

RICHARD H. BRYAN  
Governor

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STATE OF NEVADA



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**NUCLEAR WASTE PROJECT OFFICE**

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OFFICE OF THE GOVERNOR

Capitol Complex

Carson City, Nevada 89710

(702) 885-3744

April 16, 1984 - 01

Mr. Robert E. Browning, Director  
Waste Management Division  
Office of Nuclear Material Safety & Safeguards  
U. S. Nuclear Regulatory Commission  
Washington, D.C. 20555

Dear Mr. Browning:

As we discussed, enclosed please find a copy of a work scope from a contract that my office has entered with the Desert Research Institute of the University of Nevada System regarding hydrogeologic research and assessment at the Yucca Mountain site.

This contractor will be the principal advisor to my office on hydrogeologic issues associated with the proposed project, and as a result, I thought you would have an interest in reviewing this work program. Upon your review, I would be pleased to discuss any issues associated with this work that you might be concerned with.

I would also like to reiterate my commitment to share data and to cooperate with you and your staff in the undertaking of this project and look forward to our continued coordination of activities and events.

Should you have any questions or wish to discuss this matter further, please do not hesitate to contact me.

Sincerely,

Robert R. Loux  
Director

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Encl.

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WM Project 11  
Docket No. \_\_\_\_\_

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<b>Nuclear Waste Project Office</b> <b>Robert R. Loux</b>		4/16/84	4/23/84	WM-84377
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<b>Proposal to the NWPO "Hydrogeologic Research &amp; Assessment Program for the Proposed Yucca Mountain HLW Repository Site"</b>		<b>JBunting</b>	<b>4/23</b>	
ENCLOSURES				
Note: MKnapp BMiller JBunting		Please see me re how we review & coordinate this internally.		
		Closed per telecon w/ Bob Loux on 9/25/84.		



*Ticket for Bunting*

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Miller }  
Bunting }*  
*RSB  
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Loux 4/6/84

PROPOSAL TO THE NUCLEAR WASTE PROJECT OFFICE  
STATE OF NEVADA

HYDROGEOLOGIC RESEARCH AND ASSESSMENT PROGRAM  
FOR THE PROPOSED YUCCA MOUNTAIN  
HIGH-LEVEL NUCLEAR WASTE REPOSITORY SITE

February 1984

Submitted by:

Water Resources Center  
Desert Research Institute

  
Warren C. Kocmond  
Acting President  
Desert Research Institute

  
Paul R. Fenske  
Executive Director  
Water Resources Center

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## PROPOSAL TO THE STATE OF NEVADA:

### HYDROGEOLOGIC RESEARCH AND ASSESSMENT PROGRAM FOR THE PROPOSED YUCCA MOUNTAIN HIGH-LEVEL NUCLEAR WASTE REPOSITORY SITE

#### INTRODUCTION

This proposal to the Nuclear Waste Project Office, State of Nevada (State) is a solicited proposal and a product of discussions between representatives of the Water Resources Center, Desert Research Institute (WRC-DRI), and the State of Nevada Nuclear Waste Project Office. Representatives of both organizations have been actively dealing with the U.S. Department of Energy (DOE) proposed Yucca Mountain high-level radioactive waste repository since preliminary identification of the site by DOE. Dr. M. D. Mifflin, with support of the WRC-DRI faculty, has represented the WRC-DRI in the development of the proposed program. The principal State representatives, Mr. Robert Loux and Mr. Carl Johnson, have interacted with the DOE in preparation for State participation as determined by the Nuclear Waste Policy Act of 1982. Both the State and WRC-DRI representatives independently recognized, early on, the need for effective organization and response by the State and its technical resources to protect and promote the State interests during the site assessment and licensing activities of DOE and NRC.

The choice of Yucca Mountain on the Nevada Test Site (NTS) by the DOE as a potential high-level radioactive waste repository for commercial wastes has created the unprecedented need for extensive and highly technical investigations, the Nevada Nuclear Waste Site Investigation (NNWSI) of the DOE. The professional faculty of the WRC-DRI and the State desire to fully evaluate and judge the NNWSI technical investigations and licensing procedures performed by the DOE and the NRC. The objective is to determine, independently for Nevadans, whether or not the site has the compability to isolate and contain the wastes during the emplacement period and radioactive life of the proposed repository. In addition, it is recognized that heretofore no high-level waste repository meeting the licensing requirements and standards as established in 10 CFR 60 has

been licensed in the United States, and that the proposed repository medium of Yucca Mountain represents a unique technological challenge in accurate assessment of repository performance. Therefore, the program proposed to the State by the WRC-DRI consists of selected independent research investigations to supplement investigations which may be sponsored by the DOE and the NRC. In addition, WRC-DRI proposes direct monitoring of DOE sponsored field investigations and in-depth independent technical review of all key investigations established by the DOE and the NRC during the site characterization and site performance procedures.

A particularly important area of concern with respect to the proposed high-level radioactive waste repository is the hydrology associated with the site. Water (liquid and vapor) is the agent recognized as most likely to transport radionuclides from the buried waste to points within the hydrologic system where future generations would be exposed to the radioactivity. Over the thousands of years that the repository must successfully contain the radioactivity, it is water that is most likely to come into contact with the wastes and move radionuclides from the repository to other locations within the hydrologic regimen. It is therefore recognized that the hydrogeological and closely related investigations of the proposed repository are of paramount importance, particularly when it is also recognized that Nevada, the most arid state in the nation, is heavily dependent upon its very limited ground-water resources and can expect continuous intense development and management of the same.

The Water Resources Center, Desert Research Institute, University of Nevada System is widely recognized for research and training programs in hydrology. The WRC-DRI proposes to act as the consultant for the State in the Yucca Mountain assessments in the broad technical field known as hydrology. The faculty of the WRC-DRI has long been involved with research in ground water throughout the state, and has special experience in the NTS area through association with weapons testing programs at NTS. Since 1962 there have been ground-water studies related to radionuclide migration and hydrologic safety of underground nuclear testing by DOE and predecessor agencies. There is also lengthy experience in working with DOE and its many contractors.

## WRC Relationships to the DOE and the NRC

While the work of the WRC-DRI is generally scientific research, politically charged issues and mission oriented organizations frequently stimulate much of the research performed by the WRC. Historically, an attempt has been made by the WRC to remain scientifically objective and independent of the positions advocated by funding entities.

As established in the past with respect to all contracts and grants, the official position and policy of the WRC-DRI is that of a research organization and not that of an advocate of policies of funding entities, such as the DOE or the State. Therefore, the WRC policy objective in the proposed program is to insure the best independent scientific assessment and judgment that can be developed on hydrologic questions, and it will execute this policy through normal scientific criteria and standards of professional performance.

The single most important source of funding for WRC research for over more than 20 years has been the DOE and predecessor agencies. The majority of this research has been related to the NTS weapons testing program. To present, considering all Centers of DRI, there have been only two studies funded that are part of the DOE NNWSI:

- 1) The archaeological studies of Yucca Mountain by the Social Science Center (SSC) of DRI.
- 2) An air quality study of Yucca Mountain by the Atmospheric Science Center (ASC) of DRI.

A water resources literature review of the NTS for Sandia National Laboratories by the WRC was also indirectly related to the DOE NNWSI program at an early stage (Principal Investigator, Dr. Richard French). No hydrogeologic role for the DOE NNWSI has been part of the WRC program, nor is one anticipated. The U.S. Geological Survey is the prime DOE contractor for hydrologic and hydrogeologic studies in the DOE NNWSI. Other DOE contractors, such as the National Laboratories, also have important supportive contracts on hydrologic issues.

On an individual WRC faculty member basis the following professional relationships with DOE or other NNWSI principals exist:

Dr. Paul Fenske  
Executive Director, WRC-DRI:

Program Manager for the WRC-DOE contract, past member of DOE Peer Review Committee on the NNWSI. Consultant to Rockwell International on the hydrogeology of the proposed basalt repository in Washington. Consultant to NRC on research.

Dr. Martin Mifflin  
Research Professor, WRC-DRI:

Present or former principal investigator on DOE contracts relating to water supply investigations and development. Consultant to NRC on the hydrogeology of Yucca Mountain and salt repository sites.

Dr. John Hess  
Associate Research Professor, WRI-DRI:

Co-principal investigator on numerous DOE hydrogeochemistry oriented research programs at the NTS, and consultant to NRC on the hydrogeochemistry of Yucca Mountain.

Several other WRC faculty members have worked in the past or are working on DOE projects not related to the DOE NNWSI.

Dr. Fenske's present and past professional relationships with DOE are considered by the WRC to have the potential to generate conflicts of interest in the WRC proposed program for the NNWSI. In the past he has served on the peer review committee for Yucca Mountain for the DOE. His overall responsibility for the WRC contract with DOE, of which a few tasks are or have been related to the DOE NNWSI, tends to create a potential conflict of interest in a general way. Therefore, he will not participate directly in the proposed program except as a reviewer of appropriate documents. It should be stated, however, that he supports the WRC's

important consultant role to the State and is administratively responsible for all activities of the WRC.

Dr. Mifflin and Dr. Hess currently hold key consulting positions with NRC on the hydrogeologic questions of Yucca Mountain as a repository. From the perspective of both the researchers and the NRC, key roles in the State's NNWSI research, review, and monitoring program and review functions for NRC are compatible until the NRC is in a licensing action. At such time they cannot represent both the State and the NRC. Until that time, the scientific objectives of both the State and NRC are mutual, that is, effective and thorough assessment of the site. The conflict that could develop during the licensing process is that NRC and the State may disagree as to the suitability of the site in terms of licensing requirements being met.

Another type of potential conflict may arise during the review process conducted for the State by the WRC. NRC documents may also be reviewed, and these in part may reflect the work of Drs. Mifflin and Hess. In such cases, the reviewers clearly should not review their own work. This situation, in an operational sense, is similar to research results produced by the WRC. External review is desirable when the issues involved are key to the State's interest. As the results of external reviews will not be modified by WRC before transmittal to the State, impartial reviews of both NRC findings and WRC research results as well as DOE findings are an integral part of the WRC plan. Similarly, past investigations performed by the faculty of WRC may come under review because of direct relationships to Yucca Mountain hydrogeology. In cases where the technical contents are key to the State interest, external review is appropriate.

The WRC-DRI does not presently have and does not anticipate an important role as research contractor for DOE sponsored NNWSI research on the hydrogeology of Yucca Mountain. This role is being performed by the U.S. Geological Survey and several National Laboratories. However, because of the special expertise of some members of the Desert Research Institute faculty, it is conceivable that some research activities in specialized areas of investigation might develop over the history of the DOE NNWSI

investigations. Should the potential of such activities develop, two steps will be taken by the WRC-DRI:

- 1) Inform the State of the potential relationship with DOE to determine if an unacceptable conflict would be established.
- 2) Insure that DRI faculty with prime responsibility on any DOE NNWSI research has no similar responsibility on the State NNWSI program.

### WRC Internal Organization

In order to separate WRC NNWSI program executive responsibility for technical review, monitoring, and research from the overall executive responsibility of the WRC-DRI, the internal WRC structure of this program has been designed as shown in Figure 1. This is very similar to the internal organization of executive responsibility followed in present and past WRC-DRI DOE contract programs. A WRC NNWSI Program Director will communicate program business directly with the State of Nevada Nuclear Waste Project Office and all working decisions related to the NNWSI program executed by the WRC or other faculty of the DRI will be made within the organizational structure displayed in the organizational chart. Figure 2 illustrates the administrative structure of the WRC and the Desert Research Institute. The WRC NNWSI Program Director will interact at the WRC Executive Director and DRI President level. The mode of actual operation will be that of a matrix management scheme, where the NNWSI Program Director and Associate Directors may also be active Principal Investigators.

A brief explanation of Figure 1 is warranted. One person is normally responsible for the communication pathway between the State of Nevada NNWSI Coordinator and the DRI. This will preclude or minimize untimely, inaccurate, or confused communication between State officials or citizens and the researchers and reviewers, and will greatly enhance effective communication in both directions.

It is anticipated that circumstances may develop where either technical reports or other documents requiring review may have risen from the efforts of Drs. Hess or Mifflin due to

investigations. Should the potential of such activities develop, two steps will be taken by the WRC-DRI:

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### WRC Internal Organization

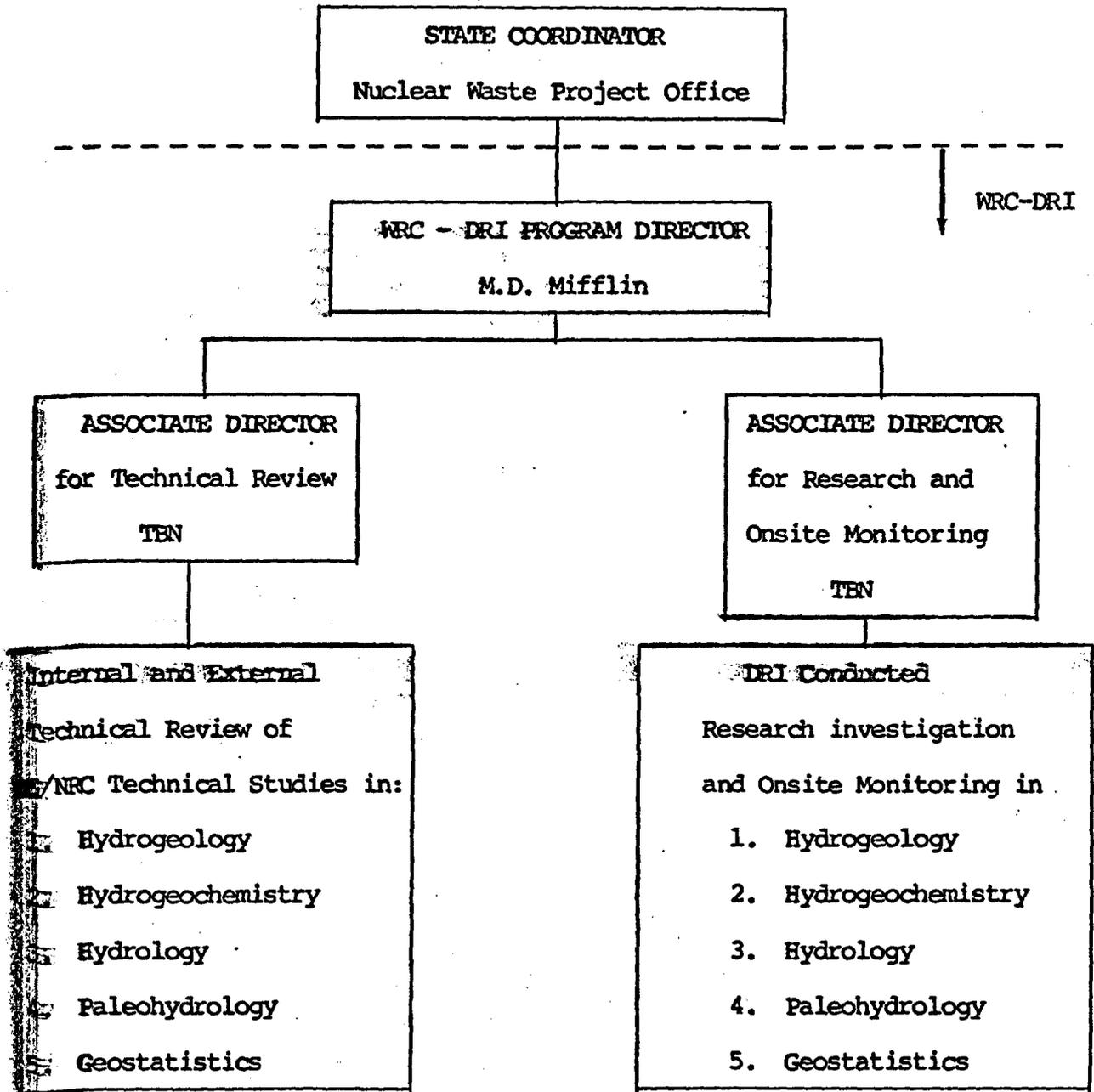
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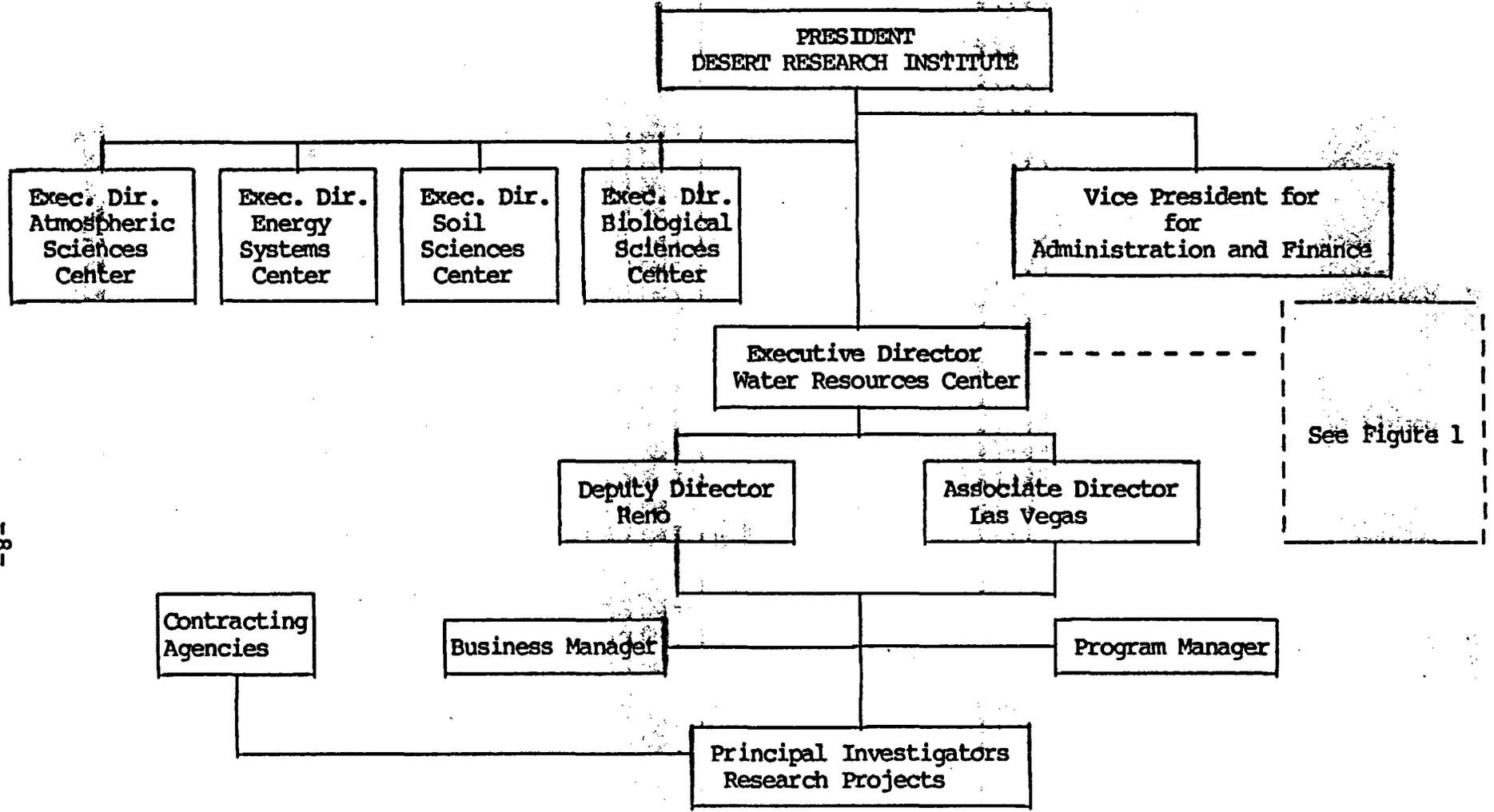
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STATE OF NEVADA

YUCCA MOUNTAIN REPOSITORY PARTICIPATION



1. Organization of the WRC NNWSI Hydrologic Review, Monitoring and Research Program.



-8-

FIGURE 2. Organization of the Water Resources Center, Desert Research Institute.

NRC contracts or previous research. In such circumstances, in consultation with the State Coordinator, an alternate path for review responsibility and communication will be established to avoid direct responsibility for review of one's own work, or review of the work of a superior who in turn would transmit the review to the State Coordinator. The State Coordinator and/or the WRC-DRI Program Director will jointly or individually identify such circumstances and jointly establish the alternate path of review responsibility within the DRI.

WRC-DRI NNWSI Associate Program Directors will have significant executive/scientific responsibilities due to the potential importance of the work and accordingly will be carefully selected in consultation with the State. In the case of Activity B (the Investigation Review function) the Program Director and Associate Director must insure that the best in-depth technical reviews are established by using both internal and external professionals, and that the results of the reviews are clearly and accurately prepared in written form. However, if they are to reflect their independent nature and professional integrity, the external technical reviews cannot be modified in terms of technical content or conclusions by the WRC-DRI faculty. These reviews may range from evaluation of raw field data collection methods to sophisticated analyses using computer codes for simulation of complex physical systems. In some cases facilities other than those of the University of Nevada System could be required during the review process. External reviewers will be contracted by the WRC in consultation with the State.

The Program Director and Associate Director of Research and Onsite Monitoring must insure that each WRC investigation is performed and documented to the highest standards of scientific experimentation. Results of these investigations, if either compatible or contradictory to DOE or NRC findings, must be able to stand up to intense and detailed review by the scientific community as a whole. Most of the research is developmental in nature, so that some methodologies employed are not already documented in the scientific literature. The WRC research therefore needs to be as carefully executed and as well documented as the investigations sponsored by DOE, which are generally supported by significantly larger budgets and broader based resources. In addition, they must insure

that the onsite monitoring of Yucca Mountain investigations are comprehensively executed and usefully reported.

The Associate Directors as yet have not been selected, and they appear "to be named" (TBN) in Figure 1. Ideal qualifications for the responsibilities include broad experience in hydrologic research, preferably in varied research environments or organizations, demonstrated executive skills, and broad scientific community connections. It is clear that these responsibilities would be best performed by individuals with at least 10 years of professional experience, most of which should be research oriented. They must also have a demonstrated ability to effectively interact with researchers and be acceptable to the State. Preliminary consideration has been given to both existing WRC-DRI senior faculty and new faculty members. It is anticipated that initially acting Associate Program Directors will be chosen from the experienced faculty of the WRC, and with time, permanent Associate Directors will then be established.

#### Impact of the Program on the WRC

The overall impacts of the proposed WRC NNWSI Program on the WRC-DRI are anticipated as positive. The anticipated duration, magnitude of operation, and nature of work are favorable factors for the WRC. The duration of the program of between 3 to 6 years is ideal for enhancement of faculty for specialized research execution. The program gives excellent opportunity for major progress in the research due to continuity of funding, researchers, and time allocated. The size of the research tasks are such that key researchers can devote the majority of their efforts to one or two research objectives. The research objectives associated with the assessment and performance of Yucca Mountain as a high-level waste repository are extremely challenging questions requiring new methodology and study of unknown hydrogeologic environments, and are of significance to a broad range of hydrogeologic problems as well as radioactive waste disposal. And, of equal importance, the WRC faculty recognizes that the challenge of the Yucca Mountain repository assessment is also a unique opportunity for the WRC-DRI to serve the State of Nevada on a very difficult technical and political problem of local and national

importance. The more than 20 years of WRC-DRI research and associated faculty experience on the hydrology of the State, plus the organizational structure within the University of Nevada System, makes the WRC an ideal organization to act as a key consulting body on the hydrologic technical issues of the DOE NNWSI program.

Other aspects are also viewed as positive. Part of the additional work load provided by the State program can be assimilated by existing faculty due to the lingering effects of the economic recession on the research programs. The review function is anticipated to bring to the WRC a number of outside experts for short review tenures and these visits will be beneficial to both WRC faculty and graduate students. The impact on analytical laboratories will also be positive in that sample loads will be sufficient for more efficient operation. An assured level and duration of funding for specific research objectives over several years is ideal for the development of faculty with expertise in new areas.

Negative impacts, or potential impacts, generally relate to the long term effect of scaling up to a higher level of activity, and eventually a rapid scaling down as the activities terminate. An organization such as the WRC has more difficulty in reducing the size of an overall program than expanding a program, and therefore care and adequate planning must accompany a marked increase in the size of the WRC overall program. Support of the magnitude of the State NNWSI program is unusual, and therefore future termination of that support during a relatively short period must be planned. We have considered the possible scenarios associated with the DOE NNWSI which range from abandonment within the next two or three years (total program termination) to licensing after six or more years of investigations (a continuing State program at a reduced level of activity). Recognizing the WRC must be prepared to phase out the program, the majority of new faculty will be post-doctorate and post-masters degree recipients with one year appointments, renewable for one year. Principal Investigators for most research will be experienced existing faculty. While maintaining the flexibility to rapidly scale the program up or down, this approach allows experienced WRC faculty to direct the research and other activities, including the ongoing WRC research programs.

## Project Management

The nature of the overall proposed function of the WRC-DRI is such that considerable direction, planning, and coordinating activity will be the responsibility of the Program Director. Three prime functions are recognized:

- I. Program Direction
- II. Technical Issues: Review, Planning, and Program Design
- III. Coordination (with DOE, NRC, other State and Federal agencies)

These general activities are necessary to insure a successful State program of NNWSI review, monitoring, and State sponsored research. Program direction refers to the smooth and effective internal operation of the assumed responsibilities by the WRC-DRI. Considerations include necessary faculty, facilities, and the associated planning and logistics necessary to perform the broad scope of activities.

A continuing review of technical issues and associated progress in research and investigations by all entities is an extremely important function. Issues will develop or change as investigations proceed and more data become available. The State must determine, with the assistance of the WRC-DRI, which new aspects or issues should be addressed by research and which should be covered by monitoring and review functions. In addition, the State must determine, with the assistance of the WRC-DRI, which ongoing research investigations should be continued, which should be modified, and which should be terminated in light of the evolving issues and data. These are critical functions the Program Director and his Associate Directors.

The third management function is that of the coordination required to execute monitoring, review, and research activities at the NTS. In order to successfully conduct the monitoring review and research activities, a high degree of coordination and interaction will be necessary between the WRC-DRI and DOE, associated DOE contractors (USGS, Sandia, LBL, LASL, etc.) and other Federal and State agencies. While

the WRC is experienced in cooperating with the DOE and associated contractors in other programs of research on the NTS, the very nature of the DOE NNWSI could make certain types of research or data collection activities difficult to coordinate successfully.

The protocol the WRC proposes is for the State to establish the general agreement with the DOE for access to data and associated experiments, copies of all investigative draft documents at the time of first review by DOE, and access to all research, investigative facilities and data associated with the Yucca Mountain repository, including laboratory experiments performed by DOE contractors. Some WRC faculty now have the appropriate security clearances for such access, while some additional or new faculty may need security clearance. The WRC will advise the State in the details that should be covered in negotiating the general agreement.

The WRC recommends that each State research program or other activity requiring detailed coordination and agreement between the WRC and the DOE and contractors be established on an as needed basis under the terms of the general State/DOE agreement. These coordination activities will be the responsibility of the WRC Program Director and Associate Program Directors.

#### General Proposed Approach

There can be no realistic State plan to duplicate all the hydrogeologic and closely related investigations performed by the DOE and associated contractors. There is, however, the realistic objective to carefully research recognized issues or problem areas where there is uncertainty in research approach or potential gaps in the DOE investigative approach and to validate DOE or NRC results bearing on critical site suitability issues. In addition, part of the WRC effort is to provide the State with "state-of-the-art" analyses to assure the citizens of Nevada maximized assessment of the hydrologic conditions of Yucca Mountain and an independent analysis of how well a repository in Yucca Mountain will perform over the life of the radioactivity. It is anticipated that these efforts will be useful to the State of Nevada in the series of political decisions that will be made

by Nevada, the DOE, the President of the United States, and the U.S. Congress.

#### First Year Recommended Program

The proposed program for the first year of funding is based on several considerations. These are:

- I. Orientation and established progress of the USGS hydrogeology and hydrology investigations at the Yucca Mountain site area as they are known.
- II. The orientation of the NRC licensing team, and the established 10 CFR 60 licensing criteria and associated EPA standards.
- III. The currently recognized areas where either methodology or issues have not been fully or sufficiently addressed by investigations.
- IV. Feasibility in terms of funding and logistical considerations.

The established progress by the U.S. Geological Survey, the prime DOE contractor for hydrologic studies in the NWWSI, is that of hydrologic and geologic test boreholes and wells, and test programs and experiments oriented at establishing distribution of permeability and patterns of flow on a near field, subregional, and regional scale. These programs are generally costly due to the depth of drilling and the fractured nature of the terrain. Methodologies employed are "state-of-the-art" applications of scientific techniques, many of which have been developed or adapted and perfected for the NTS hydrogeologic conditions by the USGS. To date, most of the effort has been directed toward establishing the distribution of permeable units, head or fluid potential distribution, and quantitative models of both regional and subregional flow. The USGS unsaturated zone investigative program is currently in the early stages of development with methodology and approach still unproven and experimental. Postulated conceptual models of the unsaturated zone are also unproven. The USGS hydrogeochemistry program is as yet undeveloped, and has been of secondary priority with respect to the orientation of drilling and testing programs.

The NRC licensing requirements are oriented toward the criteria and standards set forth in 10 CFR 60. These, in general, focus on ground-water travel times and directions to the accessible environment as defined (currently 10km from the zone disturbed by the repository) and repository performance (the amount of radioactivity which will reach the accessible environment, over time, after repository emplacement). For these reasons, there is an orientation towards quantitative analyses of the direction and flow rate of ground water both pre-repository and post-repository emplacement.

As investigations by both the DOE contractors and the State of Nevada progress, it is anticipated that additional hydrologic and hydrogeologic issues of special importance will become apparent. Currently, two broad issue areas have been determined by the State to be critical to its review:

- 1) unsaturated zone characterization,
- 2) regional hydrogeologic relations.

A third area, hydrogeochemistry, may also prove of equal importance as DOE investigations progress and require expanded efforts by the State. The bulk of recommended research beginning in the first year is addressed to these currently identified areas judged to be deficient in investigation or requiring verification. In our judgment, the unsaturated zone characterization program is weak, and better field methodologies need development and a broader base of useful unsaturated zone data needs to be established.

Certain initial research on hydrogeochemical aspects have also been proposed for first year funding. It is anticipated that expanded research may be warranted in both sorption studies and field hydrogeochemistry efforts due to the fractured nature of the repository terrain. Conventional hydrologic analyses (generally being followed by the USGS program) to determine flow paths and rates may prove inadequate due to the fractured nature of the terrain. A carefully established hydrogeochemistry analysis may be necessary to assess the validity of conceptual and quantitative flow models. DOE contractor results from current investigations will dictate the future level of

effort that may prove advisable to fully represent the State of Nevada interest.

Other difficult issue areas are being considered for State sponsored research. Little detailed information has been established on the location, amount, and necessary conditions for recharge in arid zones, and the associated variations of weather and climate that may help determine recharge events. A very difficult issue is that of the potential impact on an unsaturated zone repository if the climate should shift to pluvial types of climate which have occurred during the past in the region. The question is an important issue because the flux of moisture within the saturated zone could markedly increase and the distribution and position of saturation could be greatly modified, perhaps with saturation invading the repository. Distribution and amount of ground-water discharge and paths of flow could also be altered. Reliable repository performance for a permeable unsaturated zone repository depends ultimately upon a very low moisture flux. If the moisture flux would markedly increase, or saturation occur at or near the repository horizon, the repository performance in radionuclide containment would be significantly reduced. The long period of performance required, that of thousand of years, demands that climate changes be addressed. Currently, the approaches and level of importance placed on this issue area by DOE contractors is judged inadequate to reliably answer some of the key questions.

Another consideration, that of feasibility in terms of funding and logistical considerations, relates directly to DOE time tables, drilling costs, DOE program execution, and the type of data and duration of data collection periods that are necessary or desirable. Some research must begin as soon as possible so that meaningful periods of record are established before key decisions must be made. Monitoring unsaturated zone moisture conditions is a prime example. Reliable and economically feasible methodologies must be established early on in order to have opportunity to collect data during, for example, wet or dry years. The one instrumented unsaturated zone test hole recently completed by the U.S. Geological Survey cost approximately 2 million dollars. The high cost of constructing hydrological test holes and performing varied experiments is an indication of the amount of field data that can be expected with the

current methodologies being employed. Two or three saturated zone hydrologic test holes and associated experiments are equivalent to the entire first year State budget request. The State approach, therefore, must be to selectively pursue certain issue areas, and not attempt to duplicate the DOE drilling and testing judged to be well designed and executed. However, as DOE investigative programs develop and results and additional key questions become visible, it is anticipated that the State may become active in broader ranges of hydrologic investigations on a selective basis.

The final consideration from the logistic viewpoint relates to the utility and feasibility of collecting meaningful data. Methods of constructing and testing boreholes for one purpose may not be compatible for developing reliable data for another purpose. A case in point is hydrogeochemistry studies versus hydraulic studies in boreholes of great depth. Certain hydrogeochemical investigations require careful control on sampling horizons before the fluid potential in the penetrated formations equilibrate. Therefore, meaningful samples for certain hydrogeochemical studies cannot be collected from the existing boreholes and test wells. However, before extensive drilling designed for hydrogeochemical sampling is reasonable to propose, the utility of the hydraulic tests and associated measurements need to be established before there is clear justification for a large scale hydrogeochemistry drilling and testing program. Such a program might approach the cost of the current DOE drilling and testing program.

In summary, the research activities proposed and/or being considered for first year of funding have been established on the basis of several areas of consideration. The scope and balance may change as more information is developed and key issue areas change as in-depth knowledge develops, or in some areas, fails to develop. The monitoring and investigation review process will be key to the future scope of State research efforts, as will be the results of the initial State-sponsored research. A recognized problem that the monitoring and review activity, combined with State sponsored research, must overcome is the anticipated delays in the DOE release of investigative results and interpretations of NNWSI studies performed for licensing purposes. It is probable that many key investigations will undergo prolonged interpretive and review processes before release, with years

passing between the time of data collection and the released results. These delays could put the State in the position of formulating political decisions without the technical information base to support those decisions. Therefore, the monitoring and review activities have been structured to address this problem to the degree possible.

#### SUMMARY OF WRC NNWSI HYDROGEOLOGY PROGRAM

Three broad hydrologic activities are recognized as desirable in Nevada-sponsored efforts in preparing for possible DOE request for licensing of the Yucca Mountain proposed high-level waste repository. The first activity area is the on-site monitoring of hydrological investigations. The second activity area is in-depth review of technical investigation results produced by DOE and associated contractors. The third activity area is hydrological and closely related research designed to supplement DOE research with respect to key issues or sub-issues in predicting repository performance. Results of the WRC research will be subjected to the same level of review, with external peer review generally automatic.

#### ACTIVITY AREA A: Monitoring Investigations

The design of this activity is proposed as follows:

- I. Attend, by State NNWSI Coordinator request, DOE/NRC/ Contractor planning and review meetings related to hydrologic, hydrogeologic and geochemical investigations. It is anticipated that the State Coordinator or his representatives will attend all pertinent meetings between DOE and associated contractors and NRC. Some of the meetings will deal with matters unrelated to the technical issues of Yucca Mountain assessment, and others will deal with important issues of technical assessment. At this point in time it is assumed that the most efficient mode of operation is for the State Coordinator or his representative to request WRC representation at pertinent meetings, indicating the expected topical areas (and thus the appropriate WRC expertise) that should be represented. We judge this approach a

more efficient use of human resources, as considerable time can be consumed attending meetings and preparing summaries of such meetings for State review and records. Each meeting attended will be summarized by a meeting report, documenting the highlights and items of recognized importance, with submittal to the State Coordinator.

- II. The WRC will monitor all field operations where key hydrogeologic data are being collected or tests are being conducted. This activity will develop and maintain in-depth knowledge of data collection and testing activities, to allow the State and the WRC to remain current as to the progress and methodology being employed during the hydrologic investigations. The actual direct monitoring of field activities will be on a selected basis, and not necessarily direct full-time physical monitoring on all hydrogeologic testing such as drilling and pumping.

The monitoring will be accomplished by maintaining one or more field hydrogeologists in the Yucca Mountain area during drilling, testing or other operations during which data are collected that pertain to hydrologic investigations. This requires coordination with DOE (for appropriate access) and the several DOE contractors performing the investigations. To the present, field data collection is sporadic at Yucca Mountain. It will also include periodic review of data collected and status of data reduction. An attempt will be made to obtain duplicate samples or raw data sheets when appropriate, but the feasibility of this is dependent upon field circumstances and a clear agreement between the DOE and the State.

Review will be made of drilling procedures, sampling methods and sample handling, testing procedures, and other field aspects that may influence the quality of the established data and associated determinations. Periodic reports to the State will be made summarizing the observations, including progress, data acquisition, techniques, and recognized problems in methodology. The objective of the monitoring is to keep the State as well informed as proves feasible, with monthly summary reports and

annual reviews based on the monitoring information. The annual reviews will critique the procedures, estimate quality of sampling and testing, address the recognized problems associated with data collection or testing, and judge the effects of such problems on data interpretations and analyses.

ACTIVITY AREA B: Review of DOE (NRC) Investigation Documents

The WRC will establish in-depth reviews of released reports on all aspects of the hydrologic, hydrogeologic, hydro-geochemical, and geostatistical investigations related to repository performance and potential radionuclide migration. Initial review will be internal in WRC-DRI. When special outside review expertise is judged desirable, WRC-DRI will recommend and arrange for outside reviews in consultation with the State Coordinator. Each review will be documented by a report that will be submitted to the State.

The review procedure of technical reports will vary depending upon the initial review made by WRC faculty and/or the WRC Program Director and Associate Program Director. Initial review (review level #1) will form the basis of categorization as to potential importance to technical issues, quality of work, questionable aspects, and a preliminary determination if the document can be reviewed in depth within the WRC, or should receive both internal and external reviews. Review level #2 will be detailed review within the WRC by the most qualified faculty. At this point, a determination, in consultation with the State, will be made to establish if an external review (level #3) will be made. External reviews will be judged necessary if the technical content bears directly on key issues from the State's perspective, and if there is compelling reason to include an external review, such as lack of recognized expertise within the WRC. In summary, a given document may receive one to three levels of review, and will always receive one level of review. In the case of WRC research results, in consultation with the State, an external review will generally be arranged to establish broader scientific community credibility.

Considerations that will be incorporated into the reviews will be as follows:

1. Objectives and methodology in terms of the problem.
2. Data base used, source and quality of data.
3. Reasonableness and acceptability of conclusions to the scientific community.
4. Adequacy of the investigation from the State's perspective.
5. Alternative methodologies, availability of data, etc., to address the objectives.

Monthly summary reports of the review activities will be made. It is recommended, in conformance with good scientific protocol, that all technical reviews and research reports produced during the State NNWSI Program be published by the State in a timely manner and be made available for wide distribution in the scientific community. The normal test of the validity of technical findings is that imposed by the scientific community as a whole over time. The serious weakness of both the DOE and NRC mission oriented procedures in judging the contents of technical reports is the narrow peer review many are subjected to, and the high cost of duplicating the various investigations. Therefore, it is clearly in the State's interest to promote the availability of its technical assessment and research efforts to a wide audience as is possible in the scientific community. This is perhaps the most effective quality assurance incentive available in terms of DOE contractor performance and WRC performance.

#### ACTIVITY AREA C: Supplementary Hydrogeological Research

The objective of this activity is execution of research programs designed to establish specific levels of knowledge with respect to key hydrological issues in the estimated three or more years before the Yucca Mountain repository could be selected. The research objectives are directly related to anticipated key issues of repository performance and hydrogeologic assessment of Yucca Mountain and adjacent areas. They are and will be designed to supplement DOE sponsored investigations. Generally, quarterly progress reports and final reports will be submitted to the State as

research progresses. Periodically, additional research will be proposed to the State as the need for and design of the research is established.

The choice of the unsaturated zone at Yucca Mountain as a potential high-level radioactive waste repository has created the necessity for a broad spectrum of research.

Conceptually, an unsaturated zone repository in the arid climate of the region is attractive from the technical viewpoint. Based on mostly indirect evidence, minor amounts of moisture would contact the waste. Water being the prime agent which can transport radionuclides to the accessible environments, the unsaturated zone, therefore, might prove to be one of the best longterm terrestrial environments for the emplacement of such wastes. However, at least three key considerations must temper this conceptual view:

- 1) Very little direct knowledge of hydrogeologic processes in the arid zone unsaturated zones has been established.
- 2) Moisture and solute transport in unsaturated zones in general are complex and difficult to study or accurately evaluate.
- 3) The fractured and faulted tuff which constitute Yucca Mountain create both unsaturated and saturated zone hydrogeologic environments that are extremely difficult to confidently characterize with the accuracy desirable for licensing purposes.

Therefore, the DOE site investigations will necessarily be difficult and complex, the WRC licensing review difficult, and the research investigations performed by the WRC may prove to be as important in determining the technical suitability as those of DOE. However, the State and the WRC must be extremely selective in pursued research due to a difference of more than order of magnitude less of both human and financial resources, than those available to DOE, and the costly nature of most laboratory, drilling and testing procedures involved with site assessment.

The following research programs and objectives are recognized at this time as important supplementary efforts that could produce results of significant value in terms of repository assessment and predictability of repository performance:

RESEARCH PROJECT I - PHASE I:

METHODOLOGY OF INSTRUMENT EMPLACEMENT TO ACQUIRE  
RECORDS OF UNSATURATED ZONE MOISTURE MIGRATION  
IN SELECTED HYDROGEOLOGIC ENVIRONMENTS

PRINCIPAL INVESTIGATOR: M.D. Mifflin

DURATION: 1 year

General

One of the most challenging aspects of a reliable Yucca Mountain site characterization is establishing direct moisture data for assessment of moisture regimens in the thick unsaturated zones of Yucca Mountain and other environments. At present there is no widely applicable or well documented or demonstrated methodologies for characterizing moisture regimens in these environments. This research is directed at developing and testing promising methodologies currently being tested at the Desert Research Institute. If successful, more expanded research is anticipated the second and third years directed at moisture regimen monitoring in a variety of unsaturated environments (Appendix II, Unsaturated Zone Monitoring and Data Development).

Specific Objectives

Objectives of this effort include:

- 1) Establishing a methodology of emplacement of neutron access tubes, thermocouple psychrometers and other soil moisture sensing devices in the thick unsaturated zones of the Southern Nevada region.

- 2) Demonstrating the feasibility of developing directly monitored moisture migration data bases using such installations.
- 3) Developing methods of extracting soil moisture from the unsaturated zone for geochemical studies to establish independent evidence of the moisture regimen.

#### Relevance to Yucca Mountain Assessment

The choice of the unsaturated zone repository requires assessment of moisture regimens within the thick unsaturated zone at numerous locations. Most drilling techniques require fluids for drilling, and thus in-situ moisture conditions are masked by fugitive drilling fluids. Presently, the majority of the DOE NNWSI experiments for unsaturated zone regimen assessment are tied to the exploratory shaft, a very site specific limitation on data at a high cost. This project will attempt to further develop methodologies of drilling without introducing water for soil moisture sampling and instrument emplacement. Several techniques for unsaturated zone moisture collection will also be attempted for geochemical studies. The thick unsaturated zones of fractured tuff will be monitored for moisture migration from the saturated zone to land surface to fully demonstrate moisture conditions key to repository performance. Presently, there are no demonstrated methodologies that are widely applicable to the Yucca Mountain terrain.

#### Work Plan

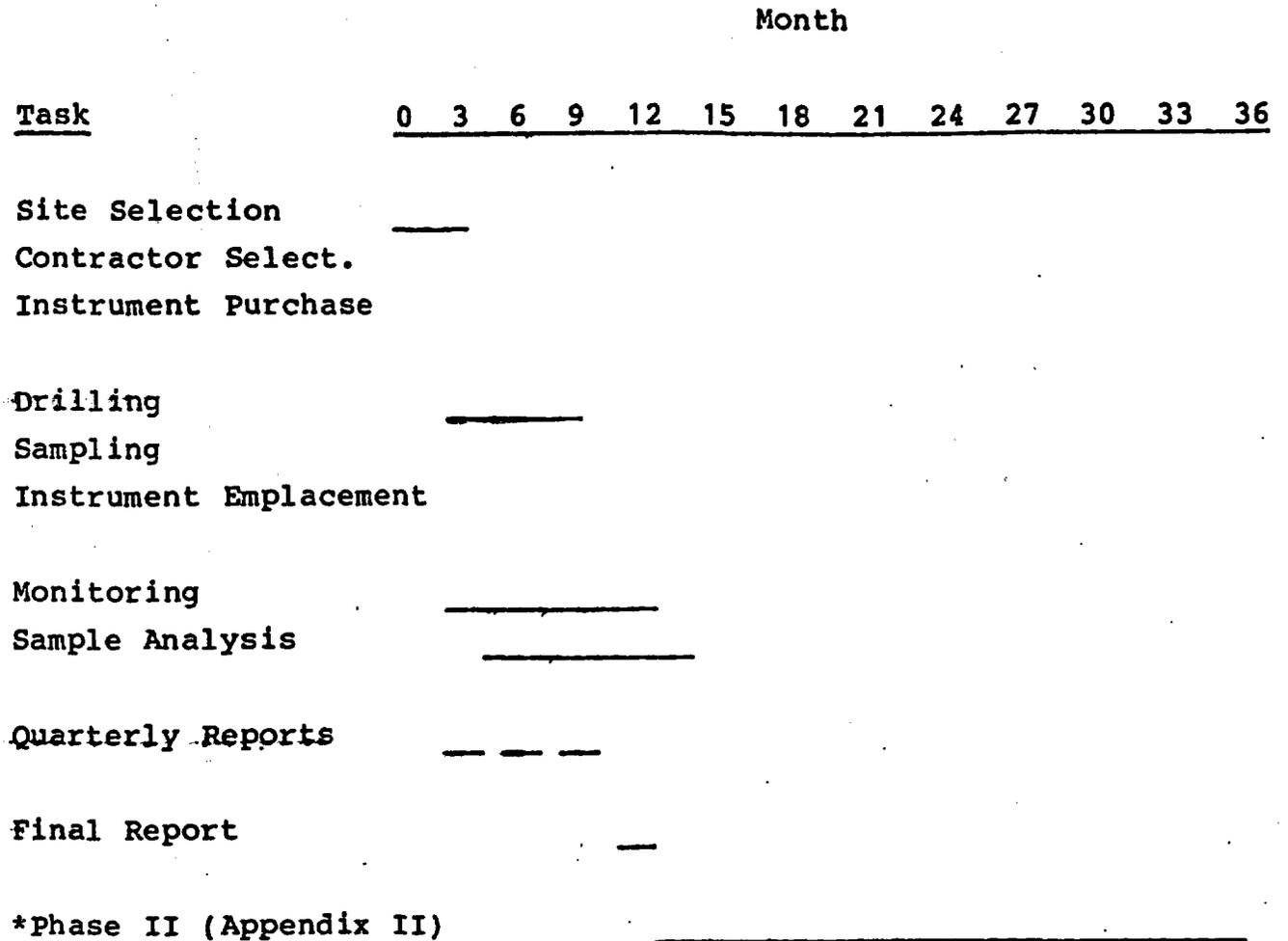
The investigation will be of one year duration to evaluate a method of air drilling and instrument emplacement already used successfully to shallow depths by DRI. Two small diameter holes will be drilled to or near the saturated zone

in fractured tuff (in areas where the water table is anticipated to be 600 to 800 feet in depth) without using water or other fluids. Several others will be shallow, concentrating on the upper 10 to 15m of unsaturated zone. Cuttings will be collected to determine whether or not water can be extracted for geochemical studies and the determination of moisture content. Neutron access tubes and thermocouple psychrometers will be installed and monitored. Experiments will be made to extract water and water vapor.

#### Anticipated Results

Based on earlier experiments using essentially the same instruments and techniques of drilling, there is a high probability of success in developing the drilling and soil moisture monitoring methodology for the thick unsaturated zones. The liquid and water vapor collection for geochemical analyses has reasonable promise but is less developed. If these approaches prove successful, an expanded program of direct monitoring of unsaturated zone moisture will be possible and will be pursued the following years (Appendix II Phase I) to broaden the unsaturated zone data base and address pluvial climate unsaturated zone moisture flux.

TIME DISTRIBUTION - UNSATURATED MOISTURE - PHASE I



\*If methodologies are demonstrated successful in the first of study.

RESEARCH PROJECT II:

REGIONAL GROUND-WATER FLOW  
AND HYDRAULIC CONTINUITY BETWEEN  
THE REPOSITORY BLOCK AND ADJACENT AREAS

PRINCIPAL INVESTIGATORS: Roger L. Jacobson and John W. Hess

DURATION: 4 years

General

The determination of ground-water flow in three dimensions, both in the repository block and surrounding areas, is of paramount importance in understanding how radionuclides may leave the repository block. This will necessitate sampling a substantial number of wells and obtain data from numerous depths. Hydrologic continuity with the surrounding areas is perhaps even more difficult to determine, and again requires numerous wells with carefully collected samples and data. In an attempt to maximize the information from the existing wells in and around the area, it is proposed to collect hydrologic data and water samples on a periodic basis. This approach will greatly increase the amount of data available to interpret hydrologic conditions. This type of assessment has proven to be extremely useful in understanding flow relationships in fractured carbonate terrains.

Cooperation with other agencies involved with the drilling program and sampling is essential for the success of this project. Sampling intervals will be located using borehole geophysics, and samples will be collected using a thief sampler where pumped samples are not feasible.

### Specific Objectives

The specific objective is to determine water movement patterns within the repository block and the connection with adjacent areas. This will be attempted by collecting data in an integrated manner, such that samples will be taken in both time and space. Samples will be collected for all major ions, several trace elements, and various environmental isotopes (tritium, carbon-14 and 13, deuterium, and oxygen-18). This information will compliment the various hydrologic parameters, such as water levels, and give a more complete picture.

### Relevance to Yucca Mountain Assessment

The relationship of this study to the repository assessment is to obtain a more thorough understanding of the pathways the radionuclides will most likely take. Documentation of this is difficult in fractured rock with relatively complex geology and hydrology. At the present time this type of problem has been successfully studied in carbonate terrains using various tracing techniques as well as time series analyses of water chemistry from wells and springs. The water chemistry variations, when compared to precipitation and other events, helps in understanding the fractured media and in particular flow rates and directions.

### Work Plan

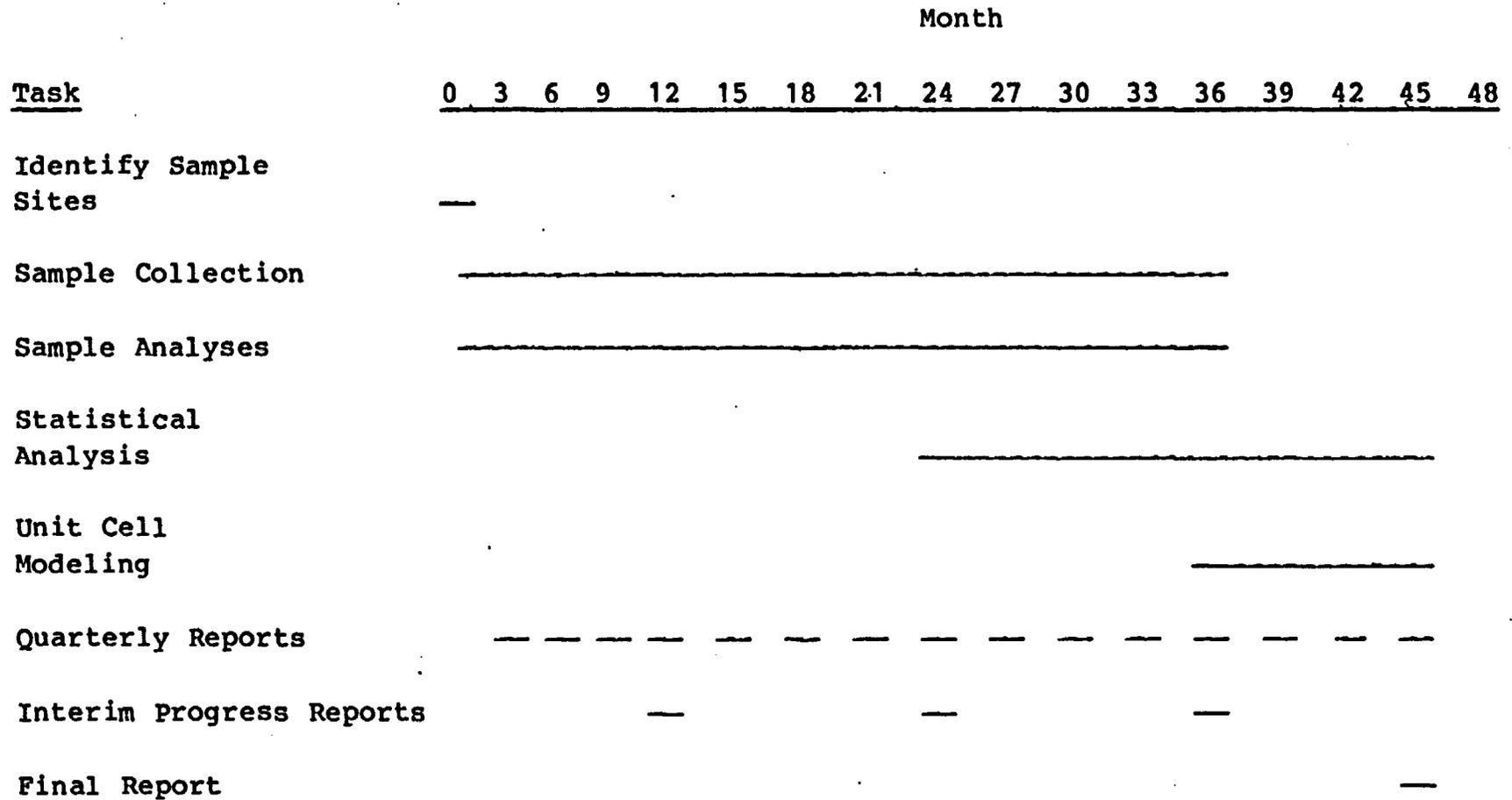
The investigation will involve sampling wells at various depths for numerous parameters. The sampling will be on a monthly basis for two years, taking careful field measurements as well as samples for laboratory analyses. Sampling will be conducted in the repository block as well as in adjacent areas and at regional discharge points. Variations

observed at different sites should help provide data to be tested using the various statistical and numerical modeling approaches. The last year of the study will involve careful statistical analyses of the time series data with particular emphasis on a lag correlation. The spatial data will be studied utilizing a mixing cell model. This model, which relies on relatively conservative elements such as tritium, deuterium, carbon-14, etc., examines inputs and outputs of volumes of saturated rock or cells and can thereby establish mixing relationships and define most likely flow paths.

#### Anticipated Results

The results will be a more clear understanding of flow within the repository block and also a better definition of any connection to adjacent flow system(s). Another anticipated result will be an enhanced picture of the potential flow paths to the regional discharge area(s).

TIME DISTRIBUTION - REGIONAL GROUND-WATER FLOW



## APPENDIX I

### ESTIMATIVE BUDGETS

The budgets established are based on indicated levels of activity and past experience. The budgets are estimated, and therefore a degree of flexibility is recommended so that funding can be shifted among categories and between the activity areas. The budgets are developed in anticipation of a rapid start-up of activities, and successful staffing with highly trained faculty.

### BASIC ASSUMPTIONS

The following basic assumptions have been adopted to establish the estimative budget for the WRC NNWSI program management, review, and monitoring functions:

#### Review Function

A total of 30 documents will be reviewed at the level 2 or 3 class of review.

Of the 30, 7 will be external level 3 reviews, with 4 of these reviews performed at WRC, and 3 other reviews performed at the experts' home bases.

Estimated average time required for level 2 and 3 detailed reviews, including reports:

WRC - 7 days

External - 10 days, WRC External 12 days

Level 1 reviews will be covered by administrative support for Project Director and Associate Directors.

Travel and per diem is included for the 4 outside reviews at WRC, no other travel is anticipated for the review function.

### Monitoring Function

One full time hydrogeologist will track the activities at Yucca Mountain.

One-half hydrogeologist will allow full coverage (about one-third at NTS) and review/collection of data at USGS, LBL, Sandia, etc.

Travel assumed for this function:

200 days of NTS per diem  
150 round trips to Yucca Mts.  
3 round trips to Denver (USGS data)  
1 round trip to Sandia  
1 round trip to LBL

### Meetings

One monthly WRC management meeting (at LV or Reno).

10 State requested meetings (each three days including travel).

Five miscellaneous (important technical conferences, etc., three days each including travel).

Project Management

Project Director	-	75%	-	Year 1
Associate Director Research and Monitoring	-	30%	-	"
Associate Director Review	-	50%	-	"
Secretary	-	100%	-	"
Quality Assurance Specialist	-	40%	-	"

After Year 1, the level of support for project management will be adjusted based on the experience established in Year 1, and the level of DOE NNWSI activities that have developed or are anticipated.

YUCCA NNWSI  
MANAGEMENT, REVIEW AND MONITORING  
YEAR ONE ESTIMATIVE BUDGET

	<u>Hr.</u>	<u>Rate</u>	<u>\$</u>
<u>PERSONNEL</u>			
Project Director - M.D. Mifflin	1500	23.68	35,520
Project Acting Assoc. Dir. - J.W. Fordham	1000	23.30	23,300
Project Acting Assoc. Dir. - J.W. Hess	600	21.47	12,882
Hydrogeologist - D.E. Zimmerman	1800	13.89	25,002
Hydrogeologist - T.B.N.	1000	13.46	13,460
Qual. Assurance Spec. - T.B.N.	800	23.20	18,560
Secretary - T.B.N.	1800	8.64	15,552
Word Proc. Spec. - T.B.N.	500	8.29	4,145
Internal Reviewers	1400	22.50	<u>31,500</u>
SUB-TOTAL			179,921
<u>EMPLOYEE BENEFITS</u>			
Permanent Employees - 27.5%			49,478
<u>TRAVEL</u>			
Air fare - Reno/Las Vegas - 36 rt @ \$128			4,608
Miscellaneous - 24 rt @ \$350/average			8,400
Car rental - 170 da. @ \$30/da. average			5,100
Project mileage - 39,000 mi. @ \$0.35			13,650
Per diem - State rate - 81 da. @ \$47.50			3,848
Per diem - Out-of-State - 76 da. @ \$75.00			5,700
Per diem - NTS rate - 200 da. @ \$22.00			<u>4,400</u>
SUB-TOTAL			45,706
<u>OPERATING</u>			
Postage & Communication 12 mo. @ \$300/mo.			3,600
Xeroxing 12 mo. @ \$150/mo.			1,800
Office Supplies 12 mo. @ \$40/mo.			480
Field Supplies 12 mo. @ \$100/mo.			1,200
Word Processor 200 hr. @ \$7.00/hr.			1,400
Computer-Mini 40 hr. @ \$58.80/hr.			2,352
Mainframe I 10 hr. @ \$360/hr.			3,600
Mainframe II 1 hr. @ \$2,250/hr.			<u>2,250</u>
SUB-TOTAL			16,682
<u>CONSULTANTS</u>			
Outside Reviewers - 672 hr. @ \$50/hr.			33,600
<hr/>			
YEAR ONE TOTAL - DIRECT COSTS			325,387
INDIRECT COSTS			<u>218,009</u>
YEAR ONE-TOTAL PROJECT COSTS			<u>543,396</u>
<hr/>			
YEAR TWO - ESTIMATED TOTAL PROJECT COSTS			\$800,000
YEAR THREE - ESTIMATED TOTAL PROJECT COSTS			\$950,000

YUCCA NNWSI  
RESEARCH-UNSATURATED-ZONE MONITORING METHODOLOGY  
YEAR ONE ESTIMATIVE BUDGET  
PROJECT I - PHASE I

	<u>Hr.</u>	<u>Rate</u>	<u>\$</u>
<u>PERSONNEL</u>			
Principal Investigator - M.D. Mifflin	180	23.68	4,262
Hydrogeologist - T.B.N.	1,000	14.81	14,810
Field Technician - T.B.N.	720	13.46	9,691
Secretary - T.B.N.	160	8.29	<u>1,326</u>
SUB-TOTAL			\$30,089
<u>EMPLOYEE BENEFITS</u>			
Permanent Employees			8,274
<u>TRAVEL</u>			
Air fare - Gainesville/Las Vegas - 2 rt @ \$550			1,100
Air fare - Reno/Las Vegas - 4 rt @ \$128			512
Air fare - Sacramento/Las Vegas - 2 rt @ \$136			272
Car rental - 15 da. @ \$30/da.			450
Project mileage - 5,000 mi. @ \$0.35			1,750
Per diem - State rate - 6 da. @ \$47.50			285
Per diem - NTS rate - 40 da. @ \$22.00			<u>880</u>
SUB-TOTAL			5,249
<u>CONSULTANTS</u>			
Soil Physicists (2) 200 hr. @ \$50/hr.			10,000
<u>EQUIPMENT</u>			
Neutron probe (Troxler Model 3222)			3,200
Psychrometer scanner, automated (Wescor PS-625)			5,500
Switch box, psychrometer - 4 @ \$350			<u>1,400</u>
SUB-TOTAL			10,100
<u>OTHER</u>			
Drilling (contractor) 1,500' @ \$32/ft.			48,000
Analyses - chemical - 20 @ \$150.00			3,000
<sup>13</sup> C - 20 @ \$35.00			700
<sup>18</sup> O - 20 @ \$35.00			700
D - 20 @ \$35.00			700
X-ray - 20 @ \$50.00			1,000
Supplies - Neutron probe wire - 1,000'			1,200
Psychrometers - 50 @ \$50.00			2,500
Lysimeters, suction - 10 @ \$45.00			450
Pipe, 3/4" PVC - 5,000' @ \$0.30			1,500
Pipe, 2" alum. - 1,500' @ \$2.50			3,750
Miscellaneous - connectors, tubing, wires, etc.			1,500
Postage & Communication - 12 mo. @ \$75/mo.			900
Office supplies - 12 mo. @ \$40/mo.			<u>480</u>
SUB-TOTAL			66,380
<hr/>			
YEAR ONE - TOTAL DIRECT COSTS			120,092
INDIRECT COSTS			<u>58,285</u>
YEAR ONE - TOTAL PROJECT COSTS			<u>\$178,377</u>
<hr/>			
YEAR TWO -			
YEAR THREE -	SEE APPENDIX II		

YUCCA NNWSI  
RESEARCH-REGIONAL GROUNDWATER FLOW  
YEAR ONE ESTIMATIVE BUDGET  
PROJECT II

	<u>Hr.</u>	<u>Rate</u>	<u>\$</u>
<u>PERSONNEL</u>			
Principal Investigator - R.L. Jacobson	180	23.29	4,192
Geochemist - J.W. Hess	180	21.47	3,865
Field Technician - T.B.N.	640	13.21	8,454
Secretary - T.B.N.	160	8.29	1,326
Graduate Research Fellow - T.B.N.	1,200	7.00	<u>8,400</u>
SUB-TOTAL			\$26,237
<u>EMPLOYEE BENEFITS</u>			
Permanent Employees			4,905
Part-time Employees			<u>101</u>
SUB-TOTAL			5,006
<u>TRAVEL</u>			
Air fare - Reno/Las Vegas - 6 rt @ \$128			768
Car rental - 6 da. @ \$30/da.			180
Project mileage - 6,000 mi. @ \$0.35			2,100
Per diem - State rate - 12 da. @ \$47.50			570
Per diem - NTS rate - 25 da. @ \$22.00			<u>550</u>
SUB-TOTAL			4,168
<u>OTHER</u>			
Analyses - sample prep. - 120 @ \$14.00			1,680
C - 120 @ \$35.00			4,200
O - 120 @ \$35.00			4,200
D - 120 @ \$35.00			4,200
Chemical - 120 @ \$150.00			18,000
ADP			1,200
Postage & Communication - 12 mo. @ \$100/mo.			1,200
Field & Laboratory Supplies - 12 mo. @ \$200/mo.			<u>2,400</u>
SUB-TOTAL			37,080
<hr/>			
YEAR ONE - TOTAL DIRECT COSTS			72,491
INDIRECT COSTS			<u>48,569</u>
YEAR ONE - TOTAL PROJECT COSTS			<u>\$121,060</u>
<hr/>			
YEAR TWO - ESTIMATED TOTAL PROJECT COSTS			\$250,000
YEAR THREE - ESTIMATED TOTAL PROJECT COSTS			200,000
YEAR FOUR - ESTIMATED TOTAL PROJECT COSTS			180,000

## APPENDIX II

### PHASE II, UNSATURATED ZONE MONITORING AND DATA DEVELOPMENT

PRINCIPAL INVESTIGATOR: M.D. Mifflin and others, T.B.N.

DURATION: 2 years plus

#### General

Unsaturated zone moisture flux is key to the long term repository performance in containing radionuclides. Presently, there is no indepth knowledge or systematic data documenting moisture regimes of thick unsaturated zones in the arid environments of Nevada. Long or short term weather or climate changes over the life of the radioactivity of the repository could change the rate of moisture flux. This research measures moisture flux in selected environments to establish comparative data for Yucca Mountain analyses. It will also provide the opportunity to compare modern analog environments and associated unsaturated zone moisture fluxes that simulate conditions which occurred on Yucca Mountain during pluvial climates based on the plant assemblages determined from fossil packrat middens.

#### Specific Objectives

The objective of this research is to establish, in the observed range of hydrogeologic environments, a direct measurement of unsaturated zone moisture regimes for comparison with analyses of the Yucca Mountain repository environments.

## Relevance to Yucca Mountain Assessment

Currently there exist no arid zone moisture flux data on hydrologic regimen documentation in thick unsaturated zones zone to judge the data and interpretations that will be derived at Yucca Mountain. Successful employment of methodologies to establish unsaturated zone regimes will permit a much enhanced assessment of Yucca Mountain unsaturated zone interpretations, particularly if the NNWSI data base is limited to the presently planned DOE assessment program for the unsaturated zone. In addition, unsaturated zone data developed in pluvial climate analog environments of the Yucca Mountain will permit another analytical approach to pluvial climate unsaturated zone flux.

## Work Plan

After Phase I is established as feasible and successful in terms of methodology, hydrogeologic environments in fractured tuffs and other media will be selected for unsaturated regimen studies. Boreholes penetrating the unsaturated zone to the saturated zone will be instrumented for direct moisture flux monitoring and geochemical sampling. Four additional sites will be selected to establish a range of environmental factors. Monitoring will be performed for as long as possible at the five sites (including the Phase I site) to develop an expanded data base on the moisture regimens within the saturated zone. At least one selected monitoring site will be an analog pluvial climate environment of Yucca Mountain as determined by packrat midden data, rock type, and terrain characteristics. As currently planned, Year 2 of Phase II will not include the establishments of additional monitoring sites.

### Anticipated Results

Developed data should give quantitative information on moisture flux at a number of monitoring sites. The approximate order of magnitude of unsaturated zone moisture flux, appropriate for Yucca Mountain during the pluvial climatic condition, may also be established. The research may also provide insight into perched water and water table position under such climatic conditions. An independent data base established by soil physics methods and hydrogeochemical techniques in thick unsaturated zones will be available for comparison with the NNWSI Yucca Mountain data and interpretations.

YUCCA NNWSI  
RESEARCH-UNSATURATED-ZONE MONITORING  
ESTIMATIVE BUDGET

YEAR 1 - PHASE II

Personnel		\$ 30,000
Employee Benefits		8,300
Travel		10,000
Consultants		10,000
Equipment		30,000
Other		
Drilling	200,000	
Analyses & Supplies	65,000	
Miscellaneous	3,000	
<b>SUBTOTAL</b>	<b>268,000</b>	
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TOTAL DIRECT COSTS		356,300
INDIRECT COSTS		<u>101,400</u>
TOTAL PROJECT COSTS		457,700

YUCCA NNWSI  
RESEARCH-UNSATURATED-ZONE MONITORING  
ESTIMATIVE BUDGET

YEAR 2 - PHASE II

Personnel		\$ 35,000
Employee Benefits		9,600
Travel		10,000
Equipment		Ø
Other		
Drilling	Ø	
Analyses	30,000	
Miscellaneous	5,000	
<b>SUBTOTAL</b>	<b>35,000</b>	
<hr/>		
<b>TOTAL DIRECT COSTS</b>		<b>89,600</b>
<b>INDIRECT COSTS</b>		<b><u>60,000</u></b>
<b>TOTAL PROJECT COSTS</b>		<b>\$149,600</b>