements, broad project focus, and non-

specific management structure encourage scope growth resulting in schedule impacts due to a lack of funding to cover increased costs. Requirements are not well defined and subject to changing interpretations that appeared overly prescriptive to the VE Study Team.

As a specific example, information collected from a perched aquifer has led the direction of subsequent work toward plume chasing without a direct connection to a PRS investigation. This approach to plume chasing will likely be costly and may deliver conflicting information that requires yet further investigation. Plume chasing will distract from focus on aquifer monitoring and will upset schedules and budgets for that effort. Some plume chasing can still be accomplished within expected budgets within this recommendation. However, this activity can be more efficiently addressed after the regional aquifer monitoring system is complete and standard RCRA procedures can commence.

Problems associated with the current hydrogeologic investigation include lack of:

(1) Specific milestones and definable end points, and

(2) Linkage of the regional aquifer characterization effort to RCRA regulatory compliance goals.

LANL could face extensive compliance review even after Workplan results are complete, since these tasks are not presented as equivalent to an RFI, nor does the NMED perceive them as equivalent to meeting any regulatory requirement other than a condition of the operating permit.

Opportunities: There is a distinct opportunity to make improvements through a new strategy that expedites operation of the monitoring well network, while building upon the knowledge obtained to date and transferring characterization activities to the RCRA corrective action process. Initial changes can be implemented within existing regulatory mandates. Later evolutions, such as the RCRA procedures already discussed, can be negotiated as the project is refocused. The new strategy calls for the following actions:

(1) Prepare a comprehensive hydrogeologic characterization report based on the extensive information already collected to date to demonstrate LANL's knowledge of LANL's hydrologic system;

(2) Refocus near-term efforts to initiate a ground water monitoring program by installing a limited number of single completion wells based on knowledge collected to date; and

(3) Create a monitoring well network installation project with full management controls that highlight overall progress towards satisfactory regional aquifer monitoring.

Nine regional aquifer wells have already been installed as part of the Workplan. Data from these wells and water supply wells that also draw from the aquifer, integrated with information from other sources, can be analyzed to demonstrate the extent of current knowledge of the regional aquifer system. Other sources of information that may be incorporated into the report include:

(1) the existing landlord operated water supply wells,

would allow them to implement cost saving measures similar to those recommended in Section 3.0 of this report. Standardized, rather than "DQO" driven, custom made data requirement definition could decrease inspection requirements and allow for more efficient use of management time. Both risk and communication analyses can be developed to address issues before they become critical. This more structured, targeted approach, based on sound project management techniques, will allow the project to meet schedules and maintain cost control.

An overall integrated schedule that incorporates all task activities and associated costs for drilling, installation, sampling and data analysis for each proposed well should be prepared. An overall analysis of the entire project based on data collected across LANL should also be completed. These project definitions can be developed in parallel and as part of the comprehensive review recommended above.

Projects conducted using sound project management processes risk fewer cost overruns and have less chance of project failure. Funding and schedules can best be justified when adequate project definitions and controls are in place. Creation of a hydrogeologic monitoring project will also allow all costs to be brought together in one place and allow costs to be collected under that title rather than the present practice of reporting them among several Task Scope Descriptions across several binders. This will make cross-well comparisons easier and increase the visibility of project progress.

Cost and Schedule Implications: The VE Study Team was not able to develop distinct management costs for that portion of LANL's Hydrogeologic Characterization Program that specifically dealt with deep well drilling. Management percentages for the full Program were also not available.

A few general hypotheses can be used to indicate the magnitude of this recommendation's impact. The estimations below posit a consistent funding base of $9.5 million, drilling costs of approximately $1 million per well, and a total ground water program duration of 10 years, with the project expected to be completed in the first two years of that time. If management costs were 8 percent of the funding base and 10 percent of that cost were saved by enhanced project management procedures, and deep well drilling for the regional acquifer monitoring system were completed in two years, then $152,000 would be saved in the duration of the project. If these same methods were then extended to the rest of the ground water program and had the same effect for the remaining eight years of the program, then an additional $608,000 would be saved.

3.0. FIELD OPERATIONS, DATA ANALYSIS, MODELING AND DATA VISUALIZATION

VE Study Team investigations led to development of several recommendations for efficiencies that can be realized in field operations and data analysis. These recommendations generally support those made in the previous sections, but could also be implemented as individual improvements. Some of these recommendations have been incorporated into the general cost estimations described in Section 5.0.

Readers should bear in mind that the VE Study Team's intent is to suggest possible new approaches. Cost and schedule impacts presented here are intended solely to show order-of-magnitude potentials. Full development of the impacts will be an important part of implementation decision-making.

1. Recommendation: Reduce the total number of the regional aquifer wells to be drilled.

Current State: There are currently 32 planned regional aquifer wells. Some of these wells may not be needed to characterize or monitor the regional aquifer.

Opportunities: With the project approximately one-third completed, the state of knowledge has significantly increased since the Workplan was initially written. Furthermore, the landlord operated water supply wells already are being sampled, and these existing wells could conceivably be included as part of an aquifer monitoring system. This information can be utilized to re-visit the original plan to determine the optimum number of wells to be installed.

Possible Solution: It is estimated that 10 to 16 wells could be eliminated from the current estimate of 32 wells, making the maximum number of monitoring wells 16 to 22. The 10 (nine regional aquifer and one intermediate) wells and water supply wells already installed could be included in the regional monitoring system. An additional regional aquifer well was planned for early initiation while the VE Study Team was at LANL. Only 6 to 12 additional wells will need to be drilled. Precise numbers of wells necessary will depend on technical decisions of LANL staff in cooperation with NMED. The VE Study Team has estimated 10 additional wells as the target for a regional monitoring system. While this number may not be the final number agreed to by NMED, it is useful for further development of this study.

Cost and Schedule Implications: Twelve wells are recommended for elimination. The number of these wells equals the 32 wells from the Workplan minus the ten deep wells presently completed or in process and the 10 further monitoring wells recommended by this study. At $1.9 million per well (including contingencies), according to the approved FY 2000 Baseline, this equates to $22.8 million avoided.

2. Recommendation: Drill all future monitoring wells to a single-completion.

Current State: Characterization wells drilled to date have included several Westbay systems. Although vertical head data within the regional aquifer have been collected, the systems installed at LANL limit other options for collecting technical data, such as performing aquifer pump tests. Difficulties with installing these Westbay systems have also caused delays and increased costs.

Opportunities: New regional aquifer wells can be considered as part of the monitoring network rather than as characterization wells. Therefore, they can be specifically designed to meet this simpler function. They can be installed as single-completion wells, with the screen intersecting the top of the regional aquifer and no intermediate screens. Each well could have the same design, and custom design procedures now in place will no longer be necessary.

Possible Solutions: The single-completion construction for the new wells will change their design and allow several benefits that impact on other recommendations in this section. Single-completion wells will:

(1) Decrease cost per well—single terminations without Westbay systems are simpler, faster, and cheaper to construct.

(2) Permit LANL to develop a standard design for each well. This will limit the management time required for well design and construction as well as limiting the "aggravation factor" multipliers that contractors normally add to their bids when intensive interaction with supervisory authorities is expected.

(3) Produce faster operations because of savings inherent in multiple drilling (sometimes termed "economies of scale"). If a single contractor is able to drill several wells and is not limited to a single well, mobilization/demobilization costs will be reduced, easier transition between wells will be possible, and contractor resources for well preparation and technical sampling can be distributed so that simultaneous well sites can be serviced. Contractor procedure simplification and rationalization may allow more wells to be completed during allowable drilling times.

(4) Enable LANL procurement to develop a general purpose contract for multiple wells that would interest more potential bidders and therefore increase competition and further lower the cost of individual wells.

(5) Allow for aquifer testing and generally increase the effectiveness of testing. Aquifer tests (as opposed to slug tests) in these single-completion wells will provide more confidence in estimated hydraulic parameters. They will eliminate potential skin effects caused by drilling fluids. Interpretation of slug tests performed on multi-port (Westbay) wells is difficult due to potential skin effects.

Cost and Schedule Implications: Single-completion wells will speed completion of the aquifer monitoring system. Economies of scale, design, management involvement, procurement efforts, and drilling operations cannot be fully examined within the scope of this VE Study, but a few hypotheses may be made. If the present drilling rate of 3.5 wells per year were doubled, then seven wells per

year would be an attainable goal, and the 10 new wells that are recommended by this study would take less than two years. If the expected funding of the project is assumed to be $9.5 million, and only two years of project duration were avoided by this recommendation, then $19 million will be avoided.

3. **Recommendation: Reduce the cost of ground water chemistry analyses, through optimization of analytical parameters and sampling frequency, using lessons learned from wells already installed.**

Current State: Each well is sampled for a full suite of constituents immediately after installation and then quarterly for a minimum of one year. All major contaminant classes, plus specific radionuclides, isotopes and various other parameters are analyzed. These represent significant expenses to the project, while providing data of questionable quality.

Opportunities: Immediately after drilling, the water samples may not be representative of the formation waters. Therefore, it is not appropriate to sample an exhaustive list of constituents. There is evidence that suggests the act of drilling compromises the representativeness of the samples. At times, drilling requires that additives be used to condition the borehole. This process leaves chemical residues in the well, which potentially interfere with certain chemical analyses. Recently, the wells have been drilled "open hole," allowing waters from separate saturated zones to commingle within the borehole. In addition, there is evidence that fresh mineral surfaces that result from the drill bit breaking up the rock during drilling may change the redox conditions of the well [Bjornstad et al., 1994 (Attachment 1), Fruchter et al., 1996]. These drilling effects must be allowed to dissipate or equilibrate with the subsurface before a representative sample can be obtained. Bjornstad et al. document the changes in redox conditions in the well during drilling, and Fruchter et al. document the changes in dissolved oxygen concentrations at a technology demonstration test site following drilling.

Possible Solutions: Allow the well to equilibrate after drilling before sampling for the full suite of constituents. It is recommended that indicator parameters be measured in place of the full suite of analytes until the newly drilled wells equilibrate. The selected analytical parameters and sampling frequency will be determined based on previous experience. During the first three quarters of sampling, a suite of general indicator parameters similar to Table 3-1, and a short list of site-specific constituents should be analyzed. The full suite of analytes can then be run after it has been demonstrated that the well has equilibrated. The indicator parameters will provide evidence of equilibration and potential contaminants. Los Alamos already has some data (e.g., oxygen-isotope data at R-22) to suggest that samples collected immediately after drilling may not be representative. These data coupled with indicator parameter data from future wells can be used to document the effects of drilling on the well and to estimate equilibration times. If future wells are installed with single-screen completions and then submitted for aquifer testing (removing water), the equilibrium process may be accelerated. The exact time for equilibration will be site- and well-construction specific.

Table 3-1. Recommended Indicator Parameters
(First Three Quarters)

Total Organic Carbon	Conductivity	Alkalinity
Total Dissolved Solids	Total Suspended Solids	Turbidity
pH (Field)	Tritium	Total Kjeldahl Nitrogen, Nitrates
Selected Radionuclides (e.g., Los Alamos Canyon)	Selected High Explosives (e.g., Cañon de Valle)	

Cost and Schedule Implications: Potential savings for this recommendation are based on the baseline sampling costs for well R13 (rounded to $57,000) minus the suggested cost for the same function from hypothetical well R-x (rounded to $21,000). An estimated $36,000 per well could be saved during the first year for each well. For the ten recommended wells, $360,000 will be saved. More precise cost figures are found in Table 5-2; sample definitions are in Tables 3-1 and 3-2. This recommendation is mentioned in Section 5.2 , #12.

Table 3-2. Quarterly Ground Water Sampling and Analysis Constituents

Constituents to be Analyzed	Budget Quantity	Unit	Unit Cost	Budget Cost
Alkt, Turb, TDS, TSS, PH, (WATWG)	5	EA	$57.00	$285
Americium 241	5	EA	$354.75	$1,774
Ammonium	2	EA	$55.13	$110
Anions	2	EA	$137.88	$276
Boron (B)	2	EA	$91.88	$184
Bromide (BR(-1))	2	EA	$57.00	$114
Carbon, Total Organic (TOC)	2	EA	$69.88	$140
Cations by Atomic Absorb (CATAA)	2	EA	$229.75	$460
Cations by Mass Spec (CATMS)	2	EA	$367.63	$735
Cyanide Reactive (CN (-1)R)	2	EA	$110.25	$221
Fluoride (F(-1))	2	EA	$46.00	$92
Gamma Spec (GAMMA Spec)	2	EA	$167.25	$335
Gross Alpha Beta Rad (GROSSAB)	5	EA	$134.13	$671
Gross Gamma Radiation (GROSSG)	5	EA	$147.00	$735
Hi Explosives, 8330 Analytes (HE)	2	EA	$345.50	$691
Humic Acid (HUMACID)	0	EA	$3,423.50	$0
Nitrate expressed as NO3	5	EA	$57.00	$285
NO2NO3	2	EA	$57.00	$114
Plutonium 238, 239/240	5	EA	$275.75	$1,379
Poly Chlorinated Biphenyls (PCB) (Sample)	2	EA	$275.63	$551
Semivolatiles w/tics	2	EA	$544.00	$1,088
Silica Dissolved	2	EA	$57.00	$114
Silica Total	2	EA	$57.00	$114
Strontium 90 (SR90)	5	EA	$266.50	$1,333
Sulfate (SO4 (-2))	2	EA	$57.00	$114
Supplies (bowls, Scoops, PPE)	2	EA	$500.00	$1,000
Total Uranium by KPA (TUKPA)	2	EA	$115.75	$232
Total Kjeldahl expressed as N (T)	5	EA	$137.88	$689
Tritium (H3)	5	EA	$200.38	$1,002
Uranium 234, 235, 238	2	EA	$275.75	$552
Volatiles w/Tics (VOAGMS)	2	EA	$312.50	$625
Geologist/Hydrologist (Sr) (Subcontractor)	8	HRS.	$102.50	$820
Industrial Hygiene Certification (Subcontractor)	4	HRS.	$73.50	$294
Sr. Remediation Special M (Subcontractor)	4	HRS.	$59.00	$236

Constituents to be Analyzed	Budget Quantity	Unit	Unit Cost	Budget Cost
Waste Coordinator (Subcontractor)	4	HRS.	$72.00	$288
Scientist (Subcontractor)	24	HRS.	$39.47	$947
Total				$18,600

NOTE: This table does not include all costs associated with the full suite of ground water analyses. Taxes and the charges for isotope sampling will increase the "Total" figure of this table to $21,000, and were left out to focus on the constituents presented in the table.

4. Recommendation: Minimize the time that the drilling rig is on-site.

Current State: Drill rigs are currently on-site an average of 72 days (based on data from wells R-7 and R-22). This time is divided into approximately 19 drilling days, 5 geophysical logging days, 28 construction days, and 20 testing days. The drill rig typically remains on site during activities other than drilling, which include testing and well completion. The drill rig incurs "standby" costs at just under $400 per hour, which pays for the rig and crew to be on hand during those activities.

Opportunities: The time the rig is on-site can be significantly reduced, saving those costs associated with standby time. Tightly controlling those activities that require standby time and eliminating or postponing some activities until after the drill rig is moved off-site can reduce standby time, thus reducing drilling costs. During some of the aquifer testing activities, a smaller "pump-setting" rig could be used instead of the larger drilling rig.

If the recommended changes in drilling strategy are adopted (Section 2.0), the testing of the intermediate zones during drilling will be eliminated and the wells will be completed as single-completion wells. These changes alone will significantly reduce the time the drilling rig is on-site. Drill time minimization is valuable by itself. Even without a change in the drilling approach, efforts should be made to minimize the time the rig is on-site.

Possible Solutions: Minimize or eliminate testing during drilling. Minimize standby time by making timely drilling decisions. These drilling decisions can be expedited by having a knowledgeable field expert who represents LANL on the drill site and by having the well testing program established before drilling. As soon as it is feasible, the drilling rig should be moved off-site to minimize rig time. Utilize alternative methods, such as a smaller "pump setting" rig, to run geophysical logs, complete the well construction and conduct the well development and aquifer testing. Currently at DOE's Hanford Site, a smaller rig with hydraulic casing jacks is used to complete the wells. The feasibility of this approach should be considered at LANL.

The well should be drilled to its final depth while minimizing stopping for characterization activities that delay the drilling of the well. An example of this is to eliminate the testing of intermediate (perched) zones during drilling; these zones can be identified after drilling using geophysical logs. It is estimated that eliminating intermediate testing would save several days. If the well were completed as a single-completion, an estimated 15 days would be saved on well-completion activities. The disadvantage of this approach is that the intermediate zones would not be sampled and hydraulic head data would not be collected. The advantage is a cost savings of almost 20 percent of the total well costs, while still identifying the location and thickness of intermediate zones from geophysical logs.

Cost and Schedule Implications: Based on discussions with LANL personnel, the rig standby time in a recent drilling contract was $374 per hour. Assuming a 12-hour day, this would result in a cost savings of approximately $81,000 per well in rig costs. Additional savings would result from reduced materials and personnel time required (valued at $22,000 [1 person, 216 hours per well, $100 average hourly cost]). Savings to LANL for reduced materials cost, about $60,000 per well for Westbay systems, should also be included.

Per well savings are thus:	
Rig Costs	$ 81,000
Personnel Time	22,000
Reduced Material Cost	60,000
Per Well Savings	$ 163,000
Savings for 10 recommended wells	$1,630,000

5. Recommendation: Implement a competitively-bid, flexible, activity-based drilling contract.

Current State: The current well drilling contract is based on time and materials pricing, and includes some fixed unit pricing. While significant improvements have been made in drilling procedures and contracting methods, costs for well drilling for three FY 2000 Workplan wells exceeded the baseline by 10 to 300 percent. Drilling costs need to be controlled so that actual costs will not exceed baseline budgets. Recent costs for drilling were between $373 and $418 per foot using the time and materials contract (wells R-22 and R-15). The recent request for bids on a fixed-price contract resulted in bid prices that are significantly more expensive than the "time and materials" contract currently used. The fixed-price per foot was bid at over $600 per foot.

Opportunities: Significant improvements in drilling methods and costs have been realized since the initiation of the project. However, opportunities to better control and reduce drilling costs using sophisticated contracting techniques exist. DOE experience with drilling at other sites can be applied to the LANL problem. These contracts, e.g., Idaho National Engineering and Environmental Laboratory (INEEL), Nevada Test Site and the Savannah River Site (SRS), typically contain multi-line item contracts that include activity-based hourly rates with fixed-price rates for particular facets of the drilling operation. For example, a fixed rate may be paid for drilling to the water table, which is then switched to activity-based rates for testing and well completion. This type of structure also allows flexibility.

There is an opportunity to develop a more cost-effective, flexible-drilling contract through a competitive bidding process. Solely fixed rate pricing is too rigid for this type of drilling project. The recent fixed-price bids received by LANL support this finding. Significant costs in the bids might also be the result of having participation by only one vendor and the complexity of the well design and testing.

Possible Solutions: Several DOE sites have developed sophisticated, cost-effective drilling contracts. Critical components of these contracts that encourage cost-effectiveness include the following:

(1) A competitive procurement process where drilling vendors are invited and actively encouraged to submit bids;

(2) A flexible cost structure that includes activity-based rates and, in some cases, fixed rates (e.g., fixed-rate to the water table and then activity-based for testing, completion etc.);

(3) Open communications between DOE/contractor project managers and vendors to solicit interest and encourage disclosure of all appropriate information;

(4) On-site, pre-bid visits to provide detailed information that allows for enhanced cost estimation;

(5) A multi-year, project basis for the scope of work to provide incentive for participation; and

(6) Stable DOE commitment and funding.

Discussions have been held with drilling project managers at other DOE sites to investigate other approaches. LANL may contact these experienced drilling representatives so they can share lessons learned and provide assistance in developing a new competitive procurement. At INEEL, where drilling conditions are similar to those at LANL, competitively-bid installations are approximately two-thirds the price of drilling at LANL. For example, drilling costs for R-22 at LANL were $373 per foot, not including well construction and installation of materials, and R-15 was estimated at $418 per foot. Well drilling, construction and materials installation at INEEL typically run $272 per foot. These two sites are not directly comparable, as the elaborate well construction at LANL significantly raises the per-foot costs. However, similar drilling equipment is being utilized to drill to similar depths. The current INEEL contract was bid by three of four vendors and was awarded to the vendor who is currently performing work at LANL. The INEEL drilling contact is Kirk Dooley (208-526-2068).

At SRS, competitively-bid, multiple line item drilling contracts have been utilized for over 14 years. Attachment 2 contains an example of an SRS drilling contract. These contracting techniques have allowed SRS to reduce drilling costs over the last 10 years. At SRS, drilling contract line items include a basic fixed unit rate price for routine operations and rig hourly rates during times when unanticipated problems are encountered or when unusual sampling or aquifer testing is occurring. Drilling contract line items were developed for varying depths. For example, drilling costs per foot could be itemized for 0 to 500 feet, 500 to 1500 feet, etc. Coring costs could also be itemized for various depth ranges. This same type of contracting structure is also being utilized at INEEL. Westinghouse Savannah River staff, in particular Janelle Janssen (803-952-7648), is available to assist the University of California (UC) or their representative in preparing a new drilling contract.

At the Nevada Test Site, extremely experienced personnel conduct drilling operations under a complex, competitively-bid contract that focuses on an hourly rate but includes a footage rate to the water table. Other line items include a standby ready rate. Wells at Nevada may be drilled to great depths, more than 5,000 feet, usually with air foam (especially below the water table) or possibly with mud added to help stabilize the borehole because they are drilling in unconsolidated materials. Some wells are completed in multiple zones with grout seals between the screen zones. Bob Bangerter (702-295-7340) is the DOE drilling contact at Nevada.

Cost and Schedule Implications: As wells are installed more cost-effectively, more wells can be installed each year given fixed funding profiles. This will speed general accomplishment of project goals and improve relationships with public stakeholders and regulators. Instead of two plus a fractional well each year, six plus a fractional well will be drilled. This will complete the proposed regional system in less than two years.

It is the VE Study Team's opinion that the current single-source contracting does not avail LANL of the lowest reasonable rates. Development of flexible contracts that minimize risk to the contractor, while maintaining cost controls, would be beneficial. These benefits were quantified by intensive discussions with LANL personnel and with drilling managers at Hanford, Idaho, Nevada and Savannah River. According to general expectations of the VE Study Team, with corroboration of drilling experts throughout the DOE complex, a new drilling contract approach conservatively has the potential to save approximately $100,000 per well. For the 10 proposed regional monitoring network wells, this would equate to a savings of $1 million.

4.0. IMPROVE RELATIONSHIP WITH NMED AND STAKEHOLDERS

During the VE Study Team's initial briefings and interviews with LANL and LAAO, it was apparent that neither DOE nor LANL has an effective working relationship with their chief regulator, the NMED. Based on the documents reviewed and other information received, the VE Study Team concluded that there is a lack of trust and a general unease between the regulators and the regulated. In the words of one VE Study Team member, the relationship is "if not broken, at least badly bent." The following series of recommendations is not generally quantifiable under normal circumstances, though some order-of-magnitude has been estimated for cost avoidance.

These relationship ideas are so critical to all other recommendations that the VE Study Team could not assure any success in its other recommendations without some measure of improvement in regulator and stakeholder relations. Put another way, unless the recommendations in this section are also adopted, the cost and project advantages presented in other sections of this report will not be achieved. For this reason, several of this section's recommendations have the cost savings effects of other recommendations attributed to them to show their importance. These attributions are not included in this study report's overall cost impact.

1. Recommendation: Improve stakeholder and regulator understanding by tailoring communication for maximum information transfer.

Current State: The VE Study Team had the distinct impression that some outside audiences may not understand the relationship of key components of the LANL Hydrogeologic Characterization Program. Particularly misunderstood are the investigation and remediation of surface and near-surface potential release sites as part of the entire effort to protect the regional aquifer and maintain its potential as a source of drinking water.

Opportunities: The VE Study Team believes a targeted effort specifically presenting the Hydrogeologic Characterization Program, defined in a prior recommendation, is essential. A broader program to increase general understanding of interrelated successes, while perhaps not immediately essential, is highly desirable, and will become more important in the future. This broad program will start with a well thought out communication plan. This plan can develop, implement, monitor and evaluate the effectiveness of LANL's communications. Improved communications will integrate the results of the regional aquifer characterization activities, the subsequent monitoring effort, and the broader Hydrogeologic Characterization Program at LANL in such a way that stakeholders and regulators not only understand it, but can also become confident in its success.

Possible Solutions: While LANL has been adept at designing and carrying out integrated characterization actions, it may have experienced a considerable lack of success communicating results. Reports, both written and oral, seem to concentrate on individual findings almost to the total exclusion of integrated general pictures. The information presented has been inappropriate for its audience, and confused rejection has resulted.

The start of successful communications could be defined in an appropriate simple plan. This need not be detailed, and would need only to define the audiences of import and the means of communication available. For each audience and each means of communication, a specific approach, tone, and level of detail could be estimated. This plan need not be developed by a single professional, and would benefit from a session with LANL staff that was professionally facilitated toward the end of defining audiences and media. Managers and staff may be surprised to find the types of audiences that can be influential, the large number of communication means available, and the simplicity of tailoring information so that it has maximum impact on each audience.

Cost and Schedule Implications: Initial plan development will require some thought and effort by project management as well as the participation of significant numbers of staff. A professional facilitator with communications experience would also be necessary to draw out the understanding that staff members already possess. To be generally successful, communications may have to be tailored by a junior staff member dedicated to the task—recent graduates with journalism or marketing experience could be prime candidates. The resulting increase in flow of useful information can be expected to decrease general friction, aid laboratory acceptance, and provide opportunities for LANL to show its capabilities to a wide national audience. Costs to create and implement the communications plan are expected to be offset by the resulting improvements in public relations. The point made earlier regarding the linkage of other recommendations in this section to cost savings presented in other sections is equally valid here.

2. Recommendation: Increase use of integrated information management and display system for stakeholder interactions.

Current State: An integrated information management system called the Facility for Information Management, Analysis, and Display (FIMAD) has been developed to support the Workplan and other ER activities at LANL. As part of FIMAD, geographic information system (GIS) mapping has been conducted with geological information. Work has been initiated to include hydrologic and chemical data in this mapping activity.

Opportunities: An opportunity for easy access to data tied to a geographical reference exists with this approach. The graphical analyses allow for graphical display that can be used for communication/presentation to many different audiences. The outputs from the GIS can be valuable tools that aid the communication of results with the stakeholders.

Possible Solutions: The VE Study Team encourages the completion and maintenance of the FIMAD and GIS. This is anticipated to be a near-term advancement that can be used throughout the project. The use of visual displays prepared using this system should be promoted in all stakeholder and regulator interactions. The graphical analyses can be used to support modeling results. The FIMAD can also be used to organize and archive data.

Cost and Schedule Implications: With these information management tools, graphical materials can be generated quickly. Therefore, cost and schedule savings should be achieved within project management decision processes. If half of a full-time equivalent (FTES) salary of $100,000 is avoided through use of these tools each year, and the project continues for 10 years, then $500,00 in costs will be avoided.

3. **Recommendation: Use the regional model to help with communication of the site conceptual model.**

Current State: The VE Study Team was impressed by the development of models by LANL scientists; however, it was unclear whether LANL is taking full advantage of the regional modeling activity in communicating the site conceptualization, which underpins the numerical model. Researchers often compartmentalize site information by discipline. Individual presentations by discipline can lead to potential stakeholder confusion on "big-picture" issues.

Opportunities: In preparing a model, much is learned about the site by evaluating and analyzing the field and laboratory data. The field and laboratory data used as input parameters for the model provide improved confidence in the resulting numerical model. The tendency of most modelers is to present the final product (i.e., the numerical model) without presenting all the analyses and assumptions underpinning the model. As a result, the reviewer of the modeling results does not have the same confidence level in the model. By presenting the analyses and assumptions leading up to the numerical model, stakeholders will likely have a better understanding of the modeling process and more confidence in modeling results. This will, in turn, lead to their enhanced understanding of the site and its impact on the Pajarito Plateau and surrounding environs.

Possible Solutions: The process for developing the regional model, including an assessment of field and laboratory data utilized as input parameters and assumptions made where data are lacking, should be presented to assist stakeholders in understanding "big-picture" concepts and issues. Different types of data (e.g., stratigraphic, geochemical, and hydrologic) should be utilized and presented to support various assumptions. The presentation should include a three-dimensional interpretation of the data, as opposed to a well-by-well summary. The presentation of this data visualization activity is very important to stakeholders and should be emphasized in all interactions.

Cost and Schedule Implications: It is difficult to quantify the impact that this recommendation will have on project and schedule. The goal is to provide stakeholders with an understandable overview of the site conceptualization. If successful, and stakeholder confidence in the site conceptualization is achieved, the impact on future work could be significant.

LANL itself can benefit from internal distribution of the same information that is recommended here. This information will allow more informed decisions to be made about where wells should be drilled and what new data is required from them. This should increase the precision of well placement and enhance the value of information derived from each individual well. If a single intermediate well is avoided by better placement and increased data usage from each well, and that well is valued at $0.3 million, then this recommendation will avoid that cost.

4. **Recommendation: Develop a better understanding of how NMED defines success.**

Current State: It is not totally clear to the VE Study Team exactly what NMED sees as specific "wins" for itself regarding the Hydrogeologic Characterization Program. Furthermore, it appears to the VE Study Team that the current process is not structured in a way that motivates both LANL and NMED to seek "win/win" solutions.

Opportunities: As part of the overall goal of improving relations with NMED, LANL should be trying harder to understand what NMED might consider a "win." Conducting the Hydrogeologic Characterization Program, whether revised or not, is an excellent way to define those actions that NMED will view as successes for itself. Opportunities of this sort should be investigated for every feature of the project. To the VE Study Team, a major "win" for NMED would be the more rapid installation of the final regional aquifer monitoring network. Smaller "wins" preceding this major win might include, for example:

- NMED acceptance of the results to date of characterization coupled with data from other sources;
- Concurrence that this data set opens the way for the transition to monitoring;
- Agreement that a focus on PRSs and, where needed, their remediation will provide additional protection for the regional aquifer; and
- Understanding that continuing efforts by LANL are not only sensible but also acceptable to other knowledgeable professionals.

Possible Solutions: If LANL decides to target and accelerate the establishment of a regional monitoring network as recommended elsewhere, it would be possible to ask NMED for suggestions that would improve the process. NMED would, therefore, share in the credit for this acceleration by its suggestions and would not only be more likely to agree with this change in the project, but would be able to justifiably feel it had contributed. A stark example of the power of this approach is the potential that NMED could be the first to announce it.

Cost and Schedule Implications: While it is not possible to directly quantify the cost and schedule implications for this recommendation, the VE Study Team believes that there can be schedule benefits in the short, near and long term and, depending on whether the specific issues are dealt with, cost saving opportunities as well. The likelihood of adverse cost impacts is small, and such efforts can build true partnerships. The cost savings presented for many, if not most, of the recommendations in Section 3.0 can be most fully realized if this recommendation is adopted.

Specific quantifiable savings that can logically be attributed to this recommendation are to minimize drill rig time and to optimize the number of geophysical logging tools. Both these recommendations will require changes to existing procedures and technical concurrence from NMED. If LANL can create conditions whereby these changes would directly contribute to NMED perceptions of its own success, the $1.4 million saved will be generally attributable to this recommendation.

A further result of this recommendation will be to arrive at agreements that identify common goals. This will minimize management time devoted to planning and other program activities. If such time is reduced by only one-half an FTES each year and one FTES is worth $200,000, then $1 million will be avoided during the remaining years of the program. For purposes of comparison, the VE Study Team used 10 years for the program's duration. This assumption is explained earlier in this report.

5. Recommendation: Identify Deliverables and Schedules Collaboratively with NMED.

Current State: The VE Study Team perceives that there are a number of disconnects between the LANL Hydrogeologic Characterization Program and the expectations of the NMED, and, perhaps, with some components of the broader group of stakeholders as well. A chronic problem appears to be the long delay time between LANL submission of data, documents, and communications and NMED responses, reactions, and concurrence. The experience of the VE Study Team is that this is not a problem unique to LANL. Nonetheless, this situation not only leads to some understandable tension between LANL and NMED, but also to inefficiencies in LANL's allocation of resources, both human and financial. DOE, LANL, and NMED may already be implementing the solution suggested below to some degree. However, the VE Study Team observed a need for all parties to recommit to a collaborative relationship.

Opportunities: As the key regulatory agency, NMED has a special status, and special efforts directed toward it need to be continuous. LANL will probably not see a radical change in its relationships, but over time the cumulation of many small increases in communication and understanding will result in greater trust by the regulator and thus a significant improvement. Improving this relationship will produce greater success throughout LANL's environmental programs.

Possible Solutions: The key overall solution is to make NMED as full a partner as possible in planning the overall work on the regional aquifer characterization and subsequent monitoring project, including such specific technical features as defining the end points for data collection efforts (and the necessary parameters), well location and screening locations, drilling techniques, and sampling frequencies, up-front, before the field work begins. One key step to improving the specific relationship with NMED is to focus more effort on jointly defining deliverables, including interim deliverables, and, if possible, the schedules associated with them. In this context, schedules mean not only schedules for LANL work, but also schedules for review, reaction, and, if possible, concurrence by NMED—recognizing that it is not possible for LANL to bind NMED to a schedule.

A corollary is to adopt a method of operation that will reduce, if not eliminate, changes in activities made in the field during actual operations. Operationally, this should be done by first picking specific tasks within the broader effort where there is some sign of disconnect between LANL and NMED, such as the drilling techniques (e.g., types of mud, if any, to be used). LANL staff should develop a good, but not final, draft proposal or white paper on a specific component of the project, arrange a meeting with the appropriate NMED staff, provide the draft in advance, and sit across the table to discuss and revise the draft in real time.

At the start of this process, it is probably unrealistic for LANL to expect formal "concurrence" from NMED across the table at the meeting; the realistic goal should be to discuss, negotiate if appropriate, and, if possible, reach an informal technical agreement with the NMED representatives. Subsequently, at an appropriate time, this component, perhaps bundled with other components that have been similarly handled, can be presented to NMED formally. One technique for this is for LANL to submit a letter to the appropriate NMED official, with copies sent to relevant NMED staff who have participated in the face-to-face discussions, which clearly presents the substance of the informal technical agreements. This letter would end by asking the NMED official to confirm

his/her understanding and concurrence with the substantive information presented in the letter. As time goes on, and the relationship improves, LANL and NMED may reach a stage in their relationship where NMED representatives are, in fact, authorized to agree across the table on certain types of activities. The subsequent letter from LANL would, instead of seeking concurrence from a higher level, simply document the agreements reached.

Some variant of this approach, which appears to be uncommon, at least in recent years, should speed the turnaround time at NMED when formal approval is required. If the topic is for information purposes (e.g., transmission of preliminary data), then the data will already be familiar to the appropriate NMED staff before it is formally submitted in report form. A key feature is to start with smaller steps, and then move to intermediate and finally larger ones. Over time, this should lead to improved relationships with various individuals, bureaus and the top leadership within NMED, and thus to improved relationships with stakeholder groups. There are a number of steps that can be taken at each meeting to cumulatively improve the delay time situation. There are several advantages to this approach.

- It will help improve the working relationship at the technical level between NMED and LANL staff.
- Over time, this approach should increase the efficiency of decision-making on both technical and non-technical issues.
- It will reduce the likelihood of unexpected letters from NMED such as the March 26, 2001, letter arriving "over the transom."
- Over time, it will increase the joint level of trust and confidence between NMED and LANL.

This approach has a few disadvantages: (a) there may be some inefficiencies in time at the start of the process, though the consultation step itself will not be very time-intensive; and (b) there may be some resistance to this new mode of interaction by NMED. These disadvantages can be mitigated by an initial high-level review. There may actually need to be a high-level agreement between LANL and NMED officials to ensure that the working levels at both organizations know this approach is expected of them.

Cost and Schedule Implications: It is not possible to precisely quantify these factors, but the VE Study Team believes both cost and schedule benefits will be realized quickly. As a simple illustration, consider the following hypothetical scenario. If there is no prior agreement on technical issues or well location before fieldwork, NMED representatives will direct one technical change per week. Assuming that the LANL response would take two full days of professional time, the cost of the response could be estimated. If drilling must be suspended for a day, the standby cost of the rig and its operators can similarly be estimated. At one such change per week during the actual drilling period, six months drilling per year, and eight more years for the total project, costs over the life of the ground water project as a whole can be postulated. These unnecessary costs will not show up as line item expenditures, of course, but will be in the total cost of the project. Most important, the VE Study Team is convinced that there will be continuing and cumulative cost and schedule impacts if some means of defining deliverables is not developed.

This scenario can be estimated under the assumptions above:

Number of weeks per year (assume 6 months of actual drilling)	6 x 4 = 24 weeks
LANL response to 1 technical change per week	2 FTE days (16 hours), inclusive of all levels
Average cost (fully loaded)	$100 per hour, or $1,600 per change
Standby time for rig and operators per technical change	1 day
Cost of rig and operators for one day ($374/hour, 12 hour day)	$4,488/change
Total per technical change	$6,088
Total per year	$146,112

If these changes can be eliminated over a projected program completion time of eight years after the aquifer project is completed, the result is a total of $1,168,896 in cost avoidance.

6. Recommendation: Work with NMED to develop a set of indicator chemicals acceptable to both LANL and NMED.

Current State: The technical features of this recommendation are presented in Section 3.0. The purpose of including this issue here is to stress the importance of collaborating with NMED by giving the specific example of establishing the set of indicator chemicals, sampling frequencies, and other operational details in order to realize appropriate cost savings. This recommendation is meant to include, but not be confined to, the sampling done immediately after the completion of a well, and until well conditions are stabilized.

Opportunities: Indicator parameters and a suite of site-specific contaminants can be used in place of the full suite of analysis as newly-drilled wells equilibrate during the first three quarters of sampling. Indicator parameters and a small number of site-specific analytes can be sampled and analyzed for the first three quarters. The full suite of analysis can then be run after the well has had a chance to equilibrate. This will save time and money and will guide the routine sampling at current and future characterization wells and future monitoring wells for the regional aquifer.

Possible Solutions: It is possible that NMED will require convincing proof for anything other than the full suite of analysis. LANL may be able, in this context, to avail itself of the independent experience of other entities that have drilled into the same or similar regional aquifers. Water supply authorities are a primary example of other agencies with similar experience. Such stakeholders may well have highly relevant insights on sampling regimes, time for stabilization, and other operational activities, as well as independent data on basic characteristics of the regional aquifer that will be very important in other respects. These stakeholders might be new additions to the scene for LANL and NMED, and will change the mix of information as well as provide a previously approved source of trusted capability.

Cost and Schedule Implications: This approach will not only lead to increased trust and better relations with the regulator, but will help ensure the specific cost savings explained in Section 3.0, in particular, Recommendation 3: Reduce the cost of ground water chemistry analyses.

Generalized efficiencies will also be developed. Once indicator chemicals are agreed to and a standard set of procedures instituted, management decisions will no longer be required for each individual well. If this eliminates only eight hours of management involvement for each of the 10

recommended wells and a LANL FTES hour for this effort is equal to $137, then $10,960 will be avoided per well. If, additionally, the well crew must stand down for this decision time, and rig costs are $374 per hour, then a further $28,560 will be avoided over the same number of wells. Thus, a minimum of $39,520 will be avoided from generalized efficiencies for each well, and $395,200 for all 10 wells.

7. Recommendation: Establish a Joint Working Group with NMED to prioritize data needs for compliance and risk.

Current State: This is an important subset of Recommendation 4, above, and one that should be undertaken after some progress has been made toward improved regulator relations. At the moment, the basis for the Workplan is not well coupled either to risk (i.e., risk to human health) or to any fixed compliance issues or milestones under the RCRA Corrective Action Program (e.g., the RCRA Facility Investigation stage, EPA's Definition of Indicators under RCRA, etc.). Instead, the current Hydrogeologic Characterization Program is seen by NMED and LANL to be a "characterization" effort that precedes the next stages under RCRA. This leads to the clear potential for an open-ended, unbounded characterization phase that will stretch out far longer than necessary.

Opportunities: The problem of an unbounded characterization effort is that goals are never met because they are not defined precisely enough. There can also be the perception that there is a lack of progress. The parallel opportunity is to begin to jointly work with NMED to specifically define the data needed in the short, intermediate and long term that will allow NMED to make the final judgments it needs to make regarding:

(1) Any current and future risk to human health via the regional aquifer (specifically, the RCRA Indicators on health and ground water); and

(2) The specific regulatory decisions it will make regarding compliance with RCRA and any additional specific or general state requirements.

It is not too early to begin to focus both LANL and NMED on the data needed on these two issues. The goal is to define what is necessary, not what is nice to have.

Possible Solutions: The best solution is to establish a Joint Working Group specifically to focus on these two charges. The Joint Working Group need not be made up solely of DOE, LANL and NMED, but could easily include either regular members or guests from EPA central or regional headquarters, private industry, professional organizations, and academia. This probably cannot be done until the level of cooperation, mutual confidence, and trust are improved on specific technical issues. The Joint Working Group would evaluate EPA regulations and guidelines on these topics, evaluate what decisions NMED has made on other facilities that bear at least some resemblance to LANL, and perhaps investigate how others (including other state agencies) have dealt with these issues. The Joint Working Group can be as successful as similar efforts elsewhere that have involved both publicly-owned and private sector installations.

Cost and Schedule Implications: The Joint Working Group would cost LANL and DOE the amount of time required for meetings, and would also require funding for members who were outside of the

LANL area. This cost would be minimal at first as the group began to meet, but could eventually amount to $20,000 to $30,000 per meeting; however, both LANL and DOE would benefit from Joint Working Group outcomes. Issues that could be contentious would become matters of professional judgment, and resolutions of regulatory questions in the New Mexico context would become victories for NMED. Such transformation of potential tension into cooperative success could smooth the way to more effective environmental programs.

While the cost savings estimated for Recommendations 2.1, 3.1, 3.2, and 3.3 will not be fully realized without the adoption of this recommendation, its own impact can be roughly estimated, and need not depend on attribution. Actual cost information bearing on this recommendation was not within the purview of VE Study Team members.

8. Recommendation: Improve and tailor reports on the results of characterization to be more "user friendly," both for NMED and for stakeholder groups.

Current State: There are a number of reports, ranging from specific well completion reports to the annual report, that have presented the results of the characterization project. Periodically there are public meetings at which oral reports are presented. For whatever set of reasons, both correspondence reviewed and anecdotes told to the VE Study Team clearly shows that both the regulator and the public would benefit from enhanced information transfer.

Opportunities: This situation will hamper, if not scuttle, the major redirection of the project from characterization to monitoring that is the primary recommendation of the VE Study Team's analysis. However, there is the distinct prospect of turning this problem around, irrespective of whether a broader communication effort is launched.

Possible Solutions: The general solution is for the subject area experts to work with communication experts to improve the nature, content, quality of the current set of reports, and especially to develop additional, briefer reports and other communication tools that are technically unassailable, but provide the "big picture" in terms more comprehensible to various audiences, including NMED, stakeholder organizations, opinion leaders in the community, the press, civic groups, school audiences, etc. In addition to subject area experts and the existing LANL and DOE communication experts (which are already budgeted, and thus for which there will be no incremental costs), there may be a role for other resources within the UC system (marketing, public relations, etc.) in the design (but not the implementation) of new reporting approaches. In this effort, all possible techniques (videos, CD-ROMs, etc.) should be considered for potential use, based on an analysis of the audiences that need to be reached. The existing GIS system can play an important role in this effort.

Cost and Schedule Implications: The VE Study Team believes that there will be no additional expense to implement this recommendation. Communication is already included in existing resources budgeted for public information. The recommended effort can fit into the current work of staff experts; these experts can and should contribute to ensuring the technical accuracy of all reports.

9. Recommendation: Develop a formal dispute resolution mechanism between LANL and NMED specifically dealing with the regional aquifer.

Current State: At this time, while there is a dispute resolution mechanism developed by EPA in the basic RCRA permit for LANL, there is no such mechanism for resolving technical, schedule, policy or other types of disputes that has been developed specifically and jointly between LANL and NMED. The Workplan, the Hydrogeologic Characterization Program in particular, and probably the entire Hydrogeologic Characterization Program in general need such a mechanism. In addition, as far as the VE Study Team could determine, the mechanism in the existing RCRA permit has never been used.

Opportunities: The absence of such a mechanism is a problem. Creating such a mechanism specifically dealing with the regional aquifer is an excellent opportunity. The creation of dispute resolution procedures, by identifying the points in the various chains of command at which different types of disputes can be resolved, will benefit both NMED and LANL. It will allow technical disputes to be resolved more quickly at a technical level, and promptly elevate other types of disputes to higher levels in LANL and NMED.

Possible Solutions: Regulated entities, both public agencies and private corporations, have in other locations, developed formal dispute resolution processes with their regulators that speed prompt resolution of certain types of disputes, and elevate others more promptly to higher levels at both organizations. The VE Study Team did not have the time to investigate whether NMED has equivalent mechanisms in place with other entities that could serve as a model for a LANL/NMED agreement. If there is no such model available for NMED, other examples can be found, both within and outside of DOE apparatus. Because of the uncertain regulatory status of the Workplan, and also the broad interest in the regional aquifer in other quarters, the VE Study Team believes that LANL should quickly explore whether NMED has an interest in jointly designing such a mechanism specifically for the regional aquifer. It is not appropriate for the VE Study Team to prescribe all the content of such a mechanism, but suggests that in this particular case, there may be room for other entities, such as water supply authorities, in an advisory role.

Typically the negotiation of such agreements involves senior level participation from all potential parties, but the importance of the regional aquifer issue alone justifies consideration of this time commitment, and can more generally help improve the relationship between the two organizations. It might also form the basis for extending the mechanism to cover other aspects of the Hydrogeologic Characterization Program.

Cost and Schedule Implications: While impossible to directly quantify, the VE Study Team believes developing such a mechanism will pay off. For instance, if regulators believe they can resolve questions about technical issues satisfactorily, they will probably not attempt to prescribe specific requirements. If only one alluvial well is avoided in this manner, the resolution mechanism will have saved considerable expense.

5.0. COST/SCHEDULE SAVINGS DEVELOPMENT

5.1 INTRODUCTION

This section presents the VE Study Team's development of estimated savings using strategies identified in earlier sections of this report. The overall savings are achieved by creating an estimate for a standardized "model" well. For perspective, actual costs for eight regional aquifer wells and one intermediate level well are shown in Table 5-1. These are the same wells shown in Table 2-1, with the incomplete well (R-5) left off.

In order to project potential costs into the future, the VE Study Team used existing materials to develop a consistent set of parameters that could be used to prepare the cost for a single model well. The approved December 16, 1999, LANL Baseline and other LANL reports were used to develop the costs. The baselined cost and work scope for 10 proposed wells (R-17, R-13, R-21, R-23, R-30, R-27, R-18, R-10, R-3, and R-4) were analyzed at the individual work element level for each well. This detailed analysis is shown in Table 5-2 at the end of this section. The scope of these wells differed widely. The purpose of the analysis was to standardize the remaining wells to be installed as part of this project and limit the scope while maintaining project integrity.

A cost estimate for a regional aquifer monitoring well, called R-x to fit into the existing R series wells, was assembled. The VE Study Team applied the recommendations for well drilling activity included in the narrative of this VE Study to proposed monitoring well R-13. Each individual work activity planned in the LANL documentation for R-13 was reviewed and compared to the regional monitoring well network strategy. This strategy was used to create a standard "R-x well cost." The standard R-x well cost estimate is $1,033,000 (rounded). A detailed breakdown of this estimate is provided in Table 5-2. While the approved LANL ER baseline contained a contingency estimate for each well, contingency costs were not included in this estimate.

Table 5-1. Completed Well Status
Note: All Costs Leave Out Quarterly Sampling Program

Well	Cost (Millions)
R-15	$1.450
R-9	$2.251
R-25	$4.648
R-12	$1.364
R-31	$1.886
R-9i	$0.285
R-19	$2.697
R-22	$1.714
R-7	$1.936

The R-x estimate was applied to each of the 10 wells recommended for aquifer monitoring system completion. It should be emphasized that although the same cost was used for each recommended well, scope differences will lead to slightly different costs among the 10 wells. For example, drilling costs were estimated on a footage basis, and the estimated total depth to the regional aquifer differs for each well. Because costs prepared for R-x activities are "high-end" estimates, differences between wells will be absorbed.

The average unit cost per well for the 10 wells estimated in the LANL Technical Scope Documentation is LANL's budget estimate per well of $1,924,055 (not including contingency). By comparing the R-x cost estimate to the 10 wells, potential savings are $8,900,551.

Cost 10 R-x Regional Aquifer Monitoring Wells	$ 10,330,000
Cost 10 Planned Regional Aquifer Wells	$ 19,240,551
Estimated Savings	$ 8,910,551

The new regional aquifer monitoring network strategy recommended by the VE Study Team addresses the possibility of reducing the number of deep wells by 10 to 16 wells. This reduction is explained in Section 3.0 and is similar to the expectations of LANL project staff. A calculation of the potential long-term savings due to the reduction in number of wells was made. The average cost per well derived from the Technical Scope Documentation is $1,924,055. Thus, the additional savings associated with the reduction of 10 regional aquifer wells is $19,240,551, while savings associated with the reduction of 16 wells is $30,784,880. Changes to the assumptions of this study will alter estimated costs and savings but not materially affect the study's recommendations.

Average unit cost estimated for 10 wells (baseline)	$ 1,924,055
Reduction of 10 planned wells (cost avoidance)	$19,240,551
Reduction of 16 planned wells (cost avoidance)	$30,784,880

It is possible that aquifer monitoring may require intermediate wells to provide adequate coverage. There is a risk that deep well data will show aquifer contamination through vertical migration from PRSs in the canyon systems that will require further definition. Further monitoring wells will likely be required as part of the RCRA process related to PRSs, both on the mesas and in the canyons. These eventualities cannot be predicted, and the VE Study Team could not explore these risks or develop a quantified estimation.

Table 5-2. Comparison Between Planned Wells and Hypothetical Follow-On Well

Paragraph Number	"Resource By Activity"	R-17	R-13	R-21	R-23	R-30	R-27	R-18	R-10	R-3	R-4	R-x
1.	Planning and Site Preparation	$124,304	$124,304	$124,304	$124,304	$124,304	$124,744	$124,304	$124,304	$124,304	$124,304	$124,304
2.	Project Management	$25,225	$24,023	$21,196	$18,569	$23,690	$29,782	$36,395	$22,540	$19,854	$17,924	$24,023
3.	Data Acquisition and Technical Evaluation	$178,311	$157,670	$152,334	$147,217	$156,240	$246,533	$299,960	$157,669	$128,334	$126,206	$95,002
4.	Drilling Activities	$932,822	$828,954	$777,999	$680,302	$871,245	$1,036,485	$1,102,879	$833,178	$717,167	$659,098	$439,951
5.	Well Construction	$172,544	$156,145	$149,422	$141,804	$152,817	$568,078	$589,857	$156,338	$146,155	$142,631	$156,144
6.	Borehole Geophysics	$15,546	$15,546	$15,546	$15,546	$14,898	$15,546	$15,546	$15,546	$15,546	$15,546	$15,546
7.	Borehole Measurements of Air Permeability	$21,859	$21,859	$21,859	$21,859	$20,948	$21,859	$21,859	$21,859	$21,859	$21,859	$0
8.	Borehole Measurements of Hydraulic Conductivity	$19,078	$19,078	$19,078	$19,078	$18,283	$19,078	$19,078	$5,348	$19,078	$19,078	$0
9.	Hydrogeologic Characterization of Ground water and Core Samples	$54,585	$57,044	$57,468	$57,044	$54,585	$59,194	$56,302	$56,302	$57,044	$57,044	$22,741
10.	Contaminant Characterization of Ground water and Core Samples	$124,420	$124,420	$124,420	$124,420	$124,420	$124,420	$123,622	$149,486	$124,420	$124,420	$0
11.	Waste Management	$22,679	$21,869	$21,869	$21,099	$21,477	$22,720	$23,490	$21,869	$21,358	$21,358	$17,964
12.	Quarterly Sampling of Ground water	$57,329	$57,329	$55,829	$57,329	$57,192	$263,965	$265,391	$46,405	$66,930	$57,329	$21,096
13.	Well Completion Report	$85,587	$85,587	$85,587	$85,587	$84,187	$90,500	$90,516	$43,343	$85,587	$90,500	$59,562
14.	Data Editing and Focused Validation	$12,938	$12,938	$12,938	$12,938	$12,688	$12,938	$12,938	$12,938	$12,938	$12,938	$12,938
15.	Well Geochemistry Report	$64,800	$64,800	$64,800	$64,800	$63,526	$64,800	$64,800	$64,800	$64,800	$64,800	$43,822
	TOTAL*	**$1,912,027**	**$1,771,566**	**$1,704,649**	**$1,591,896**	**$1,800,500**	**$2,700,642**	**$2,846,937**	**$1,731,925**	**$1,625,374**	**$1,555,035**	**$1,033,093**

*Column totals may not add due to rounding.

These well costs, except for R-x, are planning numbers contained within the FY 2000 Baseline. Cost figures which appear in Section 5 are taken from this chart. LANL estimates are from well R-13. Team estimates are from well R-x. All cost figures in Section 5 are rounded to the nearest thousand dollars.

5.2 DEVELOPMENT OF ESTIMATES

The VE Study Team identified several recommendations that could potentially create efficiencies in drilling and sampling monitoring wells at LANL. These recommendations were evaluated relative to the scope and cost elements provided in the "Resource By Activity" of deep well R-13 from LANL's approved FY 2000 Baseline. Deep well R-13 was selected because the scope was more similar than many other proposed wells to the efficiencies identified by the VE Study Team. This minimizes interpreting information in the resource cost sheets when applying opportunities based on the VE Study Team's reasoning and creating a new cost estimate for a representative well, R-x. Although R-13 was selected for developing the R-x estimate, the VE Study Team's rationale can be applied to all the proposed deep wells. The narrative describing the VE Study Team's reasoning includes links, where appropriate, to the commentary in other sections of this report.

The selected recommendations are effective in reducing costs because they simplify and standardize the well installation and sampling scope. The recommendations in Section 3.0 that can be applied to drilling, installing, and sampling the monitoring wells are shown below, together with cross-references to the activities described in Section 5.3 that follow:

- Section 3, Recommendation 2: Drill all future monitoring wells to a single-completion. Activities 4 and 9 reduce the total drilling footage and well construction costs and allow for an aquifer test to be performed. The reduction in materials and labor hours realized for single-completion wells are in addition to the savings that are part of Activity 4.

- Section 3, Recommendation 3: Reduce the cost of ground water chemistry analyses, through optimization of analytical parameters and sampling frequency. Activity 12 re-scopes sampling of formation and perched water zones to reduce analytical costs and labor hours. Cost savings of this activity are the same as those of Section 3, Recommendation 3.

- Section 3, Recommendation 4: Minimize the time that the drilling rig is on-site. Eliminating coring, air permeability, and other formation testing, as well as testing of perched water zones, can significantly reduce drill rig time. Labor costs are also reduced because intense analysis of geochemistry, petrography, and several other parameters were not required under R-x. Activities 7, 8, 9 and 10 refer to these savings.

- Section 3, Recommendation 5: Implement a competitively-bid flexible, activity-based drilling contract. Costs could be compared to those at other sites by simplifying and standardizing the drilling effort. Activity 4 develops a footage rate for drilling the borehole, which significantly reduces estimated cost.

Cost reductions for recommendations selected are quantified using the costs presented in the resource sheets of LANL's approved FY 2000 Baseline. There are several other recommendations that support or enhance the selected recommendations, such as those presented in Section 4.0. These result in a quantifiable cost savings or avoidance which could not be allocated to a specific well.

Based on a review of R-13, the analysis suggests that R-x could meet the objectives of a regional aquifer monitoring project for an estimated $1,033,000. LANL's average estimate per well is $1,924,055, not including contingency added to well costs by LANL. This estimate was achieved by focusing the scope and reducing overhead resources and budget. The analysis takes into account difficult drilling circumstances, the potential for the presence of contaminants of concern, personnel billing rates, and security and contaminant concerns unique to LANL.

5.3 Evaluation "Resource By Activity"

In order to develop a cost estimate for standard well R-x, this analysis reviewed separate resource activities for drilling, installing, and sampling for proposed regional monitoring well R-13. Each of the separate resource activities considered for R-13 is listed below, followed by an evaluation. The order of the resource activities is the same as that found in the approved LANL FY 2000 Baseline. LANL's estimated cost for that baseline is stated in the first sentence of each activity. The VE Study Team's estimated cost based on this analysis is stated in bold at the end of each activity. This analysis has been presented in tabular form in Table 5-2, where exact estimations are presented. Figures shown here are rounded, and therefore noted as approximate.

1. Planning and Site Preparation

LANL's estimated cost for this task is approximately $124,000. The scope element description includes site preparation and restoration, electric power installation, fencing, staff training, preparing a drilling plan, schedule, cost estimates, and drilling design. It also includes surveys, permits, Health and Safety Plan, Field Implementation Plan, and other documentation.

Although the VE Study Team identified potential opportunities that could be applied to this work element, the resource description breakdown was not conducive to quantifying them. For example, standardizing and simplifying the well design would simplify plan preparation and other documentation. Also, a portable diesel generator should replace installing permanent electric power, when power is needed. However, the VE Study Team did not have time to develop an estimate to include these efficiencies. Therefore, the VE Study Team's cost estimate of this effort is considered to be high. For purposes of this report, the estimate for R-x has remained unchanged from LANL's for R-x at approximately **$124,000**.

2. Project Management

LANL's estimated cost for this task is approximately $24,000. The VE Study Team did not modify this estimate. The VE Study Team's estimate may be high on a per-well basis, and remains the same under R-x at approximately **$24,000.**

3. Data Acquisition and Technical Evaluation

LANL's estimated cost for this task is approximately $158,000. It includes supervision of drilling, formation and ground water sampling, and well construction by a team with expertise in drilling technology, geology, hydrology, geophysics, and geochemistry. The activity also includes compiling and interpreting data for reporting.

The VE Study Team's well design and sampling simplifies well scope and accelerates the schedule. Drilling design is standardized and formation and ground water sampling and scope are reduced. The schedule for drilling and well construction is accelerated, and time spent reduced from five months to five weeks. The total labor hours for each labor category (i.e., geologist, etc.) were reduced to 80-120 hours for this task. The VE Study Team concluded the reduction was reasonable relative to the new scope and accelerated schedule. The total cost of this effort under R-x is approximately **$95,000**.

4. Drilling Activities

LANL's estimated cost for this task is approximately $829,000. This includes drilling contractor activities and contractor field support. It includes designing the well, drilling, standby operations, mobilization and demobilization, and field support. The scope element description also includes "well construction;" however, since there is a separate work element for well construction, it is assumed this is a typographical error.

Drilling shifts are planned at 12 hours per day. The schedule to complete the scope of work for this task under the R-x strategy was reduced to two weeks using one 12-hour shift per day. This includes placing a safety factor for rig maintenance and potential field problems. Based on the simplified scope, this appears sufficient even under the most difficult drilling circumstances. Once drilling begins, depending on conditions, overall rig time may be reduced by using multiple shifts. Such reductions have not been included in this estimate.

The VE Study Team's analysis revealed that LANL's drilling costs per foot were between $373 and $418 per foot, not including well construction, for R-22 and R-15, respectively. Drilling costs for the same drilling contractor at INEEL typically run $272 per foot, including drilling, well construction, and materials. (Materials for LANL are included in Activity 5 below—thus the INEEL per-foot figures are overstated when they are compared to Activity 4 alone.) By simplifying the drilling scope and well design, the VE Study Team believes a comparison could be made on a drilling per-foot cost basis. Adding a safety factor, a drilling footage rate of $300 per foot was applied for only drilling the borehole. It was assumed this would cover standby required during drilling and a mobilization/demobilization charge, if needed.

The VE Study Team's reasoning behind the drilling of the borehole and well design makes this comparison possible. In the case of a monitoring well in this environment, well design should be kept simple. A single well screen should be placed so that it intersects the point at which the regional aquifer was encountered. Typically, this is obvious to the driller and geologist, even if drilling mud is used. When the aquifer is encountered, drilling should continue to the end of the rod

(each rod is 20 feet), and perhaps an additional rod, if caving is expected and the drilling method does not involve a casing advance method. This would reduce the total drilling depth from 1,480 feet to approximately 1,100 feet.

Reducing the drilling scope and accelerating the schedule allowed for reducing labor hours. Although hours were reduced, the percentage of time available for each member to work on this phase of the project was maintained or increased relative to LANL's estimate. The total cost of this effort under R-x is conservatively approximately **$440,000**.

5. Well Construction

LANL's estimated cost for this task is approximately $156,000. This includes well construction materials, and well development. This funding appears adequate to perform this activity. The total cost of this effort under R-x is approximately **$156,000**.

6. Borehole Geophysics

LANL's estimated cost for this task is approximately $16,000. This task includes performing a suite of geophysical logs to provide lithologic data for stratigraphic purposes, estimate porosity, and identify fracture zones. These tools include array induction log, neutron porosity log, Formation Microimager, continuous deviation survey, natural gamma ray combinable magnetic resonance, triple litho-density logs, and videotape. The VE Study Team identified potential opportunities for possibly decreasing the cost of these tools through competitive bidding and evaluating which logging tools provided the most benefit.

Eleven downhole geophysical tools, obtained through a sole-source contract, are run in every well[3]. Geophysical logging is not competed separately. Companies that bid on drilling contracts may exclude themselves from contracts that require logging, or engage another firm as a subcontractor for this task and charge an extra percentage of that subcontract to the contract.

The current suite of geophysical logging tools should be evaluated based upon their performance in recent wells. The value of information obtained should be assessed in terms of costs. Some of the tools used may be redundant (e.g., formation microimager and borehole video both give lithologic and structural information). Evaluation of time allotted for geophysical log interpretation should also be conducted, and possibly included as part of a task development. LANL staff hours allotted for this activity have been significant in the past. Once the best tools and procedures are identified, a competitively bid geophysical logging contract could be developed. It will probably save costs and improve performance simultaneously. However, the VE Study Team did not modify LANL's estimated cost for this task. The total cost of this effort under R-x is retained at approximately **$16,000**.

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[3]Ground Water Annual Status Report for Fiscal Year 2000, Table 4.1-1

7. Borehole Measurements of Air Permeability

LANL's estimated cost for this task is approximately $22,000. The VE Study Team recommends eliminating this effort under the R-x strategy. The total cost of this effort under R-x is **$0**.

8. Borehole Measurements of Hydraulic Conductivity

LANL's estimated cost for this task is approximately $19,000. The VE Study Team recommends eliminating this effort under the R-x strategy. The total cost of this effort under R-x is **$0**.

9. Hydrogeologic Characterization of Ground water and Core Samples

LANL's estimated cost for this task is approximately $57,000. The VE Study Team recommends eliminating activities as described in the work element description under the R-x strategy, and adding an aquifer pumping test to this activity. It is assumed that ground water is not impacted at this site so it can be discharged to the ground, and only field analyses of water quality will be required. A 72-hour test is assumed; however, a 24- to 48-hour test could suffice. It is assumed a rented diesel generator will provide the power, with an assistant on-site during night hours to ensure it is fueled. A subcontractor geologist is included to set up the test, with oversight and data interpretation from scientists from EES-1, and EES-5, and one day for an Industrial Hygienist. Rental of a Hermit data logger and transducer is included.

Existing wells may be used as observation wells for this activity. If existing wells are not suitable, strategic placement of the 10 recommended new wells should suffice to perform these tests. New wells may also be sited to utilize hydrogeologic effects of the existing landlord-operated drinking water wells for the differing pumping volumes under which these wells operate. The total cost of this effort under R-x is approximately **$23,000**.

10. Contaminant Characterization of Ground Water and Core Samples

LANL's estimated cost for this task is approximately $124,000. The VE Study Team recommends eliminating this effort under the R-x strategy. The total cost of this effort under R-x is **$0**.

11. Waste Management

LANL's estimated cost for this task is approximately $22,000. This includes sampling and storage of cuttings, and ultimately their disposal. Efficiencies were identified for rental of roll-off containers and fractionation tanks due to the accelerated drilling schedule. Three months should be more than sufficient time for tank rentals. The total cost of this effort under R-x is approximately **$18,000.**

12. Quarterly Sampling of Ground water

LANL's estimated cost for this activity is approximately $57,000. This task covers the cost to collect, analyze, and evaluate ground water samples. The current scope requires eight samples to be collected for 28 different analyses, four samples for humic acid analysis, and 16 samples for

sulfate analysis. Currently, ground water samples are being analyzed both for filtered and unfiltered samples each quarter.

This task was evaluated and re-scoped to meet the opportunities identified by the VE Study Team. The VE Study Team recommends reducing the number of analyses in the quarterly samples (see Section 3.0, Table 3-1). This includes using indicator parameters for the first three quarters, followed by a full suite analysis for both filtered and unfiltered samples to meet NMED guidance. In addition, stable isotope analyses of a filtered ground water sample for $^{15}N/^{14}N$, D/H, and $^{18}O/^{16}O$ ratios were added for the fourth quarter sampling. The total cost of this effort under R-x is approximately **$21,000**.

13. Well Completion Report

LANL's estimated cost for this task is approximately $86,000. This activity covers all tasks to prepare a well completion report, including a summary of field activities, geologic log, and documentation of well construction and development. There is an efficiency and reduction in the analyses and content for the well completion report under the VE Study strategy due to simplification and standardization. Labor hours for each labor category were reduced by up to 30 percent to reflect the new scope. The total cost of this effort under R-x is approximately **$60,000.**

14. Comprehensive Data Management (CDM) Data Editing and Focused Validation

LANL's estimated cost for this task is approximately $13,000. The VE Study Team did not modify this estimate. The total cost of this effort under R-x is approximately **$13,000.**

15. Well Geochemistry Report

LANL's estimated cost for this task is approximately $65,000. Recommendations by the VE Study Team greatly reduce formation and perched water data collected. This will result in reduced scope for the well geochemistry report for this well. Labor hours for each labor category were reduced by up to approximately 30 percent to meet the new scope. The total cost of this effort should not exceed approximately **$44,000**.

16. Contingency

The VE Study Team included no contingencies for any part of their development of well R-x costs nor are any contained in recommendations found in this report.

17. Additional Possible Savings

This estimate should be considered a high-end estimate for several reasons.

- Expense drivers such as difficult drilling circumstances, the potential for the presence of contaminants of concern, intensive use of personnel with high billing rates, and security and

contaminant concerns unique to LANL may not have as much impact during drilling of future wells.

- No efficiencies in management and administration operations due to simplified contracts for multiple wells are included in this estimate. Efficiencies in drilling contractor operations from the same causes have likewise not been considered. Operational efficiencies may also save time, which will allow schedule savings.

- Aquifer monitoring wells near the river may be considerably less expensive than those further up the plateau because they will not be as deep. This factor was not included in well cost estimates, but could be quantified once future well sites are identified.

- In-depth review of information that could reduce the estimated cost of several of the activities used above was not possible due to the VE Study Team's brief review period.

APPENDIX A

DOCUMENTS REVIEWED

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U.S. Department of Energy, *RCRA Information Brief, EH-231-014/0794,* Office of Environmental Guidance, July, 1994

U.S. Environmental Protection Agency, *RCRA Orientation Manual,* current on-line edition, (www.epa.gov/epaoswer/general/orientat/

Information available on-line from EPA's RCRIS system

Information available on-line from NMED's and LANL's home pages

APPENDIX B

PERSONNEL INTERVIEWED

Name	Organization	Work Phone	E-Mail Address
Ball, Ted	LANL/ER	(505) 665-3996	TedBall@lanl.gov
Bitner, Kelly	Neptune & Co.	(505) 884-8455	bitner@neptuneandco.com
Broxton, David	LANL/ER	(505) 667-2492	broxton@lanl.gov
Canepa, Julie	LANL/ER	(505) 667-0808	jcanepa@lanl.gov
Enz, Bob	Enz, Inc.	(505) 982-5038	benz@enzinc.com
Keating, Elizabeth	LANL/ER	(505) 665-6714	ekeating@lanl.gov
Longmire, Pat	LANL/ER	(505) 665-1264	plongmire@lanl.gov
McCann, John	LANL/ER	(505) 665-1091	jmccann@lanl.gov
Nylander, Charles	LANL/ESH-188	(505) 665-4681	nylander@lanl.gov
Robinson, Bruce	LANL/EES-5	(505) 667-1910	robinson@lanl.gov
Vaniman, David	LANL/ER	(505) 667-1863	vaniman@lanl.gov

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APPENDI X C

VALUE ENGINEERING STUDY: LOS ALAMOS NATIONAL LABORATORY HYDROGEOLOGIC CHARACTERIZATION PROGRAM

ADDITIONAL OBSERVATIONS FROM VE STUDY TEAM BRAINSTORMING SESSION

Project Costs

Establish project cost for Program
Focus geophysical tools
Estimate redundancy
Competitively bid, activity-based costing
Use information from previous drillings
Build personnel hours by task rather than level of effort
Become cost conscience - Project Management (cost, scope, schedule)

- Use fixed rate and line items contract
- Incentivize drilling subcontractor
- Better cost estimate
- Cost/Benefit on different sampling on benefit of DQO changes
- Coordinate costs

Deliverables

Critique Total Quality Objective (TQO) Process and Data Quality Objectives (DQO) Process
Identify deliverables

- Focus data collection towards defined end points
- Identify data parameters up front
- Plan the Work – Work the Plan

Prioritize data needs for compliance and risk
Analyze analytical strategy (chemistry/sampling/hydrogeologic/geologic analysis)
Establish GIS for hydrogeology and chemistry data
Sensitivity Analysis use with data requirements development
Unite Ground water Program with: Risk Analysis, Previous Reviews, Other Data
Use modeling the help integrate data and communicate site conceptualization.

New Mexico Environment Department

Define new "Wins" for NMED
Improve/Document Lessons Learned
Renegotiate Work Plan
Report/Summarize state of knowledge
Identify with NMED managers
Have DOE in on negotiations with State
Work the NMED relationship

Ask for Lessons Learned from DOE in dealing with Stakeholders

Drilling

Demonstrate understanding of regional aquifer with existing data
Coordinate ER/Deep Wells/Plumes remediation as integrated project with defined end point.
Report success and close without asking for agreement
Establish full network of regional wells and complete it with minimal characterization
Alternate rig for development, logging, etc.
Drilling contract assessment – Fixed Rate vs. T&M

- Develop standard format for drilling contract (Deep Well)
- Reduce drill rig time on site (Let 'em go before analysis is done)
- Bundle several years of wells in one year
- Frequency of Sampling (Decrease)
- Length of Sampling (Years) Decrease

Develop Indicator Parameters

- Identify data parameters up-front before drilling (drop DQO sessions)

Organization

Review/define Organization Chart (responsibility/authority)

- DOE and Contractors

Develop/document internal communication plan
Establish Project Management for program

- Identify cost, scope, and schedule

Develop integrated program and allow selves more flexibility
Establish criteria for setting points for subproject milestones
Risk concepts: Assessment, Communication, Determine Uncertainties
Convert Hydrogeologic Workplan to a RFI
Increase on-site DOE involvement and skill mix
Develop comprehensive site analysis plan site-wide, not by canyon

- Change to canyon RFI as aggregate watershed approach
- Develop comprehensive strategy for specific geographic area
- Prioritize greatest area of contamination

Different reports for different audiences
Use additional public relations, marketing, communications people from University of California, DOE or elsewhere
Task Public Affairs Office
Give kudos where due
Establish a documented administrative record
Revise role of External Advisory Group (EAG)

- Eliminate conflict of interest
- Drop EAG members who are from NMED and Schlumberger

APPENDIX D

VALUE ENGINEERING STUDY: LOS ALAMOS NATIONAL LABORATORY HYDROGEOLOGIC CHARACTERIZATION PROGRAM

AUTHORIZATION MEMORANDUM FROM THE DIRECTOR, OFFICE OF PROJECT MANAGEMENT

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Attachment 2

Responsibilities for Value Engineering Study of Los Alamos National Laboratory Hydrogeologic Characterization Program (April 29 - May 4, 2001)

Ted Taylor, 505-665-7203 (Los Alamos National Laboratory (LANL) Area Office) will:

1) Present a 2-3 hour general site briefing on the morning of April 30;
2) Lead a tour of the Pajarito Plateau and selected canyons that afternoon;
3) Help set up a conference call on May 1; and
4) Provide a pre-brief invitee list for a session after 5 p.m. on Thursday, May 3rd.

Russel Edge, 505-845-5178 (Albuquerque Operations Office) will:

1) Take responsibility for the costs of team members numbered 1 through 7;
2) Inform all candidate consultants of their selection or non-selection; and
3) Allow consultants 1.5 days in addition to the study's duration to review advance material and proof the Value Engineering Report.

John Ordaz, 301-903-8055 (Department of Energy Headquarters/Office of Facilities Management and Environment, Safety and Health Support - DP-17) will:

Coordinate with the Office of Project Management (EM-6) and be responsible for costs of its representatives.

Philip Neuscheler, 202-586-7505 (Department of Energy Headquarters/Office of Project Management - EM-6) will:

1) Send a study agenda, biographies of team members, and selected program information to team members and the LANL Area Office before close of business on April 12, 2001; and
2) Coordinate the conference call planned for May 1 and inform all non-team personnel of the purpose and call-in number for this call.

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APPENDIX E

BIOGRAPHICAL SKETCHES OF VALUE ENGINEERING STUDY TEAM MEMBERS

MICHAEL BUTT

Mr. Butt has over 20 years of federal service in the development and improvement of business and technical management systems. He is currently serving as the Senior Program Analyst for the DOE Federal Energy Technology Center, Center for Acquisition and Business Excellence. His responsibilities include the achievement of the national planning process: Accelerating Environmental Cleanup: Focus on 2006. The process is designed to accelerate the cleanup, reduce overall cost and maintain DOE's commitment to meet federal and state regulations and compliance agreements.

Mr. Butt served as a Senior Program Analyst in the Office of Cost and Performance Analysis where he reviewed Environmental Management (EM) programs to ensure technical validity and cost effectiveness. He developed and promulgated EM policy on cost effectiveness issues for application in programs and activities within EM. In addition, he formulated and developed EM policy for strategies and bench marking of existing and future planned EM Programs. Mr. Butt was responsible for the technical review of contract support activities on the EM-10 contract ($50 million over five years) which provided planning, technical, analytical and administrative support to DOE/HQ organizations. He also served as a senior manager on the Baseline Asset Inventory Report (BAIR) to the DOE Office of Environmental Management Policy. As the Acting Director of Strategic and Five-Year Planning for the EM Office of Planning, he managed and supervised the development of the Environmental Restoration and Waste Management (ERWM) Five-Year Plan. Mr. Butt has a B.S. from the University of the State of New York and has taken graduate courses in Systems Quality and Productivity Public Administration.

RUSSEL W. EDGE

Mr. Edge has over 14 years experience as an Environmental Scientist/Environmental Manager and 5 years experience in industrial construction. He currently serves as program lead for multi-disciplinary ground water projects that are nationwide in scope. He provides technical and regulatory advice on ground water and surface water rededication to the Director of the Environmental Restoration Division and the Area Offices that report to the Albuquerque Operations Office. Mr. Edge serves as Environmental Project Manager/Hydrogeologist on the Long Term Surveillance and Maintenance Program (LTM) of waste disposal sites administered by DOE/Grand Junction, Colorado. His duties include project planning, program direction, evaluation, future use, long range program development, and overall coordination responsibility for DOE sites with long term care needs. He was closely involved with uranium mill tailings disposal sites, entombed nuclear reactors, Nuclear Waste Policy Act (NAPA) sites, the former Pinellas weapons plant, and transition of the Weldon Springs, Missouri, and Monticello, Utah, sites to long-term stewardship.

These activities required close coordination with state and local officials, development of the technical scope of long-term management activities, oversight of sub-contractual support, regulatory interface, public relations and outreach activities.

Mr. Edge has a B.S. in Geology from West Texas State University and has done graduate work in Hydrogeology at Oklahoma State University. He is certified by the State of Arkansas as a Professional Geologist and has published a number of articles including "The Hydropunch: An In-Situ Sampling Tool for Collecting Ground water from Unconsolidated Sediments" (Ground water Monitoring VE Study, Summer 1989), and "Remediation of Low Level Radioactive Sites in the United States" (Proceedings of NATO Workshop on Environmental Restoration, Tallin, Estonia, November 1998).

TYLER J. GILMORE

Mr. Gilmore is a Senior Research Scientist with the Pacific Northwest National Laboratory (PNNL) and has over 14 years working as a technical project manager in geohydrologic research and remediation system design and development. Prior to PNNL, Mr. Gilmore worked in the petroleum industry as a well-site geologist for two years. He has directed and participated in a variety of environmental programs and managed projects for PNNL's clients dealing with RCRA and CERCLA (Superfund) Federal Regulations as well as various State Regulations. Project clients have included the Army, Navy, Air Force and DOE.

Mr. Gilmore has originated several ground water remediation and monitoring technologies, including the Reactive Well concept for creating reactive zones around ground water wells for treating contaminated ground water, a volatile organic probe, the Microsparger, for detecting volatile ground water contaminants in the field, and the use of permeable membranes for the delivery of reactants to the subsurface. He received a U.S. Patent on the Reactive Well concept and has patents pending on the Microsparger and Permeable Membranes. He recently helped successfully implement in-situ gaseous treatment system soil treatment technology, which uses hydrogen sulfide to reduce contaminants in the soil. Mr. Gilmore was also the co-principal investigator with Stanford University on the successful development and implementation of the In-Well Vapor Stripping ground water remediation system. Recent research has included the development of reduction/ oxidation manipulation techniques for use in ground water treatment including the injection of iron colloids.

Mr. Gilmore has also participated in a number of DOE internal and external VE Studies of ground water monitoring programs and remediation system design and installation projects. Most recently, he provided technical support to the DOE Pantex site in Texas for their ground water monitoring and remediation program. Mr. Gilmore has also presented a series of seminars entitled "Environmental Field Sampling, Practical Techniques from A to Z." Mr. Gilmore has an M.S. in Geology from the University of Idaho, and a B.S. in Geology with a Physics minor from Colorado State University.

STEPHEN HUDSON

Mr. Hudson is a graduate of Virginia Polytechnic Institute and State University with an A.A. in Agriculture Technology, where he specialized in Business Management. He is currently responsible for leading VE Studies, developing conference programs and designing informational exhibits. He has been assistant team leader for Value Engineering workshops that reviewed architectural plans, construction schedules, and budget estimations for a variety of government and private facilities. His clients include water treatment facilities, colleges and universities, correctional facilities, public schools, hospitals and medical facilities, and government agencies (U.S. Geological Survey, U.S. Department of Energy, and Virginia State Government).

DAWN S. KABACK, PH.D.

Dr. Kaback has over 20 years of experience in environmental and natural resources science and technology. She is responsible for planning, organizing, staffing, directing and business development for the Denver office of Concurrent Technologies Corporation (CTC). She is currently involved in managing technical management support and project management contracts for the DOE, the U.S. Department of Defense (DoD), and the Environmental Protection Agency (EPA). Dr. Kaback supports the DOE Office of Science and Technology (EM-50) for a number of activities, including work for the Subsurface Contaminants Focus Area. Dr. Kaback is Director of the Ground water Remediation Technologies Analysis Center (GWRTAC), funded by DOE, DoD, and EPA.

Dr. Kaback's area of expertise is that of subsurface contaminants, fate and transport, characterization and remediation. She provides expert advice for the DOE Pinellas Plant in Florida and technical support to EPA's RTDF Team on NAPL Cleanup. She is also an expert advisor for DOE's Tanks Focus Area, specializing in characterization and tank closure. Dr. Kaback is on the Board of Directors for the National Ground water Association and is an editor for the journal *Ground water Monitoring and Remediation.* She has served on a National Academy Committee on Water Resources Research for the U.S. Geological Survey. Dr. Kaback received her Ph.D. in Geochemistry/Geological Sciences and her M.S. in Geological Sciences from the University of Colorado. Dr. Kaback also has a B.S. in Earth and Space Science from the State University of New York at Stony Brook.

JAMES W. MERCER, PH.D.

Dr. Mercer is an expert in hydrogeology, and has developed modeling techniques to explore subsurface flows. His Ph.D. thesis topic was in geothermal reservoir analysis, where he focused on ground water flow and heat transport. While finishing his Ph.D., Dr. Mercer joined the U.S. Geological Survey (USGS) as a hydrologist in the Northeastern Research Group. He continued to work in the area of geothermal energy, expanding his efforts into multi-phase flow of steam and water in the subsurface. Before incorporating thermal effects into multi-phase flow, Dr. Mercer considered isothermal multi-phase flow of oil and water. During this time, Dr. Mercer expanded his research efforts into solute transport and water quality issues by examining saltwater intrusion in water supply aquifers. Dr. Mercer then applied his multi-phase flow experience to the dense non-aqueous liquid (DNAPL) problems at Love Canal hazardous waste site and other sites near Niagara Falls.

Dr. Mercer is known for his contributions to science. In 1985, he received the Wesley W. Horner Award of the American Society of Civil Engineers for work at the Love Canal hazardous waste site. In 1994, Dr. Mercer received the American Institute of Hydrology's Theis Award for contributions to ground water hydrology. Dr. Mercer has served on the National Research Council's Water Science and Technology Board and is a member of the U.S. EPA Science Advisory Board. He is also co-author of the book, *DNAPL Site Evaluation*

PHILIP E. NEUSCHELER

Mr. Neuscheler has 17 years experience in cost engineering, value engineering, life cycle costing, contracting, and budget activities. As a Federal employee, Mr. Neuscheler has worked in the U.S. Department of Energy (DOE), Office of Environmental Management's Project Management Office on cost engineering and value engineering projects. His responsibilities have included activities such as external regulation project definitions and cost estimates, cost reviews, bench marking, baselines, and historical cost documentation. In addition, he has served as a Contracting Officer and Budget Manager. In the US Army, Mr. Neuscheler was a company commander in Viet Nam, Senior Army Protocol Officer during Desert Storm and Comptroller of the Special Forces.

In private industry, Mr. Neuscheler has produced Navy system acquisition and fleet maintenance budgets; designed a graduate engineering program for 400 Algerian students; reviewed Swiss industry for the Department of Defense; and trained the Saudi Bedouin Guard's mechanized forces. Mr. Neuscheler has an M.B.A. in Management Science from Columbia University, and an M.A. in Economic Development from the University of Wisconsin. He is a Certified Associate Value Specialist, a Certified Project Manager, and a Certified Professional Logistician.

GLENN PAULSON, PH.D.

Dr. Paulson has over 30 years experience in state and federal government, academia, and private industry. He is a veteran of over 100 Superfund site cleanups and emergency response actions. He has served as a consultant and advisor to corporations, law firms, a variety of academic and other not-for-profit institutions, and labor-management organizations in the construction industry.

Dr. Paulson is currently the president of Paulson and Cooper, Inc., an environmental consulting company with offices in Jackson Hole, Wyoming and Adjunct Professor of Environmental Health Sciences at the Medical University of South Carolina. Dr. Paulson has served as the Director for The Center for Hazardous Waste Management at the Illinois Institute of Technology, Vice President, Clean Sites, Inc., Vice President and then Senior Vice President, National Audubon Society, Assistant Commissioner, New Jersey Department of Environmental Protection, and Staff Scientist, Natural Resources Defense Council.

From 1990-1996, Dr. Paulson was a member of the Board on Radioactive Waste Management of the National Academy of Sciences, and for over 30 years he has been a member of Academy committees on ground water treatment, hazardous waste site ranking systems, buried wastes and numerous other topics. He served as a charter member of the Secretary of Energy Advisory Board and the first chairman of DOE's Environmental Management Advisory Board. He was a member of several Office of Technology Assessment advisory panels on DOE issues, and a member of advisory committees for the U. S. Environmental Protection Association, the National Institute of Health, and the U. S. Department of the Interior, and is a Fellow of both the American Association for the Advancement of Science and the American Institute of Chemistry.

Dr. Paulson received his Ph.D. in Environmental Sciences and Ecology from The Rockefeller University, New York, NY and a B.A. in Chemistry (Honors) from Northwestern University, Evanston, IL. In addition, Dr. Paulson holds an Honorary Doctor of Science Degree from Long Island University.

ERICK R. (BOB) RATZER

Mr. Ratzer has 12 years experience working as a design and construction engineer and 6 years experience working as a cost engineer. He has already completed four baseline cost reviews at Los Alamos National Laboratory as a DOE team member. He has an M.S. in Business Administration from Utah State University and a B.S. in Ocean Engineering from Texas A&M University. Mr. Ratzer is a registered professional civil engineer in New Mexico.

MICHAEL L. SPACE

Mr. Space has 15 years experience in site characterization, regional aquifer studies, regulatory compliance, and project management. He is currently a technical advisor to DOE AL on environmental and waste management issues at several DOE sites, including LANL. In addition, Mr. Space has overseen drilling projects/subsurface characterizations over large regional areas and smaller sites in both alluvial and hard rock environments. Previously employed by the New Mexico Environment Department (NMED), Mr. Space has an excellent working relationship with NMED and has negotiated and achieved NMED/EPA regulatory closure at contaminated sites owned and operated by federal agencies and private clients. Mr. Space is well-versed in all applicable environmental regulations. He has authored over 50 published articles, environmental assessments, site characterization/rededication reports, and technical evaluations. Mr. Space has B.S. and M.S. degrees in Geosciences and is a certified professional geologist and registered environmental manager.

APPENDIX F

COMMENTS BY LOS ALAMOS NATIONAL LABORATORY

LANL's comments were documented in *Los Alamos National Laboratory Response to "Value Engineering Study, Los Alamos National Laboratory, Ground Water Protection Program, August 2001" Pre-Publication Draft*, dated September 17, 2001. The VE Study Team reviewed these comments and changed parts of the report where improvements were warranted. During a telephone conference on October 10, 2001, all comments were adjudicated. LANL comments that did not lead to changes in the report are reproduced here along with italicized team responses. Comments that resulted in changes or showed agreement are not included. Comment numbering corresponds to LANL's initial numbering. All section, page and paragraph references are to the VE Study Report.

12 Section 2.1, Ground Water Investigations, p. 8, ¶ 4

This paragraph states that the overall environmental strategy of the Hydrogeologic Workplan is risk-based and that ultimately the characterization of the regional aquifer is driven by the need to identify potential risks to human health and the environment. Except for the fact that every environmental law and regulation is intended to protect human health and the environment, the Hydrogeologic Workplan is not a risk-based plan. The Hydrogeologic Workplan describes a body of data collection and data analysis that is intended to characterize the hydrogeologic setting to gain an understanding of the hydrogeologic setting adequate to design a monitoring network capable of detecting water quality threats and/or to support ground water monitoring waiver demonstrations.

The series of decisions established in the Hydrogeologic Workplan are shown in a flow diagram (Hydrogeologic Workplan Figure 1-3) and are listed for each aggregate in the DQO process outputs (Hydrogeologic Workplan Appendix 4). These decisions seek to establish if saturated zones have been impacted by contaminants and to determine the pathways of contaminant migration. The location of contamination and the transport pathways were considered the most important factors in designing a monitoring network. This is also the initial information needed by the Environmental Restoration Project in assessing potential releases and, where necessary, evaluating remedial options and monitoring needs. The Hydrogeologic Workplan identifies the data required to resolve the decisions.

The Laboratory has an existing ground water monitoring network, analytical results from which are reported annually in the Environmental Surveillance Report, and all of the wells installed pursuant to the Hydrogeologic Characterization Program will be candidates for inclusion in the monitoring network. When the Hydrogeologic Workplan is fully implemented, it is anticipated that there will be sufficient data to complete the evolving design of an enhanced site-wide monitoring network and for the Environmental Restoration Project to have identified areas where further ground water investigations are necessary as part of the RCRA corrective action process. One objective of the Hydrogeologic Workplan is to identify areas of the Laboratory with ground water contamination. However, determining the nature and extent of contamination and the risk posed by that contamination is the responsibility of the Environmental Restoration Project, and is not within the scope of the Hydrogeologic Workplan. The Workplan was intended to be the integrated

characterization phase necessary for two different programs to carry out their related missions— institutional environmental monitoring and environmental restoration— in a coordinated and cost-effective fashion.

12. The VE Study Team disagrees with LANL's comment that the Hydrogeologic Workplan is not related to risk-based goals. The last sentence of paragraph four in the document "Ultimately the characterization of the regional aquifer is driven by a need to identify potential risks to human health and the environment" is the key reason for performing the investigation.

13 Section 2.1, Ground Water Investigations, p. 8, ¶ 5
The first sentence states that 10 wells have been completed. It is important to note that not all of the wells cited in the report have been completed under the auspices of the Hydrogeologic Workplan. Ten wells that have been completed are Hydrogeologic Workplan characterization wells: R-5, -7, -9, 9i,-12, -15, -19, -22, -25, and 31. Two other wells have been completed to investigate the extent of contamination: CdV-R-15-3 and CdV-R-37-2.

13. The VE Study Team was told verbally while on site that well CdV-15-3 was required directly due to impacts identified in monitoring well R-25, and not from RCRA compliance activities associated with a specific SWMU (though it is understood that R-25 is located near an area of concern). Thus the VE Study Team lumped CdV-15-3 with the other ten monitoring wells.

15 Section 2.1, Ground Water Investigations, p. 10-11, ¶ 3
This paragraph states that "impending decrease in funding will certainly require changes in project scope," and that the VE Study was primarily targeted to develop alternative approaches that could mitigate the restrictions caused by decreased funding. This thinking was based only on consideration of the decreasing Environmental Restoration baseline, and did not consider the program partnership with Defense Program funding and the fact that DP funding had been historically less than budget requirements. Unfortunately, the study was predicated on only one variable, i.e., decreased ER funding, and did not consider another alternative, i.e., increasing funding in order to meet RCRA/HSWA regulatory requirements at the Laboratory.

15. The VE Study Team evaluated LANL's implementation of the Workplan because, as the External Advisory Group (an external technical advisory group that LANL has contracted to assist on technical issues) has said, "its scope is unbounded." The VE Study Team does recognize that LANL has made improvements in their monitor well installation program, but wells are still costing much higher than other DOE facilities with similar geologic challenges. Increasing funding for this project will not solve this problem.

19 Section 2.2, Recommendations, p. 12, Recommendation 1, ¶ 4 Opportunities
This section of the VE Study document is fraught with confusion regarding existing RCRA regulatory compliance objectives. The first paragraph claims that there is a "distinct opportunity to make improvements through a new strategy that expedites operation of a monitoring well network, while building upon the knowledge obtained to date and transferring characterization efforts to RCRA." The Laboratory is currently implementing the hydrogeologic characterization under RCRA requirements, and does not need to transfer efforts to RCRA. The operation of a monitoring well

network (that needs to be carefully designed and located on the basis of a site-wide hydrogeologic understanding) will not necessarily replace the regulatory requirements to perform characterization or nature and extend contaminant studies (e.g., plume chasing). Therefore the three recommendations described as part of this paragraph do not comport with the current regulatory requirements. Each of the recommendations is addressed as follows.

(1) "Prepare a comprehensive hydrogeologic report on the regional aquifer based on the extensive information already collected to date to demonstrate LANL's knowledge of the regional aquifer system;"

Although the Laboratory agrees that a significant amount of information has been collected during the past four years of implementation of the Hydrogeologic Workplan, complementing other existing hydrogeologic information regarding the regional aquifer, the objective of the characterization work has been much more comprehensive than just a focus on the regional aquifer. The NMED expects the Laboratory to complete a comprehensive study of the stratigraphy, geochemistry, and hydrogeology on a site-wide scale so as to satisfy the specific HSWA module requirements and the written objectives of the Hydrogeologic Workplan. A narrow focus just on the regional aquifer will not meet the NMED expectations, nor the regulatory compliance goals of the Hydrogeologic Workplan. The Laboratory publishes a Ground Water Annual Status Report each fiscal year that describes the evolution of site-wide conceptual model and details the new information gained through the year's characterization efforts. This annual characterization report will continue, per the commitment with NMED. Although it would be premature to prepare a comprehensive hydrogeologic report at this time, such a report is envisioned during FY 05 as a final deliverable in completing the Workplan.

(2) "Refocus near-term efforts to initiate a regional aquifer monitoring network by installing a limited number of single completion wells;"

The Hydrogeologic Workplan is not a monitoring well project. The Laboratory is in the process of developing a comprehensive site-wide characterization of the hydrogeologic setting, developing an improved understanding of the hydrogeology and ground water pathways in order to support the design and installation of additional monitoring wells that are either required by NMED or found to be desirable by the Laboratory and DOE. At this time, the hydrogeologic characterization is not complete enough to enable the prudent design and location of monitoring wells. However, as the characterization effort continues, the location and design of characterization wells will continue to emphasize strategic monitoring use of the wells subsequent to characterization, as has been done to date under the program. Additionally, the current DQO re-iteration is detailing the final three-year scope of the characterization program, and it is anticipated that only a limited number of characterization wells (e.g., 6-12 wells) will be required to complete the characterization. Also, many of these wells may indeed be constructed as single completion wells. Thus, during the first quarter of FY 02, the final scope and deliverable(s) for the Workplan will be negotiated and established with NMED.

(3) "Create a monitoring well network installation project with full management controls that highlight overall progress towards satisfactory regional aquifer monitoring."

As stated regarding number (2), the Laboratory believes that it is premature to design and construct a monitoring well network or create a monitoring well network installation project, especially solely based on the regional aquifer. However, the Laboratory will continue to judiciously site and construct characterization wells, which can be strategically located for future use as monitoring wells. The Water Quality & Hydrology Group's (ESH-18) Ground Water Monitoring Plan is currently being revised to include the characterization wells and account for other institutional ground water monitoring strategies. All of these efforts are on-going and being implemented along a parallel path. The Laboratory's ultimate ground water monitoring network will be similar to the existing network in that it will include ground water monitoring from alluvial aquifers, intermediate perched aquifers, and the regional aquifer, providing monitoring data for publication of the Annual Environmental Surveillance Report and supporting monitoring requirements in other regulatory permits held by the Laboratory. Thus, the focus of the ground water monitoring network will not be limited to the regional aquifer, as suggested by the VE Study.

19. The VE Study Team realizes that NMED's focus is not limited to the regional aquifer. However, the stated purpose of the plan is to collect sufficient information to establish a ground water monitoring network. It is the VE Study Team's opinion that there is a considerable amount of data that could be used to prepare a comprehensive report. A purpose of this report is that it will identify any remaining data gaps that could be filled while drilling and installing the remaining wells. At this point, it is unclear to the VE Study Team that LANL has compiled the existing information in a manner in which a clear scope can be defined and negotiated with NMED for future wells and completion of the program. The present process, if continued, will likely create inefficiencies that will affect cost and schedule. A Hydrogeologic Workplan has not been required at any DOE site, including Sandia National Laboratories, which is under NMED jurisdiction. All other DOE sites utilize the RFI process for hydrogeologic characterization. Thus, the VE Study Team believes there is flexibility in the process and execution of the Hydrogeologic Workplan that LANL could take advantage of to meet stated goals.

20 Section 2.2 Recommendations, p. 13, Recommendation 1, ¶ 1 Opportunities

The first paragraph states: "This can tell a compelling story and confirm that impacts to the regional aquifer have been minor...Based on its review of existing information, the VE Study Team anticipates that such a report (which could be part of a ground water compliance plan) will be a turning point in LANL's ground water project...It will demonstrate to regulators and other stakeholders that the regional ground water system has been characterized to the extent necessary to enable the establishment of an effective long-term monitoring network." As stated in other response comments, the NMED and the Laboratory are not solely interested in the regional aquifer. The NMED's RCRA program (as well as other ground water programs regulated under the New Mexico Water Quality Control Commission Regulations) focuses on the uppermost ground water affected by releases or discharges. Thus, the Laboratory must consider alluvial and intermediate perched ground water in any ground water protection program and regulatory compliance strategy. The Laboratory does not require the VE Study Team's suggested ground water compliance plan. The Laboratory already has a comprehensive set of permits and permit conditions that define a compliance program for ground water, and indeed is operating in compliance of same. As stated elsewhere in this response, the characterization work is not yet complete, so as to adequately demonstrate to regulators and stakeholders that the regional ground water system has been

characterized. There is still extant information and data that will be required to accomplish this objective.

20. One of our recommendations is to evaluate perched water zones, whether in the alluvium, or intermediate zones, as part of the RCRA corrective action process, and for the Workplan to primarily concentrate on the regional aquifer. The geology at each well location can still be evaluated by collecting cuttings, tabulating drilling rates, and use of other techniques.

21 Section 2.2 Recommendations, p. 13, Recommendation 1. ¶ 2 Opportunities
This paragraph recommends that the "conversion of existing characterization wells to their new function as monitoring wells should be clearly defined...Well locations and depths should focus on the eastern boundary...The investigation of alluvial and perched systems should be separated from the regional aquifer investigation and integrated into the RFI process at specific PRSs." As stated previously, the Laboratory is already in the process of revising the Ground Water Monitoring Plan to include the resulting characterization wells into the ground water monitoring network. The Laboratory does not agree that well locations and depths should focus on the eastern boundary. A focus on the eastern boundary assumes that the boundary is the sole point of compliance. However, many of the water supply wells for the Laboratory and Los Alamos County are within the LANL boundaries. Thus the points of compliance are more complex than just the down-gradient boundary. Also, because the NMED's regulatory programs address uppermost ground water, ground water monitoring may be required across the Laboratory, and especially immediately downgradient from sources of contaminates. Points of compliance, monitored natural attenuation, and decisions on other related regulatory strategies will surely dictate widespread location of monitoring wells. Lastly, the present characterization program is cost-effectively gathering information on intermediate perched ground water in specific locations as wells are drilled down to the regional aquifer. Indeed, characterization of the shallow alluvial ground water and intermediate perched ground water is currently being conducted by the ER Project pursuant to RFI Workplans pertinent to specific PRSs. In this case, the ground water characterization program is the beneficiary of this characterization information. However, the coincident investigation of intermediate perched ground water while drilling regional aquifer wells under the Hydrogeologic Workplan is viewed as complementary to the ER RFI process, and in many instances will result in cost avoidance for the ER Project due to the fact that the ER Project will utilize the data gained during characterization to address data needs vis a vis having to drill additional well(s).

21. The VE Study Team disagrees with LANL's comments. The team does not consider the eastern boundary as the sole focus for monitor wells, obviously any point of exposure (including public water supplies) would need to be part of an overall monitoring program. However, because of the direction of regional ground water flow and the area east of the Pajarito Plateau being a discharge zone, it seems this would be a priority. It is also certain that monitor wells, in alluvium, perched zones, and in the regional aquifer might be required as part of the RCRA corrective action process. Finally LANL's assertion that "the present characterization program is cost-effectively gathering information on intermediate perched ground water" is not supported by actual costs.

22 Section 2.2 Recommendations, p. 13, Recommendation 1, ¶ 3 Opportunities
The third paragraph on page 13 reiterates much of the text on page 12, but in addition contains several erroneous conclusions stated as benefits. The paragraph assumes that a comprehensive report detailing the hydrogeology of the regional aquifer will be completed in six months, seven to eight years earlier than the current schedule estimates at the present rate of drilling. This assumption is in error in that it does not take into account the true resources and time frame required to write such a comprehensive report. Moreover, the assumption does not take into consideration that the iterative nature of the Hydrogeologic Workplan allows for fewer wells than the proposed 32 regional aquifer wells to be drilled in order to meet the characterization objectives. In other words, one cannot predict the schedule of the Workplan based on the present drilling rate due to the changing number of wells required.

The second benefit listed in this paragraph assumes that a detection monitoring system can be implemented earlier, and that this will provide a clear and much faster response to intense public and regulatory concern and provide a clear and unambiguous focus on assessment of current or potential risk to public health. This assumed benefit in the VE Study document makes several assumptions, for example:

(1) The document assumes an intense public and regulatory concern, yet the VE Study Team did not interview any public or regulatory personnel to judge their specific concerns.

(2) The document assumes that a detection monitoring system is what is being asked for and needed. Under RCRA/HSWA not one of the three ground water monitoring requirements have been placed on the Laboratory, as yet. For example, within RCRA/HSWA, there are three structured and sequential monitoring programs, i.e., detection monitoring, compliance monitoring, and corrective action monitoring. To date, none of these monitoring programs has been required by NMED. Although the Laboratory and/or DOE may desire to voluntarily install monitoring wells for their own purposes, prudence would dictate that time and money could be saved by waiting for the NMED to require RCRA/HSWA monitoring, and then properly locate the required well(s) based on sound hydrogeologic characterization of the Pajarito Plateau.

(3) The document assumes that this new strategy will initially be a shift of focus within the current Workplan, and would require no immediate approval by regulatory authorities. This assumption has no basis and is untrue. The Hydrogeologic Workplan is a RCRA/HSWA regulatory compliance document, and changes must be approved by the NMED.

22. The VE Study Team disagrees with LANL's comments. With regard to the need for a comprehensive document that describes the current state of knowledge, one team member has observed repeated inquiries from stakeholders and regulators as to where the information is written down. The reply from LANL was consistently that the report has not been written or the study is incomplete etc.

23 Section 2.2, Recommendation 2, p. 14

The "Current State" description and "Opportunities" suggests that an integrated comprehensive cost and schedule document is lacking. The project management of the hydrogeologic characterization activities has evolved over the past four years such that all of the drilling activities in support of the Hydrogeologic Workplan are integrated in a comprehensive plan that is incorporated into the ER Baseline. A separate work breakdown structure is in place that defines scope, schedule and cost for each well of the project. An integrated schedule that incorporates all task activities and associated costs for drilling, installation, sampling and data analysis for each well has been prepared and was available for review by the VE Study Team. The project has been successful in reducing costs in every aspect of the drilling program and meeting its schedule commitments. However, the data analysis activities, e.g., data management and modeling, are not integrated with the drilling activities in the ER Project baseline. Although these activities are described in Task Scope Descriptions (TSDs), they have not been meshed with the drilling activities, and thus, even though all of the complementary parts of the project are in the baseline, a complete hydrogeologic characterization project baseline has not been assembled in one place. This has been recognized as a weakness and there is a concerted effort to integrate all hydrogeologic characterization activities in one management package.

The "Current Condition" and "Opportunities" descriptions further opines that the Data Quality Objective (DQO) Process that is applied to well design contributes to delays and expanded costs. The DQO process is used to ensure that wells are designed such that the necessary data can be collected from them. In the absence of such a process, it is unclear what basis would be used to design wells. The recommendation suggests that a "standardized", one-size-fits-all well design would be more efficient. Although this approach may have merit if the goal is to install piezometers, but since these wells are characterization wells, this short-sighted perspective would lead to a penny-wise, pound-foolish approach wherein standardized wells are installed only to have to add more wells at a later time to collect other necessary data.

The "Cost and Schedule Implications" section of this recommendation suggests that well drilling is a two-year long activity under the 10-year long Ground Water Protection Program (a reference to the Ground Water Protection Management Program Plan, see comment #2). The well drilling is done under the auspices of the Hydrogeologic Workplan, intended to be complete in no longer than seven years from NMED approval of the Workplan. The thrust of the Ground Water Protection Management Program Plan regarding monitoring is expected to continue considerably longer than 10 years.

23. The VE Study Team agrees with the portion of LANL's comment regarding the fact that there have been improvements in the drilling program. However, the drilling program is only one part of the picture. The segmented nature of the approach to the work is obvious by the mere fact that not all the activities related to the drilling program are reflected in the baseline or even come from the same funding source. This situation lends itself to potential inefficiencies. The VE Study Team agrees with LANL that this is a weakness. On the second point, regarding the DQO process, the VE Study Team is not taking exception to the use of DQO. The VE Study Team believes that without taking a risk-based approach (i.e., contaminant source, pathway, receptor), it is difficult to determine what data really is necessary. The approach of LANL appears to be to collect as much

information out of each borehole as possible in the hope that someday it may be needed. This has resulted in complex well design and a multitude of testing and sampling, all of which increases the overall scope and cost. The last point relative to the potential management cost savings is a good one. The VE Study Team's point is that these activities are so segmented and spread throughout so many WBS codes it is difficult to determine the amount of management support.

26 Section 3.0 Field Operations, Data Analysis, Modeling and Data Visualization, p. 17, Recommendation 2, ¶ 1 Current State and Opportunities:
Under the description of "Current State," the document states that characterization wells drilled to date have included several Westbay systems so that intermediate hydrogeologic information could be collected, and that this has caused delays and extra cost. Please note that the Workplan was written by the Laboratory, and approved by DOE and NMED, to collect characterization information on the intermediate perched ground water zones encountered during drilling to the regional aquifer. When such intermediate ground water was observed, and especially if continuing monitoring was desirable, it was more cost-effective to employ the Westbay system in a single borehole than to side-step the drill rig and drill a dedicated intermediate depth well. Furthermore, one of the foremost uses of the Westbay multiple completion systems has been the monitoring of numerous screens at depth in the regional aquifer for the collection of vertical head data. This data has been viewed as the most important data collected to date for purposes of constructing an accurate numeric model of the regional aquifer. Thus, the document has erroneously described the use and purpose of the Westbay systems, and unfairly characterized them as causing delays and extra cost.

26. The VE Study Team disagrees with LANL's comment. To clarify our position, the first paragraph of Recommendation 2, Current State, on page 17 has been modified to read as follows: "Characterization wells drilled to date have included several Westbay systems. Although vertical head data within the regional aquifer have been collected, water sampling results have been suspect, and aquifer pump tests cannot be performed. Difficulties with installing these Westbay systems has also caused delays and increased costs." Again, the need for intermediate depth data may be addressed in the RCRA corrective action process based on potential risk.

31. Section 4.0, p. 24
This section describes the relationship between DOE/LANL and NMED as "if not broken, badly bent." The VE Study Team did not interview personnel from NMED or any other stakeholders, thus the nine recommendations in this section are based solely on the perceptions of one-half of the relationship. It seems inappropriate that nearly a quarter of this report (23 percent) is dedicated to criticizing a relationship for which only half the information has been evaluated. LANL does recognize the critical importance of maintaining and continuously improving the working relationships with the regulators and other stakeholders. Communication efforts, within budgetary constraints, will continue to be part of the implementation of the Hydrogeologic Workplan.

The Hydrogeologic Workplan included a plan for communication. It consisted of four formal communication opportunities every year: three quarterly meetings and one annual meeting, each documented by minutes distributed after the meetings. These meetings are the opportunity for regulators and stakeholders to get status reports on the various aspects of the characterization, evaluate proposals on changes to the characterization, and provide feedback on concerns they may

have with regard to the progress or other technical aspects. Although originally proposed for NMED only, the stakeholders were also invited to participate in the meetings. Over the past four years there has been a significant increase and broadening of attendance by NMED bureaus, neighboring Pueblos, the Northern New Mexico Citizens Advisory Board, and environmental advocacy groups. Another communication mechanism included in the Hydrogeologic Workplan is the production of an annual status report on the accomplishments and findings from the year that it is published and widely distributed.

Informal communication is frequent with the regulators. The regulators are provided the weekly drilling report and are consulted on many major decisions or field changes. The regulators are provided the Field Implementation Plans for each well for informal input. Further, the NMED has split water samples from nearly every borehole that has been drilled to date.

In addition to these communication mechanisms, an External Advisory Group (EAG) was formed in 1999 to provide independent peer review of the Hydrogeologic Workplan activities. The EAG is composed of six individuals, each with expertise in areas important to hydrogeologic characterization. Two times a year the EAG holds a stakeholder-only discussion session intended to air concerns, issues, or grievances. The EAG has noted a steady increase in regulator and stakeholder satisfaction with the Hydrogeologic Characterization Program during these sessions.

Regulator and stakeholder access to data collected under the Hydrogeologic Workplan was considered to be a very important part of maintaining the relationship. To respond to this need, the Water Quality Database was developed and is accessible via the Internet.

Due to funding constraints, this effort has not gone as quickly as was planned. However, the data is available in tabular formats and the revisions necessary to provide data in geographical formats have begun.

31. The VE Study Team acknowledges the efforts by LANL described in this comment. However, there is reason to believe there is room for improvement. For example, NMED's letter to LANL dated March 16, 2001 expresses serious concerns regarding modeling efforts, use, and presentation as well as identifying issues associated with the data characterization packages.

34. Section 4.0, Recommendation 3, p. 26

This recommendation focuses on using the regional aquifer model as a communication tool. Modeling of the hydrogeologic system involves interconnected models of the vadose zone under mesa top sites, vadose zone beneath canyons, and the regional aquifer. The models are interconnected because the output of one model is input to the next. The results of these modeling efforts are presented at every quarterly and annual meeting. These modeling efforts were presented as they were being developed and refined, which may have been confusing to regulators and stakeholders; however, it was deemed to be better than waiting several years until the modeling was "done" before presenting it. The modeling will continue to be the primary analytical and communications tool for the hydrogeologic characterization work.

34. The VE Study Team appreciates the challenges LANL faces in their modeling efforts. Our recommendation is to work on presenting the information in a comprehensive manner, instead of in a segmented fashion.

35 Section 4.0, Recommendation 4, p. 27

This recommendation focuses on what NMED considers success. The recommendation appears to be based on what the VE Study Team thinks that NMED would consider a success. In the absence of any discussions with NMED, the bulk of this recommendation is an unsupported assumption. The Laboratory recognizes the need to reach consensus with NMED in defining the "end state" of the Hydrogeologic Workplan. A regular feature of External Advisory Group reviews is to bring together the managers of DOE, LANL, and NMED to work out issues and to define the end state that would be acceptable to all organizations. This is a very important aspect of implementing the Hydrogeologic Workplan and the efforts to reach consensus with NMED will continue.

35. The VE Study Team does not agree with LANL's assertion that what NMED would consider a success is "an unsupported assumption." Several of the VE Study Team members have extensive experience with NMED personnel on RCRA compliance and ground water issues. Please see response to 31.

36. Section 4.0, Recommendation 5, p. 28

This recommendation suggests that the NMED is unaware of schedules and deliverables and proposes collaborative planning as a solution. LANL agrees with this recommendation and has always had such a collaborative process. The deliverables and schedules for the year are collaboratively planned with NMED and other stakeholders during the annual meeting held in March. The agreed upon schedule and deliverables can be adjusted, if necessary, during quarterly meetings held in October, January, and June. A more formal process was proposed by the DOE, LANL, and NMED managers during the annual meeting in March 2001, wherein LANL will write a letter describing the planned schedule and deliverables following the annual meeting in March. Stakeholders will also receive the planned schedule and deliverables in order to allow for stakeholder participation in establishing the scheduled work for the following year. Due to uncertainties in the budget for FY02, the letter for NMED and stakeholders was not submitted until September. Nevertheless, this process is in place and will be followed to the extent possible for the remainder of the Hydrogeologic Workplan activities.

36. The VE Study Team recognizes the process described by LANL in its response, and believes this is a good start. However, annual and/or quarterly meetings may not be enough. Moreover, there is insufficient comprehensive data presented at the annual meeting to make meaningful decisions. This observation has been made by at least one VE Study Team member and echoed by several stakeholders.

41 Section 5.0, Cost/Schedule Savings Development, p. 35

This section of the draft document presents the VE Study Team's development of estimated savings for the project by the use of an estimate for a standardized "model" well. The Laboratory disagrees with this approach and finds this section to be highly subjective and misleading. Use of a standardized well for cost estimate comparison is not appropriate for the Laboratory project due to

the extreme variability and complexity of the subsurface in which the investigations are conducted. The Laboratory has performed cost estimates for each characterization well based on the expected geologic strata to be encountered, the depth of the well, the number of screens to be installed, and other physical factors. These cost estimates form the basis of the deep well drilling project baseline (described elsewhere in this response). The Laboratory's management of the Ground Water Characterization Program makes every attempt to control costs through execution of the well drilling activities. As efficiencies are gained from cost control measures, the baseline cost estimates are adjusted providing a constant stream of refinement to the cost estimates based on actual costs. It is the Laboratory's opinion that it is highly unlikely that the standardized well approach will accurately reflect the true costs and savings to this or any drilling program.

41. The VE Study Team disagrees with LANL's comment regarding cost-effectiveness. The costs associated with this program do not support LANL's comment. For example, LANL's deep wells are averaging about $1.9 million each (excluding R-25), some of the most expensive throughout the DOE complex. The VE Study Team compared the cost of drilling at INEEL versus LANL. As stated in the report, the VE Study Team found that LANL's drilling costs per foot were between $373 and $418 per foot, not including well construction for R-22 and R-15 respectively. Drilling costs for the same drilling contractor at INEEL typically run $272 per foot including drilling, well construction and materials. The cost of a well completion report alone is $184,000 at LANL, which exceeds comparable documents at other DOE sites.

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ATTACHMENT 1

GENERATION OF HYDROGEN GAS AS A RESULT OF DRILLING WITHIN THE SATURATED ZONE

BY: BRUCE N. BJORNSTAD, JAMES P. MCKINLEY,
TODD O. STEVENS, SHIRLEY A. RAWSON,
JAMES K. FREDRICKSON, AND PHILIP E. LONG\

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Generation of Hydrogen Gas as a Result of Drilling Within the Saturated Zone

by Bruce N. Bjornstad, James P. McKinley, Todd O. Stevens, Shirley A. Rawson, James K. Fredrickson, and Philip E. Long

Abstract

Hydrogen gas was discovered within the steel casing above standing water in a percussion-drilled borehole on the Hanford Site in south-central Washington state. In situ measurements of the borehole fluids indicated anoxic, low-Eh (<-400 mV) conditions. Ground water sampled from adjacent wells in the same formation indicated that the ground water was oxygenated. H_2 was generated during percussion drilling, due to the decomposition of borehole waters as a result of aqueous reactions with drilled sediment and steel from the drilling tools or casing. The generation of H_2 within percussion-drilled boreholes that extend below the water table may be more common than previously realized. The ambient concentration of H_2 produced during drilling was limited by microbial activity within the casing-resident fluids. H_2 was generated abiotically in the laboratory, whereby sterilized borehole slurry samples produced 100 times more H_2 than unsterilized samples. It appears that H_2 is metabolized by microorganisms and concentrations might be significantly greater if not for microbial metabolism.

Introduction

The Yakima Barricade Borehole (YBB), located on the U.S. Department of Energy's (DOE) Hanford Site (Figure 1), was drilled as part of a DOE research program to investigate microbial processes in deep subsurface environments and to evaluate geochemical and geohydrological controls on subsurface microorganisms. The borehole was sited free of nearby surface or ground water contamination, and penetrated a relatively thick (740 feet [225 m]), heterogeneous sedimentary sequence that overlies Columbia River basalt (CRB) (Figure 2) and in which hypotheses relative to the controls of microbial activity could be tested.

A combustible gas, determined to be H_2, was detected during drilling of the YBB. Tests were performed to evaluate the mechanism by which H_2 was concentrated within the borehole. This paper will present evidence for the generation of H_2 in boreholes during percussion drilling below the water table and propose mechanisms of H_2 generation and their implications for safety during drilling.

Combustible gas was detected in the borehole while drilling within a fluvial, sedimentary sequence of the Neogene-age Ringold Formation. These sediments consisted predominantly of well-rounded, clast-supported gravels in a moderately to well-sorted arkosic, sandy matrix. Gravel-size clasts included detrital basalt of local origin, along with granitic, quartzitic, and volcanic-porphyry clasts derived from distant

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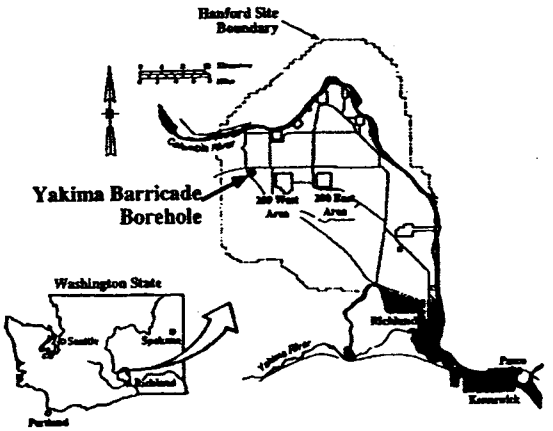

Figure 1. Location map of the Hanford Site and the Yakima Barricade Borehole (YBB).

source areas surrounding the Columbia Plateau (Goodwin 1993). Petrographic analysis of fluvial Ringold gravels from comparable strata in nearby boreholes indicated quartz was the predominant constituent (about 50 percent), with subordinate, subequally abundant feldspar and lithic rock fragments. About half (13 percent) of the lithic clasts were mafic volcanics (i.e., indigenous CRB) followed in abundance by intermediate-to-silicic volcanics, quartzite, and granitic clasts.

The hole was drilled using the percussion cable-tool method. With this method, continuous, telescoping carbon-steel casing was driven downward to maintain the borehole opening within the unconsolidated to semiconsolidated suprabasalt sediments of the Hanford and Ringold formations (Figure 2). The casing was advanced as material from the bottom of the hole was removed with a core barrel. New sections of casing were welded on about every 10 feet as the borehole deepened. Below the water table, fluid within the borehole directly contacted subsurface strata only at the bottom of the casing. Broken small fragments of larger clasts were retrieved from the core barrel after drilling advanced the borehole. During drilling a dark, sediment-laden slurry developed within the cased portion of the borehole below the water table, which lay at a depth of 327 feet (100 m). When the bottom of the borehole was 420 feet (128 m) below the surface and ~100 feet (30 m) below the water table, a small explosion lifted a 1-cm-thick solid steel plate several centimeters off the top of the casing during routine welding operations. After the explosion, a combustible gas analyzer (CGA) used near the top of the casing indicated the presence of a combustible gas. Drilling operations were suspended until the identity and source of the gas(es) could be determined.

Methods

The origin and nature of the combustible gas in the wellbore was investigated with a series of analyses of the borehole gas, borehole fluids, formation ground water, and formation sediments. The borehole gas was

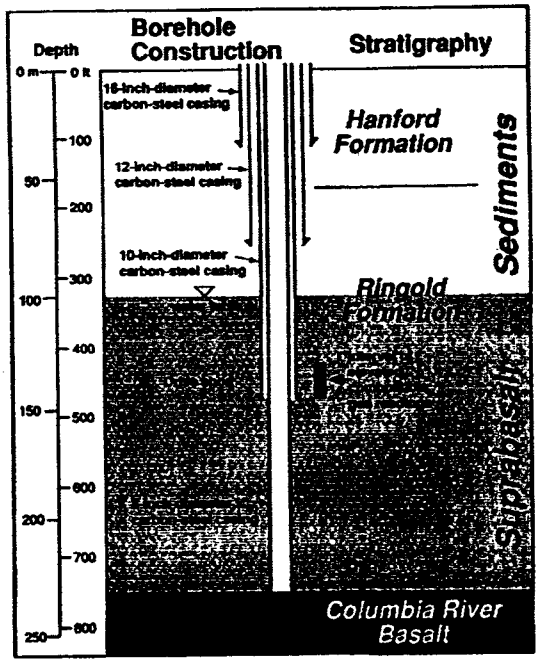

Figure 2. Borehole construction and stratigraphy at the YBB. A total of four strings of telescoping carbon-steel casing was used to advance the borehole to a total depth of 748 feet (227 m). Combustible gas was first detected at the 425-foot (130-m) depth (100 feet [30 m] below the water table) while drilling in saturated Ringold Formation sediments. The levels of combustible gas remained relatively low <20 percent of the LEL after the ~475-foot [144 m] depth).

analyzed in the field with Sensodyne™ sampling tubes and in the laboratory using gas chromatography (GC). Headspace samples for GC analysis were collected periodically using a sterile hypodermic needle and a gas-tight syringe. After the explosive gas was first detected, the lower explosive limit (LEL) of the atmosphere within the borehole relative to pentane was measured with the CGA at least twice daily. Subaqueous temperature, dissolved oxygen (D.O.), electrical conductivity, pH, and Eh were measured in situ with the Hydrolab Datasonde-3™ at depths within several feet of the bottom of the borehole. This instrument was calibrated in the laboratory prior to deployment. The platinum oxidation-reduction electrode was calibrated using quinhydrone buffer solutions, and the D.O. cell was calibrated against sparged and atmosphere-saturated tap water; pH and conductivity electrodes were calibrated against purchased standards. The geochemistry of formation water was evaluated by monitoring these hydrochemical parameters near the bottom of the borehole while pumping water from the top of the water column within the casing. The ground water introduced into the casing after pumping was sampled using the downhole AMS Sampler™, which allowed sampling at specific, predetermined depths within the borehole fluid column. Geologic samples from the bottom of the borehole were logged and described at least every 5 feet (1.5 m) or more frequently at changes in lithology.

Selected bulk samples retrieved from the core barrel were analyzed for particle-size distribution by dry-sieving (≥62-micron fraction) and hydrometer analysis (<62-micron fraction).

Several experiments were conducted with the borehole slurries to determine their role in H_2 production. The borehole slurry was characterized by analysis of its density, particle-size distribution, and clay mineralogy. Density was determined as the mass per unit volume of borehole fluid. Particle-size distribution for suspended slurries was measured using the hydrometer technique (Gee and Bauder 1986). Clay mineralogies were determined by x-ray diffraction. Borehole fluids were also analyzed for H_2 and CH_4 by transferring 125-mL subsamples of water from the downhole sampler into glass gas-sampling tubes immediately upon recovery. A 5-mL bubble of pure nitrogen gas was introduced by syringe, displacing 5 mL of slurry. Gases were extracted after vigorous shaking for 120 seconds by transferring the gas bubble to a tube containing N_2-saturated water; 1 atm pressure was maintained by displacing equivalent volumes during the transfer. The extracted samples were transported to the laboratory (approximately 30 minutes travel time) and analyzed by GC with thermal conductivity detection on a Hewlett-Packard 5890 Series II chromatograph with a Supelco 100/120 mesh Carbosieve S II molecular sieve 10-inch × 0.125-inch stainless steel column. The carrier gas was N_2, at a flow rate of 30 mL/min. The injector temperature was 120 C, the detector temperature was 250 C, and the oven temperature was incrementally increased from 50 C to 250 C at 20 degrees per minute. The detector polarity was negative.

Borehole slurry samples were either used as received or autoclaved (i.e., sterilized) before use so that the role of microorganisms in the generation or consumption of H_2 could be assessed. The most probable number (MPN) of aerobic bacteria was determined in these samples. Samples were degassed initially and then incubated in closed vials in the laboratory at room temperature in both air and N_2 atmospheres over a two-week period.

Results and Discussion

A number of tests confirmed the presence of H_2. A sampling tube specific to H_2 was lowered into the borehole headspace and indicated ≥2 percent H_2. Additional confirmation came from two samples, collected from 6 m below the top of the casing on consecutive days, which indicated concentrations of 1.2 and 1.5 percent H_2 (Table 1). During the collection of these gas samples, CGA readings taken at the sample depth registered 40 percent of the LEL (equivalent to 1.6 percent H_2), in agreement with the laboratory results (Table 1). Monitoring with the CGA indicated combustible gas at levels ranging from 0 to 100 percent of the LEL from depths of 3 to 25 feet (1 to 8 m) below the top of the casing (Figure 3). Because the atmosphere near the top of the casing may not represent borehole headspace with depth, only those LEL measurements taken >12 feet (4 m) from the top of the casing are shown in Figure 3.

Table 1
Laboratory Analyses of Gas Samples Within the Borehole

	Sample #1	Sample #2
Collection Date:	6/8/92	6/9/92
Analytical Method:	Mass spectrometry (%)	Thermal conductivity detector (TCD) (%)
N_2	80.5	82.5
O_2	18.3	15.9
CO_2	0.03	0.03
CH_4	<0.01	0.03
H_2	1.2	1.5

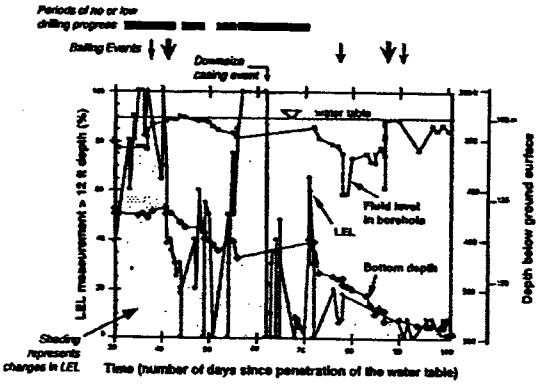

Figure 3. Plot of the LEL, fluid level, and bottom depth vs. time.

Hydrogen gas is combustible over a greater range in concentration (4.0 percent to 74.2 percent) than pentane gas (1.4 percent to 7.8 percent), which was used to calibrate the CGA (CRC 1965). Therefore the LEL readings measured with the CGA are 35 percent greater than the actual LEL for hydrogen gas in the borehole, but still provide a relative measure of H_2 concentration in the borehole headspace. The results of CGA measurements with and without a carbon filter were the same, indicating that the combustible gas was of low molecular weight (i.e., complex hydrocarbons were not present).

Depth to water and depth to the bottom of the borehole are also plotted in Figure 3 to show the relationship between drilling activities and the LEL. Fluid levels within the borehole fluctuated dramatically depending on the density of the slurry; densities increased with time since bailing. The variation of LEL with time clearly shows that LEL was highest when little or no progress was made in deepening the borehole. During such times the slurry stagnated within the borehole casing. In most cases sharp declines in the LEL correlate with borehole bailing, which allowed fresh formation water to enter through the bottom of the casing; the introduction of oxygenated water reduced or arrested H_2 generation. For example, the first LEL peak occurred during a period (beginning after ~35 days)

Table 2

In Situ Borehole Fluid Measurements Performed Before and After Bailing/Pumping

Date	State of Borehole Fluid	D.O. (mg/L)	Eh (mV)	pH	Temp. (C)	H_2 (ppm)	CH_4 (ppm)
Before Bailing/Pumping (stagnant)							
8/14/92	Dense slurry after drilling	0	−456	8.0	22.5	43,000	103
8/17/92	Dense slurry after drilling	0	−409	8.0	21.1	37,000	76
After Bailing/Pumping (introduction of formation waters)							
8/4/92	Bailed and pumped overnight	4.9	184	7.5	20.8	88	0
8/18/92	Bailed and pumped	3.1	250	7.6	21.1	390	0

when little drilling progress was made because of extensive sampling and difficult drilling conditions. Elevated LEL levels ended after a bailing event (40 to 45 days) that was followed immediately by a more normal rate of drilling advance. Another example of the correspondence between bailing and LEL occurred at approximately 77 days. Some short reductions in drilling progress corresponded with spikes in LEL (e.g., the spike occurring at 47 days). An abrupt decrease in LEL that occurred at 62 days coincided with placement of the 8-inch-diameter casing inside the 10-inch-diameter casing. Such a dramatic decrease in LEL suggests that combustible gas was being generated by reactions between the borehole fluids and the casing lining the inside of the borehole. The LEL remained relatively low except for a few short peaks that followed within 10 days of downsizing the casing. The new casing was apparently responsible for decreasing the LEL, since the condition of the slurry did not change and no bailing took place during or soon after downsizing the casing.

In situ measurements of casing-resident borehole fluids indicated that the fluids were anoxic and highly reducing. In contrast, samples of ground water, derived from the formation after bailing and pumping, contained significant concentrations of D.O. and displayed positive Eh values (Table 2). In situ measurements were performed several times with a Hydrolab Datasonde-3™ lowered to within several feet of the bottom of the borehole. Introduction of fresh water at the bottom of the casing caused a rapid response in the datasonde (Figures 4A and 4B), with D.O. and Eh quickly rising from 0.2 to 4.9 mg/L and 90 to 184 mV, respectively, and then stabilizing over a short period of pumping (less than 30 minutes). To reduce the quantity of fine-grained particles suspended in the aqueous samples, the borehole was bailed prior to pumping. The slightly oxidative conditions within the casing at the start of pumping may have been established by the introduction of oxygenated formation water into the borehole during bailing. In a subsequent test, pumping was stopped, and D.O. and Eh of the borehole fluid dropped dramatically and stabilized at an anoxic, reducing state after 400 minutes (6.6 hours) (Figures 4C and 4D). The pH also increased slightly with time, as ground water reacted with suspended solids within the casing.

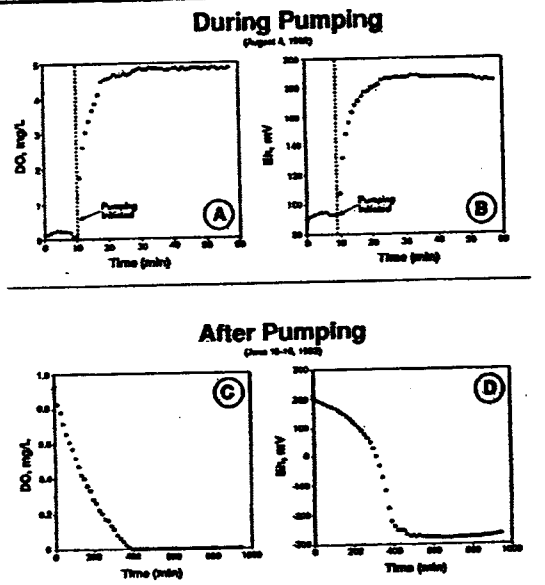

Figure 4. Changes in oxidation-reduction potential and dissolved oxygen within borehole fluids before (A and B) and after (C and D) pumping of fluids from the borehole. A and B show an abrupt change in borehole conditions induced by introduction of formation water by pumping and discharging at the surface. C and D demonstrate a slow return to anoxic, reducing conditions within the borehole after the pump was shut off.

During drilling, fine particles from the formation and drilling process were mixed into the standing column of borehole fluid, creating a dense slurry. Thus, with drilling time and with no substantial influx of formation water, the density of the borehole fluid increased. Variations in the density of the slurry caused fluid levels within the casing to vary by as much as 80 feet (25 m) (Figure 3). Both smectitic and illitic clays and quartz were identified in the slurry. Density measurements of the borehole slurry ranged from 1.20 to 1.35 g/cm^3. Assuming an average particle density of 2.65 g/mL, the suspension was calculated to consist of approximately 12 volume percent sediment. The larger clasts retrieved from the core barrel were compared with Ringold Formation gravels collected from outcrop, which were generally well rounded and unbroken. Drilled gravels showed smaller average clast size and

increased angularity. Particle-size distributions also showed a decrease in particle size (i.e., an increase in sand fraction and decrease in gravel fraction) as a result of pulverization during drilling (Figure 5). The suspension thus contained some drilling fragmented gravels along with sediment fines.

Hydrogen and methane detected in borehole slurry samples did not originate from the formation ground water. This is demonstrated in Table 2, which shows that formation water obtained after bailing is low in H_2 and devoid of CH_4. Historical data indicated that wells developed in the unconfined aquifer elsewhere on the Hanford Site were also low in H_2 (Early et al. 1986). Borehole slurry samples, on the other hand, contained up to 4.3 percent H_2 and small amounts of CH_4 (Table 2). Methane was probably produced in the borehole slurry by anaerobic bacterial consumption of H_2 and, possibly, by oxidation of the carbon-steel casing (Daniels et al. 1987).

Laboratory Generation of Hydrogen Gas

To confirm that H_2 could be produced at low temperatures by the interaction of crushed detrital material and steel shavings with ground water, H_2 was produced in the laboratory from borehole slurry samples (Figure 6). In unsterilized slurry samples, H_2 concentrations were ≤1 percent of the headspace, regardless of whether the headspace was air or N_2. In the autoclaved (i.e., sterilized) slurry, H_2 concentrations approached 10 percent of headspace volume (N_2 headspace) within two weeks. These results suggested that H_2 was generated via reactions in the slurry and not by the microbial fermentation of organic matter. It is common for microorganisms to utilize H_2 as an energy source (Atlas and Bartha 1993). Analysis of the unsterilized borehole slurry indicated microbial populations of $>10^6$ MPN of aerobic H_2-utilizing bacteria/cm^3. These results suggest that hydrogenotrophic bacteria present in the borehole slurry are capable of growing on H_2 via such reactions as:

$$6H_2 + 2O_2 + CO_2 \rightarrow [CH_2O] + 5H_2O \quad (1)$$

where $[CH_2O]$ is taken to represent biomass, or

$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O \quad (2)$$

under anoxic conditions where anaerobes convert H_2 to CH_4. Reaction 2 may lead to accelerated corrosion of the steel casing (Daniels et al. 1987).

Hydrogen Gas Generation in the Subsurface

Previously Reported Sources of Hydrogen Gas

The origin of H_2 at numerous locations worldwide is uncertain; possible causes of H_2 generation range from mantle degassing to chemical interaction between clastic sediments and ground water following deposition (Molchanov 1968). An extensive survey of deep (>3300 feet [1000 m]) subsurface fluids in the former Soviet Union indicated that normal background concentrations for

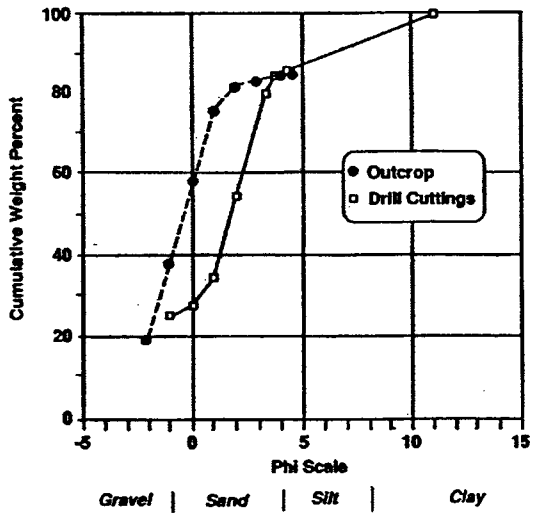

Figure 5. Comparison of particle-size distributions between disturbed (drill cuttings) and undisturbed (outcrop) Ringold Formation coarse-grained sediments.

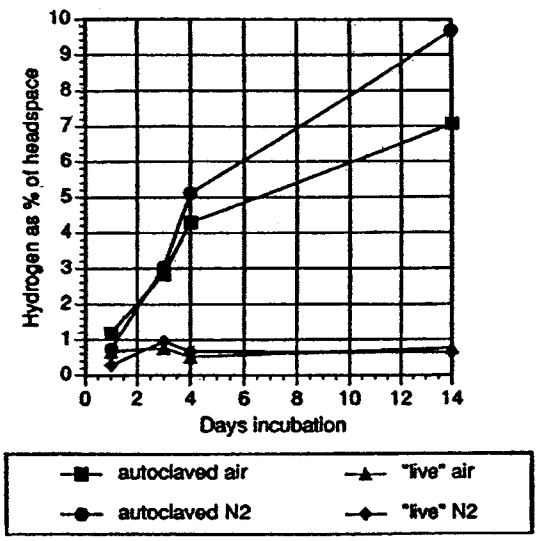

Figure 6. Laboratory production of H_2 gas in slurry samples from the YBB. Unsterilized ("live") samples yielded smaller quantities of H_2 than sterilized (autoclaved) samples, suggesting H_2 generation is abiotic. Headspace gas (N_2 or air) did not significantly affect the results.

dissolved H_2 were on the order of a few mL/L, but there were wide regions where concentrations of hundreds of mL/L or more were detected (Shcherbakov and Kozlova 1986). These regions of very high H_2 concentration coincided with major fault zones that might act as conduits for gas migration from depth. Anomalously high concentrations of H_2 (up to 99 percent) have been observed bubbling out of springs in areas of serpentinization in Oman (Neal and Stanger 1983) and California (Barnes et al. 1972). Up to 3 percent H_2 concentrations have been measured along faults following tectonic activity in Japan (Wakita et al. 1980).

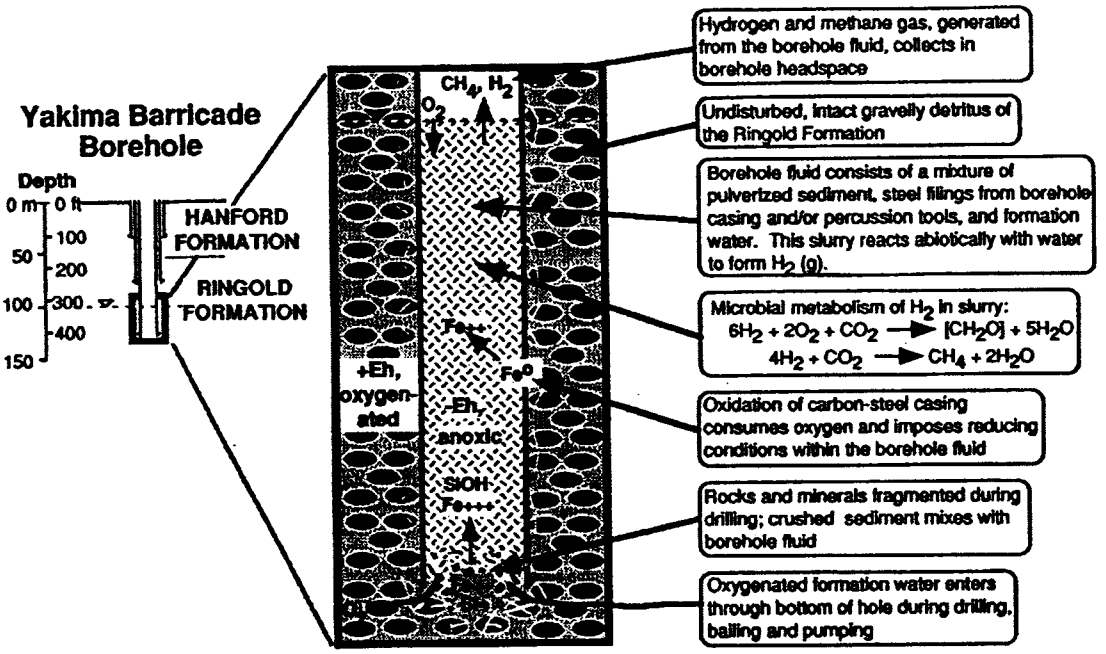

Figure 7. Model of H_2 generation during percussion drilling.

Chemical reactions that might yield H_2 include (1) oxidation of transition metal oxides or hydroxides either in the presence of heated water (Arnorsson 1986; Freund 1984) or in lower-temperature serpentinization reactions (Barnes et al. 1972; Neal and Stanger 1983; Goebel et al. 1984; Angino et al. 1984); (2) reaction of ground water with broken-bond oxygen radicals at mineral faces following mechanical deformation (e.g., faulting) (Kita et al. 1982); (3) release of molecular hydrogen from its point of formation at oxide mineral crystal-lattice defects (Freund et al. 1981; Freund 1984); and (4) dissolution from within mantle minerals (Bai and Kohlstedt 1992).

Although the formation of H_2 at near-surface temperatures is generally considered to be unlikely, field evidence suggests that low-temperature hydrogen gas generation can occur (Molchanov 1968). Goebel et al. (1984) considered several H_2-generating sources and processes in Kansas and concluded that low-temperature serpentinization reactions were the most likely cause. On the basis of isotopic analyses, Neal and Stanger (1983) concluded that low-temperature formation of H_2 during weathering of ultramafic rocks was the source of elevated H_2 in ground water in Oman. Their calculations also ruled out the possibility that significant concentrations of H_2 might come from a high-temperature source.

In general, few mechanisms have been identified whereby H_2 could be generated via rock-water interactions. A hypothesis advanced by Neal and Stanger (1983) and others suggests that the reduction of oxygen and the abiotic generation of H_2 via chemical interactions between rock and water depend on the availability of reduced (ferrous) iron. Assuming an appropriate redox status, a hydrogen-producing reaction can take place at ambient temperatures and pressures (Shcherbakov and Kozlova 1986) when ferrous iron oxide reacts with water.

The crushing of silicate minerals, themselves, may also lead to H_2 generation. The breaking of silicate bonds during crushing of the sediment, and the associated production of Si· and Si-O· radicals, has been suggested as a hydrogen-producing reaction by Wakita et al. (1980) and Kita et al. (1982). The chemical reaction between H_2O and fresh rock and mineral surfaces exposed during crushing generates H_2 at room temperature and pressure by the following reaction:

$$Si\cdot + H_2O = SiOH + 0.5\ H_2 \qquad (3)$$

where Si· represents an ephemerally charged species at the silicate mineral surface. As these free radical sites are neutralized, H_2 generation will cease. This reaction mechanism has produced small quantities of H_2 gas in the laboratory (Kita et al. 1982) and may be significant in tectonically active areas with regional fault zones capable of transmitting and concentrating H_2 in the subsurface.

Source(s) of Hydrogen Gas at the Yakima Barricade Borehole

Hydrogen at the YBB was assumed to have originated by either (1) low-temperature interactions between ground water and the crushed detritus in the borehole slurry (rock fragments and steel shavings from the casing and percussion tools, suspended in formation water); or (2) concentration of dissolved H_2 from degassing of the surrounding strata. The origin of the H_2 at the YBB was thus considered to result from drilling activities or

undetermined geochemical processes peculiar to the strata being penetrated.

The results of this study demonstrated that H_2 could indeed have been generated abiotically by mechanical and physicochemical processes within the cased portion of the borehole, as suggested by Angino et al. (1984). Our conceptual model of H_2 generation in the YBB is shown in Figure 7. H_2 is generated by percussion drilling below the water table as a result of chemical interactions between formation water and steel casing, steel shavings, and lithic fragments. Dissolved oxygen originates with oxygenated ground water entering the borehole at the base of the casing and dissolving where the water table interfaced with the overlying air column; reactions occurring within the slurry and between the ground water and casing consume oxygen and lower the Eh. Water is disassociated by reaction with ferrous and metallic iron after consumption of available O_2. Dissolved H_2 could not have originated from formation water at the YBB, since H_2 decreased dramatically and CH_4 was undetectable after bailing and pumping (Table 2). Bailing and pumping forced fresh water from the formation into the bottom of the borehole to replace stagnant fluids.

Other potential sources for H_2 in the subsurface environment near the YBB are similarly not plausible. Migration of organic and inorganic contaminants and their degradation products is unlikely because the YBB is located hydraulically upgradient of known contaminant sources or plumes, and analysis of the fluids within the borehole did not indicate the presence of any contaminants. Tectonic activity near the YBB, venting of H_2 from deeper sources, and microbial fermentation can be eliminated as mechanisms of H_2 generation because ground water in the aquifer does not contain significant amounts of H_2. The ground water sampled from developed wells within the unconfined aquifer elsewhere at Hanford also had a much higher redox potential (−175 to +225 mV) (Early et al. 1986) than the stagnant borehole fluids (Table 2), which has inhibited H_2 generation. Furthermore, microbial fermentation of organic matter at the YBB is an unlikely mechanism for H_2 generation because the experimental evidence indicated that microbial activity consumed H_2 in the borehole slurry. Broken-bond oxygen radicals at the surfaces of crushed sediments as a controlling process in H_2 generation was unlikely because free radicals are probably short-lived within the YBB; elevated LEL (i.e., elevated H_2 concentrations) coincided with periods of poor drilling progress when little freshly crushed suspended material was generated (Figure 3).

The reaction of steel casing and/or steel shavings generated during percussion drilling with formation waters is a possible source of H_2 at the YBB. Steel shavings may be produced by the percussion tools during repeated movement of the tools during drilling. This is corroborated by Pearson et al. (1989), who concluded that excess hydrogen is generated from the corrosion of metallic iron in the borehole, based on the oxidation potential of the hydrogen couple (H^+/H_2).

The freshly exposed rock and mineral surfaces, derived from the pulverization of suprabasalt sediments and mixed with the water from the formation during drilling, may accelerate the reduction of both oxygen and water within the borehole fluids. Neal and Stanger (1983) reached a similar conclusion with regard to a dissimilatory stage of ground water evolution: "Whilst this second stage mechanism (i.e., decomposition of water) might at first seem implausible at low temperatures, there is convincing laboratory and theoretical evidence to show that it can take place, albeit erratically, in the presence of a catalyst such as some transition metal hydroxides." Neal and Stanger (1983) suggest that the presence of nickel-iron alloys, natural in the ultramafic source rocks within their study area, could also act as catalysts for H_2 generation. It is possible that the carbon-steel alloy composition of the casing plays a similar role in generating H_2 at the YBB.

Summary and Conclusions

Field analyses and laboratory experiments indicate that H_2 is generated at ambient temperatures and pressures via mechanical and physicochemical processes occurring during percussion drilling below the water table. In view of the common use of carbon-steel casing and the pulverization associated with percussion drilling, the phenomenon of H_2 generation during drilling may be more common than had previously been realized (Angino et al. 1984). At the Hanford Site, dozens of boreholes have been drilled via percussion methods to significant depths below the water table with no documented reports of hydrogen gas. However, H_2 is not routinely monitored and the presence of explosive gases would likely have been erroneously attributed to the buildup of other compounds (e.g., methane). Combustible gases may also have been undetected because they were in concentrations below the explosive limit, perhaps due to microorganisms metabolizing the H_2 as an energy source.

At sufficient concentrations, H_2 generated during drilling could be a safety concern, especially in percussion-drilling operations. Hydrogen may not be a significant concern with other types of drilling, or where significant numbers of H_2-utilizing bacteria are present. If microorganisms are inhibited within the borehole by environmental conditions (e.g., low temperatures, toxic substances, abrupt shift to anoxic conditions), H_2 concentrations may rise. During percussion-drilling operations in saturated systems, precautions should be taken to monitor borehole headspace for hydrogen gas. Frequent bailing or pumping during drilling may help to avoid elevated H_2 concentrations. Specific mechanisms of H_2 generation via sediment-water interactions within the borehole have not been identified but will be the subject of further study.

1.0 SCOPE

1.1 General Description of the Service

The Environmental Protection Department (EPD) of the Westinghouse Savannah River Company (WSRC) is seeking qualified companies to provide drilling services. Contracts will be awarded for following types of work:
Type A - Monitoring well installation and abandonment
Type B - Environmental soil borings
Type C - Geotechnical borings and piezometer installation
Subcontractors may bid on one or more of these categories.
A maximum of 3 awards will be made for Type A work. One award will be made for Type B work. A maximum of 2 awards will be made for Type C work.

All drilling activities must follow the specifications set forth in WSRC 3Q5 "Hydrogeologic Data Collection." The pertinent sections of this manual have been enclosed with the Attachments and are identified in Section 2.3.

1.2 Background

Geologic information is obtained and monitoring wells are installed around waste disposal sites and other facilities at the Savannah River Site (SRS) as required by regulatory agencies and for site investigations. Soil samples are taken to determine extent of soil contamination. Coreholes are drilled and geophysically logged to provide subsurface geologic information. Hydropunch samples are taken to delineate groundwater contamination, and monitor wells are installed to identify and monitor areas where contamination of ground water may occur. Wells that are no longer in service are abandoned by over-reaming or milling the casing. Geotechnical borings are drilled for subsurface characterization.

The Savannah River Site is located in the Atlantic Coastal Plain province and is underlain by generally unconsolidated sand, clays and carbonates. The unsaturated zone at SRS ranges from 10 to 150 feet in thickness. Perched water tables are present in some areas. Hard, crystalline rocks such as schist and gneiss are found at a depth of 1000 to 1200 feet.

During the next two-years, the level of activity for all of the above mentioned work has been estimated in order to provide a generalized frame of reference for subcontractors to make their bids and for WSRC to evaluate these bids. This estimate is comparable to recent activity levels at SRS. The total volume of work to be performed is estimated in the price schedule and may be higher or lower for particular activities. The estimated work load includes:

- drill 15 coreholes for geologic information
- drill 20 hydropunch borings
- Install and develop 120 monitoring wells (some of these wells will be cored)
- abandon 20 wells
- drill 120 shallow soil borings
- drill 60 geotechnical borings

2.0 REFERENCE DOCUMENTS

2.1 Definitions

2.1.1 Acronyms

GET	WSRC General Employee Training
CAT	Consolidated Annual Training
RCA	Radiologically Controlled Area
RWT II	Radiation Worker Training
SRS	Savannah River Site
STR	WSRC Subcontractor Technical Representative
WSRC	Westinghouse Savannah River Company

2.1.2 Field definitions

2.1.2.1 Standby with crew:

Standby with crew will generally be paid for delays caused by WSRC or WSRC representatives. Examples of this include but are not limited to: 1) waiting for Rad Con coverage in RCA's, 2) time necessary for technical oversight to evaluate or consult with WSRC personnel concerning geologic conditions, 3) time spent conducting geophysical logging (equipment set up and while the probe(s) is traversing the borehole). Standby will not be paid for delays caused by driller's error, breakdown of, or repairs to equipment, or for any delay due to the driller's inability to procure, provide, or maintain the necessary equipment, materials, services, or supplies to enable the job to continue.

2.1.2.2 Standby without crew:

Standby without crew will be paid for: 1) certain cases of inclement weather, 2) time spent waiting for grout to set up after surface casing is set, and 3) times when a rig is already on standby with crew and the subcontractor utilizes the crew from the standby rig to perform other duties.

2.1.2.3 Downtime:

Downtime is defined as any time a rig is scheduled to work, but due to subcontractor personnel, logistic, or mechanical problems work cannot proceed. Downtime will be tracked by the STR and given serious consideration in evaluating subcontractor performance and future awarding of other projects. The STR has the authority to require rigs with greater than 10% downtime to be removed from the plant site. Mobilization charges will not be paid for replacement rigs. Downtime does not include stoppages for scheduled maintenance.

2.1.2.4 Inclement weather:

WSRC will pay standby with crew when rain is not heavy enough to stop normal drilling operations but the oversight cannot conduct geologic sampling. WSRC will not pay standby for other weather-related shutdowns made at the discretion of the subcontractor. The subcontractor must consider the safety of their personnel when evaluating possible weather related shutdowns of drilling operations.

In the event that WCRS places a drill rig on standby due to inability to sample the standby will not exceed 8 hours in a given day or will be a sufficient number of hours to bring the total working hours and standby to 8 hours. If a rain day occurs on Friday and 40 hours have already been worked standby will only be accrued until the crew is released by the Technical oversight or STR.

No work can proceed in Radiologically Controlled Areas when it is raining. Rad Con will determine when work can proceed. Standby with crew will be paid for a maximum of 8 hours in a single day. At the direction of the STR the drill crew may be released and the rig put on standby without crew for a maximum of 8 hours in a single day.

2.1.2.5 Lost circulation:

For the purpose of this contract, lost circulation is defined as sufficient loss of fluid to prevent the reasonable advancement of the drill hole. In the past, circulation has been lost in approximately 10%

of the wells drilled. The subcontractor will be expected, under the footage pay rate, to take measures to regain circulation for approximately one work day after circulation is lost. From that point WSRC will pay for efforts to regain circulation at the hourly rig rate. Lost circulation materials must be approved by the STR. The subcontractor will be expected to supply additional water trucks as needed as part of the hourly rig rate. WSRC expects the subcontractor to have management and technical support available without delay to help solve circulation problems. If adequate technical support is not available the job will be shut down until such time as support is available. The subcontractor will not be reimbursed for time spent waiting on technical support.

2.1.2.6 Work day:
A normal working day outside a Radiologically Controlled Areas is 7 a.m. to 5 p.m. Monday through Friday. Working hours in an RCA may be reduced to 8 hours unless arrangements can be made with Rad Con to extend these hours. The drilling company will be compensated for a minimum of 8 hours per day of work in an RCA. No standby will be accrued past 5 p.m. Longer hours may be worked if arrangements are made with the STR. All SRS holidays (11) are observed, unless prior arrangements are made to work. If WSRC requires additional hours be worked such as weekends, an overtime surcharge is included in the price schedule. Routine work that extends beyond 5 p.m. is not covered as overtime. Additional definitions of bid line items are provided in the price schedule.

2.2 Codes, Standards, Orders, Regulations
OSHA 29 CFR Part 1910.120
South Carolina Well Standards and Regulations R. 61-71.

2.2.1 SRS Documents
The procedures that are relevant to the activities of this contract are contained within WSRC 3Q5, HYDROGEOLOGIC DATA COLLECTION and the E9 manual.
The relevant chapters are as follows:

Chapter 4:	Technical Oversight requirements : Water supply wells, ground water monitoring wells, and soil foundation borings (Attachment 9).
Chapter 6:	Soil Boring Procedures (Attachment 5)
Chapter 7:	Ground Water Monitoring Well Drilling and Installation (Attachment 1)
Chapter 8:	Ground water sampling with the Hydropunch (Attachment 8)
Chapter 10:	Ground Water Monitoring Well Abandonment Attachment 6)
Chapter 12:	Borehole Geophysical Logging (Attachment 2)

E9 Manual - Procedures specific for geotechnical sampling
Procedure SGS-GT-209 Piston Sampling (Attachment 10)
Procedure SGS-GT-210 Standard Penetration Test (Attachment 11)

Service Subcontractor General Safety Rules (Attachment 4)

The applicable procedures and specifications identified in WSRC 3Q5 and the E9 manual may be revised before the contract expires. If and when these changes occur the subcontractor will be notified in writing and provided with copies of the revised sections. Any changes are expected to be relatively minor and will not significantly impact the basis for contract bids. In the event that changes impact the billing items, changes will be negotiated accordingly.

3.0 WORK REQUIREMENTS
3.1 Technical requirements
3.1.1 Equipment requirements

Type A Work Monitoring well installation and abandonments
Subcontractors must have a minimum of 3 drill rigs available for use at SRS. These rigs must be capable of mud rotary drilling and well installations to 500 feet. One rig must be capable of wire line coring to 500 feet. One rig must be capable of augering to 130 feet. At least one of these rigs shall be capable of both augering and mud rotary drilling. The rig to be used for abandonments must be a top head drive and capable of overdrilling well casing to a depth of 200 feet. Casing diameters range in size from 2-6" ID. A bit with a guide stinger must be available for reaming PVC casing. All workers must have 40 hours of OSHA 1910.120 Hazardous Waste Operations Health & Safety Training, 8 hour update as necessary, and a fit for duty letter. Radiation Worker Training may be required for some projects.

Type B Work Environmental borings
Subcontractors must have a minimum of 2 drill rigs available for use at SRS. These rigs must be capable of augering and split-spoon sampling to 130 feet. All workers must have 40 hours of OSHA 1910.120 Hazardous Waste Operations Health & Safety Training, 8 hour update as necessary, and a fit for duty letter. Radiation Worker Training may be required for some projects.

Type C work: Geotechnical borings
Subcontractors must have a minimum of 2 rigs available to SRS. Each rig must be capable of mud rotary drilling to 300 feet. One rig must also be capable of mud rotary drilling to 300 feet and augering to 120 feet. Each rig must be capable of simultaneous advancement (Dual Rotary) of a minimum 4 inch casing with the capability of tripping the inner rod in and out to allow for sampling. Typically, geotechnical borings which go below the water table will be mud rotary drilled and split spoon sampled. Geotechnical borings above the water table are typically augured and split spooned. Unless directed otherwise, all samples must be taken according to ASTM standards. An automatic trip hammer may be required on some projects. Some geotechnical projects will require workers to have 40 hours of OSHA 1910.120 Hazardous Waste Operations Health & Safety Training. Radiation Worker Training may be required for some projects.

Subcontractors may bid on 1 or more types of work. If a subcontractor bids on more than 1 type of work the maximum number of rigs that must be available is 3. However, the drill rigs the subcontractor provides must be capable of meeting the technical requirements for each type of work. For example a subcontractor bidding on Type 1 and Type 3 work must have a minimum of 3 rigs total but be capable of covering the equipment capability requirements for both Type 1 and Type 3 work.

The subcontractor will be responsible for the procurement, delivery, inspection, and preparation of consumable materials for drilling and well construction. This includes, but is not limited to: well casing, well screens, filter pack, drilling mud, grout, submersible pump (and related hardware), cement, protective posts, etc. Specifications for these materials are found in WSRC 3Q5 Chapter 7 Well Installations: Water Table wells, Monitoring wells below the Water Table and Piezometer wells (Attachment 1). It will be the responsibility of the subcontractor to transport these materials to the drill site. WSRC will provide a centrally located lay-down yard for interim storage of a reasonable quantity of supplies and materials in order to facilitate project logistics. The subcontractor shall be responsible for inventory control and materials management to prevent work stoppage or slow downs due to availability of supplies and materials. All materials used in the actual construction of a well must be approved by the Subcontract Technical Representative (STR) or a designated representative.

The subcontractor must provide all equipment (drill rigs, down-hole tools, portable or dug mud pits, water trucks, crew transport vehicles, steam cleaners, and all other support equipment) necessary to successfully complete a project. Each rig must be equipped with a mud scale, marsh funnel, and a 200 foot long weighted tag line. The weight must be stainless steel. All equipment must be in excellent working condition. The STR reserves the option to require the replacement, without additional mobilization fees, of drill rigs with down time exceeding 10% of operating time (excluding regularly scheduled maintenance).

3.1.2 Geophysical logging
Subcontractors will be required to provide digitally recorded geophysical logging services as outlined in WSRC 3Q5 Chapter 12: Borehole Geophysical Logging (Attachment 2). The required suite of logs for this contract include short & long normal resistivity, spontaneous potential, natural gamma ray, single point resistance, sonic, and borehole caliper. The subcontractor shall supply WSRC with the digitized log in an ASCII format on an IBM compatible floppy disk. When more than one run is made in a borehole the subcontractor must merge the data. The subcontractor may subcontract or supply in-house service. Geophysical logging is included in the line item price schedule. The subcontractor is responsible for scheduling logging services. Standby will not be paid for delays caused by logging schedules.

In certain instances SRS may furnish the geophysical logging services. In these cases SRS will be responsible for scheduling the logging. The drilling subcontractor will be paid standby for any scheduling delays as well as when the logging is in process.

3.1.3 Communications: All subcontractors must be capable of two-way radio or telephone communication between each drilling crew and field supervision. Technical oversight will also be provided with two-way radios for operational and emergency communications with WSRC management personnel.

3.1.4 Additional equipment and material requirements

- a sign for each work site indicating hard hat & safety glasses are required.
- absorbent (ground up corn cobs) to soak up any fuel oil or hydraulic fluid spills and to absorb leaks dripping from equipment.
- personal protective equipment for employees (hard hat, safety glasses, gloves, dust masks, hearing protection).
- plastic to place beneath the rig
- barricade rope
- eye wash station: Per the WSRC 8Q manual an eyewash station is required when the drilling crew has material on site that would be injurious, corrosive, toxic, or flammable. The eyewash station must meet the OSHA requirement of delivering .4 gpm for 15 minutes and must be capable of delivering water to both eyes simultaneously.
- drinking water for the drilling crew
- wash water: Wash water must be from a potable source. Soap and a towel must also be available.

Costs for the above items are to be accounted for in footage rate bids.

3.1.5 Disposal of drill cuttings and drilling fluids
At most drilling locations, cuttings and fluid can be placed on the ground. For locations where cuttings cannot be placed on the ground WSRC will provide metal skid pans. Each pan holds approximately 400 gallons. The pans will be emptied by WSRC. WSRC will pay standby for delays caused by disposing of drill cuttings. The subcontractor may be requested to supply a spoils truck for drilling fluid

collections. There is a line item in the price schedule for a truck. Experience has shown that the best way to transfer drill cuttings to the skid pan is using a desander. The actual method used will be left to the descretion of the subcontractor.

3.2 WSRC Furnished Material, Equipment, Services

WSRC will provide:

- Training required in Section 3.4.3
- WSRC will provide land use, site clearance, work clearance permits, and specifications for monitoring well and piezometer installations/ abandonments.
- WSRC will provide access roads (if required) for each well drilling site and general clearing of well sites will be . However, the subcontractor may have to provide some minor handwork clearing and/or light back hoe site preparation.
- All potable water to be used for drilling and grouting. Water loading stations are located at the Central Shops area and B area (adjacent to the well Building) See map in Attachment 3.
- Lay down area adjacent to the well building for parking vehicles and storing materials
- Skid pans to contain cuttings. WSRC will empty the pans on an as needed basis.
- When working in Radiologically Controlled Areas (RCA) and other certain instances subcontractors will be asked to provide crews to operate the WSRC rig (CME-75). Hourly rates for the drill crew are included in the price schedule. WSRC will provide all support equipment and supplies for these jobs. In some cases subcontractor equipment will be used in RCA's. This is discussed further in Section 3.4.2.
- On occasion WSRC may supply all or part of the well construction materials for a given project. This will be specified prior to startup of the project.
- WSRC personnel will assist the subcontractor with on site administrative procedures so that a drilling project can be accomplished in a timely and cost effective manner.
- Hydropunch sampling: A hydropunch sampler is used to obtain water samples without installing a monitor well. SRS will furnish the Hydropunch when it is used. Procedures for use are found in Attachment 8.

3.3 Quality Requirements

The subcontractor shall ensure that their employees working on this project fully understand the scope and method of the work. The subcontractor shall ensure that each work crew has copies of the documents identified in Section 2.2.1 on each drill rig working at SRS. It is the subcontractor's responsibility to ensure that all employees are familiar with and understand the drilling and safety procedures and requirements.

3.4 Site Conditions

3.4.1 General site access requirements

3.4.1.1Orientation

All subcontractor personnel will be required to obtain an SRS access badge (red badge). Necessary forms for badging will be provided by WSRC. All persons applying for site access must be U. S. citizens.

All personnel must attend a one day General Employee Training (GET) class and pass the exit test. Safety, security, occupational health, and environmental concerns will be addressed. These

orientations may be scheduled by the subcontractor. After successful completion of GET, each employee must pass a drug and alcohol screen. Finger printing and a security film complete the badging requirements. The entire badging process will last approximately 1 1/2

days. A badge is valid for 1 year. Consolidated Annual Training must be taken before the badge is renewed. Subcontractors will not be reimbursed for this orientation. Employees will be subject to random drug testing throughout the contract duration. The subcontractor is not reimbursed for time spent drug testing.

3.4.2 Work in Radiologically Controlled Areas (RCA)

3.4.2.1 Radiation Worker Training

SRS will provide Radiation Worker Training for employees required to work in an RCA. This consists of 3 days of classroom training with a written and practical exit exam, a whole body count, and a bioassay sample. SRS will reimburse subcontractors only for the successful completion of the training at the personnel hourly rates provided in the price schedule. Additional training which may be required by SRS will also be reimbursed at personnel hourly rates.

3.4.2.2 Use of subcontractor equipment in RCA's

Occasions may arise when subcontractor equipment will be required to work in Radiologically Controlled Areas. If any equipment becomes contaminated and cannot be decontaminated and released from SRS, WSRC will purchase the equipment at the fair market value of the equipment. SRS will make every effort to decontaminate and/or segregate contaminated equipment, or parts of equipment, from uncontaminated equipment. The fair market value of the equipment to be used in the RCA is included in the price schedule. The subcontractor shall provide an updated list and fair market value of equipment to be used in the RCA on an annual basis.

3.4.2.3 Personnel monitoring in RCA's

When working in RCA's, Rad Con will provide all personnel monitoring and equipment screening. Drillers will follow all HP instructions. The drilling subcontractor will be reimbursed by WSRC at the standby rate for any delays caused by HP monitoring or difficulties containing and disposing of drill cuttings. All actual drilling in RCA's will be done at the RCA rig hourly rate or personnel hourly rates.

3.5 Period of Performance/Schedule

3.5.1 Schedule

Contracts are expected to be awarded in September 1998. The contracts will have a duration of 2 years from the date of award. There will be an option to extend the contracts 1 year.

Geotechnical borings, environmental borings core holes, ground water monitoring wells, and piezometers are installed (or abandoned) on an "as needed" or project basis. Once an area has been identified as requiring the installation (or abandonment) of monitoring wells, a program plan is written by SRS personnel. The project is then assigned to one of the subcontractors based on expertise, previous contract performance, a cost/benefit analysis for a specific project, and/or current utilization by WSRC of other subcontractors.

A subcontractor selected for a specific drilling project will initially be notified by telephone and furnished a copy of the program plan. The subcontractor will have a maximum of 10 working days after receiving the program plan to visit the drilling locations and inform the STR of access requirements or specific needs for the job. Material needs can be estimated using the program plan. The STR will answer any questions concerning materials estimation and approve estimates before materials are ordered. Materials should be ordered promptly so as to not interfere with the timely startup and completion of the job. The subcontractor must be able to begin work within 15 working days from the work authorization date given by the STR.

3.6 Subcontractor and Personnel Qualification/Certification

3.6.1 Corporate Experience Requirement

The drilling corporation shall have been in business a minimum of one year. The Program Manager must have five or more years drilling experience.

3.6.1 Personnel Qualification and Experience Requirement

The drill rig operators must be certified in the proper category by the state of South Carolina and have a minimum of two years experience in the type of drilling the subcontractor is providing. South Carolina certified drillers with less than 2 years of experience may be approved by the STR on a case by case basis. Driller's resumes must be included in the proposal.

Workers are required to have 40 hours of OSHA 1910.120 Hazardous Waste Operations Health & Safety Training. Proof of training and a fitness for duty letter must be given to the STR prior to a person starting work. The majority of the work is level D requiring a hard hat, safety glasses, and steel-toed boots. Modified level D work will require hard hat, safety glasses, steel-toed boots, Tyvek coveralls, and gloves. Level C will include a respirator. All level C work will be done at the rig hourly rate. No eating, drinking, or smoking will be allowed inside the rope barricade of a work site at any time. Failure to comply with health and safety guidelines may result in the removal of the employee from SRS.

3.6.2 Driller Duties and Responsibilities

Drillers are required to conduct all drilling activities in accordance with the pertinent sections of WSRC 3Q5 identified in Section 2.3. Drillers will be responsible for keeping a detailed daily activities report documenting all activities that directly affect technical aspects of the project, invoice or billing considerations, and materials use. This record must be acceptable to the STR. The driller or drilling contractor is responsible for completion and submittal of the SCDHEC Water Well Record.

3.6.2.1 Documents to be located at the work site.

The driller must maintain copies of the appropriate sections of WSRC 3Q5 identified in Section 2.3 on each drill rig working at SRS. It is the subcontractor's responsibility to ensure that all employees are familiar with and understand the drilling and safety procedures and requirements. MSDS sheets for all chemicals present must also be at the drilling location.

3.6.2.2 Daily work reconciliation

The driller or drilling contractor is responsible for reconciling pay items with technical oversight on a daily basis. Oversight will submit pay items based on the Subcontractor Expense Record (Attachment 7) which will be developed specifically for each category of work. WSRC will approve payment based on this record. The driller and oversight will sign the record at the end of each work day if each agree on the pay item quantities recorded. If a disagreement occurs, it is the responsibility of the subcontractor to resolve any disagreements on pay items with the STR before invoices are submitted.

3.7 Deliverables

The subcontractor will be required to provide South Carolina certified drillers, drill rigs with necessary ancillary support equipment, well construction materials, and support personnel. The subcontractor shall also deliver digitized data for geophysical logging services as specified in Section 3.1.2.

3.8 Safety

The subcontractor must submit a description of the company Health and Safety Plan. The minimum safety requirements to be addressed in the Health and Safety Plan are provided in Attachment 4. It is the responsibility of the subcontractor to conduct operations in

accordance with all applicable local, state, and federal regulations. Failure to do so may result in the removal of the subcontractor from the project. Safety audits will be conducted by WSRC representatives.

3.9 Locking of monitor wells

Monitor wells and piezometers must be locked when ever physically possible during construction. The locking caps and locks will be furnished by the subcontractor.

3.9 Technical Submittals for Proposal

The subcontractor shall submit the following technical information with their proposal.

- Resume of program manager
- Resumes of drillers that will work at SRS
- List of equipment with depth and sampling capabilities
- References

4.0 ACCEPTANCE OF SERVICES

4.1 Final Acceptance Methods

The subcontractor will have sole responsibility for the successful completion of each project. WSRC will pay only for a completed project. For projects taking longer than one month, payment will be made for work completed during that month. Final payment for a project will not be paid until all the wells have been inspected and accepted. Any task not completed to WSRC 3Q5 specifications or any well that is not successfully completed and fully operational due to subcontractor workmanship or materials failure, will not be paid for by WSRC. WSRC will not reimburse the subcontractor for any materials or equipment lost down the drill hole. The subcontractor is responsible for proper closure well or borehole abandoned due to failure of material or workmanship.

4.2 Inspection/Testing Requirements

All materials used in well installation must be inspected by the driller for defects before being placed in the borehole. Screen slot size must be verified by the drilling company using a feeler gauge. Technical oversight will document the materials inspection. All other materials used in pump installation must be visually inspected for defects. The drilling company is responsible for correcting any problems due to defective materials or installation procedures. SRS should be notified of any defective material or problems with well installation prior to the completion of work.

4.3 Marking and Identification

After a well is installed, the well number must be written on the outside of the casing using a permanent marker. After the protective casing is installed the well number must be written on both the 3 inch PVC flow meter support post and on the inside of the protective casing cover using indelible ink. When the pump and well head materials are installed, the well number must be written on the inside of the flow meter cover. Failure to properly identify the monitor wells in clusters where 2 or more wells are located will result in the drilling contractor pulling the pump and verifying the well depth with the STR or technical oversight present so that proper identification can be made. This shall be done at no cost to WSRC.

4.4 WSRC Surveillance and Audits

The WSRC Project Managers and the STR will make regular visits to the drilling locations to monitor the progress of the subcontractor. Safety audits will also be conducted by WSRC personnel.

5.0 ATTACHMENTS

Attachment 1 WSRC 3Q5 Chapter 7 Ground Water Monitoring Well Drilling and Installation.
Attachment 2 WSRC 3Q5 Chapter 12: Borehole Geophysical Logging
Attachment 3 SRS map
Attachment 4 Service Subcontractor General Safety Rules.
Attachment 5 WSRC 3Q5 Chapter 6: Soil Boring Investigations
Attachment 6 WSRC 3Q5 Chapter 10 Ground water Monitoring Well Abandonment.
Attachment 7 Daily Expense Record
Attachment 8 WSRC 3Q5 Chapter 8 Ground water sampling with the Hydropunch.
Attachment 9 WSRC 3Q5 Chapter 4 Technical Oversight requirements: Water supply wells, Groundwater monitoring wells, and soil foundation borings.
Attachment 10 Procedure SGS-GT-209 Piston Sampling
Attachment 11 Procedure SGS-GT-210 Standard Penetration Test
Attachment 12 R.61-71: Well Standards and Regulations, SCDHEC form

Note: 3Q5 chapters do not include attachments.

Type A Price Schedule: Monitor Well Installation

Activity	Materials	+	Labor	=	Subtotal	x		Quantity	=	Total
I. **MOBILIZATION (for task)**					_____/mob		_____	15		_____
Mobilization (between holes)					_____/mob		_____	35		_____
II. **DRILLING (rates include drilling mud)**										
Mud rotary drilling										
10" or less					_____/ft		_____	4000		_____
>10-15"					_____/ft		_____	1000		_____
>15-20"					_____/ft		_____	300		_____
Ream Borehole of Soil										
10" or less					_____/ft		_____	4500		_____
>10-15"					_____/ft		_____	4000		_____
>15-20"					_____/ft		_____	500		_____
Coring (wire line)*										
0-250'					_____/ft		_____	5000		_____
250-500'					_____/ft		_____	800		_____
Auger drilling										
4-1/4" hollow stem 0-160'					_____/ft		_____	300		_____
4" solid stem 0-160'					_____/ft		_____	100		_____
6 1/4" ID (10" OD) auger (0-50')					_____/ft		_____	140		_____
Split spoon - 2" OD (per sample)					_____/ea		_____	40		_____
3" OD (per sample)					_____/ea		_____	80		_____

Activity	Materials +	Labor =	Subtotal x		Quantity =	Total
Shelby tube (per sample*		_____/ea	_____/ea	_____	25	_____
Geophysical logging*						
Mobilization			_____/mob	_____	20	_____
Set up			_____/hole	_____	20	_____
Standard suite of logs			_____/ft	_____	3000	_____
Standard suite plus sonic			_____/ft	_____	500	_____
Additional paper copies			_____/copy	_____	10	_____
Borehole deviation survey (Sure-shot)			_____/shot	_____	10	_____
III WELL INSTALLATION						
Surface casing* No Mill Coat						
12" ID		_____/ft	_____/ft	_____	200	_____
10" ID		_____/ft	_____/ft	_____	600	_____
8" ID		_____/ft	_____/ft	_____	600	_____
1 inch PVC installation			_____/ft	_____	400	_____
1 inch PVC casing (flush coupled)			_____/ft	_____	250	_____
1 inch PVC slotted screen			_____/ft	_____	50	_____
1 inch bottom plug			_____/ea	_____	5	_____
2 inch PVC installation			_____/ft	_____	4000	_____
Casing			_____/ft	_____	3400	_____
Bottom plugs			_____/ea	_____	50	_____
Slotted screens (5 or 10 ft sections)			_____/ft	_____	600	_____

Activity	Materials +	Labor =	Subtotal x		Quantity =	Total
Centralizers			_____/ea	_____	140	
4 inch PVC installation			_____/ft		1200	_____
Casing		_____/ft		_____	1100	_____
Bottom Plugs		_____/ft		_____	10	_____
Centralizers		_____/ft		_____	30	_____
Slotted screens (10 foot sections)		_____/ea		_____	100	_____
Wire wrapped 4" ID (10 foot sections)		_____/ft		_____	30	_____
Wire wrapped 4" ID (5 foot sections)		_____/ft		_____	20	_____
Stainless steel wire wrapped (4" x 5')		_____/ft		_____	25	_____
Activity						
4"steel (T & C) casing		_____/ft	_____/ft	_____	300	_____
4" steel bottom plug		_____/ea		_____	2	_____
6" PVC Installation			_____/ft	_____	400	_____
Casing		_____/ft		_____	300	_____
Bottom plugs		_____/ea		_____	8	_____
Centralizers		_____/ea		_____	20	_____
Wire wrapped (10 foot sections)		_____/ft		_____	100	_____
Slotted (10 foot sections)		_____/ft		_____	60	_____
6" Steel Installation			_____/ft	_____	300	_____
Casing (threaded & coupled)		_____/ft		_____	220	_____
Bottom plug		_____/ea		_____	2	_____

Activity	Materials +	Labor =	Subtotal x		Quantity =	Total
Centralizers		_____/ea		_____	10	_____
Stainless Wire wrapped screen (10 foot sections)		_____/ft		_____	80	_____
Filter Pack Installation			_____/sack	_____	400	_____
Filter pack sand (100 lb sack)		_____/ea		_____	380	_____
Fine sand (100 lb sack)		_____/ea		_____	20	_____
Filter Seal Installation *			_____/seal	_____	40	_____
Bentonite pellets		_____/ea		_____	90	_____
Grout (94 lb sack)*		_____/ea	_____/sack	_____	2000	_____
Well Development*						
Bailing			_____/hour	_____	200	_____
Swab & air lift (with dual coalescent filters)			_____/hour	_____	400	_____
Temporary submersible pump			_____/hour	_____	300	_____
Pump installation (4 inch) (includes installation of pump, riser, pipe, liquid level pipe, and well head materials)			_____/well	_____	10	_____
Pump Installation Materials						
Pump (Grundfos 10S05-9 including heat shrink couplings, stainless steel cable clips, and 1 inch PVC liquid level pipe bottom plug)			_____/well	_____	10	_____
1 inch riser pipe & couplings including tie wraps			_____/ft	_____	400	_____
Liquid level pipe with bottom plug			_____/ft	_____	400	_____
Stainless steel cable			_____/ft	_____	400	_____
Electrical wire (10-3)			_____/ft	_____	400	_____

Activity	Materials +	Labor =	Subtotal x		Quantity =	Total
Well Head Materials **(4 inch well)**						
Materials referenced in WSRC 3Q5, Chapter 7, Water Table Well Installation: Figure 3, Numbers 9, 10, 11, and Figure 5a, Numbers 15 through 32 constitute one unit			_____/unit	_____	10	_____
Pad installation materials **(4 inch well)**						
Materials referenced in WSRC 3Q5, Chapter 7 Water Table Well Installations: Figure 3a, Numbers 1-7		_____/well	_____/well	_____	10	_____
Pump installation **(2 inch well)** (includes installation of pump, riser pipe, and well head materials)			_____/well	_____	35	_____
Pump (Grundfos Redi-Flo 2)						
50 foot lead length		_____/ea		_____	15	_____
75 foot lead length		_____/ea		_____	15	_____
100 foot lead length		_____/ea		_____	10	_____
125 foot lead length		_____/ea		_____	8	_____
150 foot lead length		_____/ea		_____	5	_____
175 foot lead length		_____/ea		_____	4	_____
200 foot lead length		_____/ea		_____	4	_____
225 foot lead length		_____/ea		_____	2	_____
3/4 inch Riser pipe and couplings including tie wraps		_____/ft		_____	1500	_____
Pad installation materials **(2 inch well)**						
Materials referenced in WSRC 3Q5 Chapter 7 Water Table Well Installations: Figure 4, Numbers 1-5, Where #3 is 4"x4"x5'		_____/well	_____/well	_____	40	_____

Activity	Materials +	Labor =	Subtotal x		Quantity =	Total
Well head materials referenced in WSRC 3Q5 **(2 inch well)** Chapter 7 Water Table Well Installations, Figure 4a, numbers 16 through 32 constitute one unit		_____/unit		_____	40	_____
Peizometer pad						
Materials referenced in WSRC 3Q5 Chapter 7: Figure 2		_____/well	_____/well	_____	15	_____
IV **Hourly Rates (rate includes all necessary equipment and crew to operate the rig)**						
5T smeal or equivalent			_____/hour	_____	90	_____
Drill			_____/hour	_____	180	_____
Drill rig inside RCA			_____/hour	_____	180	_____
Drill crew to work inside RCA (rig, water truck, and drill rod provided by WSRC - supplier will provide steam cleaner and hand tools)			_____/hour	_____	120	_____
Standby (rig & Crew)			_____/hour	_____	150	_____
Standby (rig only)			_____/hour	_____	100	_____
WELL ABANDONMENTS						
I. Mobilization for abandonments (per task)*			_____/mob	_____	2	_____
Mobilization for abandonments (per hole)*			_____/mob	_____	10	_____
II. Reaming out PVC casing & grout						
6" diameter casing or less			_____/feet	_____	600	_____
Overdrilling steel casing						
4 ½" OD or less with grout						
0 - 100'			_____/feet	_____	300	_____

Activity	Materials	+	Labor	=	Subtotal	x		Quantity	=	Total
100 - 200'					_____/feet		_____	100		_____
4 ½ - 6 5/8" OD with grout										
0 - 100'					_____/feet		_____	200		_____
100 - 200'					_____/feet		_____	100		_____
Casing removal					_____/feet		_____	700		_____
Wiper pass (12" or less)					_____/feet		_____	200		_____
Grout (per sack installed)*	_____/sack				_____/feet		_____	600		_____

Activity **Hourly Rates will be worked at the request of SRS**

	Labor x	Quantity =	Total
I. Personnel			
S.C. certified driller	_____/hour	100	_____
Driller's helper	_____/hour	200	_____
Welder and welding equipment	_____/hour	10	_____
Overtime surcharge (for drilling crew)	_____/hour	100	_____

II. Miscellaneous equipment	Rate with Operator	x Quantity	+ Rate	x Quantity	=	Total
Water truck (500 gallon minimum)	_____/day	5	_____/week		1	_____
Spoils truck (1000 gallon minimum)	_____/day	5	_____/week		1	_____
Backhoe	_____/hour	20	_____/week		1	_____
Pickup Truck	_____/hour	20	_____/week		1	_____

III. Miscellaneous equipment	Rate w/o Operator	x Quantity	+ Rate	x Quantity	=	Total
Water Truck (500 gallon minimum)	_____/day	5	_____/week		4	_____
Spoils truck (1000 gallon minimum)	_____/day	5	_____/week		4	_____
Backhoe	_____/hour	20	_____/week		2	_____
Steam cleaner	_____/hour	5	_____/week		2	_____

IV. Drilling Fluid Additives (lost circulation materials)	Material	x Quantity	=	Total
Quick Gel	___/50 lb sack		400	_____
Benseal	___/50 lb sack		20	_____

Activity	Hourly Rates will be worked at the request of SRS	Labor x	Quantity =	Total
	Micatex		___/50 lb sack	50 _____
	Cotton seed hulls		_____/ per lb.	2000 _____
	Hole plug		_____/ sack	50 _____
	Revert		___/ 25 lb sack	25 _____
	Sodium phosphate		_____/ sack	15 _____
GRAND TOTAL				_____

* PRICE SCHEDULE EXPLANATIONS

Mobilization for the task includes transportation of all rigs and support equipment to and from SRS and the pre-job Health and Safety briefing. Rigs should be steam cleaned before they are brought on site. No mobilization will be paid if an additional rig is brought on to a project for well development.

Mobilization (between holes): This includes deconning all rigs and down hole equipment and site cleanup upon vacating the location

Coring: The minimum acceptable core diameter is 94 mm. The specific coring system is left to the discretion of the supplier.

Shelby tube: Includes the tube, end caps, wax, and a means to melt the wax.

Geophysical logging: The logging footage costs include 6 paper copies of the log and 2 copies of the floppy disk with the digitized data. The standard suite of logs is noted in section 3.2.1. Additional paper copies of the log are included as a line items.

Surface casing: The footage cost for steel casing installation includes making and welding centralizers to the casing, setting the casing, and welding (including welding machine and welders) the joints together.

Filter seal installation: includes installing bentonite and allowing for 2 hours of hydration.

Group: grout may be mixed by hand or ordered by the truck load.

Activity **Hourly Rates will be worked at the request of SRS** **Labor x Quantity = Total**

Well development: The specific type of well development is typically determined at the start of a project. Bailing requires a 20 foot PVC bailer and a water truck or tank to add water into the well. Swab and reverse air lift requires an air compressor with filters to keep oil from being introduced into the well. The temporary submersible pump will be furnished by SRS. No mobilization between holes is paid for well development.

Drill rig inside RCA: This includes the rig, water truck, and ancillary equipment that has had the fair market value determined. The crew is also part of the hourly rate.

Equipment for work in RCA's

Provide fair market value for equipment to do the following work: Core to 350 feet, ream borehole to 14 inches, drill boreholes to 10 inches, take shelby tubes, install wells and develop wells, build pads and set pumps. (The generator for well development will be provided by WSRC).

Equipment	Fair Market Value
Rig	_____
Core rods (per foot)	_____
drill rod (per foot)	_____
Additional Equipment	
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

List any additional equipment and fair market value