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**GEOCHEMISTRY RESEARCH PLANNING FOR THE
UNDERGROUND STORAGE OF HIGH-LEVEL NUCLEAR WASTE**

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ABSTRACT

This report is a preliminary attempt to plan a comprehensive program of geochemistry research aimed at resolving problems connected with the underground storage of high-level nuclear waste. The problems and research needs were identified in a companion report to this one, (Apps et al., 1982). The research needs were taken as a point of departure and developed into a series of proposed projects with estimated manpowers and durations.

The scope of the proposed research is based on consideration of an underground repository as a multiple barrier system. However, the program logic and organization reflect conventional strategies for resolving technological problems.

The projects were scheduled and the duration of the program, critical path projects and distribution of manpower determined for both full and minimal programs. The proposed research was then compared with ongoing research within DOE, NRC and elsewhere to identify omissions in current research. Various options were considered for altering the scope of the program, and hence its cost and effectiveness. Finally, recommendations were made for dealing with omissions and uncertainties arising from program implementation.

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1. INTRODUCTION

1.1 INTRODUCTION

An examination of the problem of disposing of high-level radioactive waste underground shows that chemical processes strongly affect waste containment. In this report an attempt is made to develop a plan for conducting geochemistry research to resolve problems relating to this method of disposal. The plan is based on knowledge available at the time of preparation, and therefore the conclusions and recommendations presented here are subject to change as more information becomes available, or as schedules and priorities for implementation of the waste isolation program change.

This report is the last of three on geochemistry research sponsored by the Nuclear Regulatory Commission. The first has already been published (Apps et al., 1982). The second by Carnahan, (1982) is under review. The first report entitled "The Status of Geochemical Problems Relating to the Burial of High-Level Radioactive Waste, 1982", is a companion to this report. It is composed primarily of surveys of existing problems. After each survey, conclusions are drawn and recommendations made regarding the need for future research. The recommendations are used to formulate research proposals. Both the recommendations and the proposals are repeated in this report as a departure point for developing the research plan.

Research planning is an ambitious undertaking, particularly when research, by its very nature, involves uncertainties as to the final outcome. Yet the need for new technology for radioactive waste disposal is so great that a directed research effort to this end is called for, especially to resolve major as-yet-unanswered questions in the geochemistry field.

In planning a research program, it is important to know what are the programmatic and technical objectives. These are discussed in Section 1.2.1. The objectives cannot be attained without resolving a number of technical questions or issues. Responding to these questions involves a logical progression of steps from initial definition of the problems involved through laboratory research, computer simulations, field testing and verification, and finally to repository design and construction. Because of the unusual performance requirements for a geologic waste repository, i.e., waste containment for periods of possibly in excess of tens of thousands of years, the research and development needs are more elaborate than needed for conventional engineering design and construction. In Section 1.2.2, the logical progression through research, development, and implementation is delineated.

The logic defines the way in which the research program is implemented, and how it is integrated with the repository construction program. However, it does not identify the technical questions holding up repository design. To do this, we need a framework through which the questions can be identified and related to each other. This is done by considering a repository as a system, which consists of a series of subsystems and components. Section 1.2.3 analyses the geologic repository as a system of barriers.

The geochemistry research plan is developed using the repository barrier system as a point of departure, while simultaneously accommodating the logic discussed in Section 1.2.2. The approach is outlined in Section 1.3 and discussed in greater detail in Apps et al., 1982 and Chapter 2 of this report. The plan is executed in nine steps:

- (1) Review the current status of knowledge regarding the chemical aspects of subsurface waste isolation.
- (2) Identify technical questions.
- (3) Address and resolve, the technical questions or recommend further research.
- (4) Identify specific research projects emerging from the recommendations and assign priorities. Classify the research by major
- (5) Estimate the level of effort required and duration of each research project.
- (6) Compare proposed research with that currently in progress in DOE, MRC and elsewhere.
- (7) Identify precursor and successor projects.
- (8) Work out schedules.
- (9) Consider issues that cannot be resolved in the time frame permitted, and uncertainties in the program plan.

The plan finally developed in this report contains many individual projects. However, not all aspects of geochemistry were addressed for budgetary and personnel reasons. Therefore, some issues have not received commensurate attention. Individual projects are classified according to basic scientific research topics or research elements rather than according to barrier components, although the logic of the plan as outlined in Section 1.2.2 is retained. Section 1.3 concludes with a discussion of the level of research investigation required to satisfy regulatory requirements. The final state of planning, which deals with technical omissions and the uncertainties arising from implementation, is reviewed briefly in Section 1.4 and discussed in greater detail in Chapter 3 of this report.

The sequence of steps in developing the research plan are illustrated in Figure 1.1 so that the relationship of each step to the next can be more clearly recognized.

Figure 1.1 Approach to geochemistry research planning for the underground storage of high-level nuclear waste

1.2 APPROACH TO GEOCHEMISTRY RESEARCH PLANNING

1.2.1 Objectives

The objectives for domestic waste management planning and implementation were defined in the IRG document (Interagency Review Group on Nuclear Waste Management, March 1979, p. 15-18). The primary objective is that:

"Existing and future nuclear waste from military and civilian activities (including discarded spent fuel from the once-through nuclear power cycle) should be isolated from the biosphere and pose no significant threat to public health and safety."

Additional technical objectives are that:

- o "The selected technical option must meet all relevant radiological protection criteria as well as any other applicable regulatory requirements; although zero release of radionuclides cannot be assured, any potential releases should be within pre-established standards and, beyond that, be reduced to the lowest level practicable.
- o "The technology selected for waste disposal, as well as the reasons for its selection, must be well understood, clearly articulated, and widely accepted."
- o "The existence of residual technical uncertainties must be recognized and provided for in the program structure."

These objectives were taken into account in the planning of geochemistry research. The technical objective concerning the residual technical uncertainties is very important. Public acceptability of any proposed solution to the isolation of radioactive waste will require that the residual technical uncertainties be resolved through laboratory and field verification. It is difficult to provide for public acceptability in the program structure. However, it should be attempted to avoid serious omissions of scientific evaluation prior to licensing of a repository.

Public acceptance of underground waste disposal will depend on a successful demonstration of model predictability. Varanini (1979, p. 33) points out that "The real lack of scientific verification, we believe, will create a policy stalemate. Public concern will not be allayed by paper studies and engineering exercises in the absence of hard scientific evidence."

Although progress is being made, there is presently no consensus regarding what constitutes sufficient scientific verification. Hence no means of defining the level of certainty that will be needed. (For the approach taken by the U. S. Department of Energy and supported by a court decision, the reader is referred to U.S. Department of Energy 1980, DOE/NE-0007, Supp. 1, p. 1-6.) In this report no attempt is made to estimate the certainty by which predictions of radionuclide containment might be made.

Yet, there should be ample opportunity to develop a capability to do this while the proposed program is under way. As the program is refined and various accomplishments are met, the level of confidence should improve and a comparative level of risk established that could be used as a basis in policy decisions.

A geologic waste repository will probably consist of a system of natural and engineered barriers to radionuclide migration. The dimensions of the barriers, their physical properties, and the thermal and hydrologic conditions pertaining to the repository will define the environment through which radionuclides will migrate. Predicting the migration of radionuclides leached from a breached container in deeply buried rocks over periods of between 10^3 and 10^6 years is without precedent. Comprehension of the chemical processes and the use of models to make quantitative predictions of these processes will be required. Furthermore, the correctness of the models must be demonstrated in the field and laboratory to validate the scientific concepts used in making the predictions.

Geochemistry research planning should be based on what can be accomplished with existing research techniques, and what in the judgement of the participating scientists constitutes the best means of solving the critical questions requiring resolution. A large amount of research has yet to be done before a satisfactory predictive capability becomes available. This does not mean that problems must be solved beyond all reasonable doubt, only that reasonable quantitative estimates should be made for processes that are presently known only approximately.

1.2.2 Development of a Logical Approach to Research, Development and Implementation

Several surveys have been made in the last few years relating to the scientific needs for radioactive waste management (e.g., American Physical Society, 1978; Interagency Review Group, 1979; U.S. Department of Energy, 1970; 1979; Klingsberg and Duguid, 1980;) each reiterating essentially the same general approach with varying levels of detail. Figure 1.2 shows a logical sequence of actions in part suggested by the foregoing authors, to resolve the geochemical problems with the necessary scientific rigor. These steps follow the classical scientific approach to a complex problem, but recognize the need for technological implementation of the findings, i.e., construction of a repository.

An important difference between this report and earlier approaches is the emphasis placed on geochemical verification through the study of natural systems. While earlier approaches assume complete reliance on short-term field validation of models and trust long-term extrapolations (to 10^6 y), it is assumed in this report that natural systems involving processes taking place over 10^2 to 10^7 years can be used to provide the needed validation. Computer models describing radionuclide migration can simulate observed natural processes and the two compared as a means of identifying errors, omissions or oversimplifications in the models.

Figure 1.2 Logic chart to identify geochemical needs for the process

ify geochemical needs for the isolation of high level radioactive waste

Greater confidence can then be attached to processes covering the time interval between field validation studies (whose duration is rarely greater than 10 years for logistical reasons) and the maximum anticipated isolation time requirements.

The difficulties inherent in the selection of and evaluation suitable analogues cannot be underestimated, but this is the only course open in ensuring that mathematical modeling can be usefully applied when direct experimental verification is impossible.

The normal approach in clarifying scientific or technological issues is to proceed through a logical sequence of actions, i.e.

- (1) Definition of the problem and identification of objectives.
- (2) Interpretation of laboratory experiments or natural phenomena.
- (3) Development of a hypothesis explaining the observed phenomena.
- (4) Construction of a conceptual model.
- (5) Testing of the model through laboratory and field studies.
- (6) Elucidation of the processes introduced in the hypothesis and refinement of the model.
- (7) Testing of the model on other systems to ensure that it is valid.

For reasons already discussed, this approach is not easy to apply to waste repository design. Nevertheless, it is essential that experimental verification be employed. Varanini (1979, p. 24) points out, "Not only is it possible that assumptions may be wrong, important natural processes may be overlooked, or parameters may be missing, but also the analyst may have oversimplified the mathematical framework [of the model]." He further emphasizes "... that repository safety assessments are not predications of what will happen, rather they are predications of what might happen given a set of assumptions and the development of a given sequence of possible or plausible events and processes." To overcome the difficulties, a modified approach is suggested, complementary to that normally used in solving scientific or technical problems. It includes the following steps:

- (1) Definition of the problem
- (2) Laboratory research and conceptual modeling
- (3) Development and testing of computer simulations
- (4) Laboratory and field testing of radionuclide migration

- (5) Verification of predictive capability over long time spans using natural systems
- (6) Site selection and characterization
- (7) At Depth Testing
- (8) Construction

The geochemistry research program plan is based on the assumption that these steps will be followed. Brief explanatory descriptions are given below.

- (1) Definition of the Problem

This initial step will, in the context of the geochemical aspects of waste isolation, include consideration of the physical and chemical mechanisms controlling radionuclide transport, and identification of the information required for hydrological modeling. Experts in geochemistry will determine the most plausible mechanisms and define a program of research establishing the validity of their concepts. A multiple barrier system will be assumed.

- (2) Laboratory research and conceptual modeling

This step implements research designed to ascertain whether postulated geochemical transport processes affecting radionuclide transport are valid. Conceptual models describing source terms and sorption phenomena will be formulated. Supporting thermodynamic data, needed to interpret experiments, will be obtained from the literature or determined experimentally. Owing to the complexity and differing environmental conditions of engineered and natural barriers, different models may be needed to describe conditions peculiar to each barrier. Engineered barriers adjacent to the waste may even require coupled thermomechanical-hydrological-geochemical models to describe their behavior adequately.

- (3) Development and testing of computer simulations

This step will make use of geochemical algorithms in computer simulations of engineered and natural barrier performance. Because almost all computer simulations use numerical methods for their solution, analytical solutions are needed to compare the results of the numerical methods. A computer simulation can also be a valuable tool in forcing the investigator to recognize the parameters needed to describe a system adequately, in estimating the sensitivity of the output to variations in these parameters, and in designing experiments both to establish the validity of the model and to gain insight in the mechanisms controlling radionuclide transport.

(4) Laboratory and field testing of radionuclide migration

Integrated geochemical and transport models, once validated, will be used to design laboratory and field tests to verify the correctness both of the geochemical algorithms, and the transport model(s). Laboratory tests possess the advantage of a controlled environment and convenience of monitoring. However, the possibility cannot be ruled out that such tests do not replicate in-situ conditions. Furthermore, testing in the laboratory is not amenable to experiments where large-sized rock samples are needed. Therefore, both laboratory experiments and field tests should be considered, the emphasis depending on objectives and anticipated outcome.

(5) Verification of predictive capability over long time spans

The only way to verify predictions of radionuclide behavior over very long time spans is to look at natural geological processes replicating as closely as possible the waste repository conditions. Such natural analogues should be selected with care to permit computer simulations to be reconciled with field observations. If major discrepancies arise, then either the simulation contains an incorrect formulation of radionuclide transport or the field observations have been incorrectly interpreted. Several evaluations of different analogues may be necessary before sufficient confidence can be gained in the predictive capability of computer simulations.

(6) Site selection and characterization

By site characterization is meant all initial evaluation work performed prior to and for preparation of the site characterization report. Characterization is required of the host rocks in both near and far field. All parameters necessary for quantification of radionuclide migration must also be determined, including the anticipated radionuclide flux leaving the waste package, the magnitude, rate and direction of groundwater flow, and the effective surface area and sorptive properties of the host rock minerals.

The hydrologic and geochemical properties of the host rock are inseparable when considering radionuclide migration. The contribution the chemical evolution of groundwater makes in verifying hydrological models, should therefore be considered as well as the effect that waste storage might have on groundwater chemical composition.

(7) At Depth Testing

At depth testing will require the sinking of a shaft and construction of an underground facility to access the in situ environment. Tests could include simultaneous measurements of thermomechanical and hydrologic properties and in-situ radionuclide transport in the host rock. Backfill studies to determine the feasibility of replicating optimum radionuclide retardation properties of the backfill and the tendency for it to change its physical and chemical properties over time, or react with the host rock, should also be evaluated under varying thermal gradients. Finally, at depth testing, provides exceptional opportunities for hydrochemical characterizations, thereby facili-

tating the refinement of hydrological models.

(8) Construction

The construction phase will allow for a continuation of activities started during site characterization and at depth testing, and permit a more intensive evaluation of near-field conditions. Testing with real waste is a practical possibility at this stage.

1.2.3 The Waste Repository as a Barrier System

High level radioactive waste disposal has so many institutional, regulatory, scientific, and technological aspects to it that a systems approach is now considered to be the only way by which the problems may be analysed and appropriate action taken in meeting overall objectives. Uncertainty exists in defining the hierarchy of subsystems involved and their interactions. Although it is entirely beyond the scope of this report to analyze this hierarchy, the reader should be aware of its existence and the impact it has on geochemistry research planning.

The U. S. Department of Energy's National Waste Terminal Storage Program uses a systems approach with the goal of permanently containing radioactive waste in a geologic repository. The geologic repository itself is a subsystem composed of natural and engineered barriers. Each barrier is designed to fulfill a specific function or functions, among which is preventing or retarding the release of radionuclides to the accessible environment. The behavior of each barrier is dependent on its thermomechanical, hydrologic, and chemical properties. However, the predicted release of radionuclides from the barrier system will depend on the interactive behavior of all barriers. The barriers normally recognized are:

- (1) Waste form
- (2) Canister
- (3) Overpack
- (4) Backfill
- (5) Near field and far field

The first three of these barriers constitute the waste package and are not addressed in this report. Of the remainder, the backfill constitutes an engineered barrier, whereas the near and far fields consist of natural barriers comprising the host rock in which the repository is constructed. The near field is separated from the far field, possibly somewhat arbitrarily, in that the former occupies a volume of rock which is affected by the emplacement of the waste, either mechanically (by rock breakage), thermally (by heat generated by the waste), or chemically (by grouts or other chemically reactive constituents used to modify the host rock in expectation of enhancing radionuclide containment).

The system of engineered and natural barriers should be designed to meet all criteria governing radionuclide release into the accessible environment. Given this restraint, the barrier system design may allow engineering ingenuity to meet the overall requirements. The dimensions of engineered barriers, however, are largely constrained by conventional mining technology.

The barrier system capacity may vary depending on site location, host rock type and choice of waste form. In some cases, additional engineering barriers may needlessly complicate performance predictability, or provide no increase in environmental protection while substantially increasing the cost of waste disposal (Claiborne, 1982) however, standard engineering practice has rarely if ever been applied to problems such as those encountered in repository design, and operational uncertainties over the long time periods required for isolation may require an extraordinary level of redundancy to ensure public acceptance.

Appendix A, "The Geologic Repository as a Barrier System," defines a representative barrier system, and its subsystems and components. Also included are the parameters affecting radionuclide migration, technical questions needing resolution, and relevant regulations, technical rules and definitions from 10 CFR Part 60 pertaining to the geochemical aspects of the barrier system. The technical questions are the basis for the reviews incorporated in Apps et al., (1982), as described in the following section.

1.3 DEVELOPMENT OF A GEOCHEMISTRY RESEARCH PLAN

Geochemistry research planning first and foremost must lead to the implementation of a geochemistry research program that will demonstrate that high-level radioactive waste can be isolated from the accessible environment while meeting NRC technical rules and EPA standards. Secondly, it must be subject to the realistic restraints of manpower, facilities, and budgets. Finally, it should be responsive to time schedules for licensing and construction of an underground repository. Research plans directed towards specific goals should also consider alternative strategies in case a given course of action fails. Uncertainties in meeting goals mean that estimates of required budgets, manpower and time will be somewhat nebulous. Nevertheless, some kind of plan is better than none at all, and even if imperfect, will serve to channel research and development efforts more effectively. Furthermore, it may also serve to refine NRC technical rules.

1.3.1 Steps involved in developing the plan

The overall approach to developing a plan for the resolution of geochemistry research problems involves a sequence of steps: Steps 1 through 4 are given in Apps et al, (1982). Part of step 3 and steps 4 through 9 are given in Chapter 2 of this report. The steps are:

- (1) Review the current status regarding the chemical aspects of subsurface waste isolation.

A multiple-barrier system consisting of both engineered and natural barriers as discussed in the preceding section is assumed to be the eventual configuration of the repository. The host rock will be selected from those currently considered to be most plausible, i.e., domal and bedded salt, basalt, tuff, granite, and shale. The review process is accomplished by assessing the current status of knowledge through a reading of the current literature and evaluation of research underway by DOE and others.

(2) Identify technical questions.

Through (1) above, major technical questions are identified requiring resolution. The technical questions are classified according to their relationship to the barrier system, as illustrated in Appendix A.

(3) Address and resolve the technical questions or recommend further research.

The underlying problem is surveyed and evaluated, and an effort is made to go as far as possible in attempting to resolve the questions through preliminary calculations and estimates. Conclusions are drawn from the evaluations and appropriate recommendations are made.

This phase of the planning effort involved individual evaluations by professional staff members in the Geochemistry Group at the Lawrence Berkeley Laboratory. Their evaluations are presented separately in Apps et al., 1982. Not all questions posed were addressed because the number of questions was greater than could be accommodated with available funds and the diversity and expertise required to answer all questions was not available. The findings, conclusions, and recommendations of the scientific staff are given in Apps et al., 1982.

(4) Identify specific research projects emerging from the recommendations and assign priorities. Classify research by major topics.

Although the critical questions posed were based on the system of engineered and natural barriers surrounding the buried radioactive waste, it was found that the recommendations showed substantial overlap or addressed problem areas that had broader implications than the narrower focus of the critical questions upon which the recommendations were based. Therefore, the projects emerging from the recommendations were grouped according to seven major topics:

- o Bounding conditions
- o Transported forms
- o Transport mechanisms
- o Retardation mechanisms
- o Physical/chemical properties of barriers

- o Chemical transport algorithms
- o Field evaluations.

This structure has two advantages: First, it avoids repetition of similar topics for different barriers; secondly, it allows for a generally sequential flow of information to the final stage of research establishing the feasibility of the storage of underground radioactive waste. The research projects are listed in Chapter 2 of this report and in Apps et al., 1982.

- (5) Estimate the level of effort required and duration of each research project.

Very approximate estimates were made of the levels of effort expected and duration required for each project. These estimates were based on the scientific judgement of qualified staff with experience gained in similar research, and reasonable assumptions regarding the staff required and the level of education and experience needed to accomplish the project. More detailed estimates could not be made without scoping of individual projects; a task that would be neither productive nor appropriate at this stage of planning.

- (6) Compare proposed research with that currently in progress by DOE, NRC, and elsewhere.

This was accomplished by compiling a list of all projects known to be funded as of fiscal year 1981.

- (7) Identify precursor and successor projects.

Projects that must be accomplished before other projects can be completed should be identified and their relationship to future projects determined.

- (8) Work out schedules.

This phase of the planning was undertaken using CFMG, a computer code developed at the Lawrence Berkeley Laboratory to facilitate the planning and organization of complex projects. Milestones were established and resource requirements determined.

- (9) Consider issues that cannot be resolved in the time frame permitted and uncertainties in the program plan.

The final stage of program planning deals with the problems arising from the need to reconcile the idealized research needs with the practicality of limited budgets, manpower availability, and the technical and time restraints of the real world.

1.3.2 Level of Research Investigation Required to Satisfy

Regulatory Requirements

Research, by its very nature, involves uncertainty. Therefore, any estimates of the level of research needed to resolve the waste isolation issue must necessarily be imprecise. However, a number of restraints can be placed on the research so that the effort expended will be directed towards resolving issues productively, efficiently, and within the time limits imposed.

First, complete resolution of all aspects of a problem is not required but only those sufficient to allow a prudent scientist to proceed with confidence to the next stage of an investigation. This approach can be more cost-effective and time-efficient than traditional research techniques but also involves a greater risk of error.

Secondly, it may not be necessary to perform any research on some topics because calculations would show that their impact on the final outcome would be negligible. A naive example of this would be the study of strontium-90 migration. Strontium-90 would have decayed to infinitesimal concentrations after 1000 years of storage, or if it were to be released from a canister immediately after burial, would never find its way to the accessible environment before complete decay (Wood, 1980). This restriction on the level of research should also be tempered by exceptions known to occur in all research activities. For example, investigation of strontium-90 migration may be the basis for elucidating transport mechanisms of a radionuclide such as radium-226, or a relatively innocuous radionuclide may be part of a chain of daughter products, one of which could be quite toxic. Thus the migration behavior of the whole chain might have to be studied.

Another factor affecting the research effort is that not all research needs can be identified a priori. To find out whether previously unidentified research needs exist, it is sometimes necessary to proceed with either insufficient or nonexistent input, using only reasonable estimates or suppositions to get to the point where further research needs become apparent.

The research effort can be limited by restricting the environmental conditions under which waste is stored. This has been covered in Chapter 2 of Apps et al. (1982). In addition, relaxation of environmental standards, specification of a lower maximum temperature, a mandatory 1000-year confinement of radionuclides to the canister or limitation of the number of engineered barriers, all decrease research needs. However, these must be balanced against the possibility of increased risk or uncertainties.

1.4 RECOMMENDATIONS FOR DEALING WITH UNCERTAINTIES.

This topic, which is the subject of Chapter 3, covers two major areas of uncertainty and recommendations to resolve them; (a) technical omissions of the plan, and (b) uncertainties arising from implementation of the plan.

1.4.1 Technical Omissions of the Plan

Nine issues not examined in the course of development of the plan are discussed. They are:

- (1) Natural analogues
- (2) Radiolysis
- (3) Design of laboratory and field experiments
- (4) Radionuclide getters
- (5) Effect of differing host rocks on radionuclide containment
- (6) Borehole plugging material interactions with host rock
- (7) Transuranic element daughters
- (8) Radionuclide adsorption on mineral substrates
- (9) Development of geochemical field monitors.

These issues may have an important bearing on the geochemistry research program, but they must first be evaluated.

1.4.2 Uncertainties Arising from Implementation of the Plan

Under this topic, the following issues are considered:

- (1) Implementation
- (2) Manpower
- (3) Costs
- (4) Organization
- (5) Timing of projects within the program
- (6) Interfacing with other programs.

All these issues can be addressed with further refinement of the present plan.

2. RECOMMENDED RESEARCH PLAN

2.1 INTRODUCTION

The recommended research plan in geochemistry, presented in this chapter, has evolved from the recommendations made by scientists in the process of reviewing a series of critical questions given in Apps et al. (1982). The coverage is not complete because the availability of staff and resources were unequal to the magnitude of the task. Nevertheless, it is believed that the most important issues have been covered and few major topics remain uninvestigated. The plan incorporates all aspects of research including theory, modeling, and both laboratory and field experimentation. The conventional approach discussed in Chapter 1 has been taken, i.e., from problem definition through laboratory and field testing.

This chapter is divided into four sections in addition to the introduction. The first identifies key research needs. The second compares these needs with ongoing research, and the third discusses the schedule of the plan. In the final section, various options and issues are discussed.

2.2 KEY RESEARCH NEEDS

Key research needs were identified through a multistep process using the recommendations of Apps et al., (1982). The recommendations are as summarized in Table 2.1. The table includes assignment of priorities to the recommendations and the action taken with respect to each recommendation. These are discussed further below.

2.2.1 Priorities

Five levels of priority are assigned to the recommendations from Chapters 2.0 and 3.0 of Apps et al., (1982). They are as follows:

(1) Leads to research of the highest priority in the area of geochemistry. A problem probably requiring resolution before radioactive waste can be stored underground.

(2) Leads to research of second priority. May be essential that it be completed before storing waste underground at a given site.

(3) Would, if implemented, provide valuable supporting information, increasing the credibility of underground waste disposal.

(4) Neither essential nor critical to the emplacement of radioactive waste but may, if implemented, facilitate more rapid resolution of existing uncertainties.

(5) Restricts scope of proposed research or require no further action.

Most recommendations given in Table 2.1 either lead logically to further geochemistry research or place bounds on the extent of such research.

[text continued on page 26]

Table 2.1 Summary of Recommendations, Priorities, and Project Assignments Emerging from the Evaluation of General and Specific Problems.

Section/Subject)	Problem	Recommendations	Priority	Assignment*
2.2.1 Bounding the physical and chemical conditions	A generic approach to research on radionuclide migration would be too extensive without restricting the scope to realistic environmental conditions.	1. The effect of pressure between 1 and 500 bars on the compaction of backfill materials and the relation of this to porosity, permeability, and radionuclide migration should be investigated.	A	Project 5.2
		2. Long-term changes in chemical and physical properties of backfill and host rocks should be investigated at temperatures to 300°C.	B	Project 1.1
		3. Radionuclide sorption and complexation should be studied on a restricted suite of radionuclides to 175°C.	A	Limit scope of studies on radionuclide behavior to 175°C
		4. Radionuclide sorption studies should be restricted to clay minerals, iron oxides, micas, one or two commonly occurring zeolites, feldspars, and silica.	E	Limit mineral substrates in studies
		5. The significance of selected minerals on specific radionuclides should be evaluated, e.g., the sorption of trivalent actinides on apatite should be investigated.	B	As above
		6. A satisfactory means of characterizing surface area in relation to radionuclide sorption should be investigated.	C	Project 5.6
		7. The fundamental relationship between radionuclide sorption mechanisms and surface area should be investigated.	D	Projects 4.1
		8. Groundwater sampling procedures should be developed to allow for uncontaminated sample procurement.	B	Projects 1.2, 7.8

)in Apps et al., 1982

*Projects are described in numerical order in Table 2.2.

Table 2.1 (cont.)

Section/Subject	Problem	Recommendations	Priority	Assignment ^a
2.2.2 Toxic radionuclides in spent reactor fuel after 1,000 years	It is not clear which radionuclides are most toxic and which ones should be investigated with respect to their migration through repository barriers.	1. An evaluation of the specific biological toxicity of ⁷⁹ Se, ¹⁰⁷ Pd, and ¹²⁵ Sb should be made since realistic values of the MPC's may be substantially higher than the general category value. If their biological toxicities are not substantially lowered from the general category value, research studies should be initiated.	A	Outside the scope of geochemistry, but should be initiated immediately because of its impact on geochemistry research
		2. An evaluation of the biological toxicity of the actinide decay chains should be made that result in the assignment of overall MPC values for their short-lived daughters, e.g., as was done with ²²² Rn and its decay daughters.	B	Outside the scope of geochemistry, but should be initiated because of its impact on geochemistry research
2.3.1 Inorganic complexation	Data availability, especially at elevated temperatures, and modeling mixed electrolyte behavior at high ionic strengths are deficiencies hindering progress in radionuclide transport calculations. Calculations lacking essential data on complexing will tend to overestimate retardation due to sorption and precipitation.	1. A consensus is needed with regard to hazard ranking of toxic radionuclides.	A	See Section 2.2.2
		2. Formation constants of complexes of radionuclides with common groundwater ligands (OH ⁻ , Cl ⁻ , HCO ₃ ⁻ , CO ₃ ²⁻ , SO ₄ ²⁻ , F ⁻) should be obtained.	B	Limit scope of projects 2.1, 2.3.
		3. Formation constants of the most important complexes should be determined over the range 25-175°C.	B	As above
		4. Improved methods for correlating and predicting stability constants should be developed, including the effects of temperature. Data should be applied to model chemical interactions and transport of radionuclides.	B	Output of projects 2.1, 2.3 is input for 6.2 and 6.5

¹In App's et al., 1982

^aProjects are described in numerical order in Table 2.2.

Table 2.1 (cont.)

Section/Subject	Problem	Recommendations	Priority	Assignment
2.3.2 Organic complexation	Organic complexing with metal ligands in groundwater may be significant and could affect radionuclide K_d 's and migration behavior.	1. Basic chemistry of radionuclide-organic complexes is largely unknown. Migrating species must be identified and studied.	B	Projects 2.3, 7.1
		2. The stability constants, electrochemical data, and chemical characteristics of radionuclide/humic-fulvic acids, related carboxylic acid complexes and other organic complexing agents should be determined for the purpose of future analyses, and identification and prediction of chemical reactions involving these complexes under geological conditions.	A	Project 2.6
		3. Interactions of radionuclide-organic complexes with mineral surfaces should be studied with respect to organic ligand content at specific sites.	B	Project 4.3
2.3.3 Colloids and particulate transport	There is ample evidence for the formation of colloids and suspended particulates in groundwaters. Both pseudocolloids and true colloids could form, but little information about conditions of formation, long-term stability, or potential for migration is available. Their significance should be established.	1. The nature, properties, and radionuclide content of colloidal forms produced through degradation of high-level wastes should be determined.	C	Project 2.7
		2. Attempts should be made in the laboratory to produce true colloidal forms of insoluble species of the important waste radionuclides under conditions anticipated for the groundwaters at a proposed storage site. If there is an indication of true colloid formation, research should be extended to study the conditions for the formation, stability, and migration behavior of the colloids.	B	Project 2.8
		3. Concentrations, particle-size distribution, and migration properties of colloidal material suspended in underground waters should be measured, especially in basalt, tuff, and granite.	C	Project 7.2
		4. The mineralogy and chemistry of particulate matter in deep aquifers at specific sites should be investigated.	C	Project 7.3
		5. Sampling methods free of contamination from suspended particulates due to drilling should be developed.	C	Projects 1.2, 7.8

Section/Subject)	Problem	Recommendations	Priority	Assignment*
2.3.4 Colloid diffusion	The significance of colloid transport should be established.	<p>1. Further investigations should be conducted to assess the magnitude of the effect of charge on colloidal particle transport.</p> <p>2. The relative importance of colloidal particle transport in the overall analysis of radionuclide release and transport through the backfill should be evaluated. Sensitivity studies and comparative numerical analyses with transport processes other than diffusion should be done to establish priorities for further research in and analysis of transport scenarios.</p>	B C	Project 3.5 Project 3.5
2.4.1 Solubility constraints on fission products	Solubilities of salts of several potentially toxic fission product radionuclides, such as ^{79}Se , ^{99}Tc , ^{107}Pd , ^{126}Sr , ^{129}I , ^{210}Pb , and ^{226}Ra are not well determined. Therefore maximum concentrations in solution cannot be calculated.	<p>1. The behavior of selenium in groundwater should be determined.</p> <p>2. The most stable oxidation state of Tc in groundwater should be established.</p> <p>3. The relative importance of Sn and Pd solution species and their effect on Sn and Pd solubility in the natural environment should be determined.</p>	B B C	Project 2.1 Project 2.1 Projects 2.1, 4.9
2.4.2 Solubility constraints on actinides	Solubilities of salts of actinides are not well determined. Therefore, maximum concentrations in groundwaters cannot be estimated.	<p>1. The solubilities of trivalent actinide phosphates and carbonates should be determined.</p> <p>2. The formation constants for trivalent and tetravalent actinide carbonate complexes should be measured.</p> <p>3. Efforts should be directed toward measurement of actinide compound solubilities as a function of temperature to determine whether solubilities decrease with increasing temperature.</p>	B B B	Project 4.10 Project 2.3 Project 4.10

)in Apps et al., 1982

*Projects are described in numerical order in Table 2.2.

Table 2.1 (cont.)

Section/Subject	Problem	Recommendations	Priority	Assignment ^a
		4. Hydrolysis constants for tetravalent actinides, especially $\text{An}(\text{OH})_4$ and $\text{An}(\text{OH})_6^{2-}$, should be measured. Neutral and negative hydrolyzed species may dominate in neutral and alkaline solutions. Verification is needed.	B	Project 2.3
		5. The importance of UO_2^{2+} and PuO_2^{2+} to the solubilities of UO_2 and PO_2 in natural environment should be established experimentally.	B	Project 2.3
		6. A few trivalent and tetravalent actinide silicate solubilities and complex formation constants should be measured to establish their relative importance.	B	Project 4.10
2.4.3 Sorption (ion exchange) data	The sorption behavior of elements found in the radioactive waste is needed to develop models that predict radionuclide migration, especially with respect to the engineered barrier region.	1. Chemical conditions existing in the backfill and near-field host rock should be defined at the time of expected loss of canister integrity. Research should consist of an experimental program augmented by theoretical and modeling studies of chemical interactions.	B	Projects 1.1, 2.4, 5.1
		2. Sorption studies should be expanded to include the full range of anticipated host rock types and important phases lining the cavities and fractures of these rocks.	B	Limit mineral substrates in studies
		3. The temperature range of sorption studies should be extended to at least 175°C and should include empirical or theoretical determination of temperature dependence.	B	Limit scope of studies or radionuclide behavior to 175°C. Project 4.4
		4. Data obtained from the studies recommended in 1-3 should be integrated with existing and new models of chemical interactions and transport in the backfill region.	A	Projects 4.4, 6.2, 6.4

^aIn Appa et al., 1982^aProjects are described in numerical order in Table 2.2.

Table 2.1 (cont.)

Section/Subject)	Problem	Recommendations	Priority	Assignments ^a
2.4.4 Effects of long-term nonequilibrium water-rock interactions on radionuclide retardation	Many reactions between radionuclides and host rocks may not be readily observable in short-duration laboratory experiments, but may dominate transport processes in situ.	1. A laboratory and theoretical program should be conducted to determine the effect of long-term nonequilibrium rock-water reactions on radionuclide retardation.	A	Projects 4.3, 4.6
		2. State-of-the-art surface analytical techniques should be used to quantify slow diffusion rates over experimentally realistic time periods at repository temperatures.	A	Projects 4.7, 4.8
		3. A mechanistic model should be formulated to extrapolate to long-term conditions. Confirmatory in situ field tests should be carried out.	A	Projects 6.10, 7.13
		4. The chemistry and mineralogy of site specific aquifer surfaces of near- and far-field host rocks should be characterized in detail.	A	Project 7.7
2.5 Transport models incorporating chemical reactions	Present transport models do not incorporate comprehensive chemical reactions that adequately simulate radionuclide transport.	1. The levels of sophistication required of chemical algorithms describing radionuclide transport must be addressed, especially with respect to complex chemical reactions in the near field.	A	Project 6.5
		2. An adequate treatment of precipitation, including reversible dissociation, must be incorporated in radionuclide transport models.	A	Projects 6.1, 6.5
		3. Transport models should be validated using dynamic column experiments if such transport processes are deemed necessary to the understanding of radionuclide migration.	A	Project 6.14
3.2.1. Low permeability backfill materials	Permeabilities and porosities of backfill materials may drastically affect the degree of containment of radionuclides.	1. The hydraulic conductivity and porosity of specific backfill materials as a function of compaction pressure and chemical saturation state should be defined experimentally.	A	Project 5.2
		2. Better estimates of related parameters should be defined for actual repository conditions; e.g., hydraulic gradients should include site specific temporal variations in hydraulic, thermal, and chemical potential gradients. Diffusivities of specific radionuclides should be measured in clays as a function of compaction pressure and electrolyte concentration.	A	Project 7.9

^aIn Apps et al., 1982^{*}Projects are described in numerical order in Table 2.2.

Table 2.1 (cont.)

Section/Subject	Problem	Recommendations	Priority	Assignment*
3.2.2 Diffusional transport of radionuclides through a nonsorbing barrier	In order to estimate the extent to which radionuclides would be contained in the backfill, the limiting case of a nonsorbing barrier in spherical geometry must be considered first.	1. The source term must be defined. Data should be acquired on dissolution rates of waste form, degree of congruity of dissolution, identities of possible solid secondary phases formed in the source region, and identities and concentrations of solute species produced in dissolution or in equilibrium with secondary phases.	A	Projects 4.9, 4.10
		2. Transport properties pertaining to engineered barriers must be measured, i.e., diffusion coefficients of solute species and tortuosities. If convective transport is also included, estimates of barrier dispersivities, porosities, and permeabilities are required.	A	Projects 1.1, 3.2, 7.12
		3. Modeling of transport processes through multiple layered media should be undertaken.	B	Project 6.12
		4. Further investigation should be made of transport modeling in the temporal domain following disappearance of the source term, i.e., complete dissolution of the waste form and solid.	B	Project 6.13
		5. Transport modeling should be extended to arrays of waste canisters surrounded by barrier materials.	B	Project 6.12
		6. Cross-diffusional coupling and coupling of mass fluxes to thermal fluxes should receive more attention.	C	Project 6.7
3.2.3 Transport of radionuclides through the backfill with sorption	Estimates are needed of barrier effectiveness in retarding radionuclides so that barrier function may be better defined and optimized and the problem of far-field containment be better defined.	1. More realistic models are needed to assess the effectiveness of engineered barriers in reducing the rate of radionuclide migration. Such models should incorporate realistic boundary conditions and modeling of the host-rock environment. Fractured media should be considered. The chemical interactions included should adequately predict migration rates.	A	Projects 6.1, 6.5, 6.12, 6.13
		2. Acceptability criteria should be developed that do not depend on biosphere dilution. A biosphere relevance factor should be defined and computed for each repository.	A	Outside scope of geochemistry research

*In Apps et al., 1982

*Projects are described in numerical order in Table 2.2.

Table 2.1 (cont.)

Section/Subject	Problem	Recommendations	Priority	Assignment*
3.2.4 Criticality potential in a repository	Fissile isotopes may be redistributed in a geologic repository and become critical.	1. Criticality assessments should address the physical or chemical feasibility for the accumulation of fissile isotopes in canisters or adjacent geologic and backfill materials.	C	Project 6.15
		2. Assessments made under 1 should be compared with analogous natural systems.	C	Outside scope of present evaluation
3.3.1 Effect of waste emplacement on the near-field environment	Phase changes in rocks caused by radioactive heating could cause unanticipated effects on radionuclide migration.	1. Further evaluation should be made of post-repository-closure response of host rocks to re-saturation, thermal stresses, intrusion of backfill, and backfill overpressures.	C	Outside scope of geochemistry research
		2. Introduction of oxygen scavengers in backfills should be considered, particularly in granitic, rhyolitic, tuffaceous, or oxidized sedimentary terranes where ferrous ion concentrations in host-rock minerals are very low.	B	Projects 5.4, 5.5, 7.15
		3. The transient generation of a steam pocket adjacent to the waste canisters should be investigated for chemical and physical changes that would adversely affect radionuclide containment.	C	Project 1.9
		4. Spalling and chimney formation resulting from compaction of poorly consolidated backfill should be investigated and the consequences of increased groundwater circulation established.	C	Outside scope of geochemistry research
		5. Alteration of basalts and granites under hydrothermal conditions expected in a repository should be reviewed in greater depth and expected secondary minerals predicted for given bulk chemical compositions.	B	Project 5.1
		6. The mechanism of fracture sealing by secondary minerals in shales should be examined more thoroughly and techniques developed to ensure such mechanisms might operate in the near field of a repository.	A	Project 3.3
		7. Further review and research is required to understand the effects of near-field mineral alteration and geomechanical changes on radionuclide transport.	B	Project 7.11

) in Apps et al., 1982

*Projects are described in numerical order in Table 2.2.

Table 2.1 (Cont'd)

Section/Subject)	Problem	Recommendations	Priority	Assignment*
3.3.2 Effects of temperature gradients on permeability in the near-field region	It is not known how the near-field host rocks will respond chemically to thermal gradients.	1. Further research on this subject should be postponed until the detailed thermal history of a repository can be calculated.	B	Project 7.11
		2. If thermal gradients and maximum temperatures are large enough to induce geochemical dissolution and precipitation, then mass transport experiments should be conducted under simulated thermal conditions using site specific material.	B	Projects 2.2, 7.9
3.4 Groundwater dating	Some means of estimating the age of groundwaters is needed to reconcile hydrological predictions in the far-field.	1. Groundwater dating techniques should be applied as a site evaluation method, using as many techniques as possible. Studies should be conducted to determine whether changes in groundwater chemistry will affect age measurements.		Project 7.5
		2. Research should continue on the multiple application of several dating techniques to get better evidence of the applicability of each technique.		Project 7.4
		3. More attention should be paid to groundwater sampling methods and the size of sample realistically recoverable yet still representative. Sampling quality must be adequate for the most sensitive method.		Project 7.8
		4. A new emphasis needs to be placed on research using water dating techniques to detect low-volume but high-velocity paths through an otherwise slow-moving groundwater system.		Project 7.6

)in Apps et al., 1982

*Projects are described in numerical order in Table 2.2.

2.2.2 Classification

Recommendations are broadly classified into seven elements, each element representing a stage in the evaluation process to clarify the geochemical problems.

These elements are:

1. Bounding conditions
2. Transported forms
3. Transport mechanisms
4. Retardation mechanisms
5. Physical/chemical properties of barriers
6. Chemical transport algorithms
7. Field evaluations

Element 1, Bounding Conditions, contains recommendations that serve largely to define the scope of research needs specified in the remaining six elements. Elements 2, 3 and 4 are directly concerned with recommendations relating to radionuclide transport and to clarification of the mechanisms involved. Element 5 contains recommendations having a bearing on the interrelationship of geochemical processes with the physical nature of the barrier system. Recommendations are here aimed at resolving issues requiring classification before chemical transport algorithms can be usefully employed in predictive modelling. Element 6 addresses issues relating to the development of valid transport algorithms. Finally, there must be some means of verifying as far as is possible, the theoretical, experimental and model concepts evolving from the recommendations of elements 2 through 6. These are incorporated as recommendations for field evaluations in element 7. This element also contains recommendations for studies designed to clarify and bound problems defined in elements 2 through 5.

The organization of these elements differs from that of the issues presented Chapter 1-3 in Apps et al., (1982). This is because it was found that the recommendations emerging from the evaluations in this report had broader implications than the classification based on barriers alone. It is also consistent with the logic developed in Section 1.2.2, which allows for a sequential flow of information from the development of concepts through field verification. Furthermore, it avoids repetition of similar topics for different barriers.

The recommendations classified according to elements 1 through 7 lead naturally to both the specification and delineation of research needs. The final column of Table 2.1 represents the disposition of each recommendation. Where projects are proposed, they are coded according to the classification scheme listed above. Proposed research is summarized in Table 2.2 starting on page 28. Not all of the recommendations would lead to research activities however. Some involve no action or alternatively limit the scope of proposed research.

2.2.3 Level of Effort

The levels of effort for the completion of research for each project, and given in Table 2.2, are in reality intuitive estimates based on the judgement of experts in the same or related fields. Better estimates can not be made at this stage of program development. The level of effort could vary, depending on the scientific staff ultimately responsible for a project. Accurate estimates would also necessitate detailed task breakdowns for each project, a laborious exercise that would require the participation of potential principal investigators, and which is beyond the scope of this report. The initial guesses may be optimistic, as is invariably the case, and more careful scoping may project greater efforts than are given here.

Final planning prior to implementation may also necessitate that a particular research project be accelerated to resolve a particular issue earlier in the course of the program. An accelerated project would require additional scientific staff who might not perform the needed research in as efficient a manner as a smaller group would over a longer period.

2.2.4 Time Requirements

Estimates of time requirements to complete a project suffer from the same limitations as those for levels of effort (above). Time requirements are also constrained by the need to accomplish sufficient research to accommodate DOE schedules for construction a repository. The duration of various projects should therefore be adjusted to meet this schedule, and the levels of effort altered accordingly. A rigorous attempt to meet this constraint has not been attempted in the present planning effort.

Time requirements are also given with each project in Table 2.2.

2.2.5 Cost

The present cost of supporting one staff scientist at a major research institution is approximately \$100K p.a. This figure includes basic salary, fringe benefits, overhead and supporting services, but does not cover the cost of technicians, capital equipment or other unusual expenses. This approximate figure may be used to estimate both annual and cumulative costs for the geochemistry research program.

2.3 COMPARISON WITH ONGOING RESEARCH

Summaries of research programs underway in 1981, and relating to the chemistry of waste isolation in geologic repositories both in the United States and elsewhere, are summarized in Appendix B. These projects are correlated with the proposed research emerging from the recommendations from Apps et al., (1982) as indicated at the foot of each project page in Table 2.2. Many of the ongoing research projects are specific to particular rock types and these have also been identified for each project.

[text continued on page 91]

Table 2.2. Proposed Projects.

ELEMENT 1. BOUNDING CONDITIONS

Project: 1.1 (CHANGES IN BACKFILL PROPERTIES)

Title: Investigate, in the laboratory, long-term changes in physical and chemical properties of backfills subjected to repository conditions. (P = 500 bars max, T = 300°C max.)

Priority: B Changed physical and chemical properties of the backfill will influence the rate of radionuclide migration in as yet undetermined ways. This will affect predictions of radionuclide containment at a given repository.

Justification: The physical and chemical properties of backfills and host rocks can change markedly in the time between waste emplacement and possible release of radionuclides (1,000 years). The initial properties of the barrier media may therefore bear little relationship to those encountered by migrating radionuclides.

Expected Results: Properties of backfills and host rocks will be determined. Those whose properties cannot be predicted will be rejected as suitable barrier media.

Effort†: FTE p.a. - 8; Duration - 3 years

Notes: This project applies primarily to backfill. Comparison with natural analogues, e.g., Project 5.1, would help. Task would be simplified if lower repository temperatures were permitted by policy.

Link*					Existing Projects			
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
	7.11		19?	21,22 45?			35?	18?,20 44,89, 90

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 1 (cont.)

Project: 1.2 (UNCONTAMINATED SAMPLING)

Title: Develop groundwater sampling procedures for uncontaminated sample procurement.

Priority: B If the research is not successfully accomplished, estimation of radionuclide migration rates through the barrier system will be impaired, and predictions of the degree of containment of a given repository will be less certain. This could necessitate rejection of an otherwise acceptable site.

Justification: Uncontaminated groundwater samples are essential for establishing baseline conditions and interpretation of regional and local hydrology. Existing techniques are not adequate, particularly in low-permeability formations.

Expected Results: Downhole and underground samplers will be capable of securing a sample of water sufficient for comprehensive chemical and isotopic analyses.

Effort†: FTE p.a. - 4; Duration - 2 years

Notes: Engineering design and fabrication are included.

Link*					Existing Projects			
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
	7.8			3,21†				

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 1 (cont.)

Project: 1.3 (GROUNDWATER OXIDATION STATE)Title: Develop and demonstrate a definitive means of characterizing the oxidation state of groundwaters.Priority: B See Project 1.2.Justification: The transport of several toxic radionuclides is dependent upon oxidation state (e.g., ^{99}Tc , ^{240}Pu , ^{239}Pu). Also, canister integrity and engineered barrier properties are affected by oxidation state. Unambiguous and reliable methods of measuring the oxidation state in groundwaters have not been demonstrated.Effort†: FTE p.a. - 1.5; Duration - 2 yearsExpected Results: A satisfactory fieldable technique will be developed.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
	7.8			103?				2,98

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 2. TRANSPORTED FORMS

Inorganic ComplexesProject: 2.1 (COMPLEXES OF FISSION PRODUCTS)

Title: Investigate the inorganic complexes of fission product elements such as Se, Sn, Pd, and Tc at temperatures to 175°C in natural groundwaters.

Priority: A Migration rates of the listed fission products under repository conditions are not known. Therefore there is presently no means of defining barrier parameters necessary for their containment. Without this knowledge, criteria will not exist to determine the acceptability of a given site.

Justification: The aqueous speciation of selenium and the relative importance of Sn and Pd complexes in solution are not known. It is also not clear what the most stable oxidation state of Tc is in solution. Complexation of these elements with respect to common anions such as OH^- , Cl^- , HCO_3^- , CO_3^{2-} , SO_4^{2-} , and F^- should also be investigated.

Expected Results: The chemistry of Se, Sn, Pd, and Tc in groundwater will be determined. Initial results will be obtained at 25°C, possibly narrowing scope of research at temperatures to 175°C.

Effort†: FTE p.a. - 3; Duration - 2 years

Notes: The significance of these species may be modified as a result of estimates of maximum fluxes of these elements based on the solubilities of precipitated solids as determined under Project 4.9. Groundwater compositions at elevated temperatures must also be known.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
	3.1			3				91
	4.1							
	4.4							
	6.3							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 2 (cont.)

Inorganic Complexes (cont.)Project: 2.2 (MASS TRANSPORT IN A THERMAL GRADIENT)

Title: Conduct mass transport experiments in the laboratory under simulated thermal conditions using site specific material from the near-field region.

Priority: B Changes in physical properties of near-field host rocks will affect the rate of radionuclide migration in as yet undetermined ways. This will affect predictions of radionuclide containment at a given repository.

Justification: It is not known how mass transport in thermal gradients may affect permeability and porosity in the near field. The purpose of this project is to elucidate chemical processes that might occur and establish their significance.

Expected Results: Qualitative estimates of chemical transport in the near field will be accomplished.

Effort†: FTE p.a. - 2; Duration - 2 years

Notes: This project is similar to Project 5.2, but relates specifically to near-field alteration from specific sites.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
2.4	6.5	15?,35,	15?,35,	21		4,12	13?,14	20?,71
	7.9	38	38					
	7.10							
	7.11							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 2 (cont.)

Inorganic Complexes (cont.)Project: 2.3 (COMPLEXES OF ACTINIDES)

Title: Investigate inorganic complexation of actinides and their daughters at temperatures to 175°C in natural groundwaters.

Priority: A Without information on the inorganic complexation of actinides and their daughters in the temperature range of interest, it will be impossible to predict the barrier thickness or compositions required to contain them. This could affect the design of a repository and selection of a site.

Justification: Little is known about aqueous inorganic speciation of actinides and some of their daughters under conditions expected in typical groundwaters. Specifically, the complexation constants of relevant actinides (especially Am and Cm) with phosphate and the complexation constants of trivalent and tetravalent actinides with carbonate and hydroxyl species should be measured. In addition, the role of UO_2^+ and PuO_2^+ in controlling solution concentrations should be established.

Expected Results: The role of actinide complexes in radionuclide transport will be clarified.

Effort†: FTE p.a. - 3.5; Duration - 3 years

Notes: Significance of these complexes may be modified as a result of estimates of maximum fluxes of elements based on solubilities of precipitated solids as determined under Project 4.10. Groundwater compositions at elevated temperatures must also be known.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
2.4	3.1		19?					2,16,
	4.2							17,90?,
	4.4							99
	6.3							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 2 (cont.)

Inorganic Complexes (cont.)Project: 2.4 (FLUID COMPOSITION TO 300°C)

Title: Investigate experimentally, in the laboratory, the effect of chemical reactions on fluid composition in the backfill and near field at temperatures between 25 and 300°C.

Priority: C Groundwater composition at elevated temperatures influences radionuclide migration by affecting the degree of complexing. The groundwater composition is itself determined by the barrier medium. Therefore this project has implications for barrier selection and waste containment. However, existing thermochemical and experimental data may already give first-order estimates of significance.

Justification: Groundwater composition is modified by reaction with the barrier medium at elevated temperatures. This effect must be understood in predicting long-term processes of alteration (Projects 1.1 and 2.2) and radionuclide transport (Projects 2.1 and 2.3).

Expected Results: The variation in groundwater composition as a function of temperature will be determined.

Effort†: FTE p.a. - 2.7; Duration - 3 years

Notes: Lack of thermodynamic data on solid phases as a function of temperature and thermodynamic properties of aqueous species could hinder accomplishment of this project.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
	2.2			3,21				2?,16?
	2.3							
	6.2							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 2 (cont.)

Organic ComplexesProject: 2.5 (ORGANIC COMPLEXES)

Title: Investigate organic complexes of important fission product elements and actinides.

Priority: B If organic complexes of actinides are significant, they could influence radionuclide containment in a repository, thereby affecting repository design and site selection.

Justification: If organic complexes are present in groundwater, their identification and significance in transporting radionuclides should be established.

Expected Results: Certain organic complexes will be found significant in a limited number of environments.

Effort†: FTE p.a. - 4; Duration - 2 years

Notes: Estimates of effort required are very speculative. This research depends on a prior demonstration of significance from field measurements under Project 7.1.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
7.1	4.3 6.3			3,59?				1,2?, 16?,90

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 2. (cont.)

Organic Complexes (cont.)Project: 2.6 (HUMIC-FULVIC ACID COMPLEXES)Priority: B See Project 2.5.Title: Determine the stability constants, electrochemical data, and chemical characteristics of radionuclide/humic-fulvic and related carboxylic acid complexes.Justification: Naturally occurring humic-fulvic acids and related carbolic acid complexes may be major complexing agents of several important radionuclides.Effort†: FTE p.a. - 3; Duration - 2 yearsExpected Results: Stability constants of complexes of humic-fulvic acids with significant radionuclides will be determined.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
7.1	4.3 6.3			3				37,49?

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 2 (cont.)

ColloidsProject: 2.7 (COLLOIDS FROM HLW)Title: Examine the properties and radionuclide content of colloidal forms produced through the degradation of high-level wastes by groundwaters.Priority: C If colloids form in significant amounts, radionuclide containment could be decreased, thereby affecting repository design and site selection.Justification: Colloidal particles as a source of radionuclides is neither established nor quantified. This should be done.Expected Results: Concentration of colloidal particles and the resulting radionuclide flux will be determined. If significant, it should be incorporated in transport models.Effort†: FTE p.a. - 2; Duration - 2 years.Notes: The significance of the transport mechanism has yet to be demonstrated. If radiocolloid transport is negligible, then production of radiocolloids at the source will not be significant.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
3.5	6.13			3,21?				85?

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)**ELEMENT 2 (cont.)****Colloids (cont.)****Project: 2.8 (RADIONUCLIDE COLLOIDS)**

Title: Produce true colloids of insoluble species of important radionuclides under groundwater conditions anticipated at the waste-storage site.

Priority: B See Project 2.7.

Justification: Changes in oxidation state or concentrations of other components in the groundwater can cause gross supersaturation and consequent colloid formation. The potential significance of this phenomenon should be established.

Expected Results: The conditions under which colloid formation could occur and with which elements will be determined. The significance of radionuclide colloids in radionuclide migration will be established.

Effort†: FTE p.a. - 2; Duration - 2 years

Notes: This research will depend on data being available from Projects 2.1 and 3.3.

Link*					Existing Projects			
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
3.5	6.13		19?					1,17, 85?

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 3. TRANSPORT MECHANISMS

Project: 3.1 (DIFFUSIVITIES RESEARCH)Title: Measure diffusion coefficients of solute species to 175°C.Priority: B Higher diffusion rates of radionuclide species at elevated temperatures will decrease radionuclide containment. This effect must be taken into account because of its impact on repository design and site selection.Justification: Diffusion coefficients are known only for a limited number of solute species at 25°C. Data on relevant species to 175°C must be obtained to permit adequate modeling of radionuclide transport.Expected Results: Data on diffusion coefficients of relevant species will be obtained.Effort†: FTE p.a. - 4; Duration - 2 yearsNotes: Diffusion coefficients of most aqueous species are similar. Scope could be reduced with a few actual measurements. Relevant species must be identified through Projects 2.1 and 2.3.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
2.1	6.6							54?,101?
2.3	3.3							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)**ELEMENT 3 (cont.)****Project: 3.2 (DIFFUSIVITIES)**

Title: Establish significance of variation in diffusion coefficients among different aqueous radionuclide complexes and their variation with temperature.

Priority: C Variations in diffusion rates of species in solution will influence the relative retardation of different radionuclides in the backfill. This will affect repository design and site selection, which, however, is expected to be minor.

Justification: Variation in the magnitude of diffusion coefficients of different aqueous species may be small in comparison with the magnitude of errors from other sources when predicting radionuclide migration. This needs to be established before further research is done on this subject.

Effort†: FTE p.a. - 1; Duration - 1 year

Expected Results: The significance of diffusion coefficient variations will be established and predictions of radionuclide migration will be made.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other

3.1

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 3 (cont.)

Project: 3.3 (CROSS DIFFUSIONAL COUPLING)

Title: Investigate significance of cross diffusional coupling and coupling of mass fluxes to thermal fluxes.

Priority: C See Project 3.2.

Justification: The significance of cross coupling of diffusional fluxes and coupling of mass to thermal fluxes is neither established nor quantified. These phenomena should be evaluated to 175°C.

Expected Results: The significance of the phenomena will be determined.

Effort†: FTE p.a. - 1; Duration - 2 years

Notes: Should the phenomena studied prove significant, further research will be needed. Species to be studied will be identified under Projects 2.1 and 2.3.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other

3.1 3.4

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 3 (cont.)

Project: 3.4 (CROSS DIFFUSIONAL COUPLING RESEARCH)

Title: Determine magnitude of cross diffusional coupling and coupling of mass fluxes to thermal fluxes.

Priority: C See Project 3.2.

Justification: If cross coupling of diffusional fluxes and coupling of mass to thermal fluxes is proved significant, these phenomena should be quantified to 175°C.

Effort†: FTE p.a. - 4; Duration - 2 years

Expected Results: Data on the magnitude of the cross diffusional coupling phenomena will be obtained.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
3.3	6.7							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 3 (cont.)

Project: 3.5 (COLLOID DIFFUSION)

Title: Determine experimentally whether colloidal particles will diffuse through rock and backfill pores. Establish the relative importance of radionuclide transport by colloid diffusion.

Priority: C If radionuclide-containing colloids diffuse at a significant rate, they could affect radionuclide containment in the backfill. This will impact repository design and site selection, which, however, is expected to be minor.

Justification: Calculations show that gravity settling will remove all uncharged particles greater than 0.01 μm from solution, thereby suggesting that colloidal transport may not be significant unless the particles are charged. Theoretical predictions on uncharged colloids must be verified experimentally. The effect of charge on colloid transport must be established. Sensitivity studies should establish whether transport of radionuclide-containing colloids is significant.

Expected Results: Theoretical results will be verified.

Effort†: FTE p.a. - 2; Years - 2

Notes: Results of this study will affect relevance of Projects 2.5 and 2.6.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
	2.7							85?
	2.8							
	6.8							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 3 (cont.)

Project: 3.6 (INTERPRET BACKFILL CHANGES)

Title: Reconcile experimental studies of long-term changes in physical and chemical properties of backfill materials with chemistry of existing groundwater.

Priority: A The selection of backfills possessing the needed integrity and stability is essential to the design of a waste repository. Without this knowledge, radionuclide containment and canister integrity is thrown in doubt.

Justification: The mechanisms bringing about changes in backfill properties must be understood if long-term projections are to be made regarding the stability of backfill materials.

Effort†: FTE p.a. - 1; Duration - 1 year

Expected Results: Mechanisms will be identified and quantified.

Link*					Existing Projects			
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
1.1	6.5			21,22				20
2.4	7.11							
6.1								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 4. RETARDATION MECHANISMS

AdsorptionProject: 4.1 (ADSORPTION FUNDAMENTALS)

Title: Examine the fundamental relationship between selected radionuclide sorption mechanisms and the surface area of mineral aggregates.

Priority: D Information on sorption fundamentals will facilitate the development of models describing radionuclide transport, possibly accelerating the resolution of geochemistry issues.

Justification: The relationship between mineral surface area and radionuclide adsorption is not clearly defined. Without understanding both the mechanisms of adsorption or their relationship to surfaces of minerals and mineral aggregates (rocks) K_d 's cannot be defined in terms of measurable rock properties. There is therefore no way of relating laboratory sorption studies to field conditions.

Expected Results: A basis for models relating sorption phenomena (K_d 's) to specific surfaces of rocks will be obtained.

Effort†: FTE p.a. - 4; Duration - 3 years

Notes: This study requires fundamental knowledge of sorption of selected fission and actinide elements, much of which is in the process of being obtained.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
2.1	5.6		37?	3				1,54,
4.5	6.4							84?
4.6								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 4 (cont.)

Adsorption (cont.)Project: 4.2 (SORPTION ON SPECIFIC MINERALS)Title: Examine sorption of selected radioelements on specific minerals.Priority: B The selective sorption of some radionuclides by specific minerals may have a major effect on radionuclide retardation. This could affect backfill selection, repository design, and site selection.Justification: Some radionuclides may sorb preferentially on relatively minor minerals in host rocks, e.g., trivalent actinides on phosphates or technetium on sulfides. Consequently, these minerals could strongly affect migration of specific radionuclides. This possibility should be clarified.Expected Results: Minor phases having significant retardation impact with respect to specific radionuclides will be identified.Effort: FTE p.a. - 2; Duration - 3 yearsNotes: The magnitude of this study is difficult to estimate because the scope of research needed is not known.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
2.3	6.4		19?	3,103				1?,54
4.5	6.4							
4.6								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 4 (cont.)

Adsorption (cont.)Project: 4.3 (ORGANIC SORPTION)Title: Study sorption of radionuclide organic complexes on mineral surfaces.Priority: B See Project 2.5.Justification: If organic complexes are significant in causing radionuclide transport, then their sorption properties must be understood.Expected Results: The sorption of organic complexes as a function of aqueous phase and substrate composition will be obtained.Effort†: FTE p.a. - 3; Duration - 2 yearsNotes: This research should be initiated only after the importance of metal organic complexes has been established and organic species identified (Projects 2.4 and 7.1).

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
2.5	6.5			3				1?
2.6	6.9							
4.5								
4.6								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 4 (cont.)

Adsorption (cont.)Project: 4.4 (SORPTION TO 175°C)Title: Conduct a few carefully controlled adsorption experiments at temperatures to 175°C to establish empirical or preferably theoretical temperature dependence of sorption.Priority: A Because sorption of radionuclides could be dramatically affected by temperature, radionuclide retardation would be likewise affected in a repository. This would impact repository design and site selection.Justification: Virtually nothing is known about the temperature dependence of adsorption. This should be understood, as it could have a significant effect on retardation in the thermal regime of the repository.Expected Results: Adsorption as a function of various solution parameters and temperature for one simple case (e.g., Cs) and one or two other important radionuclides (e.g., Tc and Pu) will be determined.Effort†: FTE p.a. - 3; Duration - 3 yearsNotes: Experiments are expected to be difficult to perform.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
2.1	6.4		55?	3,21?			55?	1,84
2.3								
4.5								
4.6								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 4 (cont.)

Adsorption (cont.)Project: 4.5 (MINERAL SURFACE CHANGES I)

Title: Conduct laboratory and theoretical studies to determine long-term changes in mineral surfaces and their effect on radionuclide adsorption.

Priority: A Long-term sorption reactions could have a dramatic effect in retarding radionuclides in the far field. This would have ramifications in repository design and site selection.

Justification: Research is needed to establish the validity or otherwise of short-term sorption studies and to assess the impact of "weathered" surfaces on sorption.

Expected Results: Preliminary findings will be obtained to establish whether short-term tests of radionuclide adsorption are meaningful.

Effort†: FTE p.a. - 2; Duration - 2 years

Notes: Experiments may be difficult to design. Results may affect Projects 4.1 to 4.4.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
4.4	4.1			3?			14?	1?,54
	4.2							
	4.3							
	4.4							
	4.6							
	6.10							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 4 (cont.)

Adsorption (cont.)Project: 4.6 (MINERAL SURFACE CHANGES II)

Title: Conduct laboratory and theoretical studies to determine long-term changes in mineral surfaces and their effect on radionuclide adsorption.

Priority: A See Project 4.5.

Justification: Research is needed to establish the validity or otherwise of short-term sorption studies and to assess the impact of "weathered" surfaces on sorption.

Expected Results: A final determination will be made as to whether short-term tests of radionuclide adsorption are meaningful. Long-term effects will be quantified.

Effort†: FTE p.a. - 2; Duration - 2 years

Notes: Experiments may be difficult to design. Results may affect Projects 4.1 to 4.4.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(E)	Basalt	Tuff	Granite	Shale	Other
4.5	4.1			3			14 ²	17,54
	4.2							
	4.3							
	4.4							
	6.10							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 4 (cont.)

Ion ExchangeProject: 4.7 (SCOPE GRAIN BOUNDARY AND VOLUME DIFFUSION)

Title: Perform scoping studies of grain boundary and volume diffusion mechanisms in appropriate minerals at temperatures to 175°C using state-of-the-art techniques (e.g., XPS and Auger electron spectroscopy).

Priority: A Given boundary and volume diffusion could strongly influence radionuclide retardation and thereby affect repository design and site selection.

Justification: The significance of these mechanisms in retarding radionuclides is not established.

Expected Results: It will be determined whether these mechanisms are important and whether further research should be done.

Effort†: FTE p.a. - 2; Duration - 1 year

Notes: Care should be taken in the selection of appropriate radioelements for study. Continuation of study is Project 4.7.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other

4.8

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)**ELEMENT 4 (cont.)****Ion Exchange (cont.)****Project: 4.8 (STUDY GRAIN BOUNDARY AND VOLUME DIFFUSION)**

Title: Perform detailed studies of grain boundary and volume diffusion in appropriate minerals to 175°C.

Priority: A See Project 4.7.

Justification: Output from Project 4.5 indicates that such mechanisms are significant and relevant to radionuclide migration.

Expected Results: A determination will be made as to whether short-term tests of radionuclide adsorption are meaningful. Long-term effects will be quantified.

Effort†: FTE p.a. - 2; Duration - 3 years

Notes: See note in Project 4.6.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
4.7	6.10							1?

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 4 (cont.)

PrecipitationProject: 4.9 (Sn AND Pd SOLUBILITY)

Title: Determine the relative importance of Sn and Pd solution species and their effect on Sn and Pd solubility in the natural environment.

Priority: B Sn and Pd solubility should be determined to establish whether special measures need to be taken in designing the barrier system of a repository.

Justification: Research on solid phases of specific radioelements is needed to ascertain the maximum concentration of these elements in natural groundwaters and whether they are significant in controlling radionuclide transport.

Effort†: FTE p.a. - 2; Duration - 3 years

Expected Results: Relevant phases will be identified and their solubility products obtained.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other

6.3

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 4 (cont.)

Precipitation (cont.)Project: 4.10 (ACTINIDE PRECIPITATES)

Title: Identify and determine solubility products of trivalent actinide phosphate compounds and trivalent and tetravalent carbonates and silicates of actinides.

Priority: B It is expected that actinide solid phase solubilities will be relatively low. However, they must be quantified in order to establish whether special measures need to be taken later in designing the barrier system of a repository.

Justification: Same as Project 4.9

Effort†: FTE p.a. - 3; Duration - 3 years

Expected Results: Same as Project 4.9

Link*				Existing Projects				
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
	6.3		19					22,17, 84

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 5. PHYSICAL/CHEMICAL PROPERTIES OF BARRIERS

Precipitation (cont.)Project: 5.1 (ALTERATION OF BASALTS AND GRANITES)

Title: Review and quantify alteration of basalts and granites under the hydrothermal conditions expected in the near field in a repository. Predict anticipated secondary minerals for given bulk compositions.

Priority: A Understanding how basalts and granites alter in the near field is needed so that the suitability of these rocks as hosts for a repository can be evaluated. This will affect site selection.

Justification: Considerable uncertainty exists as to how basalts and granites will alter in the near field when subjected to the thermal pulse caused by radionuclide decay.

Effort†: FTE p.a. - 1; Duration - 1 years

Expected Results: Semiquantitative estimates will be made of the secondary phase assemblages expected during alteration in the near field.

Link*					Existing Projects			
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
	5.3			21,22?, 34			12?,42?	

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 5 (cont.)

Project: 5.2 (BACKFILL COMPACTION)

Title: Evaluate the effect of pressure on the compaction of backfill materials and the relation of this to porosity, permeability, tortuosity, specific surface area, diffusivities of ions, and radionuclide migration as a function of temperature and chemical saturation state.

Priority: A This research is needed so that the performance of engineered backfill barriers may be predicted. This affects repository design.

Justification: Most studies of radionuclide sorption are made on disaggregated or uncompacted material, neither of which is representative of in situ conditions. The effect of compaction must be evaluated to assess its significance.

Expected Results: The variation in physical parameters as a function of pressure, temperature, and chemical saturation state will be obtained.

Effort: FTE p.a. - 4; Duration - 4 years

Notes: Experiments could be difficult to perform because of transient behavior. The project could be divided into subtasks.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
	6.11	35	35	22				
	7.9							
	7.11							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 5 (cont.)

Code: 5.3 (PRECIPITATION AND PERMEABILITY)

Title: Conduct mass transport experiments to measure dissolution and precipitation and its effect on permeability and porosity of backfill and host rock materials at temperatures to 300°C.

Priority: A See Project 1.1.

Justification: Temperature gradients around canisters may induce chemical migration that will effect permeability and porosity of the barrier medium.

Expected Results: Variations in permeability and porosity as a function of time and thermal gradient will be obtained. The information may be incorporated into a single model.

Effort†: FTE p.a. - 2; Duration - 3 years

Notes: This project is similar to Project 2.2 but relates primarily to backfill alteration.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
5.1	7.9 7.10 7.11	15?	15?	21?,22?				

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 5 (cont.)

Project: 5.4 (OXYGEN UPTAKE)

Title: Perform laboratory studies to measure the uptake of oxygen in granites, rhyolitic tuff, or oxidized argillites.

Priority: B Project may affect backfill barrier design, especially if waste is stored in granitic or acidic tuffaceous rocks.

Justification: Low oxygen uptake in rocks poor in ferrous iron could lead to long-term persistence of oxidizing conditions unless appropriate remedial action is taken.

Effort: FTE p.a. - 0.5; Duration 2 years

Expected Results: A quantitative measure of oxygen uptake will be made and remedies recommended.

Link*						Existing Projects			
In	Out	Salt(D)	Salt(E)	Basalt	Tuff	Granite	Shale	Other	
	5.5				103?				

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 5 (cont.)

Project: 5.5 (OXYGEN GETTERS)Title: Perform tests on appropriate oxygen getters in backfill host rocks.Priority: B See Project 5.4.Justification: Need to find means of combating problems cited in Project 5.4.Effort†: FTE p.a. - 0.5; Duration - 2 yearsExpected Results: A method for removing excess oxygen after repository closure will be identified.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
5.4	7.15			103?				

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 5. (cont.)

Project: 5.6 (SURFACE AREA AND ADSORPTION)

Title: Develop a means of measuring surface area that relates to radionuclide sorption.

Priority: C Successful accomplishment of this project would permit an easy way of characterizing barrier materials, thereby facilitating site characterization and selection.

Justification: Most traditional methods of measuring surface area yield results that show a very poor correlation with radionuclide sorption. A better method must be found.

Expected Results: A simple and effective technique will be identified for measuring surface area in the laboratory and in the field that shows a good correlation with radionuclide adsorption.

Effort†: FTE p.a. - 1.5; Duration - 2 years

Notes: This project should be run in conjunction with Project 4.1.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
4.1	7.7		55?,58?	3			55?,58?	1?,54?

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. CHEMICAL TRANSPORT ALGORITHMS

Aqueous-Solution/Solid-Phase Equilibrium ModelsProject: 6.1 (SOLUTION ALGORITHM)

Title: Develop an aqueous solution algorithm capable of incorporating all major groundwater components and suitable for modeling barrier-medium/aqueous-phase interactions to 300°C. If possible, ionic strengths should be modeled between 0 and 5. Solid phases in equilibrium with the aqueous phase should also be modeled.

Priority: A Without the capability of modeling aqueous-phase chemistry and its relationship to coexisting solid phases, there would be no means of predicting radionuclide migration through the barriers of the repository system.

Justification: This algorithm is necessary to predict the dissolution of barrier materials when subjected to thermal regimes in a repository.

Expected Results: A chemical algorithm suitable for modeling groundwater interactions will be developed, in which thermodynamic equilibrium between aqueous species and solid phases is assumed.

Effort†: FTE p.a. - 3; Duration - 3 years

Notes: Many algorithms have already been developed, but further refinement is necessary. A stumbling block is lack of adequate thermodynamic data.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
	3.6		92?	59?				71,72,
	6.2							73,84
	6.3							
	6.5							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. (cont.)

Aqueous-Solution/Solid-Phase Equilibrium Models (cont.)Project: 6.2 (SOLUTION ALGORITHM DATA INPUT)

Title: Incorporate thermodynamic data on solid phases and aqueous species in the aqueous-solution algorithm.

Priority: A See Project 6.1.

Justification: Relevant thermodynamic data must be incorporated to make effective studies of aqueous-phase barrier interactions.

Effort†: FTE p.a. - 3; Duration - 1 year

Expected Results: Data will be incorporated in a chemical algorithm capable of modeling groundwater interactions in which thermodynamic equilibrium between aqueous species and solid phases is assumed.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
2.4	6.3							84
6.1								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. (cont.)

Aqueous-Solution/Solid-Phase Equilibrium Models (cont.)Project: 6.3 (RADIONUCLIDE DATA INPUT)

Title: Incorporate in the algorithm developed under Project 6.1 aqueous speciation and solid phases of relevant radionuclide elements, including organic constituents. The system should be modeled at temperatures to 175°C.

Priority: A This project is necessary to permit predictions of radionuclide transport through the barriers of a repository. Without this, it will not be possible to predict repository effectiveness in containing radionuclides.

Justification: Radionuclide data must be incorporated to calculate maximum expected concentrations and speciation of radionuclides coexisting with solid phases. Such information is required to estimate maximum fluxes of radionuclides and to aid in the design of laboratory and field studies and their subsequent interpretation.

Expected Results: A chemical algorithm will incorporate data suitable for predicting the equilibrium behavior of radionuclides in the aqueous phase in coexistence with solid phases and in the presence of barrier materials.

Effort†: FTE p.a. - 2; Duration - 1 year

Notes: Success of this phase of development depends on the availability of suitable thermodynamic data.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
2.1	6.4							17?,84
2.3	6.5							
2.5								
2.6								
4.9								
4.10								
6.1								
6.2								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. (cont.)

Aqueous-Solution/Solid-Phase Equilibrium Models (cont.)Project: 6.4 (INCORPORATE ADSORPTION TO 175°C)Title: Incorporate radionuclide adsorption (including organics) to 175°C on appropriate mineral surfaces.Priority: A See Project 6.3.Justification: Reversible adsorption is currently assumed to be the principal mechanism that will cause retardation of radionuclides during transport. Algorithms describing adsorption are needed for the design and interpretation of laboratory and field studies.Expected Results: An adsorption model will be incorporated in the chemical algorithm.Effort†: FTE p.a. - 1; Duration - 1 yearNotes: Suitable models may already exist, but thermodynamic data are lacking. This project may start upon completion of first phase of Project 6.1.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
4.1	6.5							1,84?
4.2								
4.3								
4.4								
6.3								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. (cont.)

Transport Models Incorporating Chemical AlgorithmsProject: 6.5 (TRANSPORT ALGORITHM)

Title: Develop a transport model that incorporates a realistic description of the geometry of the barrier medium and includes appropriate modifications of the chemical equilibrium algorithms described above.

Priority: A See Project 6.3.

Justification: Such a model must be developed to provide insight into controlling mechanisms and to serve as the basis for confirmatory laboratory and field studies over realistic time spans.

Expected Results: A transport model that is consistent with laboratory and field observations will be obtained.

Effort†: FTE p.a. - 3; Duration - 2 years

Notes: Efforts to accomplish these objectives are underway, but have deficiencies. This project can start upon development of codes under Projects 6.1 and 6.4.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
2.2	6.6	62	55?, 62,			95	55?	60, 61,
3.6	6.8		92?					63, 70?,
6.1	6.9							72
6.3	6.10							
6.4	6.11							
	6.12							
	6.13							
	6.14							
	6.15							
	7.13							
	7.14							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. (cont.)

Transport Models Incorporating Chemical Algorithms (cont.)Project: 6.6 (INCORPORATE DIFFUSIVITIES)

Title: Develop a chemical transport model based on that of Project 6.4, which incorporates diffusivities of relevant complexes as a function of temperature.

Priority: A See Project 6.3.

Justification: Diffusion is the dominant transport mechanism in the engineered barrier region. Diffusivities of individual species must be incorporated in chemical transport models for accurate simulations.

Effort[†]: FTE p.a. - 2; Duration - 1 year

Expected Results: A transport model suitable for approximating chemical reactions and transport in the engineered barrier region will be obtained.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
3.1	6.7							
6.5	7.14							

[†]See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. (cont.)

Transport Models Incorporating Chemical Algorithms (cont.)Project: 6.7 (INCORPORATE CROSS DIFFUSIONAL COUPLING)

Title: Incorporate cross diffusional coupling and coupling of mass and thermal fluxes in the chemical transport model developed under Project 6.5.

Priority: C If this phenomenon proves to be statistically significant, it should be incorporated in the radionuclide transport model. See also Project 6.3.

Justification: Both chemical composition and chemical and thermal gradients will affect diffusion rates of ions. For accurate modeling, such processes should be incorporated in chemical transport models.

Effort†: FTE p.a. - 2; Duration - 2 years

Expected Results: A model suitable for simulating chemical reactions and transport in the engineered barrier region will be obtained.

Link*				Existing Projects				
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
3.4	7.14							
6.6								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. (cont.)

Transport Models Incorporating Chemical Algorithms (cont.)PROJECT: 6.8 (INCORPORATE COLLOID TRANSPORT)

Title: Incorporate diffusional and/or convective transport of colloids, pseudocolloids, and particulates in appropriate transport model.

Priority: C If diffusion and/or convective transport of colloids proves to be significant, it should be incorporated in the transport model.

Justification: If colloids, pseudocolloids, or particulates prove to be significant in the transport of radionuclides through barrier media, their transport should be modeled and then tested against laboratory and field experiments.

Effort: FTE p.a. - 1; Duration - 1 year

Expected Results: A model capable of simulating colloid, pseudocolloid, and particulate transport will be obtained.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
6.5	7.14							
6.8								
7.3								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. (cont.)

Transport Models Incorporating Chemical Algorithms (cont.)Project: 6.9 (INCORPORATE ORGANIC SORPTION)Title: Incorporate organic sorption into transport algorithms.Priority: B If organic sorption proves significant, it should be investigated in the transport model. See also Project 6.3.Justification: Organic sorption may play a significant role in retarding radionuclides.Effort†: FTE p.a. - 1; Duration - 1 yearExpected Results: A quantitative assessment of the effect of organics in transporting radionuclides will be obtained.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
4.3	6.10							
6.5								
6.8								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2* (cont.)

ELEMENT 6. (cont.)

Transport Models Incorporating Chemical Algorithms (cont.)Project: 6.10 (INCORPORATE GRAIN BOUNDARY AND VOLUME DIFFUSION)

Title: Incorporate grain boundary and volume diffusion of radionuclides and models describing long-term chemical changes in mineral surfaces.

Priority: A Subject phenomena will have a significant impact on radionuclide retardation. The phenomena must be incorporated in the transport model so that radionuclide retardation through the barrier system may be predicted.

Justification: These phenomena may be significant over the long time spans during the transport of radionuclides. Their impact on radionuclide retardation should be factored into transport models.

Effort†: FTE p.a. - 1; Duration - 2 years

Expected Results: The relative significance of grain boundary and volume diffusion and long-term changes in chemical surfaces will be assessed.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
4.5	7.14							
4.6								
4.8								
6.5								
6.9								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. (cont.)

Transport Models Incorporating Chemical Algorithms (cont.)Project: 6.11 (INCORPORATE PRESSURE EFFECTS)

Title: Incorporate in an appropriate transport model the effect of pressure and temperature on porosities and permeabilities of backfill materials (includes brine migration in salt).

Priority: B These effects should be incorporated to predict radionuclide transport through the backfill barrier of a repository.

Justification: Long-term changes in the physical properties of engineered barrier media will affect radionuclide transport. This effect should be taken into account.

Effort†: FTE p.a. - 1; Duration - 2 years

Expected Results: A model capable of simulating long-term changes in the physical properties of engineered barriers and the impact on radionuclide migration will be obtained.

Link*		Existing Projects						
In	Out	Salt (D)	Salt (B)	Basalt	Tuff	Granite	Shale	Other
5.2	7.14	35,39	35,39					
6.5								
7.11								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. (cont.)

Application of Chemical Transport ModelsProject: 6.12 (TREAT CANISTER ARRAYS AND LAYERED MEDIA)Title: Modify existing computer codes or develop new ones that can treat arrays of canisters as well as transport through multilayered media.Priority: B This is needed to predict radionuclide transport through multiple barriers of a repository.Justification: Simple cases lack flexibility in dealing with more complex repository geometry. Codes must be developed to deal with these.Effort†: FTE p.a. - 1.5; Duration - 2 yearsExpected Results: Codes capable of modeling in two or three dimensions with more complex boundary conditions will be produced.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
6.5	7.14							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. (cont.)

Application of Chemical Transport Models (cont.)Project: 6.13 (INCORPORATE SPECIAL SOURCE TERMS)

Title: Modify existing computer codes to incorporate special source term conditions such as colloid formation through the degradation of high-level wastes or transport following disappearance of the source term.

Priority: B This is needed to predict radioactive waste transport through a repository barrier system.

Justification: Current computer codes are not adequate to model special conditions and would require modification to accommodate them. Such conditions may be important in predicting long-term repository behavior.

Effort†: FTE p.a. - 1.5; Duration - 2 years

Expected Results: Modified codes capable of dealing with these special conditions will be produced.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
2.7	7.14		65?					18?
2.8								
6.5								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. (cont.)

Laboratory VerificationProject: 6.14 (LABORATORY VERIFICATION OF TRANSPORT MODELS)Title: Chemical transport models should be verified using dynamic column experiments.Priority: A It is essential to verify transport models, as these will be the only means of predicting long-term containment of a multiple barrier repository.Justification: Dynamic column experiments can be used to interpret non-equilibrium behavior during chemical transport. Such experiments are required to verify theoretical and conceptual algorithms of chemical transport processes.Expected Results: Partial verification or otherwise of computer models simulating chemical transport through barrier media will be made.Effort†: FTE p.a. - 4; Duration - 3 yearsNotes: This project may start on completion of Project 6.4.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
6.5	7.14	38?	38?	104		50		84?,94, 102,104

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 6. (cont.)

Laboratory Verification (cont.)Project: 6.15 (CHEMICAL ACCUMULATION OF FISSILE ISOTOPES)

Title: Model conditions to test for the chemical feasibility of the accumulation of fissile isotopes in geologic and backfill materials adjacent to the canister.

Priority: C As a precaution, this study should be undertaken in the event that fissile isotopes may concentrate and go critical.

Justification: Although unlikely, the possibility of radionuclides accumulating to produce a critical mass has not been ruled out. Modeling will help establish whether such a condition is likely

Expected Results: Conditions will be identified where criticality might arise.

Effort†: FTE p.a. - 1; Duration - 2 years

Notes: No follow-up research has been incorporated in the plan.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
6.5	7.14							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. FIELD EVALUATIONS

Characterization of Host Rocks and GroundwaterProject: 7.1 (ORGANICS IN GROUNDWATERS)

Title: Identify amount and nature of dissolved organic constituents in groundwater.

Priority: B If organic compounds enhance radionuclide transport, then repository sites should be selected where organic concentrations are minimal or absent. (See also Justification, below.)

Justification: Such a study is needed to establish the significance of organic components in groundwater and their ability to transport radionuclides.

Effort†: FTE p.a. - 1; Duration - 2 years

Expected Results: The impact or otherwise of organic components on radionuclide transport will be established.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
	2.5		9?,15?	10				
	2.6							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

Characterization of Host Rocks and Grondwater (cont.)Project: 7.2 (COLLOIDS IN GROUNDWATERS)

Title: Determine the concentration, size, distribution, and ,migration properties of colloidal and particulate material in groundwaters.

Priority: C If colloids or particulates enhance radionuclide transport, then sites with minimal concentration of these should be selected. (See also Justification, below).

Justification: The quantities of collodial and particulate material in groundwater are not well known. This must be recified.

Effort†: FTE p.a. - 1; Duration - 2 years

Expected Results: Concentrations of colloids and particulates in groundwater will be determined.

Link*					Existing Projects			
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other

7.3

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

Characterization of Host Rocks and Groundwater (cont.)Project: 7.3 (CHEMISTRY AND MINERALOGY OF COLLOIDS)

Title: Evaluate the mineralogy and chemistry of suspended colloids and particulates found in groundwaters.

Priority: C Such information may contribute to predicting radionuclide transport through repository barriers.

Justification: If suspended colloids and particulates are significant, these should be characterized as a basis for establishing their radionuclide carrying properties.

Effort†: FTE p.a. - 1; Duration - 1 year

Expected Results: Description of the mineralogy and chemistry of suspended colloidal and particulate material will be obtained.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
7.2	6.8							17?

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

Characterization of Host Rocks and Groundwater (cont.)Project: 7.4 (MULTIPLE APPLICATION OF DATING TECHNIQUES)Title: Continue research on the multiple application of several dating techniques to get better insight into the value of each technique.Priority: B An independent means of estimating groundwater flow in hydrologic systems is required so that the selection of a repository site can be justified.Justification: Multiple redundant groundwater dating techniques are needed in order to eliminate uncertainties in estimating groundwater ages.Effort†: FTE p.a. - 3; Duration - 4 yearsExpected Results: Refined techniques in dating groundwaters will be developed.

Link*					Existing Projects			
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other

7.6

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

Characterization of Host Rocks and Groundwater (cont.)Project: 7.5 (GROUNDWATER CHEMISTRY AND AGE MEASUREMENTS)Title: Determine whether changes in groundwater chemistry affect age measurements.Priority: B See Project 7.4.Justification: Possible sources of error in groundwater-age measurements must be detected and eliminated.Effort†: FTE p.a. - 2; Duration - 1 yearExpected Results: Parameters affecting apparent groundwater ages will be identified.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
	7.6			25		??	??	6?,56, 57,100, 101

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

Characterization of Host Rocks and Groundwater (cont.)Project: 7.6 (DATING TECHNIQUES TO DETECT LOW-VOLUME, HIGH-VELOCITY WATER)Title: Use water-dating techniques to detect low-volume, high-velocity paths through otherwise slow-moving groundwater systems.Priority: B See Project 7.4.Justification: Groundwater flow in fractured rocks may be nonuniform. Methods to determine the magnitude of such effects are required.Effort†: FTE p.a. - 2; Duration - 2 yearsExpected Results: New techniques to observe heterogeneities in groundwater flow will be developed.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
7.4								57?
7.5								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

Characterization of Host Rocks and Groundwater (cont.)Project: 7.7 (CHEMISTRY AND MINERALOGY OF SITE SPECIFIC AQUIFERS)

Title: Chemistry and mineralogy of site specific aquifer surfaces in the near and far field should be characterized.

Priority: C The information obtained from this study would aid in refining predictions of radionuclide transport at a particular site and thereby influence site selection.

Justification: Information is needed to refine predictions of radionuclide migration at a particular site.

Effort†: FTE p.a. - 1; Duration - 1 year

Expected Results: Surfaces will be characterized in terms of parameters needed to predict radionuclide migration.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
5.6		27?	8,9, 11?,32, 33,58, 64	3?,25, 34	26,29? 30?	7,10, 30?	7,23	6,16, 18? 31(anhydrite)

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

TestingProject: 7.8 (GROUNDWATER SAMPLE PROCUREMENT)

Title: Test groundwater sampling and analysis (e.g., Eh) techniques in the field to determine whether uncontaminated sample procurement is feasible.

Priority: B See Project 1.2.

Justification: Uncontaminated samples are necessary for baseline studies and hydrological interpretations.

Effort†: FTE p.a. - 2; Duration - 1 year

Expected Results: Sampling and field analysis techniques will be standardized.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
1.2				34?				16?,93,
1.3								96,99?, 100?

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

Testing (cont.)Project: 7.9 (TEMPORAL VARIATIONS IN GRADIENTS)

Title: Evaluate temporal variations in hydraulic, thermal, and chemical gradients adjacent to a thermal source simulating canister emplacement.

Priority: A See Projects 1.1 and 5.2.

Justification: Information is necessary to interpret radionuclide migration through engineered barriers.

Expected Results: Quantitative data on parameters needed for evaluation of radionuclides through engineered barriers will be obtained.

Effort†: FTE p.a. - 2; Duration - 4 years

Notes: Extensive field support will be required.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
2.2	7.14							93
5.2								
5.3								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

Testing (cont.d)Project: 7.10 (EFFECT OF TEMPERATURE GRADIENT ON NEAR-FIELD PERMEABILITY)Title: Measure the effect of temperature gradients on permeability in the near-field region.Priority: B See Projects 1.1 and 5.2.Justification: Mass transfer of rock-forming mineral constituents could have a dramatic effect on permeability in the near-field region. This must be determined through field experiments.Effort†: FTE p.a. - 4; Duration - 4 yearsExpected Results: The effect of such processes on near-field host rock permeability will be clarified.Notes: The project does not include construction of a test facility.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
2.2	7.14	15?,35?,	15?,35?,	21,22?			13?,14,	93,94
5.3		38?,46	38?,41?				43	

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

Testing (cont.)Project: 7.11 (LONG-TERM EFFECTS ON BACKFILL AND HOST ROCKS)

Title: Evaluate long-term effects in physical and chemical properties of backfill and host rocks when subject to temperatures to 300°C.

Priority: B See Projects 1.1 and 5.2.

Justification: Changes in physical and chemical properties of backfill and host rocks must be evaluated so that their properties with respect to radionuclide migration can be correctly predicted.

Effort†: FTE p.a. - 4; Duration - 4 years

Expected Results: The chemical and physical properties of backfill and host-rock materials as a function of time will be predicted.

Notes: The project does not include construction of a test facility.

Link*		Existing Projects						
In	Out	Salt (D)	Salt (B)	Basalt	Tuff	Granite	Shale	Other
1.1	6.11	37?	37?	21?, 22?,			13?, 14	89, 90
2.2				59?				96
3.6								
5.2								
5.3								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

Testing (cont.)Project: 7.12 (FIELD TESTS ON BACKFILL AND HOST ROCK ENVIRONMENT)Title: Perform field tests to characterize the backfill/host rock environment.Priority: A This stage is essential to allow prediction of the behavior of a given site and establish whether it is acceptable for radioactive waste storage.Justification: Field testing must be undertaken to ensure that the correct values of parameters are used in predictive models.Effort: FTE p.a. - 10; Duration - 2 yearsExpected Results: The backfill/host rock environment in terms of parameters needed for the final design of field studies for radionuclide migration.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
	7.13	38,46, 81	38,64?	45,49	40,50, 77	42,76, 77,78	43,75, 77	16?,44?, 78,89, 90,93, 94,96, 97

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

Testing (cont.)Project: 7.13 (FIELD VERIFICATION OF MODELS)Title: Verify model concepts through field testing.Priority: A See Project 6.14.Justification: This important subject must be accomplished to ensure that laboratory, theoretical, and conceptual evaluations of radionuclide migration are valid in the field.Expected Results: The validity or otherwise of laboratory, theory, and models will be demonstrated.Effort: FTE p.a. - 10; Duration - 3 yearsNotes: Does not include construction of a test facility. This project should be evaluated in more detail and broken down into subtasks for a better estimate of manpower.

Link*		Existing Projects						
In	Out	Salt (D)	Salt (B)	Basalt	Tuff	Granite	Shale	Other
6.5	7.14	81?	64		50	76?, 79?, 80?		52, 53, 63
7.12								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

Testing (cont.)Project: 7.14 (INTERPRET FIELD DATA)Title: Interpretation of field data.Priority: A This is the final stage in confirming the suitability of a site for radioactive waste storage.Justification: Data from field experiments must be evaluated to confirm the validity of the transport models upon which the field experiments were based.Effort†: FTE p.a. - 6; Duration - 1 yearExpected Results: The validity or otherwise of laboratory, theory, and models will be demonstrated.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
6.5		27	32,58?	28,59?	29,50	76?	58?	52,53,
6.6			64?					63,94?,
6.7								96?,99,
6.8								100,102
6.10								
6.11								
6.12								
6.13								
6.14								
6.15								
7.9								
7.10								
7.13								
7.15								

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

Table 2.2 (cont.)

ELEMENT 7. (cont.)

Testing (cont.)Project: 7.15 (TEST OXYGEN GETTERS)Title: Field test oxygen getters in backfill.Priority: B See Project 5.4.Justification: Laboratory studies as to the effectiveness and need for oxygen getters must be verified.Effort†: FTE p.a. - 1; Duration - 1 yearExpected Results: Oxygen backfill getters will be successfully demonstrated.

Link*		Existing Projects						
In	Out	Salt(D)	Salt(B)	Basalt	Tuff	Granite	Shale	Other
5.5	7.14							

†See Section 2.2.3, p. 27

*See Section 2.4.1, p. 91

It is clear from a perusal of Table 2.2 that, when the proposed research is compared with ongoing research covering the same topics, coverage is uneven and incomplete. However, the greatest difficulty lies in the possibility that ongoing projects are more comprehensive in their scope than is apparent from published project descriptions. Resolving this difficulty will require further discussions with the investigators participating in these projects, and refinement of ongoing project descriptions.

2.4 SCHEDULE

2.4.1 Development of a Schedule

A schedule of projects necessitates knowing the order in which projects can be implemented. Some projects may be executed concurrently, others must be in sequence, the product of one being the input for the succeeding project. Also, one project may require input from several precursors, or the output of one may radiate toward a suite of successors. To facilitate comprehension of the logical sequence, the links are identified beneath each project description in Table 2.2. Inputs for some projects are not necessarily required at the start of those projects. In making these links, therefore, some projects have been subdivided into segments to allow for startup prior to receipt of data from a predecessor.

As a result of several iterations, in which credit was also given to progress being made by current projects, a program was formulated which is illustrated by the schedule chart shown in Figure 2.1. The critical path in this schedule consists of those projects occupying the bottom line of the chart and those stacked immediately above the critical path projects which conform to the same time intervals. It is interesting to note that the critical path contains of the following major project categories:

1. Laboratory experiments
2. Modelling and data input to the solution algorithm
3. Development of a transport algorithm
4. Field and laboratory verification of transport models
5. Interpretation of field data.

Accomplishment of these critical path projects can be important milestones in attaining the geochemistry research program goals, as will be discussed in the following section.

The schedule indicates that a conventional research effort aimed at elucidating processes in a generic sense would take approximately 16 years. It is possible that the duration could be reduced by as much as 20 to 30 percent by adding more manpower. However adjustments of this kind may be constrained by the availability of skilled scientists. Furthermore, some aspects of a geochemistry research program have been omitted. For example,

Figure 1.2 Logic chart to identify geochemical needs for the process

Key to Figure 2.1

- 1.1 Laboratory Changes in backfill Properties
- 1.2 Laboratory Uncontaminated sampling
- 1.3 Laboratory Groundwater oxidation state
- 2.1 Laboratory Complexes of fission products
- 2.2 Laboratory Mass transport in a thermal gradient
- 2.3 Laboratory Complexes of actinides
- 2.4 Laboratory Fluid composition to 300°C
- 2.5 Laboratory Organic complexes
- 2.6 Laboratory Humic-fulvic acid complexes
- 2.7 Laboratory Colloids from HLW
- 2.8 Laboratory Radionuclide colloids
- 3.1 Laboratory Diffusivities research
- 3.2 Laboratory Diffusivities
- 3.3 Laboratory Cross diffusional coupling
- 3.4 Laboratory Cross diffusional coupling research
- 3.5 Laboratory Colloid diffusion
- 3.6 Modeling Interpret backfill changes
- 4.1 Laboratory Adsorption fundamentals
- 4.2 Laboratory Sorption on specific minerals
- 4.3 Laboratory Organic sorption
- 4.4 Laboratory Sorption to 175°C
- 4.5 Laboratory Mineral surface changes I
- 4.6 Laboratory Mineral surface changes II
- 4.7 Laboratory Scope grain boundary and volume diffusion
- 4.8 Laboratory Study grain boundary and volume diffusion
- 4.9 Laboratory Sn and Pd solubility
- 4.10 Laboratory Actinide precipitates
- 5.1 Laboratory Alteration of basalts and granites
- 5.2 Laboratory Backfill compaction
- 5.3 Laboratory Precipitation and permeability
- 5.4 Laboratory Oxygen uptake
- 5.5 Laboratory Oxygen getters
- 5.6 Laboratory Surface area and adsorption
- 6.1 Modeling Solution algorithm
- 6.2 Modeling Solution algorithm data input
- 6.3 Modeling Radionuclide data input
- 6.4 Modeling Incorporate adsorption to 175°C
- 6.5 Modeling Transport algorithm
- 6.6 Modeling Incorporate diffusivities
- 6.7 Modeling Incorporate cross diffusional coupling
- 6.8 Modeling Incorporate colloid transport
- 6.9 Modeling Incorporate organic sorption
- 6.10 Modeling Incorporate grain boundary and volume diffusion
- 6.11 Modeling Incorporate pressure effects
- 6.12 Modeling Treat canister arrays and layered media
- 6.13 Modeling Incorporate special source terms
- 6.14 Laboratory Laboratory verification of transport models
- 6.15 Laboratory Chemical accumulation of fissile isotopes
- 7.1 Field Organics in groundwaters
- 7.2 Field Colloids in groundwaters
- 7.3 Field Chemistry and mineralogy of colloids
- 7.4 Field Multiple application of dating techniques
- 7.5 Field Groundwater chemistry and age measurements
- 7.6 Field Dating techniques to detect low volume, high velocity water
- 7.7 Field Chemistry and mineralogy of site specific aquifers
- 7.8 Field Groundwater sample procurement
- 7.9 Field Temporal variations in gradients
- 7.10 Field Effect of temperature gradient on near-field permeability
- 7.11 Field Long term effects on backfill and host rocks
- 7.12 Field Field tests on backfill and host rock environment
- 7.13 Field Field verification of models
- 7.14 Modeling Interpret field data
- 7.15 Field Test oxygen getters

the present program does not address the effort necessary to characterize specific sites. Nor is research included that could reconcile laboratory and field studies with natural processes analogous to radioactive waste storage. The overall research effort would therefore be larger than indicated were these omissions to be taken into account.

Field testing in the research program presented in this report falls into two categories: (1) that which can be accomplished with drilling alone, and (2) that which requires an underground facility simulating the conditions expected in a repository. Field testing falling into the first category is necessary to resolve a number of issues prior to deciding whether to proceed with laboratory research, and should start immediately. In contrast testing requiring a dedicated facility, can only begin once laboratory research and modelling has defined the test program.* Figure 2.1 indicates that testing in a dedicated facility could start as early as five years after initiation of the program.

According to the current schedule, field verification of models must take three years. Therefore this phase of the geochemistry research program cannot be completed before fifteen years from the start of the program, to be followed by at least one year of data evaluation and interpretation. Final results and conclusions of the program therefore would not be available until seventeen years after starting the program.

While reviewing the subject of schedules, it is interesting to note the consequence of negative decisions emerging from all research projects whose objectives are to determine whether further research would be required (See 2.4.2, below). Figure 2.2 shows a schedule chart where such is the case. The reduction in scope occurs in laboratory experimental and computer modeling requirements, not in field studies. This program might fairly be described as the minimum possible, although it is quite improbable. Further reductions could not be made without seriously compromising the effectiveness of the present program in meeting its goals.

* The study of analogues could be conducted independently of both categories of field research.

2.4.2 Critical Milestones

All projects in the program have stated objectives contributing towards the overall goal of the program. In a sense, completion of each project and satisfactory resolution of that particular problem is a milestone. However, some milestones are more important than others both in terms of the direction the research program takes, and in contributing to the overall goal of the program.

Accomplishments resulting from completion of a project can be assigned to any of five categories:

1. Results and conclusions that determine whether further research is needed.
2. The acquisition of information that determines, defines or limits the scope and objectives of succeeding projects.
3. Obtaining data, acquiring information, developing techniques, or constructing equipment as necessary input for the succeeding projects.
4. Results and conclusions confirming tentative accomplishments reached earlier in other projects.
5. Decisions relating directly to the design and construction of a repository.

These categories do not help to identify a hierarchy of milestones meeting the goal of the program. However, in determining the program's magnitude and direction, milestones under categories 1 and 2 are obviously more influential. Milestones in these two categories are identified below together with the projects that may ultimately be affected. Some milestones are also critical, i.e. they must be accomplished if the program is to meet its goal. Several of these milestones lie on the critical path. The program milestones and their relationship to associated projects are amplified in the following pages. The titles and numbers of the projects are the same as those given in Table 2.2.

2.4.2.1. Milestones determining whether further research is required.

1. Project 3.2 (DIFFUSIVITIES)

Determines the significance of variations in magnitude of diffusion coefficients of radionuclide aqueous species. If the magnitude of variations is less than errors introduced by uncertainties in other parameters, then no further research will be needed. Projects affected would be 3.1, 3.3 and 6.6.

2. Project 3.3 (CROSS DIFFUSIONAL COUPLING)

Determines the significance of cross diffusional coupling. If this phenomenon is not of sufficient magnitude to exceed estimated errors due to uncertainties of other parameters, then no further research will be needed. Projects affected would be 3.4 and 6.7.

3. Project 3.5 (COLLOID DIFFUSION)

Determines experimentally whether significant colloid diffusion can occur through rock pores. If not significant, then no further research concerning colloid diffusion is required. Projects affected would be 2.7 and 2.8.

Note: Colloid transport may never-the-less take place due to convective groundwater movement.

4. Project 4.7 (SCOPE GRAIN BOUNDARY AND VOLUME DIFFUSION)

Determines the significance of grain boundary and volume diffusion mechanisms in retarding radionuclide transport. If not significant, no further research in this area is required. Projects affected would be 4.8 and 4.6.

5. Project 5.4 (OXYGEN UPTAKE)

Determines whether oxygen uptake in ferrous iron poor rocks could lead to long term persistence of oxidizing conditions in a repository. If this does not appear to be likely, or oxidizing conditions in a repository are not critical, then no further research on oxygen uptake need be performed. Projects affected would be 5.5 and 7.15.

6. Code 6.15 (CHEMICAL ACCUMULATION OF FISSILE ISOTOPES)

Determines through modelling whether fissile isotopes can accumulate to produce a critical mass. If results are negative, there is little, if any, incentive to pursue this matter further. No follow up research on this matter has been incorporated in the current geochemistry research program.

7. Project 7.1 (ORGANICS IN GROUNDWATERS)

Establish the significance of organics in groundwaters. If concentrations are less than sufficient to affect radionuclide migration, then no further research would be required (provided organics are not introduced into a repository with the waste). Projects affected would be 2.5, 2.6, 4.3 and 6.9.

2.2.4.2 Milestones Defining the Scope of Further Research

1. Project 2.1 (COMPLEXES OF FISSION PRODUCTS)

Limits the number of complexes of significant fission products to those likely to be the principal transported forms between 25 and 175°C. Project affected would be 6.3.

2. Project 2.3 (COMPLEXES OF ACTINIDES)

Limits the number of complexes of actinides to those likely to be the principal transported forms between 25 and 175°C. Project affected would be 6.3.

3. Project 2.7 (COLLOIDS FROM HLW)

Determines whether colloids from the decomposition of high level waste are significant carriers of radionuclides. If they are, then colloid transport must be considered in the subsequent transport algorithms. Project affected would be 6.8.

4. Project 2.8 (RADIONUCLIDE COLLOIDS)

Determines if and when colloids of otherwise insoluble radionuclide species might be produced as a result of supersaturation of radionuclides in the aqueous phase. If the formation of such colloids is significant, then they must be considered in subsequent transport algorithms. Project affected would be 6.8.

5. Project 3.6 (INTERPRET BACKFILL CHANGES)

Identifies and quantifies mechanisms of backfill alteration and thereby determines the nature of transport algorithms used in predicting radionuclide migration (Project 6.5) and the design of field experiments to determine long term effects of backfill interactions. Project affected would be 7.11.

6. Project 4.2 (SORPTION ON SPECIFIC MINERALS)

Identifies minor phases that could have a major impact on radionuclide retardation, and which must be considered in sorption mechanisms to 175°C. Project affected would be 6.4.

7. Project 4.5 (MINERAL SURFACE CHANGES I)

Determines whether short term tests of radionuclide sorption are meaningful and establishes the significance of long term sorption effects on radionuclide migration. This will limit the scope of several projects. Projects affected would be 4.1-4.4 and 6.10.

8. Project 4.6 (MINERAL SURFACE CHANGES II)

As above

9. Project 4.9 (Sn AND Pd SOLUBILITY)

Determines the relative importance of Sn and Pd solution species, their effect on Sn and Pd solubilities in natural systems, and how they might limit the maximum radionuclide flux of these to insignificant levels. This study might limit the input to the solution algorithm. Project affected would be 6.3.

10. Project 4.10 (ACTINIDE PRECIPITATES)

Determines solubilities of actinide precipitates in natural systems and whether they might limit the maximum radionuclide flux to insignificant levels. This study may limit the input to the solution algorithm. Project affected would be 6.3.

2.4.2.3 Milestones on the Critical Path

Projects on the critical path are summarized in Table 2.3.

TABLE 2.3 CRITICAL PATH PROJECTS

Sequence	Project No.	Title
1	2.4	FLUID COMPOSITION TO 300°C
2	2.3	COMPLEXES OF ACTINIDES
3	4.4	SORPTION TO 175°C
	4.2	SORPTION ON SPECIFIC MINERALS
4	6.4	INCORPORATE ADSORPTION TO 175°C
5	6.5	TRANSPORT ALGORITHM
6	6.6/6.7	INCORPORATE DIFFUSIVITIES/INCORPORATE CROSS DIFFUSIONAL COUPLING
	6.14	LABORATORY VERIFICATION OF TRANSPORT MODELS
	7.13	FIELD VERIFICATION OF MODELS
7	7.14	INTERPRET FIELD DATA

Some of these projects are of major importance to the program, e.g. 6.14, 7.13 and 7.14. Others, such as 6.6 and 6.7 may never be implemented, as noted earlier. Hence, projects on the critical path may change with the evaluation of the program. Those milestones on the critical path, which are deemed important at this time are:

1. Project 6.5 (TRANSPORT ALGORITHM)

A transport algorithm incorporating the solution algorithm from Project 6.1, is a prerequisite for subsequent confirmatory laboratory and field experiments demonstrating radionuclide transport concepts (Projects 6.14 and 7.13). In addition, it must be successfully accomplished before further modifications can be incorporated (e.g., Projects 6.6-6.13 that represent the outcome of concurrent experimental research.

2. Projects 6.14 (LABORATORY VERIFICATION OF TRANSPORT MODELS) 7.13 (FIELD VERIFICATION OF MODELS)

Completion of these two projects is essential to the success of the program in that they confirm the validity of preceding research and establish the feasibility or otherwise of underground radioactive waste storage.

2.4.3 Overall Manpower Requirements

Figure 2.3 is an example illustrating the manpower requirements for this program. It is assumed by this schedule and the manpower chart that all project activities will be required to complete the program. This is not necessarily so, as will be discussed below.

Table 2.4A shows the breakdown of these manpower requirements by year and by major category of research worker; laboratory experimentalist and interpreter, modeler, and field worker.

The requirements in all three categories fluctuate widely during the course of the program. Some smoothing of the workload might be accomplished in the modelling and field experimental categories, but at a risk of jeopardizing the present schedule. Furthermore, smoothing implies a certain flexibility among technical staff which is not always available. In any case, the major question is availability, particularly in laboratory experimental areas. The program, as presently conceived, is overcrowded at the front end. After the fourth year, manpower/requirements fall from an average of 49 FTE pa to an average of 15 1/2 FTE pa. Finding and directing the efforts of so many skilled scientists familiar with the problem for only four years is likely to strain available resources. However, this number must be used within the period indicated in order to accomplish the program goal within 16 years. Major redistributions of manpower would require a complete restructuring of the research program.

Figure 2.4 gives manpower distribution in the unlikely eventuality that the outcome of projects determining whether future research is required will all give negative answers. A similar problem arises with manpower distribution for this minimal program as indicated in table 2.4B.

2.4.4 Resources

Resources to accomplish the geochemistry research program can be broken down into manpower and facilities. The facilities for laboratory experimental and modeling studies are available at national laboratories and are expected to be adequate for the projects delineated. Equipment and facilities for handling radioactive substances are readily available at these institutions. No laboratory projects in the program require equipment that cannot be readily modified or fabricated in national laboratory shops.

Figure 2.3. Manpower requirements for projects

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Table 2.4

BREAKDOWN OF MANPOWER REQUIREMENTS BY YEAR AND MAJOR
CATEGORY OF RESEARCH WORKER

A. Full Program

Year	FTE															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Laboratory	38.7	36.7	37.2	27.0	12.5	10.5	13.0	10.5	7.5	1	4	4	5	1	4	0
Modeling	3.0	3.0	3.0	4.0	0.0	0	2.0	0	0	1	3	3	9	7	2	6
Field	15.0	15.0	6.0	3.0	3.0	12.0	10.0	10.0	10.0	1	0	0	10	14	10	0
Total	56.7	54.7	46.2	34.0	15.5	22.5	25.0	20.5	17.5	3	7	7	24	22	16	6

B. Minimum Program

Laboratory	37.7	36.7	23.7	13.5	9.5	7.5	9.0	6.5	6.5	0.0	0.0	0.0	5.0	5.0	4.0	0.0
Modeling	3.0	3.0	3.0	4.0	0.0	0.0	2.0	0.0	0.0	1.0	3.0	3.0	5.0	4.0	0.0	6.0
Field	17.0	14.0	6.0	3.0	2.0	12.0	10.0	10.0	10.0	1.0	0.0	0.0	10.0	10.0	10.0	0.0
Total	57.7	53.7	32.7	20.5	11.5	19.5	21.0	10.5	16.5	2.0	3.0	3.0	20.0	19.0	14.0	6.0

Figure 2.4. Manpower requirements for projects with a minimal level of research needs

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Manpower resources at national laboratories might be sufficient. Many projects funded by DOE's WRIT program have been carried out by staff at national laboratories, and staff in related geoscience and physical chemistry disciplines could be assigned to the program. However, no attempt had been made in this report to identify the strengths or deficiencies of staff in relation to current requirements of the geochemistry research program.

Specialized laboratory or modeling capabilities outside the national laboratories undoubtedly exist and could be made available, such as those found among leading corporations. University help might be utilized in some restricted cases, but it is rare that academic institutions possess either the facilities or supervisory staff to handle radioactive materials, or the managerial structure responsive to complex disciplinary programs.

The availability of both laboratory and manpower resources for the program may not therefore be a serious problem. However, it should be realized that the actual assignment of staff and coordination of a program of such a magnitude and complexity will tax the abilities of the best managers.

Regarding field programs, the principal problem here lies in the availability of a test facility. Such a facility must replicate accurately, the conditions expected to be found in a waste repository. This means that ambient temperatures and pressures must be similar. Ambient pressures may be equivalent to those found at depths to 3-4 thousand feet. While it has been emphasized that the direct effect of pressure on chemical processes can be disregarded, (section 2.1.1.1, Apps et al., 1982), several field experiments involve backfill materials that must be pressurized to repository conditions in order that their physical behavior may be correctly simulated.

Selection and implementation of a field testing program appears to be a major difficulty at present, because no facilities possessing the required conditions are available for the principal rock types, other than perhaps for bedded salt at the DOE Los Medanos facility in New Mexico. This difficulty might be overcome through judicious selection of existing deep mines, provided that political and proprietary considerations can be overcome. It is probably more realistic to schedule in situ field testing when DOE facilities become available.

2.5 OPTIONS

The present geochemistry program is unquestionably expensive, of substantial duration, i.e. 16 years, and utilizes a large pool of scientific talent. An approximate estimate of the total cost, assuming one scientist FTE equals \$100K (1982), is between \$32M and \$38M. Furthermore, the assessment of all aspects of the research needs for geochemistry program are not addressed (See Section 3.2) so that the cost of a comprehensive program could attain \$50M.

Several possibilities exist regarding alternative strategies for performing geochemistry research in support of waste repository design.

1. Stretch out the program over a longer time period
2. Accelerate the program to meet the schedule of the National Waste Policy Act
3. Limit the scope of the program, accepting greater risk
4. Modify repository specifications and thereby decrease the scope of research required
5. Some appropriate combination of the above.

These alternatives are discussed below.

2.5.1 Stretching Out the Program

This approach unquestionably has attractions, especially to those countries where there is not an immediate or pressing need to resolve the problem of disposing of high level commercial radioactive waste. It has even been advocated by R. Roy (Pennsylvania State University) for the United States program. The advantages are that overall costs of the research could be lower, due to the greater efficiency of using fewer scientists dedicated to the problem, and the benefits gained from information provided by research in associated scientific fields. However, if the whole nuclear fuel cycle is considered, and the costs to the nation of deferring resolution of the high level waste storage problem are also taken into account, with its attendant public concerns regarding the growth of nuclear power, then stretching out of the program could be inappropriate.

2.5.2 Acceleration of the Program

The program could be accelerated to meet the requirements of the National Waste Policy Act through addition of more manpower or by increasing the overlap of otherwise sequential projects. The former approach possesses disadvantages such as the need to employ a large number of scientists for a short period of time, with the inefficiencies that such an approach causes. A greater amount of project overlap might be tolerated, but at the expense of increasing management and coordination requirements.

A major stumbling block to decreasing the length of the program is the duration of the field projects. Three of the field projects are four years long. They might be shortened by various means to three or even two years. However, the phenomena to be observed, rely on the establishment of quasi static conditions, which may not to be achieved for some time after initiation of the project. Any attempt to decrease the duration of these projects must await preliminary scoping studies. Only then will it be possible to ascertain whether current estimates are unduly conservative.

Another approach is to advance the starting date of field experiments and let them start independently of laboratory, theoretical and modelling input so essential for proper design of the experiments. This approach carries with it various risks that can scarcely be justified. Investigation of laboratory research precursor projects shows that their scheduled duration is reasonable when the complexity of the problem is considered (e.g. projects 1.1, 5.2, 5.3).

2.5.3 Decreasing the Scope of Research

As conceived, the scope of the present geochemistry research program could not be decreased significantly without jeopardizing the programmatic goal. A few minor projects, e.g. project 7.7, might be eliminated and some projects relating to engineered barriers, i.e. backfills, might be integrated. However, with the presently available information, neither the duration nor the magnitude of the program could be decreased significantly.

2.5.4 Modifying Repository Specifications

A significant reduction in the maximum temperature sustained by a repository would decrease the technical difficulty of predicting the behaviour of a repository for the first few thousand years after closure. In the absence of information on the behavior of systems at temperatures greater than 100°C, KBS (Sweden) staff decided that the design of their repository would be based on temperatures not exceeding this value. They have designed such a repository and feel confident that their approach is adequate. Although further research would lead to more cost effective solutions or increase confidence in the conclusions reached, the major hurdle of establishing feasibility has been overcome.

By adopting a similar approach, and by lowering the temperature specification to around 100°C, the scope and difficulty of the proposed research could be decreased substantially. Lowering the temperature might be achieved dilution with a non radioactive matrix, by wider spacing of canister materials in the repository, or by combination of all three.

Estimating how much the research requirements would be reduced by specifying lower temperature maxima than presently planned is beyond the scope of this report. The size of a repository, and consequently its cost, could increase substantially if a lower maximum repository temperature were mandated by lack of technical confidence. Therefore the cost benefits of the research program to establish the possibility of operating at higher repository temperatures can be estimated approximately. For example, if lowering repository temperatures leads to research cost savings of \$20M, but doubling the size of the repository at an additional cost of an additional \$500M, then the logical course of action is clear, and intensifying the research effort would be justified.

Recently, Claiborne (1982) has pointed out that a multi-barrier system may not significantly decrease the probability of releasing radioactive waste from a repository because the probability of failure of the host rock waste package barrier is already so low that additional backup components would not provide a significant additional safety margin. He points out that the barriers are

essentially in series and that repository failure is likely to be due to a common cause failure of all barriers. Obviously, the elimination of barriers simplifies research needs and should decrease the costs of the research program. Yet it places a heavy reliance on the host rock barrier which is difficult to characterize. Furthermore, all the findings cited by Claiborne (1982) in questioning the efficiency of a multi-barrier approach are based only upon paper studies. Again, the trade-offs between cost and risk need to be estimated, and an acceptable basis worked out.

2.5.5 Summary

The recommended research plan developed in this chapter, evolved through a sequence of logical steps. The first involved identification of key research needs. This was accomplished by assignment of priorities and classifying the recommendations given in Apps et al., (1982). The recommendations were then formulated as projects and the level of effort of each project estimated.

The projects were then ordered in a logical sequence, most projects taking input from a precursor, and delivering output to a successor. Because of the complexity of the network thus created, a computer code, CPMG, was utilized to determine the duration, critical path, and manpower distribution of the program. Program milestones were then identified and categorized.

Some of the program milestones included decisions affecting both the magnitude and scope of work following those milestones. Therefore, manpower requirements and distribution for the program could not be anticipated precisely. However, a minimum effort program was also computed for comparison, and as a means of bracketing the range of effort that would actually be required. With this information in hand, it was possible to determine whether the resources, i.e. manpower and facilities, would be available to do the work required. This was reviewed briefly so that some idea could be given of the approach that would be required if the program were to be implemented.

Finally, consideration was given to options that might be taken in implementing the program. These included either stretching out or accelerating the program, decreasing the scope of research, or modifying the repository specifications.

3. RECOMMENDATIONS FOR DEALING WITH LIMITATIONS AND UNCERTAINTIES

3.1 INTRODUCTION

This chapter addresses the problems arising from uncertainties in the research plan described in Chapter 2. There are three kinds of uncertainties to be considered:

1. Technical omissions of the plan.
2. Uncertainties arising from the implementation of the plan itself.
3. The difficulties of reconciling the plan with the DOE schedule for constructing a waste repository.

These uncertainties will be addressed in succeeding sections, and with recommendations given for overcoming them.

3.2 TECHNICAL OMISSIONS OF THE PLAN

The research plan is comprehensive in its evaluation of the subjects investigated. However, a number of issues were not considered because of the need to reduce the scope of the investigation to manageable proportions and because of both the restricted availability and the technical skills of scientific staff. Some subjects omitted were not considered to involve serious issues, although it is always possible that they may become so. The following issues were not considered, but may be important.

1. The need to validate computer simulations of radioactive migration over long time spans through the use of natural analogues.
2. The effect of radiolysis on the oxidation state of groundwaters surrounding the canister.
3. The design of laboratory and field experiments to confirm hypotheses relating to radionuclide transport,
4. The formulation and utilization of getters to retard selective radionuclides in engineered barriers,
5. The investigation of the effects of different host rocks on radionuclide containment,
6. Consideration of the interaction of borehole plugging material with host rocks,
7. The investigation of the effect of the buildup of daughter products of transuranic elements,
8. The investigation of the status of data pertaining to radionuclide adsorption on mineral substrates,

9. Research relating to the design and construction of chemical sensors or monitors for long term (1-5 years) field tests and possibly for post-closure monitoring (up to 100 years). However, post-closure monitoring is not required by 10 CFR Part 60.

3.2.1 Natural Analogues

Nothing is more important to the waste isolation program than providing a means of independently verifying the model concepts embodied in predictions of radionuclide waste migration. The only plausible way of accomplishing this is to reconcile observations of natural systems with computer simulations of those systems, using the same models used to predict radionuclide migration. This attractive concept is unfortunately fraught with serious difficulties:

- o Choice of an analogue that adequately replicates the conditions of a repository environment or failing that, being able to select one or more analogues, that in combination will yield the required verification,
- o Having sufficient information on the natural system to test the model. In particular, the time dimension should be adequately defined,
- o Being able to combine the skills of three disciplines, viz. hydrology, geochemistry and mathematical modeling to do a creditable analysis of a given analogue.

Research on natural analogues is being conducted under NRC sponsorship, and a promising start has been made. Yet the magnitude of research required for this important phase of the waste isolation program should be augmented through DOE sponsorship. Recommendations are that a meeting of experts be convened, and the matter studied with a view to planning a consolidated program that is compatible with existing research in the waste isolation field.

3.2.2 Radiolysis

Uncertainties due to radiolysis center on changes of the oxidation state in the vicinity of the waste canister. A high oxidation state could enhance migration of certain radionuclide species (e.g. actinides in the +6 state and Tc) and play havoc with predictions of backfill retardation of these species. Nevertheless, most radiolysis is caused by the decay of short lived radionuclides such as ⁹⁰Sr and ¹³⁷Cs, so that the problem could be minimized by surface storage for the next 50 to 100 years, or by development of a canister that provides adequate shielding. Radiolysis is also limited by shielding of the backfill, and by recombination of radiolytic species after a certain concentration of radicals is reached.

It is recommended that the subject be reviewed and appropriate decisions made at that time as to whether further research is justified.

3.2.3 Design of Laboratory and Field Experiments

Testing of radionuclide migration concepts in backfill materials and host rocks is extremely difficult, if only because of the small distances travelled by retarding radionuclides during experimentally realistic times. Most experiments conducted in the field to date involve pumping waters containing tracers (usually short lived fission product isotopes) between wells several meters apart. The flow rates, host rock permeabilities, chemical composition and oxidation state of the fluid usually bear no relation to conditions expected in a repository. Therefore such tests, while better than nothing, are of limited usefulness in confirming theoretical and model concepts.

It is recommended that this subject be reviewed and brainstormed by experts so that specific tests can be recommended and designed. A plan of action that can be incorporated into the geochemistry plan should emerge from such an evaluation.

3.2.4 Radionuclide Getters

Retardation of some radionuclides might be enhanced by the deliberate incorporation of natural or synthetic "getters" in the backfill. A number of these have been proposed particularly for the retardation of ^{99}Tc and ^{129}I . Recent work on this subject is reviewed and summarized in Smith et al., (1980, RHO-BWI-ST-7, Section 2.8.2.5, pp. 2-272f.)

It is recommended that specifications be worked out for such getters, and a review and scoping effort undertaken to determine the value of incorporating getters in backfills.

3.2.5 Effect of Differing Host Rocks on Radionuclide Containment

Although this report discusses the effect of host rocks and mineralogy on radionuclide retardation in an attempt to bound the conditions of subsequent experiments, there are a number of subtleties peculiar to differing rock types. For example, basalts are poor in potassium and would therefore tend to favor the formation of smectites over illites. Granites and rhyolitic tuffs are poor in minerals that could exert a strong control over the oxidation potential in the saturating groundwaters.

It is recommended that a geochemist review further the differences between rock types and assess their significance in retarding radionuclides.

3.2.6 Borehole Plugging Materials

Although the evaluation and selection of borehole plugging materials really falls into the materials science discipline, borehole plugging materials should be selected on the basis of their physical and chemical stability over long time spans, and their chemical compatibility with surrounding host rocks. These constraints, as with backfill materials, encourage the use of natural materials or synthetic materials whose similarity to natural materials is apparent.

Projects investigating the selection of borehole plugging materials should be coordinated with the geochemistry research program to ensure that a cross fertilization of ideas takes place.

3.2.7 Transuranic Element Daughters

All discussions relating to radionuclide migration in this report ignore the effect of daughter formation resulting from the decay of transuranic elements. Some of these daughters, for example, radium, are considered very toxic. Furthermore, the complex interactions between radioactive decay and retardation of both parent and daughter can lead to concentration enhancement of the daughter and the formation of a migrating front. Although investigations of these phenomena are being pursued by T. Pigford et al. at the University of California, their significance in the context of the overall waste isolation program has not been assessed. It is recommended that this subject be evaluated and its significance determined. At that time appropriate action can be taken with respect to further research.

3.2.8 Radionuclide Adsorption on Mineral Substrates

This subject has been the *raison d'être* of the DOE WRIT program. A large amount of research has been performed and substantial progress has been made toward identifying the parameters controlling adsorption and radionuclide migration. Therefore it is hardly an issue that languishes through lack of recognition or appropriate action. Nevertheless, much research remains to be done and improved coordination and greater focus on a narrower range of critical questions is now warranted.

It is recommended that this subject be reviewed in coordination with DOE, to identify future direction of this program and determine how it should be integrated into the overall geochemistry plan.

3.2.9 Development of Geochemical Field Monitors

Monitoring radionuclide migration during field tests is both conceptually and practically difficult. Both the concentration of the radionuclide, the distance it travels during the course of the test and the amount of fluid in the pores of the rock or backfill, all necessitate specifically designed probes or sensors. This subject should be evaluated in terms of the experimental designs proposed under section 3.2.3 and recommendations made for further research and development.

3.3 UNCERTAINTIES ARISING FROM IMPLEMENTATION OF THE PLAN

It should be emphasized at the outset, that the accomplishment of the geochemistry research program plan as laid out in Chapter 2 is not burdened with uncertainties of a conceptual nature. All research proposed represents an extension of well understood principles and no individual project is expected to cause insuperable problems. Nevertheless, the proposed research does involve the study of systems far more complex, and under constraints far more demanding than most geoscience research of a similar nature done to date. Therefore, the uncertainties lie in the implementation, duration, manpower, costs, organization and timing of projects in the program. Interfacing with other programs in

hydrology, geophysics and rock mechanics is also an important consideration. Duration, manpower and costs have already been reviewed in Chapter 2.0. It remains here only to discuss the uncertainties raised by these subjects and propose appropriate courses of action.

If it is determined that the program must be completed by a given date, then the uncertainty of duration is removed from consideration. Manpower and cost estimates will require detailed planning, which goes beyond the scope of this report, before the uncertainties and appropriate responses could be delineated. At this stage, it is recommended that the following actions be taken with respect to each issue.

3.3.1 Implementation

It must be determined whether all parties involved in the waste isolation program are willing to review geochemistry research needs, accept the present plan or modifications thereof, and ensure that it is implemented. Implicit in the plan is the assumption that the program will coordinate with and interface with DOE's current projects. However, as pointed out earlier, DOE's current projects must be reviewed with principal investigator participation, to determine in detail the scope of ongoing projects before the program can be finalized and implemented.

3.3.2 Manpower

Staffing needs must be determined by review of the credentials of potential participants as well as ascertaining their availability for the projects. The impact of staff deficiencies on program accomplishment should be identified. Many programs are currently underway through DOE sponsorship that contain the staff needed for the research programs. Minor changes in direction and better coordination would ensure continuity and go towards meeting the programmatic goals. It is recommended that a detailed evaluation be made of staff availability and commitments to existing projects.

3.3.3 Costs

Given the assumption that one scientist requires \$100K for support at a major institution, the overall cost of the program will run between \$32M-38M. However there is a large measure of uncertainty in these figures, for without detailed costing by principal investigators, the estimated manpower requirements for the projects are necessarily approximate.

It is recommended that, after identification of staff, candidate principal investigators be asked to submit detailed project proposals with budget estimates of assigned tasks.

3.3.4 Organization

A research program of the complexity of that outlined in Chapter 2 must be properly organized and managed. The present method whereby a series of separate contracts are awarded to various institutions has serious disadvantages unless some mechanism is implemented to ensure that the overall program is coordinated on a continuing basis. This might be accomplished through regular quarterly contractor meetings in which representatives with decision

making authority can report on progress and make adjustments to the program in response to the accomplishment or otherwise of program milestones. The potential incompatibility of this approach with the award of contracts with clearly defined work statements is recognized.

In general, too little attention has been paid in the past to coordination of large research programs. The magnitude and technical complexity of current programs fully justifies an examination of the potential management structure and determination of the feasibility of setting up an improved structure within the present organization. It is recommended that such an examination be undertaken.

3.3.5 Timing of Projects Within the Program

As discussed in chapter 2, uncertainties exist regarding the timing of certain projects, particularly field projects, within the research program. These uncertainties might be resolved by arbitrarily specifying the start up times of field projects in the absence of input from laboratory experimental, theoretical and modelling projects. Unfortunately, this approach automatically entails risks that can be translated into uncertainties of cost, manpower, time or outcome. Given the current state of planning, this uncertainty might be decreased in two ways (a) by following through with detailed evaluations of the preceding uncertainties. This may make the problem clearer, and may suggest that it is less of a problem than expected, or (b) by extending the time taken to complete the program. The latter choice has a direct bearing on the DOE schedule for the waste isolation program, discussed in the following section.

3.3.6 Interfacing with Other Programs

No consideration has been given in the development of this document, to possible interactions of the geochemistry research program with corresponding programs in hydrology, geophysics and rock mechanics or to the design and selection of waste forms or canisters. It is clear that the geochemistry research program cannot function independently of these other programs, and due consideration must be given to their schedules and needs.

It is recommended that a survey of other programs be made to identify conflicts, and to establish the effect such conflicts have on the present program.

Scientifically, extension of the repository development program would be justified, because this would decrease the risk of premature interpretation of field work, while avoiding the premature initiation of field work. Furthermore, there is no scientific or technical need for immediate implementation of a program to bury SURF or high level waste. There are adequate interim surface storage facilities for spent fuel, and these can, if necessary be expanded to accommodate additional material. However, the institutional issues and past government commitments are such that a scientific rationale is unlikely to have much bearing on present timing.

It is recommended that both options be explored in an effort to seek a resolution to this problem. Investigation of deep underground sites has already been carried out by LBL staff under NRC sponsorship. This study, while directed towards different goals, would usefully serve as a basis for tentative site selection for generic field tests in advance of site specific characterization in dedicated DOE test facilities.

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APPENDIX A. THE GEOLOGIC REPOSITORY AS A BARRIER SYSTEM

The geologic repository is a system of artificial (engineered) and natural barriers, each barrier designed to fulfill a particular function in isolating radioactive waste from the accessible environment.

The geologic repository is divided into a hierarchy of subsystems and components. Rules and regulations governing their performance have been promulgated by the Nuclear Regulatory Commission as 10 CFR Part 60 (Code of Federal Regulations, Title 10, Part 60). These were issued in the Federal Register, Vol. 46, No. 37, p. 13971-13987, on February 25, 1981, as Rules and Regulations and in Vol. 46, No. 120, p. 35288-35296, on July 8, 1981, as Proposed Rules.

The relationship of the system components to each other and to the NRC rules and regulations must be understood in order to clarify the geochemistry issues and organize a geochemistry research plan. Figure A.1 is an organization chart showing the interrelationship of the component parts of the geologic repository system. The items enclosed in the boxes with the heavy borders are those identified and defined or conceptualized in 10 CFR Part 60. The remainder are incorporated for completeness. All are listed in Table A.1 with the definitions or conceptual explanations from 10 CFR Part 60.

Table A.2 summarizes the systems approach to a geologic repository and relates the materials and barrier parameters to critical questions concerning their function. The tasks emerging from the questions, decision points, and pertinent sections from 10 CFR Part 60 are incorporated in the table and correlated with the relevant barriers. This table is the basis for organizing the tasks in which current geochemistry research is evaluated. It also summarizes the underlying systems approach to defining geochemistry research needs for an underground waste repository. Additional sections from 10 CFR Part 60, which deal with the repository in general, or with more than one barrier, are appended after the notes in Table A.2.

Figure A.1. Organization chart to show the hierarchy of subsystems and components of a geologic repository. [XBL 828-2381]

Table A.1. Definitions and Concepts.

Accessible Environment

The accessible environment means those portions of the environment directly in contact with or readily available for use by human beings.

[§60.102, Concepts, (f)]

Backfill

See Underground Facility.

Container

A waste package includes: The container, which is the first major sealed enclosure that holds the waste form.

[§60.102, Concepts, (e)]

Encapsulating Material

See Waste Form.

Engineered System

The engineered system includes the waste packages as well as the underground facility.

[§60.102, Concepts, (e)]

Far Field

The far field is that part of the geologic setting which is unaffected by mechanical or thermal effects caused by emplacement of the geologic repository.

[Undefined by NRC]

Geologic Repository

Geologic repository means a system which is intended to be used for, or may be used for, the disposal of radioactive wastes in excavated geologic formations. A geologic repository includes (1) the geologic repository operations area and (2) all surface and subsurface areas where natural events or activities of man may change the extent to which radioactive wastes are effectively isolated from the biosphere.

[§60.2, Definitions, (h)]

Table A.1 (cont.)

Geologic Repository Operations Area

A geologic repository operations area consists of those surface and subsurface areas that are part of a geologic repository where radioactive waste handling activities are conducted.

[§60.102, Concepts, (b),(2)]

Geologic Setting

There is a large area, designated the geologic setting or site which includes the spatially distributed geologic, hydrologic, and geochemical systems that provides isolation of the radioactive waste from the accessible environment. The geologic repository operations area plus the geologic setting make up the geologic repository. Within the geologic setting, particular attention must be given to the characteristics of the host rock as well as any rock units surrounding the host rock.

[§60.102, Concepts, (c)]

High-Level Radioactive Waste

"High-Level radioactive waste" or "HLW" means (1) irradiated reactor fuel, (2) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel, and (3) solids into which such liquid wastes have been converted.

[§60.2, Definitions, (j)]

Natural Barrier System

The natural barrier system consists of all those barriers to radionuclide migration that were part of the geologic setting prior to construction of the geologic repository.

[Undefined by NRC]

Near Field

The near field is that part of the geologic setting which is affected by mechanical or thermal effects caused by emplacement of the geologic repository.

[Undefined by NRC]

Openings

See Underground Facility.

Table A.1 (cont.)

Overpack

A waste package includes: Overpacks which consist of any buffer material, receptacle, wrapper, box or other structure that is both within and an integral part of a waste package. It encloses and protects the waste form so as to meet the performance objectives.

[§60.102, Concepts, (e)]

Shafts

See Geologic Repository Operations Area.

Surface

See Geologic Repository Operations Area.

Underground Facility

The underground structure including openings and backfill materials, but excluding shafts, boreholes, and their seals, is designated the underground facility.

[§60.102, Concepts, (b),(2)]

Waste Form

A waste package includes: The waste form which consists of the radioactive waste materials and any associated encapsulating or stabilizing materials.

[§60.102, Concepts, (e)]

Waste Package

A waste package Includes:

- (1) The waste form
- (2) The container
- (3) Overpacks

[§60.102, Concepts, (e)]

Table A.2. Chemistry of Geologic Waste Isolation: Problem Definition.

System	Geologic Repository	
Subsystem	Geologic Repository Operations Area	
Barrier System	Engineered System	
Barrier Subsystem	Waste Package	
Component	Waste Form	Container and Packing Material
<u>Materials</u>	High-level waste Spent fuel rods Reprocessed waste <ul style="list-style-type: none"> • calcine • "supercalcine" • glass • high-alumina ceramics • titanates • composites 	Cast iron Carbon steel Stainless steel Copper Aluminum Titanium alloys Composites Inner and outer packing material
<u>Parameters Affecting Radionuclide Isolation</u>	N/A	N/A
<u>Questions</u>	N/A	N/A
<u>Tasks</u>	N/A	N/A
<u>Decision Points</u>	N/A	N/A
<u>Pertinent Sections from 10 CFR Part 60 (NRC)</u>	See Note 1 at end of table.	

Table A.1 (cont.)

System	Geologic Repository (cont.)	
Subsystem	Geologic Repository Operations Area (cont.)	
Barrier System	Engineered System (cont.)	
Barrier Subsystem	Waste Package (cont.)	
Component	Overpack	
<u>Materials</u>	Phosphates Clays Other substances Eh modifiers pH modifiers	
<u>Parameters Affecting Radionuclide Isolation</u>	<u>Source Release Mechanism</u> Congruent dissolution. Incongruent dissolution with precipitation of secondary phases. Solid-state diffusion. Diffusion through a porous product layer.	<u>Source Release Controls</u> Surface area of waste. Effective porosity, pinholes. Interaction with dissolved groundwater chemical components. Interaction of fission products with each other and with waste matrix. Presence of complexing agents. Eh (changing oxidation state, complexation). pH (hydroxylation, complexation).
<u>Questions</u>	What radionuclides must be considered in designing the backfill?	
<u>Tasks</u>	Toxic radionuclides in spent reactor fuel and high-level waste at various times after 1,000 years. Solubility constraints on important fission products. Solubility constraints on actinides.	
<u>Decision Points</u>	Define radionuclides that must be considered in designing the backfill.	
<u>Pertinent Sections from 10 CFR Part 60 (NRC)</u>	See Notes 2 to 5 at end of table.	

Table continues on next page.

Table A.1 (cont.)

<u>System</u>	Geologic Repository (cont.)	
<u>Subsystem</u>	Geologic Repository Operations Area (cont.)	
<u>Barrier System</u>	Engineered System (cont.)	
<u>Barrier Subsystem</u>	Underground Facility	
<u>Component</u>	Backfill	
<u>Materials</u>	Bentonite Zeolites Crushed rock Eh modifiers pH modifiers Dehydration agents Composites of above	
<u>Parameters Affecting Radionuclide Isolation</u>	<u>Conditions</u> Pressure = 100-300 bars Temperature = 350° to ambient Saturated/unsaturated Radiation Flux of a defined suite of radionuclides	<u>Physical/Chemical Properties</u> Porosity, ϕ Permeability, μ Surface area, A Tortuosity, τ Chemical composition Adsorption capacity Ion-exchange capacity
<u>Questions</u>	<p>What will be the principal effects of temperature and thermal gradients in the backfill?</p> <p>What range of maximum concentrations of released radionuclides can be expected in the groundwater if the radionuclides react with natural materials and precipitate in the vicinity of the canister?</p> <p>How will fission daughter products affect migration of significant radionuclides? Will the presence of fission products <u>enhance</u> or <u>inhibit</u> migration of other radionuclides?</p> <p>Is criticality an issue? Can we dispense with further consideration of this problem?</p>	
<u>Tasks</u>	<p>Long-term criticality potential in a repository.</p> <p>Simulation of diffusional transport of radionuclides through a non-sorbing barrier in spherical geometry.</p> <p>Low-permeability backfill materials.</p>	
<u>Decision Points</u>		
<u>Pertinent Sections from 10 CFR Part 60 (NRC)</u>	See Notes 6 and 7 at end of table.	

Table A.1 (cont.)

System	Geologic Repository (cont.)		
Subsystem	Geologic Repository Operations Area (cont.)		
Barrier System	Engineered System (cont.)		
Barrier Subsystem	Underground Facility (cont.)		
Component	Backfill (cont.)		
Materials	Bentonites Zeolites Crushed rock Eh modifiers pH modifiers Dehydration agents Composites of above		
Parameters Affecting Radionuclide Isolation	Transported Forms	Transport Mechanisms	Retardation Mechanisms
	Ionic (including complexes) Molecular (including complexes) Colloidal Particulate	Convection Advection Diffusion	Adsorption Interlayer ionic exchange Zeolite exchange Ion exchange Precipitation
Questions	<p>Bearing in mind that colloidal particles diffuse at much slower rates than ionic and molecular species, can we dispose of the colloidal particles problem if only diffusive transport occurs?</p> <p>Given a reasonable knowledge of retardation coefficients and permeabilities, how thick must a backfill be to retard critical radionuclides to innocuous levels? Are these thicknesses reasonable?</p> <p>What effect would different backfill materials have on the degree of retardation? What if, in addition to adsorption, ion exchange were to take place? How would this affect retardation? What radionuclides cannot be adequately contained by an engineered barrier?</p>		
Tasks	<p>An examination of the availability of data on complexes of elements contained in the radioactive waste package.</p> <p>Radionuclide colloid formation.</p> <p>Diffusive fluxes of colloidal particles in spherical geometry.</p> <p>Transport models incorporating chemical reactions.</p> <p>Existing sorption (ion exchange) data for backfill materials.</p> <p>Transport of radionuclides with sorption; release rates and fluxes for given backfill thickness.</p>		
Decision Points	<p>Identify radionuclides which must be considered in the near-field region.</p>		
Pertinent Sections from 10 CFR Part 60 (NRC)	<p>See Note 8 and 9 at end of table.</p>		

Table continues on next page.

Table A.1 (cont.)

System			Geologic Repository (cont.)
Subsystem			Geologic Setting
Barrier System			Natural Barrier System
Barrier Subsystem			Near Field
Component			
<u>Materials</u>			<div> <p>Salt (domal) Salt (bedded) Basalt Granite Shale Tuff</p> <p><u>Modifiers</u> Grouts Cements Intruded backfill matrices Silica gel</p> </div>
<u>Parameters Affecting Radionuclide Isolation</u>			<div> <p><u>Conditions</u> Pressure = 100-300 bars Temperature = 150°C (?) to ambient Saturated/unsaturated Flux of defined suite of radionuclides Groundwater composition pH, Eh</p> <p><u>Physical/Chemical Properties</u> Porosity, ϕ Permeability, μ • matrix • fracture Surface area Porosity, γ Chemical composition Adsorption capacity Ion-exchange capacity</p> </div>
<u>Questions</u>			<p>What effect would grout have on migration?</p> <p>What temperatures might be expected in this region?</p> <p>Is it reasonable to expect that thermal effects would cause increases (or decreases) in permeability?</p>
<u>Tasks</u>			<div> <p>Effect of temperature gradients on permeability in the near-field host rock regions.</p> <p>Effect of waste emplacement on the near-field environment and its impact on rock physical properties, mineralogy, and radionuclide migration.</p> <p>Bounding the physical and chemical conditions in the repository environment: • pressure • temperature • host rock mineralogy • groundwater composition • host rock physical parameters</p> </div>
<u>Decision Points</u>			
<u>Pertinent Sections from 10 CFR Part 60 (NRC)</u>			See Notes 10 to 19 at end of table.

Table A.1 (cont.)

<u>System</u>	Geologic Repository (cont.)		
<u>Subsystem</u>	Geologic Setting (cont.)		
<u>Barrier System</u>	Natural Barrier System (cont.)		
<u>Barrier Subsystem</u>	Near Field (cont.)		
<u>Component</u>			
<u>Materials</u>	Salt (domal) Salt (bedded) Basalt Granite Shale Tuff	<u>Modifiers</u>	Grouts Cement Introduced backfill matrices Silica gel
<u>Parameters Affecting Radionuclide Isolation</u>	<u>Transported Forms</u>	<u>Transport Mechanisms</u>	<u>Retardation Mechanisms</u>
	Ionic (including complexes) Molecular (including complexes) Colloidal Particulate	Convection Advection Diffusion	Adsorption Interlayer ion exchange Zeolite exchange Ion exchange Precipitation Pore diffusion
<u>Questions</u>	Is it likely that ion-exchange processes and precipitation could significantly retard radionuclides in the near-field region? By approximately how much? What range of thickness would be required if diffusion in the aqueous phase were the sole transport mechanism?		
<u>Tasks</u>			
<u>Decision Points</u>	Identify radionuclides which will escape the near field.		
<u>Pertinent Sections from 10 CFR Part 60 (NRC)</u>			

Table continues on next page.

Table A.1 (cont.)

System	Geologic Repository (cont.)		
Subsystem	Geologic Setting (cont.)		
Barrier System	Natural Barrier System (cont.)		
Barrier Subsystem	Far Field		
Component			
Materials	Salt (domal) Salt (bedded) Basalt Granitic Shale Tuff		
Parameters Affecting Radionuclide Isolation	Conditions Pressure = 100-300 bars Temperature = ambient Saturated/unsaturated flux of defined suite of radionuclides Groundwater composition pH, Eh	Physical/Chemical Properties Porosity, ϕ Permeability, μ • matrix • fracture Surface Area Tortuosity, τ Chemical composition Adsorption capacity Ion-exchange capacity	Transported Forms Ionic (including complexes) Molecular (including complexes) Colloidal (?) Particulate (?)
Questions	<p>Is it plausible or realistic to assume that geochemistry can be used to determine the age, history, and origin of groundwater? If so, how much effort will be required and for how long?</p> <p>If we cannot realistically do now what is questioned above, what assurance do we have that we can predict radionuclide migration in a system perturbed by other species? If we can, why?</p> <p>Can transport of radionuclides occur on particulates suspended in groundwater?</p> <p>Is the transport of radionuclides by complexing significant?</p>		
Tasks	Assessment of groundwater dating. Particulate transport in groundwater. Organic complexation of radionuclides. Effects of long-term nonequilibrium water-rock interactions on radionuclide retardation.		
Decision Points	Identify constraints required to keep all radionuclides within the far field.		
Pertinent Sections from 10 CFR Part 60 (NRC)	See Notes 20 to 23 at end of table.		

• Table A.1 (cont.)

System	Geologic Repository (cont.)	Accessible Environment
Subsystem	Geologic Operations Area (cont.)	
Barrier System	Natural Barrier System (cont.)	
Barrier Subsystem	Far Field (cont.)	
Component		
<u>Materials</u>	Salt (domal) Salt (bedded) Basalt Granite Shale Tuff	N/A
<u>Parameters</u> <u>Affecting</u> <u>Radionuclide</u> <u>Isolation</u>	<u>Transport Mechanisms</u> Convection Diffusion <u>Retardation Mechanisms</u> Adsorption Interlayer ion exchange Zeolite exchange Ion exchange Precipitation (?)	N/A
<u>Questions</u>		N/A
<u>Tasks</u>		N/A
<u>Decision Points</u>		N/A
<u>Pertinent Sections from</u> 10 CFR Part 60 (NRC)	See Note 24 at end of table.	

NOTES TO TABLE A.2

1. (2) Performance of the engineered system. (i) Containment of wastes. The engineered system shall be designed so that even if full or partial saturation of the underground facility were to occur, and assuming anticipated processes and events, the waste packages will contain all radionuclides for at least the first 1,000 years after permanent closure. This requirement does not apply to TRU waste unless TRU waste is emplaced close enough to HLW that the TRU release rate can be significantly affected by the heat generated by the HLW.

[§60.111, Performance objectives, (b),
(2),(1)]

2. (2) Protection against natural phenomena and environmental conditions. (i) The structures, systems, and components important to safety shall be designed to be compatible with anticipated site characteristics and to accommodate the effects of environmental conditions, so as to prevent interference with normal operation, maintenance, and testing during the entire period of construction and operations.

[§60.130, General design requirements
for the geologic repository operations
area, (b),(2),(1)]

3. (a) General criteria for the underground facility.

(1) The underground facility shall be designed so as to perform its safety functions assuming interactions among the geologic setting, the underground facility, and the waste package.

[§60.132, Additional design requirements
for the underground facility, (a),(1)]

4. (a) General requirements of design.

(1) Effect of the site on the waste package. The waste package shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages. The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

4 (cont.)

(2) Effect of the waste package on the underground facility and the natural barriers of the geologic setting. The waste package shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the performance of the underground facility or the geologic setting. The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

[§60.135, Requirements for the waste package and its components, (a),(1), (2)]

5. Monitoring and testing waste packages.

(a) A program shall be established at the repository for monitoring the condition of the waste packages. Packages chosen for the program shall be representative of those to be emplaced in the repository.

(b) Consistent with safe operation of the repository, the environment of the waste packages selected for the waste package monitoring program shall be representative of the emplaced wastes.

(c) The waste package monitoring program shall include laboratory experiments which focus on the internal condition of the waste packages. To the extent practical, the environment experienced by the emplaced waste packages within the repository during the waste package monitoring program shall be duplicated in the laboratory experiments.

(d) The waste package monitoring program shall continue as long as practical up to the time of permanent closure.

[§60.143, Monitoring and testing waste packages]

6. (8) Criticality control. All systems for processing, transporting, handling, storage, retrieval, emplacement, and isolation of radioactive waste shall be designed to ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety under normal and accident conditions. The calculated effective multiplication factor (K_{eff}) must be sufficiently below unity to show at least a 5% margin, after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.

[§60.130, General design requirements for the repository operations area, (b),(8)]

7. (1) Engineering barriers.

(1) Barriers shall be located where shafts could allow access for groundwater to enter or leave the underground facility.

(2) Barriers shall create a waste package environment which favorably controls chemical reactions affecting the performance of the waste package.

(3) Backfill placed in the underground facility shall be designed as a barrier.

(i) Backfill placed in the underground facility shall perform its functions assuming anticipated changes in the geologic setting.

(ii) Backfill placed in the underground facility shall serve the following functions:

(A) It shall provide a barrier to groundwater movement into and from the underground facility.

(B) It shall reduce creep deformation of the host rock that may adversely affect (1) waste package performance or (2) the local hydrological system.

(C) It shall reduce and control groundwater movement within the underground facility.

(D) It shall retard radionuclide migration.

(iii) Backfill placed in the underground facility shall be selected to allow for adequate placement and compaction in underground openings.

[§60.132, Additional design requirements for the underground facility,
(1),(2),(3)]

8. Design Testing

(a) During the early or developmental stages of construction, a program for in situ testing of such features as borehole and shaft seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock and groundwater shall be conducted.

(b) The testing shall be initiated as early as is practicable.

(c) A backfill test section shall be constructed to test the effectiveness of backfill placement and compaction procedures against design requirements before permanent backfill placement is begun.

(d) Test sections shall be established to test the effectiveness of borehole and shaft seals before full-scale operation proceeds to seal boreholes and shafts.

[§60.142, Design testing]

9. (ii) Control of releases.

(A) For HLW, the engineered system shall be designed so that, after the first 1,000 years following permanent closure, the annual release rate of any radionuclide from the engineered system into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 for the maximum amount of that radionuclide calculated to be present in the underground facility (assuming no release from the underground facility) at any time after 1,000 years following permanent closure. The requirement does not apply to less than 0.1% of the total annual curie release as prescribed by this paragraph.

(B) For TRU waste, the engineered system shall be designed so that following permanent closure the annual release rate of any radionuclide from the underground facility into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 of the maximum amount calculated to be presented in the underground facility (assuming no release from the underground facility) at any time following permanent closure. This requirement does not apply to radionuclides whose contribution is less than 0.1% of the annual curie release as prescribed by this paragraph.

[§60.111, Performance objectives, (b), (2), (ii)]

10. (b) The geologic setting shall have exhibited hydrogeologic, geochemical, and geomorphic stability since the start of the Quaternary Period.

[§60.112, Required characteristics of the geologic setting, (b)]

11. Favorable conditions

(h) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having increased capacity to inhibit radionuclide migration.

(i) Conditions that permit the emplacement of waste at a minimum depth of 300 meters from the ground surface. (The ground surface shall be deemed to be the elevation of the lowest point on the surface above the disturbed zone.)

(j) Any local condition of the disturbed zone that contributes to isolation.

[§60.122, Favorable conditions, (h)-(j)]

12. (k) Design for thermal loads.

(1) The underground facility shall be designed so that the predicted thermal and thermomechanical response of the rock will not degrade significantly the performance of the repository or the ability of the natural or engineered barriers to retard radionuclide migration.

(2) The design of waste loading and waste spacings shall take into consideration:

(i) Effects of the design of the underground facility on the thermal and thermomechanical response of the host rock and the groundwater system.

(ii) Features of the host rock and geologic setting that affect the thermomechanical response of the underground facility and barriers, including but not limited to, behavior and deformational characteristics of the host rock, the presence of insulating layers, aquifers, faults, orientation of bedding planes, and the presence of discontinuities in the host rock.

(iii) The extent to which fracturing of the host rock is influenced by cycles of temperature increase and decrease.

[§60.132, Additional design requirements for underground facility, (i) Engineered barriers, (k), (1), (2)]

13. Potentially adverse conditions

Evidence of dissolution of soluble rocks.

[§60.123, Potentially adverse conditions, (b) Adverse conditions in the disturbed zone, (5)]

14. Potentially adverse conditions, continued.

(13) Conditions in the host rock that are not reducing conditions.

(14) Groundwater conditions in the host rock, including but not limited to high ionic strength or ranges of Eh-pH that could affect the solubility and chemical reactivity of the engineered system.

(15) Processes that would reduce sorption, result in degradation of the rock strength, or adversely affect the performance of the engineered system.

(16) Rock or groundwater conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts.

[§60.123, Potentially adverse conditions, (b) Adverse conditions in the disturbed zone, (13-16)]

15. (e) Design of subsurface openings.

(1) Subsurface openings shall be designed to maintain stability throughout the construction and operation periods. If structural support is required for stability, it shall be designed to be compatible with long-term deformation, hydrologic, geochemical, and thermomechanical characteristics of the rock and to allow subsequent placement of backfill.

[§60.132, Additional design requirements for underground facility, (e), (1)]

16. (e) Design of subsurface openings.

(3) Subsurface openings shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding rock over the long term. The size, shape, orientation, and spacing of openings and the design of engineered support systems shall take the following conditions into consideration--

(i) Natural stress conditions.

(ii) Deformation characteristics of the host rock under normal conditions and thermal loading.

(iii) The kinds of weaknesses or structural discontinuities found at various locations in the geologic repository.

(iv) Equipment requirements.

(v) The ability to construct the underground facility as designed so that stability of the rock is enhanced.

[§60.132, Additional design requirements for underground facility, (e), (3)]

17. (f) Rock excavation. The design of the underground facility shall incorporate excavation methods that will limit damage to and fracturing of rock.

[§60.132, Additional design requirements for the underground facility, (f)]

18. Design of shafts and seals for shafts and boreholes.

(b) Shaft and borehole seals.

(2) At the time of permanent closure, sealed shafts and boreholes will inhibit transport of radionuclides to at least the same degree as the undisturbed units of rock through which the shafts or boreholes pass. In the case of soluble rocks the borehole and shaft seals shall also be designed to prevent groundwater circulation that would result in dissolution.

(3) Contact between shaft and borehole seals and the adjacent rock does not become a preferential pathway for water.

(4) Shaft and borehole seals can accommodate potential variations of stress, temperature and moisture.

(5) The material used to construct the seals are appropriate in view of the geochemistry of the rock and groundwater system anticipated deformations of the rock and other in situ conditions.

[§60.133, Design of shafts and seals for shafts and boreholes]

19. (d) rock excavation. The methods used for excavation shall be selected to reduce to the extent practicable the potential to create a preferential pathway for groundwater or radioactive waste migration or increase migration through existing pathways.

[§60.134, Construction specifications for surface and subsurface facilities, (d)]

20. Favorable conditions

(c) The nature and rates of hydrogeological processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

[§60.122, Favorable conditions, (c)]

21. Favorable conditions, continued

(d) The nature and rates of geochemical processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

[§60.122, Favorable conditions, (d)]

22. Favorable conditions, continued

(g) Geochemical conditions that (1) promote precipitation or sorption of radionuclides; (2) inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; and (3) inhibit the transport of radionuclides by particulates, colloids, and complexes.

[§60.122, Favorable conditions, (g)]

23. Favorable conditions, continued

(f) A host rock that provides the following groundwater characteristics—(1) low groundwater content; (2) inhibition of groundwater circulation in the host rock; (3) inhibition of groundwater flow between hydrogeologic units or along shafts, drifts, and boreholes; and (4) groundwater travel times, under prewaste emplacement conditions, between the underground facility and the accessible environment that substantially exceed 1,000 years.

[§60.122 Favorable conditions, (f)]

24. (b) Performance of the geologic repository after permanent closure. (1) Overall system performance. The geologic setting shall be selected and the subsurface facility designed so as to assure that releases of radioactive materials from the geologic repository following permanent closure conform to such generally applicable environmental radiation protection standards as may have been established by the Environmental Protection Agency.

[§60.111, Performance objectives,
(b),(1)]

Additional Sections from 10 CFR Part 60 Pertinent to Repository Geochemistry

Licence Application

(c) The Safety Analysis Report shall include:

- (1) A description and analysis the site at which proposed geologic repository operations area is to be located with appropriate attention to those features that might affect facility design and performance. The assessment shall contain an analysis of the geology, geophysics, hydrology, geochemistry, and meteorology of the site and the major design structures, systems, and components, both surface and sub-surface that bear significantly on the suitability of the geologic repository for disposal of radioactive waste.
- (2) A description and discussion of the design, both surface and sub-surface of the geologic repository operations area including:
 - (iii) information relative to materials of construction (including geologic media, general arrangement, and approximate dimensions)
 - (3) A description and analysis of the design and performance requirements for structures, systems, and components of the geologic repository which are important to safety. The analysis and evaluation shall consider (iii) the effectiveness of engineered and natural barriers, including barriers that may not be themselves a part of the geologic repository operations area against the release of radioactive material to the environment.

[§60.21, Content of application (c)]

Decommissioning

(a) The DOE shall submit an application to amend the license prior to decommissioning. The application shall consist of an update of the license application and environmental report submitted under §60.21 and 60.22 including:

(3) Geologic, geophysical, geochemical, hydrologic and other site data that are obtained during the operational period pertinent to the long-term isolation of emplaced radioactive wastes.

(4) The results of tests, experiments and any other analyses relating to backfill of excavated areas, shaft sealing, waste interaction with emplacement media and any other test experiments or analyses pertinent to the long-term isolation of emplaced waste within the geologic repository.

[§60.51, License amendment to decommission]

Subpart F- Performance Confirmation

(a) The performance confirmation program shall ascertain whether:

(1) Actual subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review; and (2) Natural and engineered systems and components required for repository operation or which are designed or assumed to operate as barriers after permanent closure are functioning as intended and anticipated.

(b) The program shall have been started during site characterization and it will continue until permanent closure.

(c) The program will include in situ monitoring laboratory and field testing and in situ experiments as may be appropriate to accomplish the objective as stated above.

(d) the confirmation program shall be implemented so that:

(1) It does not adversely affect the natural and engineered elements of the geologic repository.

(2) It provides baseline information and analysis of that information on those parameters and natural processes pertaining to the geologic setting that may be changed by site characterization construction and operational activities.

(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository.

(4) It provides an established plan for feedback and analysis of data and implementation of appropriate action.

[§60.140 General requirements]

APPENDIX B. LIST OF RESEARCH PROJECTS CURRENT IN 1981

REF.ID - 1 CATEGORY - MASS TRANSPORT

ROCK.TYPE - GENERAL

REF.TYPE- PROJECT - Trace-Element Transport in Geologic Media

PRINCIPAL INVESTIGATORS: Seitz, M. G.; Couture, R. A.

LOCATION: Argonne National Lab., Ill. 60439

FUNDING AGENCY: DOE.

COMMENTS: Study fundamental mechanisms that underlie transport by fluid flow of trace elements in rocks.

INFORMATION SOURCES FOR THIS PROJECT: DOE/ER-0071 (Aug. 1980)

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REF.ID - 2

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Migration of Heavy Element Chemical Species
in Geologic Strata

PRINCIPAL INVESTIGATORS: Fried, S. M.; Friedman, A. M.; Sullivan, J. C.

LOCATION: Argonne National Lab. Ill. 60439

FUNDING AGENCY: DOE.

COMMENTS: Study the fundamental parameters affecting the rate of transport of radionuclides from a potential nuclear waste site located in deep geologic media. Specific concerns are conditions that affect oxidation states and hence the migration rates of various actinide ions that may be leached by ground water from a source emplaced in a deep geologic repository.

INFORMATION SOURCES FOR THIS PROJECT: DOE/ER-0071 (Aug. 1980)

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REF.ID - 3 CATEGORY - MASS TRANSPORT

ROCK.TYPE - BASALT, OTHER

REF.TYPE- PROJECT - Investigation of Mechanisms that Control Concentration of Radionuclides in Geologic Solution

PRINCIPAL INVESTIGATORS: Rai, D.; Strickett, D. G.

LOCATION: Pacific Northwest Lab., Richland, Wash. 99352

FUNDING AGENCY: DOE.

COMMENTS: Determine the mechanisms and the effects of various factors (such as pH, Eh, complexing and competing ligands, tracer concentration, oxidation state of the element, solid phases, etc.) in controlling the concentration of elements in solutions in equilibrium with different geomedias. Contaminated Hanford soils were used to determine the factors or mechanisms controlling the concentration of Pu and Am in solutions contacting these soils.

INFORMATION SOURCES FOR THIS PROJECT: DOE/ER-0071 (Aug. 1980)

REF.ID(S) OF ASSOCIATED DOCUMENTS: PNL

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REF.ID - 4 CATEGORY - NUCLIDES/ROCK INTERACTIONS

ROCK.TYPE - GRANITE, OTHER

REF.TYPE - PROJECT - Chemical Migration by Contact Metamorphism in Granite-Carbonate Rocks

PRINCIPAL INVESTIGATORS: Laul, J. C.

LOCATION: Pacific Northwest Lab., Richland, Wash. 99352

FUNDING AGENCY: DOE.

COMMENTS: Study the migration of major, minor, and, in particular, trace elements during contact metamorphism between granite and carbonate rocks. Specific emphasis will be on the rare earth elements and barium (Ba), strontium (Sr), rubidium (Rb), cesium (Cs), zirconium (Zr), hafnium (Hf), nickel (Ni), thorium (Th) and uranium (U). The geologic site under study is the Notch Peak intrusion near Delta in western Utah.

INFORMATION SOURCES FOR THIS PROJECT: DOE/ER-0071 (Aug. 1980)

REF.ID(S) OF ASSOCIATED DOCUMENTS: PNL

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REF.ID - 5 CATEGORY - NATURAL ANALOGUES

ROCK. TYPE - GENERAL

REF.TYPE - PROJECT - Identification of Environments Providing
Effective Multiple Natural Barriers to Radionuclide Transport

PRINCIPAL INVESTIGATORS: Hale, W. E., USGS, Albuquerque

LOCATION: Contact: G. D. DeBuchananne, 703-860-6976

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP

COMMENTS: Identify or contribute to the identification of environments with hydrodynamic, geochemical, and geologic characteristics that provide independent multiple natural barriers to the migration of radionuclides and that may warrant intensive study.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC 11033 (Draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: USGS

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REF.ID - 6 CATEGORY - POTENTIAL SITES, U.S.

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - National Screening of Geologic Environments

PRINCIPAL INVESTIGATORS:

LOCATION: Contact R. R. Nicks, 614-424-4406

DURATION: Two years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Identify portions of conterminous U.S. with potential for waste isolation, based on a comprehensive literature search of geologic and environmental data.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC 11033 (DRAFT) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI

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REF.ID - 7 CATEGORY - SITE CHARACTERIZATION, SOUTHEASTERN U.S.

ROCK.TYPE - ARGILLACEOUS, CRYSTALLINE

REF.TYPE - PROJECT - Geologic Evaluation of Southeastern U.S.

PRINCIPAL INVESTIGATORS: Marine, I. W., Sandia Research Laboratory

LOCATION: Contact: R. R. Nicks, 614-424-4406

DURATION: two years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Evaluate potential of geologic formations in southeastern U.S., especially crystalline rocks of Piedmont Province and argillaceous rocks of the Southeastern Coastal Plain, for the disposal of radioactive wastes.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, SAND

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REF.ID - 8 CATEGORY - SITE CHARACTERIZATION, PALO DURO AND DALHERT BASIN, TEXAS

ROCK.TYPE - BEDDED SALT

REF.TYPE - PROJECT - Evaluation of West Texas Bedded Salt

PRINCIPAL INVESTIGATORS: Handford, C. R., TBEG

LOCATION: Contact: W. E. Newcomb, 614-424-7685

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Evaluate regional geologic and hydrologic environments of Palo Duro and Dalhart Basins of West Texas where extensive bedded salt occurs; assist in selecting study areas for detailed characterization; and to inventory the natural resources of the basins.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC 11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, RHO

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REF.ID - 9 CATEGORY - SITE CHARACTERIZATION, PARADOX BASIN

ROCK.TYPE - BEDDED SALT

REF.TYPE - PROJECT - Geologic Evaluation of Paradox Basin

PRINCIPAL INVESTIGATORS: McMillan, D. (UGMS); Hite, R. (USGS);
Conwell, F. (Woodward-Clyde)

LOCATION: Contact: N. A. Frazier, 614-424-7688

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: To conduct, in sequence, regional, area, and site investigations for purposes of identifying, characterizing, and licensing a repository in bedded salt.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC 11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, USGS

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REF.ID - 10 CATEGORY - POTENTIAL SITES, U.S. - CRYSTALLINE

ROCK.TYPE - CRYSTALLINE

REF.TYPE - PROJECT - Survey of Crystalline Rock

PRINCIPAL INVESTIGATORS: Winar, R. M. (Participant: Dames and Moore)

LOCATION: Contact: R. R. Nicks, 614-424-4406

DURATION: One year

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Perform reconnaissance survey of occurrences of crystalline rocks in the U.S. with potential for radioactive waste isolation.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC 11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI

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REF.ID - 11 CATEGORY - HOST ROCKS, ROCK SALT

ROCK.TYPE - ROCK SALT

REF.TYPE - PROJECT - Salt Permeability

PRINCIPAL INVESTIGATORS: Wayland, J. R.

DURATION: Three years

FUNDING AGENCY: USGS/ESTP.

COMMENTS: Assess permeability of southeastern New Mexico rock salt for gas and liquid migration studies.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIE 11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/ALO/WIPP, SAND

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REF.ID - 12 CATEGORY - HOST ROCKS, GRANITE

ROCK.TYPE - PROJECT - Properties of Granite and Other Crystalline Rocks

PRINCIPAL INVESTIGATORS: Peterman, Z. E.; Byerlee, J. R. (USGS),

LOCATION: Contact: E. R. Roseboom, 703-860-6631

DURATION: 5 years

FUNDING AGENCY: DOE/ESTP/USGS.

COMMENTS: Assess properties of granite and other crystalline rocks in a generic manner as a guide to future exploration for repository sites.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC 11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: USGS

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REF.ID - 13 CATEGORY - HOST ROCKS, ARGILLACEOUS

ROCK.TYPE - ARGILLACEOUS

REF.TYPE - PROJECT - Laboratory Evaluation of Argillaceous Rocks
for Nuclear Waste Containment

PRINCIPAL INVESTIGATORS: Brunton, G. (Participant: ORNL)

LOCATION: Contact: R. R. Nicks, 614-424-4406

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Perform fundamental investigation of physico-chemical
properties of argillaceous rocks, and to identify and document their
suitability as waste repository hosts.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC 11033 (draft) April
1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, ORNL

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REF.ID - 14 CATEGORY - HOST ROCKS, SHALE

ROCK.TYPE - SHALE

REF.TYPE. - PROJECT - Shale Structure Studies

PRINCIPAL INVESTIGATORS: Weaver, C. (Participant: Georgia Inst. of
Tech.)

LOCATION: Contact: J. O. Duguid, 614-424-4773

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Determine effect of elevated temperature on
chemical/physical structure of shales.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC 11033 (draft) April
1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI

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REF.ID - 15 CATEGORY - ROCK/SOLUTION INTERACTIONS

ROCK.TYPE - SALT

REF.TYPE - PROJECT - Effect of Water on salt Repository

PRINCIPAL INVESTIGATORS: Baes, C., ORNL

LOCATION: Contact: J. F. Kircher, 614-424-4871

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: To gain information sufficient to predict credibly the consequences of any plausible form of water breaching a salt repository that might compromise the integrity of that repository. Study effects on water on salt, in terms of dissolution rates and reprecipitation, and as functions of temperature, flow rate and salt particle size distribution.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC 11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, ORNL

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REF.ID - 16 CATEGORY - RADIONUCLIDE TRANSPORT

ROCK.TYPE - NA

REF.TYPE - PROJECT - Geochemistry of Transuranium Elements

PRINCIPAL INVESTIGATORS: Cleveland, J. M. (participant: USGS)

LOCATION: Contact: G. D. DeBuchananne, 703-860-6976

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Characterize chemical and physical forms of transuranium elements in contaminated natural water and to determine interactions of these elements with other solutes. To interpret this information so that it can be used to develop criteria for identifying repository sites where the ground-water properties would minimize the formation of soluble, mobile transuranic species.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC 1103 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: USGS

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REF.ID - 17 CATEGORY - RADIONUCLIDE/SOLUTION INTERACTIONS

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Thermodynamic Properties of Actinides

PRINCIPAL INVESTIGATORS: Edelstein, N., LBL

LOCATION: Contact: J. F. Kircher, 614-424-4871

DURATION: Three years

FUNDING AGENCY: DOE/ESTT.

COMMENTS: Provide thermodynamic data on the species, oxidation states, and concentrations of radionuclides in solution under geologic repository conditions.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC 11033 (DRAFT) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, LBL

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REF.ID - 18 CATEGORY - WASTE/ROCK INTERACTIONS, LEACHING

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - WRIT (Waste Rock Interaction Technology),
Leaching

PRINCIPAL INVESTIGATORS: Bradley, D., PNL

LOCATION: Contact: J. F. Kircher, 614-424-4871

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: To determine waste form release rates and help provide source terms for consequence analysis. To characterize candidate waste forms, to measure leach rates with solutions and under conditions simulating expected repository conditions, and to determine effects of physical and chemical factors on release mechanisms.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC 11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, PNL

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REF.ID - 19 CATEGORY - WASTE/GEOMEDIA INTERACTIONS

ROCK.TYPE - BEDDED SALT

REF.TYPE - PROJECT - Transuranic Waste Characterization: Studies
Under Conditions of Geologic Isolation

PRINCIPAL INVESTIGATORS: Molecke, M. A. (SLA), LASL, SRL, UNM

LOCATION: Contact: M. A. Molecke, 505-264-0781

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Obtain data and predictive analytical models on interaction
and degradation behavior of existing and development TRU wastes in a
bedded salt repository.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April
1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/ALO/WIPP,

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REF.ID - 20 CATEGORY - ENGINEERED BARRIERS

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Engineered Barriers

PRINCIPAL INVESTIGATORS: Simpson, D. R. (Lehigh)

LOCATION: Contact: D. P. Moak, 614-424-7125

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Consider engineered barrier concepts as they affect
near-field isolation.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC 11033 (draft) April
1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI

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REF.ID - 21 CATEGORY - ENGINEERED BARRIERS

ROCK.TYPE - BASALT

REF.TYPE - PROJECT - Waste/Barrier/Rock Interactions in Basalt

PRINCIPAL INVESTIGATORS: RHO, PSU, PNL .

LOCATION: Contact: M. J. Smith, 509-942-7782

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: To determine hydrothermal interactions which will occur following a worst circumstance breach of engineered barrier system. Hydrothermal experiments will be conducted at elevated temperatures and pressures to simulate effects of depth and radiogenic heating.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-110133 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL/BWIP, RHO, PNL

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REF.ID - 22 CATEGORY - ENGINEERED BARRIERS - CANISTERS, BACKFILL, OVERPACK MATERIALS

ROCK.TYPE - PROJECT - Engineered Barrier Optimization

PRINCIPAL INVESTIGATORS: RHO, PNL

LOCATION: Contact: M. J. Smith, 509-942-7782

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Initial literature search to determine candidate materials for canister, overpack, and backfill. Do hydrothermal tests to assess the materials' stability in hydrothermal environment. Evaluate potentials for radiation damage of selected candidate materials.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL/BWIP, RHO, PNL

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REF.ID - 23 CATEGORY - POTENTIAL SITES, U.S. - ARGILLACEOUS

ROCK.TYPE - ARGILLACEOUS

REF.TYPE - PROJECT - Survey of Argillaceous Rocks

PRINCIPAL INVESTIGATORS: Johnson, K. S.; Gonzales, S.

LOCATION: Contact: R. R. Nicks, 614-424-4406

DURATION: 2 years

FUNDING AGENCY: DOE/ESTP. .

COMMENTS: Perform reconnaissance survey of occurrences of argillaceous rocks in the U.S. with potential for radioactive waste isolation.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-111033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI

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REF.ID - 24 CATEGORY - HOST ROCKS, GRANITE, SALT, SHALE

ROCK.TYPE - SALT, GRANITE, SHALE

REF.TYPE - PROJECT - Expected Repository Environments

PRINCIPAL INVESTIGATORS: Claiborne, H. C. (ORNL); Rickertsen, L. D. (SAI); Callahan, G. D. (RE, SPEC)

LOCATION: Contact: G. Raines, 614-424-783

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Identify reference conditions in salt, shale, and granite repositories to serve as guide for; scientists conducting material performance tests, engineers preparing design of repositories, technically conservative conditions to be used as bases for DOE application of a license, and scientists and engineers developing waste forms.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI and ORNL

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REF.ID - 25 CATEGORY - SITE CHARACTERIZATION, COLUMBIA PLATEAU

ROCK.TYPE - BASALT

REF.TYPE - PROJECT - Regional Geology of the Columbia Plateau

PRINCIPAL INVESTIGATORS: RHO, State of Oregon, Idaho, Washington, USGS, others

LOCATION: Contact: T. A. Curran, 509-942-6409

DURATION: To Sept. 1981

FUNDING AGENCY: DOE/RL/BWIP.

COMMENTS: Provide support for site selection and evaluation; input for site characterization report, environmental report, and draft environmental impact statement. The knowledge obtained from this effort will be used to characterize surrounding regional geology and natural geologic events that occurred or may occur in the future.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

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REF.ID - 26 CATEGORY - SITE CHARACTERIZATIONS, NTS
Nevada Test Site (NTS) and Vicinity

PRINCIPAL INVESTIGATORS: Leap, D. I. (USGS)

LOCATION: Contact: Scott Sinnock, 505-264-2365

DURATION: Two to six years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Assess and digitally model in two dimensions hydrologic flow system of the NTS and surrounding areas.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/NVO, UGS

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REF.ID - 27 CATEGORY - SITE EVALUATION, GULF COAST SALT DOMES

ROCK.TYPE - DOME SALT

REF.TYPE - PROJECT - Evaluation of Gulf Coast Salt Domes (Texas, Louisiana, Mississippi)

PRINCIPAL INVESTIGATORS: Pauls, D. E. (LETCO); Kreidler, C. W. (TBEG); Martinez, J. D. (LSU); Spiers, C. A. (USGS); Ryals, G. (USGS); Paulson, O. (USM)

LOCATION: Contact: P. F. Patchick, 614-424-7693

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS. Evaluate regional geologic and hydrologic environment of Gulf Interior Region where numerous salt domes occur; select study areas for detailed characterization; to inventory natural resources of the basin.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/OWI, USGS

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REF.ID - 28 CATEGORY - NUMERICAL ANALYSIS, RADIONUCLIDE TRANSPORT, PASCO BASIN

ROCK.TYPE - BASALT

REF.TYPE - PROJECT - Integrated System Description of Basalt Hydrologic Regime, Preliminary Model Adaptations, and Modeling of Potential Credible Scenarios

PRINCIPAL INVESTIGATORS: Wash., Dept. of Ecol.; Georesults; BCS Richland RHO; USGS: State of Inc.; Research Management Association

LOCATION: Contact: R. L. Biggerstaff, 509-942-7206

DURATION: 1979-1992

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Provide numerical analysis techniques for evaluation of radionuclide movement within the hydrologic system at the candidate site and within the Pasco Basin.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-1103 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL/BWIP, RHO, USGS

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REF.ID - 29 CATEGORY - SITE EVALUATION, YUCCA MOUNTAIN AREA, NTS

ROCK.TYPE - TUFF

REF.TYPE - PROJECT - Characterization of Yucca Mountain Area,
Nevada Test Site

PRINCIPAL INVESTIGATORS: Dixon, G. L. (USGS); Crowe, B. M. (LASL);
NVO Support Contractors

LOCATION: Contact: Scott Sinnock, 505-264-2365

DURATION: One to six years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Assess geologic geophysical and hydrologic characteristics
of Yucca Mountain portion of southwestern NTS in sufficient detail to
permit judgement about suitability of a contained site(s).

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-1103 (draft) April
1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/NVO, USGS, LA

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REF.ID - 30 CATEGORY - SITE EVALUATION, NTS

ROCK.TYPE - TUFF, GRANITE

REF.TYPE - PROJECT - Evaluation of Candidate Areas, Southern
Nevada

PRINCIPAL INVESTIGATORS: Smedes, H. W. (USGS)

LOCATION: Contact: Scott Sinnock, 505-264-2365

DURATION: Two to four years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: To identify the most promising localities for waste
isolation in southern Nevada, with special emphasis on the southwest
quadrant of the Nevada Test Site (NTS).

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April
1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/NVO, USGS

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REF.ID - 31 CATEGORY - HOST ROCKS, ANHYDRITE

ROCK.TYPE - ANHYDRITE

REF.TYPE - PROJECT - Anhydrite Studies

PRINCIPAL INVESTIGATORS: Dean, W. E. (USGS)

LOCATION: Contact: E. R. Roseboom, 703-860-6631

DURATION: Three years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Evaluate suitability of anhydrite as medium for radioactive waste repository; to inventory and summarize geologic, hydrologic, physical, and chemical characteristics of anhydrite occurrences in the conterminous U.S. and to identify areas and topics for more intensive investigation.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: USGS

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REF.ID - 32 CATEGORY - SITE CHARACTERIZATION, GROUNDWATER SYSTEMS, WIPP

ROCK. TYPE - PROJECT - Characterization of Local Ground-Water System at WIPP

PRINCIPAL INVESTIGATORS: Gorzales, D. D. (SLA); Mercer, J. W. (USGS)

LOCATION: Contact: D. D. Gonzales, 505-264-8849

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Obtain description of hydrologic systems for radionuclide migration modeling at WIPP. These will include potentiometric levels, permeabilities, transmissivities, flow rates, and water samples from wells penetrating water-bearing units in WIPP area. Do hydrologic testing of commercial exploratory holes penetrating evaporites near the boundaries of WIPP area.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/ALQ/WIPP, SAND, USGS

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REF.ID - 33 CATEGORY - HOST ROCKS, SALT

ROCK.TYPE - SALT

REF.TYPE - PROJECT - Evaporite Origins and Phase Relations in the WIPP Area

PRINCIPAL INVESTIGATORS: Lambert, S. J. (SLA)

LOCATION: Contact: S. J. Lambert, 505-264-7876

DURATION: Four years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: To determine, empirically and theoretically, conditions of stability and phase relations of evaporite minerals for evaluating effects of physicochemical perturbations of heating experiments and hole plugging experiments.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/ALO/WIPP, SAND

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REF.ID - 34 CATEGORY - WASTE/GEOMEDIA INTERACTIONS

ROCK.TYPE - BASALT, OTHER

REF.TYPE - PROJECT - Characterization of Waste Form and Geologic Environment for BWIP

PRINCIPAL INVESTIGATORS: RHO, LBL, Hanford Engineering Dev. Lab., PNL

LOCATION: Contact: M. J. Smith, 509-942-7782

DURATION: To Sept. 1984

FUNDING AGENCY: DOE/ESTP.

COMMENTS: To obtain physical, chemical, and structural data from analyses of candidate waste forms, natural ground waters, and potential geologic barriers. This information is necessary to interpret experimental results and assess the degree to which hydrologic transport of toxic waste materials is inhibited by geologic media such as basalt and associated secondary minerals and interbed materials.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL/BWIP, RHO, LBL, PNL

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REF.ID - 35 CATEGORY - WASTE/LOCK INTERACTIONS, BRINE MIGRATION

ROCK.TYPE - SALT

REF. TYPE - PROJECT - Near-Field Waste-Rock Interactions

PRINCIPAL INVESTIGATORS: Roy, D. M. (PSU)

LOCATION: Contact: D. P. Moak, 614-424-7125

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Investigate consolidation (compaction) behavior of crushed salt and to study brine migration in polycrystalline salt in a thermal gradient. To determine nature of any chemical or mineralogical changes in, or interaction between, various waste forms and host rock (primarily shale).

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI

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REF.ID - 36 CATEGORY - ENGINEERED BARRIERS - WASTE
PACKAGE/GEOMEDIA INTERACTIONS

ROCK.TYPE - SALT

REF.TYPE - PROJECT - Salt-Brine-Waste-Canister Interactions

PRINCIPAL INVESTIGATORS: Potter, R.; USGS

LOCATION: Contact: J. O. Duguid, 614-424-4773

DURATION: Three to four years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Determine likely interactions among salt, brine; canisters, and waste at a range of temperatures and pressure that may be considered in disposal of high-level radioactive waste or spent fuel, and to determine the properties of resultant reaction products at temperatures up to 300°C.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/OWNI, USGS

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REF.ID - 37 CATEGORY - NEARFIELD, WASTE PACKAGE/GEOMEDIA
INTERACTIONS

ROCK.TYPE - ROCK SALT

REF.TYPE - PROJECT - High-Level-Waste-Container Interactions with
Rock Salt and Brine

PRINCIPAL INVESTIGATORS: Molecke, M. A.; SLA

LOCATION: Contact: M. A. Molecke, 505-264-0781

DURATION: Three years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Provide data and assess impacts of interaction potentials
of high-level waste forms and containers with the WIPP geologic,
near-field environment.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April
1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/ALO/WIPP, SAND

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REF.ID - 38 CATEGORY - BRINE MIGRATION

ROCK.TYPE - SALT

REF.TYPE - PROJECT - Brine Migration

PRINCIPAL INVESTIGATORS: Shefelbine, H. C. (SLA); Lambert, S. J.
(SLA); Sattler, A. R. (SLA); Roedder, E. (USGS)

LOCATION: Contact H. C. Shefelbine, 505-264-1926

DURATION: Four years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Determine physicochemical properties of fluid inclusions in
native rock and in artificially imposed heat fields. To evaluate
potential of fluid inclusions for waste form degradation and
radionuclide migration by performing laboratory, bench-scale, and
in-situ experiments for assessment of brine migration phenomena.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April
1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/ALO/WIPP, SAND, USGS

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REF.ID - 39 CATEGORY - HOST ROCKS, SALT - THERMOMECHANIC STUDIES

ROCK.TYPE - ROCK SALT

REF.TYPE - PROJECT - Salt Model Pillar Studies

LOCATION: Contant: G. Raines, 614-424-7832

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Understand long-term creep behavior of salt as a function of temperature, stress, and time.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, ORNL

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REF.ID - 40 CATEGORY - WASTE/GEOMEDIA INTERACTIONS

ROCK.TYPE - TUFF

REF.TYPE - PROJECT - Tuff Study

PRINCIPAL INVESTIGATORS: Tyler, L. D. (SLA); Wolfsberg, K. (LASL),
Contractors, NVO Support

LOCATION: Contact: Scott Sinnock, 505-264-2365

DURATION: Four years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Develop and apply means to characterize near-field response of selected tuff units to simulated thermal, mechanical, chemical, and fluid conditions created by emplacement of high-level radioactive waste. Welded and nonwelded tuffs from the Nevada Test site will be studied in both laboratory and in situ environments.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/NVO

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REF.ID - 41 CATEGORY - HOST ROCKS, ROCK SALT - THERMOPHYSICAL PROPERTIES

ROCK.TYPE - ROCK SALT

REF.TYPE - PROJECT - Thermal-Structural Interaction in Salt--
Laboratory Experiments

PRINCIPAL INVESTIGATORS: Wayland, J. R.; Wawerski, W., SLA

LOCATION: Contact: J. R. Wayland, 505-264-7639

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Provide thermophysical properties of WIPP rock salt and surrounding media and to obtain data on elastic and creep behavior to support development of appropriate constitutive models.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

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REF.ID - 42 CATEGORY - HOST ROCKS, THERMOMECHANICAL STUDIES

ROCK.TYPE - GRANITE

REF.TYPE - PROJECT - Material Properties of Stripa Granite

PRINCIPAL INVESTIGATORS: Witherspoon, P. A., LBL

LOCATION: Contact: M. M. Lemcoe, 614-424-5688

DURATION: Three years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Measurement of the material properties of carefully selected rock samples from the granite rock mass at the Stripa mine that are needed to understand the hydraulic, thermal, and rock mechanic behavior of the fractured rock mass.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, LBL

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REF.ID - 43 CATEGORY - NEARFIELD, WASTE/GEOMEDIA INTERACTIONS

ROCK.TYPE - ARGILLITE

REF.TYPE - PROJECT - Argillite Study

PRINCIPAL INVESTIGATORS: Tyler, L. D. (SLA); Wolfsberg, K. (LASL)

LOCATION: Contact: Scott Sinnock, 505-264-2365

DURATION: Sept. 1980

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Characterize the near-field response of argillite to simulated thermal, mechanical, and chemical conditions created by emplacement of high-level radioactive waste.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/NVO, SAND, LA

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REF.ID - 44 CATEGORY - ENGINEERED BARRIERS, BOREHOLES, CEMENT

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Borehole Plugging--Cement and Geochemical

PRINCIPAL INVESTIGATORS: Mather, K. (U.S. Army, Waterways Experimental Station); Roy, D. M. (Penn. State Univ.)

LOCATION: Contact: F. L. Burns, 614-424-571

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Develop a better basic understanding of the parameters that relate to placement and long-term stability of cementitious composites, to evaluate the geochemistry of cement-based materials, and to help determine longevity and durability of cementitious composites in repository environment.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI

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REF.ID - 45 CATEGORY - ENGINEERED BARRIERS, BOREHOLES

ROCK.TYPE - BASALT

REF.TYPE - PROJECT - Borehole Plugging in Basalt

PRINCIPAL INVESTIGATORS: --, RHO, Woodward-Clyde

LOCATION: Contact: M. J. Smith, 509-942-7782

DURATION: 1979-1992

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Develop and demonstrate technology needed to effectively seal all man-made openings to a nuclear waste repository within the basalts of Columbia Plateau.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL/WIPP, RHO

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REF.ID - 46 CATEGORY - HOST ROCKS, DOME SALT

ROCK.TYPE - DOME SALT

REF.TYPE - PROJECT - Thermomechanical and Brine Migration In Situ Tests in Dome Salt at Avery Island

PRINCIPAL INVESTIGATORS: Krause, W., RE, SPEC

LOCATION: Contact: R. A. Cudnik, 614-424-4825

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Provide field engineering support to in situ tests at Avery Island Mine examining thermomechanical effects and brine migration in dome salt.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI

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REF.ID - 47 CATEGORY - INTERNATIONAL PROGRAMS, U.S./FRG "

ROCK.TYPE - DOME SALT

REF.TYPE - PROJECT - U.S./Federal Republic of Germany (FRG)
Cooperative Efforts in Asse

PRINCIPAL INVESTIGATORS: Newby, D., Westinghouse, AESD

LOCATION: Contact: R. A. Robinson, 614-424-4172

DURATION: Continue until Salt Test Facility becomes available.

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Develop and perform field tests, initially involving brine and gas migration waste/rock interaction, at the Asse Salt Mine, FRG, which has capabilities currently unavailable in U.S.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI

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REF.ID - 48 CATEGORY - LAB TESTING - ROCK CORES, THERMOMECHANIC

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Ultra-Large Rock Core Tests

PRINCIPAL INVESTIGATORS: Witherspoon, P. A., LBL

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Perform lab testing to: 1) investigate effects of scale, state of stress, fluid pressure, and temperature on measured properties of rocks and rock fissures; 2) conduct site-specific core testing (i.e., Stripa, BWIP, NTS); and 3) investigate relationship between fissure permeability and dilatancy due to shear loading.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, LBL

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REF.ID - 49 CATEGORY - IN SITU TESTING - HOST ROCKS, BASALT

ROCK.TYPE - BASALT

REF.TYPE - PROJECT - Near-Surface Test Facility Design,
Construction and Operation

PRINCIPAL INVESTIGATORS: RHO

LOCATION: Contact: H. B. Dietz, 509-942-6881

DURATION: Oct. 1977 through Sept. 1982

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Design and construction of a multipurpose Near-Surface Test Facility for in situ testing of basalt.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

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REF.ID - 5G CATEGORY - RADIONUCLIDE MIGRATION

ROCK.TYPE - GRANITE

REF.TYPE - PROJECT - Nuclide Migration Studies in Fractured
Granite: Climax, NTS

PRINCIPAL INVESTIGATORS: Coles, D., LLL

DURATION: Four years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Study radionuclide migration in fractured granite; compare in situ retardation factors with lab values; and model fracture flow in granite and calibrate the model using in situ values.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, LLL

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REF.ID - 51 CATEGORY - RADIONUCLIDE MIGRATION

ROCK.TYPE - TUFF

REF.TYPE - PROJECT - Nuclide Migration Studies in Tuff: G-Tunnel, NTS

PRINCIPAL INVESTIGATORS: Johnstone, K. (LASL), SLA, ANL

LOCATION: Contact: R. A. Robinson, 614-424-4172

DURATION: Four years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Controlled field experiments to define radionuclide migration through tuffs; to determine whether available material properties and models are sufficient to scale from laboratory to bench to field.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, SAND, ANL

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REF.ID - 52 CATEGORY - NATURAL ANALOGUES, OKLO

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Natural Fission Reactor Program, Oklo

PRINCIPAL INVESTIGATORS: Cowen, G., LASL

DURATION: Three years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Identify migration paths of some of the mobile fission products and reconstruct paleohydrology and transport history.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI

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REF.ID - 53 CATEGORY - MODELING, MASS TRANSPORT

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Geochemical Study for Verification of Complex
Solute Transport Models

PRINCIPAL INVESTIGATORS: Grove, D. B., USGS

LOCATION: Contact: G. D. DeBuchananne, 703-860-6976

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Select field sites suitable for obtaining data on substantial number of chemical reactions and attempt to verify complex nonconservative solute-transport models of the type that would be useful in studying potential waste disposal sites. Sites where leaching of uranium is occurring are most promising in yielding such data. One of the sites used in the project is near Casper, Wyoming, where U.S. Bureau of Mines is doing uranium leaching experiments. Data from this site and others will be used in the project.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: USGS

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REF.ID - 54 CATEGORY - MASS TRANSPORT

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Mechanistic Studies of Trace Constituent
Sorption and Migration in Geologic Media

PRINCIPAL INVESTIGATORS: Rai, D., PNL

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Study chemical migration in rocks.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/OBES, PNL

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REF.ID - 55 CATEGORY - RADIONUCLIDE MIGRATION, ROCK/SOLUTION INTERACTIONS

ROCK.TYPE - SALT

REF.TYPE - PROJECT - Geochemical Studies for Nuclide Migration (WIPP)

PRINCIPAL INVESTIGATORS: Fortney, D. R.; Dosch, R. G., SLA

LOCATION: Contact: D. R. Fortney 505-264-5576

DURATION: Three years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Determine sorptive capacities for radionuclides in rock/solution systems of southeastern New Mexico and perform assessment of radionuclide migration modeling.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/ALO/WIPP, PNL, SAND

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REF.ID - 56 CATEGORY - AGE DATING, GROUNDWATER

ROCK.TYPE - NA

REF.TYPE - PROJECT - Ground-water Dating

PRINCIPAL INVESTIGATORS: SRL, (Helium); U. of Arizona (Chlorine); LBL (Uranium)

DURATION: Continuing with emphasis on application

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Develop methods of dating ground water older than 50,000 years. This capability would provide information on past rates of ground-water flow in vicinity of repository and aid in verification of predictive models used for determining future of ground-water flow.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, LBL, SAND

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REF.ID - 57 CATEGORY - AGE DATING

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Geochronology

PRINCIPAL INVESTIGATORS: Doe, B., USGS

LOCATION: Contact: E. R. Roseboom, 703-860-6631

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Develop new methods to determine ages of rocks, ground water, and events.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: USGS

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REF.ID - 58 CATEGORY - SITE CHARACTERIZATION, ROCK/SOLUTION INTERACTIONS, SE NEW MEXICO

ROCK.TYPE - SALT, OTHER

REF.TYPE - PROJECT - Characterization of Southeastern New Mexico Rocks and Waters

PRINCIPAL INVESTIGATORS: Lambert, S. J., SLA

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Obtain basic geochemical data on subsurface materials in southeastern New Mexico for brine migration, radionuclide sorption, and borehole plugging studies and to determine history of rock/solution interaction.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/ALO/WIPP, SAND

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REF.ID - 59 CATEGORY - MODELING, WASTE PACKAGE/GEOMEDIA
INTERACTIONS

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Chemical Environment Modeling

PRINCIPAL INVESTIGATORS: RHO, LBL

LOCATION: Contact: M. J. Smith, 509-942-7782

DURATION: Oct. 1978 through Sept. 1984

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Characterize chemical environment in the vicinity of the buried waste packages as a function of time. Long-range predictions of potentially mobile radionuclide material in the near field can be utilized in conjunction with hydrologic flow information to produce a model which quantitatively assesses biohazard potential as a function of distance or time from emplacement.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL/BWIP, RHO, LBL

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REF.ID - 60 CATEGORY - MODELING, MASS TRANSPORT

ROCK.TYPE - NA

REF.TYPE - PROJECT - Solution of Solute Transport Equations

PRINCIPAL INVESTIGATORS: Grove, D. B. (USGS)

LOCATION: CONTACT: G.D. DeBuchananne, 303-860-6976

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Seek new methods to solve the partial differential equations that define flow and reaction of mass through porous media.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: USGS

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REF.ID - 61 CATEGORY - MODELING, RADIONUCLIDE TRANSPORT

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Development of Analytical Transport Models

PRINCIPAL INVESTIGATORS: Bedford, T., LBL

LOCATION: Contact: H. C. Burkholder, 614-424-7834

DURATION: Four years

FUNDING AGENCY: DOE/ESTP.

COMMENTS: To provide analytical standards capability for the calculation of radionuclide transport in porous media and apply it in support of performance assessment activities of NWTs program.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, LBL

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REF.ID - 62 CATEGORY - MODELING, BRINE MIGRATION, ROCK/SOLUTION INTERACTIONS

ROCK.TYPE - ROCK SALT

REF.TYPE - PROJECT - Brine Migration Modeling

PRINCIPAL INVESTIGATORS: Olander, D. (UCB)

LOCATION: CONTACT: J. F. Kircher, 614-424-4871

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Develop a comprehensive model of brine migration in natural rock salt.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI

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REF.ID - 63 CATEGORY - MODELING, MASS TRANSPORT

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Solute Transport in the Unsaturated Zone

PRINCIPAL INVESTIGATORS: Rubin, J., USGS

LOCATION: Contact: D. G. DeBuchananne, 703-860-6976

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Develop data-based laboratory- and field-tested models useful for predicting transport of waste nuclides in the unsaturated zone. The models must include particular effects of water content upon dispersion and selected chemical processes during seepage of solutions through water-unsaturated sediments.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: USGS

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REF.ID - 64 CATEGORY - SITE EVALUATION

ROCK.TYPE - SALT

REF.TYPE - PROJECT - Nuclear Waste Repository Safety Assessment

PRINCIPAL INVESTIGATORS: Brannen, J. P. (SLA); Tierney, M. S. (SLA)

LOCATION: CONTACT: J. P. Brannen, 505-264-1280

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: To provide a WIPP site-specific assessment of long-range consequences of emplacement of nuclear wastes in Salado salt formation.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/ALO/WIPP, SAND

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REF.ID - 65 CATEGORY - RADIONUCLIDE TRANSPORT

ROCK.TYPE - SALT

REF.TYPE - PROJECT - Radionuclide Transport

PRINCIPAL INVESTIGATORS: Brannen, J. P. (SLA)

LOCATION: Contact: J. P. Brannen, 505-264-1280

DURATION: One year

FUNDING AGENCY: DOE/ESTP.

COMMENTS: To couple source-term assumptions into models for radionuclide movement in the WIPP environment.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/ALO/WIPP, SAND

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REF.ID - 66 CATEGORY - PROGRAM COORDINATION AND REVIEWS

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Technical Integration and Support

PRINCIPAL INVESTIGATORS: Lotts, A. L., ORNL

LOCATION: CONTACT: G. Raines, 614-424-7832

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Provide technical support to ONWI in a broad range of areas relating to geologic disposal and to coordinate all ONWI work at ORNL

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, ORNL

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REF.ID - 67 CATEGORY - PROGRAM COORDINATION AND REVIEWS

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - NNWSI (Nevada Nuclear Waste Storage Investigations), Technical Project Coordination

PRINCIPAL INVESTIGATORS: Lincoln, R. C.; Tyler, L. D. (SLA); Twenjofel, W. S., and Dixon, G. L. (USGS); Wolfsberg, K., Crowe, B. M. (LASL); Ramspott, L. D. (LLL)

LOCATION: Contact: Scott Sinnock, 505-264-2365

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Provide coordination and integration of NNWSI technical investigations; to assure appropriate exchange of information among NNWSI contractors; to exchange information with other aspects of the NWTs Program; and to advise DOE on technical merits of investigative activities in terms of progress toward a capability for repository construction.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/NVO, SAND, USGS, LLL

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REF.ID - 68 CATEGORY - PROGRAM COORDINATION AND REVIEWS

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Geological Exploration Review Group

PRINCIPAL INVESTIGATORS: Hambelton, W. W.; Remson, I.; Bloom, A. L.; Ross, H.; Smith, C. I.

LOCATION: CONTACT: R. B. Laughon, 614-424-4267

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Provide independent evaluation of ONWI Geologic Exploration Program.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI, ONWI

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REF.ID - 69 CATEGORY - PROGRAM COORDINATION AND REVIEWS

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Earth-Science Review Group

PRINCIPAL INVESTIGATORS: Parker, F. (Chairman); Bird, J.; Cook, N.; Pinder, G.

LOCATION: Contact: W. A. Carbiener, 614-424-4507

DURATION: Continuing

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Obtain independent, critical review of earth-science program and projects and to obtain guidance in program planning.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE/RL-C/ONWI

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REF.ID - 70 CATEGORY - ROCK/SOLUTION INTERACTIONS -
THERMOMECHANICAL STUDIES

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Reservoir Dynamics Related to Nuclear Waste Storage

LOCATION: Person in charge: P. A. Witherspoon, Geosciences Program, LBL

FUNDING AGENCY: DOE.

COMMENTS: Heat released by radioactive decay of Nuclear waste in an underground repository causes long-term thermal disturbance in the fluid flow in fractured rock mass of repository. Studies in regional thermally induced convection around and above the repository in the rock mass are being made.

INFORMATION SOURCES FOR THIS PROJECT: DOE/ER-0071 (Aug. 1980)

REF.ID(S) OF ASSOCIATED DOCUMENTS: LBL

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REF.ID - 71 CATEGORY - ROCK/SOLUTION INTERACTIONS, RADIONUCLIDE
TRANSPORT

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Rock-Water Interactions

PRINCIPAL INVESTIGATORS: Apps, J. A., LBL

LOCATION: Person in charge: P. A. Witherspoon, Geosciences program,
LBL

FUNDING AGENCY: DOE.

COMMENTS: The project is designed to elucidate chemical reactions between common rock-forming minerals and aqueous phase under subsurface conditions. The results will help determine mechanisms responsible for chemical changes in rocks saturated with groundwater, particularly with regard to processes operating in geothermal reservoirs and during mass transport of radionuclides in water-saturated rocks.

INFORMATION SOURCES FOR THIS PROJECT: DOE/ER-0071 (Aug. 1980)

REF.ID(S) OF ASSOCIATED DOCUMENTS: LBL

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REF.ID - 72 CATEGORY - MODELING, MASS TRANSPORT

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Chemical Transport in Natural Systems

LOCATION: Person in charge: P. A. Witherspoon, Geosciences Program,
LBL

FUNDING AGENCY: DOE.

COMMENTS: Develop conceptual models of solute transport in natural flow systems, using chemical reactions based on thermodynamic concepts applicable to irreversible (or non-equilibrium) processes. Concurrently with the theoretical studies, experimental studies of sorption of cesium ions and uranyl ions on surfaces of a smectite clay and on silica are being conducted. Objectives are to determine thermodynamic properties of sorption processes and evaluation of significance of kinetic effects during sorption.

INFORMATION SOURCES FOR THIS PROJECT: DOE/ER-0071 (Aug. 1980)

REF.ID(S) OF ASSOCIATED DOCUMENTS: LBL

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REF.ID - 73 CATEGORY - MASS TRANSPORT

ROCK.TYPE - NA

REF.TYPE - PROJECT - Thermodynamics, Kinetics and Transport in Aqueous Electrolyte Solutions

PRINCIPAL INVESTIGATORS: Miller, D. G.; Wolery, T. J.

LOCATION: Person in charge: R. N. Schock, Geosciences, Lawrence Livermore Laboratory

FUNDING AGENCY: DOE.

COMMENTS: Study mechanism and kinetics of selected geochemical processes, especially those involving the isolation of radioactive wastes. Diffusion and osmotic coefficients of certain electrolyte solutions are being measured, and computer equilibrium codes to predict speciation, solubility, and reactions in various mineral solution systems are being developed.

INFORMATION SOURCES FOR THIS PROJECT: DOE/ER-0071 (Aug. 1980)

REF.ID(S) OF ASSOCIATED DOCUMENTS: LLL

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REF.ID - 74 CATEGORY - INTERNATIONAL PROGRAMS, USSR

ROCK.TYPE - SALT, GRANITE, OTHER

REF.TYPE - PROJECT - USSR, Radioactive Waste Management Program

COMMENTS: For a number of years, USSR has practiced disposal of non-HLW by injection of liquids into deep, porous strata. They are evaluating geologic disposal of solid wastes in salt, granite and sandstone formations. Activities include criteria development, repository design and engineering, testing of prototype and studies of bulk rock behavior.

INFORMATION SOURCES FOR THIS PROJECT: TID-29442, 1979, p. G-10, and PNL-3333, March 1980, p. 79.

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REF.ID - 75 CATEGORY - INTERNATIONAL PROGRAMS, BELGIUM

ROCK.TYPE - CLAY

REF.TYPE - PROJECT - Belgium, Radioactive Waste Management Program

COMMENTS: Belgium's proposed 5-year plan in Waste Management Research and Development (1978-1982) includes work to be done mostly under the framework of the Commission of European Communities. With co-sponsorship of OEC, Belgium is developing clay repository technology (site and media characterization, corrosion effects, repository design, risk analysis and in situ tests) and intends to have a test repository operational at Mol by 1983. Evaluation of preliminary tests indicates that tunnels and underground facilities can be constructed in the Boom clay formations at Mol, at depths up to 250 m, and that a thermal load of about 15 kw per hectare can be tolerated. Heater experiments and the construction of a test chamber (350 m long by 30 m wide) under the Mol site are planned.

INFORMATION SOURCES FOR THIS PROJECT: TID-29442, 1979, p. G-9 and PNL-3333, March 1980, pp. 23-26.

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REF.ID - 76 CATEGORY - INTERNATIONAL PROGRAMS, SWEDEN

ROCK.TYPE - GRANITE

REF.TYPE - PROJECT - Sweden, Karn-Bransle-Sakerket (KBS): Nuclear Fuel Safety Project

LOCATION: Karn Bransle Sakerhet, Box 5864, s102, 48 Stockholm. Sweden

DURATION: Since 1977

COMMENTS: Project begun as result of Sweden's Stipulation Law passed in April 1977. U.S. has bilateral agreement with Sweden for limited scope cooperative program in field testing experiments and in techniques related to measuring fluid movement through fractures in a granite rock system, utilizing the Stripa Mine in Sweden. These results will provide data useful for evaluating U.S. granite as a terminal storage repository.

INFORMATION SOURCES FOR THIS PROJECT: TID-29442, p. G-9 1979

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REF.ID - 77 CATEGORY - INTERNATIONAL PROGRAMS, JAPAN

ROCK.TYPE - GRANITE, TUFF, SHALE

REF.TYPE - PROJECT - Japan, Radioactive Waste Management Program

PRINCIPAL INVESTIGATORS: Atomic, Energy Bureau of Japan

DURATION: Since mid-1970's

COMMENTS: Japanese Atomic Energy Research Institute, under subcontract with Mitsubishi Metals Corp., is making a survey of potential sites in Japan. Granite, basalt, zeolitic tuff, shale and diabase are identified as possible host rocks. Japan is also considering seabed as potential sites. Japan plans to begin geologic disposal demonstration tests in 1985, and have a licensed industrial scale repository for TRU and high level wastes by 2000.

INFORMATION SOURCES FOR THIS PROJECT: TID-29442, 1979, p. G-6 and PNL-3333, March 1980, p. 58

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REF.ID - 78 CATEGORY - INTERNATIONAL PROGRAMS, FRANCE

ROCK.TYPE - GRANITE, SALT, OTHER

REF.TYPE - PROJECT - France, Radioactive Waste Management Program

COMMENTS: The planned disposal method is emplacement in deep geologic formations. Those presently under study are rock salt and crystalline. Disposal in granite has been evaluated for the site at La Hague, and plans are underway to evaluate a number of crystalline sites. France is also contributing to studies on seabed disposal. The target date for first pilot plant repository (alpha-bearing waste only) is 1985.

INFORMATION SOURCES FOR THIS PROJECT: TID-29442, p. G-4, and PNL-333, March 1980, pp. 41-43

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REF.ID - 79 CATEGORY - INTERNATIONAL PROGRAMS, UK

ROCK.TYPE - GRANITE, OTHER

REF.TYPE - PROJECT - United Kingdom, Radioactive Waste Management Program

COMMENTS: UK plans to provide waste repository for high-level and alpha-bearing wastes. Options include land, seabed, and sub-seabed disposal. Milestones include selecting the site for a repository, 1984; starting a pilot disposal operation with radioactive glass, 1992; and operation of the repository, 2000. Project participants include the Department of the Environment, Institute of Geologic Sciences, and AERE-Harwell. Sites selected for exploratory drilling and in situ investigations include crystalline rock, argillaceous and evaporite formations. A conceptual design for a repository in hard rock has been prepared. The preferred site will be selected in 1984, when decision will be made between seabed and deep geological disposal sites.

INFORMATION SOURCES FOR THIS PROJECT: TID-29442, 1979, p. G-3, and PNL-333, March 1980, p. 76.

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REF.ID - 80 CATEGORY - INTERNATIONAL PROGRAMS, CANADA

ROCK.TYPE - SALT, GRANITE

REF.TYPE - PROJECT - Canada, Radioactive Waste Management Program

LOCATION: Atomic Energy of Canada Limited, Whiteshell Nuclear Research Establishment, Pinawa, Manitoba R0e 1L0

COMMENTS: Continued effort in a studying salt technology and investigating granite formations as potential storage sites. Many potential repository sites have been located, most of them in granite formations in the Precambrian shield of Ontario Province. A test site has been established in a small granitic body at White Lake to permit testing equipment and concepts. Research drilling had begun at Atikokan, Ontario, to test rock formations for possible disposal sites. Areas of major research and development emphasis include repository site characterization, radionuclide migration, hydrology, thermal and mechanical properties of rock formations, repository design and borehole plugging.

INFORMATION SOURCES FOR THIS PROJECT: TID-29442, 1979, p. G-5 and PNL-3333, March 1980. pp. 32-34

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REF.ID - 81 CATEGORY - INTERNATIONAL PROGRAMS, FRG

ROCK.TYPE - DOME SALT, OTHER

REF.TYPE - PROJECT - Germany, Radioactive Waste Management Program

COMMENTS: Since 1965, FRG has focused waste disposal technology research on work at the Asse salt mine. The mine receives wastes on a routine basis much like a scaled-down version of pilot plant for DOE defense waste in New Mexico. The mine has been used for large-scale experimental disposal of low-and intermediate-level wastes. R&D activities have included development of cavern construction technology, testing of various techniques for placing waste containers in repositories, rock mechanics studies, in situ measurements of thermal and hydrologic parameters and safety analyses. U.S. participation in Asse experiments will be carried out by Westinghouse AESD, consisting of experiments in brine and gas migration, tests developed from previous work at Avery Island and Asse, and waste/host rock interaction tests.

INFORMATION SOURCES FOR THIS PROJECT: PNL-3333, March 1980, pp. 43-48, INTERDISCIPLINARY SCIENCE REVIEW, V. 5, No. 4, pp. 292-303, DOE/TIC-11033 (draft), April 1980, p. D-65.

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REF.ID - 82 CATEGORY - HOST ROCKS, REFERENCE REPOSITORY
CONDITIONS

ROCK.TYPE - SALT, BASALT, TUFF, GRANITE, OTHER

REF.TYPE - PROJECT - Reference Repository Conditions Interface
Working Group (RRC-IWG)

PRINCIPAL INVESTIGATORS: Raines, G. E. Members are:, Chairman, ONWI; Bibler, N. E., SRL, Defence, Claiborne, H. C., ORNL, Salt Repository Environment, Hoopingarner, K. R., Rockwell (BWIP), Basalt, Hubbard, N., ONWI, Geochemical environment, Hunter, T. O., SNL (WIPP), Salt, Lynch, R. W., SNL (NNWSI), tuff, McElroy J. L., PNL, Commercial high-level waste, Osnes, J. D., RE, SPEC, Granite, Rickertsen, L. D., SAI, Shale.

COMMENTS: Develop reference repository conditions to serve as guide for: a) scientists conducting material performance test, b) engineers preparing design of repositories, c) technically conservative conditions to be used as basis for DOE license applications, and d) scientists and engineers developing waste forms. Present plans call for completion of generic reference repository conditions for salt, basalt, tuff, and granite by Dec. 1981. Shale has been assigned a lower priority and RRC work on this rock type has been discontinued. However, interim conditions for all five rock types will be published as ONWI reports in the near future.

INFORMATION SOURCES FOR THIS PROJECT: Preprints, "Development of Reference Conditions for Geologic Repositories for Nuclear Waste in the USA", paper presented at Materials Research Society, annual Meeting, Boston, Ma., Nov. 1980. (Raines, G. E., ONWI)

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REF.ID - 83 CATEGORY - RESEARCH PROGRAMS, U.S.

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - ESTP (Earth Science Technical Plan for Disposal of Radioactive Waste in a Mined Repository)

PRINCIPAL INVESTIGATORS: Wunderlich, R., DOE Richland Operations, Columbus, MacGregor, I., DOE-HQ, Sinnock, S., Sandia, NNWSI, Cooley, C., DOE-HQ, Dudley, W., USGS, NNWSI (Nevada), Duguid, J., Battelle, ONWI, Evans, G., Rockwell-Hanford, Basalt Waste Isol. Proj., Klingsberg, C., DOE-HQ, Lincoln, R., Sandia, NNWSI, MacGregor, I., DOE-HQ, Roseboom, E., USGS, Schneider, R., USGS, Sinnock, S., Sandia, NNSI, Stewart, D., USGS, Stevens, P., USGS, Trask, N., USGS Weart, W., Sandia, WIPP.

FUNDING AGENCY: DOE/ESTP.

COMMENTS: Identification of four or five potential sites, redirection of research from generic to site specific characterization, resolution of related technical questions, and preparation of a detailed plan by each component of NWTs Program.

INFORMATION SOURCES FOR THIS PROJECT: DOE/TIC-11033 (draft) April 1980

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REF.ID - 84 CATEGORY - U.S. PROGRAMS, WRIT

ROCK.TYPE - GENERAL, OTHER

REF.TYPE - PROJECT - WRIT (Waste/Rock Interactions Technology)

PRINCIPAL INVESTIGATORS: Serne, R. J., Proj. Manager

LOCATION: Pacific Northwest Laboratory, Richland, Wash. 99352

DURATION: Continuing

FUNDING AGENCY: DOE/Battelle.

COMMENTS: Geochemical investigations of mechanisms that control radionuclide behavior in their interactions with geologic media and with engineered barriers. Areas of investigations during FY 1980 include leach mechanisms, rock-radionuclide retardation studies, solution chemistry, waste package tests, and computer modeling. During FY 1981, WRIT research plans will cover these areas: 1) Computer predictor codes: complete prototype nuclide release, leaching and thermodynamic computer predictor codes; use these to help interpret experimental data to assist NWTs safety assessment. Verify these models through lab studies, compare results with field data when available. 2) NWTs waste plans (waste package plan, site characterization, and selection plan): Input to these plans, work with the two NWTs radionuclide field experiment as preparation for comparisons of WRIT lab results to the field results when available. 3) Waste-form leaching and nuclide sorption: Compile and evaluate past data; continue studies on mechanisms that control waste-form leaching and nuclide sorption; complete studies on solubility of actinide oxides under air-equilibrated conditions; establish practical ways to control reducing Eh values in lab experiments; establish useful methods for waste- package performance evaluation and dynamic sorption tests on intact core materials. 4) Initiate U and Th disequilibrium studies on field samples.

INFORMATION SOURCES FOR THIS PROJECT: WRITE, Tech. Prog. Plan, FY-81, June 1980

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REF.ID - 85 CATEGORY - RADIONUCLIDE TRANSPORT

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Mobility of Radioactive Waste Materials in
Subsurface Migration by Particulate Transport

PRINCIPAL INVESTIGATORS: Georgia, Inst. of Technology

DURATION: FY 1978

FUNDING AGENCY: NRC.

INFORMATION SOURCES FOR THIS PROJECT: DOE/EDP-0064 (Sept. 1980)

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REF.ID - 86 CATEGORY - SITE TECHNOLOGY

ROCK.TYPE - BASALT

REF.TYPE - PROJECT - High Level Waste Site Technology

PRINCIPAL INVESTIGATORS: Rockwell, Hanford Operations

DURATION: Continuing

FUNDING AGENCY: DOE.

INFORMATION SOURCES FOR THIS PROJECT: DOE/EDP0064 (Sept. 1980)

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REF.ID - 87 CATEGORY - U.S. PROGRAMS, WIPP

ROCK.TYPE - SALT

REF.TYPE - PROJECT - WIPP (Waste Isolation Pilot Plant)

DURATION: Continuing

FUNDING AGENCY: DOE/NRC.

COMMENTS: WIPP- Los Medanos site, Eddy County, New Mexico, a facility for the demonstration of disposal of TRU only and for research and development with high level wastes. Studies at WIPP include laboratory investigations, bench-scale studies in large block of salt, a series of preliminary measurements in existing mines, and development of analytical models for predicting the behavior of a repository. For detailed summary description, see Chap. 8 of DOE/EIS-0026 (Oct. 1980).

INFORMATION SOURCES FOR THIS PROJECT: DOE/EIS-0016 (Oct. 1980)

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REF.ID - 88 CATEGORY - RESEARCH PROGRAMS, U.S.

ROCK.TYPE - SALT

REF.TYPE - PROJECT - Evaluation of Scientific and Technical Aspects of Certain Programs Involving the Management of Radioactive Wastes

PRINCIPAL INVESTIGATORS: National Academy of Sciences

DURATION: 1955-

FUNDING AGENCY: NRC.

COMMENTS: NAS was one of the earliest group involved with research in underground disposal of radioactive waste. In 1955, AEC asked a committee of NAS to examine the issue of permanent disposal of radioactive waste. The joint conclusion of NAS and NRC (1957) was that 'the most promising method of disposal of high-level waste was in salt deposits'. They recommended salt for further evaluation because of its thermal and physical properties. This led to several studies that consider salt as potential sites. 1980.

INFORMATION SOURCES FOR THIS PROJECT: DOE/EIS-0026 (Oct. 1980)

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REF.ID - 89 CATEGORY - WASTE PACKAGE PERFORMANCE

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Monitoring Waste Package Condition

PRINCIPAL INVESTIGATORS: TBD, (will be coordinated with DOE, USGS, Bureau of Mines)

DURATION: FY 1982

FUNDING AGENCY: NRC.

COMMENTS: Determine critical parameters that describe waste package performance in a repository. Assess and test methods for monitoring parameters and waste package performance during operation of the repository and during the period of potential waste retrieval. Assess compatibility of package design and placement with proposed monitoring methods.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM FOR ACRS PRESENTATION, June 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: NUREG

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REF.ID - 90 CATEGORY - BACKFILLS

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Performance of Backfill materials

PRINCIPAL INVESTIGATORS: UNDES, (In conjunction with in situ measurement verification to be accomplished in underground facilities under Fin B3038 by Lawrence Berkeley Laboratory)

DURATION:

FUNDING AGENCY: NRC.

COMMENTS: Evaluate types of backfill and methods of emplacement in excavated underground spaces. Assess mechanical and hydrological properties of backfills and effects of incomplete backfilling on fracturing and long-term containment capability. Assess effects of potential mineralogical and structural changes due to long-term underground conditions (e.g., temperature pressure, and radiation). Include consideration of mechanical properties resulting from the inclusion of components needed to assure chemical retardation of radionuclides. Test backfills in available underground facilities, including test chambers excavated by different methods to evaluate effects of fracturing.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM FOR ACRS PRESENTATION, June 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: NUREG

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REF.ID - 91 CATEGORY - SIMULATION, WASTE/SOLUTION INTERACTIONS

ROCK.TYPE - NA

REF.TYPE - PROJECT - Effects of Complexation of Metal Ions by Monobutyl and Dibutyl Phosphate in Simulated Nuclear Waste Solution

PRINCIPAL INVESTIGATORS: Bowis, State College

DURATION: FY 1981

FUNDING AGENCY: NRC.

COMMENTS: Determine the nature and extent of complexation of metal ions by monobutyl phosphate and dibutyl phosphate. Identify mechanism by which monobutyl phosphate and dibutyl phosphate complex prominent metal ions in simulated waste tank environment. Determine effects of pH on complexation and resulting sludge formation.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM FOR ACRS PRESENTATION, June 22, 1981.

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REF.ID - 92 CATEGORY - RESEARCH PROGRAMS, U.S.

ROCK.TYPE - BEDDED SALT

REF.TYPE - PROJECT - Risk Methodology Development for Waste Isolation in Bedded Salt

PRINCIPAL INVESTIGATORS: NRC

DURATION: FY 1981

FUNDING AGENCY: NRC.

COMMENTS: To provide Nureg reports describing the development and application of risk assessment methodology for waste isolation in bedded salt. To demonstrate application of methodology in evaluating specific repository sites and in showing compliance with the EPA standards and with 10-CFR-60. Plan to produce eighteen NUREG reports documenting methodology and its application, ten published papers, six computer models with user manuals.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM FOR ACRS PRESENTATION, June 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: NUREG

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REF.ID - 93 CATEGORY - IN SITU TESTING - HOST ROCK, HYDRO-THERMAL STUDIES

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - In Situ Hydrologic Parameters Measurements

PRINCIPAL INVESTIGATORS: UNDES, (will be coordinated with DOE and Bureau of Mines)

DURATION: -

FUNDING AGENCY: NRC.

COMMENTS: This research will measure hydrologic parameters of a large mass of rock in situ, and at depth under ambient heat and water pressure conditions permitting evaluation of the containment capability of proposed sites. Measurements include: hydraulic conductivity in sealed underground chambers; water pressure in horizontal drill holes; effective porosity; and temperature. Preparatory work under this project will include fracture mapping, borehole logging, and design and fabrication of scientific instruments. The experiment will encompass three stages: (a) determination of ambient conditions (baseline) by measurement of rock and water characteristics; (b) measurement of same parameters as heat is applied; and (c) continued measurement of the same parameters as the rock and water cool as the heater is turned off.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM
FOR ACRS PRESENTATION, June 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: DOE

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REF.ID - 94 CATEGORY - MASS TRANSPORT

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Unsaturated Flow and Transport Thru Fractured
Rock Related to High-Level Waste Repositories

PRINCIPAL INVESTIGATORS: UNDES, (will be coordinated with DOE and
USGS)

DURATION: FY 1981

FUNDING AGENCY: NRC.

COMMENTS: Identify and evaluate state-of-the-art field and laboratory methods for measurement of unsaturated flow factors pertinent to determining containment capabilities of high-level waste repository sites. Factors may include infiltration rates, matrix properties liquid-vapor potential, volumetric moisture content, solute potential and temperature gradients. Emphasis will be on assessment and development of analytic methods to characterize and predict liquid and vapor water movement and simultaneous solute transport through unsaturated fracture rock over long time spans. Monitoring will be addressed in the field studies designed to evaluate state-of-the-art techniques. Both matrix and fluid chemistry will also be addressed. Data synthesis and analysis techniques, including computer code modeling, will be performed as needed. Advance the state-of-the-art as approved by the Project Officer.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM
FOR ACRS PRESENTATION, June 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: NUREG, DOE, USGS

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REF.ID - 95 CATEGORY - MODELING, MASS TRANSPORT

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Ground Water Transport

PRINCIPAL INVESTIGATORS: Arizona, University of

DURATION: FY 1981

FUNDING AGENCY: NRC.

COMMENTS: This project will test the validity of the current practice of predicting groundwater flow through rock by use of a model which assumes uniform rock mass and porosity. The ongoing work in this project is evaluating existing methods for predicting groundwater flow, dispersion, and sorption of dissolved solids in fractured crystalline rocks. The results show that equations for groundwater flow in fractured rocks must be validated by field and laboratory tests to show that they are physically sound. The following will be done to improve the predictive capability: a) mathematical formulas used to predict flow in fractured rocks will be evaluated, tested by field experiments and improved if needed. b) Analytical procedures for field injection tests and the efficiency of a group of non-toxic tracers of water movement with a range of sorptive properties will be tested and evaluated. c) Results of the field experiments will be used to examine and revise existing theory in an iterative process. d) The adequacy of existing computer programs for solving mass transport equations will be evaluated.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM FOR ACRS PRESENTATION, June 22, 1981.

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REF.ID - 96 CATEGORY - SITE SUITABILITY - ROCK/GROUNDWATER

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Monitoring for Changes in Rock and Ground Water Conditions

PRINCIPAL INVESTIGATORS: UNDES, (will be coordinated with DOE and EPA)

DURATION: -

FUNDING AGENCY: NRC.

COMMENTS: Assess and test direct and indirect methods for monitoring and recording the long-term effects of thermal loading and earth movement on rock deformation and stress, on the physical and chemical characteristics of ground water, and on the possible release of radioactive material to the environment during excavation, waste emplacement and after backfilling. Assess systematic programs for sampling and monitoring which involve consideration of optimum spatial and temporal distribution of samples and relationship between in situ and laboratory measurements. Include provisions to modify or devise new programs as required to monitor site suitability and the hydrologic balance. Evaluate requirements for data reduction and management; and systems for feedback of collected information for consideration in design, construction, closure and related efforts

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM FOR ACRS PRESENTATION, June 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: NUREG, DOE, EPA

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REF.ID - 97 CATEGORY - ENGINEERED BARRIERS, BOREHOLES

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Mechanisms and Effects of Seal Degradation

PRINCIPAL INVESTIGATORS: TBD, (will be coordinated with DOE)

DURATION: FY 1981

FUNDING AGENCY: NRC.

COMMENTS: The characteristics and mechanisms of borehole and shaft failure will be determined and consequences of seal degradation will be assessed relating to impacts on an operating repository and ultimate effects on the long term radionuclide containment capabilities of repositories. The research includes: study of the effects of heat from radioactive waste, and of columnar loading, on groundwater flow as borehole or shaft seals degrade; a development of understanding of the conditions and characteristics of convection currents that could exacerbate deleterious impacts; assessment of the potential of steam driving and/or entraining water; and development of methods for predicting impacts on aquifers and radionuclide containment.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM FOR ACRS PRESENTATION, June 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: NUREG, DOE

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REF.ID - 98 CATEGORY - ENGINEERED BARRIERS, BOREHOLES

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Exploratory Borehole Geochemical Measurement

PRINCIPAL INVESTIGATORS: UNDES, (will be coordinated with DOE's WRIT Program)

DURATION: -

FUNDING AGENCY: NRC.

COMMENTS: Evaluate potential methods of making geochemical measurements such as oxidation/reduction potential and capacity, and chemical composition through exploratory borings either from the surface or from within an exploratory shaft or tunnel. Assess and quantify limitations and uncertainties using current techniques. Assess the need for making in-situ measurements to confirm or augment laboratory measurements and identify the costs and benefits of various techniques.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM FOR ACRS PRESENTATION, June 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: NUREG, DOE, PNL

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REF.ID - 99 CATEGORY - ACTINIDES/SOLUTION INTERACTIONS

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Natural Chemical Complexation of Actinides in Groundwater

PRINCIPAL INVESTIGATORS: Lamont, (coordinated with WRIT)

DURATION: FY 1981

FUNDING AGENCY: NRC.

COMMENTS: Assess the importance of chemical complexation of actinides by comparing actinide partitioning in natural waters bearing high carbonate, sulfate and chloride concentrations with natural waters bearing low concentrations of these anions. Emphasis will be placed on evaluating plutonium and americium derived from nuclear weapons testing fall-out so that the natural behavior of these elements over a time span of 25 to 30 years can be determined. Distribution coefficients of actinides in laboratory prepared samples will be compared with actinide distribution under actual field conditions so that the complexing mechanisms which control the natural Kd of actinides can be defined. Bounding conditions for the transport of Pu and Am species in carbonate, sulfate and chloride waters will be established. The importance of oxidation state on complexing will be assessed by comparing the actinide partitioning in natural waters from oxidizing environments with waters from reducing environments. The effects of competing ions will also be evaluated.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM FOR ACRS PRESENTATION, June 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: NUREG, DOE, PNL

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REF.ID - 100 CATEGORY - NATURAL ANALOGUES, AUSTRALIA

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Radionuclide Migration Around Uranium Ore
Bodies: Analogue of Radioactive Waste Repositories

PRINCIPAL INVESTIGATORS: (AAEC), Australian Atomic Energy Commission

DURATION: FY 1981

FUNDING AGENCY: NRC.

COMMENTS: Determine rates of radionuclide migration in geologic systems using the naturally occurring radionuclides U-238, U-234, Th-230, Th-230, and Ra-226. These empirical data will be used to validate migration rates (retardation coefficients) and distances that are calculated from laboratory determined parameters and used in conceptual models of radioactive waste behavior. A natural analog will provide a means of checking the experimental values. The migration behavior of uranium, thorium, and radium from ore bodies if analogous in certain respects to the migration of radionuclides from breached or leaking high-level radioactive waste repositories. The Australian environment is favorable for measuring rates of radionuclide migration during the past 1000 to 1,000,000 years for U, Th, and Ra within a wide range of weathering and oxidation-reduction conditions. These migration rates will be used to assess the level of confidence that the NRC can place on transport models for licensing purposes. The AAEC will provide observed and laboratory geochemical data and a description of the geologic and hydrologic environment and ore body source term needed to verify existing codes. These data will be used by NRC and its other contractors in the verification of transport models.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM
FOR ACRS PRESENTATION, June 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: NUREG

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REF.ID - 101 CATEGORY - AGE DATING, GROUNDWATER

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Confirmatory Research Related to Dating of Groundwater

PRINCIPAL INVESTIGATORS: University of Arizona

DURATION: FY 1980, FY 1981

FUNDING AGENCY: NRC.

COMMENTS: Assess the capabilities of using isotopic ratios for groundwater dating, resolve problems of interpretation of divergent results, and test the limitations of alternative methods of ground water dating. The significance of the subsurface origin of carbon-14 and tritium will be verified in the field by testing nearly static ground water and water from aquifers rich in thorium and uranium. The influence of hydrogeological phenomena on groundwater dating will be pursued, namely: (a) the diffusion of non-radioactive carbon ions into water-bearing fissures in dense rock, and (b) selective ion filtration by confining and/or retarding beds adjacent to aquifers.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM FOR ACRS PRESENTATION, JUNE 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: NUREG

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REF.ID - 102 CATEGORY - RADIONUCLIDE/GEOMEDIA INTERACTIONS

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Geochemical Assessment of Nuclear Waste Isolation

PRINCIPAL INVESTIGATORS: Lawrence Berkeley Laboratory

DURATION: FY 1981

FUNDING AGENCY: NRC.

COMMENTS: By means of laboratory measurements, the contractor will evaluate the capabilities, limitations, and uncertainties of methods of measuring geochemical properties and of predicting radionuclide migration rates in the near field and the far field of a geologic repository. The contractor will assess the following issues and identify potential problems/inadequacies with current procedures and measurement techniques: (1) Canister/overpack-backfill chemical interactions; (2) Near-field host rock interactions and mechanisms; (3) Far field host rock interactions; (4) Adequacy of predictive models for nuclide migration; and (5) Verification of models using geologic analogies.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM
FOR ACRS PRESENTATION, JUNE 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: LBL

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REF.ID - 103 CATEGORY - MASS TRANSPORT

ROCK.TYPE - BASALT

REF.TYPE - PROJECT - Valence Effects on Adsorption

PRINCIPAL INVESTIGATORS: ORNL

DURATION: FY 1981

FUNDING AGENCY: NRC.

COMMENTS: Assess laboratory methods of determining valence state (and controlling Eh) that are being used, or could be used, in experiments on multivalent elements. The contractor will evaluate the effect of poor valence state control on laboratory measurements of distribution coefficients (Kds). The contractor will identify and test methods for improving the valence state control of adsorption measurements particularly under reducing conditions and compare these techniques to standard techniques used for sorption measurements on multivalent nuclides. The contractor will conduct a limited number of measurements of sorption of Tc, Np and U by basalt, sulfides and hydrous oxides and compare the results with the results of other laboratories which use standard techniques. The contractor will use electrochemical techniques to investigate the kinetics of reactions of potential repository species, that known to be important, reducing agents, with multivalent nuclides present in HLW so that the actual importance of these species on waste isolation can be assessed. The contractor will evaluate impacts of repository operation on the natural oxidation/reduction conditions and provide input for assessing the impacts of inaccurate Eh measurements on performance modeling.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM
FOR ACRS PRESENTATION, JUNE 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: ORNL

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REF.ID - 104 CATEGORY - SIMULATION. WASTE/GEOMEDIA INTERACTIONS,
LEACHING

ROCK.TYPE - GENERAL

REF.TYPE - PROJECT - Laboratory Analog of Waste Leaching and
Migration

PRINCIPAL INVESTIGATORS: Argonne National Laboratory

DURATION: FY 1981

FUNDING AGENCY: NRC.

COMMENTS: The rates of movement of radionuclides through laboratory analogs of breached waste packages and components of underground repository facilities will be measured and the results will be compared to that predicted from results of simpler leaching and sorption tests on waste forms and geologic media. The results will also be compared with the available field data. The measurements will be conducted on a laboratory-scale model that simulates ground water flowing through a repository. Parameters to be controlled and measured in this test will be liquid flow path, flow rate, temperature, changes in substrate (mineralization), initial ground water composition, pressure, and radiation field. Components of repository to be included in the tests are waste form (glass) backfill (bentonite) and near-field host rock (basalt and other rocks to be specified later). These starting materials should include materials anticipated to be present more than 1000 years after waste emplacement.

INFORMATION SOURCES FOR THIS PROJECT: NRC WASTE MANAGEMENT PROGRAM
FOR ACRS PRESENTATION, JUNE 22, 1981.

REF.ID(S) OF ASSOCIATED DOCUMENTS: ANL

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