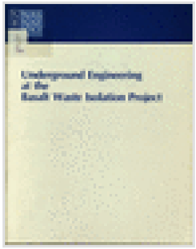

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U.S. National Committee for Rock Mechanics
Commission on Engineering and Technical Systems
in cooperation with the
Board on Radioactive Waste Management
Commission on Physical Sciences, Mathematics, and Resources
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TASK GROUP

Underground Engineering
at the
Basalt Waste Isolation Project

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EXECUTIVE SUMMARY

A special task group was organized by the U.S. National Committee for Rock Mechanics and the Board on Radioactive Waste Management of the National Research Council to address issues relating to the geotechnical site characterization program for an underground facility to house high-level radioactive waste of the Basalt Waste Isolation Project (BWIP). Intended to provide an overview of the geotechnical program, the study was carried out by a task group consisting of ten members with expertise in the many disciplines required to successfully complete such a project.

The task group recognized from the outset that the short time frame of this study would limit its ability to address all geotechnical issues in detail. Geotechnical issues were considered to range from specific technical aspects such as in-situ testing for rock mass permeability; rock hardness testing in the laboratory; or geologic characterizations and quantification of joints, to broader aspects of design philosophy, data collection, and treatment of uncertainty. The task group chose to focus on the broader aspects of underground design and construction, recognizing that the BWIP program utilizes a peer review group on a regular basis which reviews the specific technical questions related to geotechnical engineering. In this way, it was hoped that the review provided by the task group would complement those prepared by the BWIP peer review group.

The task group consisted of professionals in key fields needed to design underground structures from industry, academia, and government. All were volunteers in giving their time. The group met twice for two-day meetings, consisting of briefings given by BWIP staff from the Department of Energy (DOE), its contractors, and the Nuclear Regulatory Commission (NRC), task group deliberations, and report writing.

The task group understands that complex relationships exist among the various parties involved in this program, including the BWIP project office in Richland, Washington, Department of Energy headquarters in Washington, D.C., and the Nuclear Regulatory Commission. The task group deliberately chose not to comment on the nature of these relationships. Therefore, all of the recommendations in the report are addressed to the sponsor of this report, the BWIP project office, even though it is understood that some project activities were undertaken at the request and under the guidance of DOE headquarters, while others were undertaken as a result of rules and regulations from the Nuclear Regulatory Commission. The task group chose not to make any distinctions in its recommendations, but simply to address those issues that were affecting the technical quality of the geotechnial program.

The following recommendations are a result of the work of the task group:

1. The task group views the current design process as being driven by licensing requirements and recommends that this emphasis be reconsidered.

The objective of the DOE program is to construct a repository for high-level nuclear waste safely and efficiently. The primary considerations should include the construction aspects of this project and the operational requirements of the repository. Licensing should not inappropriately dominate the site characterization planning process.

2. The performance objectives and design criteria should be stated clearly and concisely in a single document.

The task group had difficulties in extracting and prioritizing the performance objectives of this project because of the many diverse documents involved. It is thought that a single compendium of these performance objectives and design criteria would lead to better understanding and coordination among the various disciplines and departments involved in this project.

3. The documentation should include a description of the conceptual models for behavior and discussions that relate data collection activities to the conceptual models.

Such discussions should state the purpose of the testing, explain how the results will be used, and should note the limitations of the tests. A clear understanding of the relationship between the conceptual model and data collection should be evident.

4. Data collection for alternative designs should be a part of the site characterization program, to account for the uncertainties in ground conditions.

Uncertainties are always a part of underground projects; both the design and construction method should be able to accommodate these uncertainties. The task group felt that the BWIP program does not adequately recognize this uncertainty, particularly during the data collection activities planned in the exploratory shaft facility. The program should include data collection that relates to alternative designs--or contingency designs--so that the program can proceed when unanticpated ground conditions are encountered during construction.

5. A thorough and consistent approach to treating uncertainties, using established analytical techniques, should be included in the program.

6. The program planning should recognize that an observational approach is needed during the site characterization phase and during construction. Provisions for performance monitoring during construction and operation should be a part of the program.

It was also apparent to the task group that the observational approach was not accommodated well by the quality assurance program.

The quality assurance program does not easily accommodate likely changes in field testing, changes in laboratory testing, and changes in design as the actual ground conditions are uncovered. The quality assurance program should be reviewed in detail by experts in the field of underground design and construction. This effort should involve the Nuclear Regulatory Commission, since NRC oversight activities will be closely tied to the recommendations resulting from such an effort.

7. A multidisciplinary approach is needed to conduct efficiently and effectively a site characterization program of this magnitude. Interaction among the technical staff should be actively and forcefully pursued to guarantee this multidisciplinary approach.

8. Regular interaction with other project offices, national research institutions, foreign institutions studying similar problems, and professionals at scientific forums should be encouraged.

9. Where appropriate, BWIP should adhere to nationally or internationally recognized test standards.

10. Considerable developmental research is needed to address adequately the technical issues of designing and constructing a nuclear waste repository at the depths considered.

Many of the scientific answers to questions which must be addressed by the BWIP program to provide confidence in the effectivenes of a repository design are going to be found in state-of-the art research programs. A significant investment in underground developmental research should be undertaken now to assure that the answers are available for purposes of design and construction.

11. Attention should be given to the instrumentation program for site characterization and performance monitoring during construction.

- Construction specifications for the exploratory shaft and test facility should be written in anticipation of interference and unanticipated delays resulting from the testing program.
- The number of personnel allowed access to the test facility should be made compatible with the needs of the testing program.
- Funding considerations and lead-time for the development of specialized instrumentation should be given careful consideration during the planning phases of site characterization.
- The procurement process for instrumentation should be reviewed. Instrument specifications should be complete and realistic; prequalification of instrument suppliers should be introduced; a realistic acceptance testing program should be instituted; and sole-source contracting should be a part of the procurement process, as appropriate.

12. The possibilities and limitations for using geophysical techniques to assist in characterizing the site should be explored more fully.

13. This project is highly visible (appropriately), and the ability to communicate to the experts and the public the purpose and progress of the work, and the consideration given to each of the issues, is an important aspect of the project. The documentation, presentation material, and briefings should be clear, concise, and coordinated.

INTRODUCTION

This report, Underground Engineering at the Basalt Waste Isolation Project, was prepared at the request of the Geosciences and Technology Division of the Basalt Waste Isolation Project (BWIP), U.S. Department of Energy. The report is a product of a special task group, organized by the U.S. National Committee for Rock Mechanics and the Board on Radioactive Waste Management of the National Research Council, to study those issues that relate to the geotechnical site characterization program required for the engineering of a high-level nuclear waste repository in basalt. The intent of the study has been to provide an overview of the geotechnical program at BWIP, to address the broader aspects of geotechnical design philosophy, data collection and treatment of uncertainty.

Given the brief nature of this study, the task group was not able to address in detail the many technical issues involved with the underground engineering of this project. It did, however, recognize several generic issues that are key to the success of most underground construction projects and critical to the design and construction of an underground nuclear waste repository. In addition, the task group offered some recommendations on presentation which would lead to improvements in the technical quality of the work at BWIP.

Several generic issues are illustrated by specific technical examples. These examples are intended to be illustrative in nature only. An example is used either to explain or emphasize a particular issue. It was not always possible in the course of preparing this report to research exhaustively the information that well might impact a particular example. If a specific example is presented incompletely, the reader is cautioned to note that it is the generic issue itself, and not the specific technical example, that is of importance.

PROCEDURE

The members of the task group were selected for their special expertise in key fields that are needed to design underground structures, including hydrology, in-situ stress, geotechnical instrumentation, numerical modeling, underground construction, field geology, and mine design. Of the ten members, three were from government institutions, three were from private practice, and four were from academia. All were volunteers in giving their time to this study.

The task group convened twice, for two-day meetings. The first meeting was held in Richland, Washington, at the BWIP project offices, where the task group was briefed by BWIP staff and their contractors about the hydrology, geology, and geotechnical program. The second meeting was held several weeks later at the National Research Council offices in Washington, D.C. It included discussions with representatives of the Nuclear Regulatory Commission and with representatives from the Office of Civilian Radioactive Waste Management of DOE headquarters in Washington, D.C.

The task group had available to it, in addition to the briefing materials prepared by BWIP:

- a draft of Chapter 1.0, "Geology," of Site Characterization Plan for the Basalt Waste Isolation Project;
- a draft of Chapter 2.0, "Geoengineering," of Site Characterization Plan for the Basalt Waste Isolation Project;
- a draft of Chapter 6.0, "Conceptual Design," of Site Characterization Plan for the Basalt Waste Isolation Project;
- Annotated Outline for Site Characterization Plans;
- Issues Hierarchy for a Mined Geologic Disposal System;
- Code of Federal Regulations-Energy, Title 10, Chapter 1, Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories; Licensing Procedures";
- a draft of Systems Engineering Management Plan;
- Project Management Plan for the Basalt Waste Isolation Project;
- Repository Horizon Identification Report;
- Task V, Engineering Study No. 5, Shaft Optimization;
- Task V, Engineering Study No. 6, Tunnel Optimization;
- Task V, Engineering Study No. 7, Waste Emplacement Optimization;
- Task V, Engineering Study No. 10,;
- Task VI, Final Report #2, Ground-Control Strategy for the Nuclear Waste Repository in Basalt;
- a draft of Rock Mechanics Technical Plan;
- drafts of study plans involving special geotechnical problems;
- Environmental Assessment; and
- draft of System Engineering Management Plan.

PROGRAM TOPICS

The following thirteen areas were found to have problems whose resolution could lead to a more effective geotechnical site characterization program.

1. Design for Licensing vs Design for Performance and Construction

The task group views the current design process as being driven by licensing requirements, drafted by the Nuclear Regulatory Commission, and formalized in Rules and Regulations, Title 10, Chapter 1, Part 60, entitled "Disposal of High-Level Radioactive Wastes in Geologic Repositories-Licensing Procedures." It is recognized that every effort must be made to satisfy these requirements, but there is concern that the requirements have become the focus for design efforts, to the exclusion of other equally important performance and construction criteria. It is not apparent that the underground design and site characterization plan pays sufficient attention to engineering considerations relating to performance and construction.

For example, much emphasis has been given to the magnitude and direction of the in-situ stress. Tunnel shapes and orientations have been selected for conceptual design primarily on the basis of the in-situ stress characteristics. No discussions could be found regarding the construction procedure and its relationship to tunnel shape. The effect of using a tunnel boring machine will be different from drill-and-blast construction. This type of direct consideration of the construction process in the planning of a site characterization program was not found in the documentation and briefings available to the panel.

It is recommended that the BWIP staff reconsider the emphasis given to licensing requirements and promote performance criteria and construction considerations in their planning. The whole concept of satisfying the elements described in 10 CFR Part 60 appears to dominate the decision making of the program to the detriment of equally important construction and operational aspects of the program. The objective of this entire exercise is to build a repository in a safe and effective manner, and licensing is a part of that objective, but licensing requirements should not dominate the process.

2. Performance Objectives and Design Criteria

The task group had difficulty in extracting from the various documents the technical performance criteria for which the BWIP facility will be designed. The Mission Plan for the Civilian Radioactive Waste Management Program contains "a hierarchy of generic issues;"[1] the Issues Hierarchy for a Mined Geologic Disposal System presents "the issues the DOE will use to guide development of site characterization plans;"[2] the draft of Performance Allocation Guide is "a method for guiding the testing program;"[3] and the General Requirements for a Mined Geologic Disposal System and the Waste Management Systems Requirements and Descriptions contain "functional and operating requirements as well as design and operating-efficiency requirements."[4] Each of these documents apparently includes items that relate to performance objectives and design criteria, but it is not clear which document takes precedent, if any. An attempt was made in the Environmental Assessment to describe the broader scale licensing requirements, but the more specific performance objectives of the repository are found in several documents.

Items are available in diverse places in diverse documents, but clear and concise statements of the design criteria and the performance objectives were not found; nor could the task group find a clear exposition of the characteristics and behavior of the rock mass assumed for purposes of developing a conceptual model in the documents reviewed and briefings given. Since these criteria form the basis for the conceptual model, which in turn affects the proposed testing program, it is important to have a clear delineation of such criteria and any assumptions made regarding rock mass behavior.

For example, an objective of this project is to understand the nature of the hydrologic flow in the interflow zones. Three assumptions might be made regarding the material characteristics in these zones; each would result in a different conceptual model which in turn would lead to a different testing approach to validate the model. One assumption might be that the zones are highly brecciated and therefore should be treated as having homogeneous flow characteristics. Another assumption might be that the zones are somewhat brecciated and should be considered as having heterogeneous flow characteristics. A third assumption might be that the zones consist of tube-like structures that would result in horizontal flow characteristics, orders of magnitude different from the flow characteristics in the vertical direction.

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[1] U.S. Department of Energy. 1986. Issues Hierarchy for a Mined Geologic Disposal System (OGR/B-10). Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. p iii.

[2] Ibid.

[3] U.S. Department of Energy. (not in print). Performance Allocation Guide (draft). Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. p 1.

[4] U.S. Department of Energy. (not in print). Site Characterization Program, Section 8.0 (draft). Washington, D.C.: U.S. Department of Energy. p 8.8-8.

If appropriate criteria have been selected and made, they are buried in a variety of sections in various documents. This is a shortcoming because a clear understanding of the criteria and a coherent compendium of the assumptions should form the basis for the succeeding steps of the design process.

It is recommended that a single coherent list of performance objectives, design criteria, and assumptions be prepared. Such a document would encourage coordination among the disciplines and departments, would set the basis for the conceptual design, and would make peer reviews such as this proceed more smoothly.

3. Establish the Relationship Between Design, Underlying Models and Data Collection

The relationship that ties data collection to the design and underlying models should be emphasized. The task group would like to see more effort made to elucidate specifically why certain tests are planned, and how each test will be used to validate the conceptual models, such as the hydrologic, geologic, structural, and construction models.

For example, Task V, Engineering Study Number 6, Tunnel Optimization, discusses the conceptual design of the tunnel system, and notes in the executive summary the following two points:

- "Epoxy resin bolt performance at temperatures up to 140° F (60° C) should be verified, and the epoxy formulation developed further, if required."
- "Grouted rock bolts should be analyzed and tested to determine compatibility with the rock under temperatures that may be encountered in placement drifts."

The tunnel optimization study, which presents the conceptual design for the tunnel system, assumes that rock bolts will be used to support the rock during construction, but notes that currently available equipment has not been tested under the conditions anticipated at the depths of the proposed repository. The 1986 version of the draft Rock Mechanics Technical Plan does not indicate that such tests and evaluations are, in fact, included in the plan. The bridge from conceptual design to testing has not been made.

The need for bridging from conceptual design to data collection is evident in other aspects of the design process also. BWIP proposes to utilize extensive computer models to analyze the behavior of the repository. Field tests in the exploratory shaft facility are to be used to validate the computer models. The link between the models and the field tests is not clearly stated in the documentation. The documentation should respond to questions such as:

- What are the appropriate conceptual models?
- What is the purpose of the field test?
- What data will come out of the field test for use in testing the conceptual model?
- What are the limitations of the model?
- What are the limitations of the field test?

- How do the boundary conditions in the field test relate to assumed boundary conditions in the model?
- How does the scaling factor affect the interpretation of the field test?
- What are the anticipated ranges of values that will result from the field test? and,
- Is the proposed instrumentation capable of measuring to the required accuracy over the anticipated range?

The answers to questions such as these provide a solid basis for conducting tests in the exploratory shaft facility. The task group recommends that this approach to developing and documenting a data collection and testing program be adopted by the BWIP staff.

4. Data Collection for Alternative Designs

An adequate site characterization program for underground construction must include additional data collection and developmental research in areas not necessarily associated with the conceptual design, but perhaps related to an alternative design. Designers of underground construction projects must be well aware of their limited ability to forecast the actual conditions of the rock mass encountered during the course of an excavation. A well-known adage notes that the final plan for building an underground structure cannot be known with certainty until the structure is completed. As unexpected conditions are encountered, the design and construction must be able to cope and change as needed to construct a facility that will meet the performance criteria. A site characterization program should recognize this need, and include a certain amount of data collection to support alternative designs or designs in alternative units if required.

For example, the program is apparently committed to the Cohassett formation as the geologic unit for the repository. Given the uncertain nature of the formation, it might be prudent to continue to collect limited data from one or two other units at this early phase of site characterization. A tremendous expenditure will be made to implement the site characterization program. It would be imprudent to make such a large investment, then not use that investment to the fullest. As the exploratory shaft is being lowered, sampling or perhaps limited drifting and testing, should be undertaken in additional units. The Cohassett might prove to be an inappropriate unit for siting a nuclear waste repository, and the BWIP program should be prepared to consider another unit. In addition, data from other units will also add to the ability to predict the behavior of the Cohassett. Therefore, the collection of data on other units as the shaft is lowered should be a part of the site characterization program.

5. The Role of Uncertainty

Although there is much experience with underground construction in the United States, certain aspects of such a task are fraught with uncertainty. The natural environment, the duration of the design life, and the many man-induced processes affecting the repository are such aspects. The design and construction of underground structures is more an art than a science. The BWIP program should give consistent consideration to the role of uncertainty in the design and construction of this project. Indeed, federal regulations require explicit consideration of uncertainty in the licensing process of radioactive waste repositories and this has to be based on considerations of uncertainty in design and construction among others (Einstein and Baecher, 1986). While the draft System Engineering Management Plan, and Environmental Assessment address this issue, it is not something that is routinely and consistently discussed in the other documentation. When addressed, the terminology and procedures are inconsistent and in conflict with those of other practitioners in this area.

For example, some procedures for considering uncertainty involve "performance allocation" which is used to decide which tests should be utilized at what level of detail. Certain system components of the repository are selected, then "performance measures" and "performance goals" for each component are delineated. "Performance confidences" are determined for each component. Ultimately, the results of tests and analyses described by the Site Characterization Plan should attain these goals and confidences.

The objective of this "performance allocation" procedure and the intent to assess uncertainties is appropriate. However, the procedure applies new and confusing terminology to well-established decision-making analytical techniques. It can lead to erroneous statements. For instance, no unique relation can be established between "performance goals and their confidences" and "parameters and their confidences." (Also, the different use of the term "confidence," which has a well-established meaning, is confusing and unnecessary.)

The "performance allocation" procedure is oriented toward the licensing requirements and distinguishes between "licensing criteria" and "performance goals." If exploration and test planning methods based on decision analysis were applied, such distinctions would not be required.

In contrast to the problems noted above, a satisfactory and comprehensive consideration of uncertainty is included in the draft Project Management Plan and in the Environmental Assessment. In the former, several sources of uncertainty are identified--the ranking process recognizes most aspects of decision making under uncertainty, and recommendations that alternative courses of action proceed on this basis are included. In particular, it suggests that uncertainties in different performance attributes be considered and that risk analyses be conducted. In the Environmental Assessment, the system and some of the details of a probabilistic risk assessment (PRA) procedure are presented. Somehow, however, it seems that the statements in these two documents have not found their way into the others; in particular, with regard to consequences on exploration, testing, design, and construction.

It is recommended that the concepts indicated in the System Engineering Management Plan be implemented in the form of a thorough and unified approach to treating uncertainties. Such an approach (Einstein and Baecher, 1986) would provide, on the basis of a consistent systematic procedure, methods for:

- planning of exploration and testing,
- comparison of different design, construction, and operating alternatives,
- consideration of natural and man-made hazards, and
- probabilistic risk assessment.

6. The Observational Approach

The typical underground engineering project uses an observational approach from start to finish. Such a method involves preliminary exploration that feeds into a conceptual design based on the "most likely ground condition" and contingency conceptual designs for other conditions. Such designs include the determination of critical performance parameters which will be measured during construction, and a prediction of their magnitude. The design should also determine the type, location, and frequency of a performance monitoring system. As construction proceeds, the results of the performance monitoring feed back into the conceptual design where the design is modified to accommodate the actual conditions encountered during excavation.

The task group was pleased to note the observational approach in the draft study, Ground Control for the Nuclear Waste Repository in Basalt. The study addresses the ground control requirements through the entire lifetime of the facility. The study notes that initially, a strong reliance on analytical methods will be needed. As experience with facility construction is gained, specific empirical methods can be developed to guide the construction that follows. This integrated design-construction approach makes the best use of the observational method. It makes efficient use of experience gained on site and encourages the use of new developments in underground technologies.

The task group did recognize, however, that plans for quality assurance appear to run counter to the observational method. Current quality assurance methods typically require preapproved specified procedures for testing as well as preapproved instrumentation. In theory, the program has some flexibility to accommodate changes in testing methods and instrumentation, but in practice, the long approval process for these procedures discourages change and innovation. The quality assurance activities that are a part of the BWIP program must consider the unique aspects of underground design and construction that require constant optimization of procedures and equipment as changes in ground conditions are encountered.

For example, the design of the instrumentation program that will complement the testing in the exploratory shaft facility must be responsive to the ground conditions as they are revealed. The quality assurance procedures must be highly flexible to accommodate changes in the testing and instrumentation procedures. A series of "what if" scenarios with corresponding courses of action might be the way to approach such a quality assurance program.

There is concern that quality assurance activities developed for use in designing and constructing nuclear power plants on the surface of the ground are being allowed to serve as a model for quality assurance activities for underground construction. This is not an appropriate way to achieve a successful underground project. The task group recommends that DOE convene specialists in underground construction with specialists in traditional quality assurance programs to develop a quality assurance program specific to the needs of underground activities. Such an effort should include close liaison with the Nuclear Regulatory Commission, since NRC oversight activities will be closely tied to the results of this effort. This is essential if the program is to gather the appropriate underground data, and to avoid delays and cost overruns during construction of the test facility.

7. A Multidisciplinary Approach

It is not the intent of the task group to offer suggestions on issues pertaining to management of the program. The expertise of the group is technical. However, where these issues affect the quality of the technical program, the group felt an obligation to address them.

Underground construction is a dynamic process. The ground affects the behavior of the excavated opening, imposing loads on the support and often dictating changes in construction method. The excavation affects the behavior of the ground, unloading and loading the rock mass, and changing established groundwater flow patterns. This dynamic process requires that geologists, hydrologists, structural and geotechnical engineers, geophysicists, geochemists, and construction practitioners work together.

If this project is to be completed successfully, a multidisciplinary approach to design and construction is required. There seems to be a fair amount of communication on a personal level between different groups working on BWIP; however, rock mechanics design work does not seem to be closely tied to the work in the laboratory or the work in the near-surface test facilities. It appears that even simple tests must be requested by letter routed through "appropriate channels." Similarly, coordination among groups in the preparation of study plans appears to be lacking. For example, there appears to be a lack of consistency in the proposals for geophysical tests and mapping approaches for the exploratory shaft among the various (draft) study plans. Another example involves cooling-joint and tectonic-joint study plans, which are separate documents at present. Although understandable from a geologic point of view, this approach does not seem conducive to coordinated exploration, and study plans for cooling joints and tectonic joints should be integrated.

The task group is concerned that interaction among the technical staff necessary to complete this project successfully has not been incorporated into the management of the program, and recommends that this be done. Individual staff members recognize that communication among disciplines is important, but such interaction does not appear to be stressed in the program. This interaction should not be a discretionary matter--rather, it should be actively and strongly encouraged.

8. Scientific Insulation

Much work has been done and is being done currently in nuclear waste storage technologies in the United States and abroad. The BWIP program should take care not to become insular.

Research and technology in other countries has oftentimes outpaced that in the United States, and the program at BWIP could benefit from this research. For instance, a geophysical cross-hole testing program at Stripa in Sweden to attempt to link the hydrologic behavior of rock with its geophysical properties should be of direct interest to BWIP technical staff. Similarly, the behavior of underground openings in the mines of Elliot Lake, Ontario, should be studied for an understanding of support behavior under high horizontal stresses.

Participation in scientific forums and regular visits to research institutions in the United States and abroad should be an active part of the BWIP program. Participation should include contributions to these scientific forums as well as attendance. Regular presentation of BWIP progress to the scientific community at such forums would benefit the program greatly as a method of peer review.

Regular interaction with other project offices within the Department of Energy and the Department of Defense would also greatly benefit the program. Some of the technical staff seemed unaware of design approaches and research efforts that are under way at offices in Carlsbad, Chicago, Columbus, and Las Vegas. For example, significant efforts have been made to define requirements, performance, and development needs for instrumentation in a salt repository environment at the proposed site in Deaf Smith County, Texas (Shuri and Green, 1987), and several detailed measurement procedures have been written. Some of the issues relating to deformation, stress, stress change and temperature measurement are also applicable to BWIP.

It is recommended that regular interaction with other project offices, national research institutions, foreign institutions studying similar problems, and professionals at scientific forums be encouraged.

9. Standards

Where appropriate, BWIP should adhere to nationally or internationally recognized test standards. Chapter 2.0, "Geoengineering," of the Site Characterization Plan refers to "BWIP operating procedures" in connection with test methods but makes no comment on equivalence or comparability to American Society for Testing and Materials standards or to International Society for Rock Mechanics "suggested methods." It appears that a significant effort may have gone into the design and construction of in situ test equipment which performs the same function as equipment already described in ISRM or ASTM publications. If this is so, it is especially surprising in this program because the Nuclear Regulatory Commission has just concluded a three-phase multi-year contract with ASTM to develop rock mechanics property standards for use in the national nuclear waste isolation program. Twenty draft standards have been produced (some of which are in print) and about ten more will be produced shortly.

As matters now stand, there is no way of establishing clearly the comparability of the data presented in Chapter 2.0, "Geoengineering" of Site Characterization Plan for the Basalt Waste Isolation Project, to rock property data at other sites. The intent of OMB Circular A119 (Federal Participation in the Development and Use of Voluntary Standards), which requires the use of recognized standards, appears to have been omitted from the BWIP effort. The task group recommends that this shortcoming be addressed.

10. Technology Development

The task group did not see sufficient evidence of developmental research which is aimed at solving issues that are typically out of the realm of current practice. If this project is to be completed successfully, previous engineering practice must be augmented with new concepts that come out of a solidly based developmental research program designed to meet the needs of a nuclear waste repository.

The engineering profession does not have experience to predict such things as flow and transport in large volumes of fractured rock, coupled thermal-mechanical behavior of basalt at great depth, strength and deformability of basalt at great depth, in situ stress variation with cavern construction in basalt, and rock support requirements for basalt at great depth. Developmental research is needed to address issues such as these.

For example, the use of existing empirical prediction methods to estimate the type and amount of rock support required to stabilize the tunnels is likely to be inappropriate for BWIP (Environmental Assessment, 1986). These methods were developed for rock types other than basalt with quite different characteristics and behavior. Research to adjust these empirical methods for basalt and the depths being considered for the repository may be required.

Instrumentation research is likely to be required for the conditions anticipated in the Cohassett formation. Test results and instrument behavior in the existing surface test facility do not help predict conditions at the depth of the repository. Two examples will be given. First, the task group is unaware of a proven instrument capable of making adequate measurements of stress change at depth. The BWIP designer must circumvent this shortcoming in technology, or must pursue a developmental research program in an attempt to fill the gap. Second, instruments currently available for measuring in situ stress at depth may be affected adversely by the close fracture spacing, and research and development may be required to overcome this problem.

The task group recommends that the BWIP staff prioritize research and development which should be undertaken now to address issues which are not yet clearly understood by the geotechnical community, but which must be addressed to accomplish an underground nuclear waste repository.

11. Underground Testing and Geotechnical Instrumentation

In contrast to conventional civil and mining projects, the exploratory shaft and test facility at BWIP will be constructed for the primary purpose of conducting underground observations and testing. The success of the underground testing program will be determined in large part by the extent to which the testing needs, rather than the construction requirements, drive the program. The degree of success ultimately achieved by the instrumentation will depend significantly upon the nature of the construction/testing interaction. The leading role of testing and instrumentation during the site characterization phase of the project should be appreciated by all parties, and construction needs (e.g., schedule constraints) should not be allowed to override the needs of the testing program. This point should be fully appreciated when preparing the construction specifications, which should be written in anticipation of interference and unanticipated delays associated with specific testing/instrumentation activities.

The testing program will require significant staffing by experienced geotechnical personnel. Staffing needs should be planned carefully, and any limitations on the number of personnel accessing the test facility should be made compatible with the needs of the testing program. It is not clear that this has been done.

Development of appropriate instrumentation requires adequate funding and lead time. These needs should be given careful attention at the beginning phases of the project. The geotechnical instrumentation manufacturing industry in the United States is relatively small, consisting of a few firms with limited resources and a total annual business on the order of $10 million. They serve an established civil and mining industry market with a wide product range, 30 to 40 percent custom-built, and generally do so without large government research and development funds. Consequently, they are understandably cautious and skeptical of investing in the specialized requirements of instrumentation for studies relating to the disposal of high-level radioactive waste, which is perceived to have a limited future market. The demands of BWIP will require coordination and cooperation between manufacturers and those engineers responsible for designing tests and procuring instruments. Research for instrumentation development and modification should be given attention at these early phases of the project. The task group recommends that appropriate and timely funding be made available.

The typical practice for procuring instrumentation in the civil and mining engineering industries is to use low-bid procurement procedures and imprecise specifications. This practice often leads to low survivablity rates for the instruments. Reputable manufacturers are sometimes forced to cut corners in design and manufacture to underbid each other. Lengthy procurement specifications, aimed at circumventing this problem, have been tried unsuccessfully. Comprehensive specifications are difficult to write because of uncertainties in defining site-specific installation conditions and operating environments which are inherent in underground projects.

The task group recommends that consideration be given to methods for procuring specialized instrumentation. The task group believes that quality instrumentation can be obtained by adherence to four basic quidelines:

- Procurement specifications must be complete and realistic, with necessary research and development concluded prior to specification development. The lead time and cost of this development may be considerable.
- Prequalification of instrument suppliers should be used in the procurement process.
- A realistic acceptance testing program must be implemented for each instrument type.
- Instruments should be procured in compliance with Federal Procurement Regulations, following a strategy that will result in the procurement of instruments that meet the essential needs of the program. Some instruments can be obtained competitively, but provisions should be made for procuring others under sole-source contracts. It is relevant to note that more than 50 percent of U.S. Government procurement dollars in FY 1982 were spent on contracts awarded on a sole-source basis (Perlman, 1985). As discussed in the Appendix, there is ample precedent for procuring instruments on a sole-source basis in order to avoid "receiving a product that merely meets the minimum requirements of the solicitation, instead of the one that is best for the job."

The task group believes that the layout and selection of instrument types could be optimized further. Four examples will illustrate this optimization. First, the current plans for plate-bearing tests apparently do not include a multi-position borehole extensometer below the plate. The absence of this instrument severely reduces the worth of the test. Second, current plans for the mine-by test include two lateral observation galleries. It may be possible to eliminate one gallery by designing the appropriate instrumentation. For example, a "sliding micrometer" was used from a single gallery in the mine-by test at Grimsel (Kovari et al., 1987). Substantial cross-checks and greater coverage of deformation data can perhaps be obtained by using a precise deflectometer (Kovari et al., 1979). With this instrument, for a borehole 30 m long, the repeatability of deformation measurement perpendicular to the axis of the borehole appears to be ± 2 to 3 mm (i.e., the instrument is far more precise than any version made in the United States). Both the sliding micrometer and deflectometer are commercially available from the manufacturer in Switzerland. Third, the sliding micrometer has been used successfully during thermomechanical testing at Stripa (Leijon, 1986), and it may be an appropriate instrument for use during BWIP full-scale heater testing. Finally, nested piezometers are planned in an attempt to determine hydraulic gradients, with a required measurement accuracy of 25 mm of head. The sealing and transducer details are critical for this measurement, and are likely to require further research and development by BWIP.

12. Geophysics

The task group did not include a geophysicist, and is reluctant to comment in detail on this subject. However, the task group believes that geophysics should be a prominent part of the site characterization program. This project involves the characterization of nearly 250 Km^3 of material (controlled area study zone), and the use of geophysical techniques to supplement other data collection procedures might be an effective characterization technique. The use of geophysical techniques for site characterization of underground projects is under investigation by other federal agencies involved with large excavations in the United States, including tunnels for the superconducting super collider (a DOE-sponsored project), tunnels for defense installations, and the evaluation of dam abutments for dam safety purposes. Remote characterization of geologic masses was selected by the U.S. National Committee for Rock Mechanics as the topic of the 1987 Annual Review of U.S. Progress in Rock Mechanics. BWIP might find it useful to coordinate its activities in geophysics with activities sponsored by the other federal agencies.

13. Presentation Format

The task group was concerned about the proliferation of documents that:

- use jargon specific to the BWIP program without prior definition. For example, Issue 4.1 in the Issues Hierarchy, "Can the higher-level findings required by 10 CFR Part 960 be made for the qualifying condition of the preclosure system guideline and the disqualifying and qualifying conditions of the technical guidelines for surface characteristics, rock characteristic, hydrology, and tectonics?"
- appear to be accomplishing the same objective under different terminology. For example, BWIP is using such documents as the "Mission Plan," the "Generic Requirements," the "Issues Hierarchy," and the "Function Design Criteria," all of which appear from the titles to serve the same objective. The task group knows this is not the case, but suggests that one document be prepared to summarize the mission/requirements/issues/criteria.

Joseph Pulitzer eloquently recognized this issue when he wrote the following:

> Put it before them briefly so they will read it,
> clearly so they will appreciate it,
> picturesquely so they will remember it
> and, above all, accurately
> so they will be guided by its light.

It is understood by all that this is a project with some highly unusual design considerations that make this a unique effort in underground construction. This project, more than most other projects, will benefit from peer review. However, peer review can only be facilitated if the BWIP staff can successfully communicate the key design points to the professional community. The task group is disconcerted that it took a dozen people, and a considerable stack of paper, to brief a group of knowledgeable engineers and scientists about the underground program. Effective peer review, and communication with the public, will not proceed unless the BWIP staff can improve the presentation of this project to others.

The task group recommends that glossaries be included in all the significant documents. A clear understanding of the terminology in use with this program will benefit the program participants as well as its reviewers. Some professional advice on presentation formats for briefings might be in order as well.

FINDINGS AND RECOMMENDATIONS

The task group found that a comprehensive program to address the geotechnical issues relating to the storage of radioactive waste underground has been instituted by BWIP. All of the key disciplines including, among others, geology, hydrology, geomechanics, geochemistry, mining engineering, geophysics, civil engineering, and geotechnical instrumentation are represented in the plans of the program. However, some geotechnical issues were not being addressed adequately and the following recommendations are made with respect to these issues:

1. Licensing should not inappropriately dominate the site characterization planning process. The objective of the DOE program is to construct a repository for high-level nuclear waste safely and efficiently. The primary considerations should include the construction aspects of this project and operational requirements of the repository.

2. The performance objectives and design criteria should be stated clearly and concisely in a single document.

3. The documentation should include a description of the conceptual models for behavior and discussions that relate data collection activities to the conceptual model. Such discussions should include the purpose of the testing, how the results will be used, and should note the limitations of the test. A clear understanding of the relationship between conceptual model and data collection should be evident to the reader.

4. Data collection for alternative designs should be a part of the site characterization program to account for the uncertainties in ground conditions.

5. A thorough and unified approach to treating uncertainties using established analytical techniques should be included in the program.

6. The program planning should recognize that an observational approach is needed during the site characterization phase and during construction. Provisions for performance monitoring during construction and operation should be a part of the program. Similarly, the quality

assurance program should accommodate the observational approach. The quality assurance program should be developed by experts in the field of underground design and construction. This effort should involve the Nuclear Regulatory Commission, since NRC oversight activities will be closely tied to the recommendations resulting from such an effort.

7. A multidisciplinary approach is needed to conduct efficiently and effectively a site characterization program of this magnitude. Interaction among the technical staff should be actively and forcefully pursued to guarantee this multidisciplinary approach.

8. Regular interaction with other project offices, national research institutions, foreign institutions studying similar problems, and professionals at scientific forums should be encouraged.

9. Where appropriate, BWIP should adhere to nationally or internationally recognized test standards.

10. Considerable developmental research is needed to address adequately the technical issues of designing and constructing a nuclear waste repository at the depths considered.

11. Attention should be given to the instrumentation program for site characterization and performance monitoring during construction.

    - Construction specifications for the exploratory shaft and test facility should be written in anticipation of interference and unanticipated delays resulting from the testing program.
    - The number of personnel allowed access to the test facility should be made compatible with the needs of the testing program.
    - Funding considerations and lead time for the development of specialized instrumentation should be given careful consideration during the planning phases of site characterization.
    - The procurement process for instrumentation should be studied. Instrument specifications should be complete and realistic; prequalification of instrument suppliers should be introduced; a realistic acceptance testing program should be instituted; and sole-source contracting should be a part of the procurement process, as appropriate.

12. The possibilities and limitations for using geophysical techniques to assist in characterizing the site should be explored.

13. This project is highly visible (appropriately) and the ability to communicate to the experts and the public the purpose and progress of the work and the consideration given to each of the issues is an important aspect of the project. The documentation, presentation material, and briefings should be clear, concise, and coordinated.

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APPENDIX

Extract from:

Perlman, R.S. 1985. "Sole Source Contracts, Basic Principles and Guidelines." pp. 187-222 in Briefing Papers, No. 83-7, v. 6 (July), Briefing Papers Collection 187, Washington, D.C.: Federal Publications, Inc.

> Despite the fact that the general policy of the Government is to acquire goods and services on a competitive basis, most Government procurement dollars are spent on contracts awarded noncompetitively (i.e., sole source contracts). Of the $146.9 billion spent by the Federal Government in fiscal year (FY) 1982 for goods, $79.2 billion (54%) was expended noncompetitively.
>
> Questions regarding the use (or overuse) of sole source procurements concern every member of the procurement community. From the Government's standpoint, if a contract is improperly awarded on a sole source basis, the Government may pay higher prices than if competition had been sought. On the other hand, failure to permit a sole source award in appropriate circumstances may unnecessarily (a) increase the price paid for the item, (b) place a greater administrative burden on Government personnel, since competitive procurements require approximately twice as much work as sole source awards, and (c) cause the Government user to receive a product that merely meets the minimum requirements of a solicitation, instead of the one that is best for the job.