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WM Project 16
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(Return to WM, 623-SS)

Mr. J. O. Neff, Program Manager
NWTS Program Office
Department of Energy
505 King Avenue
Columbus, Ohio 43201

Dear Mr. Neff:

Enclosed are the meeting minutes of the second meeting of NRC and DOE/NPO Prepatory to the submittal of the salt site site characterization plan (SCP). The attachments to the minutes are not enclosed since both NRC and DOE already have a complete set. If you have any questions please call Robert Johnson (FTS 427-4676) of my staff.

Sincerely,

ORIGINAL SIGNED BY

Hubert J. Miller, Chief
High-Level Waste Technical
Development Branch
Division of Waste Management

Enclosures: Subject Meeting Minutes

cc: L. Casey, DOE/NPO
C. George, DOE/HQ

8402010424 830707
PDR WASTE
WM-16 PDR

OFC	WMHT RJ	WMHT					
NAME	RLJohnson:ag	HMiller					
DATE	83/07/07	7/7/83					

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MINUTES OF THE SECOND MEETING OF NRC AND DOE/NPO PREPARATORY TO SUBMITTAL OF SALT SITE SCP

JUNE 27-28, 1983
SILVER SPRING, MARYLAND

Background and Facts

NRC, DOE/NPO and contractor representatives met at the NRC offices in Silver Spring, Maryland on June 27-28, 1983 to discuss questions related to DOE's preparation of the salt Site Characterization Plan (SCP). The agenda, (attachment 1) was followed and completed. A list of actual attendees is also attached (attachment 2). None of the state representatives were in attendance.

The meeting minutes which consist primarily of observations, and agreements keyed to the agenda topics were drafted before the close of the meeting, read, and signed by H. Miller of the NRC and J. Neff of DOE. What follows here is the typed and edited version of the signed rough record. The attached copies of the viewgraphs and handouts give more detail about the meeting. They were provided to the attendees and will be transmitted to the invited state contacts in Louisiana, Mississippi, Texas and Utah.

Observations and Agreements

1. NRC Licensing Process

    a) A presentation was made by NRC (Miller) on the high level waste licensing process. The process by which licensing findings will be made by the Atomic Safety and Licensing Board (ASLB) and the Commission was described (Attachment 3). NRC explained that hearing schedules before the ASLB during licensing for construction authorization are dependent upon the quality of the information available. Therefore, it is critical for both DOE and NRC to use the prelicensing period to make sure the information available for licensing is complete, relevant and of adequate quality (Attachment 3).

Miller emphasized that the licensing process is a legal process and this awareness needs to be communicated to the DOE contractor staffs. Also, expert judgment alone is not adequate for hearings before the ASLB, rather, data needs to be presented.

b) DOE wanted to know what mechanisms were to obtain agreement with NRC on licensing information needs. NRC (Miller) explained that there is a range of NRC guidance products, all of which have one goal - establish what information is necessary and sufficient for a license application. These products include the SCA, SCA updates (reviews of DOE semi-annual reports), Generic Technical Positions, Site Technical Positions, meeting minutes, and letters. Formal regulatory guides are not anticipated except for format guides for the SCP, SER, etc. NRC believes that Licensing Topical Reports prepared by DOE can also be good starting points for reaching agreements.

c) NRC explained that issue "resolution" during prelicensing means that the NRC staff considers that there is sufficient information to complete its licensing assessments. Resolution does not mean "closing out" an issue in the sense that it will not come up in licensing. The NRC staff will not make the final licensing findings. However, the hearing process will not begin until the NRC staff completes its review and is satisfied that "reasonable assurance" exists that 10 CFR 60 requirements have been met.

2. BWIP/SCA Executive Summary

a) NRC (Miller) reviewed the major concerns about the BWIP SCR which were expressed in the NRC BWIP SCA Executive Summary.

b) NRC stated that questions about the nature and extent of underground testing should be a major focus for early discussions since they determine the length of site characterization. Specifically, coupled thermal-mechanical-hydrogeological- geochemical processes are difficult problems involving much judgment. For such a problem strong concensus within the technical community would be advantageous. Some experts (including NRC consultants, such as LBL) have proposed very large scale, long duration tests of thermal effects; NRC has not yet established this position. NRC believes that DOE should take the lead and establish the level of underground testing and give its rationale.

c) DOE asked if lateral, exploratory drifting could continue after License Application (LA) since such drifting will likely take a longer period of time than exists for site characterization. NRC responded by stating this should be done the during the site characterization period. Testing after LA should only be confirmatory and should not make inroads into new technical areas. Confidence must exist at the time of LA to make a finding of reasonable assurance.

d) NRC (Greeves) explained that questions related to shaft construction, sealing, and data collection from the shaft are important areas to address and document before shaft construction begins and commitments are effectively made to one mode of shaft construction or another. This need is identified in a recent NRC letter and should be a matter for review in an early workshop.

e) NRC expressed concern about BWIP's lack of consideration of alternative interpretations of data and suggested NPO take measures to include such alternative interpretations. NRC felt it was important to quantify uncertainties.

3. Level of Detail in the SCP

a) DOE questioned the level of detail that should be in the SCP (Attachment 12). NRC handed out a matrix (attachment 4) describing the types of information (i.e., data, methods, analyses, plans and procedures) that should be provided or made available at the time of SCP submittal. NRC recognizes that all information can not be presented in the SCP, but that appendices, references to the SCP and available on-file information can also be used (Attachment 5). The matrix formed the basis for a decision on what level of detail would be sufficient in a SCP.

b) DOE proposed that an example issue write up would be prepared for and discussed in the upcoming Waste Package workshop. NRC agreed that this example would be a good way to further discuss appropriate level of detail in the SCP.

c) NRC stated the level of detail in the SCP should be the same as that in the LA. NRC recognizes that data is gathered over time but that data that has been collected should be made available in just as much detail as the complete data base that will be used in licensing.

d) In response to a question by DOE as to compliance with the RG 4.17 Part B on reporting existing data, NRC stated that this part of the RG was a detailed "checklist" only. If an item is not available it obviously cannot be reported, and it should be covered under data gathering plans.

e) i. The position taken by NRC staff in the BWIP SCA with respect to the level of information needed on conceptual design and on the need to specify interim performance requirements (expressed in terms of quantified reliability requirements) for the engineered systems such as waste package was reviewed. In addition to the BWIP SCA, a draft NRC Staff Technical Position Paper on Conceptual Design Information Requirements was briefly discussed and provided to NPO for comment (attachment 9).

ii. Some questions from DOE were raised about why it was necessary to provide in the SCP what the specific, interim reliability requirements on waste package and engineered systems are. NRC (Miller) stated this was needed to allow determining what constitutes an adequate test program (i.e., reasons stated in the BWIP SCA and the draft NRC Staff Technical Position Paper on Waste Package Reliability (attachment 11) were summarized. Miller indicated that this was consistent with DOE comments on draft versions of the technical rule which effectively argued that the impact of numerical performance objectives on the waste package and engineered barriers is not known until the required level of reliability is established. He indicated that consistent with NRC's response to those comments, NRC staff agrees with this but considers that the process for establishing needed reliability (which is related to what constitutes "reasonable assurance") must occur during the prelicensing phase and that it be an iterative process which takes account of variable site specific factors. He indicated that NRC staff is effectively allowing the DOE to take the lead in proposing what constitutes a reasonable and realistic set of reliability requirements.

iii. In connection with this, a number of questions, comments and concerns were raised by DOE. These are identified in the following questions and NRC responses are given, where this was possible during the meeting.

- The NRC position is that the SCP needs only specify what the reliability requirements or targets are to establish the background for getting agreement on what constitutes an adequate test program --- as opposed to the SCP having to contain sufficient data and evaluations to support predictions now of a level of confidence targeted for licensing. Is this true?

  NRC response: Yes.

- Is the thrust of NRC's position that reliability targets should apply to the natural systems as well as to the engineered systems.

  NRC response: No. NRC has avoided taking a position that interim reliability requirements be specified for aspects or parameters of the natural systems. We have taken the above position in an area where it can best be applied and where it is most needed -- the engineered systems and waste package. The fact that reliability requirements need not be specified for the natural system does not diminish the natural system's importance or applicability to the isolation of wastes. The NRC position is consistent with the thrust of DOE's comments on the technical rule.

- At what level of detail must interim reliability requirements be specified? Do the many parameters and factors which determine performance of engineered barriers and waste package have to now have reliability requirements specified for them? The underlying concern is that needed flexibility in design development and data gathering would be eliminated by an overly detailed set of reliability requirements.

NRC response: NRC (Miller) indicated that it was the NRC's position that reliability requirements be established on an interim basis at the time of SCP at least at the broad performance level. A highly detailed breakdown of the engineered systems into subcomponents and individual parameters which determine performance of these components followed by the establishment of reliability requirements for each of these parameters is something that will obviously take some time and will have to occur through a process such as that described in the BWIP SCA and depicted in Figure 9.2. The timing and the level of detail at which reliability requirements must be specified is a matter for negotiation. NRC distributed copies of a draft technical position on waste package reliability (attachment 11).

- DOE raised concern about NRC's position requiring a "probabilistic" approach as opposed to a more traditional approach where factors affecting performance of a component of a system are identified and information gathered on these parameters.

Questions were raised about what does NRC specifically mean by the need for specifying reliability requirements. How does this relate to probabilistic assessment? Is this the same as quantifying uncertainties?

NRC response: NRC used the following example to convey what is meant as reliability requirements. Performance requirements for the waste package might be: there should be X percent confidence that no more than Y percent of the waste packages will fail in less than Z years. This would require establishing quantitatively (specified in terms of probability distribution functions) the range of uncertainty on key parameters, on the models, and on other factors which introduce uncertainty into the performance assessment. In this sense, it is the same as quantifying uncertainty.

- One view expressed by a DOE contractor (J. Parry) was that NRC should specify what reliability requirements should be. He indicated that some preliminary calculations by DOE indicated that thousands of measurements would be needed in order to achieve high levels of reliability (95% that 95% of the waste packages will not fail in 1,000 years). Some estimates are that there would need to be more tests than there are waste packages.

  NRC response: DOE is in the best position to weigh all of the factors, including site specific factors and other, non-quantifiable programmatic factors such as cost, to propose what is a realistic and reasonable reliability level. Chapter 9, Figure 9.2, of the BWIP SCA describes the iterative process by which this should most appropriately occur (Attachment 10, figure 2).

iv. Miller indicated that this whole question was one of high priority at all sites as it profoundly impacts the direction that the DOE program should take at the present time. Therefore, NRC staff considers the matter should be taken up with representatives from all sites at an early time to assure that it can be treated in a satisfactory manner in the SCPs currently under preparation.

v. NRC expressed concern for integration across disciplines e.g., rock mechanics specialists coordinating with hydrologists; NRC feels DOE needs to take the lead on sensitivity studies to highlight the most important parameters so that if NRC begins emphasizing some aspect which DOE can show to be not critical to the performance objectives focus can be reestablished on the more important aspects. Also, in this connection NRC pointed out that Chapter 9 of the BWIP SCA describes this process. NRC also provided an early draft of an NRC paper titled "Identification of Specific Licensing Information Needs." (attachment 10).

4. Issue Resolution Status at License Application

a) In response to DOE questions, NRC's stated that all issues related to 10 CFR 60 must be addressed and findings made before construction authorization. While the concept of "reasonable assurance" by its very nature recognizes that these uncertainties exists, no issues can remain for findings in later stages of the licensing process. NRC stated that full issue resolution would be needed at the time of LA, but that they recognize that uncertainties will still exist and state that these uncertainties must be quantified. In other words all uncertainties on issues may not be removed at LA so long as there is reasonable assurance that uncertainties have been bounded and can be accommodated.

5. Data Incorporation into SCP

a) NRC agrees with the general approach described by DOE (attachment 12); however, the specific data presented should be a topic for each technical workshop to discuss and agree upon.

b) NRC stated that the principle concern in citing lack of "QA details" (as referred to in the BWIP SCA) lies in the area of implementing procedures which are distinct from administrative procedures.

6. Integration of Plans and Procedures into SCP

a) No NRC "concurrence" is required for DOE plans. Rather, prudence dictates that there be timely consultation on plans before investigations are carried out. Discussions should be held with NRC to discuss plans so that NRC can comment on their sufficiency, consult on interpretations of data; identify potential licensing issues; agree upon the sufficiency of available information and data; and agree upon methods and approaches for the acquisition of additional information and data needed to facilitate NRC reviews and evaluations and to resolve such potential licensing issues. This is consistent with item 2e in the NRC/DOE procedural agreement (Morgan/Davis Agreement, attachment 8).

b) DOE's comments (attachment 12) were discussed and NRC again discussed the NRC matrix (attachment 4) on level of detail. NRC stated which plans and procedures that are given in the SCP is negotiable and that what is wanted is all plans and procedures to be available to NRC on a timely basis. Some might appear in the SCP, others in SCP references. NRC would like procedures to be provided as references in SCP rather than only made available. NRC handed out selected pages of the BWIP SCA Executive Summary and Chapter 10 (attachment 5) for guidance on the level of plans to be included in the SCP.

c) The mechanism for making plans and procedures available to NRC should be a major topic for discussion and agreement in specific technical workshops.

7. Issue Identification Logic

a) DOE asked if NRC believed that there was one appropriate method or logic for issue identification. NRC stated that any reasonable method used by DOE to identify issues was acceptable. NRC observed that the overview of the DOE logic process presented in the meeting appears to be reasonable. It is the results of the process that are important. The completeness and relevance of the issues would be the focus of NRC review. NRC noted that describing the logic and process of issue identification will give confidence to all parties that a systematic and comprehensive approach has been used.

b) There was agreement on the definition of "issue" as presented in the BWIP SCA. It is defined as simply a question that must be resolved to complete licensing assessments of the site and design suitability in terms of 10 CFR 60. Issues are not necessarily matters of controversy.

8. Chapter 10 Format Approach

a) DOE presented an alternative format for Chapter 10 than is outlined in NRC Regulatory Guide 4.17. NRC is not requiring the format for chapter 10 in 4.17 to be followed literally. NRC indicated that DOE's format is acceptable as it meets the basic logic of presentation where (a) issues are clearly identified, (b) current uncertainties are fully presented, and (c) plans for reducing uncertaintities to acceptance levels are presented.

b) A DOE contractor representative (Glora) proposed an approach for the SCP section titled Additional Issues for NRC Review (Section 10.2.5 in RG 4.17).

This section's objective would be to summarize those issues which DOE believes have enough information for licensing. NRC thought this might be redundant, and that there may be a case for eliminating that section of the Reg. Guide but that NRC would certainly comment on the DOE positions. NRC made it clear that issues can not be closed out or resolved by this mechanism. Only the ASLB and the Commission during licensing can "close out" an issue in making findings.

9. Preliminary List of Issues

a) DOE gave NRC a preliminary list of issues for the three salt basins (attachment 13) and requested that NRC provide feedback within a month concerning the logic, hierarchy and relationships of plans to issues and performance objectives. NPO makes no claim of completeness of the issues at this stage of development. NPO requests further feedback on the logic be supplied at the next workshops relative to the waste package issue writeup NPO will present at that time. Given this schedule and the present limited resources available to NRC for salt review, the DOE issues list will only be reviewed for obvious problems at this time. NRC believes that issues should be one of the major topics discussed in each of the future technical workshops.

10. Comparison of Morgan/Davis Agreement and Salt Agreement

a) NRC marked their comments on the Salt project agreement (attachment 7) and provided it to NPO. NPO will redraft the Salt project agreement to update it and be consistent with the wording in the Morgan/Davis agreement (attachment 8).

b) NRC provided NPO a list of their thoughts on informal consultation NRC would like to implement (Attachment 6). NPO expressed some concerns and felt that we should keep the current process but reexamine the issue on a regular basis.

11. Procedures for Data Access

a) DOE has directed ONWI to separate data reports from analysis reports to facilitate release. Presently a catalogue of data is being prepared to aid in access. Procedures for data access are being prepared by DOE/ONWI based on the catalogue concept.

These procedures will be given to NRC in two weeks as a basis for establishing an acceptable specific procedure for information release meeting the general Morgan/Davis agreement. NRC commented favorably upon the concept of cataloging data analyses, test data, and plans and procedures under development, to permit NRC to identify selected documents which could be used as effective focusing mechanisms for consultation.

12. Future Meetings

DOE plans a series of meetings with States to review the current data base. The first meeting will be held on July 19/20 to plan a schedule and agenda for these meetings. DOE and NRC agree that NRC will be involved in these meetings. It was agreed that technical meetings between DOE and NRC will be held as follows:

- Waste Package — August
- Performance Assessment — October
- Other meetings will be proposed by NRC considering meetings being set up with the States.

NRC requested that a meeting be set up between the staff of the Battelle Columbus Labs doing waste package research for NRC with ONWI. DOE agreed to set up an early meeting concerning this contract work.

LIST OF ATTACHMENTS
(Viewgraphs and Handouts)

NRC

1. Actual Meeting agenda
2. List of attendees
3. NRC licensing process viewgraphs
4. Levels of detail matrix
5. BWIP SCA pages xx-xxi and Ch. 10 Quality Assurance Program
6. DOE/NRC informal consulation
7. Markup of the DOE/NRC Salt Project Agreement
8. Morgan/Davis Agreement
9. Draft NRC Staff Technical Position on Conceptual Design Information Requirements
10. Draft NRC Staff Position Paper on Identification of Specific Licensing Information Needs
11. Draft NRC Staff Technical Position on Waste Package Reliability

DOE

12. DOE/NPO and ONWI viewgraphs
13. Preliminary list of DOE issues for the three salt basins.

DOE/NRC MEETING AGENDA

Attachment 1

Enclosure
To: Neff
from: Miller
7/7/83

June 27, 1983

8:30 a.m.

Introduction and Comments	NPO/NRC
NRC Licensing Process	NRC
Reading of BWIP/SCA Executive Sumary	NRC
Break	
Level of Detail in SCP	NPO/ONWI
Issue Resolution Status at LA	NPO/ONWI
Lunch	
Data Incorporation in SCP	NPO/ONWI
Integration of Plans and Procedures in SCP	NPO/ONWI
Comparison of the Davis/Morgan Agreement and NRC/NPO Agreement	NPO/NRC
Procedures for data access	NPO/NRC
Adjourn	

June 28, 1983

8:30 a.m.

Issue Identification Logic	NPO/ONWI
Chapter 10 Format Approach	NPO/ONWI
Preparation of Minutes	NPO/NRC

MEETING ROOM: 4TH FLOOR CONFERENCE ROOM, WILLSTE BUILDING

SILVER SPRING, MARYLAND

Attachment 2

LIST OF ATTENDEES
2ND DOE/NRC PRE-SCP MEETING FOR THE SALT PROJECT
JUNE 27 and 28, 1983
SILVER SPRING, MARYLAND

ACTUAL ATTENDEES	ORGANIZATION
Bob Johnson	NRC/WMHT
Mile Glora	Battelle/ONWI
Hank Bermanis	Weston (UE&C)
Julia Corrado	NRC/WMHT
Jack Parry	Battelle/ONWI
J.H. LaRue	RHO/BWIP
David Tiktinsky	NRC/WMHT
Ludwig Hartung	NRC/WMHT
Phil Justus	NRC/WMHT
Leslie Casey	DOE/NPO
Jerry S. Szymansui	DOE/NPO
Hubert J. Miller	NRC/WMHT
R.W. Klingensmith	Battelle/ONWI
J. T. Greeves	NRC/WMHT
Robert H. Schuler	Weston
Virgil Lowery	DOE/HQ
Bob Wright	NRC/WMHT
Seth Coplan	NRC/WMHT
Tilak Verma	NRC/WMHT
Larry Chase	NRC/WMHT

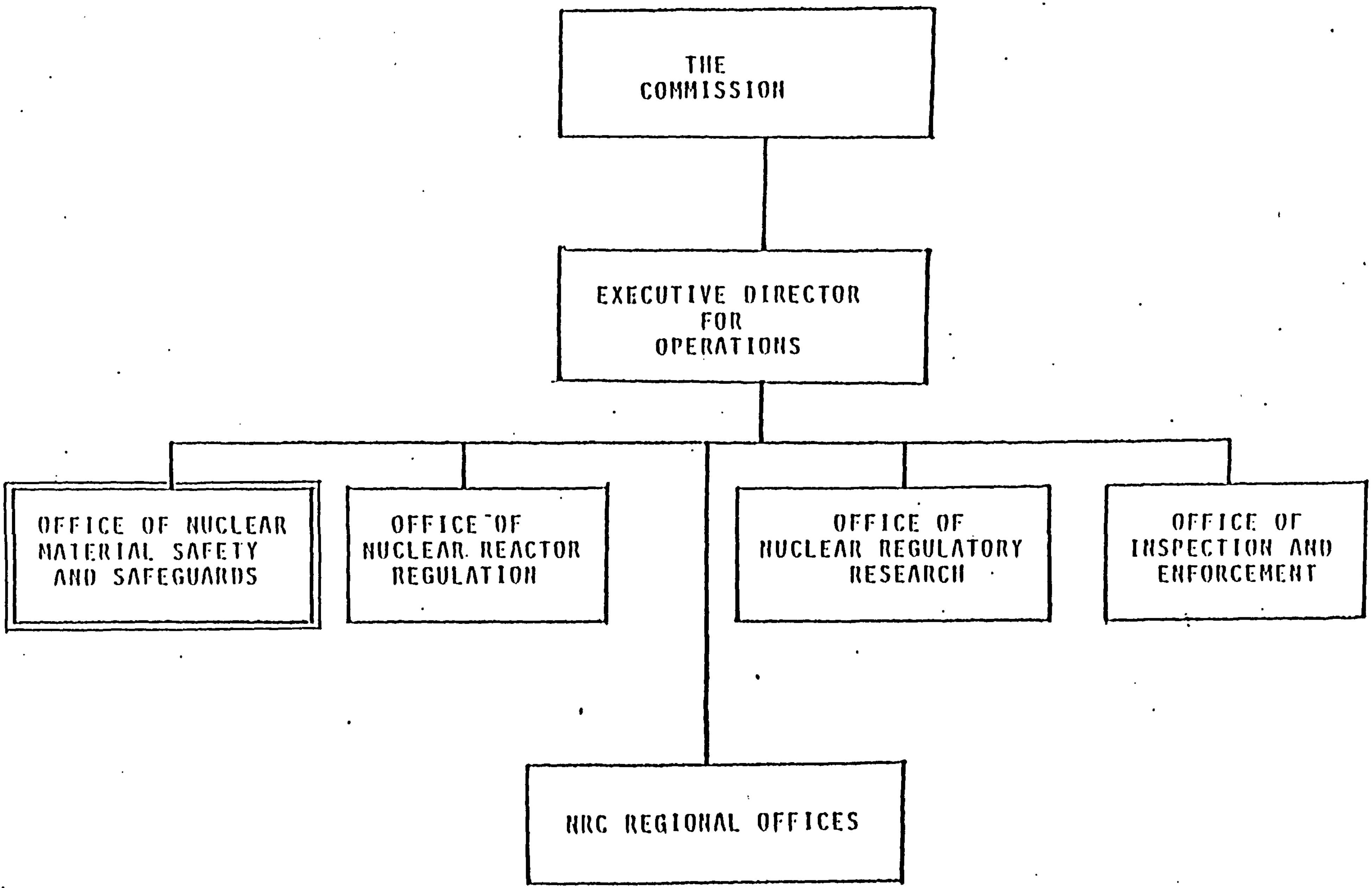
NRC LICENSING
PROCESS

J. DAVIS
W. OLMSTEAD
R. BROWNING
H. MILLER
S. COPLAN

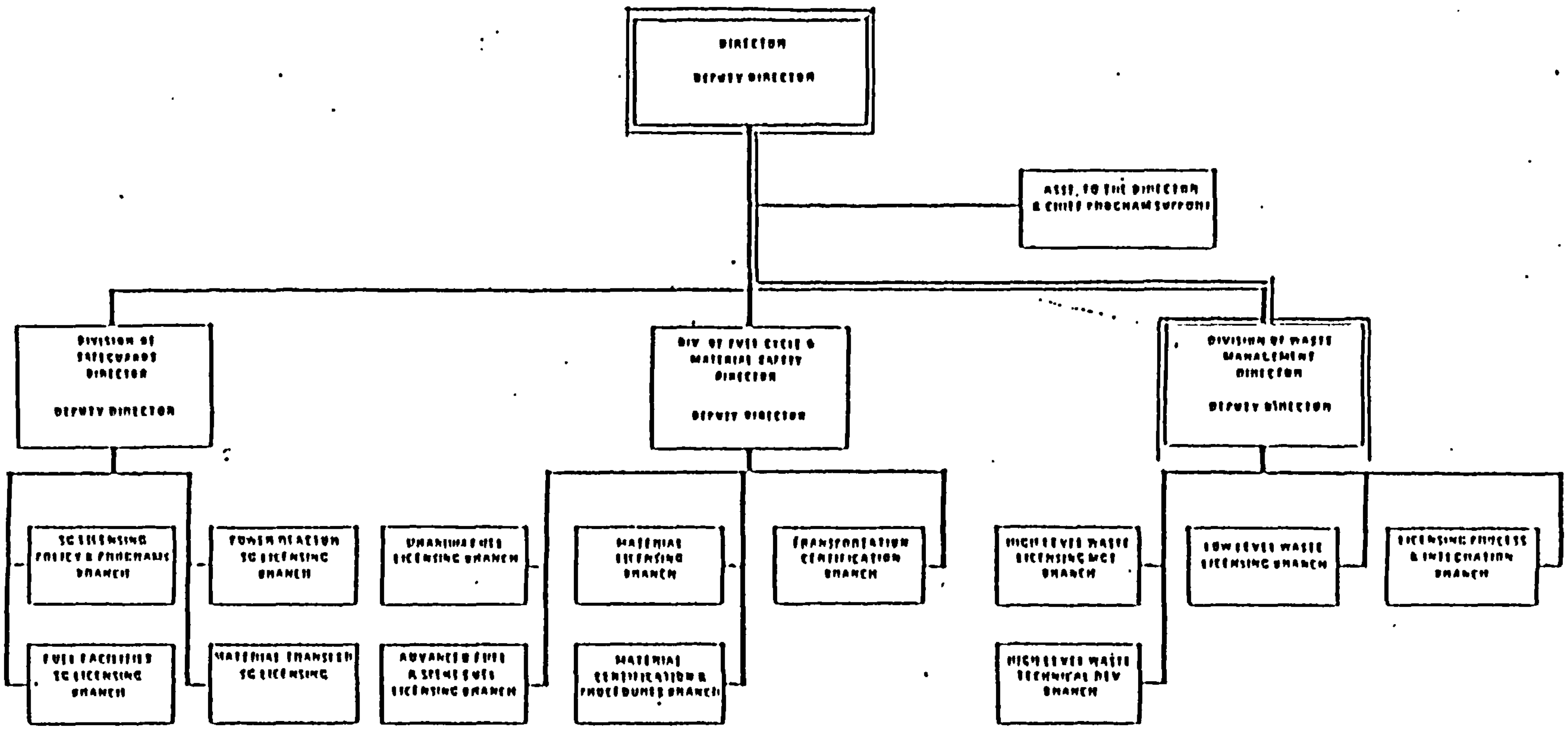
JUNE 16, 1983

Attachment 3

NUCLEAR REGULATORY COMMISSION



OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS



1/28/83

<u>QUESTIONS</u>

- DOES NRC STAFF MAKE LICENSING DECISION?

- DOES DOE ONLY PROVIDE DATA WITH NRC DOING THE ANALYSIS FOR LICENSING?

- WHY DOES NRC STAFF HAVE TO LOOK AT DETAILS NOW -

    - OF DATA BEING GATHERED?

    - OF DATA GATHERING METHODS?

- ISN'T QUALITY ASSURANCE ONLY REQUIRED <u>AFTER</u> LICENSING? WHY IS IT REQUIRED NOW?

- WHAT IS REQUIRED WITH RESPECT TO DOCUMENTATION?

    - OF DATA?

    - OF DATA COLLECTION METHODS?

- DOES <u>ALL</u> DATA HAVE TO BE MADE AVAILABLE?

- CAN'T DATA CONSIDERED TO BE NO GOOD BE WITHHELD?

- WHAT PARTIES HAVE STANDING IN HEARING PROCESS?

- CAN PARTIES INSIST LEGALLY THAT DATA BE MADE AVAILABLE? CAN THEY INSIST THAT DRAFTS OF DOCUMENTS BE MADE AVAILABLE?

- ISN'T "EXPERT JUDGEMENT" AND "ASSERTION" ENOUGH IN LICENSING?

- WHAT IS THE PROCESS THAT ESTABLISHES WHAT "REASONABLE ASSURANCE" IS?

- DOES A DETERMINATION ON WASTE PACKAGE, DESIGN AND ENGINEERED BARRIER PERFORMANCE OCCUR AFTER A DETERMINATION ON CONSTRUCTION AUTHORIZATION? ISN'T THE CONSTRUCTION AUTHORIZATION FINDING JUST A FINDING ON SITE SUITABILITY?

- WHAT'S TO PREVENT NRC FROM RUNNING THE DOE PROGRAM?

LICENSING PROCESS

- O REVIEW LICENSING PROCESS
- O POTENTIAL PROBLEM AREAS
  - ° FAILURE TO ADDRESS ISSUES EARLY
    - \- INADEQUATE FACTS AND DATA PROVIDED
  - ° CONCEALMENT OF INFORMATION
- O CASE HISTORIES
  - ° FOCUS ON PROBLEM AREAS
  - ° REVIEW SOME SUCCESS STORIES

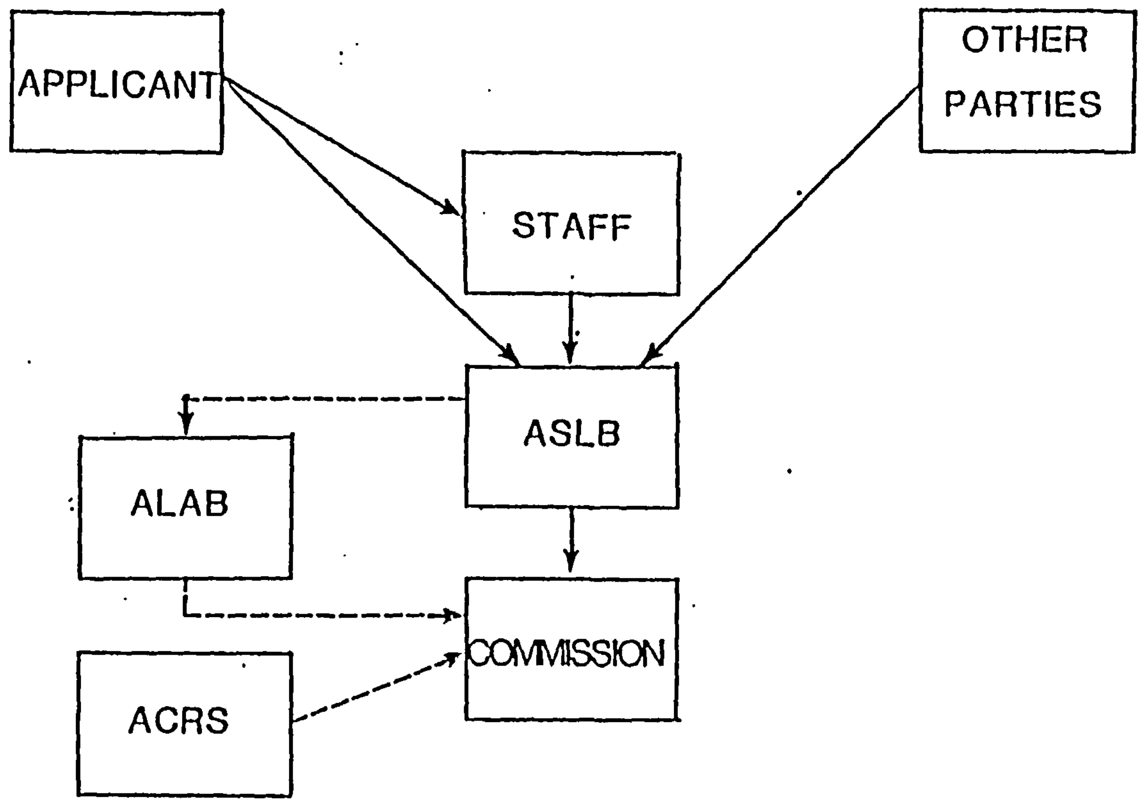
HLW LICENSING DECISIONS

- CONSTRUCTION AUTHORIZATION STAGE
- WASTE EMPLACEMENT STAGE
- SITE CLOSURE STAGE

HEARINGS:

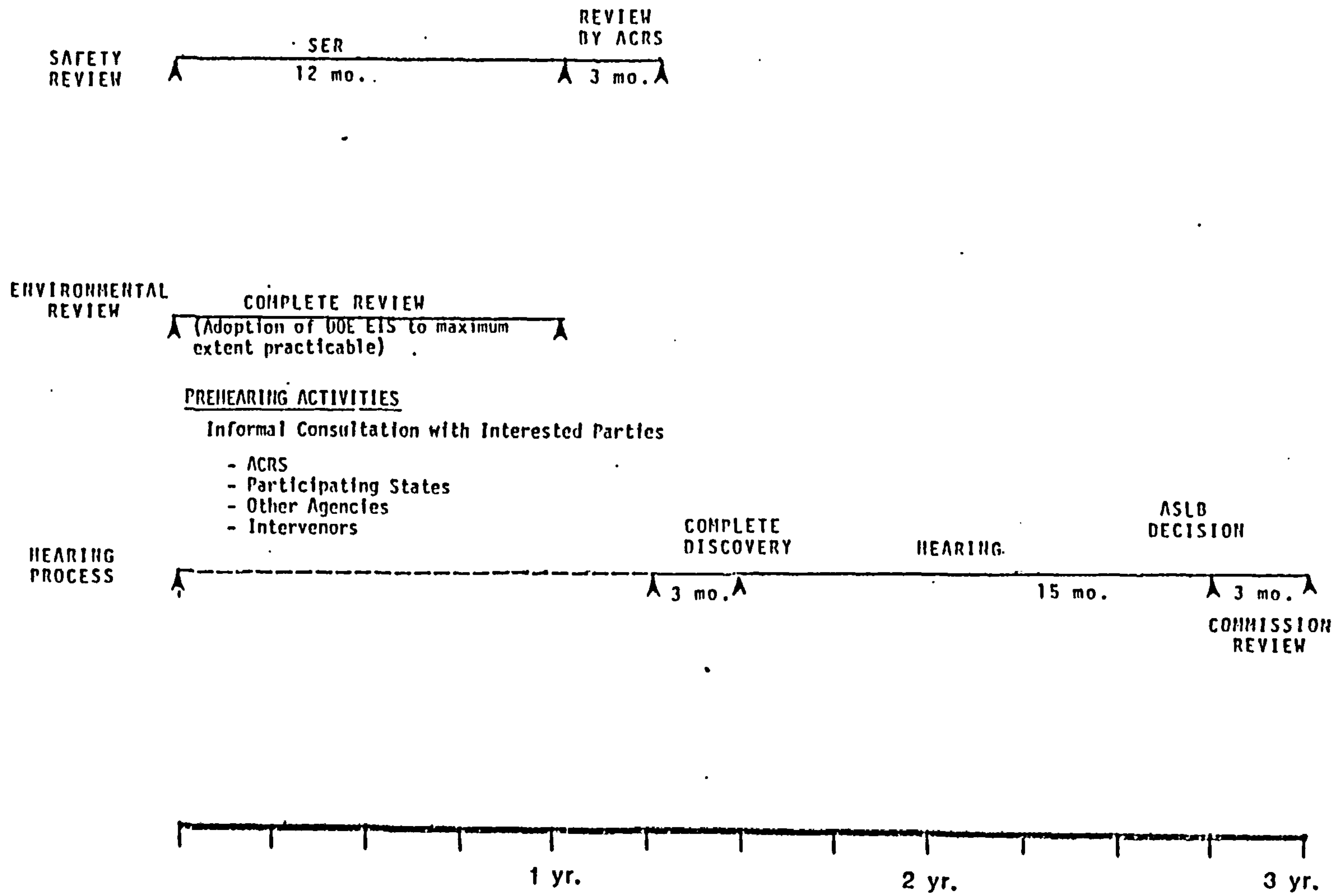
LEGAL, ADJUDICATORY PROCESS

- O BURDEN OF PROOF ON APPLICANT
- O INDEPENDENT ADMINISTRATIVE LAW BOARD
- O RULES OF EVIDENCE APPLY
- O MULTIPLE COEQUAL PARTIES
- O OPPORTUNITY FOR DISCOVERY AND CROSS EXAMINATION
- O FINDING BY BOARD: "REASONABLE ASSURANCE" THAT 10CFR60 CRITERIA WILL BE MET?



HLW DECISION PROCESS

SCHEDULE ESTIMATES FOR HLW REPOSITORY



HEARINGS:

PROCESS REQUIRES

- COMPLETE, TECHNICALLY DEFENSIBLE RATIONALE
- SUPPORTING FACTS AND DATA COLLECTED UNDER QUALITY ASSURANCE PROGRAM
- CONSIDERATION OF UNCERTAINTIES AND ALTERNATIVE INTERPRETATIONS
- COMPLETE DOCUMENTATION

NRC STAFF REVIEW

- INDEPENDENT DATA REVIEW
  - QUALITY (DETAILS OF DATA COLLECTION METHODS)
  - COMPLETENESS
  - RELEVENCE
- REVIEW DOE PERFORMANCE ASSESSMENT
- COMPLETE AND INDEPENDENT PERFORMANCE ASSESSMENT
  - ADDRESS UNCERTAINTIES AND ALTERNATIVE INTERPRETATIONS
- PROPOSE FINDINGS TO ASLB

CASE HISTORIES

- O DIABLO CANYON
- O CRBR/BARNWELL
- O GESMO
- O MIDLAND

PRELICENSING CONSULTATION

- EARLY/ONGOING
- INTERACTIVE
- SITE-SPECIFIC
- FLEXIBLE
- OPEN
- DOCUMENTED

PRELICENSING CONSULTATION

- o EARLY/ONGOING
- o INTERACTIVE/REAL TIME PROCESS
- o SITE-SPECIFIC
- o FLEXIBLE
- o OPEN
- o DOCUMENTED

NRC
PRODUCTS

- ALL HAVE EXACT SAME PURPOSE - ESTABLISH WHAT INFORMATION IS NECESSARY AND SUFFICIENT FOR LICENSE APPLICATION

- FLEXIBILITY TO ALLOW FOR VARIABLE, CHANGING CIRCUMSTANCES - VARIABLES:

  - SITES
  - TIMING/STAGE OF DEVELOPMENT
  - LEVEL OF DETAIL
  - TECHNICAL DISCIPLINE
  - POLICY VS. TECHNICAL
  - DOE SCHEDULE

NRC PRODUCTS

- SCA
- SCP UPDATE REVIEWS
- GENERIC TECHNICAL POSITIONS
- SITE TECHNICAL POSITIONS
- MEETING MINUTES
- STAFF LETTERS

Attachment 4

LEVEL OF DETAIL MATRIX

	SCP	SCP REF DOC'T	ON FILE/AVAILABLE
• DATA { • RESULTS • METHODS } • DATA ANALYSES	← SELECTED AND SUMMARY WITH REF TO DETAILS	→	ALL[2]
• PLANS/PROCEDURES SCA FIG. 10.2	GENERAL/ COMPLETE	ALL[1]	ALL[1,3]
• CONCEPTUAL DESIGN	← SEE STAFF PAPER		→

1 SUPPLIED WITH SCP (AT LATEST)

2 OPPORTUNITY BEFORE SCP SUBMITTED TO REVIEW RESULTS AND METHODS DURING WORKSHOPS WHICH ARE NOT IN SCP OR SCP REFERENCES

3 TIMELY AVAILABILITY OF PROCEDURES IS NEEDED. PROCEDURES SHOULD BE GIVEN IN SCP FOR EARLY SITE CHARACTERIZATION STUDIES OR BEFORE WORK BEGINS FOR STUDIES LATER IN SITE CHARACTERIZATION (PAGE XX AND XXI OF BWIP SCA)

Attachment 5

BWIP SCA, NUREG-0960, vol 1

(18) The SCR identifies the major performance issues; generally discusses the overall performance assessment methodology; and gives a brief description of the sequence of activities that will be followed to fully develop the performance assessment program. However, the SCR does not adequately identify significant items in performance assessment methodology that may be of concern. Such items include: location and description of the boundaries where release limits are to be applied (such as location of the accessible environment); numerical modeling methods; treatment of uncertainties; code validation and documentation; and comprehensive scenario development and probability estimation. Although the SCR identifies development of performance assessment criteria, plans, and procedures, as a task for completion in fiscal year (FY) 1983, the NRC staff cannot evaluate the completeness of this activity because of lack of detail (see pages 9-11 through 9-16).

Quality Assurance Program

(19) A well-organized and implemented quality assurance (QA) program is essential to ensure that data collected during site characterization is of sufficient quality to withstand the scrutiny of licensing assessments. The SCR analysis of the QA administrative program described in the SCR indicates that a relatively well developed program has been established. However, details on implementation of the QA program are not presented. As an example, the QA program requires development of test plans for each major testing program. However, in most of the major technical areas, test plans are neither presented nor referenced in the SCR. Thus, the QA program is not adequately documented to provide assurance of reliability of much of the site characterization data being collected (see page 10-1).

FOLLOW-UP OF CONCERNS AND COMMENTS ON THE SITE CHARACTERIZATION PROGRAM

As discussed above, in many areas the SCR does not provide enough information about planned testing to determine whether adequate information for licensing will be produced. Only generalized descriptions of planned testing are provided. The SCR does not give a definitive description of the parameters to be controlled and measured in planned tests, or analyses that show how the tests adequately bound the range of potential limiting conditions that are important to performance of the aspect of the repository being investigated.

The need for more specific information stems from the complex nature of the questions being addressed in the site characterization program. Given the large number of variables that can control the nature and rate of significant processes important to site and engineered system performance, and the varying conditions that are likely to exist throughout the performance period, a very selective, bounding approach to investigations may be useful. Because any single laboratory or field test constitutes an extremely large oversimplification of actual conditions, a careful and clearly documented strategy that identifies the approach to be taken and factors to be considered in planning specific tests is crucial. This strategy is not in the SCR. As there will be a large judgmental factor involved in the identification of specific experiments to be run, the strategy should be clearly documented so it can be reviewed by the NRC staff and other interested parties.

In commenting on the lack of specific definition of test plans, the NRC staff is aware of the need for flexibility to account for the exploratory, developing nature of the investigations. The initial investigation steps must be conducted before a full program can be developed. The relative importance of various aspects of the program will change as investigations proceed. Therefore, the staff recognizes that a phased approach to testing, as described for many areas in the SCR, is necessary. Flexibility is required not only to make fine adjustments in the investigations on a particular subsystem or technical program area, but also to make major shifts in the overall program, based upon the results of ongoing system performance assessments. The relative priorities among the investigations of the subsystems will change as data are gathered, analyzed, and evaluated.

RG 4.17 recognizes the need to be able to make changes and maintain flexibility in the site characterization program:

> The DOE program of site characterization will be a phased process. NRC expects that data included in the SCR may be better defined and more detailed for early phases of site characterization (e.g., testing in the exploratory shaft) and less detailed for later phases (e.g., testing in an underground facility with two shafts).

However, for testing currently being conducted or planned as the first stage of future investigations, definitive plans must be documented.

The staff does not expect that these plans should have been presented in the SCR itself. They may more appropriately be contained in reference documents and technical program test plans (such as those referenced and provided on hydrologic testing.) Instances where such essential information is lacking are specifically identified in this report. A detailed description of what is missing and why such information is essential is given in each case.

The SCR represents the first milestone in site characterization, a process that will run through several years. The SCR also provides a basis for ongoing, consultative interactions between DOE and NRC staffs. Such interactions will provide the opportunity for a more complete understanding, on the part of the NRC staff, of the site characterization plans. This will pave the way for exchange of views on the kinds and methods of investigations to be undertaken--all in the spirit of focusing site characterization on means to provide the information needed for licensing. Because of the long lead time involved in planning, technical interactions must be scheduled well in advance of the investigations themselves.

10 QUALITY ASSURANCE PROGRAM

10.1 Introduction

Section 60.11(a) of proposed 10 CFR 60 identifies quality assurance (QA) as a key element of site characterization activities for a nuclear waste repository. An adequate QA program is necessary to ensure confidence in the geotechnical data obtained for site characterization and to support potential licensing of the BWIP site.

10.2 Description and Evaluation of the BWIP QA Program

SCR Chapter 18 addresses 10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," as required by proposed 10 CFR 60, Subpart G. The administrative procedures presented in the SCR are based on the 18 criteria of 10 CFR 50, Appendix B and appear to be relatively well developed. However, detailed test plans and technical procedures are not provided or referenced in most of the technical areas described in the SCR. An important element of a QA program is that there be documented procedures guiding the activities related to safety (10 CFR 50 Appendix B, Criterion V). Therefore it is necessary that detailed technical procedures be developed for each technical area following the requirements spelled out in the administrative QA procedures. These technical procedures should contain instructions for actual performance of testing and investigations. In addition to providing a framework for an adequate QA program, DOE should also provide evidence of proper implementation of the program. In the description of site characterization activities in the SCR, a detailed description of the QA procedures (as described in SCR Section 18.5) in each program area is lacking (e.g., detailed QA program for the exploratory shaft is not provided, see page 14.3-73). This concern is discussed in more detail in the following narrative.

An important first question in conducting licensing assessments will relate to quality of data used in support of the license application for the proposed site and repository design. In addition to questioning relevance and completeness of data supplied in the license application, the licensing process must explicitly address the question of whether or not data are of adequate quality so that licensing determinations can be made with reasonable confidence.

The quality of data is virtually determined by the specific data gathering methods and procedures that are used. It is important, therefore, that specific methods to be used in data gathering and in the site characterization program be the subject of the prelicensing consultation between DOE and NRC. The need to deal with the question of data gathering methods was identified in RG 4.17 (Section 1.3).

10.2.1 Level of Detail of Plans and Procedures Needed

The SCR does not present adequate details regarding implementation of site characterization plans. A complex technical program must be based on a systematic approach to planning and controlling the program. The plans controlling the conduct of a data gathering program are of varying levels of detail. They should go from identification of general performance objectives and criteria to detailing specific technical procedures. Figure 10.1 illustrates this, and it is consistent with what the staff understands the BWIP planning structure to be. Quality assurance must be applied at all levels of the program.

As shown in Figure 10.1, site characterization planning must start by considering EPA and NRC criteria. After a site is selected for further investigation, specific issues are identified, based on regulatory criteria and preliminary evaluation of repository performance.

The program can then be divided into program areas related to technical disciplines. These program areas then identify information needed to resolve issues in the site characterization program. From these information needs, test plans are developed. These test plans are an integration of activities and identify how the testing will be accomplished. As part of the test plans, detailed test procedures and instructions are developed.

The development of the test plans and test methods is an important element in providing quality assurance for site characterization data. Figure 10.2 illustrates the development and chronology of events in planning and performing a testing program. This also shows the role of QA throughout the procedure, including how QA procedures incorporate reviews by (1) technical management and (2) peer review groups.

Figure 10.2 also illustrates the point where data should be documented (i.e., document test results) prior to analysis of test results. All data should be recorded under full QA requirements at this point in the test program. This data should be available to all interested parties (e.g., NRC, State programs, etc.) for inspection at an early date after it is documented.

In reviewing the SCR, the staff generally found that test plans and test procedures were not provided or referenced (see Figure 10.1). The SCR stops at the "information needs" level. The information presented is very general and does not give the staff enough detail to provide comments on test plans. Some procedures have been examined in previous workshops with DOE, but the staff expected this information to be at least referenced in the SCR. The staff recognizes that not all test plans and procedures may be needed at this time. However, some test plans (e.g., exploratory shaft and waste package development testing) should be available for QA review. Each chapter of this Draft SCA includes comments on the level of detail of the plans provided and gives examples of deficiencies.

10.3 NRC Conclusions and Comments

SCR Chapter 18, "Quality Assurance," addresses the 18 criteria of 10 CFR 50, Appendix B, and its appears to be relatively well developed. However, details on implementation of the QA program are not presented.

Comments on QA needs in various technical program areas are provided in the relevant chapters and Appendix B of this Draft SCA. The NRC staff's specific comments on QA are as follows:

(1) Many documents are referred to in the discussion of the QA program. These include: implementing functional procedures manuals, the BWIP procedures manual, the Rockwell data package manual, and the Rockwell functional manual. However, these are not listed as references at the end of the chapter. No BWIP document is referenced at the end of the QA chapter. So that implementation of the QA program described in Chapter 18 can be monitored, all of these documents should be identified and referenced in the QA chapter.

(2) SCR Section 18.11 states that test plans are prepared for each major test program. However, few detailed test plans are referenced in the SCR for any of the major test programs mentioned. For example, the discussion of the exploratory shaft in Chapter 17 does not reference any detailed test plan. Because this activity was scheduled for January 1983, a detailed QA program and test plan for the exploratory shaft (as mentioned on SCR page 14.3-73) should be available now. This specific item was raised to DOE in January 1983 (Miller, 1983) and is discussed in Section 6.3.3. Further, few of the planned individual tests listed in the SCR provide any reference to test plans. Also, RG 4.17 requested a description of the QA program to be applied to each planned test and a discussion of the limitations and uncertainty in the data. No such details are included in any of the plans listed in SCR Chapters 13 through 16. Plans that contain the technical procedures to be used during site characterization activities should also be made available for review.

(3) SCR Section 18.3 does not address the methods to be used to define the degree to which analytic methodologies should be validated for application to any particular time in repository history. Methods for reliability analyses, as well as requirements for establishing reliability design requirements for components and systems, should be developed early in the design program. Reference is made to DOE-RL Order 5700.2 (DOE-RL, 1982) and DOE Order 6430 (DOE-HQ, 1981) which identify the process for design and planning. These documents contain the information to be presented in the conceptual design. The SCR does not contain reference to such information. DOE should address this area in the near future.

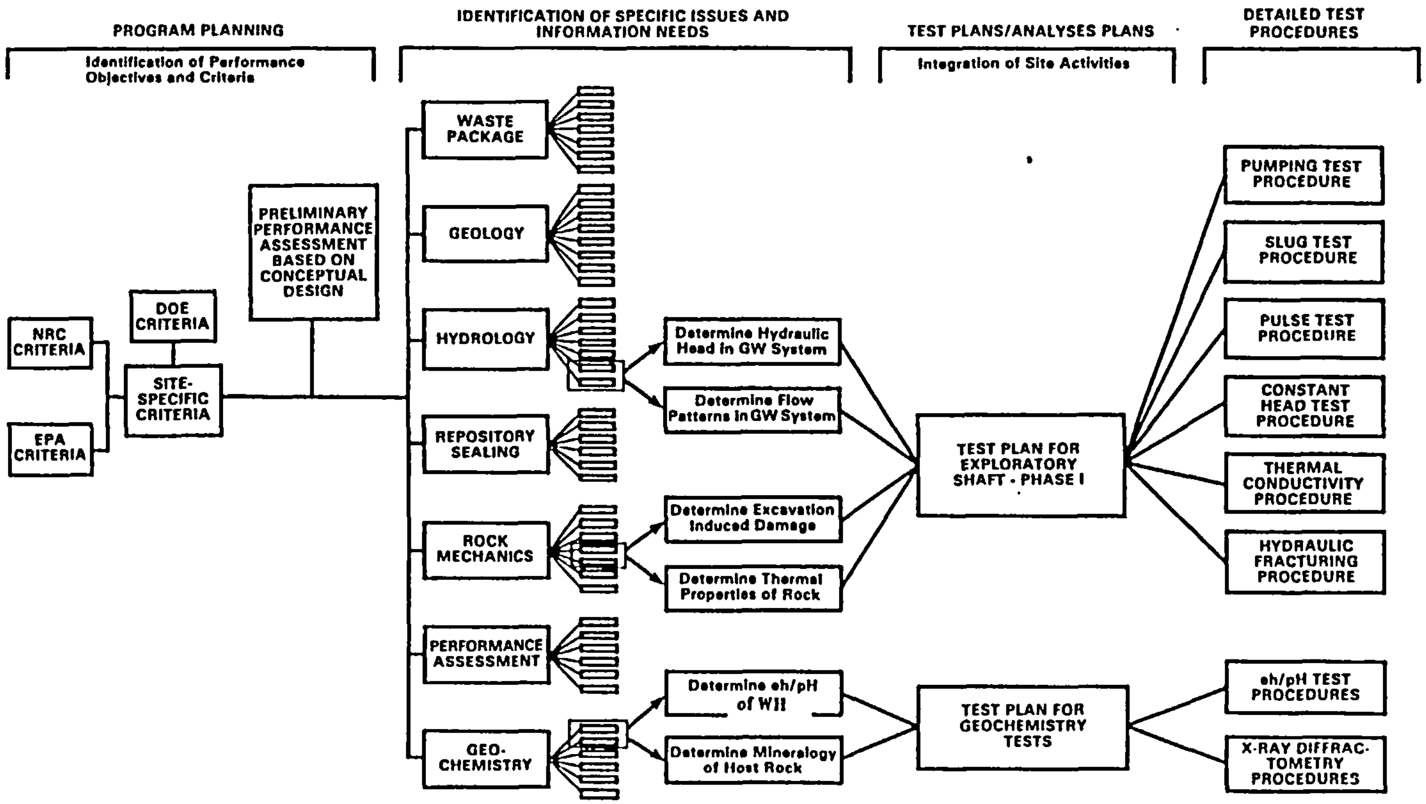
In summary, although the administrative procedures appear to be relatively well developed, the SCR is deficient because it does not provide or reference enough detail on the QA methods to be used in each technical area for the staff to make an independent evaluation of the quality of data being gathered and to be gathered.

REFERENCES

DOE-HQ, 1981, "General Design Criteria for Department of Energy Facilities," DOE Order 6430 (Draft), U.S. Department of Energy, Washington, D.C., June 10, 1981.

DOE-RL, 1982, "Project Management Systems," DOE-RL Order 5700.2, U.S. Department of Energy, Richland Operations Office, Richland, Washington, March 15, 1982.

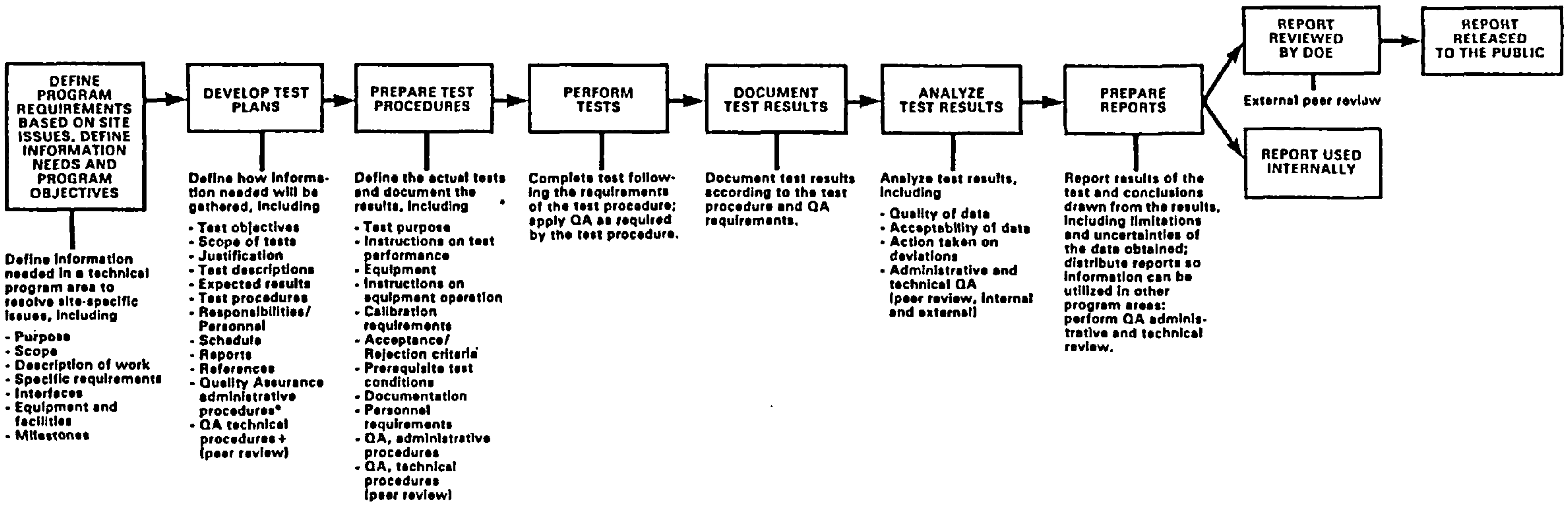
Miller, H. J., NRC, letter to J. H. Anttonen, BWIP, "Additional Information Request on the BWIP Exploratory Shaft Construction and Sealing Program," January 13, 1983.



SCOPE OF DIAGRAM:
To show levels of detail involved in developing a technical program.

PURPOSE OF DIAGRAM:
To convey the various levels of detail in planning and controlling a technical program; to define level of detail necessary in executing a technical program properly.

Figure 10.2 Test method development (illustrative)



*QA administrative procedures include procedures for: (1) document control; (2) documented instructions, procedures, and drawings; (3) control of materials, equipment, and services; (4) use of qualified personnel; (5) inspections; (6) documented test plans; (7) control of test equipment; (8) control of samples; (9) nonconformance reports; (10) corrective action; (11) peer review (both management and technical); (12) audits.

+QA technical procedures include the actual internal and external peer reviews (both management and technical).

SCOPE OF DIAGRAM:
To show chronology of events in development of a testing program.

PURPOSE OF DIAGRAM:
(1) To show a breakdown sequence of development of plans to resolve problem of timely access to data by NRC. (2) To show the involvement of QA, both administrative and technical, in each step of program.

Figure 10.1 Technical program control: test plans and procedures (illustrative)

Attachment 6

DOE/NRC INFORMAL CONSULTATION

TYPES OF ACTION	CLEARANCE	DOCUMENTATION
1. STRAIGHTFORWARD CLARIFICATIONS		
o Any staff or contractor	None	None required. If significant, telecon memo to identified lead staff
o Request for clarification on reports/papers etc where there are ambiguities.		
2. INFORMATION EXCHANGE DISCUSSION/ INFORMAL CONSULTATION		
o Identified Individuals, Senior staff in each of the major technical areas.	None required. (Staff and Contractors other than those identified would get clearance through identified individuals)	Telecon memo's — brief handwritten notes exchanged between agencies, placed in document rooms. Copies provided to management according to respective agency procedure.
o Free exchange of information, questions, opinions and other consultation.		
o Technical or policy positions are not authorized. These are developed and documented in forms that receive the technical and managment reviews and concurrences that are part of respective agency internal procedures. (E.g., SCA's, technical positions, formal letters, etc.)		
~~o These consultations do not substitute~~		
3. HARD COPY EXCHANGE OF DRAFT DOCUMENTS UNPUBLISHED DATA AND ANALYSES		
o Identified individuals	Normal agency concurrence requirements	Written communication

Attachment 7

DISTRIBUTION:

106
WMHT r/f
NMSS r/f
CF
REBrowning
MJBell
PAltomare
JGreeves
LChase & r/f
PDR
HMiller

106/LC/83/06/08/0

WMHT: 106

JUN 1 1 1983

Mr. J. W. Bennett, Director
Geologic Repository Division
Nuclear Waste Policy Act Office
Department of Energy
Washington, D.C. 20545

for your file
lc

Dear Mr. Bennett:

In response to the request in your letter of May 27, 1983, we are enclosing a copy of the agreement signed by NRC and DOE, concerning information exchange on salt.

We have also sent four copies of the agreement noted above to Mr. Jefferson O. Neff at the DOE/NWTS Program Office, as you have requested.

Sincerely,

ORIGINAL SIGNED BY

Hubert J. Miller, Branch Chief
High-Level Waste Technical
Development Branch
Division of Waste Management

Enclosures:
NRC/DOE Information Exchange
Agreement

OFC	WMHT	WMHT					
NAME	LChase:ag	HMiller					
DATE	83/06/08	6/13					

Revise to recognize Davis/Morgan Agreement.

AGREEMENT BETWEEN NRC AND DOE REGARDING INFORMATION EXCHANGE AND CONSULTATION ON SITE CHARACTERIZATION PROGRAM AND LICENSING INFORMATION NEEDS FOR POTENTIAL REPOSITORY SITES IN SALT PRIOR TO THE SUBMITTAL OF A LICENSE APPLICATION FOR CONSTRUCTION AUTHORIZATION FOR A REPOSITORY

~~Authorized representatives of the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC) through this document agree to a series of meetings directed at consultation on the site characterization program and licensing information needs of importance to the potential future licensing of a repository in salt. The nature of and conditions for the meetings are as follows:~~

Substitute/adopt general Procedural Agreement language

1. ~~Workshops will be held to:~~

   a. ~~Allow review and discussion of data and information gathered from investigations to date.~~

   b. ~~Allow consultation on potential issues, remaining information needs and plans for gathering the needed information to resolve issues.~~

dated

2. Workshops for the salt site(s) recommended for detailed site characterization will include the following topics: hydrogeology, geochemistry/waste package, design of surface and underground facilities, geology/stability, performance assessment, and quality assurance. A final slate and frequency of meetings will be established following a general DOE/NPO Program Review tentatively scheduled for April, 1983.

3. NRC written requests for information from the Battelle Office of Nuclear Waste Isolation (ONWI) will be directed to Jefferson O. Neff, Program Manager of the DOE's National Waste Terminal Storage (NWTS) Progrm Office (DOE/NPO), rather than specific contractors with a c.c. to J. W. Bennett, Director, Geologic Repository Division and C. H. George, Team Leader, Salt/Granite Project Team, both of DOE-NE-22. The DOE/NPO point of contact for information is Leslie Casey. Lawrence Chase, Program Manager - Salt Program, will serve as contact and NRC coordinator for DOE written requests for information from NRC. These requests will be directed to Dr. Chase at the NRC, High-Level Waste Technical Development Branch (WMHT), with a copy to Mr. Hubert J. Miller. The NRC point of contact for information requests is Robert L. Johnson (FTS 427-4676). With the experience gained from the workshop meetings and information exchanges, consideration will be given to identifying additional points of contact to assure a continuing and adequate exchange of information.

- dated.

- broader points of contact.

see attached

4. In consultation with the other party agency, the Host Agency will prepare an agenda and proposed list of attendees a minimum of 20 working days prior to each meeting. Comments concerning the agenda and the list of proposed attendees will be provided to the Host Agency a minimum of 10 working days prior to each meeting. The Host Agency will make available a finalized agenda a minimum of 5 working days prior to each meeting. Meeting discussions will be restricted to the topics delineated on the agreed agenda. Host Agency is defined as the agency requesting a meeting and/or workshop.

5. NRC/NPO reviews and workshops should cover only data/information items that are relevant to potential licensing of salt sites. Information bearing solely on other NWTS projects, or which require presence of representatives from other sites, will not be discussed.

Superceded

6. ~~NPO cleared and published reports will be given to NRC. Routine transmittals of NPO cleared and published reports will be made directly to NRC. Information made available to NRC from the clearance process, meetings, and workshops may be used by NRC staff to formulate comments and raise issues about salt sites. However, NRC will take into consideration the extent to which the data has been subject to appropriate DOE review. Any additional information needs will be a valuable indicator to NPO as to what potential information gaps exist and may influence priorities for documentation. The requested information will be supplied once it has become documented in a referenceable fashion. Within 60 days after the first information exchange meeting tentatively scheduled for April 1983, DOE will identify the individual steps in the clearance process where information, data and data analysis will be available to the NRC.~~

Sign on Spot

7. Meeting commitments and observations will be summarized within three weeks into a formal written record of each workshop signed by the DOE/NPO/NRC representatives to assure that there is a common understanding of what has transpired.

Superceded

8. ~~The signatories to the agreement shall establish a continuing dialogue to insure that the objectives of this agreement are fulfilled, as well as to raise any major potential technical licensing questions at an early time.~~

9. DOE/NPO and NRC will brief each other on budgets and scopes of work potentially relevant to licensing a repository once each year on an agreed upon basis.

10. Nothing in this agreement shall alter the responsibility of DOE/NPO and NRC to meet its own commitments for informing the public, States and Indian Tribes of ongoing and planned activities.

11. The terms of this agreement may be amended at any time by mutual consent, in writing, and specifically will be reevaluated at the time of the first submittal of the first SCP to the NRC.

Mark W. Frei
for J. W. Bennett, DOE
Director
Geologic Repository Division

Date: May 19, 1983

H J Miller
Hubert J. Miller, NRC
Chief
High-Waste Technical
Development Branch

Date: June 13, 1983

R C Wunderlich
for Jefferson O. Neff, DOE-NPO
Program Manager
NWTS Program Office

Date: May 3, 1983

Lawrence Chase
Lawrence Chase, NRC
Program Manager
High-Level Waste Technical
Develpment Branch

Date: June 7, 1983

Attachment 8

PROCEDURAL AGREEMENT BETWEEN THE U.S. NUCLEAR REGULATORY COMMISSION AND THE U.S. DEPARTMENT OF ENERGY IDENTIFYING GUIDING PRINCIPLES FOR INTERFACE DURING SITE INVESTIGATION AND SITE CHARACTERIZATION

This Procedural Agreement outlines procedures for consultation and exchange of information which the Commission (NRC) and the Department (DOE) will observe in connection with the characterization of sites for a geologic repository under the Nuclear Waste Policy Act of 1982. The purpose of these procedures is to assure that an information flow is maintained between the two agencies which will facilitate the accomplishment by each agency of its responsibilites relative to site investigation and characterization under the National Waste Policy Act (NWPA). The agreement is to assure that NRC receives adequate information on a timely basis to enable NRC to review, evaluate, and comment on those DOE activities of regulatory interest in accordance with DOE's project decision schedule and thereby facilitate early identification of potential licensing issues for timely staff resolution. The agreement is to assure that DOE has prompt access to NRC for discussions and explanations relative to the intent, meaning and purpose of NRC comments and evaluations on DOE activities and so that DOE can be aware, on a current basis, of the status of NRC actions relative to DOE activities.

This Procedural Agreement shall be subject to the provisions of any project decision schedule that may hereafter be established by DOE, and any regulations that may hereafter be adopted by NRC, pursuant to law. In particular, nothing herein shall be construed to limit the authority of the Commission to require the submission of information as part of a general plan for site characterization activities to be conducted at a candidate site or the submission of reports on the nature and extent of site characterization activities at a candidate site and the information developed from such activities.

1. <u>NRC On-Site Representatives</u>

   As early as practicable, following area phase field work, NRC on-site representatives will be stationed at each site undergoing investigation principally to serve as a point of prompt informational exchange and consultation and to preliminarily identify concerns about such investigations relating to potential licensing issues.

2. <u>Meetings</u>

   From the time this agreement is entered into, and for so long as site characterization activities are being planned or are in progress, DOE and NRC will schedule and hold meetings periodically as provided in this section. A written report agreed to by both DOE and NRC will be prepared for each meeting including agreements reached.

a. Technical meetings will be held between DOE and NRC technical staff to: review and consult on interpretations of data; identify potential licensing issues; agree upon the sufficiency of available information and data; and agree upon methods and approaches for the acquisition of additional information and data as needed to facilitate NRC reviews and evaluations and for staff resolution of such potential licensing issues.

b. Periodic management meetings will be held at the site-specific project level whenever necessary, but at least quarterly, to review the summary results of the technical meetings; to review the status of outstanding concerns and issues; discuss plans for resolution of outstanding items and issues; to update the schedule of technical meetings and other actions needed for staff resolution of open items regarding site characterization programs; and to consult on what generic guidance is advisable and necessary for NRC to prepare. Unresolved management issues will be promptly elevated to upper management for resolution.

c. Early technical meetings will be scheduled to discuss written NRC comments on DOE documents such as Site Characterization Plans, DOE's semi-annual progress reports, and technical reports to foster a mutual understanding of comments and the information or activities needed for staff resolution of the comments.

d. In formulating plans for activities which DOE will undertake to develop information needed for staff resolution of potential licensing issues, DOE will meet with NRC to provide an overview of the plans so that NRC can comment on their sufficiency. These discussions will be held sufficiently early so that any changes that NRC comments may entail can be duly considered by DOE in a manner not to delay DOE activities.

e. Schedules of activities pertaining to technical meetings will be made publicly available. Potential host States and affected Indian tribes will be notified and invited to attend technical meetings covered in this section (Section 2, Meetings). The notification will be given on a timely basis by the DOE. These technical meetings will be open meetings with members of the public being permitted to attend as observers.

3. Timely Release of Information

   a. Data collected during site investigations will be made available to NRC on a current, continuing basis after the DOE (or DOE contractor) quality assurance checks that are inherent in determining that the data has been obtained and documented properly.

   b. DOE's analyses and evaluations of data will be made available to NRC in a timely manner.

4. Site Specific Samples

   Consistent with mutually agreed on procedures, DOE will provide NRC with site specific samples to be used by NRC for independent analysis and evaluation.

5. Agency Use of Information

   It is understood that information made available to either Agency under this agreement may be used at that Agency's option in carrying out its responsibilities.

6. Project Specific Agreements

   Project specific agreements to implement the above principles will be negotiated within 120 days of the time this agreement is entered into. These project specific agreements will be tailored to the specific projects to reflect the differences in sites and project organizations.

7. Nothing in this agreement shall be construed as limiting forms of informal consultation not mentioned in this agreement (for example, telephone conversation or exchanges of reports). These other consultations will be documented in a timely manner.

RL Morgan
Robert L. Morgan, Project Director
Nuclear Waste Policy Act
Project Office
U.S. Department of Energy

Date: 6/27/83

John G. Davis
John G. Davis, Director
Office of Nuclear Material
Safety and Safeguards
U.S. Nuclear Regulatory
Commission

Date: 6/17/83

NRC STAFF TECHNICAL POSITION
ON CONCEPTUAL DESIGN
INFORMATION REQUIREMENTS

1. BACKGROUND

10 CFR 60 and the Nuclear Waste Policy Act (NWPA) of 1982 require that DOE submit to NRC detailed information concerning the conceptual design of repository facilities in connection with the submission of site characterization plans. (Fill in specific citations). This staff position addresses the question of (a) what kinds of information and (b) what the level of detail of information about repository conceptual design are necessary and sufficient to assure that all licensing information requirements have been identified and the right kinds and quantity of testing are planned.

2. TECHNICAL POSITION

2.1 Necessary and Sufficient Kinds and Level of Detail of Conceptual Design Information

2.2.1 Information on the conceptual design must be provided in sufficient detail to permit a determination about the completeness and relevancy of planned site characterization activities. (Footnote this to indicate that site char. includes field and lab work on all aspects of design, including engineered barriers and waste package as indicated in Part 60.) Specifically, sufficient information must be provided to determine a) that all licensing information requirements have been identified and b) that the right kinds and amounts of testing are planned to meet those requirements.

2.2 Additional Exploratory Points

2.2.1 The conceptual design must allow for current uncertainties concerning site parameters or other factors which will determine performance of repository. That is, the conceptual design must allow for a reasonable bounding of conditions where there is uncertainty. For example, potential rock stress and strength conditions must be enveloped in the design assumptions supporting the configuration of underground openings.

2.2.2 With respect to the performance of engineered components of the repository system, such as the waste package, in containing and isolating waste, interim performance requirements should be established during the conceptual design stage. These performance requirements should be specified in quantitative terms that can be related to the numerical performance objectives of 10 CFR 60. This information is required in order to determine what amount of information will be necessary and sufficient for a licensing determination to be made on whether or not there is reasonable assurance that these performance objectives are met. Testing needs are dependent on the reliability required in performance assessments.

2.2.4 Identification of alternative design concepts for the overall repository facility or components of the system is acceptable and indeed likely necessary to allow for (a) uncertainties in site parameters and (b) flexibility to make trade-offs between subsystem components. However, a single, comprehensive repository system must be identified in the conceptual design (at least on a tentative basis) in order to be able to establish specifically how much information will be needed to support the performance assessment as required in 10 CFR 60.

3. <u>DISCUSSION</u>

Attachment 1 lists in more detail required elements of conceptual design information which should be submitted in connection with Site Characterization Plans.

A determination of what specific information at each site will be needed must be made on a case-by-case basis applying the general principles presented under "Technical Position" above. Specific definitions of "conceptual design" which exist within various DOE programs or in various other engineering applications are in many

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cases not good statements of what is necessary and sufficient in meeting these information needs. Examples of these specific details can be found in the BWIP DSCA.

(CONSIDER HOW TO REVISE THIS TO COVER ALSO THE QUESTION OF WHAT KINDS INFORMATION, AT WHAT LEVEL OF DETAIL, WILL BE NEEDED AT THE LICENSE APPLICATION STAGE TO SUPPORT THE LICENSING ASSESSMENTS.)

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ATE	83/06/24					

ATTACHMENT 1
CONCEPTUAL DESIGN INFORMATION REQUIREMENTS

(List here in a systematic, tiered fashion specific information needs. List example of information needed with explanations that can be related to the problem of determining what information must be produced from site characterization investigations -- what testing needs to be done to support assessment of performance.)

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Attachment 10

DRAFT

STAFF POSITION PAPER

IDENTIFICATION OF SPECIFIC
LICENSING INFORMATION
NEEDS

U.S. Nuclear Regulatory Commission

June 22, 1983

TABLE OF CONTENTS

DRAFT

LIST OF FIGURES

DRAFT

1 INTRODUCTION

This paper generally describes the approach to licensing of high-level waste (HLW) repositories that has been adopted by the U. S. Nuclear Regulatory Commission (NRC). It summarizes the activities of the NRC staff prior to the initiation of formal licensing proceedings for construction authorization. These activities are aimed at establishing what must be contained in the license application. Therefore, they also are intended to establish what must be achieved by U. S. Department of Energy (DOE) investigations during the site characterization period at sites being considered for disposal of HLW.

Principally, this paper focuses on the process the NRC staff has chosen for establishing specifically how much site characterization work is needed and enough. In other words, this paper addresses the practical question of how many of what kind of tests and analyses are needed and sufficient to support licensing findings. It describes the specific process by which DOE can obtain detailed guidance they can use in determining what resources should be allocated for investigating each distinct aspect of the repository system. The process provides a mechanism for dealing with the competing demands for limited resources available for site characterization activities.

The alternative approaches which were considered for resolving the above questions are discussed, and the systematic, iterative process chosen is described. Finally, the level of NRC involvement with DOE site characterization activities is discussed.

2 GENERAL APPROACH TO LICENSING

2.1 Regulatory Foundation

Regulatory procedures, criteria and standards have been established for the disposal of high-level radioactive waste. They provide both the procedural and technical framework for the HLW program. NRC issued the final HLW licensing procedures of 10 CFR Part 60, in February 1981 and the final technical criteria in May 1983. In December 1982, the U.S. Environmental Protection Agency published proposed standards (40 CFR 191) for release of radionuclides from a repository. In addition, the Nuclear Waste Policy Act of 1982 (Waste Act) specifies procedures and schedules to be followed by DOE, NRC, and EPA in connection with the characterization, selection and licensing of HLW repositories. It adopted the fundamental principles of 10 CFR 60 including site characterization prior to licensing, insitu testing and substantial interaction between concerned parties.

2.2 General Approach to Licensing

Siting, designing, licensing and constructing a geologic repository is a unique, first-of-kind project for which there are no precedents. Assessing repository performance at the time of licensing with sufficient information and acceptable assessment methods is a very complex technical challenge requiring the interaction of numerous technical desciplines using state-of-the-art technology and even developing new technology.

As mentioned above, NRC regulations and the Waste Act both require substantial NRC-DOE interactions throughout the repository development program. Therefore, NRC's HLW licensing approach is based on NRC staff involvement throughout the repository program, from planning for a potential site through licensing repository construction, waste emplacement and decommissioning. NRC's role at the time of licensing is to provide an independent review and assessment of the performance of a HLW repository with respect to 40 CFR 191 and 10 CFR 60.

2.3 Specific Characteristics of Prelicensing Consultation Process

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NRC's prelicensing role is to conduct early and ongoing consultation with DOE to assure that the acceptable type, amount, and quality of information will exist at the time of licensing. NRC's prelicensing approach, is to establish and document on a timely basis what information is needed in a license application to perform a licensing assessment. NRC's prelicensing activities relate to three major questions:

1) What are the potential specific questions, or issues, that will have to be answered to make licensing findings?

2) What is known from the investigations to date (in terms of the issues) and what are the current uncertainties of these investigations?

3) What are the plans and proposed test procedures for getting needed additional information which will be used to support the license application and adequately reduce the uncertainties in performance to an acceptable level?

Given the unique and complex nature of the issues involved in the development and licensing of a high level waste repository, there must be a period of informal interaction between the NRC staff and DOE before licensing. This consultation would establish specifically what information will be needed to permit determining with reasonable assurance whether or not a proposed site and repository design meets performance standards.

Many site characterization investigations and other data gathering efforts involve long lead times in planning and execution. These lead times are necessary because of the nature of the technical issues about complex natural systems and development of engineered barriers. Therefore, it is imperative that consultation between DOE and NRC start early, prior to the time that significant site characterization activities begin.

Other points about prelicensing consultations is that they must be flexible and ongoing. Site characterization activities are exploratory in nature and can proceed only in a step-by-step manner. Details on plans for tests and investigations are determined by the results of testing previously completed. This is particularly true with investigations about geology and site features.

Finally, the consultation process must be open and carefully documented. This will assure that the process provides opportunity for involvement by the public and all interested parties, such as the technical community, States and Tribes, other government agencies. Also, clear and complete documentation will avoid revisiting issues previously resolved but not adequately recorded.

2.4 Consultation Mechanisms and Products

The principal mechanism for prelicensing consultation is submission of a Site Characterization Plan (SCP) as required by the Nuclear Waste Policy Act and the NRC regulations (refered to as a Site Characterization Report (SCR)). The SCP is a one-time only document that will be prepared before site characterization at each site. It includes what is known and not known about both the natural and engineered systems and the plans for site characterization. The NRC staff will review each SCP and document its analysis of the basic thrust and strategy of the DOE program in a Site Characterization Analysis (SCA) which is provided to DOE for guidance and also issued for public comment. Where possible, the NRC staff analyses presented in the

SCA will be based on and reference positions that are documented in other NRC guidance documents such as Site Technical Positions, Generic Technical Positions and Formal Reports.

The results of DOE's investigations, the identification of new issues that may arise, and changes in DOE's plans for future investigations will be submitted to NRC on a continuing basis as site characterization proceeds and formally through semi-annual updates as required by NRC regulations. In response to the SCP updates, NRC provides continual guidance to DOE by preparing SCA updates.

Given the broad scope and great depth of the data gathering programs at potential sites, it is obvious that effective consultation during the critical prelicensing period cannot consist only of SCP's and SCA's. While these documents must deal comprehensively with all the site-specific issues at a broad level of detail, they are supplemented by a mix of other consultation mechanisms aimed at a more specific level of detail. For example, NRC staff have begun a program of detailed, documented technical meetings covering the major technical areas at Hanford, NTS, and salt sites. These are open, carefully documented meetings. Conclusions and observations in the meeting summaries are supported by informal NRC contractor trip reports that are transmitted to DOE with the meeting summaries. These technical meetings provide a mechanism to directly discuss details of existing information and plans with the DOE staff and contractors. They also are aimed at improving mutual understanding in areas which involve judgement such as interpretations of data or assumptions made in modeling.

In addition, the NRC staff, in consultation with DOE is developing generic and site-specific technical positions on leading technical issues. Some issues, such as information needs to resolve borehole and shaft sealing, lend themselves to generic treatment for efficiency. Generic technical positions provide a mechanism for formally and visibly establishing staff positions on generic issues to provide guidance to DOE on what must be achieved in the various investigations at potential repository sites. Site specific issues are documented in site technical positions. Site technical positions were devised to provide maximum flexibility in completing a series of technical positions of sufficient formality to get staff positions on record and to DOE. Site technical positions are concise (few-pages) to assure the flexibility required to establish NRC staff positions early on in an efficient and effective manner.

A variety of consultation mechanisms and products is necessary and appropriate to document licensing information needs early on in the HLW program. This variety provides the NRC staff the flexibility to assure that its job is done in the most efficient, complete, responsive and responsible manner possible. The basic purpose of <u>all</u> these NRC prelicensing activities is clear and fixed. It is to establish and <u>document</u> on a <u>timely</u> basis what information is needed in a license application to perform lincensing assessments.

Additional descriptions of the NRC guidance products are in the staff paper titled NRC High-Level Waste Management Products.

3 ESTABLISHING LICENSING INFORMATION NEEDS

3.1 <u>Nature of the Problem</u>

The most immediate problem facing DOE with respect to site characterization activities is "specifically, how much of what types of information is needed and enough?" or "how much testing and analyses is needed and enough?" What approach should be taken for answering these questions?

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Establishing information needs to predict performance of any complex, technical system involving a large number of components and many different technical disciplines is difficult. It is very difficult to make decisions about allocation of available resources to the individual areas of the overall system particularly when the information about the system is only slowly developing. Specifically, these decisions are complicated when the basic constitutive relationships which link performance of the system components to each other and to the overall system are so imperfectly known or not known at all in the beginning.

The number of parameters, their interactions and the scope of investigations that might be needed to understand precisely the performance of the complex repository system is potentially staggering. Literally, hundreds of parameters and thousands of data points can be identified as determining the performance of a repository system. When each of the potentially soluble forms of radionuclides in the waste package are considered, under the full range of geologic, hydrologic, and chemical conditions that will exist over long periods of time in the waste package, near and far-field, it is obvious that the number of specific tests that might, on a first cut at the problem, be proposed is likely to be greater than could ever be done in a reasonable time, and more than needed to determine repository performance with confidence. This is true in the near-field of waste package where radiation, high temperatures and temperature gradiants will add to the complexity. It is also true in the natural systems which are inherently highly complex and variabile. It is clear that a program of enormous dimensions <u>could</u> <u>be</u> invisioned to completely characterize and understand the large volume of the natural system surrounding a geologic repository.

To some extent, judgement and experience can lead inargueably to identification of the more important components and the specific parameters which must be measured to obtain at least a general understanding of system component performance. For example, groundwater flow is clearly the primary natural process that will be involved with radionuclide transport. Furthermore, to understand the groundwater flow system around the repository, hydraulic conductivity and groundwater pressure gradients must be determined. However, the next and more difficult question is "how many specific measurements are needed or are enough?" Decisions must be made about site characterization programs -- about the relative importance of various aspects of respository system performance and allocation of limited resources to investigations of each aspects.

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The complexity and vast dimensions of this problem described above contrast sharply with the existing, practical constraints. While public health and safety certainly is of ultimate concern, the real world limitations of available resources, schedules established by public law and limits of technology can not be ignored; they add a further load to the already burdensome problem.

Clearly, the above problem must be resolved before licensing in order to support a finding of reasonable assurance that there is compliance with the performance objectives of 10 CFR 60. The problem is a practical one demanding a solution so that the limited resources and time available to them during the site characterization period can be most effectively used. A solution is also needed so that the NRC staff can give proper and effective guidance to DOE, as well as directing its own internal activities including supporting research programs.

3.2 Alternative Approaches

The NRC staff considered two approaches to resolving the problem of establishing licensing information needs. The first is the perscriptive approach, and the second is the systematic, iterative process.

3.3.1 Prescriptive Approach

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The prescriptive approach involves the NRC staff specifying before site characterization how much of what type of information is needed and the level of acceptable uncertainty (reliability) that must be achieved in the measurements. Then, the DOE investigators would be free to select the methods of measurement and analysis.

One way to implement this approach, which has great intellectual appeal, involves deriving from overall system performance requirements, individual component and subcomponent performance requirements. This would be the way to establish, in turn, required levels of uncertainty that must be obtained in measurements and in turn the types and amounts of information needed. The other other way to implement this approach would be arbitrarily prescribing required uncertainty levels that must be achieved in system component performance and parameter measurements.

An apparent advantage of the prescriptive approach is that it would ostensibly give DOE investigators freedom to select the methods of data collection and analysis and the amount of information needed. In theory it would also give them a fixed, unambiguous target for their investigations and reduce uncertainty about regulatory requirements. While this approach would be ideal, it is, unfortunately, the NRC staff's experience that this is not possible. In reality such prescription by the NRC staff would be very constraining, contradicts the approach taken in 10 CFR 60 and is simply not possible for such a complex, first-of-a-kind program as a geologic repository.

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In early revisions of 10 CFR 60, NRC proposed several numerical performance objectives; however, there was concern that these numerical performance objectives would prevent DOE from being able to allocate performance to subsystem components on a site-specific basis. Recognizing the need for such flexibility the final rule was revised to clarify that the numerical performance objectives would be applied in a flexible manner. There is diversity in the potential sites presently being investigated by DOE as well as for potential, future siting areas. In order to take full advantage of the unique attributes of a site as well as to compensate for a sites' weaknesses, DOE will need flexibility to develop designs and plan its site characterization program. Such flexibility would not exist with a prescriptive approach. For example, the prescriptive approach would not allow, providing less reliability in a waste package at a site, having demonstrable and highly favorable site features, than in a waste packages at a site with poorer or less certain site features. Because site features will be different at each site, it does not make sense for NRC to establish highly prescriptive reliability requirements on a generic basis before site characterization.

It would also not make sense as a matter of practical policy to establish requirements because the tradeoffs to be made at one site between subsystem components are complex questions which potentially involve far more than just matters of public health and safety. Program resources and schedules must also be considered. For example, the Waste Act limits the time period for site characterization before a selection on one site is made. The applicant rather than the regulator should take the lead on these tradeoffs. The regulator only has responsibility for assuring that the safety standards are met.

It is impractical to rigorously derive and prescribe meaningful, quantitative performance requirements before site characterization. This is due to the combination

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of a high level of uncertainty in both site information and understanding of constitutive relationships between system components together with the lack of finely developed site-specific performance assessment methods. For example, as documented in the NRC staff analysis of the BWIP SCR the uncertainty in such fundamental parameters as groundwater travel time ranges over nearly six orders of magnitude. The maximum travel times are on the order of several tens of years (i.e., far less time than needed for the waste to decay to innocuous levels) to a million years.

Finally, it is literally impossible to specify in advance how many tests will be necessary due to the exploratory nature of the program. What tests will be finally ~~required, depends on~~ the results of the testing itself: if the inital tests results are spread over a wide range of values (high uncertainty), a large amount of testing may be needed to narrow the range; on the other hand if the early tests tend to cluster around a single value, few, if any, additional tests may be needed.

One example to illustrate the avove point involves a single test for effective porosity with a result that is between .01% and .0001%. Effective porosity is directly proportional to groundwater travel time, which is an important element in repository performance. The above range of effective porosity values would mean a two order of magnitude range of calculated groundwater travel times (e.g., 10,000 to 100 years). How much more testing will be needed? The general answer is that enough testing needs to be done to permit a reasonable estimation of groundwater travel time; however, no one can answer now the question as to how many more tests will be needed. That will depend on the range of values in the next few tests and the degree of precision that can be obtained in the test methods.

Also, how much testing will be necessary to understand a particular site feature depends on a number of matters. 1) The precision of available testing methods is important: the less precise method the more tests are needed. 2) The relative significance of the feature in repository performance must be taken into account: more needs to be known about features that are critical to performance than about features that are less critical.

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The above discussions clearly describe why prescription of how much information is needed for licensing before site characterization begins will inevitably fail. This failure will likely become the focus of much attention and energy which would detract from ongoing constructive investigations. Also, such apparent misdirection and readjustment of program requirements would adversely effect public confidence in the program.

In summary, the prescriptive approach is inappropriate for the following reasons: 1) needed program flexibility is denied; 2) requirements based on high degrees of uncertainty are not meaningful; and 3) such an approach will inevitably confuse licensing, distract from the resolution of the real technical issues and might destroy the public's confidence in the decision making process.

3.3.2 Systematic, Iterative Process

General

Is the NRC staff saying that there is no rational basis upon which to settle the problem of establishing how many of what type of test are needed and enough? The answer is no. There is a rational process for establishing what information is required for licensing or put in other words, what must be accomplished in the site characterization program. This process was described in the SCA for the Hanford Site (NUREG-0960).

The principal characteristics of this systematic, iterative process are:

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1. At each site DOE will take the lead in identifying the specific information that will be required to assess performance of the repository system. This is consistent with its role in the repository development and licensing process. DOE will have generated the data base upon which uncertainties including data gaps will be identified. Also, they have the responsibility for developing the conceptual repository designs including waste containment systems, upon which the identification of information needs must also rest.

2. Without a large data base to support rigorous assessments, there is still a sound basis for identifying information needs sufficiently well to begin a program of investigations. The basis upon which information needs are identified is the identification of the performance assessment methods that will be used to determine compliance of the repository system of natural and engineered barriers with 10 CFR 60 requirements. Specific data needs can be identified from consideration of the performance assessment methods, including scenarios and associated conceptual and mathematical models that will be used; the simplifying assumptions underlying the methods; and the needed input parameters to such models (See Figure 1).

   By considering specific assessment methods in a systematic way (e.g., using decision tree analysis) together with some limited quantitative sensitivity studies and expert judgement, the relative importance of information needs can be established.

3. The precision with which information needs are identified and limited resources allocated among competing demands will increase with time. First, the

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constitutive relationships that link performance of various components of the system to each other and to the overall system performance are better understood as investigations proceed. Second, the knowledge of the parameters required by applying the various constitutive models become better known. The identification of information needs must, therefore, be altered with time as investigations proceed.

4. Quantitiative sensitivity studies must be attempted from the beginning in identifying information needs. These should be performed at several different levels: at the overall system level as well as at the level of individual system components, or at a level which evaluates selected important aspects of the problem such as groundwater flow. These studies should allow for the full range of uncertainties existing with respect to each parameter and in the models themselves.

   Given the large uncertainties at the beginning of investigations about the basic consitutive models linking system components, efforts to do overall system performance sensitivity analyses may likely be impracticable. Nevertheless, continuing to attempt them will force a strong focus on areas of greatest uncertainty. Eventually, an overall performance assessment will be required in licensing. Starting early to attempt doing them and continuing such efforts is essential despite early "failures".

5. NRC's role in this process is one of conducting many selective and independent assessments concurrently with DOE following the process described below.

   Initially, this will involve qualitative analyses and expert judgement to identify important issues (See Appendix C, BWIP SCA), release scenarios, and various conceptual models. Some selective mathematical and numerical models will be selected and used in various sensitivity studies. Using this knowledge, information needs and data collection and analysis methods and procedures will be slectively and independently evaluated.

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Detailed Discussion

The elements of the systematic, iterative process and their interactions are shown in the simplified logic diagram in Figure 2. This process is a flexible sequence of elements.

The initial element (1) in the systematic, iterative process is to establish the present level of understanding about the site. This is followed by the identification of the performance issues (2) which eventually must be addressed to determine whether the site and the engineered system will comply with NRC regulations. These issues are the basis for the development of specific assessment methods (3), including conceptual, mathematical, and numerical models. Inputs and assumptions to these models help determine the information needs that must be addressed during site characterization.

Of all the steps in the systematic, iterative process, sensitivity studies (4) are a critical element since they can be conducted at several levels using a variety of methods to determine what are the essential information needs.

In some areas, it is also necessary for DOE to establish initial (preliminary) component requirements (5) in parallel with the development of assessment methods and sensitivity studies. These requirements should evolve along with the program and therefore will be adjusted as the whole process is repeated when new information or

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methods are developed. The nature of many of these requirements can be inferred directly from the performance issues, and, once they have been established, they also make an essential contribution to identifying information needs. Acceptable levels of uncertainty are also established here, and directly affect the amount and quality of data needed. This is also the step where relative component performance contributions (trade-offs) are adjusted to compensate for uncertainties in various components.

Steps 1 to 5 all contribute to identifying information needs (6). Once these needs have been identified, the establishment of test plans and procedures follows directly (7), and forms the basis for generating data and determining the uncertainties associated with them (8). These data and uncertainties can be then used to upgrade the sensitivity studies and the assessment methods and refine the component requirements. This process by its nature must be an evolving, iterative one. It must start with the use of substantial judgement, relatively simple models, and sparce information. As the program proceeds and more data are gathered, the process and its steps will become more refined until acceptable level of uncertainty can be reached and findings made (9).

4 LEVEL OF NRC INVOLVEMENT WITH DATA COLLECTION AND ANALYSES

The NRC staff's approach to and level of review of DOE site characterization programs and prelicensing activities in general, stems from what its responsibility is in licensing. The job of the NRC staff reviewers in licensing will be to critically evaluate data and analyses submitted in the license application in support of the proposed repository site and design and to <u>independently</u> draw conclusions about whether regulatory requirements and performance objectives are met.

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Experience has shown that early and ongoing NRC staff technical reviews are essential to assure that the DOE site work is providing information needed for the NRC staff to do an independent assessment at the time of licensing. The DOE site work is by definition exploratory, one phase of the program depending upon results of previous phases. Effective NRC staff review requires keeping current with the large volume of data being generated so that issues can be raised at an early time and thus assure that DOE programs are redirected to resolve them. Also, informal consultation with DOE investigators is required on an ongoing basis in each of the many technical areas involved. This data review and consultation process involves more than review of Site Characterization Plans (SCP) and preparation of formal Site Characterization Analyses (SCAs) by NRC staff. Supplementing and preceding the SCAs are documented site reviews and technical meetings, and single-issue site technical positions. These have proven to be required in heading off problems in ongoing programs. For example, at the Hanford site, the staff identified the need for significant redirection in costly hydrogeologic testing programs which were not yielding relevant data.

In general, NRC's review will consist of the following three elements. First, the staff will review on a selected basis (as dictated by experience and judgement) data and information at all levels down to primary, raw data. Second, the staff will selectively review detailed information on <u>how</u> data was collected and analyzed. Both of these reviews are needed to make an independent conclusion on the relevancy, amount, and quality of information. Finally, data included in DOE analyses, as well as that collected but not explicitly used, will be independently analyzed using the staff expertise, judgement and experience and that of supporting contractors. This analysis will include mathematical models and computer codes. As a minimum, an overall groundwater flow and radionuclide transport model and code will be exercised incorporating inputs on source term and flow and transport parameters. This selective analysis will support the staffs conclusions regarding adequate numerical modeling methods and modeling results.

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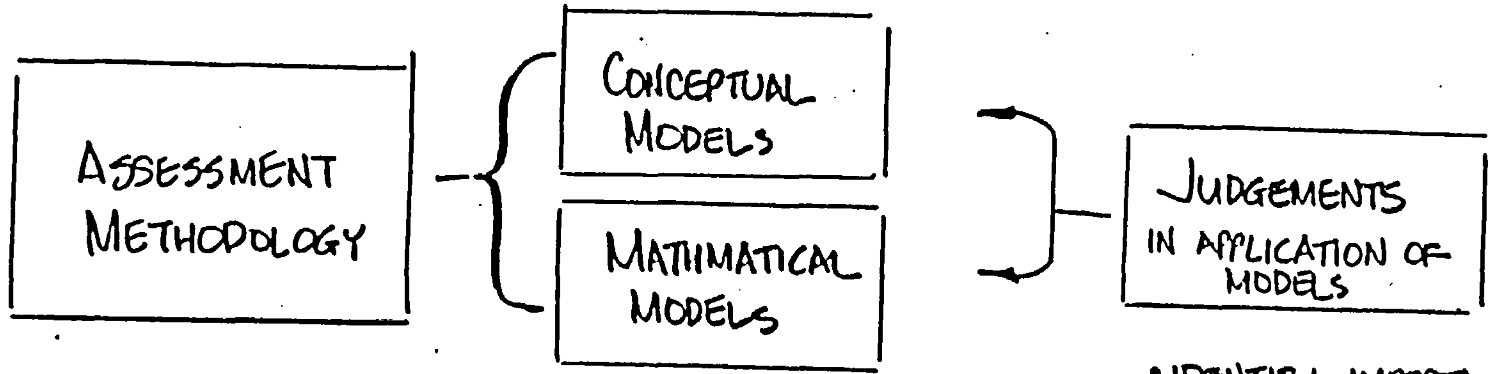

- IDENTIFY IMPORTANT PROCESSES
- SIMPLIFYING ASSUMPTIONS / MATH MODEL SELECTION
- ASSESSMENT PROCESS / SCENARIOS
- MODEL INPUTS
- MODEL "VALIDATION"
- COUPLING OF MODELS
- CONCEPTUAL MODEL DEVELOPMENT

COMPONENTS OF ASSESSMENT METHODOLOGY

FIG. 1

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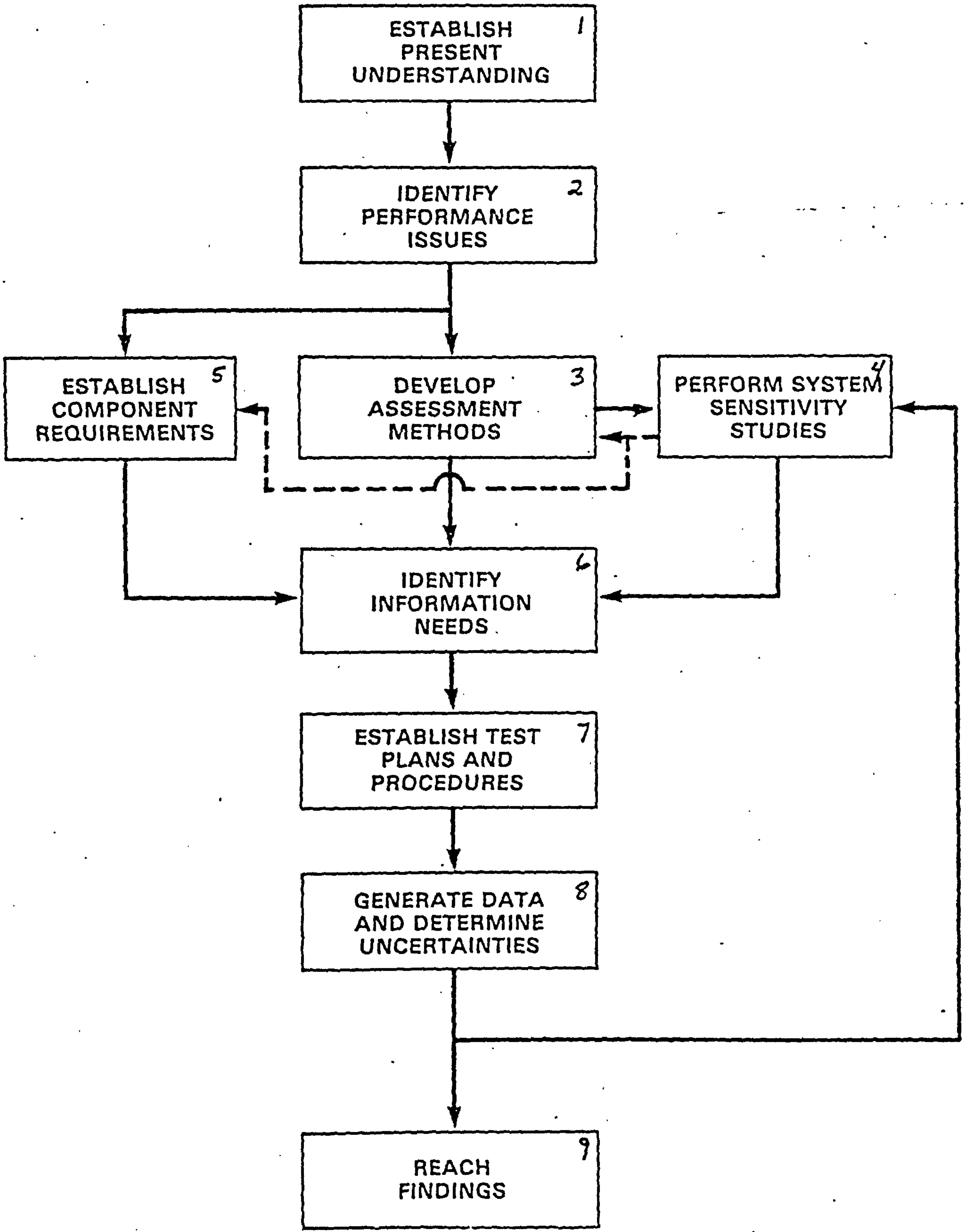

Figure [redacted] ~~Site characterization program logic~~ 2 Systematic, iterative process

Attachment 11

NUREG-0997
LIMITED DISTRIBUTION

DRAFT TECHNICAL POSITION

ON

WASTE PACKAGE RELIABILITY

May 1983

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ABSTRACT

A method for the evaluation of reliability of a high-level waste package to comply with the requirements of 10 CFR 60 is being proposed. The method is based on the repetitive use of a performance model for values of the model parameters which span their range of uncertainty. The techniques for selecting values for the input parameters, viewed as random variables, and for generating empirical correlations among experimental data are described and illustrated with an example of a simplified waste package analysis.

1. INTRODUCTION

1.1 Presentation of the Document

The Code of Federal Regulations in the proposed Part 10 CFR 60 requires that the applicant for a license to operate a repository demonstrate, among other requirements, that the waste package will contain the waste for 300 to 1000 years (depending on the thermal load to the geologic repository) and that the engineered barrier system (the waste package and the underground facility) will control the subsequent annual release of any radionuclide to no more than one part in one hundred thousand of the amount contained after 1000 years, assuming no release. Although the controlled release requirement is on the engineered barrier system, the applicant will need to demonstrate substantial contribution by the waste package unless it can be demonstrated that the underground facility alone can meet the controlled release requirement.

The NRC will not require absolute proof of zero release during the containment period or of a yearly controlled release from the engineered barrier system of 1 part in 10^5 thereafter; it shall be demonstrated, however, that the proposed waste package design provides reasonable assurance of compliance with both performance criteria.[1,2]

This Draft Technical Position (DTP) aims to clarify the information and analyses that would be expected of the applicant in order to substantiate before the NRC the anticipated performance of the proposed waste package over a period of 10,000 years. In particular, this DTP individuates the general method of probabilistic reliability analysis as an acceptable framework to identify, organize and convey the necessary information to satisfy the criterion of reasonable assurance of waste package performance according to the regulatory requirements during the containment and controlled release periods. The demonstrated level of reliability of the waste package that will be considered as satisfactory for the criterion of reasonable assurance is not defined at this time. The fundamental consideration that waste package reliability should be compatible with the overall reliability of the repository system as specified by environmental standards which may have been established by the Environmental Protection Agency should serve as a preliminary guide.

For the sake of clarity, the proposed methodology for evaluating reliability is illustrated with a simplified sample calculation in Appendix A.

1.2 Definitions

Confidence Parameter (of a model). A model parameter reflecting the uncertainty of the model with respect to the reference data base and with respect to the model overall applicability based on expert opinion.

Confidence Level (of a reliability estimate). The probability that the predicted reliability estimate will be achieved.

Distribution Function (of a random variable). The mathematical function which determines the probability that under stated conditions, a random variable, x, will assume a value not exceeding some fixed real number, x_a.

Failure. The termination of the ability of a part or group of parts to perform its intended mission under specified conditions.

Probability. The limiting value of the relative frequency with which some events occur under stated conditions.

Random Variable. A quantity which takes different values with different probabilities.

Reliability. The probability that a part or group of parts will meet a functional requirement under specified conditions for a given period of time.

1.3 Proposed Approach to Waste Package Reliability Analysis

Major components of the waste package system are the primary waste form, the waste form container, and packing materials. Ideally, it would be desirable to predict the performance of such a complex system during the operational life of a repository through the aid of comprehensive, fully deterministic models which span all possible failure modes in the presence of the evolving near-field environment. The usage of such models should be warranted by the availability of an adequate data base which provide values of the relevant model parameters with a sufficient degree of accuracy. In practice however, only a few simplified models have been presented in the literature, and the relevant data have a great degree of uncertainty. Therefore it seems more appropriate, at present, to resort to a scheme to predict failure probabilities based on the application of simple phenomenological models. In this scheme, one identifies a radionuclide release scenario, formulates and justifies the relevant models, determines ranges and distributions of the associated parameters viewed as random variables, samples among these according to a probabilistic technique, and determines the predicted failure times. Reliability is then calculated.

In broader terms, the proposed approach for evaluating the reliability of a high-level waste package consists of the following steps:

1. Identifying the types of known failures that, on the basis of engineering judgement, are physically possible for the waste package for a given repository system in the sense of not violating physical laws. This is done on the basis of an exhaustive review of the relevant literature and exploratory experimentation under the guidance of general principles and existing knowledge of failure types in other systems which have points of similarity with the system under consideration. The process of identification is complete when an independent review fails to reveal new possible failure types.

2. Evaluation and preliminary dismissal of those processes which are physically possible under some conditions but physically impossible under the repository conditions. For example, a type of corrosion of metallic components may be possible in a salt environment but not possible in a basalt environment. This process is complete when all failure types previously identified are either dismissed or explicitly retained for further analysis. The reasons for dismissal in each case are documented with defensible arguments, and in sufficient detail so as to facilitate subsequent reviews and possible re-evaluations.

3. For each of the failure types retained for further analysis, a model is constructed. The model describes the conditions which may lead to the failure, predicts when the failure may occur, and the immediate results of the failure. The nature of the failures, the state of knowledge, and the role of the individual failure in the overall failure of the repository dictates the level of detail required and the

model uncertainty which is tolerable. This process is complete when for each of the failure modes there is a model and the justification of the model is documented, not only as to nominal values but as to statistical uncertainty and distribution forms of the predictions.

4. Properties describing the environmental conditions of the repository and parameters which are relevant to the selected models are analyzed and their values are measured or calculated. This process is complete when all the links between observable and measurable properties and parameters of the repository system are identified, their values and uncertainties obtained, their probability distributions ascertained and justified.

5. Once the set of system properties, models and parameters is available, they are combined in a scheme that serves to explore all interactions modeled and predict failure probabilities. Because failures tend to be mainly due to a combination of unfavorable circumstances that may occur in nature, a scheme to predict failure probabilities such as Monte Carlo simulation would be desirable, and it could be practical and acceptable. Other probabilistic schemes might be acceptable as well. Indeed, a preferred scheme can not be identified at this time, due to the fluid state of the field of high level waste repository design.

These steps are illustrated in the sample calculation provided in Appendix A.

2. REGULATORY POSITION

2.1 Information Required For Evaluation Of Reliability

Purpose and Applicability

The applicant will submit to the NRC a Safety Analysis Report (SAR) in accordance with the requirements of the Code of Federal Regulations (10 CFR 60.21). The prediction of reliability of the waste package will be part of the SAR.ǂ This report will conform to the guidelines of a Standard Format.

The applicant should strive for clear, concise presentation of the information provided in the SAR. The required information should include:

1. Waste package design configuration and materials specification
2. Conditions that bind the repository environment
3. Material properties of the selected waste package components
4. Failure mode and effects analysis
5. Quantitative reliability analysis of the proposed waste package design
6. Overall confidence of the Reliability Analysis
7. Quality control assurances

2.1.1 Waste Package Design Configuration and Materials Specification

According to 10 CFR 60, the waste package includes:

(1) The waste form, which consists of the radioactive waste proper and any associated encapsulating or stabilizing materials.

(2) The container, which is the first major sealed enclosure that holds the waste form.

ǂIf a format and Content Guide for the SAR is issued by the staff, then the information identified below is to be considered supplementary to the waste package portion.

(3) Overpacks, which consist of any additional vessel receptacle, wrapper, box or other structure, that are both within and an integral part of a waste package and provide additional containment of the waste.

(4) Packing material, which may control the flow of groundwater, condition the chemistry of the groundwater reaching the container or overpack, and retard the transport of radionuclides from the waste after the container is breached.

This constitutes four major barriers. A specific waste package system is considered in Appendix A for the purpose of illustration.

In the SAR, the applicant will submit drawings and schematics of the proposed waste package design with emphasis on its geometrical configuration. Limited material specifications shall be included for the sake of clarity.

2.1.2 Environmental Conditions

In the prediction of reliability of the waste package, the applicant should show the extreme range of conditions that bind the environment to which the waste package may be subject throughout its life. This is accomplished by providing ranges of values for the following factors of environmental concern:

- temperature field
- groundwater chemistry (including pH, Eh, oxygen and hydrogen fugacities)
- radiation field
- pressure and stress fields

These factors influence singly or concurrently all degradation modes of waste package components, as shown in Table 1. In particular, temperature is expected to be the most important environmental factor, since it affects practically all physico-chemical parameters.

Table 1

Degradation Modes of Waste Package Components and Relevant Environmental Factors for Reliability Analysis

Waste Package Component	Degradation Mode	Environmental Factor‡
Primary Waste Form	Leaching	A,B,C
	Phase Changes	A,B,C,D
	Fracturing	A,B,C,D
Structural Metal Components	Corrosion	A,B,C,D
	Hydrogen Embrittlement	A,B,C,D
	Leaching	A,B,C
Packing Material	Chemical Failure	A,B,C
	Phase Changes	A,B,C,D
	Fracturing	A,B,C,D

‡A – Temperature field
B – Groundwater chemistry
C – Radiation field
D – Pressure and stress fields

2.1.3 Material Properties

In the prediction of waste package reliability, the applicant should list, for each waste package component, material properties necessary to accomplish reliability analysis. These may include original composition and mechanical, chemical and thermal charcteristics, and their expected dependence on the repository environmental factors as they change with time. These properties impact on the design functions of each waste package component and constitute an indispensable data base for evaluating performance. For the sake of illustration, an abridged list of expected properties to be provided by the applicant, and the function they impact on is reported in Table 2 for a generic packing material.

2.1.4 Failure Mode and Effects Analysis

In the SAR, the applicant should list all possible, identified failure modes of each waste package component and their retention or dismissal for further analysis. This preliminary analysis, generally called Failure Mode and Effects Analysis - FMEA, is qualitative in nature.[17] It is expected to result in the reduction of the set of possible failure modes to only those which are relevant under the range of repository conditions identified in Section 2.1.2. This set of significant failure modes will be called design failure modes. In the dismissal of potential failure modes, the applicant should consider the natural variability of environments to which the package will be exposed. The dismissal of any given failure mode should be discussed and documented.

Special forms of the kind shown in Table 3 are useful for documenting an FMEA. Furthermore, the interrelations between design failures can be summarized by means of event trees.

2.1.5 Quantitative Reliability Analysis

For each of the design failure modes and for each basic process determining the evolution of environmental conditions and material property changes, the applicant should supply predictive equations. For each predictive equation, the applicant should provide the theoretical foundation, experimental verification or other form of validation, and an analysis of the

Table 2

Material Properties of Generic Packing Material
for Reliability Analysis

Function	Properties
Groundwater Exclusion	Porosity Permeability Hydraulic Conductivity Swelling pressure
Radionuclide Retention or Retardation	Dispersivity Diffusivity Tortuosity Radionuclide Loading Capacity
Mechanical Stability	Elasticity Moduli Modulus of Resilience Rupture Moduli Atterberg Limits Activity
Heat Transfer	Thermal Conductivity Thermal Diffusivity Emissivity Overall Heat Transfer Coefficient‡
Resilience to Hydrothermal Alteration	Thermal Expansion Coefficient T-V-P Points for Change of Phase
Groundwater Conditioning	Eh-pH Stability Fields Solubility Limits Sorption with Respect to O_2

‡under both water saturated and non-saturated conditions

Table 3

Exemplary FMEA Documentation for Failure Modes of a Waste Package Component

Waste Package Component	General Failure Mode	Identified Failure Modes	Design Failure Modes
Waste form container (low carbon steel)	Chemical	Uniform corrosion Pitting '' Galvanic '' Crevice '' Intergranular '' Bacterial '' Erosion '' Stress corrosion cracking Hydrogen damage Selective leaching	Uniform corrosion Pitting '' Stress corrosion cracking Hydrogen embrittlement
	Mechanical	— — — — —	— — —
	etc.		

uncertainty of prediction associated with the equation. The uncertainty of the equation should be established through statistical evaluation of the scatter of reference data and through a survey of expert opinions. In addition, for all the data required for the predictive equation, the applicant should supply probability distributions. From this information, a quantitative reliability analysis of the proposed waste package design should be possible.

In order to perform a quantitative reliability analysis of the proposed waste package design, the applicant should combine the various models for design failure modes, material properties changes, and evolution of the waste package environment in a composite model called the performance model. By the use of the performance model and the random variables representing the data and the uncertainty of the individual models used, the applicant should then derive the probability distribution of the times to containment and controlled release failure. A scheme to predict failure probabilities such as a Monte Carlo simulation would be desirable and it is implemented in this document (Appendix A). Other probabilistic schemes might be acceptable as well. Indeed, a preferred scheme cannot be identified at this time due to the fluid state of high level waste repository design.

2.1.6 Overall Confidence of the Reliability Analysis

The applicant should state the overall confidence level of the submitted reliability analysis. The assessment of confidence levels is an inductive process which can be achieved by such techniques an expert opinion survey, e.g., a Delphi method.

2.1.7 Quality Control/Assurance

In order to provide assurance that the design, construction, and operation of the proposed repository is in conformance with applicable regulatory requirements and with the design bases specified in the license application, 10 CFR 60 requires that a Quality Assurance Program (QA Program) be established by the applicant.

The QA program should assure confidence in the reported distributions for the material parameters used in the performance model. Indeed, design reliability specifications are an integral component of any QA program.[18,19]

3. REVIEW PROCEDURE AND ACCEPTANCE CRITERIA

A definitive selection of a necessary and sufficient set of critical parameters and models of mechanisms, such that their consideration insures completeness of the review of the waste package reliability analysis will not be possible until the waste package design is defined, because the importance of a given parameter or model depends on its role in the whole scheme.

There are, however, some basic system parameters and models that can be identified initially and that are expected to form a core of critical items to deserve attention during review. These will occupy the bulk of this section. Other parameters and phenomena not included in this review may become important as the analysis of particular designs matures. They will be included in the licensing review as the developing experience dictates the need.

3.1 Failure Mode Analysis

The failure mode analysis consists of a description of the mechanisms and processes that are liable to lead to a failure of the system to perform its intended function under the expected repository conditions. It contains in narrative form, the modes of failure considered in the analyses and design failure modes. The interrelations between components failures may be summarized by means of event trees.

The review of the failure mode analysis serves the reliability specialist to define the failures that need to be analyzed further to calculate the reliability of the system.

The acceptability the failure mode analysis depends on the completeness of the phenomena considered in their formulation. There are no practical methods to prove completeness other than a documented record of search and analysis of alternative failure modes such that repeated detailed review by competent technical persons fails to produce new credible failure modes. Such review should be conducted at a pace that will allow the reviewers to explore alternatives suggested by the review, and should result in documentation of the alternatives considered and dismissed.

3.2 Quantitative Reliability Analysis

In order to calculate the reliability of a waste package design in a geologic repository, a Monte Carlo simulation method can be useful and is adopted in this DTP.

In this method one views the parameters of the waste package performance model as random variables with given distribution functions, samples among these with an appropriate technique based on a random number generator approach, and determines performance. The process is repeated several times in order to simulate any combination of parameters or environmental conditions considered possible for the design. When some of the component models have uncertainties in themselves, in the sense that even if the input were known perfectly the output would be uncertain, one accomodates this by introducing in the component model an extra random variable to represent the model uncertainty.

Alternatively, in a Monte Carlo simulation an analogous stochastic process is set up which behaves as much as the actual problem as possible. The modeled process is then observed, and the results are tabulated and treated as if they were the outcome of an experiment. The technique is illustrated in the worked example reported in Appendix A.

Acceptability of a Monte Carlo simulation calculation depends on the proper selection of a performance model, numerical inputs, random sampling technique, and algorithms and computer programs. These are reviewed independently as follows.

3.2.1 Performance Model

A waste package performance model will be composed of component models addressing basic functions or processes within the waste package system. The validity of the performance model depends on the completeness with which the individual component models describe all phenomena of importance, and, in final analysis, on their success in predicting experimental results.

In order to insure completeness of the review, the derivation of predictive equations for the purpose of correlation of experimental results should be described in sufficient detail to allow independent verification and reconstruction of the predictive equation by qualified practitioners. For widely used predictive equations in the public domain, e.g., conventional heat transfer correlations, identification of sources and reference to publications is sufficient. For predictive equations developed specifically for evaluation of waste package performance and used in the reliability assessment, the data base used for the derivation of the equation should be provided in tabular form either originally or by reference to published reports still in print. The analysis of the data should include an analysis of correlation between the independent variables, measures of goodness of fit of the regression in the form of significance levels of the estimate of regression coefficients, and analysis of residuals to demonstrate the form of the distribution function of the expected errors.

Models to be used for Monte Carlo calculations of propagation of errors or uncertainties will result, for practical reasons, in relatively simple algorithms. For example, temperature calculations will be probably reduced to one-dimensional models to keep computer time within practical limits. In cases where such simplifications are needed, the models will require further validation of the simplifying assumptions by comparison against detailed calculations, accepted to serve as bench-marks.

Since the design of high level waste packages is not sufficiently defined to permit a complete specification of the performance model, the following considerations should serve as a guideline. It is expected that a performance model should be composed of the following component models:

- A temperature model able to predict the temperature at any point in the waste package as a function of time.
- A heat source model able to predict the rate of heat generation in the waste as a function of time.
- A radiation model able to predict gamma dose rates in the packing material.
- A water chemistry model able to predict the parameters of interest such as pH, Eh and salt concentrations as a function of temperature, radiation and time.

- A corrosion model able to predict corrosion rates as a function of temperature and water chemistry.
- A solubility limited leach model able to predict release rates of radio-isotopes as a function of time, temperature and water chemistry.
- A packing material transport model able to predict concentrations of isotopes as a function of time, water flow, temperature and water chemistry.
- A water flow model able to predict groundwater flow as a function of time, perhaps accounting for temperature gradients.
- A mechanical failure model able to predict damage to the canister due to stresses.

3.2.2 Numerical Data and Constants

The basic criterion for acceptance of numerical data to be used in models or correlations is reproducibility. For experimental data, the conditions of the experiment should be stated or referenced such that the results can be reproduced within stated experimental error by a qualified practitioner. For derived data, the results should be computable from the supplied or referenced sources.

All constants and parameters resulting from experimental measurements and used in the analysis of performance or reliability of the package should be presented with an estimate of the error or confidence interval. In the case of experimental data having uncertainties larger than a few percent, an estimate of the expected distribution of errors should be provided. All basic experimental data used for the derivation of models should be provided in a form, such as tables or references to available publications of numerical data, that will permit that any derived correlation or predictive model used in the analysis of reliability be reconstructed as the need arises during the review. Data in the form of plots is not acceptable for the justification of models unless accompanied by tabulations of the numerical values. References to data in unpublished, draft or out-of-print reports or publications are not acceptable.

3.2.3 Random Sampling Technique

Reliability calculations based on Monte Carlo simulation necessitate the repetitive use of the waste package performance model with different values of the input parameters viewed as random variables. Accuracy improves the larger the number of cases which are analyzed for each calculation. For these reasons a conflict exists between economy and accuracy of reliability calculations. This conflict is expected to be resolved by selecting an appropriate technique which samples randomly among the input parameters of the model.

The review should insure that the chosen random sampling technique correctly selects parameters values which reflect the original probability distributions, and that any pair of independent parameters are indeed uncorrelated when selected in small samples. Conversely, in a reliability calculation, total lack of correlation between all parameters may not actually represent the real situation. For example, in the cases of the thermal conductivity and the specific heat of the host rock, there may not be a firm functional dependence between them, but they may not be really independent either. Thus, the chosen random sampling technique should have the capability of treating correlation between random variables when needed.

The technique used for the sample calculation of Appendix A is known in the literature as the ''Latin Hypercube Sampling Plan'' (SAND-79-1473; 1980), which produces samples of random variables with rather uniform coverage and controlled correlation. Other sampling techniques may be acceptable as well, provided proper justification be given with reference to the open scientific literature, or, if originally developed, by providing analyses of actual tests runs.

3.2.4 Algorithms and Computer Programs

The basic criterion for acceptance of results obtained through the use of algorithms and computer programs shall be independent reproducibility of computed results by a qualified practitioner and disclosure of the method, computer program listings, and details of computation in sufficient detail to allow a completely independent analysis, unless an alternative fully documented computational method exists in the public domain capable with the same data to reproduce the results within the necessary accuracy. This exception serves to protect proprietary methods that may have advantages of speed, accuracy or cost.

APPENDIX A

RELIABILITY ANALYSIS ILLUSTRATION

A.1 INTRODUCTION

To serve as an illustration of the techniques to be used for realiability analysis calculations, one of the waste package designs described in the Site Characterization Report for the Basalt Waste Isolation Project (DOE/RL82-3) was selected for analysis. This design, henceforth called Sample Design, involves borosilicate glass, a carbon steel canister and a basalt-bentonite packing in horizontal emplacement holes.

Techniques to factor in expert opinion in defining models uncertainty and overall confidence levels are not shown in this illustration.

This illustration does not attempt to produce a complete analysis but only to show for a few components how the probability of failure is derived. The use of simplified descriptive models is illustrated by the thermal and transport models. Similarly, the development of a predictive equation is illustrated in the case of the corrosion model, where techniques are shown that could be used to justify the model, if appropriate data were available.

A.2 FAILURE MODE AND EFFECTS ANALYSIS

For the purpose of this illustration, and without a judgement as to the probability of other failure modes, the only design failure modes of the Sample Design package to be considered are (a) pitting corrosion of the metal canister followed by (b) leaching of the glass and (c) transport of radioisotopes through the packing material. It is further assumed that the packing material is saturated with water and that the chemical composition of the water saturating the packing material is not modified by the effects of ionizing radiation.

A.3 QUANTITATIVE RELIABILITY ANALYSIS

In order to perform a quantitative reliability analysis of the waste package sample design, a stochastic process is set up whereby a waste package is chosen at random from an infinite population, representing state-of-the art knowledge about waste packages material parameters, and it is emplaced at random within the saturated repository, the fate of the waste package being later determined by the performance model.

In accordance with the simplified FMEA of Section A.2, the adopted performance model consists of a temperature model, a canister corrosion model, and a combined leaching and radioisotope migration model. In general, the canister corrosion, leaching and migration models should be interrelated to a water-chemistry model which in turn should receive inputs from the temperature and ionizing radiation models. A water-chemistry model is not available at this time, therefore the water chemistry is treated as a set of inputs (with appropriate uncertainty ranges). An ionizing radiation model is not included since its output cannot be used meaningfully. The various component models are individually obtained as follows.

A.3.1 Package Temperature Model

In this illustration, the package temperature model serves essentially to predict canister temperature as a function of time, as temperature constitutes an important input to the corrosion model.

Clearly, a rigorous calculation using one of the three dimensional heat conduction codes such as HEATING6 (ORNL-NUREG-CSD-2; 1982) would be appropriate for accurate calculation of temperatures. However, performing one run of HEATING6 is in itself a substantial computer effort which precludes its use in a performance model to be used in a Monte Carlo simulation.

In order to derive a simplified model, the three-dimensional heat conduction problem is reduced to two coupled one-dimensional cases encompassing a far field effect and a near field effect. With reference to Fig. A.3.1, the far field of the repository is defined as that portion of the geologic formation where the details of the spatial distribution of the heat sources (waste packages) is unimportant for temperature profiles calculations. The area between the far field and the repository center line is termed the near field.

Heat diffusion in the far field is assumed to take place by conduction, and the temperature profile away from the near field can be obtained as a function of time by assuming instantaneous transfer of heat across the near

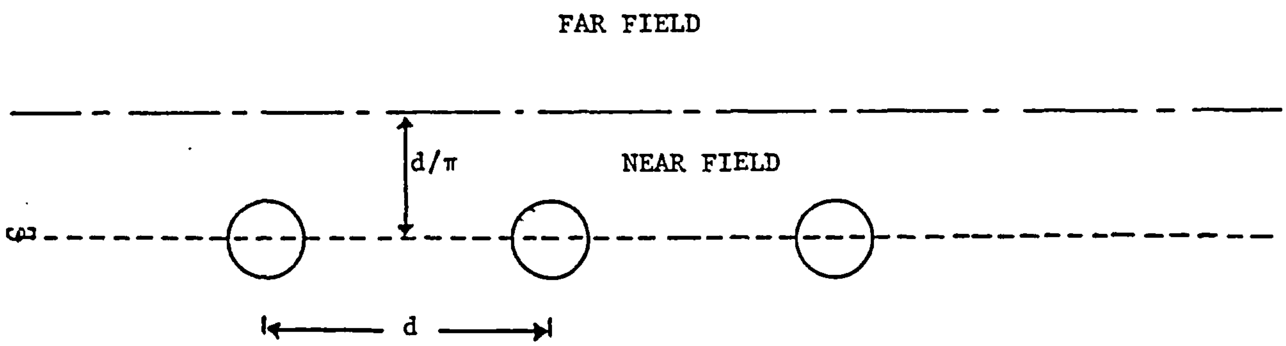

Figure A.3-1

field to the lower boundary of the far field. This overestimates the temperature profile away from the source, but it is an increasingly accurate estimate as time goes by. In particular, as it is shown in Appendix C, the temperature at the near-field/far-field interface is given as:

$$T_F(t) = \frac{1}{K}\left(\frac{k}{\pi}\right)^{1/2} \sum_{i=1}^{n} \frac{a_i}{\lambda_i} \Delta(\sqrt{\lambda_i}t) + T_o \qquad (A.3\text{-}1)$$

where k and K represent the thermal diffusivity and conductivity in the far field, respectively; a_i, λ_i empirical coefficients in the expression for the decay heat per unit area when this is fitted to an expression of the form:

$$f(t) = \sum_{i=1}^{n} a_i \exp(-\lambda_i t); \qquad (A.3\text{-}2)$$

$\Delta(x)$ is the Dawson's integral defined as follows:

$$\Delta(x) = \exp(-x^2) \cdot \int_0^x \exp(+t^2)\, dt \; ; \qquad (A.3\text{-}3)$$

and T_o is the geothermal, background temperature before emplacement of the waste.

According to the hypothesis of instantaneous heat transfer in the near field, heat conduction in the near rocks is treated as a sequence of steady state states characterized by a temperature drop across the near field:

$$\Delta T = T_N - T_F \qquad (A.3\text{-}4)$$

where T_F is given by Eq. (A.3-1). An expression for this ''steady state'' temperature drop can be obtained by considering conduction through concentric cylinders representing the waste package plus a suitable portion of the host rock. In particular, the radius, R, of the outermost cylinder is related to the distance, d, between emplacement holes through the expression:

$$R = d/\pi. \qquad (A.3\text{-}5)$$

Equation (A.3-5) is obtained by assuming the outer surface area of the cylindric shells to be equal to the floor area of the repository. Thus, the temperature at the repository floor is:

$$T_N = T_F(t) + \Delta T \tag{A.3-6}$$

where ΔT is obtained by a proper application of the formula

$$\Delta T = \frac{P}{2\pi KL} \ \ln\ (D_2/D_1) \tag{A.3-7}$$

representing the steady-state temperature drop between two concentrical cylindrical shells of diameter D_1 and D_2 respectively.

Validation of this model is discussed in Appendix C.

A.3.2 Canister Corrosion Model

As indicated by the simple FMEA analysis of Section A.2, the only design failure mode considered for the waste form canister is pitting corrosion. Other failure modes could be analyzed as well through the techniques presented in this section.

The model to be developed for this illustration assumes that pitting corrosion differs from uniform corrosion through a multiplicative pitting corrosion factor. Thus, uniform corrosion data are analyzed first, and fitted to a predictive equation dependent on a small number of parameters, whose significance to the corrosion process is statistically calculated. Furthermore, uncertainty of the prediction is taken into account through a multiplicative factor derived from statistical considerations about the internal consistency of the data. Both the model uncertainty factor and the model parameters are viewed as random variables with appropriate ranges of uncertainty and distributions.

A.3.2.1 Reference Data Base

In order to formulate a predictive equation for the corrosion rate on empirical grounds, a reference experimental data base should be used which covers the spectrum of conditions expected in the repository during the period of interest. In other words, the population sampled by the experimental data should fairly reflect the population of conditions for which the prediction is needed. Such a data base is not available at present.

For the purposes of illustration, reference is made here to the collection of data used by Westinghouse in AESD-TME-3113 for steel. These data have been assembled in a consistent form in Table A.3-1. In this table, originally reported uniform corrosion rates have been converted to uniform corrosion depth by multiplying by the duration of the experiment, which is also recorded. Data originally reported as ''Average Corrosion Rate'' have been interpreted as uniform corrosion rate. When the results were described as corresponding to oxic or anoxic conditions without specifying the oxygen content, oxygen concentration values of .1 and 3 ppm have been assumed respectively. For brine and seawater, the chlorine ion concentration has been assumed to be 200,000 and 20,000 ppm respectively. All the steel compositions and water chemistries have been lumped together into a single population for the purposes of the forthcoming analysis. Thus, Table A.3-1 constitutes a data base of 55 cases spanning a broad spectrum of temperatures and chlorine and oxygen concentrations. The data base has many shortcomings, of which the most important are want of long term cases and inhomogeneity of the sample. In addition, a substantial correlation exists in these data. For example, all of the long term cases were observed in low temperature oxic conditions at the Gatun Lake in fresh water.

A.3.2.2 Uniform Corrosion

The selected mathematical form of the expression for the depth of uniform corrosion is

$$U_C = K \cdot \exp\left(\frac{a}{T}\right) \; O^{b} \cdot Cl^{c} \cdot t^{n} \qquad \text{(A.3-8)}$$

Table A.3-1

Steel Corrosion Data Base

Material	Temp °C	Chlorine ppm	Oxygen ppm	Unit Corrosion mm	Pitting Corrosion mm	Time years
1018Steel	250	200000	.1	.14	NA	.083
1018Steel	250	20000	.1	.034	NA	.083
1018Steel	250	200000	3.	.59	NA	.083
1018Steel	250	20000	3.	.91	NA	.083
1018Steel	70	200000	.1	.0058	NA	.083
1018Steel	25	200000	.1	.0025	NA	.083
27C Steel	25	20000	3.	.19	NA	1.
Cast Iron	250	200000	.1	.106	NA	.083
Cast Iron	250	200000	.1	.148	NA	.083
Gray Cast	25	20000	3.	.25	NA	1.
Cast I,80-7	250	50	1.	.0019	NA	.083
Cast I,80-7	250	50	1.	.0021	NA	.083
Cast I,22-8	250	50	1.	.0163	NA	.083
Cast I,22-8	250	50	1.	.0022	NA	.083
Cast I,142-12	250	50	1.	.0009	NA	.083
Cast I,142-12	250	50	1.	.0024	NA	.083
Cast I,166-3	250	50	1.	.0008	NA	.083
Cast I,166-3	250	50	1.	.0020	NA	.083
Cast I,136-04	250	50	1.	.0019	NA	.083
Cast I,136-04	250	50	1.	.0025	NA	.083
Steel A570	250	6000	.01	.0254	NA	.083
Steel A53B	250	6000	.01	.0232	NA	.083
Steel C75	250	6000	.01	.0191	NA	.083
Steel 1010	250	6000	.01	.0297	NA	.083
Steel CortemA	250	18980	.03	.0169	NA	.083

Table A.3-1 (Cont'd.)

Steel Corrosion Data Base

Material	Temp °C	Chlorine ppm	Oxygen ppm	Unit Corrosion mm	Pitting Corrosion mm	Time years
Steel 1080	250	18980	.03	.0338	NA	.083
Steel A570	250	30000	.01	.0741	NA	.083
Steel A53B	250	30000	.01	.0508	NA	.083
Steel C75	250	30000	.01	.0338	NA	.083
Steel 1010	250	30000	.01	.0804	NA	.083
Steel A570	250	60000	.01	.0908	NA	.083
Steel A53B	250	60000	.01	.0761	NA	.083
Steel C75	250	60000	.01	.0148	NA	.083
Steel 1010	250	60000	.01	.0866	NA	.083
Steel A570	250	120000	.01	.2325	NA	.083
Steel A53B	250	120000	.01	.2308	NA	.083
Steel A53B	250	120000	.01	.2650	NA	.083
Steel C75	250	120000	.01	.1691	NA	.083
Steel 1010	250	120000	.01	.2875	NA	.083
Steel CortenA	250	145833	.03	.0042	NA	.083
Steel 1018	250	145833	.03	.0063	NA	.083
Steel CortenA	250	159416	.03	.0741	NA	.083
Steel 1018	250	159416	.03	.1417	NA	.083
Cast Iron 22-8	250	159416	1.0	.1058	NA	.083
Cast Iron 22-8	250	159416	1.0	.1483	NA	.083
Cast Steel 27C	25	70	3.0	.21	.76	1.00
Cast Steel 27C	25	70	3.0	.30	NA	2.00
Cast Steel 27C	25	70	3.0	.36	NA	4.00
Cast Steel 27C	25	70	3.0	.48	1.70	8.00
Cast Steel 27C	25	70	3.0	.66	2.49	16.00
Gray Iron 3.2	25	70	3.0	.18	1.32	1.00
Gray Iron 3.2	25	70	3.0	.30	NA	2.00
Gray Iron 3.2	25	70	3.0	.38	NA	4.00
Gray Iron 3.2	25	70	3.0	.58	2.69	8.00
Gray Iron 3.2	25	70	3.0	.84	2.74	16.00

Note: NA - not available.

where

U_C = Uniform Corrosion Depth [mm]
T = Absolute Temperature [K]
O = Oxygen Concentration [ppm]
Cl = Chlorine Concentration [ppm]
t = Time [years]
K = Uniform corrosion factor

For the purpose of data fitting, Eq. (A.3-8) is first linearized through a logarithmic transformation, using the natural log, and by using an inverse transformation on the absolute temperature. Then, in order to make sure that the chosen variables in Eq. (A.3-8) are indeed independent of each other, a Pearson correlation matrix is computed between the transformed variables in terms of the reference data base. The correlation matrix is reported in Table A.3-2.

Table A.3-2

	INVTEMP	LCHLOR	LOXYG	LUCORR	LTIME
INVTEMP	1.0000	.1582	.2808	.0145	.7447
LCHLOR	.1582	1.0000	-.5221	.7314	.0368
LOXIG	.2808	-.5221	1.0000	-.2724	.3525
LUCORR	.0145	.7314	-.2724	1.0000	.2265
LTIME	.7447	.0368	.3525	.2265	1.0000

A substantial correlation exists between time and temperature, reflecting the fact that all of the data for long times corresponds to 25°C temperatures. The correlation between oxygen and chlorine levels is also substantial.

In order to illustrate the effect of the strong correlations between some of the variables in Eq. (A.3-8), a multivariate regression of the transformed data has been performed using the program REGRESSION of the Statistic Package for the Social Sciences (SPSS), a general purpose collection of statistical programs. The results of the regression are presented in Table A.3-3.

Table A.3-3

Variable	Regression Coeff.	Standard Error
Ln (Time)	1.658	.223
Ln (Oxygen)	.114	.101
(1/Temp)	-1625	.557
Ln (Chlorine)	.466	.0646
Intercept	.764	.863

The effects of correlation between the data leads to a power of time equal to 1.658 which implies an accelerating rate of corrosion with time. A result which is contrary to experience. Thus, even if, as a fit of the data, the regression reduces the variance to 37% of the original, it leads to misleading results as a method of extrapolating corrosion to longer times.

In an effort to reduce the effects of correlation among the data, the last 10 data, representing long term experiments, are separated and the two groups of data are analyzed independently. Since the data of this second subset of 10 points contains only time, uniform corrosion and pitting corrosion as variables, it is used to derive the time dependence. The results of a regression between logarithm of uniform corrosion and logarithm of time gives a coefficient of regression of 0.4689 with a standard error of .0339. If the normality assumption is made such that the .001 quantile corresponds to 3.09 standard deviations, the range can be estimated as 0.4689 $\pm$.1047=.3639 to .5736. This estimate of the range of the exponent of time is based on corrosion of steel and gray iron in fresh water at 25°C in the Gatun Lake and it does not necessarily represent the uncertainties of applicability of the data to repository conditions. However, to proceed with the illustration, that range is adopted.

Once the time dependence is obtained, the fit of the data for the other coefficients is continued by considering the new transformed dependent variable defined as

$$LL = Ln\ (U_c) - .4689\ Ln\ (t) \qquad (A.3\text{-}9)$$

The Pearson correlation matrix for the first group data is given in Table A.3-4. The strong correlation between the oxygen and chlorine is expected to affect the results. Table A.3-4 shows that temperature is very weakly correlated with the new dependent variable, LL, and hence with the depth of uniform corrosion.

Table A.3-4

	INVTEMP	LCHLOR	LOXYG	LL
INVTEMP	1.0000	.1582	.2808	-.0822
LCHLOR	.1582	1.0000	-.5221	.7423
LOXYG	.2808	-.5221	1.0000	-.3242
LL	-.0822	.7423	-.3242	1.0000

A regression of LL against the inverse of the temperature and the logarithms of the oxygen and chlorine is shown in Table A.3-5.

Table A.3-5

Variable	Regression Coeff.	Standard Error
Ln (chlorine)	.543	.072
Ln (oxygen)	.200	.107
(1/Temp)	-1402	517
intercept	-4.148	1.074

From this analysis of the data, the following predictive equation is derived:

$$U_C = e^{-4.148}\ t^{0.469}\ e^{-\frac{1402}{T}}\ Cl^{0.543} O^{0.2}$$

$$= 0.0158\ t^{0.469}\ e^{-\frac{1402}{T}}\ Cl^{0.543} O^{0.2} \qquad \text{(A.3-10)}$$

Since the independent variables are dimensional numbers which may take large values and the exponents have been truncated, the errors introduced by the truncation are compensated by adjusting the uniform corrosion factor to reduce to zero the mean of the logarithm of the residuals. The resulting predictive equation is

$$U_C = 0.03725\ t^{0.469}\ e^{-\frac{1402}{T}}\ Cl^{0.543}\ O^{0.2} \qquad \text{(A.3-11)}$$

A.3.2.3 Statistical Uncertainty of the Model

In order to test Eq. (A.3-11) against the original data and calculate the uncertainty of the model, the residuals of the fit of Eq. (A.3-11) to the data are computed and analyzed. To accomodate the wide range of the data, the residuals are taken as the difference between the natural logarithm of the observed uniform penetration depth minus the natural logarithm of the predicted penetration depth. Ultimately this will yield a multiplicative adjustment factor representing the uncertainty of Eq. (A.3-11) in reproducing the actual data. The statistical techniques used hereafter can be found in standard textbooks such as References 14 and 15.

Table A.3-6 shows the case number, the material identifier, the natural logarithm of the uniform corrosion depth observed, the natural logarithm of the predicted uniform corrosion depth and the difference or residual between the logarithms of the observed and predicted uniform penetration depths. Inspection of the residuals shows that the cases 46 to 55 which correspond to the data taken in the Gatun Lake are highly underpredicted. In general, when data from different sources are grouped together, as is done in this illustration, the homogeneity of the resulting sample should be tested by an analysis of variance of the residuals. In this case, the difference is such that simple inspection shows that the Gatun Lake data is different from the rest.

In order to show the distribution of the residuals, the cumulative distribution of residuals is plotted on normal probability paper to test for normality. Figure A.3-2 shows the plot of the normalized residuals to the calculated standard deviation of 2.109. The diagonal line represents a perfect normal distribution, and the plot of an empirical distribution from a sample from a normally distributed population is expected to show a random scatter about this line. The larger the sample, the less scatter the points will have.

In the plot, one can clearly identify the group of the Gatun Lake data at about +1.8 standard deviations. The data shows systematic trends for the non Gatun Lake data which comes from the known lack of homogeneity of the data.

Table A.3-6
TABLE OF RESIDUALS

CASE	MATERIAL	LOG U.CORR	LOG P.U.CORR	DIFFERENCE
1	1018Steel	-1.96611	-0.97071	-0.99540
2	1018Steel	-3.38140	-2.22102	-1.16038
3	1018Steel	-0.52763	-0.29047	-0.23716
4	1018Steel	-0.09431	-1.54078	1.44647
5	1018Steel	-5.14990	-2.37749	-2.77241
6	1018Steel	-5.99147	-2.99472	-2.99674
7	27C Steel	-1.66073	-2.39749	0.73675
8	Cast Iron	-2.24432	-0.97071	-1.27360
9	Cast Iron	-1.91054	-0.97071	-0.93983
10	Gray Cast	-1.38629	-2.39749	1.01119
11	CastI 80-7	-6.26590	-5.01386	-1.25204
12	CastI 80-7	-6.16582	-5.01386	-1.15195
13	CastI 22-8	-4.11659	-5.01386	0.89727
14	CastI 22-8	-6.11930	-5.01386	-1.10543
15	CastI 142-12	-7.01312	-5.01386	-1.99925
16	CastI 142-12	-6.03229	-5.01386	-1.01842
17	CastI 166-3	-7.13090	-5.01386	-2.11703
18	CastI 166-3	-6.21461	-5.01386	-1.20074
19	CastI 136-04	-6.26590	-5.01386	-1.25204
20	CastI 136-04	-5.99147	-5.01386	-0.97760
21	Steel A570	-3.67301	-3.33529	-0.33772
22	Steel A53B	-3.76360	-3.33529	-0.42831
23	Steel C75	-3.95807	-3.33529	-0.62278
24	Steel 1010	-3.51661	-3.33529	-0.18132
25	Steel CortemA	-4.08044	-2.49024	-1.59021
26	Steel 1080	-3.38730	-2.49024	-0.89706
27	Steel A570	-2.60234	-2.46137	-0.14097
28	Steel A53B	-2.97986	-2.46137	-0.51849
29	Steel C75	-3.38730	-2.46137	-0.92593
30	Steel 1010	-2.52074	-2.46137	-0.05938
31	Steel A570	-2.39910	-2.08499	-0.31411
32	Steel A53B	-2.57571	-2.08499	-0.49072
33	Steel C75	-4.21313	-2.08499	-2.12814
34	Steel 1010	-2.44646	-2.08499	-0.36147
35	Steel A570	-1.45887	-1.70861	0.24974
36	Steel A53B	-1.46620	-1.70861	0.24240
37	Steel A53B	-1.32803	-1.70861	0.38058
38	Steel C75	-1.77727	-1.70861	-0.06866
39	Steel 010	-1.24653	-1.70861	0.46208
40	Steel CortemA	-5.47267	-1.38302	-4.08965
41	Steel 1018	-5.06721	-1.38302	-3.68419
42	Steel CortemA	-2.60234	-1.33466	-1.26768
43	Steel 1018	-1.95404	-1.33466	-0.61938
44	Cast Iron 22-8	-2.24621	-0.63335	-1.61286
45	Cast Iron 22-8	-1.90852	-0.63335	-1.27517
46	Cast Steel 27C	-1.56065	-5.46815	3.90750
47	Cast Steel 27C	-1.20397	-5.14306	3.93909
48	Cast Steel 27C	-1.02165	-4.81797	3.79632
49	Cast Steel 27C	-0.73397	-4.49289	3.75892
50	Cast Steel 27C	-0.41552	-4.16780	3.75229
51	Gray Iron 3.2	-1.71480	-5.46815	3.75335
52	Gray Iron 3.2	-1.20397	-5.14306	3.93909
53	Gray Iron 3.2	-0.96758	-4.81797	3.85039
54	Gray Iron 3.2	-0.54473	-4.49289	3.94816
55	Gray Iron 3.2	-0.17435	-4.16780	3.99345

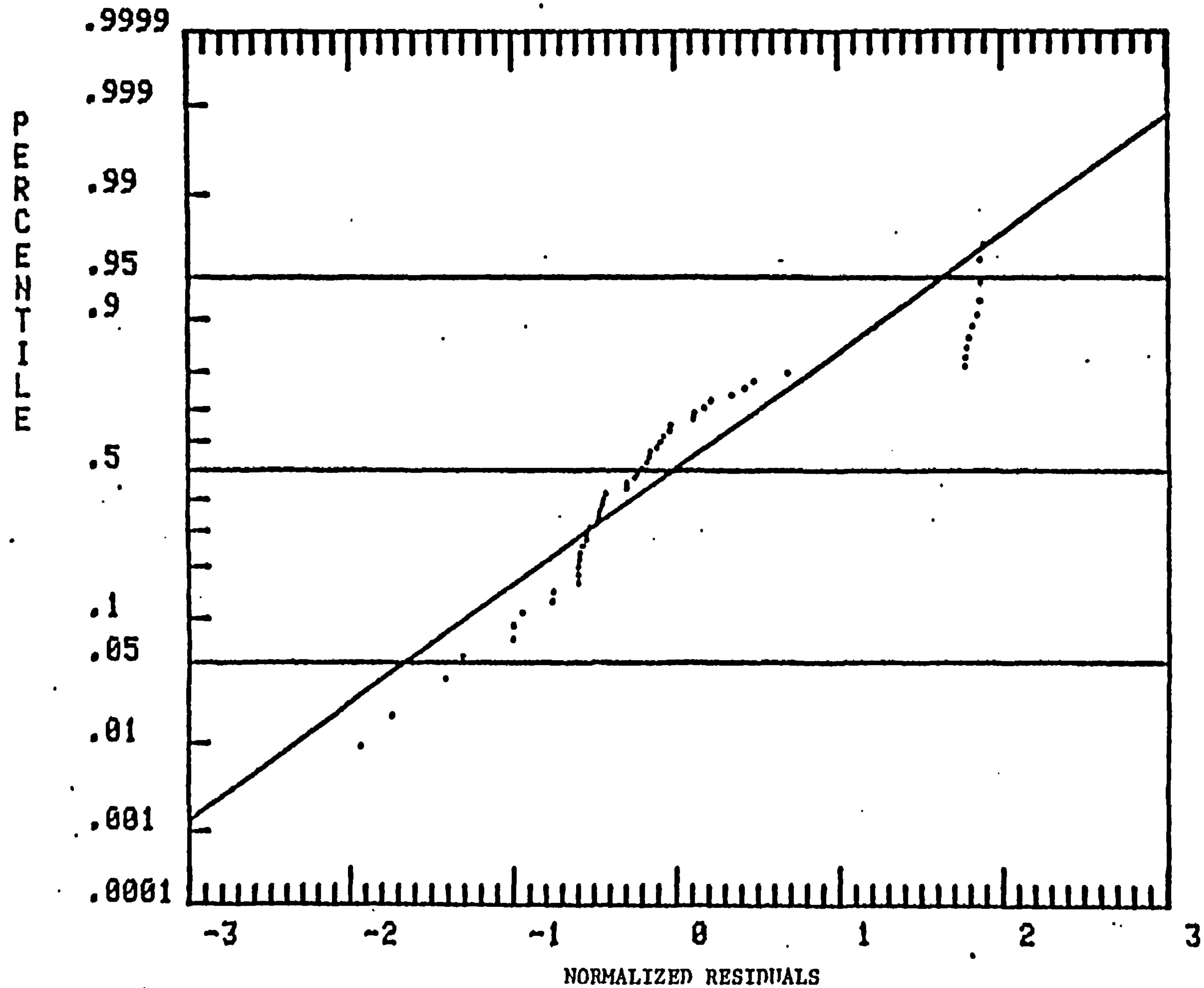

Figure A. 3-2 Cumulative Distribution of Residuals.

To continue with the illustration, and disregarding the evidence of the normal probability paper plot, the data are tested for the hypothesis that the distribution of residuals is normal. For this test, the empirical cumulative probability distribution is computed and it is compared with the assumed cumulative distribution. The statistic used is the analog of the Kolmogorov-Smirnov test as described by Lilliefords. In this test, the empirical cumulative distribution, in this case normalized, is compared with the assumed distribution in the hypothesis testing, and the maximum of the absolute vertical difference is recorded as the statistic. Table A.3-7 shows the results of intermediate steps of the Kolmogorov-Smirnov test. The residuals are normalized to standard deviation one and sorted in increasing order. The first column shows the case number in the data base to which the point corresponds. The second column shows the normalized residual. The third column shows the empirical cumulative probability values. The values at both ends are adjusted to the average of the corresponding two extreme values to avoid the problem of probability zero or one. The last column is the quantile of the normal probability distribution which correspond to the argument in the second column. For example, on the row corresponding to case #7, the residual is positive and equal to .34 standard deviations and 76% of the cases have smaller (in the algebraic sense) values. A normal distribution would have 64% of the cases below .34 standard deviations. The maximum absolute value of the difference corresponds to case 30 and is equal to .1839 which is the statistic of interest. This statistic can not be interpreted on the basis of the tables of critical values for the classical Kolmogorov-Smirnov statistic because the parameters of the assumed distribution are determined from the sample itself. The critical values determined by numerical calculation by Lilliefords should be used. For 99% confidence level, the critical value given is

$$\frac{1.031}{\sqrt{n}}$$

Since the sample size n is 55, the critical value is 0.1458, therefore we must reject the hypothesis of normality. The test can be interpreted as indicating that the chance of a sample of 55 cases from a normal distribution giving a deviation larger than .1458 is less than 1%. However, to continue with the illustration, the assumption will be made that the residuals are distributed normally with zero mean and standard deviation equal to 2.109.

Table A3-7
KOLMOGOROV-SMIRNOV TEST

CASE#	RESIDUAL	PROBABILITY EMPIRICAL	PROBABILITY ASSUMED
40	-1.93910	0.02727	0.02625
41	-1.74685	0.03636	0.04033
6	-1.42090	0.05455	0.07767
5	-1.31453	0.07273	0.09432
33	-1.00906	0.09091	0.15647
17	-1.00379	0.10909	0.15773
15	-0.94794	0.12727	0.17157
44	-0.76474	0.14545	0.22222
25	-0.75400	0.16364	0.22543
45	-0.60462	0.18182	0.27272
8	-0.60388	0.20000	0.27297
42	-0.60107	0.21818	0.27391
11	-0.59366	0.23636	0.27638
19	-0.59366	0.25455	0.27638
18	-0.56933	0.27273	0.28458
2	-0.55020	0.29091	0.29110
12	-0.54620	0.30909	0.29247
14	-0.52414	0.32727	0.30010
16	-0.48289	0.34545	0.31460
1	-0.47197	0.36364	0.31848
20	-0.46353	0.38182	0.32150
9	-0.44562	0.40000	0.32794
29	-0.43903	0.41818	0.33033
26	-0.42534	0.43636	0.33530
23	-0.29529	0.45455	0.38389
43	-0.29368	0.47273	0.38450
28	-0.24585	0.49091	0.40290
32	-0.23268	0.50909	0.40800
22	-0.20309	0.52727	0.41953
34	-0.17140	0.54545	0.43195
21	-0.16013	0.56364	0.43638
31	-0.14894	0.58182	0.44079
3	-0.11246	0.60000	0.45522
24	-0.08598	0.61818	0.46573
27	-0.06685	0.63636	0.47334
38	-0.03256	0.65455	0.48701
30	-0.02816	0.67273	0.48876
36	0.11493	0.69091	0.54576
35	0.11841	0.70909	0.54714
37	0.18044	0.72727	0.57161
39	0.21908	0.74545	0.58671
7	0.34932	0.76364	0.63657
13	0.42543	0.78182	0.66473
10	0.47945	0.80000	0.68418
4	0.68583	0.81818	0.75358
50	1.77912	0.83636	0.96239
51	1.77963	0.85455	0.96243
49	1.78227	0.87273	0.96264
48	1.80000	0.89091	0.96407
53	1.82564	0.90909	0.96604
46	1.85272	0.92727	0.96803
47	1.86769	0.94545	0.96909
52	1.86769	0.96364	0.96909
54	1.87200	0.98182	0.96939
55	1.89347	0.99091	0.97085

Kolmogorov-Smirnov Statistic = .183965 Case # = 30

The uncertainty in the prediction of uniform corrosion depth derived from internal consistency of the sample can be represented by a factor which is (on the basis of the above assumption) log-normally distributed. Since the natural logarithm of this factor has an estimated standard deviation of 2.109 the quantiles for .001 and .999 can be obtained from the table of quantiles of the normal distribution as

$$\exp(-2.109 \times 3.09) \text{ and } \exp(2.109 \times 3.09)$$

or

$$.00147 \text{ to } 676$$

The resulting predictive equation for uniform corrosion is then

$$U_C = 0.03725\ t^{0.469}\ e^{-\frac{1402}{T}}\ Cl^{0.543} O^{0.2}\ \varepsilon \qquad \text{(A.3-12)}$$

where ε is a random variable lognormally distributed with (0.001,0.999) range of (0.00147 to 676).

A.3.2.4 Pitting Corrosion Factor

If data are available which cover the range of conditions to be expected in the application, the ratio between the depth of penetration of pits to the depth of uniform corrosion can be determined from a regression on the data. If the quality of the data available warrants it, the distribution of the depth of pitting should be corrected by the use of extreme value theory.

The only sample data used for this illustration are those of the Gatun Lake, which does not cover anoxic, high chlorine or high temperature conditions. However, for the sake of illustration, a regression of the pit depth vs. uniform corrosion is made. The resulting regression coefficient result is 2.89 at a significance level of .53% and has 95% confidence limits of 1.12 and 4.67.

In order to assign a distribution to the ratio of pitting penetration to uniform corrosion depth in the standard format adopted in this methodology, as a range coresponding to the .001 and .999 quantiles, the assumption is made that the distribution is normal and therefore the 95% limits correspond to 1.96 sigma, at a 3.09 sigma level the range is:

$$2.89 + (4.67 - 2.89)\ \frac{3.09}{1.96} = 5.69$$

$$2.89 - (4.67 - 2.89)\ \frac{3.09}{1.96} = 0.09$$

Physically, the ratio of pitting to uniform penetration can not be less than one. Due to the lack of data to assign probabilities of the order of .001 given that the sample has 6 points, and to continue with the illustration, the pitting factor is assumed to be uniformly distributed between 1 and 6.

A.3.2.5 Pitting Corrosion Model

From the above analysis, the pitting corrosion model can be based on the uniform corrosion model through a pitting corrosion factor, yielding:

$$P_c = K_p \cdot 0.03725\ t^{0.469}\ \exp\left(-\frac{1402}{T}\right)\ Cl^{0.543} O^{0.2}\ \varepsilon \qquad \text{(A.3-13)}$$

where

P_c = Pitting Corrosion Depth [mm]

K_p = Pitting Corrosion factor, uniform distribution (1 to 6)

This model would serve for prediction over the range of times covered by the data. However, the model is to be used for extrapolation to longer times, and the effect of the uncertainty of the exponent of time factor for times of the order of 1000 years needs to be accounted. Therefore, since the range of the exponent of time has been estimated as (0.3639 to 0.5736) in the final model, the exponent of the time is taken as a random number with normal distribution and that range.

A.3.2.6 Rate Model for Pitting Corrosion

The rate of pitting corrosion can be obtained upon deriving Eq. (A.3-13) with respect to time. In particular, by considerations of the previous sections the equation for the rate of pitting corrosion reads as:

$$R_p = K_p\ 0.0372\ n\ t^{n-1} \exp\left(-\frac{1402}{T}\right) Cl^{0.543} O^{0.2}\ \varepsilon \qquad \text{(A.3-14)}$$

where

R_p = Rate of Pitting Corrosion [mm/year]

K_p = Pitting factor, uniform (1,6)

n = Exponent of time, normal (0.3639, 0.5736)

ε = Statistical uncertainty in uniform corrosion, log. normal (.00147,676)

Equation (A.3-14) factors in the statistical uncertainty of the model. Based on consensus opinion of experts, the parameter ε could include in addition to the statistical uncertainty, which reflects the accuracy of the fit to the reference data, also the uncertainty resulting from the judged adequacy of the model to account for the detailed phenomena involved.

A.3.3 Leaching Model

General Considerations

Several reactions can occur between aqueous solutions and radioactive waste forms. The resulting, overall reaction is termed ''leaching.'' Leach rates, i.e., the rates at which radionuclides pass from the solid waste form into the contacting aqueous solution, constitute the source term to all radionuclide hydrogeological transport models.

Several parameters and factors have been found to influence leaching.[3] Existing information indicates that major aspects of the long-term leaching behavior will be waste-package design dependent. Indeed, the release of species from a solid to a liquid is controlled by mechanisms involving both solid and solution species. Thus, corrosion products from the canister, overpack materials properties, aging of the waste form, thermal loading, flow rate, etc., all may make major contributions in controlling the long-term leaching behavior. Little or no data exist regarding leaching of candidate nuclear waste forms in the presence of accurate chemical compositions reflecting site specific groundwaters <u>and</u> appropriate waste package materials. Therefore, a leach model has to be based on extrapolating leach rates from rather idealized experimental conditions to the actual repository.

A.3.3.1 Model Formulation

At present, of all major variables influencing leaching, temperature is the only one, with the exception of time, which can be predicted with some degree of confidence. This suggests formulating a leach model which accounts for time and temperature effects only. The influence of other major variables, e.g., groundwater chemistry, aging of the waste form, etc., is lumped in the uncertainties associated with the selected model parameters. If $L_0(t)$ denotes the radionuclide leach rate from the primary waste form, as it is extrapolated from short-term leaching experiments, a generic leaching model in terms of time - and temperature-dependent effects is expressible as follows:

$$L_0(t) = f(t,T), \tag{A.3-15}$$

where f(t,T) is a generic function as yet to be determined. The function f(t,T) has the following properties:

$$\frac{\partial f}{\partial t}\Big|_T \leq 0, \tag{A.3-16}$$

and

$$\frac{\partial f}{\partial T}\Big|_t \geq 0, \tag{A.3-17}$$

indicating, respectively, that leaching is not a self-accelerating process under the assumed radionuclide release scenario, and that leach rates increase monotonically with the temperature of the system.

For designs in which the packing material restricts water flow around a breached canister, a postulated source term represented by a near stagnant, saturated solution seems reasonable. The closest experimental condition to this situation is realized in leaching tests performed under low flow or static conditions within the temperature range expected to exist during the containment period. Low flow leach data for PNL 76-68 glass, the candidate nuclear waste form for commercial high-level waste, are available within the temperature range 25°C to 75°C only.[5] Thus, the only relevant data are those obtained by Westsik and Peters[6] under static conditions within the temperature range 25°C to 250°C in deionized water. These data are also interesting because they do not show approach to saturation in the temperature range 75°C to 250°C, and the resulting correlation expression for the leach rate:

$$L_o(t) = n(T)\ K(T)\ t^{n(T)-1} \qquad 0 < n(T) \leq 1 \qquad (A.3\text{-}18)$$

should not depend on the parameter SA/V, the solid surface area-to-solution volume ratio.

Eq. (A.3-18) has been used before for waste package analysis calculations,[7] and it constitutes the reference leaching model for the present analysis. In particular, the parameter K shows an Arrhenius dependence on temperature, while the parameter n is approximately constant over the range 50°C to 250°C.[6,7,8] Distributions and ranges of these parameters with respect to the data of Westsik and Peters are described in Ref. [7]. In actual repository conditions the parameter n may vary with time, reflecting the complex dependence of leaching on the physical and chemical properties of the waste package and groundwater system. Indeed, one expects n to be approximately zero for leaching under near-saturation conditions, and n ~ 1 far from saturation. Thus all uncertainty regarding the effect on leaching of the evolution of the waste package-groundwater system can be lumped into the parameter n.

For the undisturbed repository release scenario, one can propose the following adaptation of Eq. (A.3-18):

$$L_o(t) = n \cdot K(T(t{=}0)) \cdot t^{n-1}, \qquad 0 < n \leq 1, \qquad (A.3\text{-}19)$$

where the parameter n should be given a uniform distribution of values between n ~ 0 and n ~ 1, and the distribution of the parameter K reflects the initial spread of leaching rates with temperature. Equation (A.3-19) should be regarded as only a tenuous extrapolation of short-term leaching data from rather idealized systems to the actual repository. Better models and better data should be used as they become available. In particular, the new models should factor in the dependence of leaching on solubility limits.

A.3.4 Dispersion Model

A.3.4.1 General Considerations

The two primary mechanisms controlling the transport of radionuclides within the overpack materials are dispersion and convection of solubilized species within the aqueous phase. These mechanisms result in a radionuclide flux, $\underline{J}_g$, given by the expression:

$$\underline{J}g = - \underline{D}^* \varepsilon \underline{\nabla} C_w + \underline{u}^* \varepsilon C_w, \qquad \text{(A.3-20)}$$

where:

- D^* - dispersion tensor; [cm^2/yr],
- ε - effective porosity of the packing material,
- C_w - concentration of the given radionuclide in the aqueous phase; [cm^{-3}],
- $\underline{u}^*$ - effective pore water velocity; [cm/yr].

The migration of radioactive species within the packing materials is retarded by sorption-desorption reactions between the aqueous and solid phases, provided the kinetics of the sorption reaction are fast enough compared to radionuclides travel times. Conventionally, sorption-desorption reactions are modeled as instantaneous equilibrium reactions according to the ''linear equilibrium isotherm''[3]:

$$K_d = \frac{C_s}{C_w}, \qquad \text{(A.3-21)}$$

where:

- K_d - equilibrium constant or ''distribution factor''; [cm^3/g],
- C_s - local equilibrium concentration of radionuclides affixed to the solid phase; [g^{-1}],
- C_w - concentration of radionuclides in the aqueous phase; [cm^{-3}].

Adopting the above description of sorption-desorption reactions, the new expression for $\underline{J}$, the flux of species in the aqueous medium becomes:

$$\underline{J} = - D \underline{\nabla} C_w + \underline{u} C_w, \tag{A.3-22}$$

where:

$$D = D^* / R, \tag{A.3-23}$$

$$u = u^* / R, \tag{A.3-24}$$

and R is a dimensionless quantity, known as the ''retardation factor,'' which is defined as follows:

$$R = 1 + K_d \rho / \varepsilon , \tag{A.3-25}$$

with

ρ - bulk density of the solid phase; [g/cm^3].

Irreversible processes like radioactive decay and fixation of radionuclides into insoluble stable phases deplete the water of contaminants and reduce radionuclide migration altogether.

Taking both reversible sorption-desorption reactions and irreversible processes into consideration, conservation of aqueous species within the packing material demands that the radionuclide concentration in the aqueous phase is given by the equation:

$$\frac{\partial C_w}{\partial t} = - \underline{\nabla} \cdot \underline{J} - \lambda C_w - F(C_w, C_s), \tag{A.3-26}$$

where $\underline{J}$ is given by Eq. (A.3-22), and:

λ - radioactive decay constant; [yr^{-1}],

$F(C_w, C_s)$- equivalent rate of fixation of the given radionuclide into an insoluble stable phase; [$cm^{-3}.yr^{-1}$].

Expressions for the function $F(C_w, C_s)$ are not available. Therefore, precipitation into stable phases is not taken into account in this illustration. This leads to the following representation of the migration process:

$$\frac{\partial C_w}{\partial t} = - \underline{\nabla} \cdot \underline{J} - \lambda C_w \qquad \text{(A.3-27)}$$

Equation (A.3-27) predicts higher concentrations of radionuclides than Eq. (A.3-26). Equation (A.3-27) represents the classical dispersion equation of radionuclides in porous media,[10] and the reference equation for further development.

A.3.4.2 One-Dimensional Solution of the Dispersion Equation

In general, the dispersion equation, Eq. (A.3-27), requires a numerical solution, which makes parametric studies extremely expensive. It is common practice, therefore, to consider one-dimensional, linear restrictions[10,11,12] of Eq. (A.3-27). This is also based on the observation that studies of groundwater flow show that longitudinal convection and dispersion are generally greater than transverse, and that uncertainties in the input data do not warrant an overly precise description of the migration process. While these arguments are widely accepted, and a one-dimensional solution to Eq. (A.3-27) is indeed sought here, comparisons of one- and three-dimensional predictions should be thoroughly investigated, both in the linear and non-linear cases as better data become available.

With reference to Fig. A.3-2, consider the one-dimensional migration of radionuclides from the surface of the original waste form towards the host rock. Assuming plane geometry and a uniform groundwater flow field in the x direction, the one-dimensional, linear specialization of Eq. (A.3-27) reads:

$$\frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial x^2} - u \frac{\partial C}{\partial x} - \lambda C , \qquad \text{(A.3-28)}$$

where the subscript ''w'' has been dropped for simplicity. Equation (A.3-28) is accompanied with adequate initial and boundary conditions. If we set equal to zero the time at which the canister fails, and if no radionuclides are present initially in the half space $x > 0$, the initial condition is:

$$C\,(x,0) = 0, \; x > 0. \qquad \text{(A.3-29)}$$

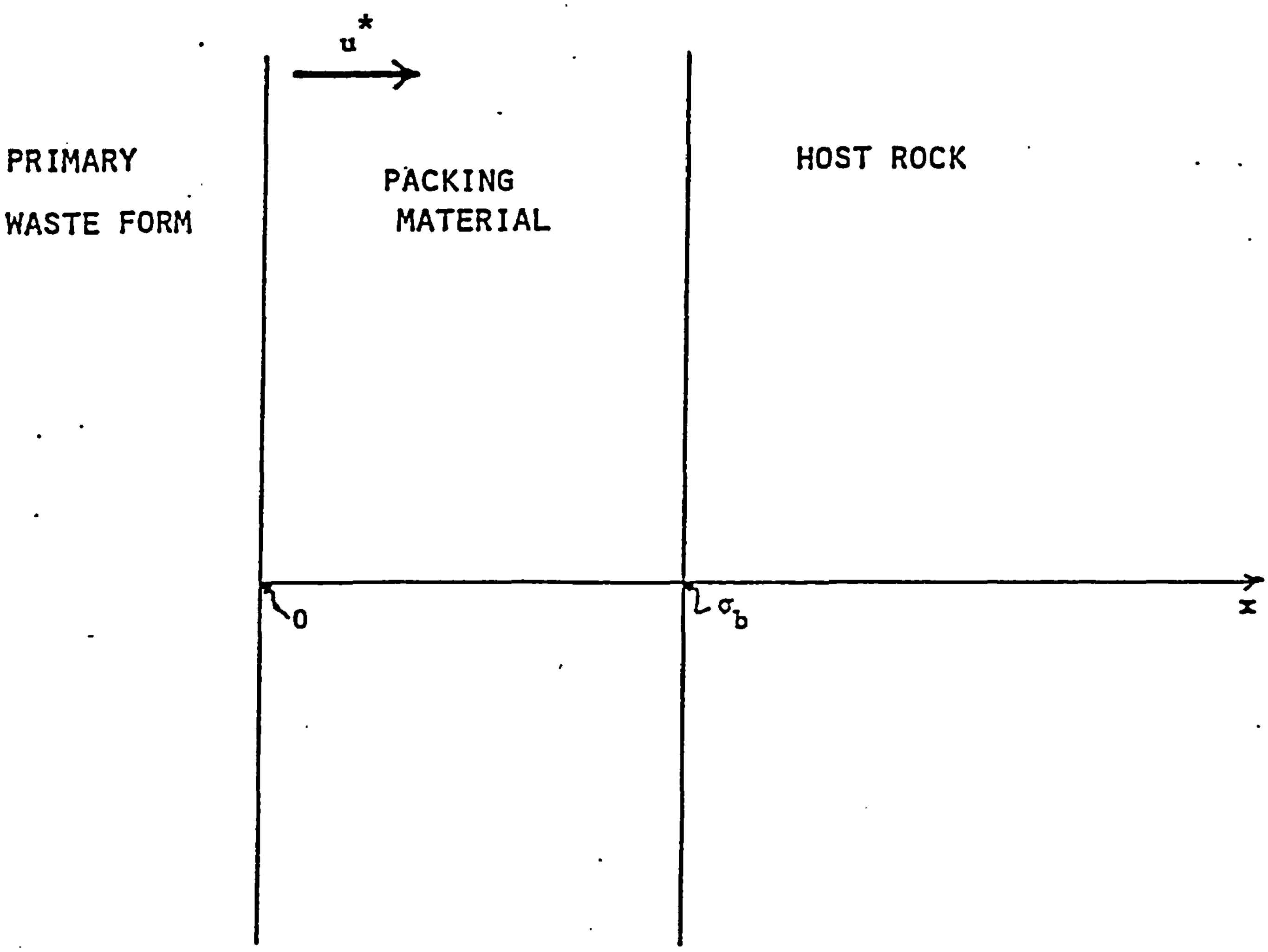

Figure A.3-3 Schematic Representation of the Waste Form - Packing Material - Host Rock System.

By continuity, the dispersion-convection flux at the waste form-packing material interface must be equal to the flux, L(t), due to leaching of radionuclides from the waste form. This yields the boundary condition:

$$- D\left(\frac{\partial C}{\partial x}\right)_{x=0} + uC(x=0,t) = L(t)/\varepsilon. \qquad (A.3-30)$$

In particular, if $L_o(t)$ denotes the leach rate of stable species per unit geometric surface area as it is extrapolated from short-term leaching experiments (Sect. A.3.3), one can account for radioactive decay processes taking place within the waste form by expressing the leach rate of each parent species as follows:

$$L(t) = e^{-\lambda(t+\tau)} L_o(t) \qquad (A.3-31)$$

where τ indicates the time needed for failure of the canister. Furthermore, cracking of the original waste form ''monolith'' increases the effective surface area for leaching of the waste form. This effect can be taken into account by multiplying the expression for $L_o(t)$ by an adequate coefficient f of value greater or equal one. Thus the overall expression for L(t) becomes:

$$L(t) = f\, e^{-\lambda(t+\tau)} L_o(t) , \qquad f \geq 1. \qquad (A.3-32)$$

Finally, far away from the waste form it must be:

$$C(+\infty,t) = 0. \qquad (A.3-33)$$

Assuming further that the host rock poses the same resistance to radionuclide migration as the packing materials, the initial and boundary value problem describing the migration of radionuclides away from the waste form becomes:

$$\frac{\partial C}{\partial t} = D\,\frac{\partial^2 C}{\partial x^2} - u\,\frac{\partial C}{\partial t} - \lambda C, \qquad x,t>0 \qquad (A.3-34)$$

$$C(x,0) = 0, \qquad x \geq 0 \qquad (A.3-35)$$

$$- D\,\frac{\partial C}{\partial x}\Big|_{x=0} + uC(x=0,t) = \frac{f}{\varepsilon}\, e^{-\lambda(t+\tau)} L_o(t), \qquad t \geq 0 \qquad (A.3-36)$$

$$C(+\infty,t) = 0 \qquad t \geq 0 \qquad (A.3-37)$$

Solution to the above system of equations is provided in Appendix B. The space- and time-dependent concentration of radionuclides within the aqueous phase is expressible as follows:

$$C(x,t) = \frac{f\, e^{-\lambda(t+\tau)}}{\varepsilon D} \int_0^t L_o(t-t')\, G(x,t')\, dt' \qquad \text{(A.3-38)}$$

where:

$$G(x,t) = \left(\frac{D}{\pi t}\right)^{1/2} \exp\left[-\frac{(x-ut)^2}{4Dt}\right] - \frac{u}{2} \exp\left(\frac{ux}{D}\right) \operatorname{erfc}\left(\frac{x+ut}{2\sqrt{Dt}}\right), \qquad \text{(A.3-39)}$$

and the function erfc(z) is the complementary error function.[13] The analogous expression for stable species is obtained by setting $\lambda=0$.

With reference to Eq. (A.3-38), if $u \neq 0$, the following asymptotic relation holds between the radionuclide concentration at a given point and the leach rate:

$$C(x,t) \sim \frac{f\, e^{-\lambda(t+\tau)} L_o(t)}{\varepsilon u} = \frac{L(t)}{\varepsilon u}, \quad x \ll ut \qquad \text{(A.3-40)}$$

If $u = 0$, and L_o is of the form suggested in Sect. A.3.3.1:

$$L_o(t) = nK\, t^{n-1}, \qquad 0 < n \leq 1, \qquad \text{(A.3-41)}$$

one has for large values of the time:

$$C(x,t) \sim \frac{f\, n\, K\, \Gamma(n)\, e^{-\lambda(t+\tau)}\, t^{n-1/2}}{\varepsilon \Gamma(n+1/2)\, D^{1/2}}, \quad x \ll (Dt)^{1/2} \qquad \text{(A.3-42)}$$

where $\Gamma(x)$ represents the gamma function.[13]

When coupled with an expression for $L_o(t)$ and an appropriate breakthrough criterion, Eq. (A.3-38) allows a first estimate of the time interval needed for failure of the packing material to contain the migrating radionuclides.

A.3.5 <u>A Criterion for Failure of the Packing Material During the Containment Period</u>

If the zero release rule during the first 300 to 1,000 years after decommissioning were to be interpreted literally, all dispersion models would predict an instantaneous failure of the packing material at the same time as the canister fails. Indeed, because of the parabolic nature of Eq. (A.3-27), any disturbance to the initial condition is predicted to be propagated at infinite velocity in the dispersing medium, and the initial pulse of radionuclides at time t = 0 would spread out instantaneously to the boundary of the medium. In the absence of a regulatory criterion to determine failure of the waste package to contain the stored radionuclides for 300 to 1,000 years after decommissioning of the repository, the following breakthrough criterion has been selected for the sake of illustration. Namely, with reference to Fig. A.3-2, failure is assumed to take place at a time t_f when the radionuclide release rate at the interface of the packing material with the host rock is greater than 10^{-8} parts per year of the inventory of the specific radionuclide in the waste package. Mathematically this is expressed as follows:

$$J \cdot \varepsilon / W > 10^{-8}, \qquad yr^{-1} \qquad \text{(A.3-43)}$$

where the quantity W indicates the total amount of material available for leaching per square centimeter of initial waste form surface.

A.3.6 <u>A Criterion for Failure of the Packing Material During the Controlled Release Period</u>

Following the containment period, waste package failure occurs, according to 10 CFR 60, when the radionuclides transfer rate from the waste package to the host rock is high enough to cause the engineered barrier system to release more than one part in one hundred thousands per year of the stored radionuclides assuming no release. For the purpose of illustration, and with reference to Fig. A.3-2, failure is conservatively assumed to take place at a time t_f when the radionuclides release rate at the interface of the packing material with the host rock is greater than 10^{-5} parts per year of the inventory of the specific radionuclide in the waste package assuming no release. Mathematically, this is expressed as follows:

$$\dot{J}\,\varepsilon/W > 10^{-5},\ \mathrm{yr}^{-1} \tag{A.3-44}$$

where the quantity W indicates the total amount of material available for leaching per unit area of initial waste form surface.

A.4 COMPUTER PROGRAM

A computer program incorporating the thermal, corrosion and leaching-transport models has been written for the repetitive computation of cases with inputs which vary according to the prescribed distributions. The program incorporates as a sub-progam the SANDIA program LHC which generates the sample of cases using a Latin Hypercube scheme. In the present implementation, any of the input parameters can be assigned a distribution type and ranges over which LHC will generate the values for the samples. A listing of the program, named WASTE, and a sample calculation are provided in a forthcoming BNL report.

A.5 RESULTS

Using the input values shown in Table A.5-1, the program was run for 476 cases.

Table A.5-2 shows a summary of the results. There were nine cases showing failure of the canister due to corrosion in less than 1000 years. All cases showed failure of containment for Technetium and one of the cases showed failure of containment for Plutonium. Failure to meet the controlled release criterion occurred in 10 cases.

From the results of 476 cases, the probability of failing the containment criterion is 2%. The probability of failing the controlled release criterion is also 2%. This does not mean that it is expected that 2% of the canisters in a repository constructed according to this design will fail, but means that there is a 2% chance that all the canisters will fail since the causes of the uncertainty are common to all canisters.

Inspection of the time to failure data shows that the failures tend to occur early, if they occur at all. This is due to the combined effect of the early high temperatures and of the decreasing rate of corrosion with time. The presence of the packing material appears to be beneficial for plutonium but shows no significant benefit for technetium. The dominant uncertainty in the time to failure is introduced by the uncertainty of the overall corrosion coefficient.

Table A.5-1
INPUT DATA

Canister Temperature Input Data

I	Decay Constants (1/year)	Fractional Power
1	1.0000000E+00	-9.5152900E-02
2	3.3333000E-01	3.1726500E-01
3	1.1111100E-01	-3.3085700E-01
4	3.7037000E-02	9.4509600E-01
5	1.2345600E-02	1.3584500E-01
6	4.1152300E-02	-4.6195500E-03
7	1.3717400E-03	2.4842000E-02
8	4.5725000E-03	-3.3234500E-03
9	1.5242000E-04	2.4997200E-03
10	5.0810000E-05	2.0536900E-03

	Lower .001 Quantile	Upper .001 Quantile	Distribution Function
Rock Properties			
Geothermal Temperture (C)	54.0000	60.0000	Uniform
Thermal Conductivity (W/M/K)	1.2500	2.5000	Uniform
Density (KG/CU.M)	2410.0000	2800.0000	Uniform
Specific Heat (J/KG/K)	820.0000	1160.0000	Uniform
Emplacement Geometry			
Pack Density (1/M/M)	.00748	0.00000	Linear
Waste Package Parameters			
Waste Age (Years)	0.0000	0.0000	Linear
Initial Power (KW)	2.1000	0.0000	Linear
Rock Shell Thermal Conductivity (W/M/K)	1.2500	2.5000	Uniform
Outer Diameter of Backfill (M)	.6860	0.0000	Linear
Thermal Conductivity of Backfill (W/M/K)	.4000	1.4000	Uniform
Outer Diameter of Overpack (M)	.3250	0.0000	Linear
Thermal Conductivity of Buffer (W/M/K)	10.0000	0.0000	Linear
Outer Diameter of Canister (M)	.3250	0.0000	Linear
Canister Thickness (M)	.0530	0.0000	Linear
Length of Canister (M)	4.1000	0.0000	Linear

Table A.5-1 (Continued)

	Lower .001 Quantile	Upper .001 Quantile	Distribution Function
Corrosion Input Data			
Pitting Factor	1.0000	6.0000	Uniform
Exponent of Time	.3639	.5736	Normal
Uniform Corrosion Coefficient (MM/YR)	.0015	676.0000	Lognormal
Chlorine (PPM)	1.0000	100.0000	Uniform
Oxygen (PPM)	.0100	3.0000	Uniform
Leaching Input Data			
Hydraulic Conductivity (CM/YR)	.0001	.3000	Uniform
Hydraulic Gradient	.0050	.0300	Uniform
Density (GM/CM**3)	2.1000	2.7000	Uniform
Porosity	.0010	0.0000	Linear
Exponent of Time	.1000	.7500	Uniform
Leach Rate Factor = (10**(X-Y/T.FAIL))*(10**Z) (GM/((CM**2)*(DAY**EN)))			
Leach Rate Factor X	3.1800	0.0000	Linear
Leach Rate Factor Y	-2424.2200	0.0000	Linear
Leach Rate Factor Z	-.4000	.4000	Uniform
Density of Glass (GM/CM**3)	3.0000	0.0000	Linear
Radius of Glass (CM)	30.5000	0.0000	Linear
Crack Factor of Glass	2.0000	40.0000	Uniform
Plutonium			
Distribution Factor (CM**3/GM)	45.0000	5200.0000	Lognormal
Diffusivity (CM**2/YR)	3.1500	315.0000	Uniform
Dispersivity (CM)	0.0000	1525.0000	Uniform
Tecnetium			
Distribution Factor (CM**3/GM)	0.0000	0.0000	Linear
Diffusivity (CM**2/YR)	3.1500	315.0000	Uniform
Dispersivity (CM)	0.0000	1525.0000	Uniform

Table A.5-2

Monte Carlo Results

Case #	Time of Can Failure yrs	Tecnetium Fract. Release per year	Plutonium Fract. Release per year
1 - 6	5162	8.4 E-7	1.4 E-30
1 -11	72	4.8 E-4	4.4 E-40
1 -52	27	8.6 E-5	1.4 E-14
1 -83	2376	1.2 E-5	2.1 E-5
1 -94	4648	NA	1.2 E-10
2 - 8	2808	4.6 E-9	3.0 E-22
2 -14	9700	5.5 E-8	2.3 E-279
2 -56	7220	5.6 E-5	2.3 E-9
3 - 8	918	6.3 E-6	3.8 E-17
3 -17	5696	4.5 E-8	3.8 E-15
3 -34	7760	3.2 E-7	1.9 E-17
3 -55	7	4.0 E-4	3.2 E-23
4 - 4	611	8.7 E-7	8.3 E-10
4 -20	308	1.2 E-5	1.7 E-17
4 -21	35	6.1 E-2	4.5 E-8
5 -16	18	3.3 E-2	3.3 E-6
5 -27	18	1.0 E-1	6.6 E-27
5 -38	3300	6.1 E-8	1.7 E-11
5 -40	2310	1.3 E-5	3.3 E-7
5 -82	4482	NA	3.3 E-13

APPENDIX B

SOLUTION TO THE INITIAL AND BOUNDARY VALUE PROBLEM EQS. (A.3-34) THROUGH (A.3-37).

With reference to the initial and boundary value problem represented by Eqs. (A.3-34) through (A.3-37), it proves convenient to make the transformation of the independent variable:

$$C(x,t)\ \frac{\varepsilon}{f} = N(x,t)\ e^{-\lambda t}. \tag{B.1}$$

In terms of the new function N(x,t) the original problem takes on the simpler form:

$$\frac{\partial N}{\partial t} = D\ \frac{\partial^2 N}{\partial x^2} - u\ \frac{\partial N}{\partial x}, \qquad x,t>0, \tag{B.2}$$

$$-D\ \frac{\partial N}{\partial x}\Big|_{x=0} + N(x=0,t) = e^{-\lambda\tau}\ L_o(t), \qquad t \geq 0, \tag{B.3}$$

$$N(\infty,t) = 0, \qquad t \geq 0, \tag{B.4}$$

$$N(x,0) = 0, \qquad x \geq 0. \tag{B.5}$$

Taking the Laplace transform of Eqs. (B.2) through (B.5), the new system of equations in terms of the transformed functions $\bar{N}(x,p)$ and $\bar{L}_o(p)$ becomes:

$$p\ \bar{N} = D\ \bar{N}'' - u\ \bar{N}', \qquad x > 0, \tag{B.6}$$

$$-D\ \bar{N}'(x=0,p) + u\ \bar{N}(x=0,p) = e^{-\lambda\tau}\ \bar{L}_o(p), \tag{B.7}$$

$$\bar{N}\ (\ \infty\ ) = 0, \tag{B.8}$$

where p is the parameter of the transformation and a prime indicates ordinary differentiation with respect to the space variable x. Equation (B.6) admits the general solution:

$$\bar{N}(x,p) = \mu\, e^{\gamma_1 x} + \nu e^{\gamma_2 x} , \tag{B.9}$$

where the two parameters γ_1 and γ_2 are defined as follows:

$$\gamma_1 = \frac{u + (u^2 + 4pD)^{1/2}}{2D} , \tag{B.10}$$

$$\gamma_2 = \frac{u - (u^2 + 4pD)^{1/2}}{2D}, \tag{B.11}$$

Choosing to operate on the main branch of the square root function, defined by the relation:

$$- \pi < \arg\ (p + \frac{u^2}{4D}) \leq \pi, \tag{B.12}$$

it turns out that:

$$\text{Re}\ [\gamma_1] > 0, \tag{B.13}$$

and

$$\text{Re}\ [\gamma_2] < 0. \tag{B.14}$$

Therefore, the particular solution of Eq. (B.6) which is of interest to us takes on the form:

$$\bar{N}(x,p) = \mu(p)\ e^{-\xi(p)x}, \qquad x \geq 0 \tag{B.15}$$

where

$$\xi(p) = - \gamma_2. \tag{B.16}$$

The function $\mu(p)$ can be obtained by combining the boundary condition Eq. (B.7) and Eq. (B.15) together. It turns out:

$$\mu(p) = \frac{e^{-\lambda\tau}}{D} \frac{\bar{L}_o(p)}{\xi(p) + u} \quad , \tag{B.17}$$

and, one can rewrite Eq. (B.15) as follows:

$$\bar{N}(x,p) = \bar{F}(p) \cdot G(\bar{x},p), \tag{B.18}$$

where:

$$\bar{F}(p) = \frac{e^{-\lambda\tau} \bar{L}_o(p)}{D}, \tag{B.19}$$

and

$$\bar{G}(x,p) = \exp\left(\frac{ux}{2D}\right) \cdot \frac{\exp\left[-\left(\frac{u^2}{4D^2}+\frac{p}{D}\right)^{1/2} x\right]}{\left(\frac{u^2}{4D^2}+\frac{p}{D}\right)^{1/2} + \frac{u}{2D}}. \tag{B.20}$$

By a property of the Laplace transforms, the function N(x,t) can be expressed as the convolution of the original functions F(t) and G(x,t). Namely:

$$N(x,t) = \int_0^t F(t-t')\, G(x,t')\, dt'. \tag{B.21}$$

The function $\bar{F}(p)$ is easily inverted yielding:

$$F(t) = \frac{e^{-\lambda\tau} L_o(t)}{D} \quad . \tag{B.22}$$

In order to invert the function $\bar{G}$ (x,p), one can observe that it is of the form:

$$\bar{G}(x,p) = \exp\left(\frac{ux}{2D}\right) \bar{H}\left(\frac{p}{D} + \frac{u^2}{4D^2}\right) \quad , \tag{B.23}$$

Therefore, its inverse must be of the form:

$$G(x,t) = D \exp\left(-\frac{u^2 t}{4D} + \frac{ux}{2D}\right) \cdot H(Dt) \tag{B.24}$$

where

$$H(t) = \mathcal{L}^{-1}\left\{\bar{H}(p)\right\}$$

$$= \mathcal{L}^{-1}\left\{\frac{\exp(-\sqrt{p}\,x)}{\sqrt{p} + \frac{u}{2D}}\right\} \tag{B.25}$$

It turns out, from the tables, that:

$$H(t) = \left(\frac{1}{\pi t}\right)^{1/2} \exp\left(-\frac{x^2}{4t}\right)$$

$$-\frac{u}{2D}\exp\left(\frac{ux}{2D} + \frac{u^2 t}{4D^2}\right)\operatorname{erfc}\left(\frac{u\sqrt{t}}{2D} + \frac{x}{2\sqrt{t}}\right) \tag{B.26}$$

Therefore, combining the above results, the function N(x,t) is expressible as follows:

$$N(x,t) = \frac{e^{-\lambda\tau}}{D}\int_0^t L_o(t-t')\, G(x,t')\, dt', \tag{B.27}$$

where:

$$G(x,t) = \left(\frac{D}{\pi t}\right)^{1/2} \exp\left[-\frac{(x-ut)^2}{4Dt}\right] \tag{B.28}$$

$$-\frac{u}{2}\exp\left(\frac{ux}{D}\right)\operatorname{erfc}\left(\frac{xt+ut}{2\sqrt{Dt}},\right)$$

Combining Eq. (B.27) and Eq. (B.1) together, the reported expression for C(x,t), Eq. (A.3-38) , follows.

APPENDIX C

TEMPERATURE MODEL

With reference to Figure A.3.1 and to the consideration of Section A.3.1, this appendix describes how a temperature model could be developed. Modeling of the decay heat is accomplished first in Section C.1. The resulting expression is then used to develop a far field temperature model in Section C.2. Treatment of the near field region is accomplished in Section C.3. Model validation, and data for the temperature model are addressed in Section C.4 and C.5, respectively.

C.1 POWER GENERATION MODEL

The parameters which determine the power as a function of time for a single waste package are the age of the waste and the type of fuel which originated it, as well as the loading of waste into the individual waste package.

The age and the type of the waste enter into the details of the decay curve, and the loading of the glass enters as a multiplier.

It is assumed that the power dissipation of the waste can be represented as

$$P = P_o \sum_{i=1}^{n} a_i \, e^{-\lambda_i t} \qquad \text{(C.1-1)}$$

where the set of a_i is normalized so that P_o is the power at t=0 and t is the time since reprocessing.

The values of λ_i and a_i can be obtained by least square fitting procedure to data produced by a fission product decay code such as ORIGEN, with appropriate corrections for the efficiency of recovery of the various elements. For example,. the contribution to the power from the noble gases should be negligible, and the volatile fission products which are not retained in the glass need to be reduced proportionately.

The decay constants λ_i can be determined from the fit of the computed results in which case they will resemble the natural decay constant of the dominant fission and activation products, or alternatively they can be taken arbitrarily in a logarithmic sequence which spans the range of natural decay constants. In any case the justification of the choice of the set of λ_i and a_i rests on the accuracy of the fit to the results of a detailed fission and activation product calculation which includes all the significant isotopes.

The expression for the power is modified to shift the origin of time to the age of the waste at the time of emplacement in the repository. If the age of the waste is t_o, then

$$P = P_o \sum_{i=1}^{n} a_i \, e^{-\lambda_i (t+t_o)} \qquad \text{(C.1-2)}$$

where t is now measured from emplacement time.

Then

$$P = P_o \sum_{i=1}^{n} a_i \, e^{-\lambda_i t_o} . \, e^{-\lambda_i t} = P_o \sum_{i=1}^{n} b_i \, e^{-\lambda_i t} \qquad \text{(C.1-3)}$$

The power after emplacement, P, normalized to the power at emplacement time P_1 can be expressed as

$$\frac{P}{P_1} = \frac{\sum_{i=1}^{n} b_i \, e^{-\lambda_i t}}{\sum_{i=1}^{n} b_i} = \sum_{i=1}^{n} c_i \, e^{-\lambda_i t}$$

The temperature of the repository resulting from the overall heat conduction of the rock formation depends on the average heat generation per unit area of repository, and this average heat generation can be represented by

$$Q(t) = m \, P_1 \sum_{i=1}^{n} c_i \, e^{-\lambda_i t} \qquad \text{(C.1-4)}$$

where

$Q(t)$ = Power per unit area of Repository [W/m^2]

m = Average number of waste packages per unit area of repository [$1/m^2$]

P_1 = Power per package at emplacement time [W]

t = Time from emplacement [year]

λ_i = Decay constant of isotope group i [$year^{-1}$]

c_i = Fraction of power due to isotope group i at emplacement time. [dimensionless]

C.2 FAR FIELD TEMPERATURE MODEL

With reference to fig. A.3.1, it is assumed that the repository is an extended plane heat source immersed in an infinite homogeneous medium initially at constant temperature. The only temperature of interest is that of the plane source.

According to the considerations of Section C.1, the heat source per unit area is taken to be a function of the form:

$$f(t) = \sum_{i=1}^{n} a_i \; e^{-\lambda_i t} \; ; \qquad \text{(C.2-1)}$$

where n is the number of isotopes groups, λ_i their decay constants and a_i coefficients for each isotope in units of cal/sec/sq meter, and depend on parameters such as dimensions of the glass block, percent loading, age of the waste, and density of emplacement on the repository floor.

From Carslaw and Jaeger, p.76, assuming heat conduction in a semi-infinite solid, the temperature at the source is:

$$T = \frac{\sqrt{k}}{K\sqrt{\pi}} \int_0^t f(t-z) \; \frac{dz}{\sqrt{z}} \; + T_o \qquad \text{(C.2-2)}$$

where

T = Temperature at time t

K = Thermal conductivity

k = Thermal diffusivity = $\frac{K}{\rho c}$

ρ = Density

c = Heat capacity

z = Dummy time variable in any consistent set of units.

Since in the real case, the heat flows in two directions, up and down, equation (C.2-2) has to be changed to:

$$T = \frac{\sqrt{k}}{2K\sqrt{\pi}} \int_0^t f(t-z) \; \frac{dz}{\sqrt{z}} \; + T_o \qquad \text{(C.2-3)}$$

Combining Eqs. (C.2-1) and (C.2-3) one obtains:

$$T = \frac{\sqrt{k}}{K\sqrt{\pi}} \sum_{i=1}^{n} \frac{a_i}{\lambda_i} \Delta(\sqrt{\lambda_i t}) \qquad \text{(C.2-4)}$$

where, the function (x) is the Dawson's integral defined as:

$$\Delta(x) = \exp(-x^2) \int_0^x \exp(+t^2)\, dt \qquad \text{(C.2-5)}$$

Therefore, the far field effect on the repository center plane can be expressed as a sum of terms, each of which requires the evaluation of a single transcendental function, the Dawson's integral.

C.3 NEAR FIELD TEMPERATURE MODEL

To compute the local temperature rises in the vicinity of the canister, the assumption is made that the problem can be treated as a one-dimensional steady-state radial heat conduction through concentric layers. In order to match the local solution with the far field solution, the outer surface of the outer shell corresponding to one canister length is made equal to the horizontal area of repository per canister. Then the outer diameter of the equivalent rock shell is

$$D = \frac{2d}{\pi} \qquad \text{(C.3-1)}$$

where

d = distance between parallel emplacement holes.

The adopted model, which is based on steady-state elementary heat conduction considerations in concentric cylindrical geometry, accepts three shells, eg. near rock, packing material (backfill) and buffer, and requires the corresponding diameters, and the thermal conductivities.

C.4 MODEL VALIDATION

In order to validate this model, several three-dimensional solutions of the heat conduction problem should be compared with the results of the model, to estimate the expected errors of prediction. It is expected that errors would tend to be systematic since the matching of the two solutions overestimates the temperature, because the thermal inertia of the near rock is neglected. Therefore, if there are enough points to compare the results, a correction function could be introduced.

The results of this simplified model, adjusted for an outer diameter of the rock shell that would represent the case of vertical emplacement holes having only one canister per hole, were compared with the results reported in NWTS-16, ''Interim Reference Repository Conditions for a Nuclear Repository in Basalt,'' for the case of spent fuel. The results for canister temperatures were found to agree with the published results within 20°C, however, it is not possible to separate errors due to the approximations made in the model from differences between input data sets.

For an actual validation of the simplified model, the results should be compared with a series of cases where the actual values of the parameters used in both calculation are known.

C.5 TEMPERATURE MODEL DATA

Data for the relative decay heat generation as a function of time is taken from the draft NWTS-16, ''Interim Reference Repository Conditions for a Nuclear Waste Repository in Basalt,'' where the data is presented in tabular form for periods of 0 to 9990 years after emplacement. Emplacement is assumed to occur 10 years after reactor discharge. The data for ''Commercial High-Level Waste'' is used in this document. This data assumes a 3:1 mix of UO_2 and mixed oxide fuels.

Decay heat data is expected to have two sources of uncertainty: the details of the fuel cycle that produced the waste, and the details of the chemical reprocessing which allow certain latitude in the fraction of actinides recovered. At later times, when most of the heat generated results from the decay of the actinides these uncertainties can be substantial.

Disregarding these uncertainties, the above set of data is taken as exact, and the data are fitted to a sum of exponential functions. The resulting set of decay constants and factors is shown in Table C.5. The decay constants are not adjusted in the fit but are fixed in a geometric scale of factor 0.3333. Some improvement on the fit could be obtained by a non-linear fit where the decay constants are taken as unknowns, but the gains are judged not to warrant the additional complication. Table C.5 shows the decay-heat data, the predictions of the fit, and the fractional error of the fit. Figure C.5-1 shows a plot of the results.

Since the data used for this fit is normalized to 10 years after discharge, and a few years does not appear to affect the results substantially, the input for the age of the fuel in the model is fixed at a point estimate value of 10 years. In the program this is implemented by entering a zero age. The performance model accomodates variable ages of the waste only if the data is normalized to zero age.

The geothermal temperature given in the BWIP-SCR, p. 6.2-6, shows a spread of about 5 degrees. Therefore, for a nominal temperature of 57 degrees centigrade, the adopted range is 54 to 60 degrees.

The thermal properties, specific heat and thermal conductivity of the basalt of the Umtanum flow are taken from the BWIP-SCR (Table 4.9), where the data is presented in the form of a range of values but without a detailed analysis or statements about probability distribution type and parameters. For the purposes of this illustration, the thermal conductivity is assumed to be uniformly distributed in the range 1.25 to 2.50 W/m°K and the specific heat also uniformly distributed in the range 820 to 1160 J/kg°K.

The basalt density is taken from BWIP-SCR (Tables 4.6 and 4.7) where the data shown exhibits a range of 2410 to 2800 kg/cu.m. For the purpose of this illustration, the thermal properties and the density are taken as independent variables which is not correct. Since this data is used in the heat conduction equation, a more realistic treatment would be to use as the input the thermal diffusivity with its appropriate range or alternatively, to use the density, thermal conductivity and specific heat with the observed values of correlation between them.

The decay heat per canister at the time of emplacement is one of the design variables which can be adjusted to control the peak temperatures, and is subject to quality control during fabrication of the waste form. For commercial high level waste, the BWIP-SCR uses the design basis value of 2210 W/-canister. For this illustration, this value is taken without uncertainty. The uncertainty of this parameter will depend on quality control limits to be determined.

The repository design described in BWIP-SCR uses an arrangement of multiple horizontal holes at a pitch of 32.6 m. This figure and the canister length of 4.1 m leads to a packing density of 0.00748 canisters/sq.m. This value overestimates the heat loading used in the far field temperature since it neglects spacing between canisters, galleries and unused spaces at the end of emplacement holes. Since this parameter is well defined and controllable, it is taken as a point estimate without range.

The BWIP-SCR gives the following dimensions for the waste package for commercial high level waste: diameter of storage hole 0.686 m, outside diameter of canister 0.325 m, canister wall thickness 0.053 m.

The thermal conductivity of the basalt-bentonite packing material has substantial uncertainties which include effects of hydration and swelling. Altenhofen[16] gives values for bentonite and bentonite-crushed basalt ranging from 0.4 to 1.4 W/m.K depending on water content.

A summary of the thermal data for the temperature descriptive model is presented in Table C.5-3.

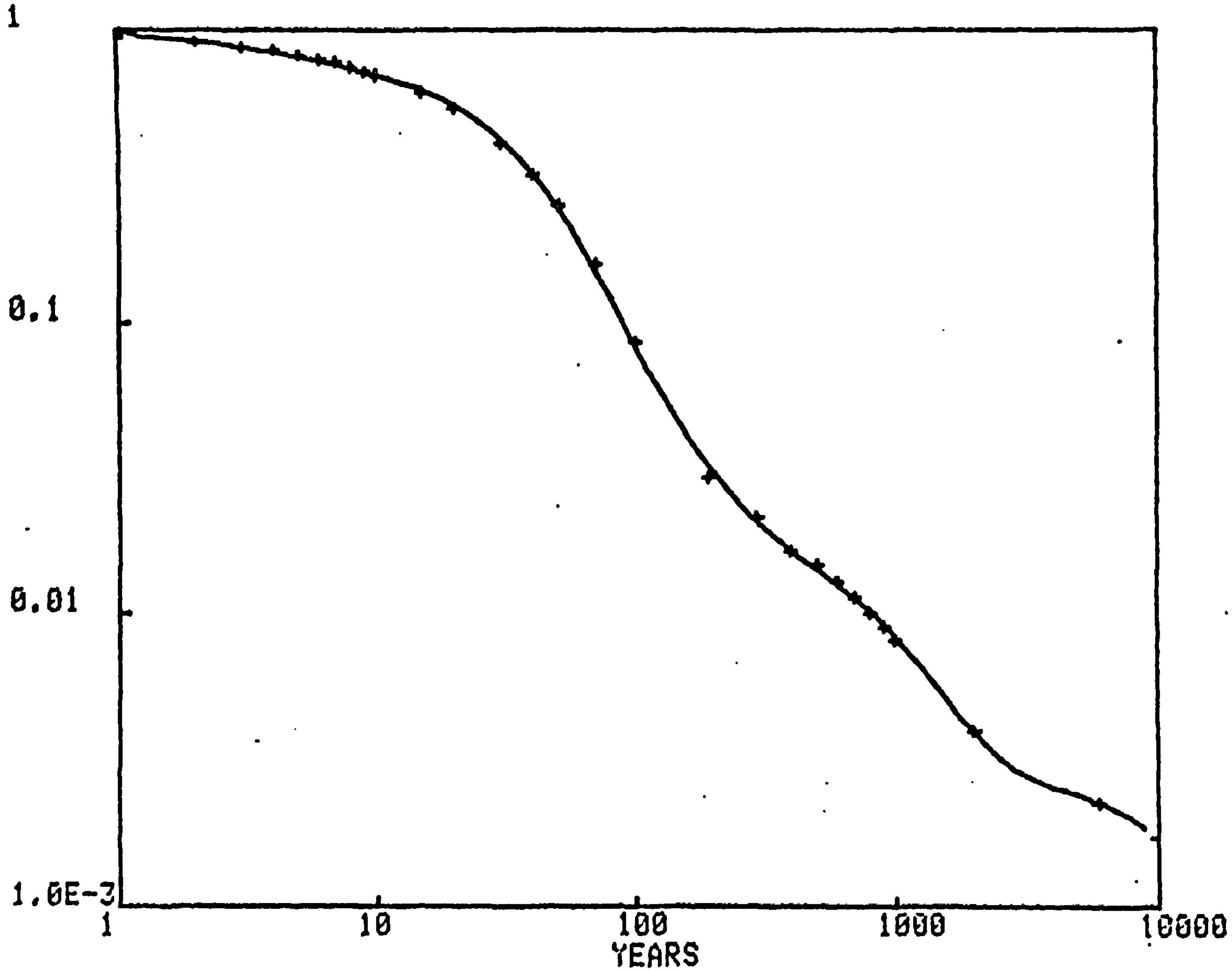

Figure C.5-1 Fit To Decay Heat Data For Commercial Waste.

Table C.5-1

Decay Heat Source Regression Results

Term #	Decay Constant [1/year]	Coefficient [-]
1	1.00000000	-0.09515290
2	0.33333300	0.31726500
3	0.11111100	-0.33085700
4	0.03703700	0.94509600
5	0.01234570	0.13584500
6	0.00411523	-0.00461955
7	0.00137174	0.02484200
8	0.00045725	-0.00332345
9	0.00015242	0.00249972
10	0.00005081	0.00205369

Table C.5-2

Decay Heat Data and Results

Time	Power Data	Power Predict.	Fractional Error
0.00	1.000000	0.993648	0.006352
1.00	0.950000	0.962611	-0.013275
2.00	0.907000	0.916657	-0.010647
3.00	0.871000	0.872934	-0.002220
4.00	0.851000	0.835403	0.018327
5.00	0.810000	0.803875	0.007562
6.00	0.783000	0.777121	0.007508
7.00	0.769000	0.753884	0.019656
8.00	0.734000	0.733144	0.001166
9.00	0.714000	0.714144	-0.000201
10.00	0.692000	0.696345	-0.006279
15.00	0.600000	0.616018	-0.026696
20.00	0.529000	0.542423	-0.025374
30.00	0.402000	0.414147	-0.030215
40.00	0.313000	0.314709	-0.005458
50.00	0.246000	0.241042	0.020155
70.00	0.157000	0.148228	0.055874
100.00	0.086400	0.082727	0.042509
190.00	0.029600	0.032286	-0.090749
290.00	0.021500	0.020599	0.041910
390.00	0.016300	0.016312	-0.000715
490.00	0.014500	0.014057	0.030572
590.00	0.012700	0.012484	0.016970
690.00	0.011300	0.011207	0.008222
790.00	0.010000	0.010107	-0.010741
890.00	0.008970	0.009145	-0.019483
990.00	0.008100	0.008300	-0.024661
1990.00	0.004040	0.003983	0.014029
5990.00	0.002300	0.002310	-0.004320
9990.00	0.001750	0.001747	0.001673

Table C.5-3

Summary of Data for Package Temperature Model

	Range	Distribution
Geothermal temperature [°C]	54,60	Uniform
Rock thermal conductivity [W/m/°K]	1.25,2.50	Uniform
Rock Density [Kg/cu.m]	2481,2800	Uniform
Heat Capacity [J/Kg/°K]	820,1160	Uniform
Packing Density [1/m/m]	0.00748,0.00748	----
ǂAge of the Waste [year]	0,0	----
Initial Decay Heat per Canister [W]	2210	----
Outer Diameter of Backfill [m]	0.686,0.686	----
Packing Material Thermal Conductivity [W/m/°K]	0.4, 1.4	Uniform
*Outer Diameter of Overpack [m]	0.325,0.325	----
*Buffer Thermal Conductivity [W/m/°K]	10,10	
Thickness of Canister [m]	0.053,0.053	----
Outer Diameter of Canister [m]	0.325,0.325	----
Length of Canister [m]	4.1,4.1	----

* Dummy values to accomodate lack of overpack.

ǂ An input of zero for the age of the waste corresponds to 10 years after discharge, because of the normalization of the decay heat function.

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Attachment 12

SECOND PRE-SCP CONSULTATION MEETING BETWEEN NRC AND DOE/NPO

APPLICABILITY OF GUIDANCE IN BWIP SCA TO SALT PROJECT

SILVER SPRING, MD
JUNE 27-28, 1983

PURPOSE OF MEETING

TO DISCUSS SCA REVIEW QUESTIONS AND TO OBTAIN NRC GUIDANCE ON SCP PREPARATION; DISCUSS THE APPROACH TO IDENTIFY ISSUES.

CHAIRPEOPLE: H. J. MILLER/NRC
L. A. CASEY/NPO

AGENDA

JUNE 27, 1983

8:30AM	INTRODUCTION AND COMMENTS	NPO/NRC
9:00AM*	LEVEL OF DETAIL IN SCP	NPO/ONWI
9:30AM	ISSUE RESOLUTION STATUS AT LA	NPO/ONWI
10:00AM	BREAK	
10:15AM	DATA INCORPORATION IN SCP	NPO/ONWI
10:45AM	INTEGRATION OF PLANS AND PROCEDURES INTO SCP	NPO/ONWI
11:15AM	ISSUE IDENTIFICATION LOGIC	NPO/ONWI
12:00	LUNCH	
1:00PM	CHAPTER 10 FORMAT APPROACH	NPO/ONWI
1:45PM	PRELIMINARY LIST OF ISSUES AND DISCUSSION	NPO/ONWI
3:00PM	DISCUSSION OF BWIP SCA EXECUTIVE SUMMARY	NRC
4:30PM	ADJOURN	

JUNE 28, 1983

8:30AM	NRC GUIDANCE PRODUCTS	NRC
9:30AM	COMPARISON OF MORGAN/DAVIS AGREEMENT VS NRC/NPO AGREEMENT	NRC/NPO
10:00AM	PROCEDURES FOR DATA ACCESS	NPO/NRC
10:30AM	BREAK	
10:45AM	DISCUSSION AND PREPARATION OF MINUTES	

LIST OF EXPECTED ATTENDEES

NRC	DOE/ONWI
H. J. MILLER	J. NEFF/NPO
L. CHASE	L. CASEY/NPO
R. JOHNSON	J. SZYMANSKI/NPO
R. WRIGHT	V. LOWREY/HQ
P. JUSTUS	L. WHITE/WESTON
J. GREEVES	M. GLORA/ONWI
	R. KLINGENSMITH/ONWI
	D. EGNER/ONWI
	J. PARRY/OWO
	J. LARUE/BWIP

*AGENDA ITEMS INCLUDE ALLOWANCE FOR DISCUSSION

NPO/ONWI BWIP SCA REVIEW

INTRODUCTION

- SCA PROVIDES VALUABLE GUIDANCE AND WILL BE USED IN PREPARATION OF SALT SCP'S
  - LEVEL OF DETAIL DESIRED BY NRC
  - CONSIDERATION OF UNCERTAINTY
  - APPROACH TO ISSUES AND PLANS INCLUDING HIERARCHY DEVELOPMENT
  - SITE PROTECTION
- NUREG'S CITED IN SCA ARE A SIGNIFICANT RESOURCE AND WILL BE CONSIDERED IN PREPARATION OF SALT SCP'S

NPO/ONWI BWIP SCA REVIEW

QUESTIONS AND CONCERNS RESULTING FROM REVIEW

- WHAT LEVEL OF DETAIL IS NECESSARY IN SCP VS THAT NECESSARY FOR LICENSE APPLICATION?
- WHAT IS THE POSITION OF NRC RELATIVE TO STATUS OF ISSUE RESOLUTION AT LA?
- WHAT METHODOLOGY SHOULD BE USED TO INCORPORATE DATA INTO SCP TO PROVIDE NECESSARY DETAIL AND STILL MAINTAIN READABILITY?
- WHAT LEVEL OF CONCURRENCE ON PLANS AND PROCEDURES IS APPROPRIATE DURING CONTINUING SITE CHARACTERIZATION, AND TO WHAT EXTENT SHOULD DETAILED PLANS BE INCORPORATED?
- WHAT IS THE MOST APPROPRIATE METHOD FOR ISSUE IDENTIFICATION LOGIC AND TRACEABILITY?
- CHAPTER 10 FORMAT
- PROCEDURES FOR DATA ACCESS

NPO/ONWI BWIP SCA REVIEW

CONCERN: WHAT LEVEL OF DETAIL IS NECESSARY IN THE SCP VS THAT NECESSARY FOR LICENSE APPLICATION?

SCA DOES NOT DIFFERENTIATE BETWEEN INFORMATION NECESSARY FOR DETERMINATION OF SITE SUITABILITY AND OTHER INFORMATION THAT WILL BE NECESSARY FOR LA, BUT WHICH IS NOT DIRECTLY RELATED TO SITE CHARACTERIZATION

NRC CITATIONS

- IT IS IMPORTANT--TO GIVE HIGH PRIORITY TO OPERATIONAL SAFETY BECAUSE APPLICATION MUST ADDRESS--COMPONENTS IMPORTANT TO SAFETY (P. 9-9)
- SEVERAL--SCENARIOS SHOULD BE CONSIDERED IN DETERMINING DOSE RATES AND SHIELDING REQUIREMENTS (APP. B, P. 76)
- VENTILATION DESIGN DOES NOT CONSIDER LOCAL RETRIEVAL NEEDS (APP. B, P. 77)

NPO/ONWI COMMENT AND POSITION

- APPROPRIATE FOR CONSIDERATION DURING DETAILED DESIGN - NEED, BUT NOT DETAILS, SHOULD BE RECOGNIZED IN SCP
- SCA APPEARS TO BE PUSHING SCP TO SAR CONTENT LEVEL PREMATURELY
  - BULK
  - UNCERTAINTY
  - UNAVAILABILITY OF DATA UNTIL RELATIVELY LATE IN PROGRAM

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NPO/ONWI BWIP SCA REVIEW

CONCERN: WHAT IS THE POSITION OF NRC RELATIVE TO STATUS OF ISSUE RESOLUTION AT LA?

IMPLICATION THROUGHOUT SCA IS THAT FULL RESOLUTION MUST BE AVAILABLE AND THAT ALL PERFORMANCE CONFIRMATION ACTIVITIES MUST BE COMPLETE.

NRC CITATIONS

- ACCORDING TO SCR FIGURE 17-9, SELECTION OF CANDIDATE SEALING MATERIALS WILL BE DELAYED UNTIL 1984. THIS--FORCES DELAYS IN OTHER WORK ELEMENTS ---. IF THERE IS ANY SLIPPAGE---THE TEST PROGRAM MAY NOT BE ADEQUATELY COMPLETED BY LICENSE APPLICATION TIME. (P.6-8)
- CERTAIN ASPECTS OF--PLANS--ARE NOT TIMELY. (P. 5-9); REGARDING GEOCHEMICAL DATA AVAILABILITY IN FY 87/88)
- SCHEDULE FOR--SEALING DESIGN SEEMS--TOO LATE FOR PROPER REVIEW. (P. 6-7)
- SCR DOES NOT EXHIBIT A COMMITMENT--TO RESOLVE KEY ISSUES BEFORE A LICENSE APPLICATION. (P. 6-11)
- OBJECTIVES AND MINIMUM REQUIREMENTS FOR RESOLVING KEY ISSUES SHOULD NOT BE AFFECTED BY SCHEDULE AND BUDGETARY REQUIREMENTS. (P. 90)
- RESOLUTION OF ISSUES--MUST BE DOCUMENTED FOR THE NRC. RECEIPT OF DOCUMENTATION IS IMPORTANT TO MAINTAINING A LA REVIEW SCHEDULE. (P. 92)

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NPO/ONWI COMMENT AND POSITION

- SCA IMPLIES FULL RESOLUTION OF ALL KEY ISSUES AND COMPLETION OF ALL TESTING BY LA. 10 CFR 60.21 AND SUBPART F RECOGNIZE NEED TO CONTINUE RESOLUTION AND CONFIRMATION PROCESS.
- THE LEVEL OF ASSURANCE IMPLIED WOULD APPEAR TO EXCEED THAT FOR ALL OTHER FUEL CYCLE FACILITIES.
- SCP SHOULD BE STRUCTURED SO THAT THERE IS A LEVEL OF REASONABLE ASSURANCE AT LA WHICH WILL CONTINUE TO IMPROVE THROUGH CONSTRUCTION AND OPERATION TO DECOMMISSIONING.
- ISSUES MAY NOT NEED TO BE TOTALLY RESOLVED AT LA SO LONG AS THERE IS REASONABLE ASSURANCE THAT UNCERTAINTIES HAVE BEEN BOUNDED AND CAN BE ACCOMMODATED.

NPO/ONWI BWIP SCA REVIEW

CONCERN: WHAT METHODOLOGY SHOULD BE USED TO INCORPORATE DATA INTO SCP TO PROVIDE NECESSARY DETAIL AND STILL MAINTAIN READABILITY?

THE NEED FOR NRC ACCESS TO PRIMARY DATA AND INFORMATION TO ALLOW INDEPENDENT EVALUATION, AND AS AN INDICATOR OF CONFIDENCE/UNCERTAINTY IS RECOGNIZED. HOWEVER, AGREEMENT SHOULD BE REACHED TO KEEP SCP WITHIN REASONABLE VOLUME BOUNDS.

NRC CITATIONS

- DETAILS FOR IMPLEMENTING THE QA PROGRAM WERE NOT PRESENTED (P.XX)
- DETAILED DESCRIPTIONS OF EXPERIMENTAL STRATEGY AND ANALYTICAL TECHNIQUES ARE NOT PROVIDED. (P. 5-4)
- PROVIDE EVIDENCE OF PROPER IMPLEMENTATION OF QA PROGRAM. (P. 10-2)
- INDEPENDENT ASSESSMENT BY NRC REQUIRES PRESENTATION OF ALL PRIMARY DATA. (APP. B, P.17)
- PRESENTATION OF RANGE AND MEAN DOES NOT PERMIT INDEPENDENT EVALUATION OF DATA (APP. B, P. 4-7)
- DOE HAS NOT SHOWN ALL DATA POINTS USED TO GENERATE MAPS. (P. 4-7)

NPO/ONWI BWIP SCA REVIEW

NPO/ONWI COMMENT AND POSITION

- SCP WILL PROVIDE, IN TEXT OR AS ATTACHMENT, ALL DATA USED: (1) TO CONSTRUCT CURVES AND PREPARE MAPS, (2) AS CALCULATIONAL INPUT, (3) BOUND ALTERNATIVE SCENARIOS AND/OR INTERPRETATIONS.
  - DATA NOT SPECIFICALLY USED WILL BE CLEARLY REFERENCED, AS WILL SOURCE OF DATA USED
- METHODS AND PROCEDURES USED TO DEVELOP DATA WILL BE BRIEFLY DESCRIBED (INCLUDING INDICATION OF CONFIDENCE, UNCERTAINTIES, OR LIMITATIONS) AND CITATIONS PROVIDED FOR DETAIL
- QA PLANS AT DOE AND PRIME CONTRACTOR LEVEL WILL BE PROVIDED AS ATTACHMENTS
  - QA APPLICABLE TO PAST ACTIVITIES WILL BE NOTED
  - AVAILABILITY OF SUBCONTRACTOR QA PLANS AND RECORDS WILL BE NOTED BUT NOT INCLUDED
  - WHAT ARE QA "DETAILS"?

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NPO/ONWI BWIP SCP REVIEW

CONCERN: WHAT LEVEL OF CONCURRENCE ON PLANS AND PROCEDURES IS APPROPRIATE DURING CONTINUING SITE CHARACTERIZATION, AND TO WHAT EXTENT SHOULD DETAILED PLANS BE INCORPORATED?

SCA IMPLICATION IS THAT ALL TEST ACTIVITIES MUST HAVE PRIOR NRC CONCURRENCE. RECOGNITION BY DOE OF NRC COMMENTS ON PLANNED ACTIVITIES DESCRIBED IN THE SCP AND MAJOR SUPPLEMENTAL PLANS (SUCH AS IN SITU TESTING) SHOULD SUFFICE FOR CONCEPTUAL APPROVAL. PRIOR REVIEW BY NRC OF ALL PLANS AND PROCEDURES IS LIKELY TO SIGNIFICANTLY DELAY PROGRAM. RECOGNITION OF NEED FOR PHASING REMAINS A PROBLEM.

NRC CITATIONS

- DOE SHOULD PROVIDE DETAILS OF WORK PLANS AS THEY ARE DEVELOPED SO THAT NRC CAN EVALUATE. (P. 4-10)
- DETAILED DESCRIPTION OF EXPERIMENTAL STRATEGY AND ANALYTICAL TECHNIQUES IS NOT PROVIDED. (P. 5-4)
- CONSIDERABLE LACK OF DETAIL IN AT DEPTH TESTS. (P. 6-10)

NPO/ONWI BWIP SCA REVIEW

NPO/ONWI COMMENT AND POSITION

- NRC'S POSITION RELATIVE TO:
  - LEVEL OF PROCEDURE AND PLAN CONCURRENCE REQUIRED IS UNCLEAR
  - ALTHOUGH APPROPRIATENESS OF PHASING IS RECOGNIZED IN SCA - SPECIFIC COMMENTS DO NOT REFLECT THAT RECOGNITION
- DOE WILL PROVIDE TEST PLANS IN SCP
- WHERE PREPARATION OF DETAILED PLANS (OR PROCEDURES) IS DEPENDENT ON THE PHASED PROCESS - RECOGNITION OF NEED WILL BE PROVIDED IN CHAPTER 10
  - EDBH
  - EXPLORATORY SHAFT
- DETAILED TEST PROCEDURES WILL BE REFERENCED WHEN THEY BECOME AVAILABLE
  - NRC WILL HAVE ACCESS TO TEST PROCEDURES, BUT PROCEDURES HAVING NO POTENTIAL IMPACT ON SITE SUITABILITY SHOULD NOT BE DELAYED FOR CONCURRENCE

NPO/ONWI BWIP SCA REVIEW

CONCERN: WHAT IS THE MOST APPROPRIATE METHOD FOR ISSUE IDENTIFICATION AND LOGIC TRACEABILITY?

NRC AND NPO/ONWI HAVE IDENTIFIED SITE CHARACTERIZATION ISSUES BY USING SIMILAR LOGIC PROCESSES. THE NRC LOGIC IS SCENARIO-ORIENTED AND LEADS TO ISSUES OF A SCENARIO OR PROCESS NATURE. THE NPO/ONWI LOGIC IS OBJECTIVES-ORIENTED AND LEADS TO ISSUES WHICH RELATE CLOSELY TO SITE CHARACTERIZATION TEST AND MEASUREMENT ACTIVITIES.

NRC CITATIONS

- LOGIC PROCESS IDENTIFIES PERFORMANCE ISSUES FROM WHICH SPECIFIC ISSUES ARE IDENTIFIED FOR VARIOUS SIGNIFICANT CONDITIONS AND PROCESSES. (SCA APPENDIX C AND FIGURES C-1, C-2 AND C-3)
- ISSUES EVOLVE DIRECTLY FROM THE PERFORMANCE OBJECTIVES OF 10 CFR 60 THROUGH A SERIES OF PERFORMANCE ISSUES AND SIGNIFICANT CONDITIONS AND PROCESSES (SCA APPENDIX C, SECTION 3)

NPO/ONWI COMMENT AND POSITION

- THE NPO/ONWI OBJECTIVES METHODOLOGY IS LOGICALLY SIMILAR TO THE NRC PERFORMANCE ISSUE/SIGNIFICANT CONDITIONS METHODOLOGY. HOWEVER, IT IS NOT CLEAR HOW THE NRC ISSUES ARE QUANTIFIED IN TERMS OF SITE CHARACTERIZATION TEST PLANS AND SUITABILITY.

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ISSUE IDENTIFICATION PROCESS

NRC (SCA FIGURE C-3)

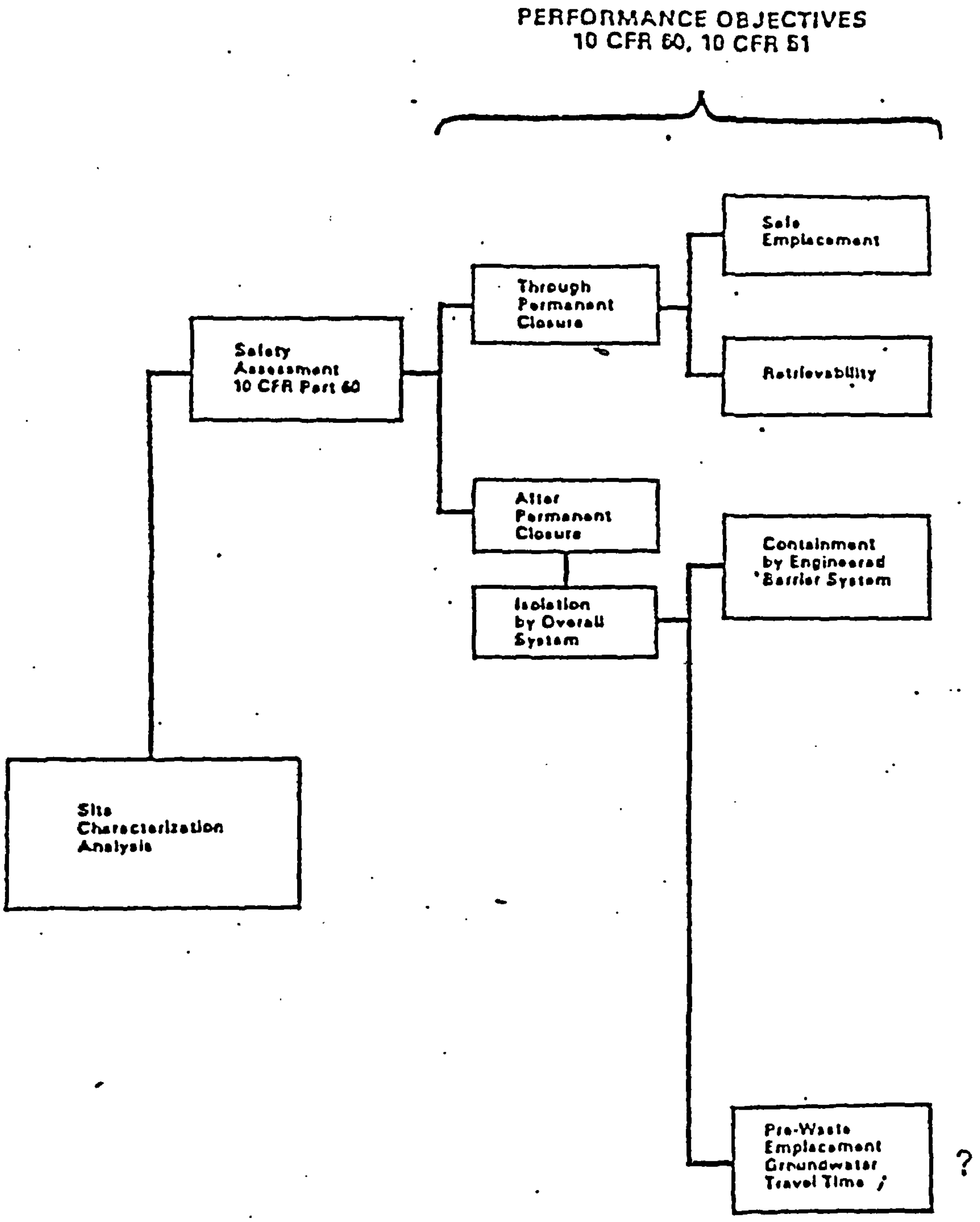
PERFORMANCE OBJECTIVES 10 CFR 60 → PERFORMANCE ISSUES → SIGNIFICANT CONDITIONS & PROCESSES → SPECIFIC ISSUES / HIERARCHY

DOE/ONWI (OBJECTIVES TREE METHODOLOGY)

PERFORMANCE OBJECTIVES 10 CFR 60 → METHODOLOGY OBJECTIVES DERIVED FROM EVENTS, CONDITIONS, PROCESSES → SPECIFIC ISSUES / HIERARCHY

ISSUE IDENTIFICATION LOGIC - NRC

(SCA FIGURE C-2)



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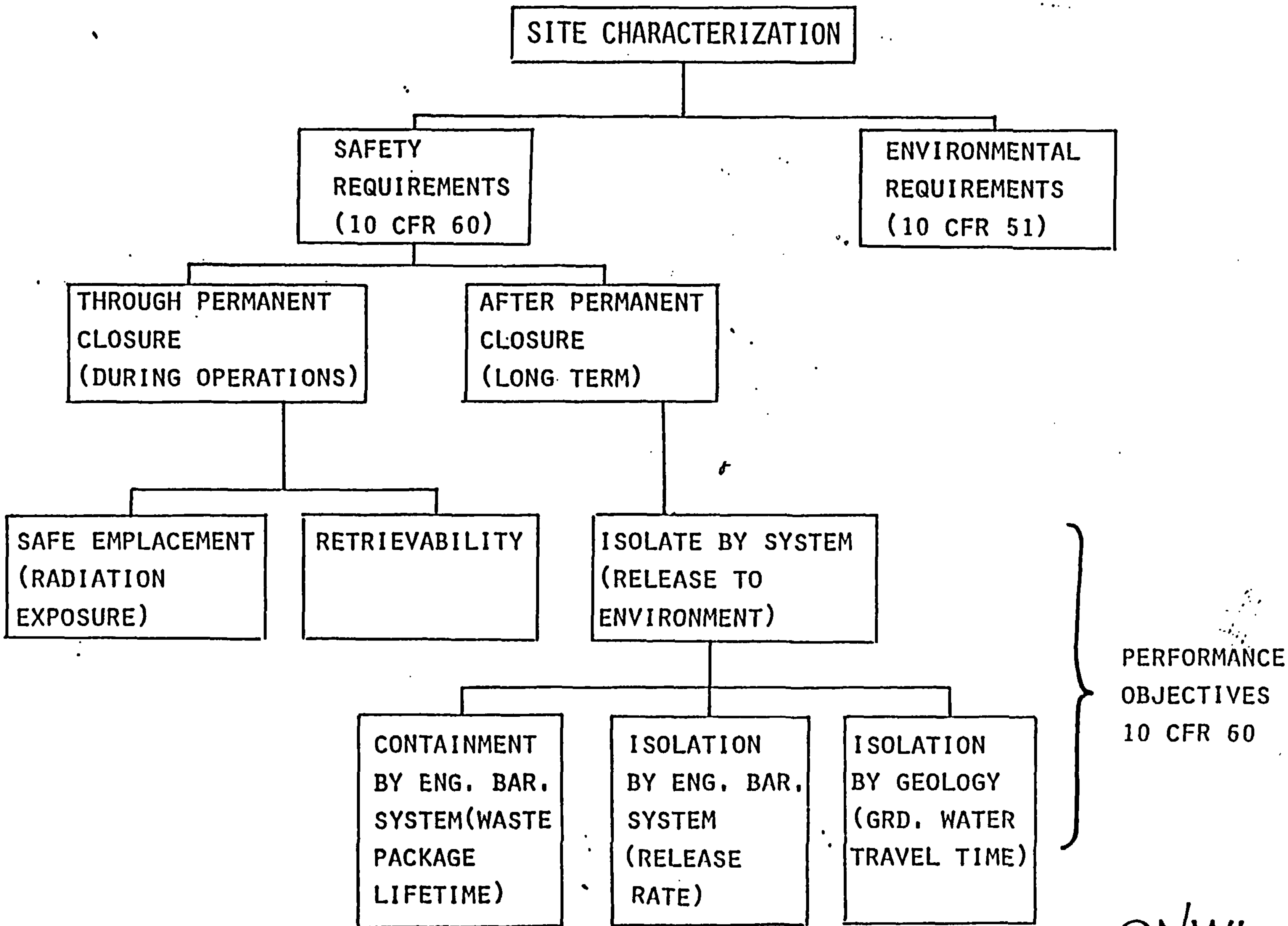
ISSUE IDENTIFICATION LOGIC - NPO/ONWI



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ISSUE IDENTIFICATION PROCESS - NRC

PERFORMANCE OBJECTIVES 10 CFR 60	→	PERFORMANCE ISSUES	→	SIGNIFICANT CONDITIONS & PROCESSES	→	SPECIFIC ISSUES HIERARCHY

EXAMPLE:

CONTAINMENT BY ENG. BARRIER	W. P. RELEASES RADIONUCLIDES	REPOSITORY INDUCED CHANGE	2.3 WHAT ARE HYDROTHERMAL CONDITIONS AT WASTE PACKAGE? 2.5 WHAT ARE PROPERTY CHANGES IN WASTE PACKAGE MATERIALS? 2.9 HOW DO EH, PH AND CHEMISTRY CHANGE IN TIME?

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ISSUE IDENTIFICATION PROCESS - NPO/ONWI

PERFORMANCE OBJECTIVES 10 CFR 60 → METHODOLOGY OBJECTIVES DERIVED FROM EVENTS, CONDITIONS, PROCESSES → SPECIFIC ISSUES / HIERARCHY

EXAMPLE:

CONTAINMENT BY
ENG. BARRIER

WASTE PACKAGE

- LIFETIME
- RELIABILITY
- ENVIRONMENT
- BRINE AVAILABILITY

1. WASTE PACKAGE CORROSION

   WHAT IS BRINE QUANTITY?
   WHAT IS BRINE COMPOSITION?
   WHAT ARE RADIOLYSIS EFFECTS?
   WHAT ARE HOST ROCK HYDRO-THERMAL PROPERTIES?
   WHAT IS FORMATION RATE OF CORROSIVE PRODUCTS?

2. WASTE PACKAGE STRENGTH

   WHAT ARE EFFECTS ON WASTE PACKAGE MATERIALS

CHAPTER 10 FORMAT

REG. GUIDE 4.17 FORMAT OUTLINE

10.1 RATIONALE FOR PLANNED CHARACTERIZATION PROGRAM

10.2 ISSUES TO BE RESOLVED AND INFORMATION REQUIRED DURING SITE CHARACTERIZATION

- 10.2.1 UNRESOLVED ISSUES RELATED TO SITE SELECTION
- 10.2.2 UNRESOLVED ISSUES RELATED TO DESIGN OF GEOLOGIC REPOSITORY OPERATIONS AREA
- 10.2.3 UNRESOLVED ISSUES RELATED TO WASTE FORM AND PACKAGE
- 10.2.4 PERFORMANCE ASSESSMENT ISSUES
- 10.2.5 ISSUES FOR NRC REVIEW

10.3 PLANNED TESTS AND EXPERIMENTS

- RELATE TO 10.2 ISSUES

10.4 PLANNED TESTING, INSTRUMENTATION, AND MONITORING

- RELATE TO 10.3

10.5 PLANNED SITE PREPARATION ACTIVITIES

10.6 MILESTONES, ANALYSES, DECISION POINTS

10.7 SCHEDULE

PLANNED NPO/ONWI APPROACH TO CHAPTER 10 FORMAT

10.1 RATIONALE FOR PLANNED CHARACTERIZATION PROGRAM

- UNCHANGED FROM R.G. 4.17

10.2 ISSUES TO BE RESOLVED AND INFORMATION REQUIRED DURING SITE CHARACTERIZATION

- UNCHANGED FROM R.G. 4.17 EXCEPT
  - 10.2.5 (ISSUES FOR NRC REVIEW) RELOCATED TO 10.4

10.3 PLANNED TESTS AND EXPERIMENTS

- CONSOLIDATE WITH NRC R.G. 4.17 SECTION 10.4
  - PLANNED TESTING, INSTRUMENTATION AND MONITORING

10.4 ISSUES FOR NRC REVIEW

10.5 PLANNED SITE PREPARATION ACTIVITIES

- UNCHANGED FROM R.G. 4.17

10.6 MILESTONES, ANALYSES DECISION POINTS

- UNCHANGED FROM R.G. 4.17

10.7 SCHEDULE

- UNCHANGED FROM R.G. 4.17

CHAPTER 10 FORMAT

BASIS FOR NPO RECOMMENDED CHAPTER 10 FORMAT REVISION

- DIFFICULT TO MAINTAIN CONTINUITY IN REG. GUIDE 4.17 FORMAT
- UTILITY TO READER IS LESSENED BY CONTINUAL NEED TO BACKTRACK AND INTEGRATE THROUGHOUT CHAPTER
- SIMPLIFY PREPARATION AND NRC REVIEW
- CONSISTENT WITH NRC SCR REVIEW PLAN

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CHAPTER 10 FORMAT

NRC SCR REVIEW PLAN

SITE ISSUE ANALYSIS FORMAT

1. NAME OF THE SITE:
2. STATEMENT OF THE ISSUE (IN FORM OF A QUESTION):
3. IMPORTANCE OF THE ISSUE TO REPOSITORY PERFORMANCE:
4. PORTIONS OF 10 CFR 60 THAT ARE DIRECTLY CONNECTED TO THE ISSUE:
5. SUMMARY OF THE PRESENT STATE OF KNOWLEDGE, WITH ANALYSIS OF UNCERTAINTIES:
6. SUMMARY OF THE ADDITIONAL INFORMATION NEEDED TO RESOLVE THE ISSUE BY THE TIME OF CONSTRUCTION AUTHORIZATION APPLICATION:
7. SUMMARY OF THE PLANNED APPROACHES TO TESTING, TESTS, TEST METHODS AND INVESTIGATIONS, AND DATA ANALYSES AND ASSESSMENTS TO PROVIDE THE INFORMATION NEEDS OF (6):
8. ANALYSIS OF (7) AS TO COMPLETENESS, PRACTICALITY AND LIKELIHOOD OF SUCCESS:

<u>REFERENCES:</u> ON A SEPARATE PAGE LIST ALL REFERENCES USED IN THE ANALYSIS.

REFERENCE, FIGURE 3, <u>NRC REVIEW PLAN FOR SITE CHARACTERIZATION REPORTS</u>

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CHAPTER 10 FORMAT

APPROACH TO ISSUES FOR NRC REVIEW - SECTION 10.4

SECTIONS 10.1 THROUGH 10.3 HAVE IDENTIFIED ISSUES, DATA NEEDS AND PLANS BEING ADDRESSED AS A PART OF DETAILED SITE CHARACTERIZATION AND RELATED ACTIVITIES. THIS SECTION PROVIDES ISSUES WHICH, IF ADDRESSED BY NRC, COULD PROVIDE USEFUL GUIDANCE TO THE SALT PROGRAM. THE ISSUES ARE IN TWO CATEGORIES:

- ISSUES THAT WOULD APPEAR TO BE RESOLVED FOR THE SITE FROM A DOE PERSPECTIVE BUT WHICH REQUIRE NRC CONCURRENCE TO REACH CLOSURE (SECTION 10.4.1).
- ISSUES THAT NEED TO BE ADDRESSED AND RESOLVED IN THE NRC DOMAIN AND WHICH ONCE RESOLVED, WILL PROVIDE VALUABLE GUIDANCE TO THE DEPARTMENT (SECTION 10.4.2).

CHAPTER 10 FORMAT

SAMPLE CONTENT OF SECTION 10.4

10.4.1 ISSUES REQUIRING NRC CONFIRMATION OF RESOLUTION

10.4.1.1 EROSION/DENUDATION. BASED ON EXISTING INFORMATION PRESENTED IN CHAPTER 3, THE DEPARTMENT CONTENDS THAT A REPOSITORY AT THE SITE WOULD NOT BE AFFECTED BY EROSION OR DENUDATION TO AN EXTENT THAT WOULD BE SIGNIFICANT TO POSTCLOSURE PERFORMANCE.

10.4.1.2 VOLANISM. BASED ON EXISTING INFORMATION PRESENTED IN CHAPTER 3, THE DEPARTMENT CONTENDS THAT VOLCANIC PROCESSES ARE NOT ACTIVE AND WOULD NOT AFFECT THE PERFORMANCE OF A REPOSITORY AT THE SITE.

10.4.1.3 POTENTIALLY ADVERSE CONDITIONS. BASED ON INFORMATION IN CHAPTERS 2, 3, 5, 6, AND 7, THE DEPARTMENT CONTENDS THAT THE "POTENTIALLY ADVERSE CONDITIONS" STIPULATED IN 10 CFR 60.122(C) (1), (4), (12), (13), (15), (16), (19) ARE NOT ISSUES REQUIRING FURTHER CONSIDERATION FOR THE SITE.

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PROCEDURES FOR DATA ACCESS

- DIRECTIVE TO ONWI TO PUBLISH DATA SEPARATE FROM ANALYSES WITHIN 30-45 DAYS OF GENERATION
- INSTITUTION OF REVISED OR NEW PROCEDURES TO ACCOMPLISH THIS
- DEVELOPMENT OF INDEXES
- DEVELOPMENT OF HANDBOOK FOR PROVIDING UNANALYZED DATA TO INTERESTED PARTIES

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PARADOX BASIN - DAVIS CANYON

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-301)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122	A	What is salt depth and thickness at test site?	Depth and thickness of repository salt bed at exploratory shaft	• Core Engineering Borehole (EBH) • Interpret seismic line in Davis Canyon
60.122 (c)(4)	B	Existence of Quaternary faults in the candidate area and within 8km (5 miles) of site.	Data on presence or absence of Quaternary displacement Subsurface configuration of faults	• Trench faults and lineations • Seismic reflection surveys • Geologic mapping and imagery interpretation
60.122	C	What is potential for strong subsurface ground motion?	Data on subsurface ground motion	• Record induced seismic motion in repository layer and on surface
60.122	D	What are potential mineral resources?	Data on oil, gas and mineral occurrences in area	• Monitor all borings for resource potential • Literature search
60.112 (b) 60.122 (c)(d) 60.122 (c)(4) 60.122 (c)(5)	E	What are past and future natural changes in hydro-geologic and geochemical regime?	Estimate on timing and magnitude of changes in precipitation	• Analysis and dating of Quaternary sediments and fossils • Investigation of historic spring sites • Chemical data from wells
60.122	F	What is seismic attentuation in the Colorado plateau?	Seismic attentuation data for Paradox Basin	• Amplitude analysis of local earthquakes

Attachment 13

PARADOX BASIN - DAVIS CANYON

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-301)
(Continued)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122	G	What is potential for differential incision/uplift rates of the Colorado Plateau?	Data on uplift and incision rates in region around Gibson Dome	• Investigate, map and date Quaternary deposits and surfaces along Colorado River near Gibson Dome location
	H	What are geomorphic processes that could affect the repository site?	Data on ages and types of Quaternary sedimentation and geomorphic processes they represent	• Quaternary mapping of Gibson Dome location • Test pits • Seismic refraction surveys
60.122	I	What are the hydrogeologic and geochemical conditions at the Gibson Dome location relative to estimating radionuclide travel times to the biosphere?	Data necessary to identify ground-water circulation patterns Bulk hydrogeologic properties of formation in the Gibson Dome area	• In situ testing of up to 13 boreholes • Lab analysis of core and fluids recovered from boreholes • Monitor existing wells • Gauge streams that cross Shay graben • Sample springs in Marble Canyon, Arizona • Install meteorological stations • Install seepage meters along Colorado River

PARADOX BASIN - DAVIS CANYON
SUMMARY OF ISSUES RELATED TO SITE SELECTION
(Reference ONWI-301)
(Continued)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (c)(10)	J	What is potential for salt dissolution?	Data on activity, extent and dissolution mechanism of Lockhart Basin	• Drill and test 5 boreholes • Excavate trenches and test pits • Geophysical surveys
60.122	K	What are ground-water resources?	Data on quality and quality of ground-water resources in area	• Obtain ground-water resources data from up to 13 boreholes to drilled-in area • Monitor existing wells in area
60.122 (c)(1) 60.122 (c)(2)	L	What is potential for man-induced changes in the hydrologic and geochemical regime?	Obtain data on range of changes possible due to man's activity	• Document existing or planned projects • Model effects of proposed projects
60.122 (d)	M	Is the minerology of the repository layer suitable?	Data on chemical and thermal properties of minerals in repository layer	• Xray chemical, thermal and isotope lab analysis

PARADOX BASIN - DAVIS CANYON
SUMMARY OF ISSUES RELATED TO DESIGN
(Reference ONWI-301)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (c)(4)	A	What is the potential for faults and fractures in the disturbed zone?	Data on subsurface deformation in vicinity of exploratory shaft	• Interpret seismic line in Davis Canyon
60.122	B	What is maximum credible earthquake?	Obtain data on spatial, temporal, and magnitude distribution of seismicity	• Continue microearthquake monitoring • Obtain earthquake data from other sources • Perform hydrofracture in boring
60.122	C	What is potential for mining induced seismicity?	Evaluation of potential for mining induced seismicity	• Hydraulic fracturing in boreholes • Modeling of conditions at Book Cliffs and site
60.122 (c)(21) 60.132 (a)(2) 60.132 (e)(1) 60.132 (e)(3) 60.132 (k)(1)	D	What is stability of subsurface openings (exploratory shaft)?	Data on geomechanical parameters for use in mathematical analysis of behavior of subsurface shafts and openings	• In situ tests • Lab testing of core • Hydrofracture tests in other boreholes
	E	What is potential for gas in underground excavations?	Data on gases that could be produced in exploratory shaft	• Monitor drilling fluids from EBH

PARADOX BASIN - DAVIS CANYON

SUMMARY OF ISSUES RELATED TO DESIGN

(Reference ONWI-301)

(Continued)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (c)(20)	F	What are hydrogeologic considerations for construction? Derations?	Shaft site specific data on aquifer characteristics	• Hydrogeologic testing in EBH
60.122 (c)(1)	G	What is potential for probable maximum flood?	Determine extent of flood plain Determine probable maximum flood Determine siting requirements or engineering factors necessary to mitigate potential impact	• Survey flood history of streams in site vicinity • Determine stream slopes, stream cross sections, area topography, geomorphology
60.122	H	Will the water quality of the Colorado River and surface water upstream and downstream from withdrawal points be affected by site characterization or repository activities?	Potential for degradation of Colorado River water quality water quality	• Study potential effects of runoff from spoil piles construction areas and the facility • Assess potential effects of surface water withdrawal on increases in salinity • Predict potential salinity increases of surface water upstream and downstream from withdrawal points if necessary • Construct surface water quality and hydrologic models, if necessary

PARADOX BASIN - DAVIS CANYON

SUMMARY OF ISSUES RELATED TO DESIGN

(Reference ONWI-301)
(Continued)

Applicable 10 CFR 60 Criteria	Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122	I Is adequate water supply available?	Water sources available within reasonable distance of site. Determine methods of acquisition and transportation.	• Identify and assess the potential for developing site specific water sources • Develop other engineering measures to conserve water • Define steps to assess legal rights to an adequate water supply • Evaluate water transportation methods and corridors.

RICHTON DOME

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-293)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (2) 60.122 (c)(5)	A	Mississippi Regional Hydrology	Results will contribute to regional hydrologic modeling.	Additional multiple wells will be completed at as many as five sites identified from the area studies. An extensive program of logging, aquifer tests, geochemical testing, and monitoring is planned.
60.122 (c),(f) 60.122 (c)(2) 60.122 (c)(5)	B	Regional Ground-Water Flow Modeling	The data and models will allow reliable interpretations of existing conditions and projections of conditions resulting from anticipated changes.	Refinement of model will continue as additional hydrologic data are obtained.
60.122 (c)(10)	C	Dome Dissolution	1. Will determine whether anomaly exists, define its extent, and determine origin of the saline water. Results will indicate relation of suspected anomaly to possible dissolution. 2. (as above)	1. Ground water from existing domestic wells will be sampled and analyzed to determine whether saline waters are present. If so, test wells will be drilled and sampled or cored to base of Hattiesburg Formation or top of caprock (about 480 feet or 146 m), with lithologic and geophysical logging and aquifer testing. Lab testing is planned for sedimentological analysis of cuttings or core and geochemical analysis of ground-water. Surface-based resistivity survey planned to evaluate lateral extent of possible anomaly.

RICHTON DOME

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-293)

(Continued

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
				2a. Initial work will involve: water sampling, lab testing, water-level measurements, and interpretation of geophysical logs from existing wells. Extent of possible anomaly will be defined by resistivity. 2b. If needed, additional wells will be completed and tested in the Wilcox Group, Cook Mountain Formation, Vicksburg Group, Catahoula Sandstone, and Hattiesburg Formation.
60.122 (c)(10)	D	Saline Surface Water	Will determine whether reported salinity is from dome dissolution, human activities, or other factors.	Selected stations will be sampled monthly and full water chemistry analysis will be run. Human influences in the area will be investigated.
60.122 (d) 60.122 (g) 60.122 (h) 60.122 (c)(8)	E	Over-Dome and Near-Dome Geochemistry	1. Results will provide model of geochemical conditions and reactions near the dome.	1. Extensive program of lab testing and interpretation will characterize the chemical environment and water/rock interactions.

RICHTON DOME

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-293)
(Continued)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
		(Rock Chemistry)	2. Will provide comprehensive descriptions of the mineral assemblages present and in depth interpretations of their origins.	2. Detailed laboratory analyses of selected core and cuttings, including petrographic, geochemical, microchemical, and isotopic techniques. Extensive interpretations to determine chemical compositions, authigenic and diagenic minerals, reactions, and related questions.
		(Water Chemistry)	3. Will provide detailed characterization of groundwater chemistry.	3. Detailed chemical and isotopic analyses of water samples from existing and new borings, measuring major anions and cations, pH, Eh, minor and trace constituents, and ratios of selected stable and radioactive isotopes. Results will be interpreted to identify chemical types of ground water, define extent of mixing, and establishing chronology of geochemical events.
60.122 (a) 60.122 (b)	F	Regional Geologic Structure	The planned investigations will provide a comprehensive understanding of regional geologic structure.	Planned investigations include: 1. A systematic compilation and organization of all available geophysical data, including purchase of proprietary data, needed to correct deficiencies, and interpretations of the integrated data set.

RICHTON DOME

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-293)
(Continued)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
				2. The postulated Phillips fault system will be investigated, first using existing seismic reflection and well data, followed by new seismic surveys if needed.
				3. All available regional geologic data will be combined into an integrated 3-dimensional model of the basin.
60.122 (a) 60.122 (e)	G	Regional Uplift/ Subsidence	Causes and rates of vertical movements will be determined.	Vertical movements indicated by the leveling data will be checked using geomorphic evidence, and air photo analysis. Records of water and hydrocarbon extraction will be examined for relation to vertical movements.
60.122 (c)(19)	H	Sulfur Exploration Wells	Potential impacts of these wells will be determined.	Field inventory to find exact locations, depth and condition. Detailed review of existing recordes. Re-entry of selected wells.

RICHTON DOME

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-293)
(Continued)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (c)(18) 60.122 (c)(19) 60.122 (c)(17)	I	Natural Resources	Potential resource conflicts will be determined. Effects of past exploration will be analyzed. Potential for accidental human intrusion will be evaluated.	Results of additional exploration will be added to the existing resource data. Specific exploration and geochemical testing will be done if needed. Potential impacts will be analyzed.
60.122 (c) 60.122 (f)	J	Geohydrologic Setting	Will provide detailed hydrologic information, including: hydrostratigraphy, aquifer properties, horizontal and vertical head distributions, flow rates, water chemistry and saline anomalies, and ages of water at various points in the hydrologic system.	Additional refinement of regional hydrostratigraphy by geologic exploration, aquifer testing, laboratory hydraulic testing on core samples, measurement of in-place fluid pressures and water levels, and determinations of water chemistry and "age".
60.122 (c) 60.122 (c)(2) 60.122 (c)(6)	K	Ground-water reservoir use and potential stress	Will provide an accurate picture of existing reservoir use, a reliable forecast of future use, and most probable projections of stresses on the ground-water system.	Existing data will be verified and future withdrawal and injection locations and rates will be projected from population and planning data. Stress models will be analyzed using various schemes of development and natural recharge/discharge variations resulting from climate change.

RICHTON DOME

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-293)
(Continued)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (c)(1) 60.122 (c)(2) 60.122 (c)(2) 60.122 (c)(6)	L	Surface Hyrdology	Surface hydrologic conditions will be verified. Surface hydrologic data will contribute to hydrologic modeling.	Additional field inspections, checking of records, lab testing and analysis to confirm projections of water use, relationship between surface water and ground water, and surface water chemistry.
60.122 (f),(g), (h) 60.122 (c)(7), (8), (9)	M	Water-Rock Reactions	Will aid in evaluating potential for migration of radionuclides through the geohydrologic system.	Geochemical analyses of core samples and of water samples will be correlated and interpreted to determine ion speciation, saturation indices, and reaction paths. Conceptual models of the water-rock geochemical processes will be developed.
60.122 (d) 60.122 (c)	M	Chronology of geochemical events	Will date various geochemical/ geological events.	Samples of anhydrite, gypsum, and calcite from various levels of the caprock will be selected for dating, using uranium disequilibrium methods.. Gypsum ages are expected to date hydration of anhydrite or precipitation of the gypsum. Calcite ages expected to date formation of limestone parts of caprock.

RICHTON DOME

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-293)
(Continued)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (d) 60.122 (g) 60.122 (h) 60.122 (c)(8) 60.122 (c)(7)	O	Sources of fluid inclusions in the salt and caprock minerals	Will provide an inventory of the fluid inclusions, their compositions, and probable/possible sources. Will provide a conceptual model of fluid migration in the salt and caprock.	Mass spectrometric analyses are planned to determine isotopic ratios in selected samples. Results will be analyzed and compared with isotopic data from the site and in the literature to evaluate sources of the fluids and their migration patterns.
60.122 (g) 60.122 (c)(8)	P	Radionuclide retardation	Will provide a conceptual model describing transport of radionuclides that might be released from a potential repository.	Solubilities and transport of the relevant radionuclides will be calculated from data compiled on flow paths, travel times, dispersivity, chemistry of the groundwater and formations, and water-rock reactions.
60.122 (a) 60.122 (c)(4)	Q	Regional Faulting	Will provide detailed description of geologic structure.	Purchase and interpretation of additional seismic reflection data. New high resolution seismic surveys.

RICHTON DOME

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-293)
(Continued)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (c)(4)	R	History of Dome Growth	History of dome movement will be confirmed.	Comprehensive program investigating near dome faulting will provide data from which history of dome movement will be interpreted.
60.122 (b)(6)	S	Suspected Quaternary Faults	Determine age, extent, and character of faulting. Detect current seismicity.	Comprehensive program addressing near dome faulting: shallow test borings with age dating and geophysical logging. High resolution seismic and resistivity surveys, remote sensing, surface mapping, and tranching on photolineaments. Microseismic network.

RICHTON DOME

SUMMARY OF ISSUES RELATED TO DESIGN

(Reference ONWI-293)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (c) 60.132 (e) 60.133 (a)	A	Overburden and Salt Stock Characteristics	Will provide detailed information on overburden, caprock, and salt properties at the borehole location.	Corehole planned to below probable repository depth. Will include geophyscial logging, hydrologic and geomechanical testing. Samples will be obtained for geochemical, geomechanical, and petrographic analysis.
60.122 (c) 60.132 (g)	B	Near Shaft Hydrology	Ground-water control requirements for excavation, lining, and operation of the shaft will be determined.	Several 8-inch or 6-inch pumping and monitoring wells will be clustered at several locations around the proposed shaft location and will be completed in aquifers that may be important for shaft construction, as determined from results of the Overburden and Salt Stock Characteristics Borehole. Aquifer properties will be determined from an extensive pump test program.
60.122	C	Near-Dome/Over-Dome Ground-Water Model	Model will be used to anticipate stresses on the ground water system from shaft construction, surface facilities, and other human influences. It will aid in evaluations of water control needs for the shaft and will help in planning continued exploration and testing.	Two-and-three dimension digital computer models will be developed, incorporating hydrologic information from formations over and near the dome and from the caprock.

RICHTON DOME

SUMMARY OF ISSUES RELATED TO DESIGN

(Reference ONWI-293)

(Continued)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (c)(2) 60.122 (c)(5)	D	Ground-Water Stresses Near Proposed Surface Facilities	Will determine impact of repository water use on the hydrologic system.	Determine present water use, projecting future water use, and analyze the effects of repository water use.
60.122 (i) 60.122 (j) 60.122 (c)(4) 60.132 (e) 60.132 (k) 60.133 (a)	E	Near Shaft Characterization	Will provide detailed information on stratigraphy, formation properties, and geologic structure near the planned shaft.	Detailed geophysical surveys in the planned shaft area, including gravity, high resolution, and dipole resistivity. Comprehensive interpretation using all available subsurface data.
60.122 (e) 60.122 (b)(5)	F	Near-Shaft Surface Mapping	Detailed surface geologic maps will aid interpretation of all other exploration in the area.	Detailed analysis of geology and topography using new air-photos at a scale of 1:6000 or larger - Will produce detailed geologic and geomorphic maps at 1:6000 scale.

RICHTON DOME

SUMMARY OF ISSUES RELATED TO DESIGN

(Reference ONWI-293)

(Continued)

Applicable 10 CFR 60 Criteria	Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (c)(12) 60.122 (c)(14) 60.122 (c)(13)	G Regional Seismicity	Seismic and tectonic conditions will be confirmed for the site.	Microearthquake network will be implaced covering the area of the dome and the Phillips fault. Interpretations of seismic and geologic data will address seismic source and tectonic stability.
60.122 (c)(1)	H Flood Analysis	Planned facility will be located and designed to avoid or mitigate flooding hazards.	Results from the investigation of surface hydrology will be analyzed for specific problems related to surface flooding. This will be considered in layout of the proposed surface facility. Any conflict will be analyzed and alternatives will be considered.
60.132 (a)(2) 60.132 (g) 60.133 (a)	I Shaft Construction Techniques	Will determine impacts on the hydrologic system and hydrologic considerations for shaft design.	Review of shaft construction and dewatering techniques. Analysis of changes in the hydrologic system from shaft construction, (using near shaft hydrologic model).

RICHTON DOME

SUMMARY OF ISSUES RELATED TO DESIGN

(Reference ONWI-293)
(Continued)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.132 (e) 60.132 (g) 60.133 (a) 60.122 (f) 60.122 (i)	J	Structure and Stratigraphy of Sediments Over and Near Dome	Will characterize stratigraphy and structure, verifying design parameters and confirming site suitability.	Additional drilling with detailed petrologic and paleontologic examination of return. Additional high-resolution seismic and resistivity surveys. Both will be used to refine interpretations of stratigraphy and structure. Particular attention to age and character of faulting.
60.132 (e) 60.133 (a) 60.122 (i) 60.122 (j) 60.122 (c)(20) 60.122 (c)(21) 60.122 (c)(4)	K	Stratigraphy and Structure in the Salt Stock	1. The planned invesitgations will provide an accurate and reliable model of the salt stock and will identify anomalous zones that may be present. 2. Will identify solution cavities or other anomalous features along edges of the dome.	1. Detailed geophysical and borehole surveys: high resolution seismic reflection and seismic refraction, electrical resistivity, borehole seismic refraction and cross-hole seismic velocity. Borehole geophysical logs including radar, long-spaced resistivity, and borehole gravity. 2. Nature of the dome/sediment interface will be evaluated using cross-hole seismic surveys, long spaced resistivity logs in boreholes, and downhole gravity. High resolution seismic reflection refraction, gravity and electrical resistivity surveys will be run over the margins of the dome.

RICHTON DOME

SUMMARY OF ISSUES RELATED TO DESIGN

(Reference ONWI-293)

Applicable 10 CFR 60 Criteria	Issue	Information to be Obtained	Activities Proposed to Resolve Issues
		3. Will provide refined estimates at dome shape.	3. A gravity survey of the area within three km of the dome, incorporating public domain and private (purchased) data as well as new field surveys. The combined data will be integrated and interpreted with computer modeling to refine estimates of dome shape.
60.122 (c)(13)	L Induced Seismicity	Potential for earthquakes from nearby oil and gas production will be determined.	Comparison of production records and historic seismicity, particularly regarding 1978 Melvin, Alabama earthquake, to evaluate possible relationship. Micro-seismic monitoring.
60.132 (e) 60.132 (k) 60.132 (d)(2) 60.122 (c)(20) 60.122 (c)(21)	M Thermal and Mechanical properties of the Salt Caprock, and Sediments	Thermal and mechanical properties will be determined.	Additional literature and generic studies. Laboratory tests on samples from test borings. Downhole and cross hole geophysical surveys, in situ stress measurements, and bore hole closure measurements to establish time dependent deformations due to deviatoric stresses.

PERMIAN BASIN

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-368)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (e)(i)(j) 60.122 (c)(16)	A	Host Rock Characteristics What is the thickness, depth and quality of the host rock?	Depth, thickness, extent, salt quality and uniformity, nature of impurities, lithology and distribution of non-salt inter-beds	• Coring • Hydrologic test wells • Engineering borehole • Stratigraphic test wells • Geophysical logging • Exploratory shaft • Seismic reflection profiling • Salt sample analyses
60.112 (a) 60.122 (a) 60.122 (c)(4)	B	Rock Fractures Are there faults and fractures in the rock that are potential hazards to construction or that provide hydrologic pathways to the biosphere?	Location, orientation, extent, nature of any offset, nature of any filling, openness, interconnection, persistence, earthquake source identification, determination of data of last movement of faults	• Coring • Hydrologic test wells • Engineering borehole • Stratigraphic test wells • Geophysical logging • Exploratory shaft • Remote-sensing studies • Geologic mapping • Gravity survey • Magnetic surveys • Statistical analysis • Microearthquake survey • Age-dating techniques • Seismic reflection profiles

PERMIAN BASIN

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-368)
(Continued)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (c)(10)	C	Salt Dissolution Has all the salt dissolution been identified; what are the rates of dissolution; is non-host rock dissolution a potential safety hazard; when did dissolution take place; is it still active?	Delineation of marginal dissolution zones, evidence of interior dissolution/subsidence/collapse	• Coring • Hydrologic test wells • Engineering Borehole • Stratigraphic test wells • Geophysical logging • Analysis of remotely sensed images and geologic and and topographic maps • Field checking maps and photos • Dissolution test wells • Fluid sampling and testing • Pump tests • Modeling
60.122 (c)(2) (c)(19)	D	Subsurface Penetrations at site and are there unknown or unrecorded deep holes in vicinity of site?	Locations, depths, diameters, drilling methods, casing left in hole, pumping/injection history, plugging records; impact of drilling and presence of well	• Air photo analysis • Ground and aerial observations • Examination of drilling records • Literature investigation • Consultation • Modeling
60.122 (c)(2) (c)(17) (c)(19)	E	Hydrocarbon Resources What is the potential for hydrocarbon production in the vicinity of the site?	Trend of Upper Pennsylvanian shelf-edge carbonates and associated structures, indentification of source beds and traps	• High resolution seismic reflection profiles • Well data compilation • Commercial exploration activity monitoring • Analysis of core samples and cuttings

PERMIAN BASIN

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-368)

(Continued)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (f) 60.122 (c)(2) (c)(5)	F	Hydrogeology Do the existing hydrologic models predict the local hydrology, flow paths and flow rates?	Apparent fresh-water heads in evaporite section; total and effective porosity, intrinsic permeability, hydraulic conductivity, storage coefficient, transmissivity, fluid viscosity and density, flow rates, flow paths, hydraulic potentials and degrees of hydraulic connection between units	• Hydrologic test wells • Stratigraphic test wells • Engineering borehole • Geophysical logging • PVT water sampling • Pump tests • Repeat-formation tests • Temperature logging • Geochemical analysis • Fluid age-dating • Numerical flow modeling
60.112 (b) 60.122 (c)	G	Surface Hydrology/Flooding Where and when does hazardous flooding occur; what is its magnitude?	• Drainage basins • 100-year flood plains • Probable Maximum Flood (PMF) for each drainage basin using the Maximum Precipitation for the region and including hydrologic factors favorable for maximum flood runoff such as sequential storms and snowmelt • The flood profile in each basin (i.e., backwater curve) • The design basis flood level	• Site selection above flood profile calculated for drainage basin • Site selection that does not have a water impoundment structure upstream the failure of which would cause a flood level approaching that of the PMF o Design Basis Flood Calculation (DBF) level at the site. Consideration of reasonable combinations of flood conditions less severe than the PMF and seismic events o Level of flooding calculation based upon localized intense precipitation on the site and upgradient areas in the vicinity

PERMIAN BASIN

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-368)
(Continued)

Applicable 10 CFR 60 Criteria	Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.130 (2)(i.ii)	II Meteorology and Climatology What are the historical extremes of climate that might be hazardous to a site?	• Available data on meteorological events such as extreme winds, precipitation, snow pack, temperatures and tornadoes occurring in the candidate area and at the site • Data systematically assembled by specialized organizations in recent years and historical data obtained from a search of information sources such as newspapers and local records • A tornado inventory for the region describing each tornado in terms of intensity, path length, and the path width • Design basis events for use in providing adequate protection	o Install meteorological tower to collect site specific data o Determination of the frequency and intensity of extreme meteorological events o Determination of applicability of offsite historic records for estimation of design basis extreme meteorological events o Calculation of design basis for fastest mile wind speed maximum and minimum air temperatures, snowpack weight and probable maximum winter precipitation amount o Description of the Quaternary paleoclimatology of the location with regard to atmospheric, hydrospheric and cryospheric aspects of the successive climatic changes based upon available geologic and biologic evidence

PERMIAN BASIN

SUMMARY OF ISSUES RELATED TO SITE SELECTION

(Reference ONWI-368)

(Continued)

Applicable 10 CFR 60 Criteria	Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.130, continued (2)(i.ii)			o Estimation of potential impacts of climatic changes including: - potential maximum and minimum change in precipitation and air temperature - potential regional wind flow regimes and precipitation patterns - potential for glaciation including times of onset, length, and severity - future changes in sea levels and cryosphere

PERMIAN BASIN

SUMMARY OF ISSUES RELATED TO DESIGN

(Reference ONWI-368)

Applicable 10 CFR 60 Criteria		Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.122 (b)	A	Seismo-tectonic conditions What are the seismotectonic conditions in the area?	Magnitude and directions of principal stresses; anomalous earthquake frequency; design-basis earthquake	• Exploratory shaft instrumentation • Hydrofracture testing • Microearthquake survey • Seismic analysis
60.122 (h) 60.122 (c)(21)	B	Geotechnical characteristics of host rock. What are the geotechnical characteristics of the host rock?	Decrepitation/temperature relation, physical and mechanical properties, creep rate, water content, interbed characteristics, fracture distribution and properties, salt composition	• Literature search • Rock core examination • Petrographic studies • Thermal/mechanical testing • Geophysical log correlations • Exploratory shaft mapping • Chemical Analyses
60.122 (c)(21) 60.130	C	Geotechnical characteristics of non-salt lithologies. What are the geotechnical characteristics of the non-salt rocks?	In situ stresses, swelling potential, open jointing, aggressive ground-water	• Core logging • Laboratory testing • Literature search • Geophysical logging • Fluid chemistry analysis
60.130		Geotechnical characteristics of surficial soils. What are the geotechnical characteristics of surficial soils?	Liquefaction potential, soil strength	• Stratigraphic test wells • Shallow borings • Soil testing
60.130	D	Ground-water design basis. What is the ground-water design basis?	Ground-water conditions	• Shallow test wells in Ogallala • Pump tests

PERMIAN BASIN

SUMMARY OF ISSUES RELATED TO DESIGN

(Reference ONWI-368)
(Continued)

Applicable 10 CFR 60 Criteria	Issue	Information to be Obtained	Activities Proposed to Resolve Issues
60.130	E Topography of site. What is the topography of the site and how does it relate to surface facility design?	Topography of site, slope failure potential, location of access corridor	o Produce topographic maps of site at one-foot contour interval • Examination of soil survey maps and other data

DOE/NRC MEETING
APRIL 19-20, 1983

PURPOSE AND SCOPE

- FIRST MEETING BETWEEN NRC AND NPO PREPARATORY TO SCR/SCP SUBMITTAL
  - ORGANIZATIONAL FAMILIARIZATION AND RESPONSIBILITIES
  - SCHEDULES IN CONTEXT OF LEGISLATION
  - INFORMATION EXCHANGE PROCEDURES AND IDENTIFICATION OF TOPICS FOR FUTURE MEETINGS
- PLANNING FOR FUTURE MEETINGS

[illegible] Packages of
EXPECTED
ATTENDEES

HANDOUTS
FOR 4/19/20/83
MEETING in
C.O., DH

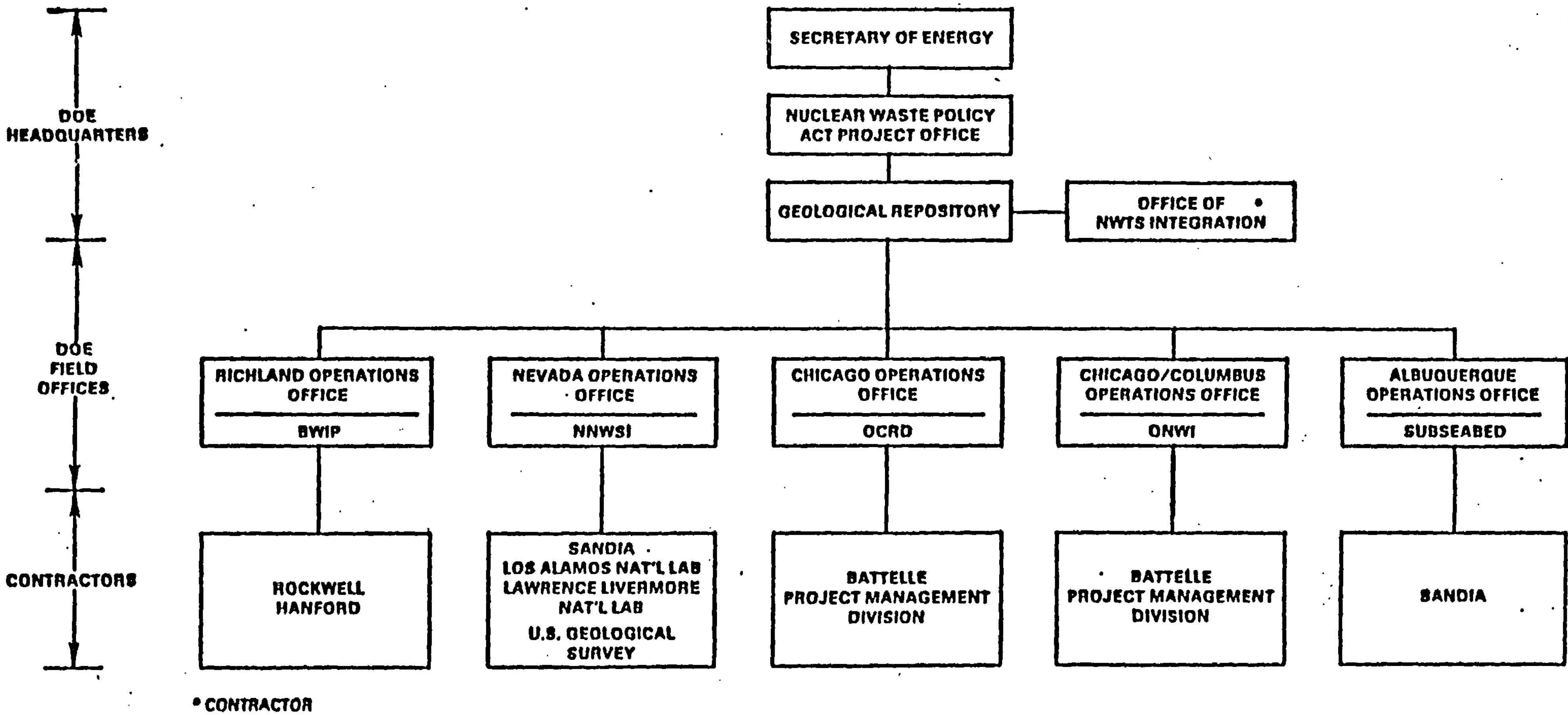
DOE/NPO

ORGANIZATION AND RESPONSIBILITY

L. A. CASEY

ONWI

BATTELLE Project Management Division



NWTS PROGRAM ORGANIZATION

DOE HQ ORGANIZATION

March 23, 1983

Geologic Repository Division

J. William Bennett
Director

J. Simon (S)

R. Stein
Deputy Director

J. Shaheen
E. Hiler (S)
S. Brown (S)

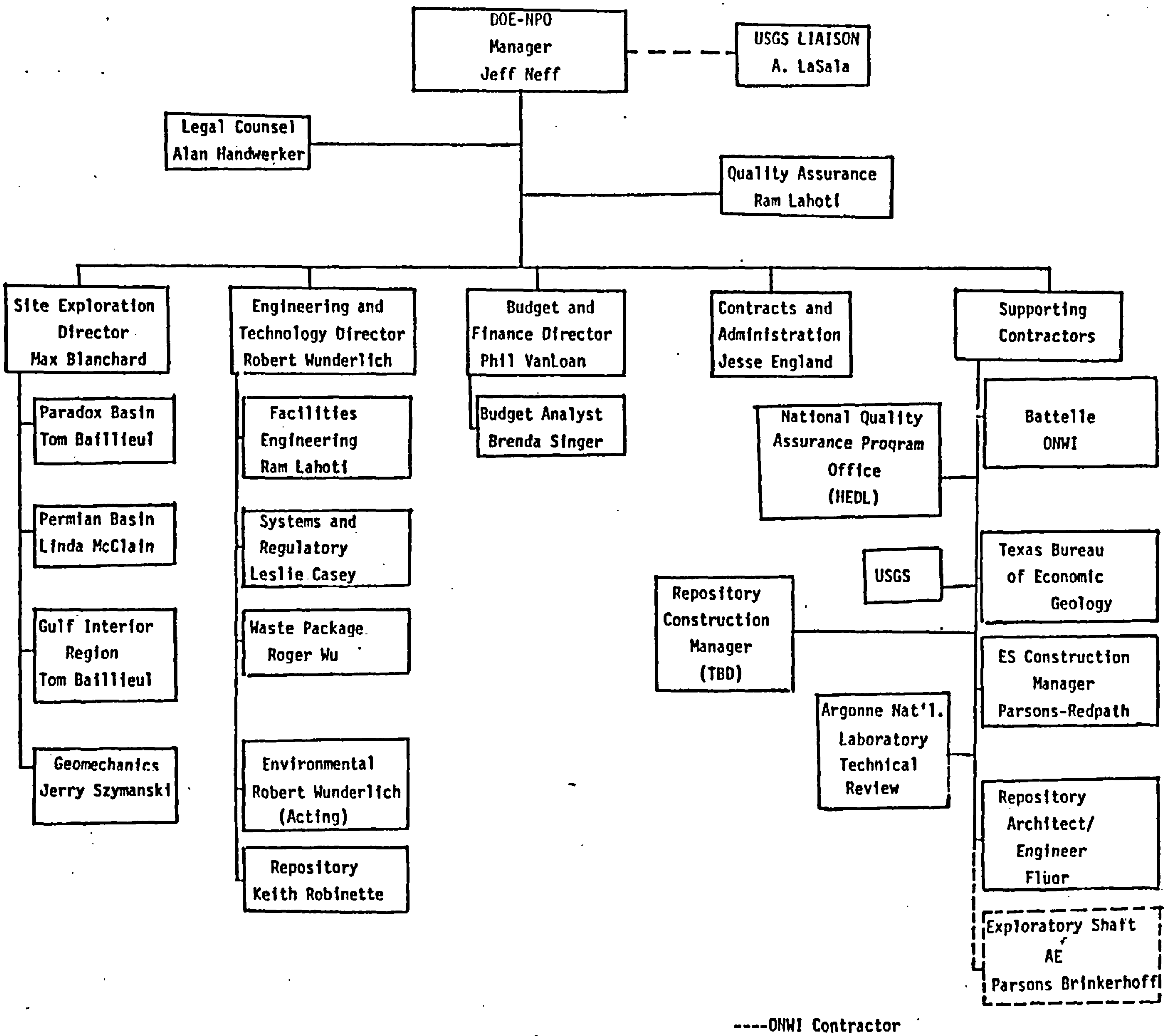
BWIP	Salt/Granite	Nevada Repository	Program Integration	Planning and Scheduling
M. Frei	C. George	J. Fiore	C. Cooley	E. Burton
V. Der C. Newton R. Coleman M. Crum (S)	J. Smiley C. Hanlon V. Lowery C. Klingsberg Vacancy (Geologist) C. Bricker (S)	T. Longo J. Vlahakis P. Minton Vacancy (Mining Engr.) G. Cinalick (S)	W. Eister Z. Kaufman C. Brooke C. Litten (S)	B. McNutt D. Pappas D. Pirkey J. Wesley (S) S. Agee (S)

5

Reponsibilities

BWIP	Salt/Granite	Nevada Repository	Program Integration	Planning and Scheduling
BWIP TEF Overall Budget 10 CFR 60	Salt 1st Repository 2nd Repository Guidelines (Technical) Granite and Other Media National Siting Plan Institutional Planning Socioeconomic/Impact Mitigation	NNWSI Disposal Fund Liaison SEB Process through Contract Signing	SSB MCC/PNL HSA International NRC, CEQ, USGS Interface Waste Form and Acceptance Specifications EPA Liaison (40 CFR 191) HQ Technical Support Contractor Transportation	Mission Plan Project Decision Schedule C&C Agreements Grants Alternative Management Studies

DOE NATIONAL WASTE TERMINAL STORAGE PROGRAM OFFICE

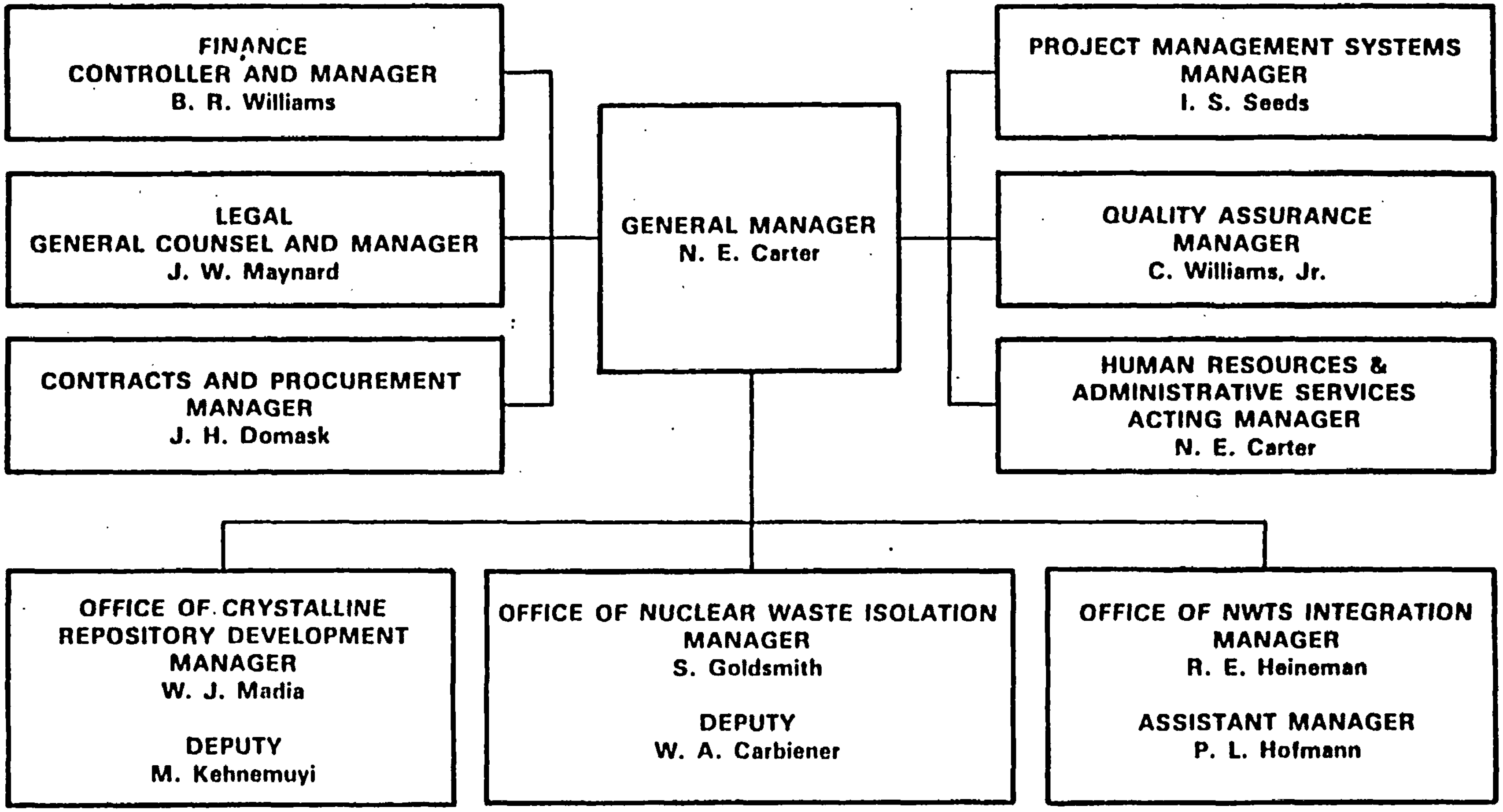


ONWI ORGANIZATION AND RESPONSIBILITY

M. A. GLORA

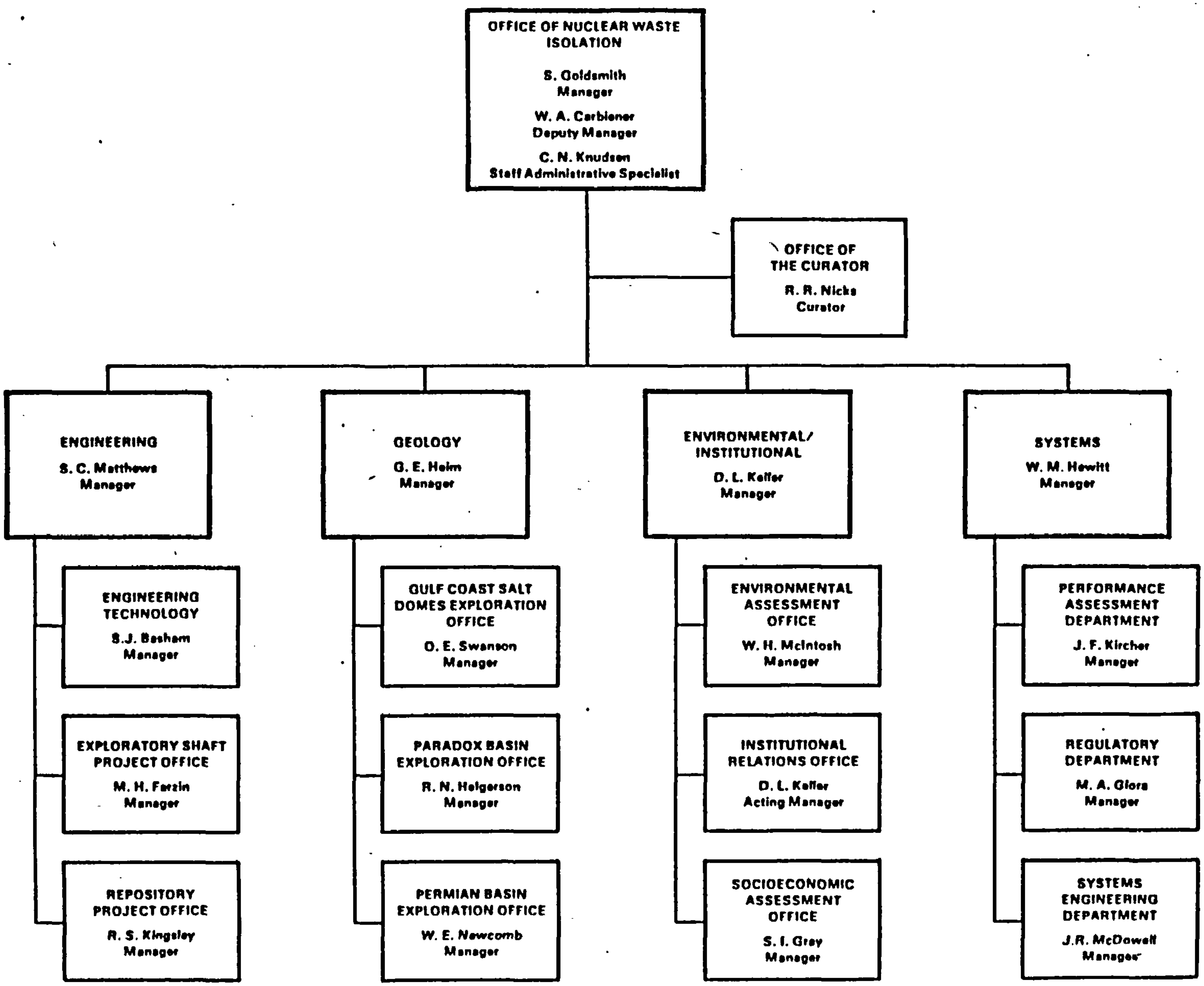
REGULATORY DEPARTMENT

BATTELLE PROJECT MANAGEMENT DIVISION



2/1/83

OFFICE OF NUCLEAR WASTE ISOLATION ORGANIZATION



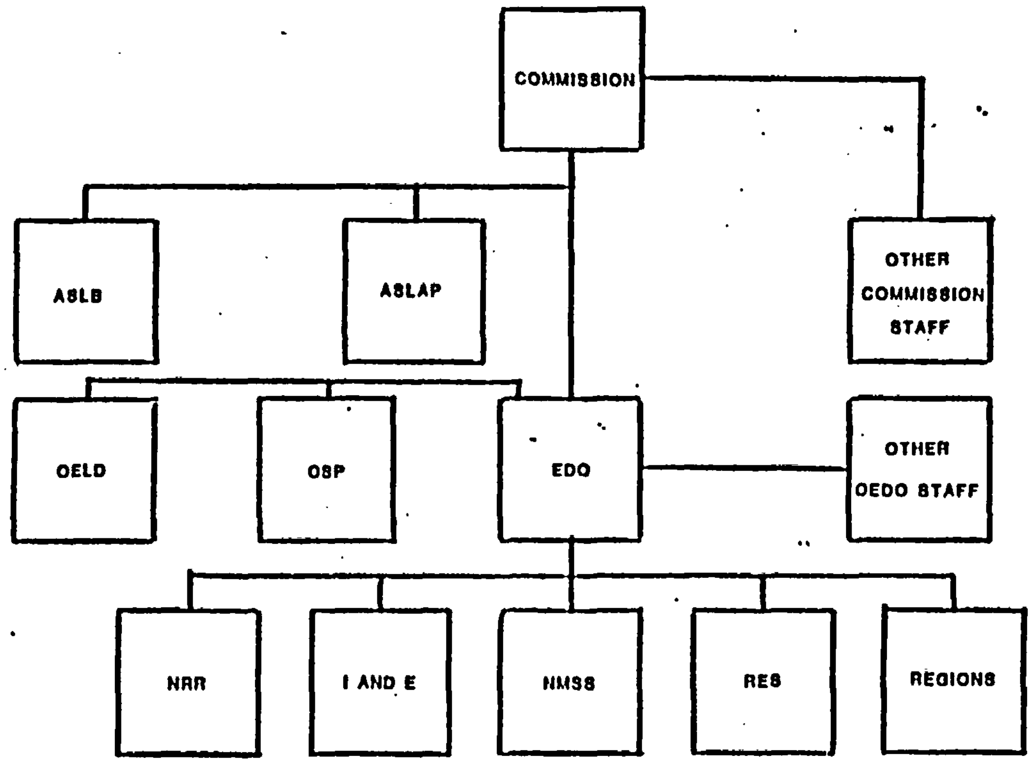
2/1-83

NRC HLW
SITE CHARACTERIZATION AND PRELICENSING ACTIVITIES

BRIEFING 4/19-20/83
NPO - COLUMBUS

APRIL 19-20, 1983

NUCLEAR REGULATORY COMMISSION

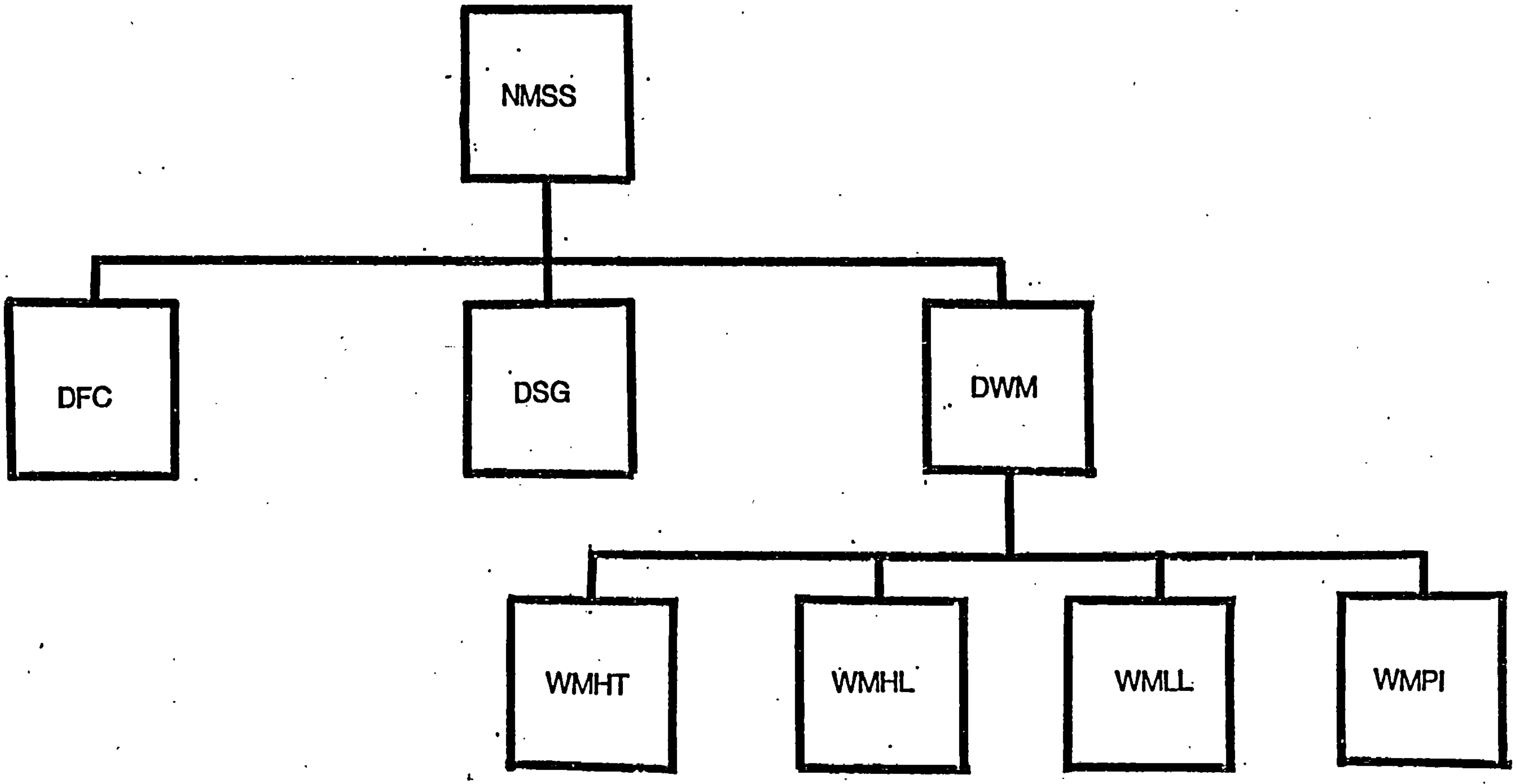


NMSS: OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS
OELD: OFFICE OF THE EXECUTIVE LEGAL DIRECTOR
OSP: OFFICE OF STATE PROGRAMS
RES: OFFICE OF NUCLEAR REGULATORY RESEARCH
REGIONS:

1 – King of Prussia, Pa.
2 – Atlanta, Ga.
3 – Glen Ellyn, Il.
4 – Arlington, Texas
5 – Walnut Creek, Ca.

BRIEFING 4/19 – 20, 1983 NPO – COLUMBUS

OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS (NMSS)



DWM : Division of Waste Management
DFC : Division of Fuel Cycle and Material Safety
DSG : Division of Safeguards

WMHT : High Level Waste Technical Development Branch
WMHL : High Level Waste Licensing Management Branch
WMLL : Low Level Waste Licensing Branch
WMPI : Licensing Process and Integration Branch

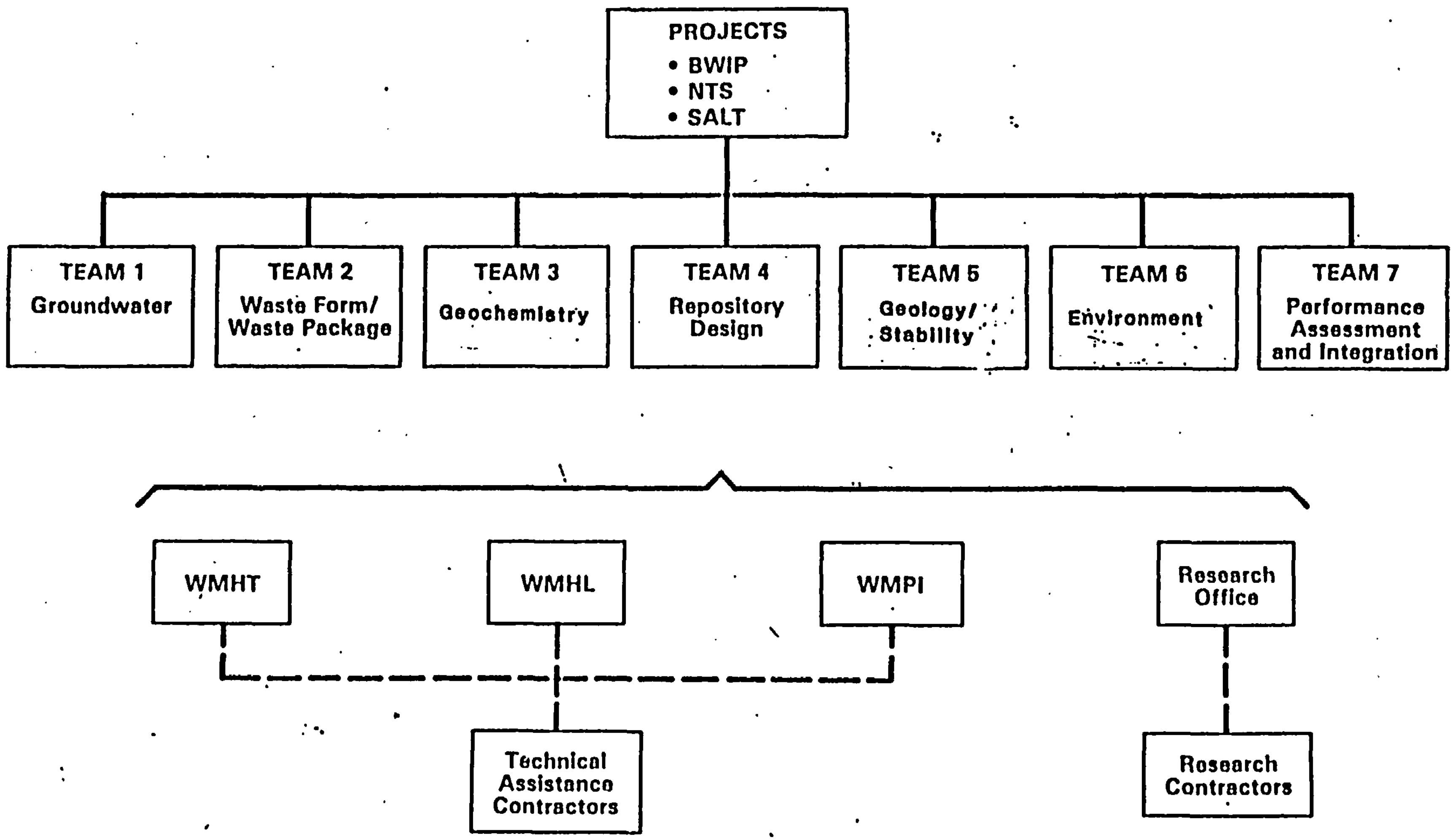
NRC Division of Waste Management
HLW Licensing

WMHT	WMHL	WMPI
•Project management •Site investigations •Facility design	•Regulation development • Performance Assessment •Waste containers • Siting Guidelines/NEPA	•State participation • Licensing Process • Integration and Control • Policy Analysis

NRC HLW Licensing Program

WMHT H. J. Miller	WMHL M. Bell	WMPI J. Bunting
DESIGN J. Greeves	PERFORMANCE ASSESSMENT M. Knapp	INTEGRATION AND CONTROL M. Kearney
SITING P. Justus	WASTE PACKAGE R. Cook	LICENSING PROCESS D. Mattson
SCP REVIEW PROJECTS S. Coplan-NTS R. Wright-BWIP L. Chase-SALT	SPECIAL PROJECTS R. Boyle	POLICY ANALYSIS State Participation Indian Tribes J. Surmeier R. Mac Dougall

SCP REVIEW PROJECTS



CONTRACT
ASSISTANCE AND RESEARCH

GROUNDWATER - GEOLOGIC INVESTIGATIONS

Golder Assoc.
Williams Assoc.
Geotrans
Lawrence Berkeley Labs
University of Arizona
U.S. Army Corps of Engineers

GEOCHEMISTRY

Oak Ridge National Labs
Lawrence Berkeley Labs
Argonne National Labs

REPOSITORY DESIGN

U. S. Bureau of Mines
Golder Assoc.
Engineers International

WASTE CONTAINERS

Brookhaven National Labs

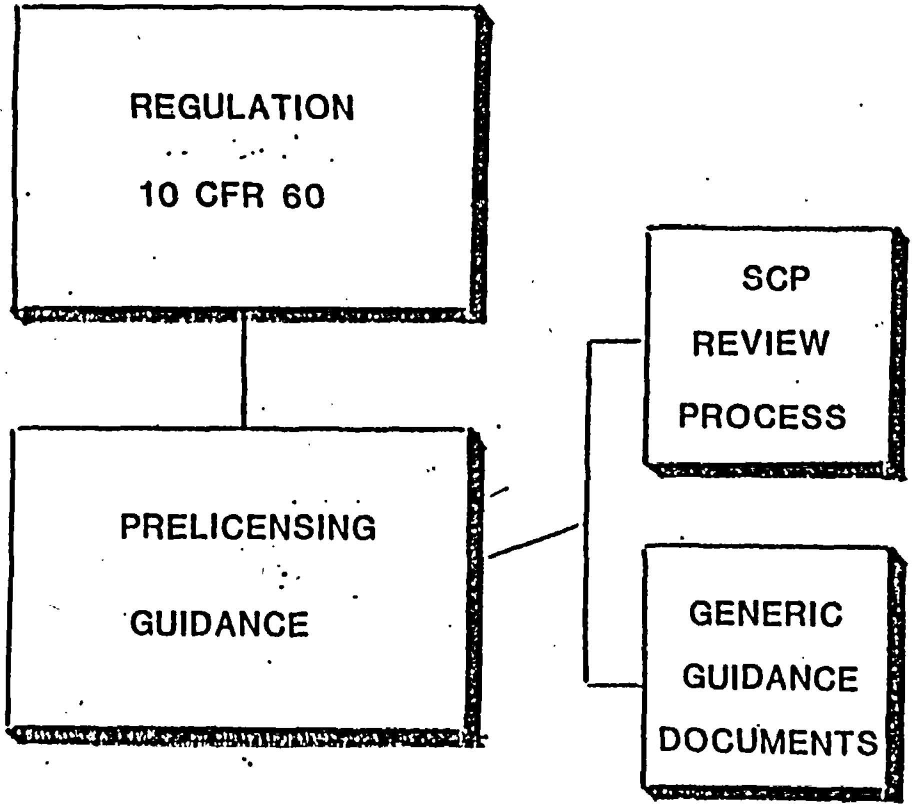
COMPUTER MODELING

Sandia National Labs
Tecknekron

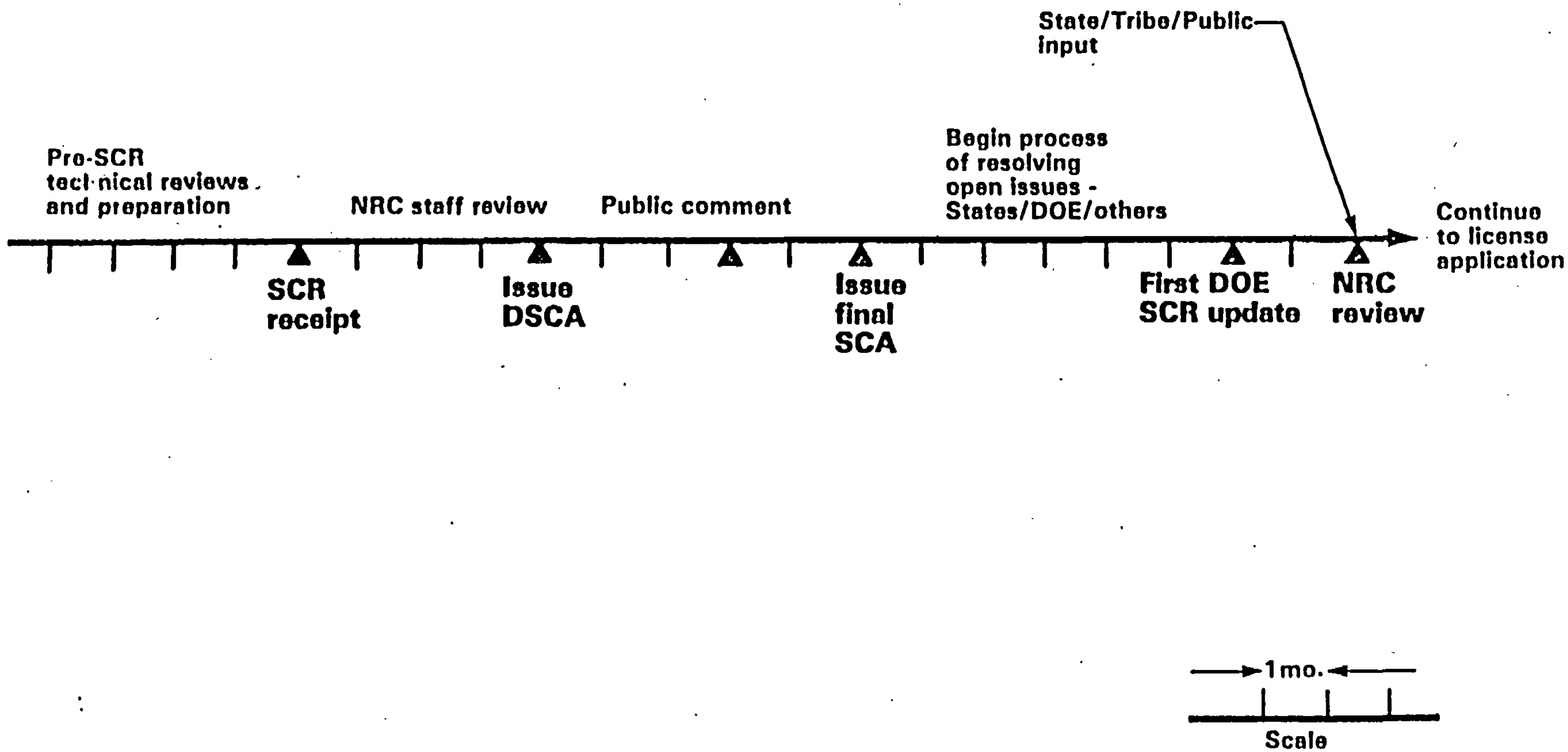
LEGISLATION/REGULATIONS

- O NWPA REINFORCES NRC CHARTER AND LICENSING APPROACH
- O INDIRECT IMPACTS
- O PROPOSED 10 CFR 60 STATUS
  - TECHNICAL RULE
  - PROCEDURAL RULE

PRELICENSING CONSULTATION



Site Characterization Review Process



HLW REGULATORY APPROACH

- PRELICENSING NRC-DOE CONSULTATION WITH PUBLIC INVOLVEMENT
  - -- INFORMAL/FLEXIBLE/INTERACTIVE
  - -- EARLY SCOPING
  - -- ONGOING PROCESS
  - -- SITE-SPECIFIC
- WHAT ARE SPECIFIC LICENSING INFORMATION NEEDS?
- NEEDS FOR COMPLIANCE DETERMINATIONS
  - -- SPECIFIC ISSUES?
  - -- WHAT CONSTITUTES ADEQUATE PROGRAMS OF DATA GATHERING AND ANALYSIS?

SITE CHARACTERIZATION PLAN (SCP)/
<u>SITE CHARACTERIZATION ANALYSIS (SCA)</u>

<u>NRC APPROACH</u>

o 3 STEP PROCESS

STEP 1:	PRE SCP PREPARATION	DOE/NRC
STEP 2:	SCP ANALYSIS	NRC
STEP 3:	POST SCP (SITE CHARACTERIZATION)	DOE/NRC

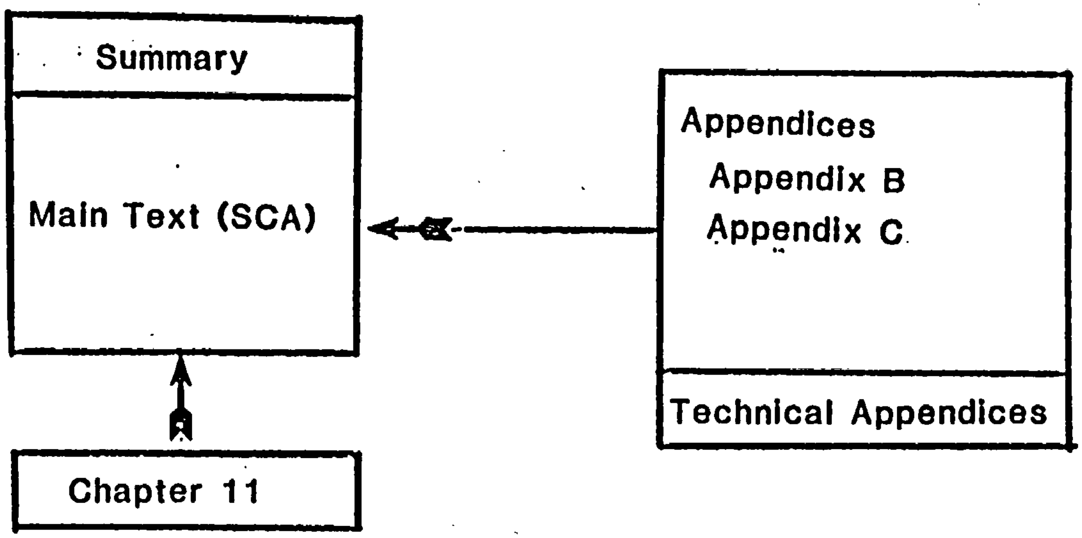
STEP 1: PRE-SCP PREPARATION

- O WORKSHOPS
- O INDEPENDENT ISSUE IDENTIFICATION
- O TECHNICAL POSITIONS
- O CONCEPTUAL MODELING
- O SCENARIO ANALYSIS
- O NUMERICAL MODEL DEVELOPMENT

STEP 2: SCP ANALYSIS

- LICENSING ISSUES
- STATUS OF CURRENT KNOWLEDGE AND UNCERTAINTIES
- FUTURE PLANS

SCA CONTENT



Summary
Main Text (SCA)
Chapter 11
Appendices
Appendix B
Appendix C
Technical Appendices

STEP 3: <u>POST-SCP ANALYSIS</u>

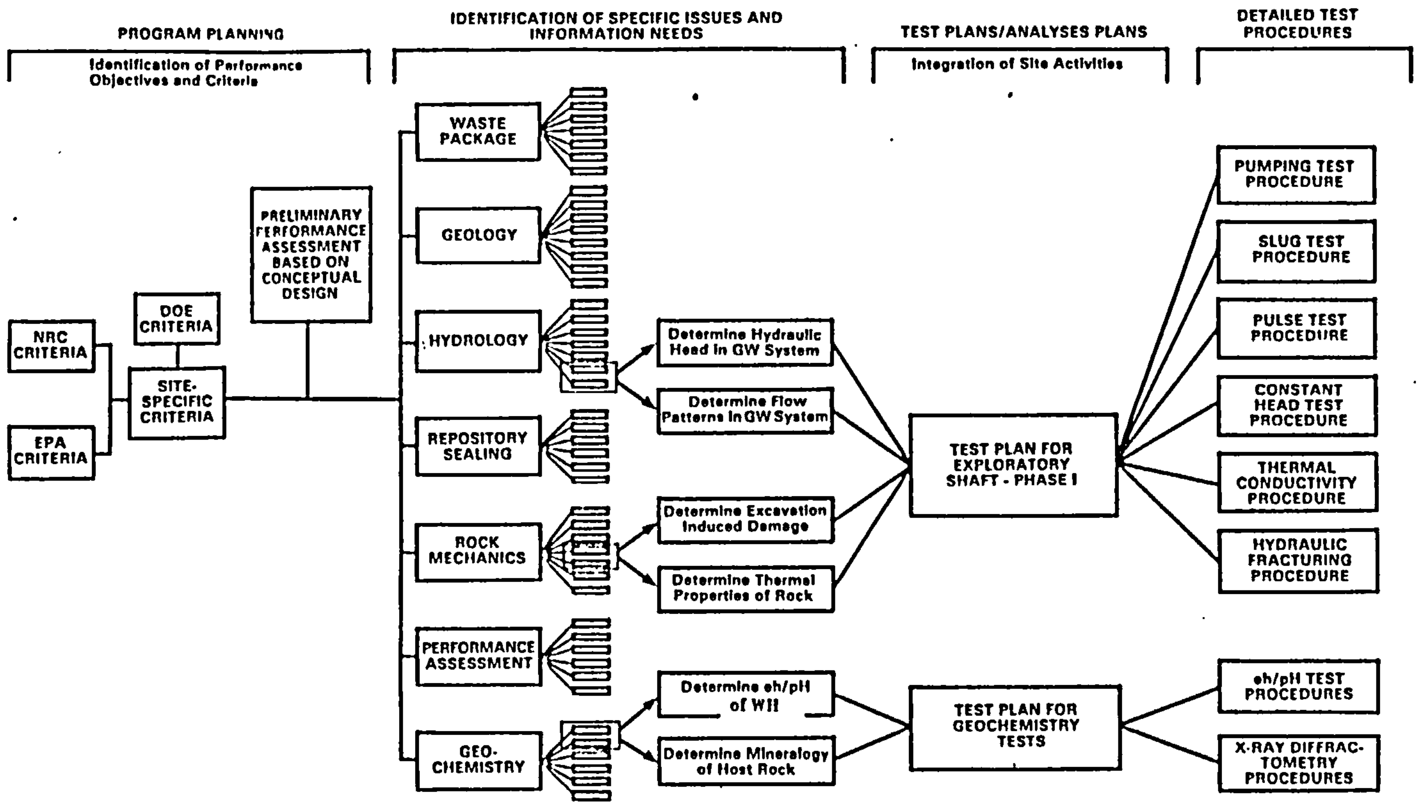
- SEMI-ANNUAL REPORTS
- CONTINUING WORKSHOPS
- UPDATES OF SCP AND SCA
- ISSUE RESOLUTION

NRC HIGH LEVEL WASTE LICENSING PROGRAM

General Discipline Area	Number of Staff	Technical Specialists
Earth Scientists	12	Geologist Groundwater Hydrologist Geochemist Geophysicist
Geotechnical and Mining Engineers	5	Geotechnical Engineer Civil Engineer Mining Engineer
Design Engineers	9	Nuclear Engineer Chemical Engineer Mechanical Engineer Materials Engineer
System Performance Analysts	6	System Analyst Radiation Health Physicists
Environmental Scientists	2	Environmental Planner Ecologist Resource Manager
Social Scientists	8	Government Relations Analyst Economist Public Policy Analyst Regulatory Affairs Specialist Information Management Specialist

11 additional staff in HLW area of NRC Research Office

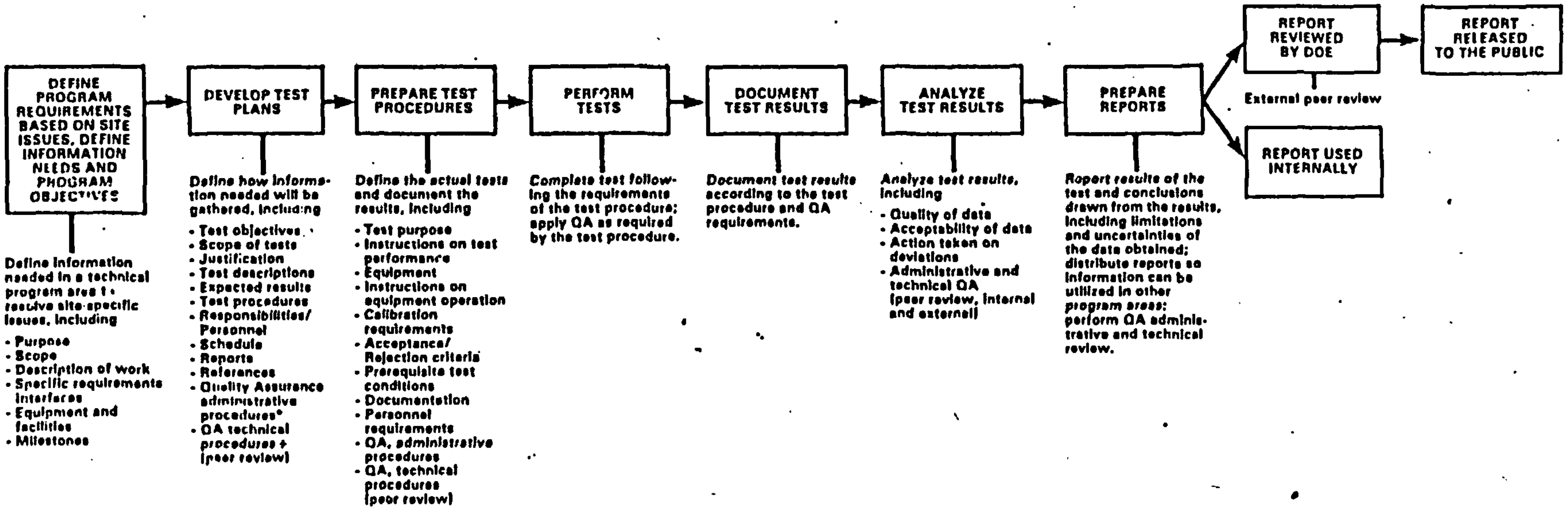
BRIEFING 4/19-20/83
NPO - COLUMBUS, OH



SCOPE OF DIAGRAM:
To show levels of detail involved in developing a technical program.

PURPOSE OF DIAGRAM:
To convey the various levels of detail in planning and controlling a technical program; to define level of detail necessary in executing a technical program properly.

Figure 10.2 Test method development (illustrative)



*QA administrative procedures include procedures for: (1) document control; (2) documented instructions, procedures, and drawings; (3) control of materials, equipment, and services; (4) use of qualified personnel; (5) inspections; (6) documented test plans; (7) control of test equipment; (8) control of samples; (9) nonconformance reports; (10) corrective action; (11) peer review (both management and technical); (12) audits.

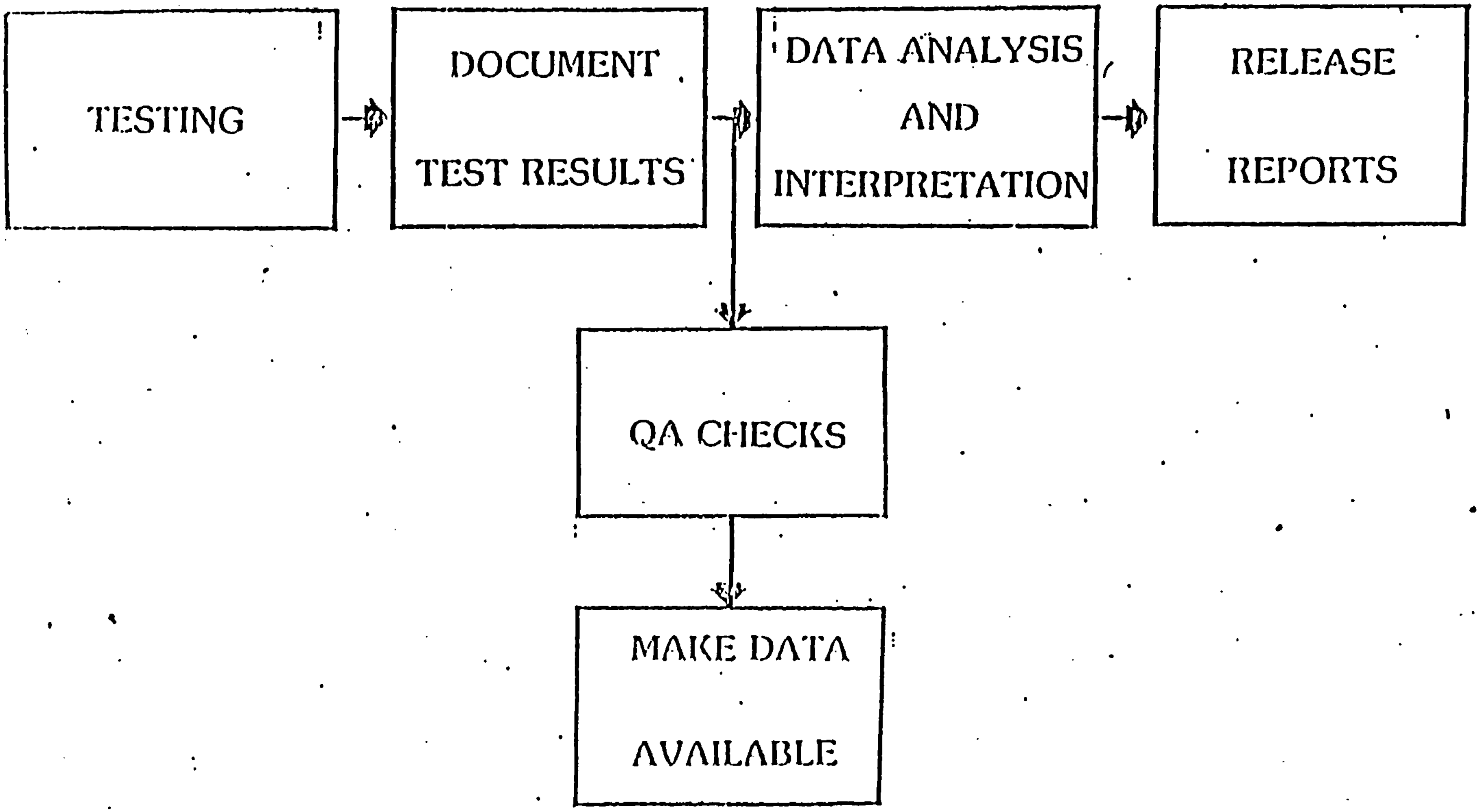
+ QA technical procedures include the actual internal and external peer reviews (both management and technical).

SCOPE OF DIAGRAM:
To show chronology of events in development of a testing program.

PURPOSE OF DIAGRAM:
(1) To show a breakdown sequence of development of plans to resolve problem of timely access to data by NRC. (2) To show the involvement of QA, both administrative and technical, in each step of program.

Figure 10.1 Technical program control: test plans and procedures (illustrative)

SEQUENCE FOR INFORMATION RELEASE



NPO/ONWI INFORMATION SYSTEM

L. ANDERSON

M. GLORA

ONWI

BATTELLE Project Management Division

DOCUMENT REVIEW AND CLEARANCE

- FEDERAL REGULATIONS REQUIRE PATENT REVIEW
- BPMD COMBINES PATENT AND POLICY REVIEWS
- REVIEWS AND SIGN-OFFS:
  - PROJECT MANAGER
  - DEPARTMENT MANAGER
  - POLICY SCREENING
  - FUNCTIONAL MANAGER
  - PATENT SCREENING
  - NPO FINAL CONTENT REVIEW
  - DOE-CH FINAL PATENT REVIEW (IF REQUIRED)
- TYPICAL REVIEW TIME: 4 WEEKS

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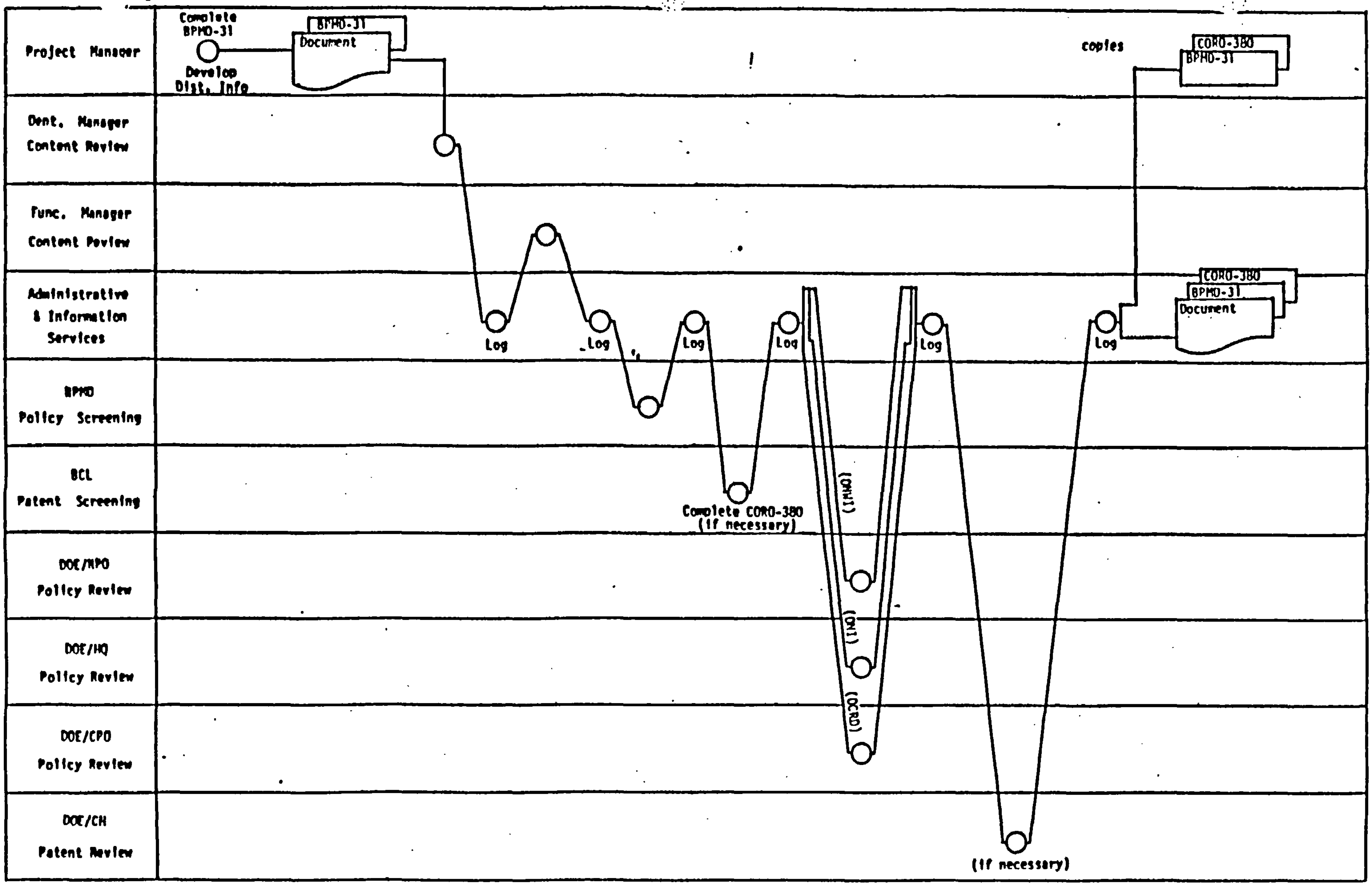

BPMO Patent/Policy Review Cycle

Battelle Project Management Division	CLEARANCE (COORDINATION) OF REPORTS, SPEECHES AND ARTICLES FOR USE OUTSIDE BPMD	DATE	SERIAL NUMBER
		CONTRACT NUMBER	

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	AUTHOR(S) AND PHONE NO.

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THE OCCASION		CITY	
		DATE	
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WILL THE PAPER BE HANDED OUT AT THE MEETING?			
WILL THE PAPER BE SUBMITTED FOR JOURNAL PUBLICATION?		IF YES, GIVE SERIAL NUMBER:	

PROJECT MANAGER	DATE	DEPARTMENT/PROGRAM OFFICE MANAGER	DATE
COMMENTS			

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BPMD PATENT REVIEW	DATE
COMMENTS	

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SPONSOR REVIEW	DATE
COMMENTS	

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SYSTEMS

- ☐ Systems Analysis.
- ☐ Systems Engineering.
- ☐ Socioeconomic Assessment.

Alternate Disposal Concepts:

- ☐ —General
- ☐ —Space
- ☐ —Very Deep Hole
- ☐ Performance Assessment.
- ☐ International Cooperation.
- ☐ Performance Assessment Computer Models.

WASTE PACKAGE

- ☐ Waste Package Plans and Criteria.
- ☐ Waste Form.
- ☐ Barrier Materials.

Design and Development:

- ☐ —Design
- ☐ —Testing

Performance Evaluation:

- ☐ —Modeling
- ☐ —Demonstration Testing
- ☐ —Natural Analogs

SITE

- ☐ Siting Strategy.
- ☐ Site Criteria and Issues.
- ☐ Site Characterization Plans.

Earth Sciences:

- ☐ —Geophysics
- ☐ —Geochemistry
- ☐ —Transport Properties

Geologic Characterization:

- ☐ —Generic Activities
- ☐ —Salt - Generic
- ☐ —Salt - Salina
- ☐ —Salt - Paradox
- ☐ —Salt - Permian
- ☐ —Salt - Gulf Coast Domes
- ☐ —Crystalline - Generic
- ☐ —Crystalline - Lake Superior
- ☐ —Crystalline - N. Appalachian

SITE, Continued

- ☐ —Crystalline - S. Appalachian
- ☐ —Argillaceous Rocks
- ☐ —Province Studies
- ☐ —National Screening
- ☐ Hydrologic Characterization.

Environmental Characterization:

- ☐ —Generic Activities
- ☐ —Salt - Generic
- ☐ —Salt - Salina
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- ☐ —Salt - Permian
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- ☐ —Argillaceous Rocks
- ☐ —Province Screening
- ☐ —National Screening
- ☐ Socioeconomic Evaluation/Assessment.
- ☐ Performance Evaluation

REPOSITORY

- ☐ Repository Plans.
- ☐ Reference Repository Conditions.

Repository Data Base Development:

- ☐ —Generic
- ☐ —Salt
- ☐ —Tuff
- ☐ —Basalt
- ☐ —Crystalline
- ☐ —Argillaceous
- ☐ Equipment Development
- ☐ Instrumentation Development.

Repository Seal Development

- ☐ —Design
- ☐ —Materials
- ☐ —Field Tests

REPOSITORY, Continued

Generic Repository Engineering

- ☐ —Design Studies and Optimization
- ☐ —Support Studies
- ☐ —Value Engineering

Repository Conceptual Design

- ☐ —Dome Salt
- ☐ —Bedded Salt
- ☐ —Tuff
- ☐ —Basalt
- ☐ —Crystalline
- ☐ Performance Evaluation.

REGULATORY AND INSTITUTIONAL

- ☐ Regulatory Plans and Criteria.
- ☐ Licensing Applications.
- ☐ NEPA Documents
- ☐ State Consultation.

TEST FACILITIES AND EXCAVATIONS

Salt.

- ☐ —Acquisition
- ☐ —Design
- ☐ —Construction/Development
- ☐ —Operation/Maintenance

Crystalline:

- ☐ —Acquisition
- ☐ —Design
- ☐ —Construction/Development
- ☐ —Operation/Maintenance
- ☐ Tuff
- ☐ Basalt.
- ☐ Argillaceous.

Support Facilities.

- ☐ —Surface
- ☐ —Underground
- ☐ Exploratory Shaft.
- ☐ Test and Evaluation Facility
- ☐ Land Acquisition.

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From S. J. Richard SR

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Title Project Manager/Geologist

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- [x] Quarterly Technical Reports.

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- [ ] Systems Analysis.
- [ ] Systems Engineering.
- [ ] Socioeconomic Assessment.

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- [ ] —Space
- [ ] —Very Deep Hole
- [ ] Performance Assessment.
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- [ ] Waste Form.
- [ ] Barrier Materials.

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- [ ] —Testing

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- [ ] —Demonstration Testing
- [ ] —Natural Analogs

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- [x] Site Criteria and Issues.
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- [ ] —Geophysics
- [ ] —Geochemistry
- [x] —Transport Properties

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- [x] —Salt - Salina
- [x] —Salt - Paradox
- [x] —Salt - Permian
- [x] —Salt - Gulf Coast Domes
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- [ ] —Crystalline - Lake Superior
- [ ] —Crystalline - N. Appalachian
- [ ] —Crystalline - S. Appalachian
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- [ ] —Province Studies
- [x] —National Screening
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- [ ] —Crystalline - Lake Superior
- [ ] —Crystalline - N. Appalachian
- [ ] —Crystalline - S. Appalachian

SITE, Continued

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- [ ] —National Screening
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REPOSITORY

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REGULATORY AND INSTITUTIONAL

- [ ] Regulatory Plans and Criteria.
- [ ] Licensing Applications.
- [ ] NEPA Documents.
- [ ] State Consultation.

TEST FACILITIES AND EXCAVATIONS

Salt:

- [x] —Acquisition
- [x] —Design
- [x] —Construction/Development
- [x] —Operation/Maintenance

Crystalline:

- [ ] —Acquisition
- [ ] —Design
- [ ] —Construction/Development
- [ ] —Operation/Maintenance
- [ ] Tuff.
- [ ] Basalt.
- [ ] Argillaceous.

Support Facilities:

- [ ] —Surface
- [ ] —Underground
- [ ] Exploratory Shaft.
- [ ] Test and Evaluation Facility.
- [ ] Land Acquisition.

```
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CURRENT STATUS OF SCR DATA BASE LIBRARY

- PILOT LIBRARY BEING ESTABLISHED AT ONWI
  - REFINE LOGISTICS AND PROCEDURES TO BE APPLIED WHEN ADDITIONAL LIBRARIES NEEDED AT SCR SUBMITTAL

ONWI

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MAG:4/19/83

ANTICIPATED PLAN FOR ESTABLISHMENT AND USE OF DATA BASE LIBRARY

- REFERENCES PROVIDED BY AUTHORS DURING SCR PREPARATION
- AVAILABILITY OF DOCUMENTS IN LIBRARY
  - REFERENCE ONLY - USE OF DOCUMENTS LIMITED TO LIBRARY
- PROVISION TO BE MADE FOR NOTING USER RECOMMENDATIONS AND COMMENTS FOR SUBSEQUENT CONSIDERATION BY DOE AND ONWI
  - REFERENCE SUITABILITY/APPLICABILITY
  - ADDITIONAL REFERENCES

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AVAILABILITY OF FIELD DATA

- EVALUATION UNDERWAY
- USE OF TOPICAL REPORTS TO BE MAXIMIZED
    - FROM SUBCONTRACTOR REPORTS
    - FROM WELL COMPLETION REPORTS
- CONCERNS ARE TO:
    - ASSURE TRACEABILITY
    - ASSURE APPLICABILITY AND DOE CONCURRENCE
    - ASSURE TIMELY AVAILABILITY

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ENGINEERING FUNCTION

S. C. MATTHEWS

ONWI

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ENGINEERING FUNCTIONAL AREA

RESPONSIBILITIES:

- TECHNICAL DIRECTION AND MANAGEMENT OF ACTIVITIES ASSOCIATED WITH ENGINEERED SYSTEMS, STRUCTURES, AND COMPONENTS

ORGANIZATIONAL COMPONENTS:

- MATERIALS DEVELOPMENT AND DESIGN ANALYSIS (ETD)
- EXPLORATORY SHAFT DESIGN, CONSTRUCTION AND TESTING (ESPO)
- REPOSITORY/PACKAGE DESIGN (RPO)

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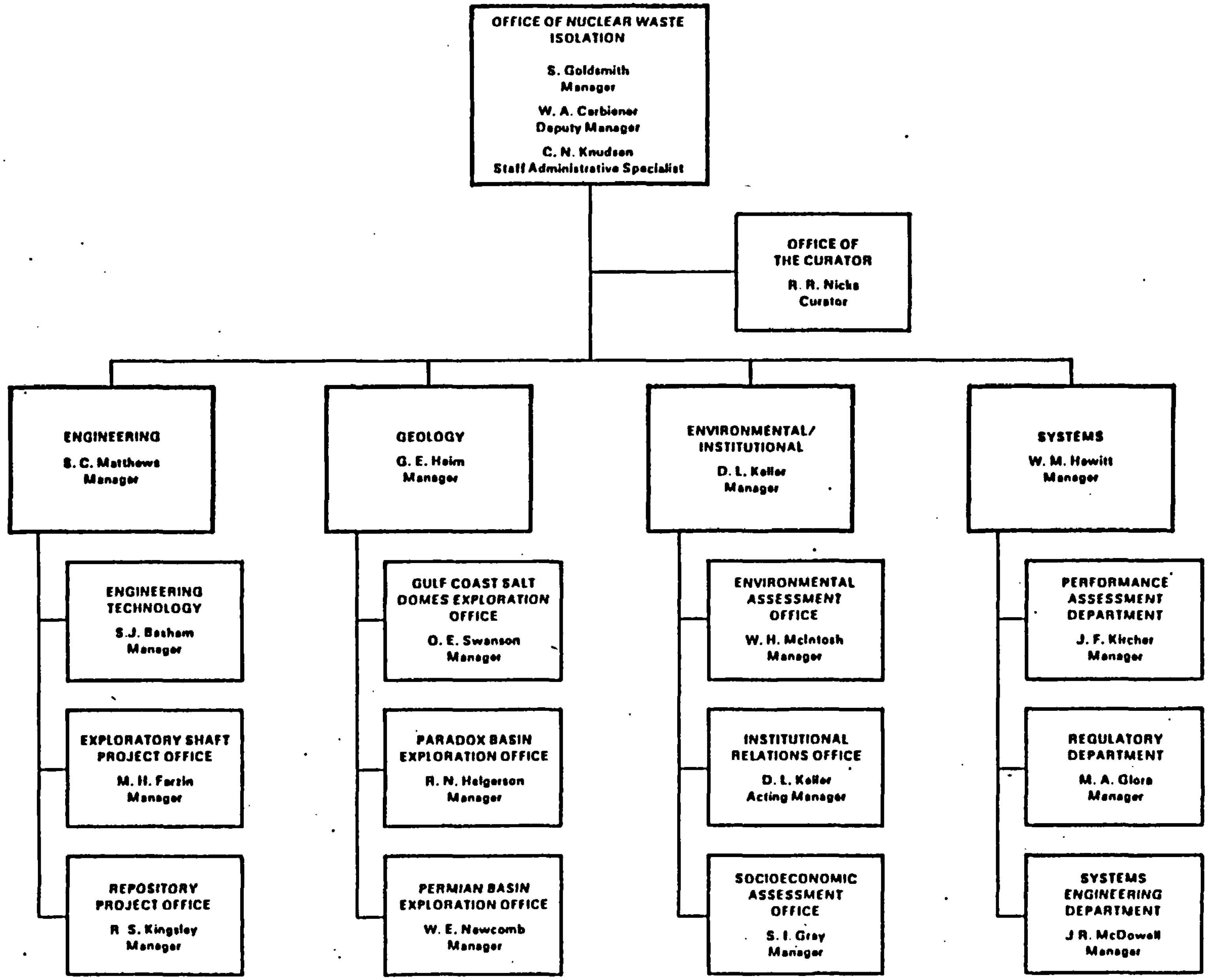
OFFICE OF NUCLEAR WASTE ISOLATION ORGANIZATION



MATERIAL DEVELOPMENT AND DESIGN ANALYSES

- DEVELOP MATERIAL PROPERTIES TO SUPPORT REPOSITORY DESIGN
- DEVELOP WASTE PACKAGE MATERIAL PROPERTIES
- DEVELOP REPOSITORY SEALING MATERIAL PROPERTIES
- DEVELOP ROCK PROPERTIES

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MATERIALS DEVELOPMENT

INFORMATION AVAILABLE:

- LEACHING OF ACTINIDES AND TECHNETIUM FROM SIMULATED HIGH-LEVEL WASTE GLASS (PNL-3152)

- SOME CHARACTERISTICS OF POTENTIAL BACKFILL MATERIALS (ONWI-449)

- * GUIDELINES FOR THE DEVELOPMENT AND TESTING OF NWTS WASTE PACKAGE MATERIALS (DOE/NWTS-34)

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DESIGN ANALYSIS

INFORMATION AVAILABLE:

- THERMO/VISCOELASTIC SIMULATION OF THE SITE A HEATER TEST AT AVERY ISLAND (ONWI-216) RE/SPEC

- PARAMETRIC STUDY INVOLVING THERMO/VISCOELASTIC ANALYSIS OF A ROOM AND PILLAR CONFIGURATION (ONWI-115)

- PRELIMINARY INVESTIGATION OF THE THERMAL & STRUCTURAL INFLUENCE OF CRUSHED-SALT BACKFILL ON REPOSITORY DISPOSAL ROOMS (ONWI-138)

*● PRELIMINARY CONSTITUTIVE PROPERTIES FOR SALT AND NON-SALT ROCKS FROM FOUR POTENTIAL REPOSITORY SITES (ONWI-450)

- CREEP AND CREEP-RUPTURE OF ROCK SALT (ONWI-244)

*● REVIEW OF CONSTITUTIVE LAWS USED TO DESCRIBE THE CREEP OF SALT (ONWI-295)

- INELASTIC THERMOMECHANICAL ANALYSIS OF A GENERIC BEDDED SALT REPOSITORY (ONWI-125)

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EXPLORATORY SHAFT DESIGN, CONSTRUCTION, AND TESTING

RESPONSIBILITY:

- MANAGE DESIGN OF EXPLORATORY SHAFT
- INTEGRATE THE ACTIVITIES OF DESIGN, CM, AND TESTING
- CONDUCT IN SITU TESTING IN EXPLORATORY SHAFT
- CONDUCT FIELD TESTING

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EXPLORATORY SHAFT

INFORMATION AVAILABLE:

- CONCEPTUAL DESIGN REPORTS FOR EXPLORATORY SHAFT FOR PARADOX BASIN, PERMIAN BASIN, AND DOMES IN GULF INTERIOR REGION (ONWI-390, 391, 392) JUNE 1983
- FUNCTIONAL DESIGN CRITERIA FOR EXPLORATORY SHAFT DESIGN (ONWI-455) JUNE 1983
- AVERY ISLAND HEATER TESTS: DISPLACEMENT AND STRESS DATA FOR THE FIRST 300 DAYS (ONWI-190(2)) RE/SPEC
- AVERY ISLAND HEATER TESTS: MEASURED DATA FOR 1000 DAYS OF HEATING (ONWI-190(2)) RE/SPEC

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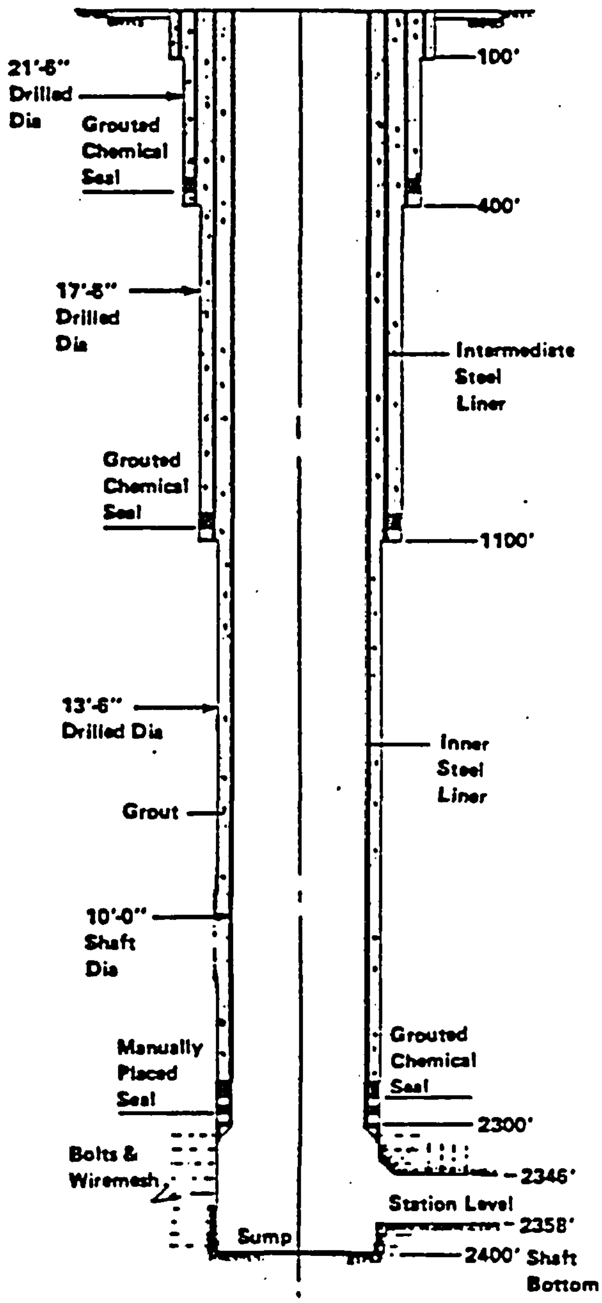
BLIND DRILLING METHOD



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SKETCH OF SHAFT CONSTRUCTION METHOD FROM
PERMIAN BASIN PRELIMINARY DESIGN

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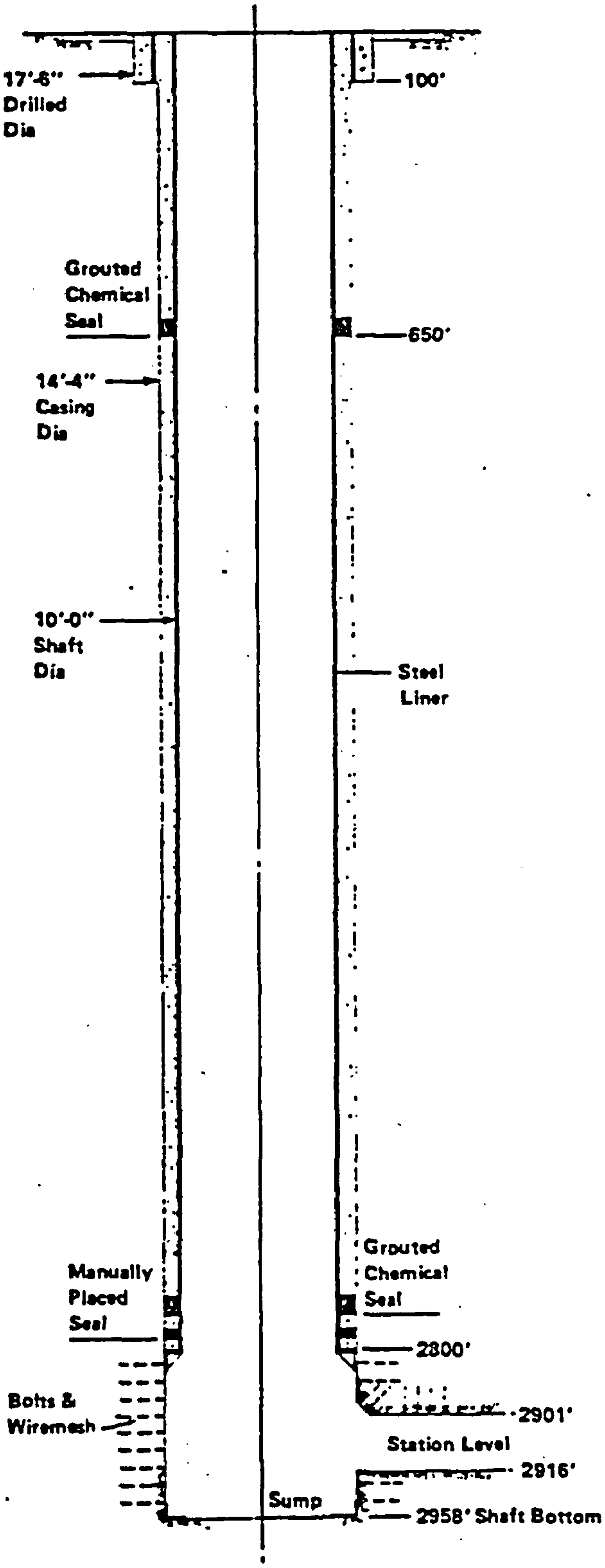
ONWI
Battelle

BLIND DRILLING METHOD



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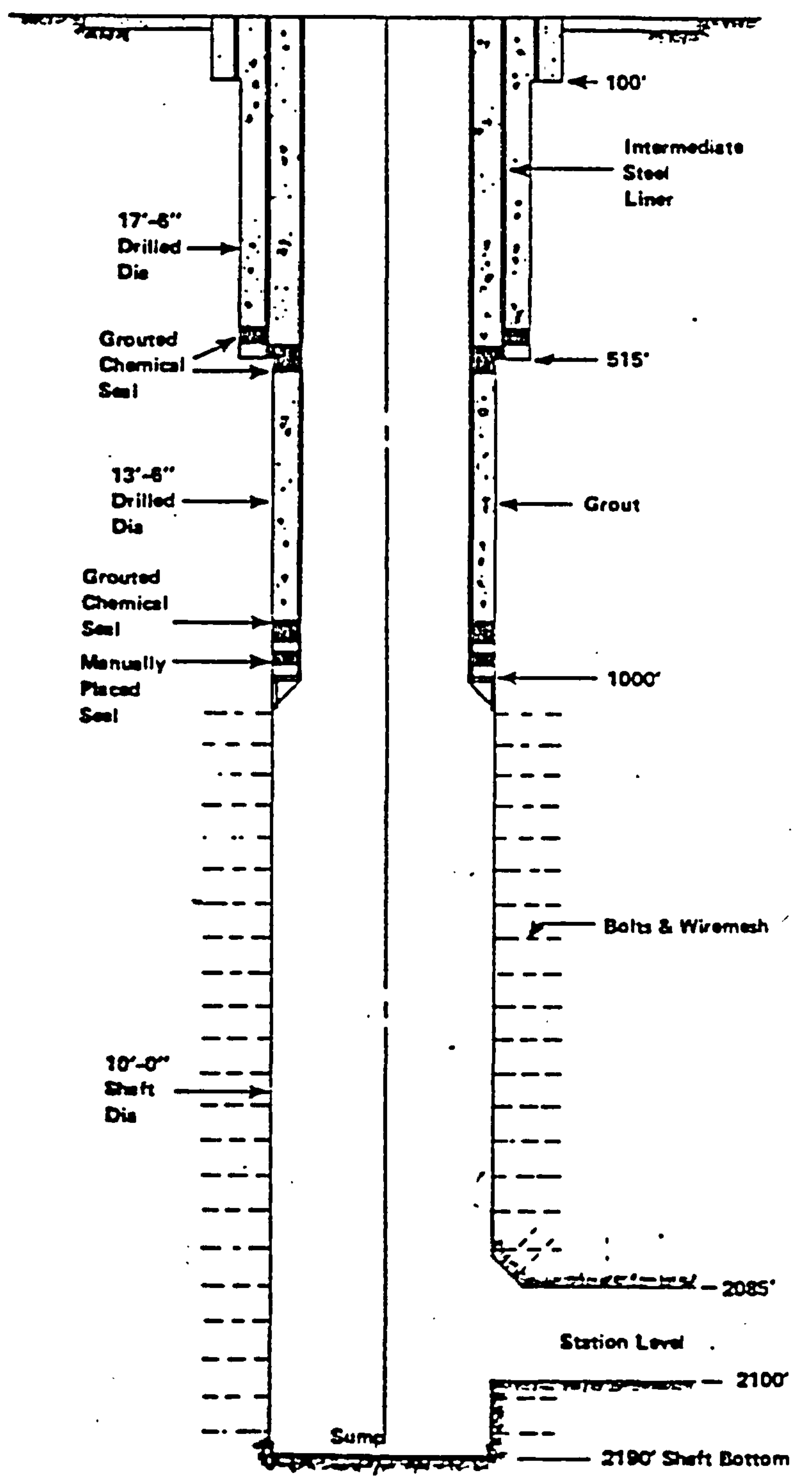
SKETCHES OF SHAFT CONSTRUCTION METHOD
FROM PARADOX BASIN PRELIMINARY DESIGN

ONWI

BLIND DRILLING METHOD



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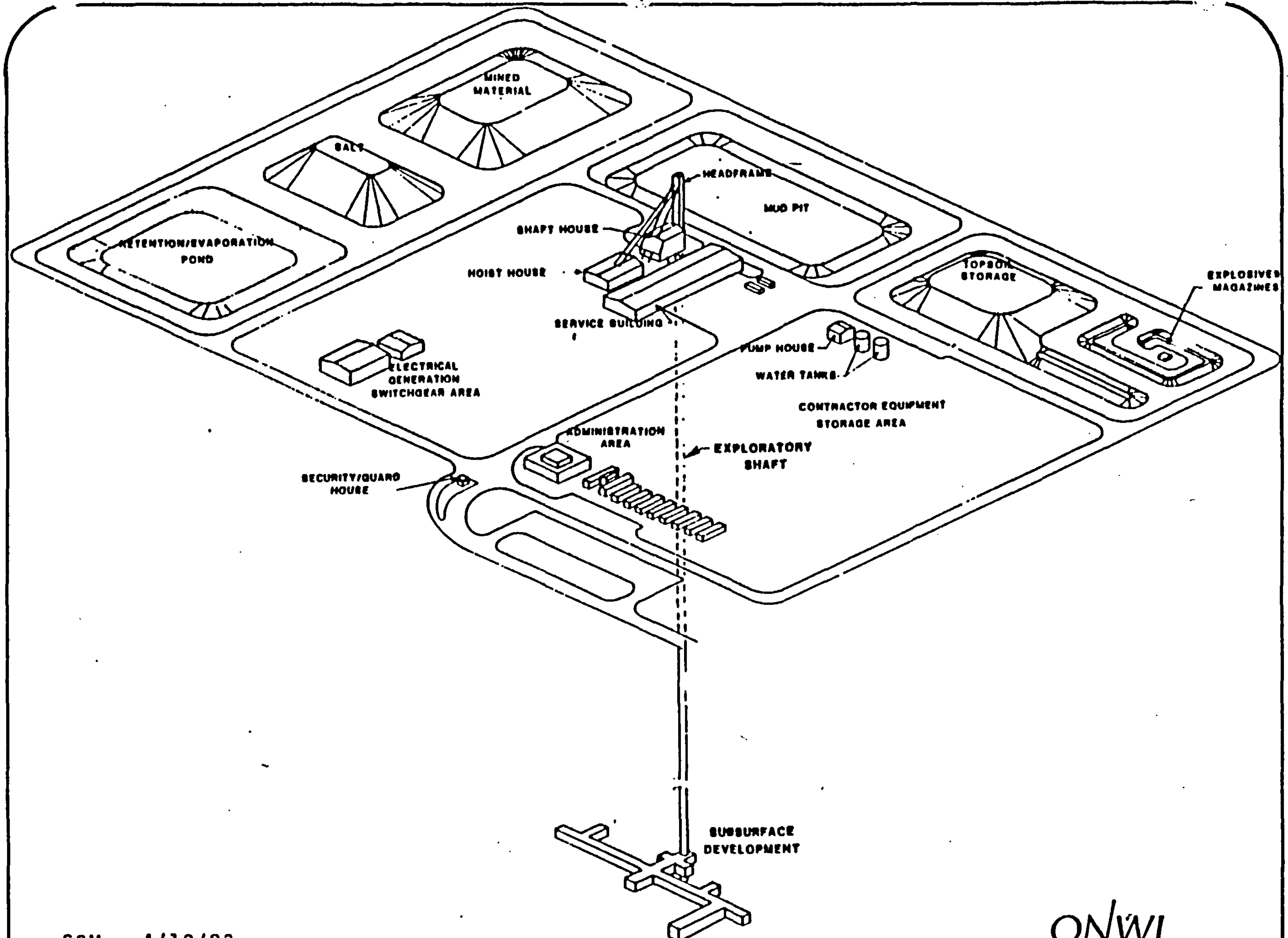
SKETCH OF SHAFT CONSTRUCTION METHOD FROM GULF INTERIOR REGION PRELIMINARY DESIGNS

ONWI



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ISOMETRIC DRAWING OF EXPLORATORY SHAFT FACILITY

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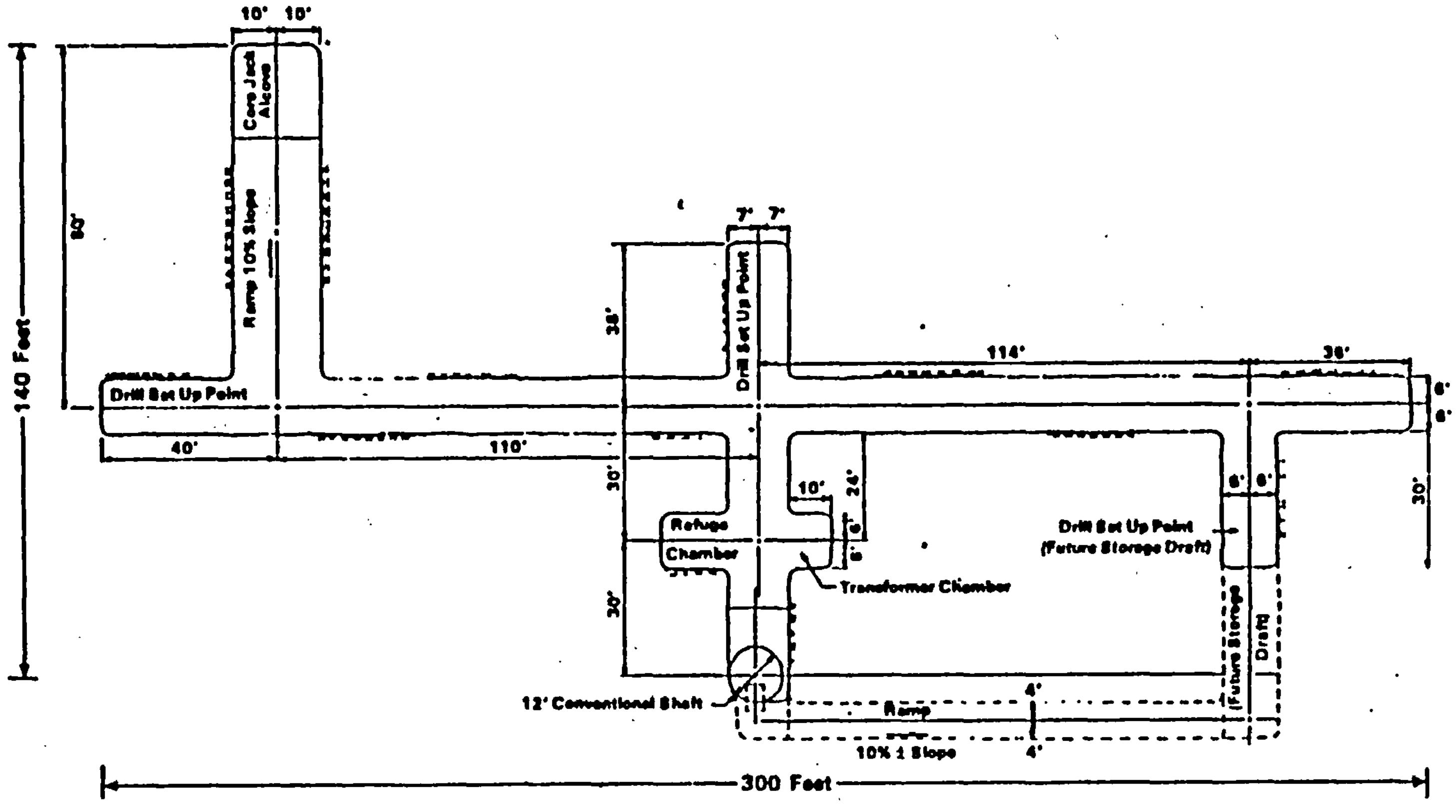
PRELIMINARY EXPLORATORY SHAFT SUBSURFACE LAYOUT



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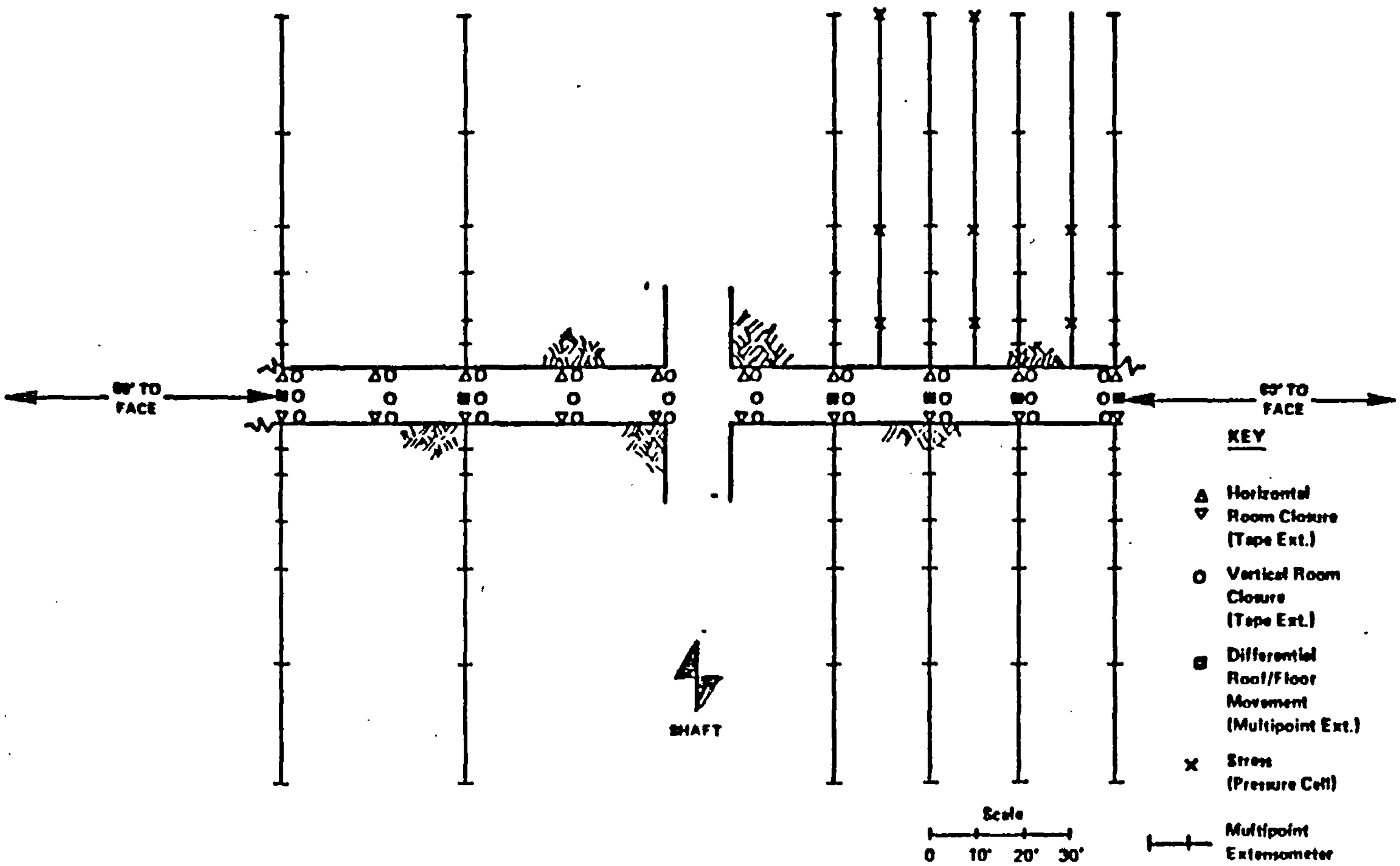

PLAN VIEW OF ES FACILITY MAIN DRIFT SHOWING
ROOM DEFORMATION INSTRUMENTATION

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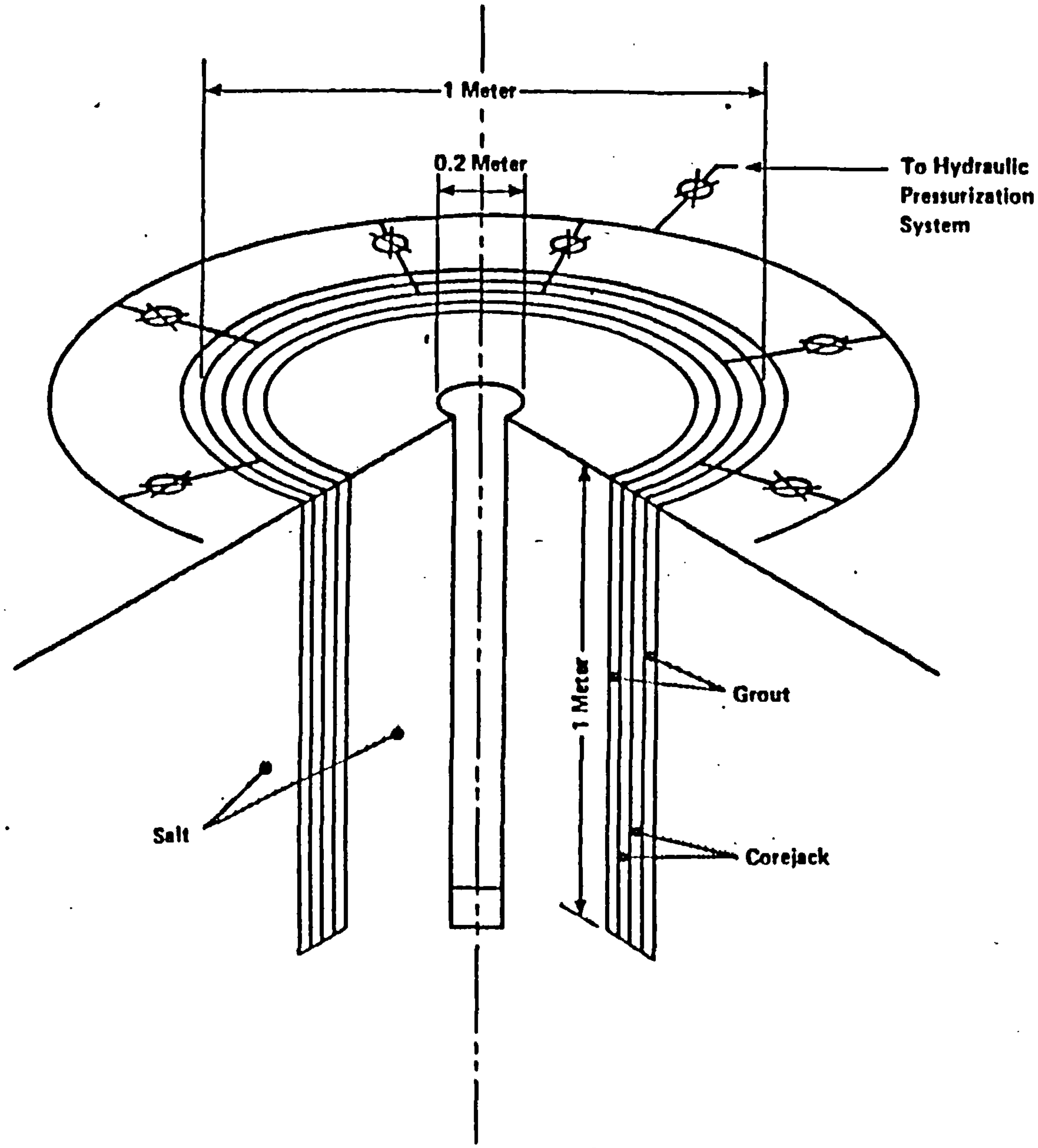

SCHEMATIC OF COREJACK SALT DEFORMATION EXPERIMENTS

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ONWI

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REPOSITORY DESIGN

RESPONSIBILITY:

- MANAGEMENT OF DESIGN FOR REPOSITORY FACILITIES
- MANAGEMENT OF DESIGN/DEVELOPMENT TESTING OF PACKAGE CONFIGURATIONS
- TECHNICAL DIRECTION AND INTEGRATION OF VARIOUS PARTICIPANTS IN THE DESIGN OF THE REPOSITORY

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BATTELLE Project Management Division

REPOSITORY DESIGN

INFORMATION AVAILABLE:

*● ENGINEERED WASTE PACKAGE CONCEPTUAL DESIGN - DHLW, CHLW, SF DISPOSAL IN SALT, ONWI-438, JUNE 1983

● NWTS CONCEPTUAL REFERENCE REPOSITORY DESCRIPTION (CRRD), ONWI-258, 1981

*● SCHEMATIC DESIGNS FOR PENETRATION SEALS FOR A REFERENCE REPOSITORY IN BEDDED SALT, ONWI-405, DECEMBER 1982

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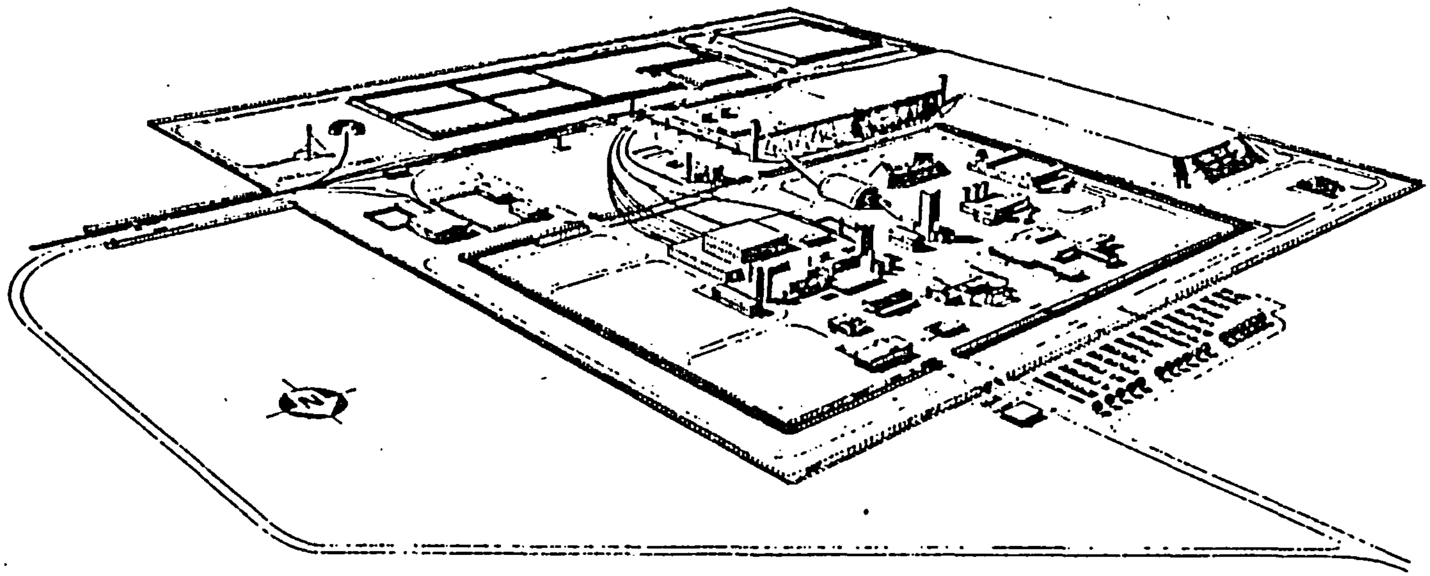

PLANT FACILITIES PERSPECTIVE

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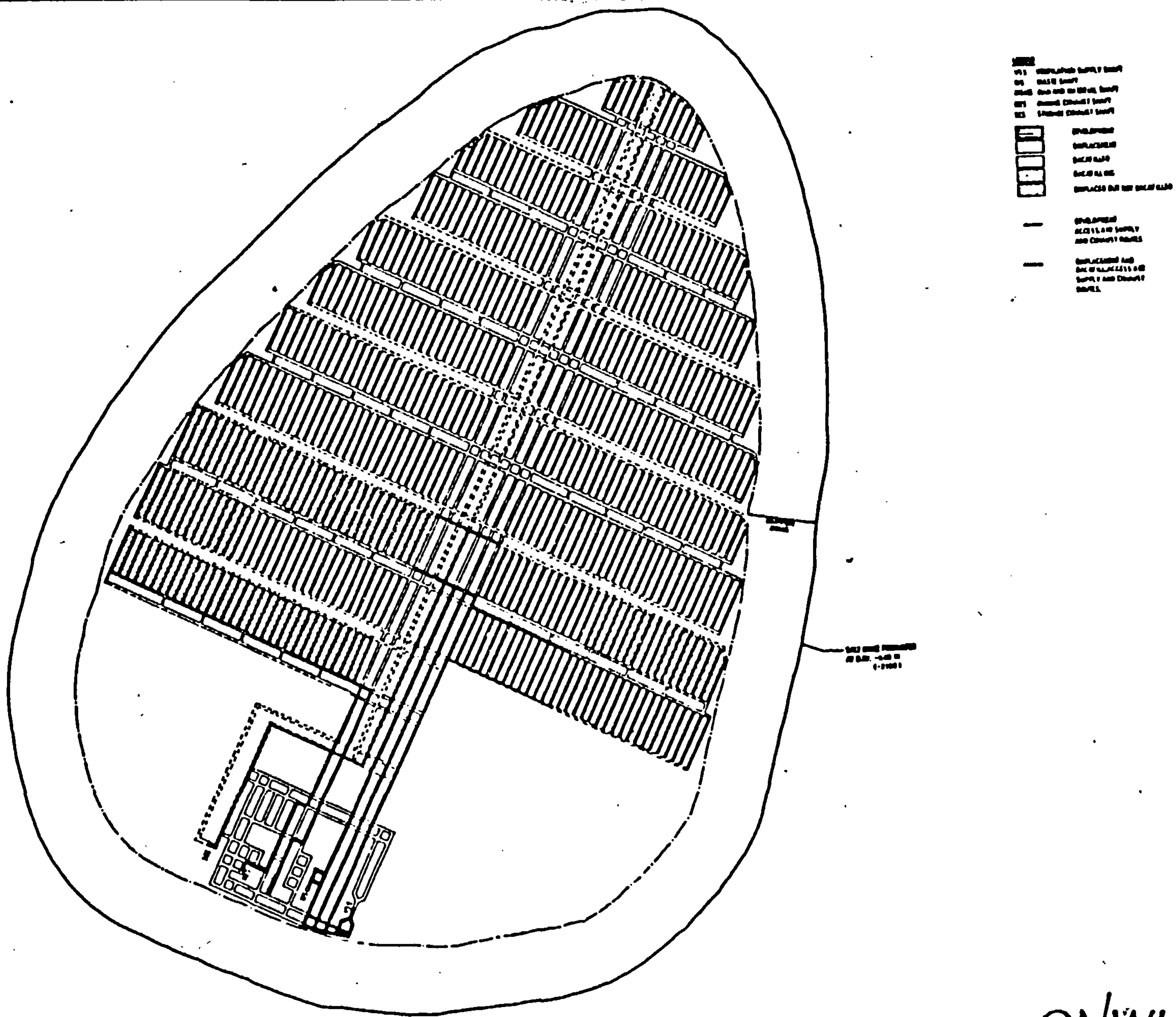

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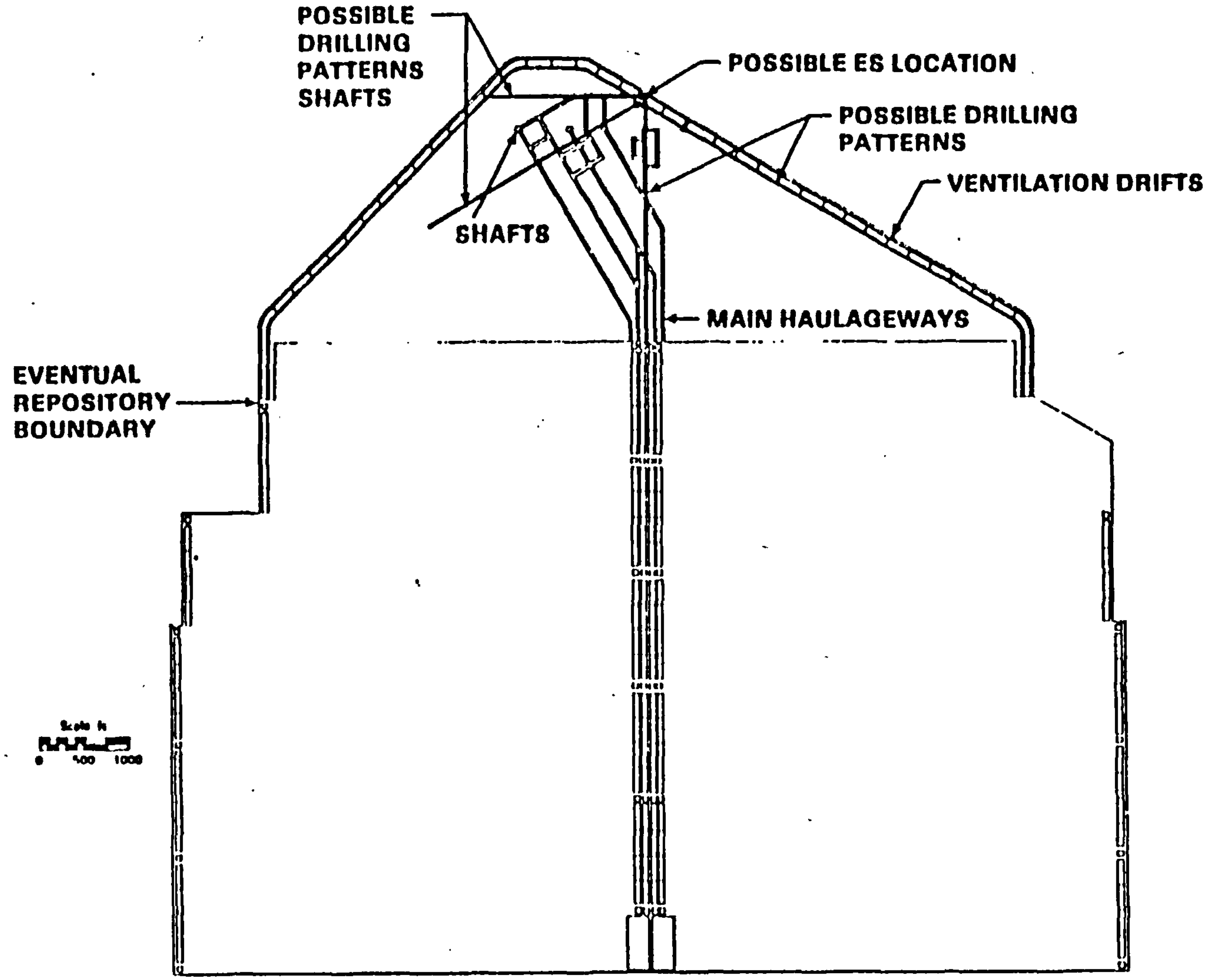
FLANK SHAFT DEVELOPMENT PLAN,
YEAR 26

SCHEMATIC LAYOUT OF EXPLORATORY BOREHOLES



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PRINCIPAL SUBCONTRACTORS

ENGINEERING

RE/SPEC INC.	SUBSURFACE ANALYSIS ON THERMAL, MECHANICAL, THERMOMECHANICAL, ROOM REINFORCEMENT, AND BRINE MIGRATION DATA FOR USE IN CONCEPTUAL DESIGN OF THE REPOSITORY
STEARNS-ROGER	CONCEPTUAL REPOSITORY DESIGN INCLUDING SURFACE AND SUBSURFACE FACILITIES, VENTILATION SYSTEMS, TRANSPORTATION, AND UTILITIES; COST ESTIMATION AND SCHEDULING FOR REPOSITORY CONSTRUCTION AND OPERATION
PENN STATE UNIVERSITY MATERIALS RESEARCH LABORATORY	LABORATORY EXPERIMENTS ON AND PERFORMANCE ASSESSMENT OF THE LONG-TERM DURABILITY OF REPOSITORY SEAL MATERIALS IN SALT
PARSONS BRINCKERHOFF/PB-KBB, A JOINT VENTURE	ARCHITECT ENGINEER FOR THE EXPLORATORY SHAFT FACILITY IN SALT: DEVELOPMENT OF THE PRELIMINARY AND FINAL DESIGN (DRAWINGS, SPECIFICATIONS, COST AND SCHEDULE ESTIMATES AND PERMITTING ACTIVITIES); PROVISION OF TITLE III INSPECTION SERVICES DURING CONSTRUCTION

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PRINCIPAL SUBCONTRACTORS

ENGINEERING, CONTINUED

WESTINGHOUSE	DEVELOPMENT OF THE CONCEPTUAL AND PRELIMINARY DESIGNS OF SPENT FUEL, COMMERCIAL HIGH LEVEL WASTE, AND DEFENSE HIGH LEVEL WASTE PACKAGES FOR A SALT REPOSITORY
D'APPOLONIA CONSULTING ENGINEERING, INC.	DOCUMENTATION ON PLUGGING, SEALING AND BACKFILL REQUIREMENTS FOR REPOSITORY DECOMMISSIONING AND SEALING; PRELIMINARY DESIGN WORK FOR PLUGS AND SEALS
TERRA TEK, INC.	PERFORMANCE MEASUREMENT OF BOREHOLE PLUGS IN BENCH-SCALE SIZE SAMPLES OF EVAPORATES; FLOW AND TRACER TESTING TO DETERMINE HYDRAULIC CONDUCTIVITY OF PLUGGED SALT SAMPLES

PRINCIPAL SUBCONTRACTORS

ENGINEERING, CONTINUED

SANDIA NATIONAL LABORATORIES	QUANTIFY CORROSION AND METALLURGICAL BEHAVIOR OF CANDIDATE HLW CANISTER AND OVERPACK MATERIALS UNDER EXPECTED ENVIRONMENTAL CONDITIONS IN SALT; STUDIES INCLUDE MECHANISMS, LONG-TERM TESTING, ACCELERATED TESTING
U.S. ARMY CORPS OF ENGINEERS	RECOMMENDATION OF MATERIALS AND SPECIFIC MIXTURES FOR USE IN CONCEPTUAL SEAL DESIGNS; CONSIDERATIONS: WORKABILITY OF MATERIALS (PLACEMENT TECHNIQUES, SETTING AND CURING TIMES, LIFT THICKNESS), GEOLOGIC COMPATIBILITY, DURABILITY

PRINCIPAL CONSULTANTS

ENGINEERING

JOHN ABLE	PROVIDES DATA ANALYSIS ON ROCK MECHANICS AND UNDERGROUND STABILITY FOR REPOSITORY AND EXPLORATORY SHAFT DESIGN
DENNIS LACHEL	DESIGN AND CONSTRUCTION OF UNDERGROUND FACILITIES FOR EXPLORATORY SHAFT
TOM CONNOLLY	MINING DEVELOPMENT AND OPERATIONS FOR EXPLORATORY SHAFT
J. SHUSTER	SHAFT CONSTRUCTION, FREEZE WALLS FOR EXPLORATORY SHAFT
NEVILLE COOK	ROCK MECHANICS AND DESIGN WORK FOR EXPLORATORY SHAFT
DOUG BALL	SUBSURFACE EXPLORATION FOR EXPLORATORY SHAFT
CHRISTOPHER J. HALL	UNDERGROUND VENTILATION DESIGN FOR EXPLORATORY SHAFT

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POSSIBLE TOPICS FOR FUTURE DISCUSSION

- SALT CREEP BEHAVIOR ONWI-450, ONWI-295
- SEAL DESIGNS ONWI-405
- WASTE PACKAGE CONCEPTUAL DESIGNS ONWI-438
- MATERIALS TESTING DOE/NWTS-34

SCM: 4/19/83

GEOLOGY FUNCTIONAL OVERVIEW

G. HEIM

ONWI

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GEOLOGIC REVIEW GROUP

MEMBER	AFFILIATION	SPECIALITY
DR. ARTHUR L. BLOOM	PROFESSOR CORNELL UNIVERSITY	GEOLOGICAL SCIENCES, GEOMORPHOLOGY
DR. WILLIAM W. HAMBLETON	DIRECTOR KANSAS GEOLOGICAL SURVEY	GEOLOGY
DR. KONRAD KRAUSKOPF	PROFESSOR AMERITUS STANFORD UNIVERSITY	GEOCHEMISTRY
DR. IRWIN REMSON	PROFESSOR STANFORD UNIVERSITY	HYDROLOGY, ENVIRONMENTAL EARTH SCIENCES
DR. HOWARD P. ROSS	UNIVERSITY OF UTAH RESEARCH INSTITUTE	SENIOR GEOPHYSICIST, GEOTHERMAL EXPLORATION
DR. CHARLES I. SMITH	CHAIRMAN DEPARTMENT OF GEOLOGY UNIVERSITY OF TEXAS AT ARLINGTON	PHYSICAL STRATIGRAPHY, SEDIMENTATION
MR. WILLIAM R. JUDD	CHAIRMAN GEOTECHNICAL ENGINEERING PURDUE UNIVERSITY	ENGINEERING GEOLOGY, ROCK MECHANICS

MEETINGS: AS REQUIRED

SCOPE: CRITICALLY REVIEW AND PROVIDE EXPERT INDEPENDENT TECHNICAL ASSESSMENT OF ACTIVITIES IN THE AREA OF GEOLOGIC EXPLORATION/CHARACTERIZATION IN SUPPORT OF QUALIFICATION OF SITES FOR THE SAFE DISPOSAL OF RADIOACTIVE WASTES

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GULF COAST SALT DOME

PRINCIPAL GEOLOGIC SUBCONTRACTORS

CONTRACTOR	RESPONSIBILITY
EARTH TECHNOLOGY CORPORATION (LAW ENGINEERING TESTING COMPANY)	GULF COAST SALT DOME GEOLOGIC PROJECT MANAGER--GATHERING, ANALYSIS, AND REPORTING GEOLOGIC DATA TO ADDRESS SITE GEOMETRY, GEOHYDROLOGY, GEOCHEMISTRY, ROCK CHARACTERISTICS, TECTONIC ENVIRONMENT, HUMAN INTRUSION.
U.S. GEOLOGICAL SURVEY (DOE PRIME)	HYDROLOGIC AND GEOCHEMICAL ANALYSIS OF TESTING AND SAMPLES FROM NWTS GULF COAST BOREHOLES TO ADDRESS GEOCHEMISTRY AND HYDROLOGY IN LOUISIANA AND MISSISSIPPI.
U.S. ARMY CORPS OF ENGINEERS (DOE PRIME)	OBTAIN AND MAINTAIN LAND ACCESS FOR LOUISIANA FIELD STUDIES RELATED TO GEOLOGY, HYDROLOGY, AND GEOPHYSICS.
LOUISIANA STATE UNIVERSITY - INSTITUTE FOR ENVIRONMENTAL STUDIES (DOE AND ONWI)	LOUISIANA SALT DOME GATHERING, ANALYSIS, AND REPORTING GEOLOGIC AND HYDROLOGIC DATA TO ADDRESS GEOMETRY, HYDROLOGIC STABILITY, GEOENGINEERING ASPECTS, AND GEOCHEMISTRY.

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GULF COAST SALT DOME (CONTINUED)

PRINCIPAL GEOLOGIC SUBCONTRACTORS

CONTRACTOR	RESPONSIBILITY
TEXAS BUREAU OF ECONOMIC GEOLOGY (DOE PRIME)	EAST TEXAS SALT DOME GATHERING, ANALYSIS, AND REPORTING GEOLOGIC AND HYDROLOGIC DATA TO ADDRESS SITE GEOMETRY, HYDROLOGIC STABILITY, GEOENGINEERING ASPECTS, AND GEOCHEMISTRY.

ONWI

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GULF COAST SALT DOMES MAJOR REPORTS

OFFICE OF NUCLEAR WASTE ISOLATION, 1979. SUMMARY CHARACTERIZATION AND RECOMMENDATION OF STUDY AREAS FOR THE GULF INTERIOR REGION, ONWI-18.

BECHTEL NATIONAL, INC., 1983. ENVIRONMENTAL CHARACTERIZATION REPORT FOR THE GULF INTERIOR REGION LOUISIANA, MISSISSIPPI, AND TEXAS STUDY AREAS, ONWI-192 THROUGH 194, PREPARED FOR OFFICE OF NUCLEAR WASTE ISOLATION.

LAW ENGINEERING TESTING COMPANY, 1981, GEOLOGIC EVALUATION OF GULF COAST SALT DOMES: OVERALL ASSESSMENT OF THE GULF INTERIOR REGION, ONWI-106, PREPARED FOR OFFICE OF NUCLEAR WASTE ISOLATION.

* OFFICE OF NUCLEAR WASTE ISOLATION, 1982, EVALUATION OF AREA STUDIES OF THE U.S. GULF COAST SALT DOME BASINS: LOCATION RECOMMENDATION REPORT, ONWI-109.

LAW ENGINEERING TESTING COMPANY, 1982, GULF COAST SALT DOMES GEOLOGIC AREA CHARACTERIZATION REPORTS, VOLUMES I THROUGH IV, ONWI-117 THROUGH 120 AND APPENDICES, PREPARED FOR OFFICE OF NUCLEAR WASTE ISOLATION.

ONWI

Office of Nuclear Waste Isolation

BATTELLE Project Management Division

GULF COAST SALT DOMES SUPPORTIVE REPORTS

U.S. GEOLOGICAL SURVEY, 1980. BASE OF FRESH GROUND WATER, NORTHERN LOUISIANA SALT DOMES BASIN AND VICINITY, NORTHERN LOUISIANA AND SOUTHERN ARKANSAS, ONWI-131, PREPARED FOR OFFICE OF NUCLEAR WASTE ISOLATION.

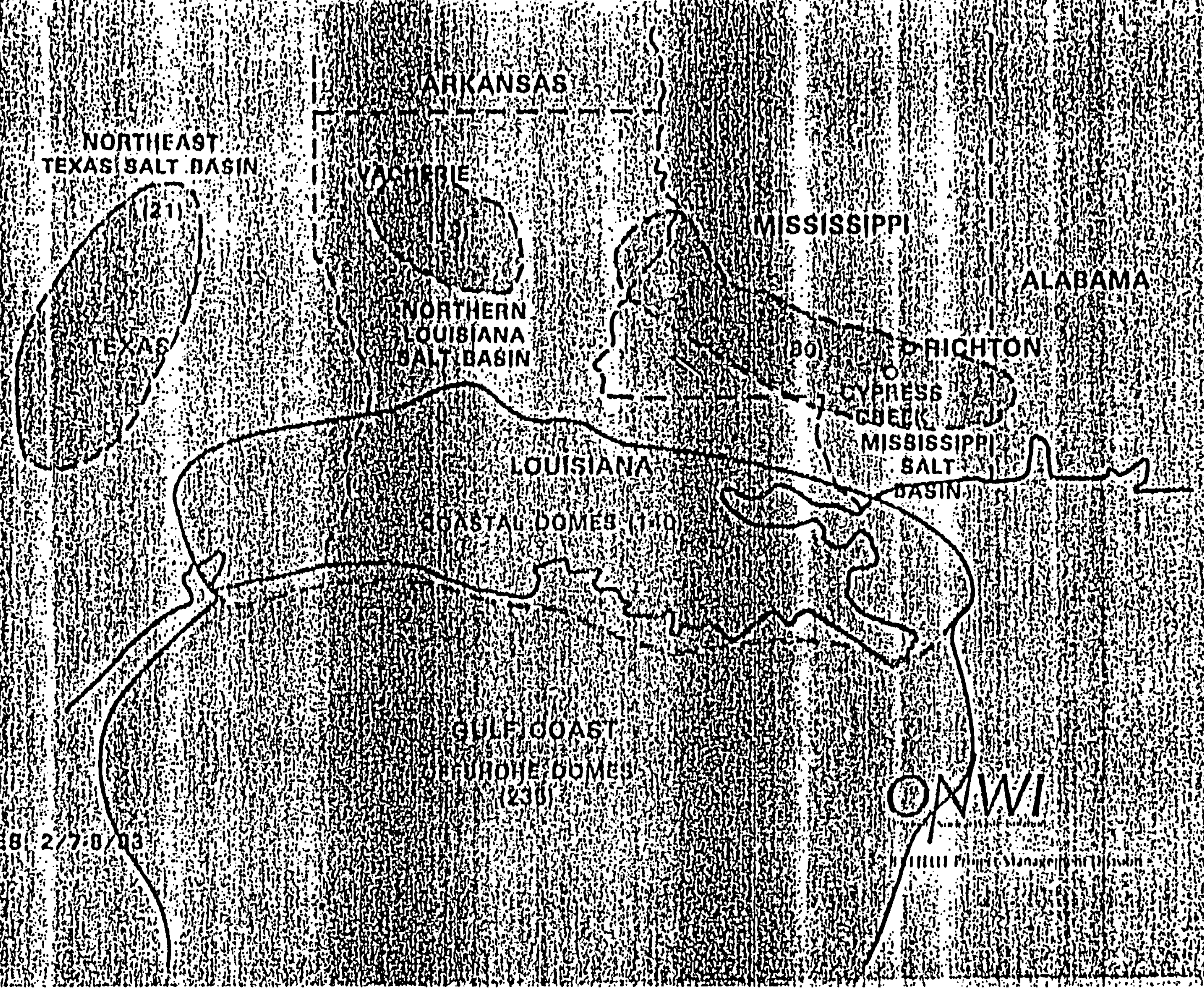
LAW ENGINEERING TESTING COMPANY, 1982. PETROGRAPHIC AND GEOCHEMICAL CHARACTERISTICS OF THE RICHTON SALT CORE, ONWI-277, PREPARED FOR OFFICE OF NUCLEAR WASTE ISOLATION.

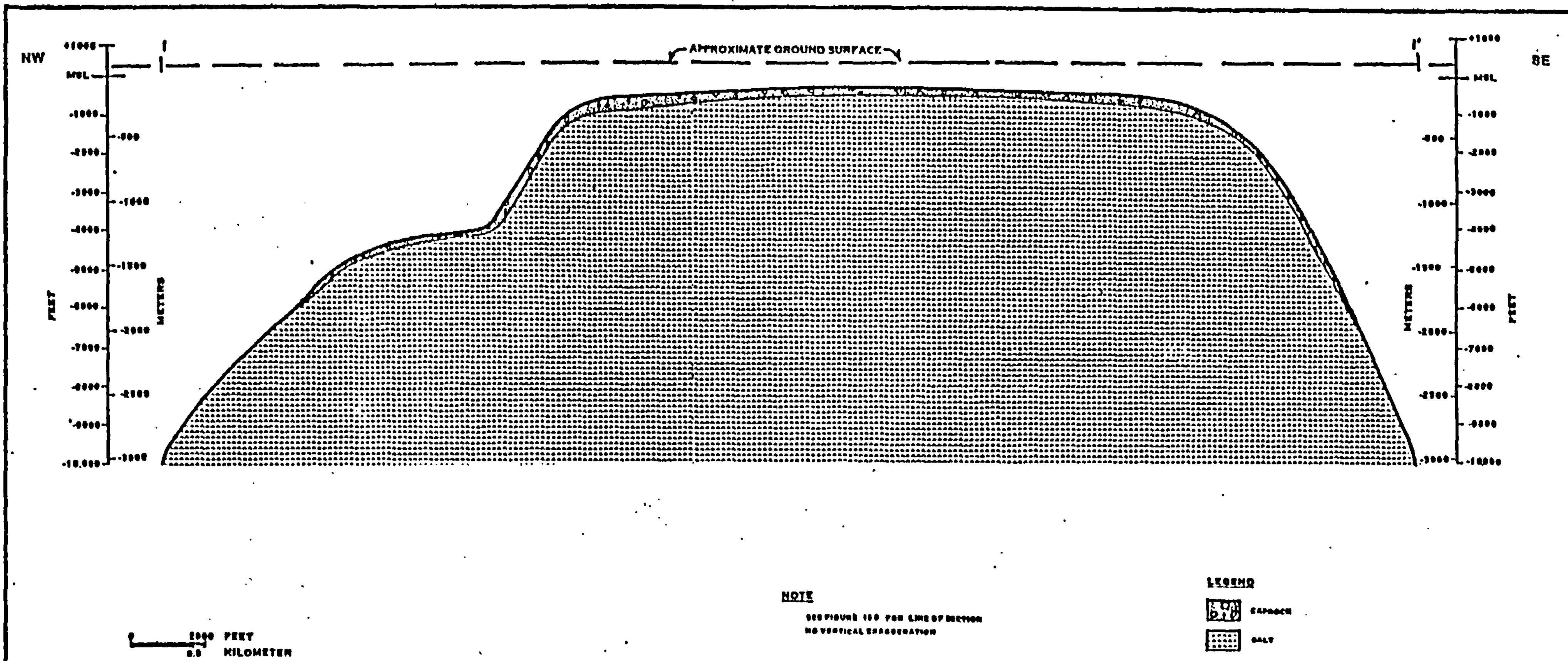
LAW ENGINEERING TESTING COMPANY, 1982. MAXIMUM POTENTIAL EROSION AND INUDATION OF SEVEN INTERIOR SALT DOMES, ONWI-278, PREPARED FOR THE OFFICE OF NUCLEAR WASTE ISOLATION.

LAW ENGINEERING TESTING COMPANY, 1983. GEOTHERMAL STUDIES FOR SEVEN INTERIOR SALT DOMES, OWNI-289, PREPARED FOR OFFICE OF NUCLEAR WASTE ISOLATION.

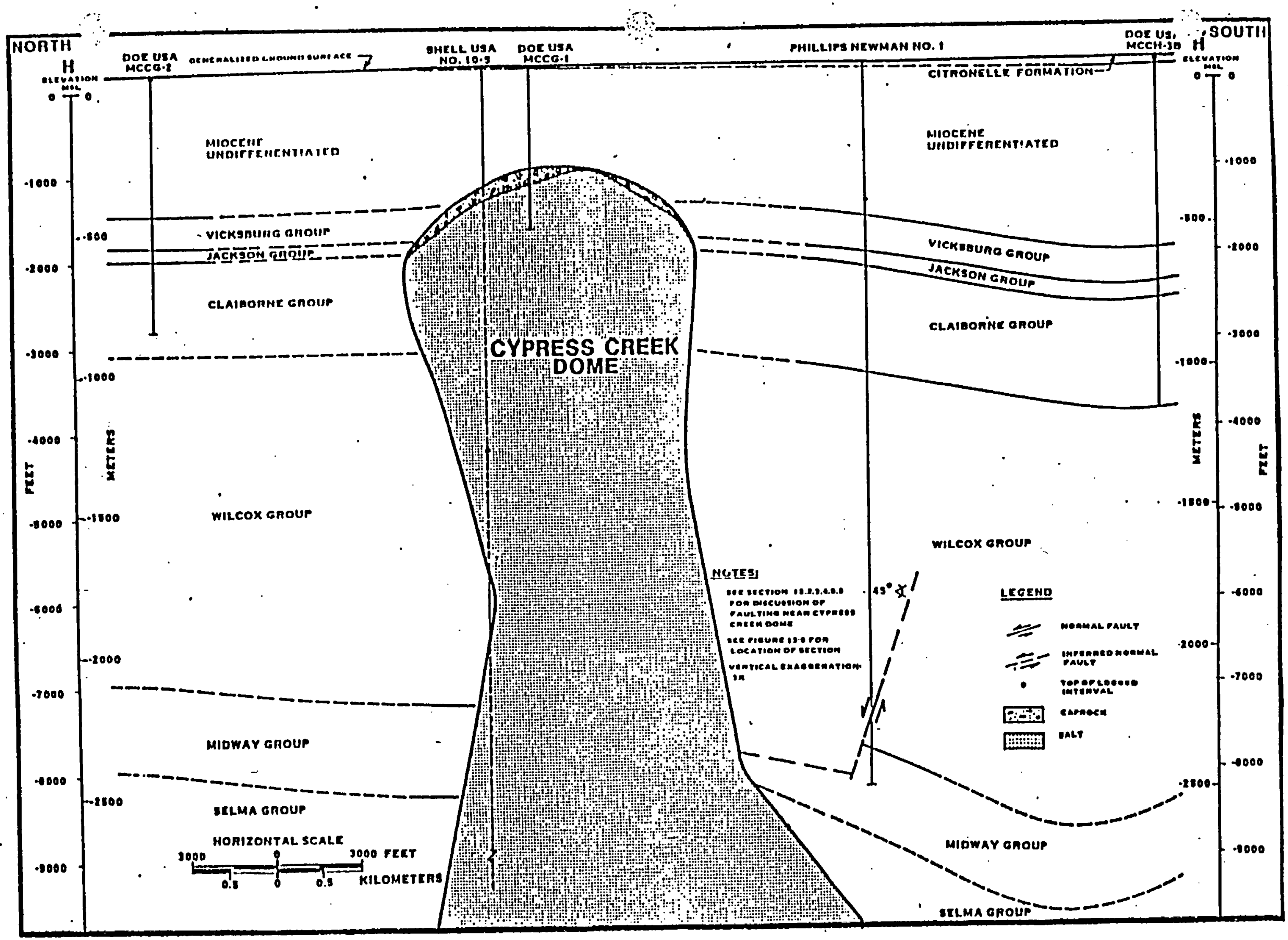
LAW ENGINEERING TESTING COMPANY, 1983. SALT, CAPROCK, AND SHEATH STUDY, ONWI-355, PREPARED FOR OFFICE OF NUCLEAR WASTE ISOLATION.

SCREENING RESULTS
GULF COAST SALT DOMES

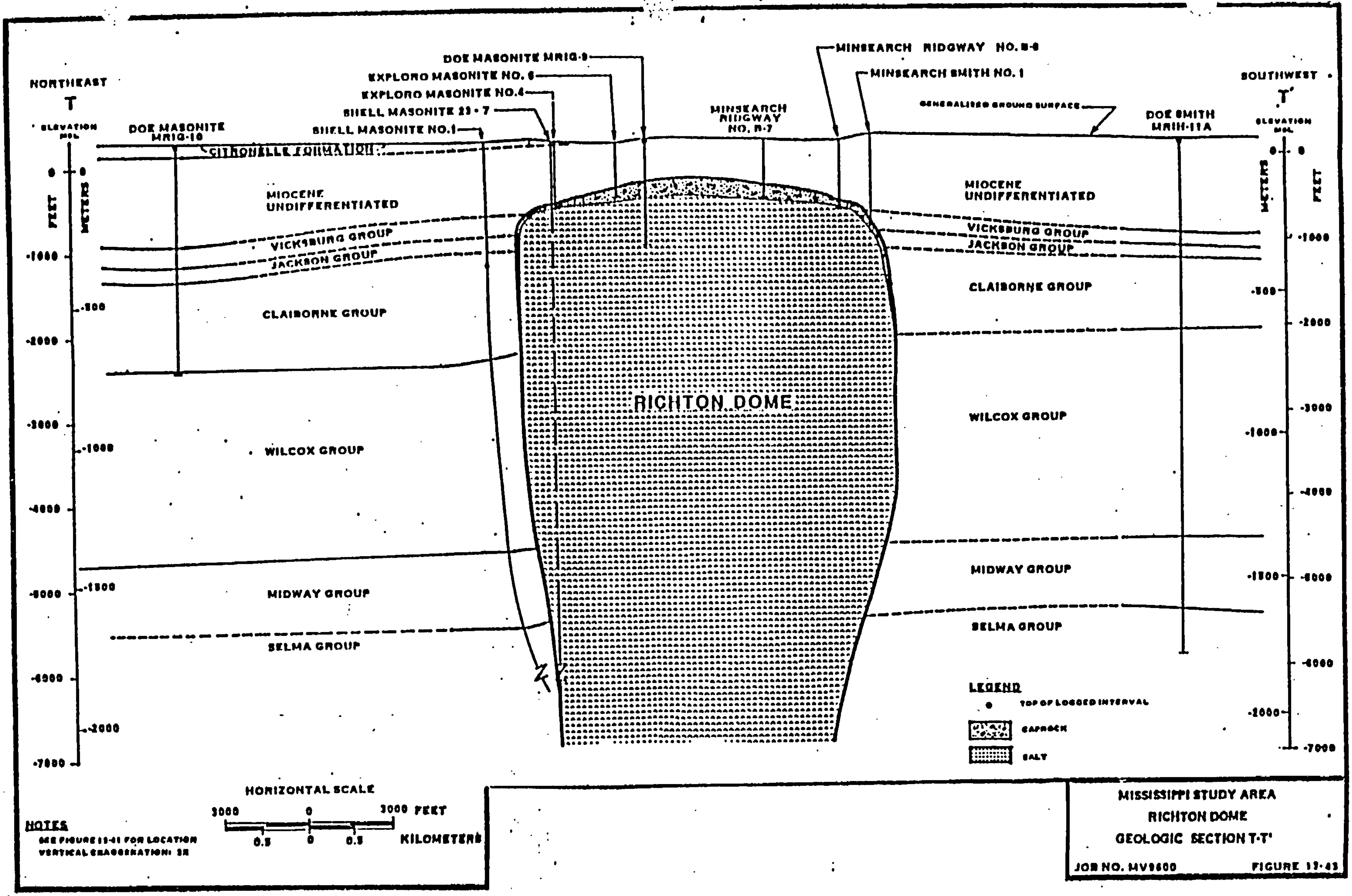




PREPARED ______ DATE ______ REVISED ______ DATE ______ REVISED ______ DATE ______ APPROVED ______ DATE 12/23/82 T-1393-9	NATIONAL WASTE TERMINAL STORAGE PROGRAM GEOLOGIC EVALUATION GULF COAST SALT DOMES LAW ENGINEERING TESTING COMPANY MARIETTA, GEORGIA	NORTH LOUISIANA STUDY AREA VACHERIE DOME GEOLOGIC SECTION I-I' JOB NO. MV [illegible] FIGURE 10-4



NORTH
SOUTH
H
DOE USA MCCG-2
GENERALIZED GROUND SURFACE
SHELL USA NO. 10-5
DOE USA MCCG-1
PHILLIPS NEWMAN NO. 1
DOE US. MCCH-3B
CITRONELLE FORMATION
ELEVATION MSL
MIOCENE UNDIFFERENTIATED
VICKSBURG GROUP
JACKSON GROUP
CLAIBORNE GROUP
CYPRESS CREEK DOME
WILCOX GROUP
MIDWAY GROUP
SELMA GROUP
FEET
METERS
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-500
-1000
-1500
-2000
-2500
HORIZONTAL SCALE
3000 0 3000 FEET
0.5 0 0.5 KILOMETERS
NOTES:
FOR DISCUSSION OF FAULTING NEAR CYPRESS CREEK DOME
LOCATION OF SECTION
VERTICAL EXAGGERATION:
45°
LEGEND
NORMAL FAULT
INFERRED NORMAL FAULT
TOP OF LOGGED INTERVAL
CAPROCK
SALT



MISSISSIPPI STUDY AREA
RICHTON DOME
GEOLOGIC SECTION T-T'
JOB NO. MV9600 FIGURE 13-43

PARADOX BASIN

PRINCIPAL GEOLOGIC SUBCONTRACTORS

CONTRACTOR	RESPONSIBILITY
WOODWARD-CLYDE CONSULTANTS	PARADOX BASIN GEOLOGIC PROJECT MANAGER-- GATHERING, ANALYSIS, AND REPORTING GEOLOGIC DATA TO ADDRESS SITE GEOMETRY, GEOHYDROLOGY, GEOCHEMISTRY, ROCK CHARACTERISTICS, TECTONIC ENVIRONMENT, HUMAN INTRUSION.
U.S. GEOLOGICAL SURVEY (DOE PRIME)	MINERALOGIC AND GEOCHEMICAL ANALYSIS OF CORE FROM NWTS PARADOX BASIN BOREHOLES TO ADDRESS GEOCHEMISTRY. GEOPHYSICAL INVESTIGATIONS TO ADDRESS TECTONIC ENVIRONMENT AND SITE GEOMETRY.
UTAH GEOLOGICAL AND MINERAL SURVEY	LITERATURE SURVEY AND GEOLOGIC MAPPING TO ADDRESS TECTONIC ENVIRONMENT AND HUMAN INTRUSION.

ONWI

BATTELLE Project Management Division

PARADOX BASIN MAJOR REPORTS

WOODWARD-CLYDE CONSULTANTS, 1980. OVERVIEW OF THE REGIONAL GEOLOGY OF THE PARADOX BASIN STUDY REGIONS. PREPARED FOR THE OFFICE OF NUCLEAR WASTE ISOLATION, ONWI-92.

BECHTEL GROUP, INC., AND WOODWARD-CLYDE CONSULTANTS, 1981. SUMMARY CHARACTERIZATION AND RECOMMENDATION OF STUDY AREAS FOR THE PARADOX BASIN STUDY REGION. PREPARED FOR THE OFFICE OF NUCLEAR WASTE ISOLATION, ONWI-36.

* WOODWARD-CLYDE CONSULTANTS, 1981. GEOLOGIC CHARACTERIZATION REPORT FOR THE PARADOX BASIN STUDY AREAS. PREPARED FOR THE OFFICE OF NUCLEAR WASTE ISOLATION, ONWI-290.

* BECHTEL GROUP, INC., AND WOODWARD-CLYDE CONSULTANTS, 1982. PARADOX BASIN AREA CHARACTERIZATION SUMMARY AND LOCATION RECOMMENDATION REPORT. PREPARED FOR THE OFFICE OF NUCLEAR WASTE ISOLATION, ONWI-291.

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PARADOX BASIN
SUPPORTING DOCUMENTS

BECHTEL GROUP, INC. AND WOODWARD-CLYDE CONSULTANTS, 1982. PARADOX BASIN SITE CHARACTERIZATION REPORT PREPARATION PAPERS GIBSON DOME LOCATION. PREPARED FOR THE OFFICE OF NUCLEAR WASTE ISOLATION, ONWI-301.

DOELLING, H. H., 1982. GEOLOGIC STUDIES OF THE SALT VALLEY ANTICLINE-PROGRESS REPORT. UTAH GEOLOGICAL AND MINERAL SURVEY OPEN-FILE REPORT NO. 30.

HITE, R. J., 1982 POTASH DEPOSITS IN THE GIBSON DOME AREA, SOUTHEASTERN UTAH. U.S. GEOLOGICAL SURVEY, OPEN-FILE REPORT NO. 82-1067.

RUSH, E. F. ET AL, 1982. REGIONAL HYDROLOGY OF THE GREEN RIVER-MOAB AREA, NORTHWESTERN PARADOX BASIN, UTAH. U.S. GEOLOGICAL SURVEY, OPEN-FILE REPORT NO. 82-107.

WOLLITZ, L. E., 1982. RESULTS OF HYDROLOGIC TESTS IN U.S. DEPARTMENT OF ENERGY'S WELLS DOE-4, 5, 6, 7, 8, AND 9, SALT VALLEY, GRAND COUNTY, UTAH. U.S. GEOLOGICAL SURVEY, OPEN-FILE REPORT NO. 82-346.

WOODWARD-CLYDE CONSULTANTS, 1982. GIBSON DOME NO. 1 BOREHOLE (COMPLETION REPORT). PREPARED FOR THE OFFICE OF NUCLEAR WASTE ISOLATION, ONWI-388.

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PARADOX BASIN
SUPPORTING DOCUMENTS (CONTINUED)

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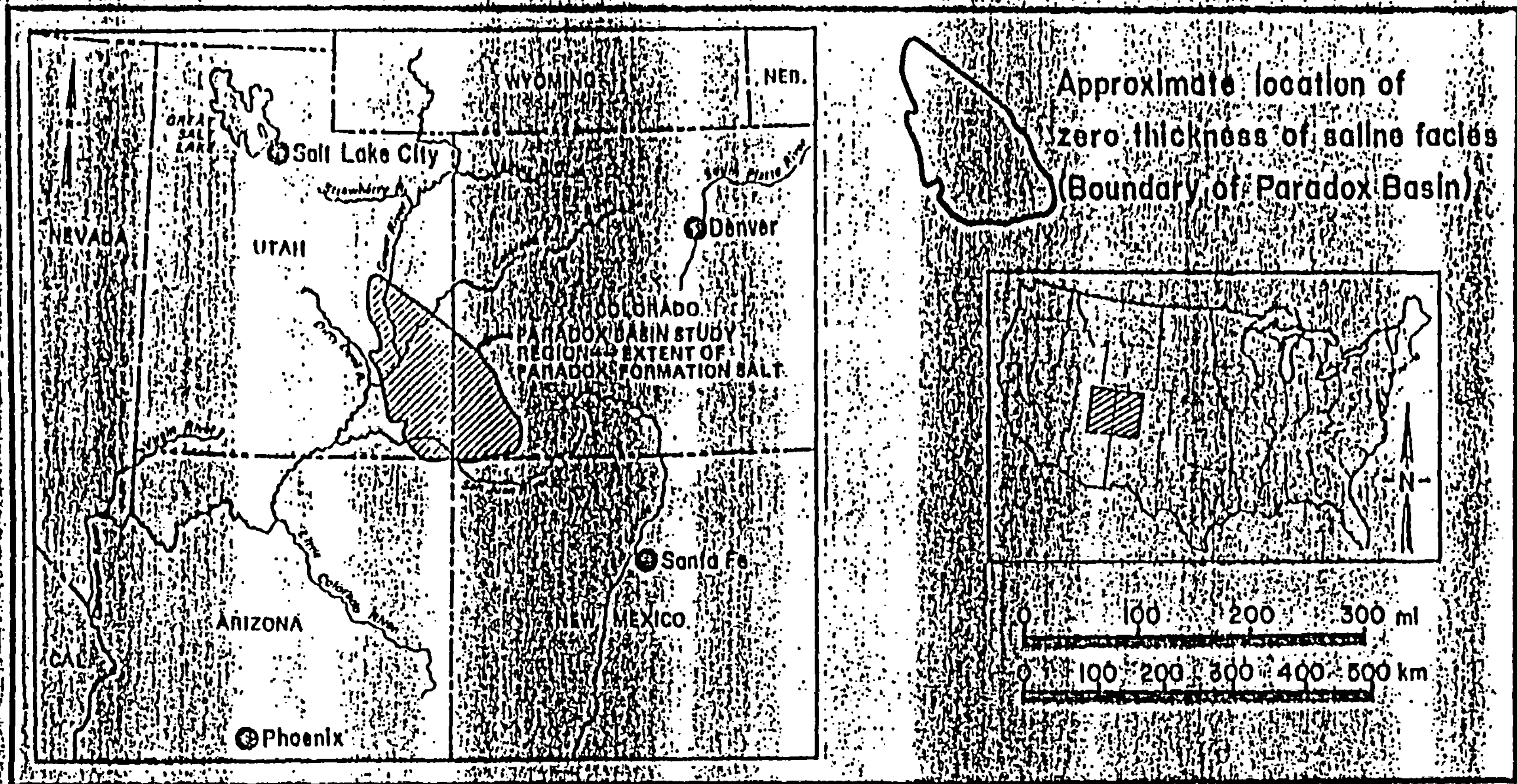

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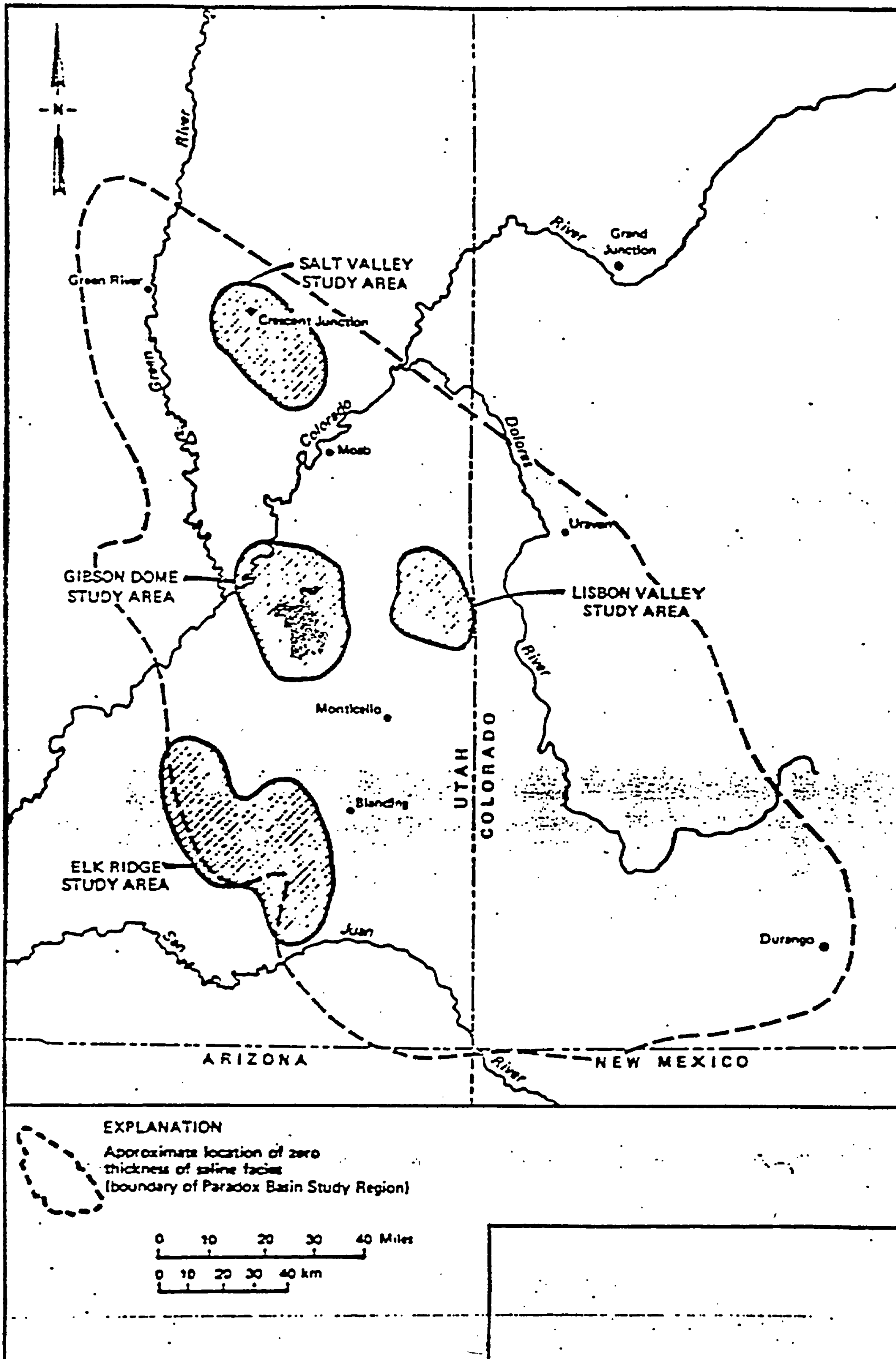
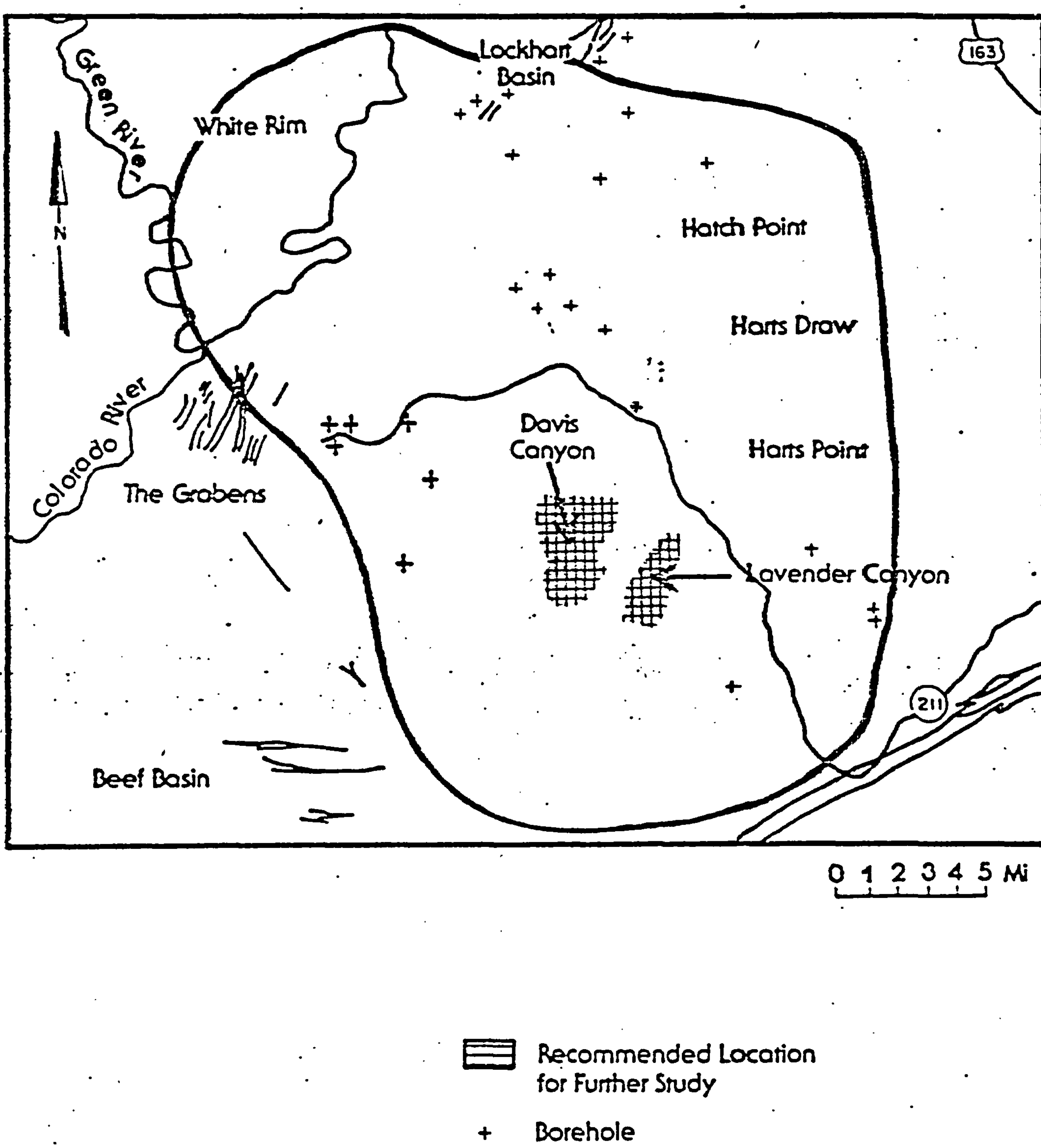
LOCATION MAP OF THE PARADOX BASIN (STUDY REGION)


N
SALT VALLEY
STUDY AREA
Green River
Crescent Junction
Grand
Junction
River
River
Green
River
Colorado
Moab
Dolores
Uravan
GIBSON DOME
STUDY AREA
LISBON VALLEY
STUDY AREA
River
Monticello
Blanding
UTAH
COLORADO
ELK RIDGE
STUDY AREA
San
Juan
Durango
ARIZONA
River
NEW MEXICO
EXPLANATION
Approximate location of zero
thickness of saline facies
(boundary of Paradox Basin Study Region)
0 10 20 30 40 Miles
0 10 20 30 40 km

Recommended Location for Further Study at Gibson Dome



STRATIGRAPHIC COLUMN

GIBSON DOME AREA

Erathem	System	Group	Rock Unit	
CENOZOIC	Quaternary		Alluvial, Eolian, and Colluvial Deposits	Exposed units in the Gibson Dome Area
MESOZOIC	Jurassic	San Rafael Group	Entrada Sandstone: Slick Rock Member	
			Entrada Sandstone: Dewey Bridge Member	
		Glen Canyon Group	Navajo Sandstone	
			Kayenta Formation	
			Wingate Sandstone	
	Triassic		Chinle Formation	
			Moss Back Member	
			Moenkopi Formation	
PALEOZOIC	Permian	Cutler Group	White Rim Sandstone	
			Upper Cutler	
			Cedar Mesa Sandstone	Gibson Dome No. 1 penetration
			Elephant Canyon Formation	
			Cutler Formation	
	Pennsylvanian	Hermosa Group	Honaker Trail Formation	
			Paradox Formation	
			Pinkerton Trail Formation	
			Molas Formation	
	Mississippian		Leadville Limestone	
			Ouray Limestone	
	Devonian		Elbert Formation: Upper Elbert Member	Presumed to occur; not penetrated in present study
			Elbert Formation: McCracken Sandstone Member	
	Cambrian		Muav Limestone	
			Bright Angel Shale	
			Ignacio Formation (quartzite)	
Pre-Paleozoic	Pre-Cambrian		Basement Complex of Igneous and Metamorphic Rock	

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FORMATION DEPTHS GD-1 BOREHOLE

ERATHEM	SYSTEM	FORMATION		DEPTH
PALEOZOIC	PERMIAN	White Rim Sandstone	Cutler Group	Exposed
		Upper Cutler Formation (Organ Rock equivalent)		0-679 feet
		Cedar Mesa Formation		
		Elephant Canyon Formation		679-1,239 feet
	PENNSYLVANIAN	Hermosa Group	Honaker Trail Formation	1,239-2,618 feet
			Paradox Formation	2,618-5,507 feet
			Pinkerton Trail Formation	5,507-5,715 feet
		Molas Formation		5,715-5,861 feet
	MISSISSIPPIAN	Leadville Limestone		5,861-6,332 feet
		Ouray Limestone		6,332-6,384 feet Not penetrated
	DEVONIAN	Elbert Formation	Upper Elbert Member	Not penetrated
			McCracken Sandstone Member	
		Aneth Formation		Not penetrated

PERMIAN BASIN

PRINCIPAL GEOLOGIC SUBCONTRACTORS

CONTRACTOR	RESPONSIBILITY
STONE & WEBSTER ENGINEERING	PERMIAN BASIN GEOLOGIC PROJECT MANAGER--GATHERING, ANALYSIS, AND REPORTING GEOLOGIC DATA TO ADDRESS SITE GEOMETRY, GEOHYDROLOGY, GEOCHEMISTRY, TECTONIC ENVIRONMENT, AND HUMAN INTRUSION
TEXAS BUREAU OF ECONOMIC GEOLOGY (DOE PRIME)	TO PROVIDE INPUT TO SITE GEOMETRY, GEOHYDROLOGY, GEOCHEMISTRY, TECTONIC ENVIRONMENT, AND HUMAN INTRUSION
U.S. GEOLOGICAL SURVEY (DOE PRIME)	TO PROVIDE INPUT TO ROCK MECHANICS
ARIZONA STATE UNIVERSITY	TO PROVIDE INPUT TO GEOCHEMISTRY
BENDIX FEC	TO PROVIDE INPUT TO GEOCHEMISTRY
PACIFIC NORTHWEST LABORATORIES	TO PROVIDE INPUT TO GEOCHEMISTRY
K. S. JOHNSON, CONSULTANT	GENERAL GEOLOGY

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PERMIAN BASIN MAJOR REPORTS

JOHNSON, K. S., AND GONZALES, S., 1978. SALT DEPOSITS OF THE UNITED STATES AND REGIONAL GEOLOGIC CHARACTERISTICS IMPORTANT FOR STORAGE OF RADIOACTIVE WASTE

* STONE & WEBSTER ENGINEERING. AREA GEOLOGIC CHARACTERIZATION REPORT - DALHART AND PALO DURO BASINS DOE/CH/10140-1 (AVAILABLE JUNE 1983)

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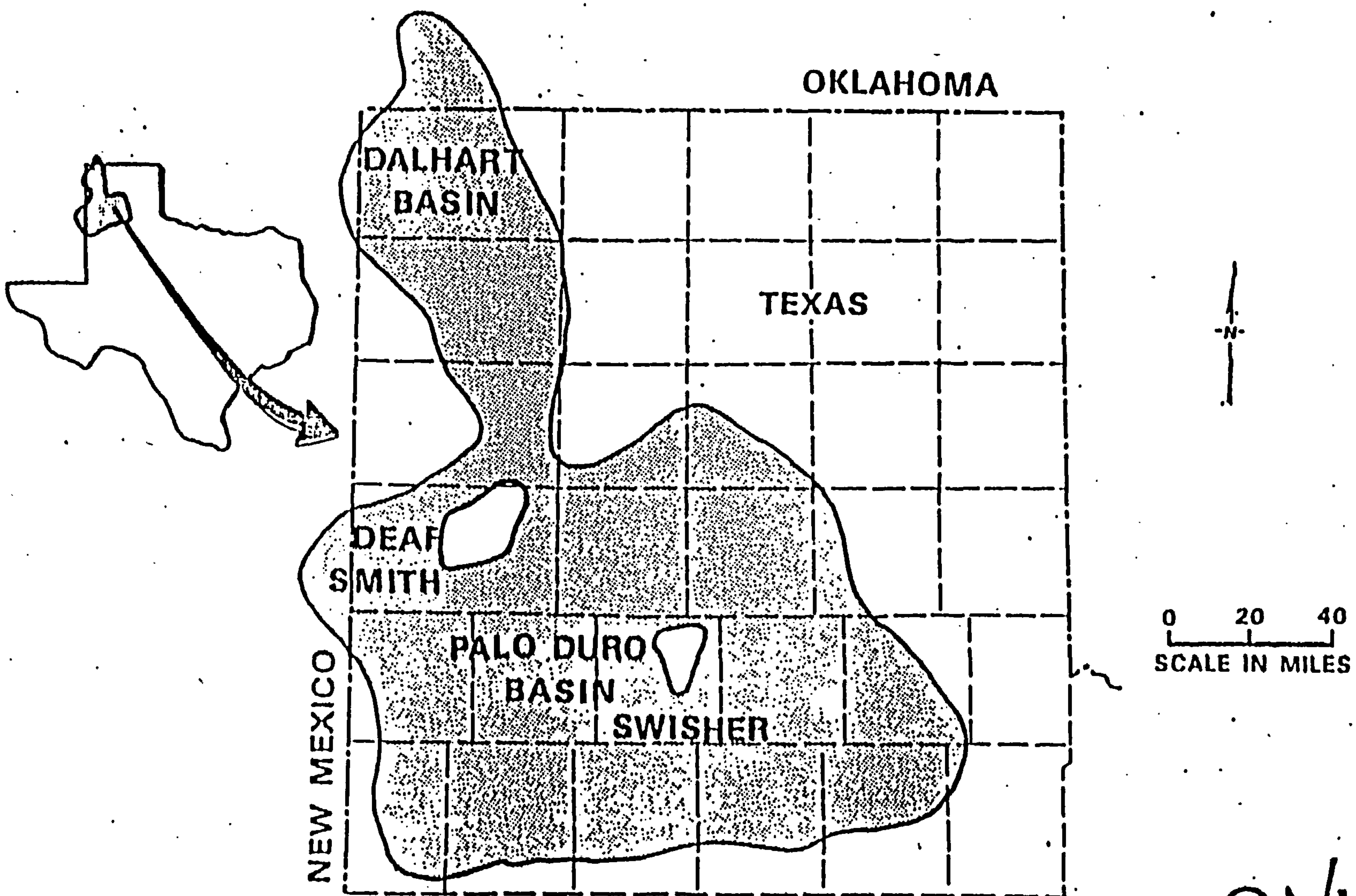
GEOLOGIC EXPLORATION — PERMIAN BASIN



WEN: 2/7-8/83

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STRATIGRAPHIC COLUMN

PERMIAN BASIN

SYSTEM	GROUP	FORMATION
QUATERNARY		RECENT FLUVIAL & LUCUSTRINE DEPOSITS
TERTIARY		OGALLALA
TRIASSIC	DOCKUM	
PERMIAN		DEWEY LAKE
		ALIBATES
	ARTESIA/WHITEHORSE	SALADO
		YATES
		SEVEN RIVERS
		QUEEN/GRAYBURG
		SAN ANDRES
	CLEAR FORK	GLORIETA
		UPPER CLEAR FORK
		TUBB
		LOWER CLEAR FORK
		RED CAVE
	WICHITA	
	WOLFCAMP	
PENNSYLVANIAN	UNNAMED SANDSTONE, CARBONATE, AND SHALE	
PRECAMBRIAN	UNDIFFERENTIATED RHYOLITE	

SALT BEARING

SYSTEMS FUNCTION

M. A. GLORA

J. F. KIRCHER

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SYSTEMS FUNCTION ORGANIZATION

MANAGER
W. M. HEWITT

- PERFORMANCE ASSESSMENT
  J. F. KIRCHER
- SYSTEMS DEPARTMENT
  J. MCDOWELL
- REGULATORY DEPARTMENT
  M. A. GLORA

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SYSTEMS FUNCTIONAL RESPONSIBILITY

RESPONSIBLE FOR PLANNING, IMPLEMENTATION AND MANAGEMENT OF ACTIVITIES ASSOCIATED WITH PERFORMANCE ASSESSMENT, REGULATORY, AND TECHNICAL BASELINE DEVELOPMENT

PERFORMANCE ASSESSMENT DEPARTMENT

- CODE DEVELOPMENT AND DOCUMENTATION
  - NATURAL SYSTEM
  - ENGINEERED SYSTEM
- ANALYTICAL SUPPORT

REGULATORY DEPARTMENT

- LICENSE DOCUMENT PREPARATION
- SUPPORT DOE/NRC INTERACTIONS
- LICENSING BASELINE EVALUATION

SYSTEMS ENGINEERING DEPARTMENT

- PROGRAM IMPLEMENTATION CONSISTENCY
- DATA BASE MANAGEMENT

REGULATORY DEPARTMENT RESPONSIBILITIES

- REGULATORY INTEGRATION
  - ONWI PROGRAM COMPLIANCE INTEGRATION
  - REGULATORY REVIEW
  - LICENSING ISSUE IDENTIFICATION
  - LICENSING PROCEDURES
  - NRC INTERACTION SUPPORT
- LICENSING
  - LEAD ONWI RESPONSIBILITY FOR LICENSING DOCUMENT PREPARATION (SCR/P, SAR, ER)
  - FORMAT AND CONTENT GUIDANCE
- SAFETY
  - SAFETY DEMONSTRATION STRATEGY
  - SUPPORT OR PROVIDE ANALYSES TO DEMONSTRATE SAFETY (RADIOLOGICAL, NONRADIOLOGICAL, ALARA)
  - SUPPORT RESOLUTION OF IDENTIFIED ISSUES AS REQUIRED
  - DEFINE AND COORDINATE INTEGRATED SAFETY ASSESSMENTS (ENGINEERED AND NATURAL SYSTEM ADEQUACY, OVERALL SYSTEM ADEQUACY)

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REGULATORY DEPARTMENT

SUBCONTRACTORS

- EMPHASIS PLACED ON REVIEWING AND APPLYING DATA AND CONCEPTS GENERATED BY OTHER ONWI COMPONENTS AND DOE CONTRACTORS

  - BECHTEL GROUP, INC.
  - NUS
  - EBASCO

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SYSTEMS ENGINEERING

ENGINEERING/INTEGRATION

- INTEGRATED SYSTEMATIC TECHNICAL DEVELOPMENT PROCESS
  - DEFINED/CONTROLLED BY SYSTEMS ENGINEERING MANAGEMENT PLAN (SEMP)
- CONTROLLED TECHNICAL BASELINE
  - CRITERIA, MAJOR ASSUMPTIONS, SPECIFICATIONS, PLANNING BASES
- CONTROLLED TECHNICAL DATA
  - KEY PARAMETRIC DATA, SUBJECT AREAS
  - OVERALL TECHNICAL DATA MANAGEMENT SYSTEM
- SYSTEM REQUIREMENTS/SPECIFICATION

ANALYSES

- SITE SELECTION COMPARATIVE ANALYSES
- REQUIREMENTS ANALYSES
- OPERATIONAL ANALYSES
- TRADE STUDIES

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SYSTEMS ENGINEERING
AVAILABLE DOCUMENTATION

- NWTS/ONWI 33 SERIES DOCUMENT INTEGRATION INTO ONWI PROGRAM BASELINE
  - NWTS-33(1)
    PROGRAM OBJECTIVES, FUNCTIONAL REQUIREMENTS, AND SYSTEM PERFORMANCE CRITERIA
  - NWTS-33(2)
    SITE PERFORMANCE CRITERIA
  - NWTS-33(3)
    REPOSITORY PERFORMANCE AND DEVELOPMENT CRITERIA
  - NWTS-33(4A)
    FUNCTIONAL REQUIREMENTS AND PERFORMANCE CRITERIA FOR WASTE PACKAGES FOR SOLIDIFIED HIGH-LEVEL WASTE AND SPENT FUEL

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PERFORMANCE ASSESSMENT

J. F. KIRCHER

APRIL 1983

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SCOPE OF PERFORMANCE ASSESSMENT ACTIVITIES

- OVER 50% OF WORK BEING PERFORMED IN-HOUSE BY ONWI INCLUDING CUSTODIANSHIP OF ALL CODES

- METHODOLOGY DEVELOPMENT ACTIVITIES
  - SELECTION AND EVALUATION OF EXISTING CODES
  - MODIFICATION AND IMPROVEMENT OF EXISTING CODES
  - DEVELOPMENT OF NEW CODES AND MODELS
  - VERIFICATION OF COMPUTER CODES
  - VALIDATION OF MATHEMATICAL MODELS
  - DOCUMENTATION IN CONFORMANCE WITH NRC GUIDELINES
  - PEER REVIEW AND ACCEPTANCE OF CODES AND MODELS

- PRECLOSURE ASSESSMENTS
  - RADIOLOGICAL AND NONRADIOLOGICAL
  - FOR ACCIDENTS AND NORMAL OPERATION
  - FOR PUBLIC AND WORKERS' HEALTH AND SAFETY

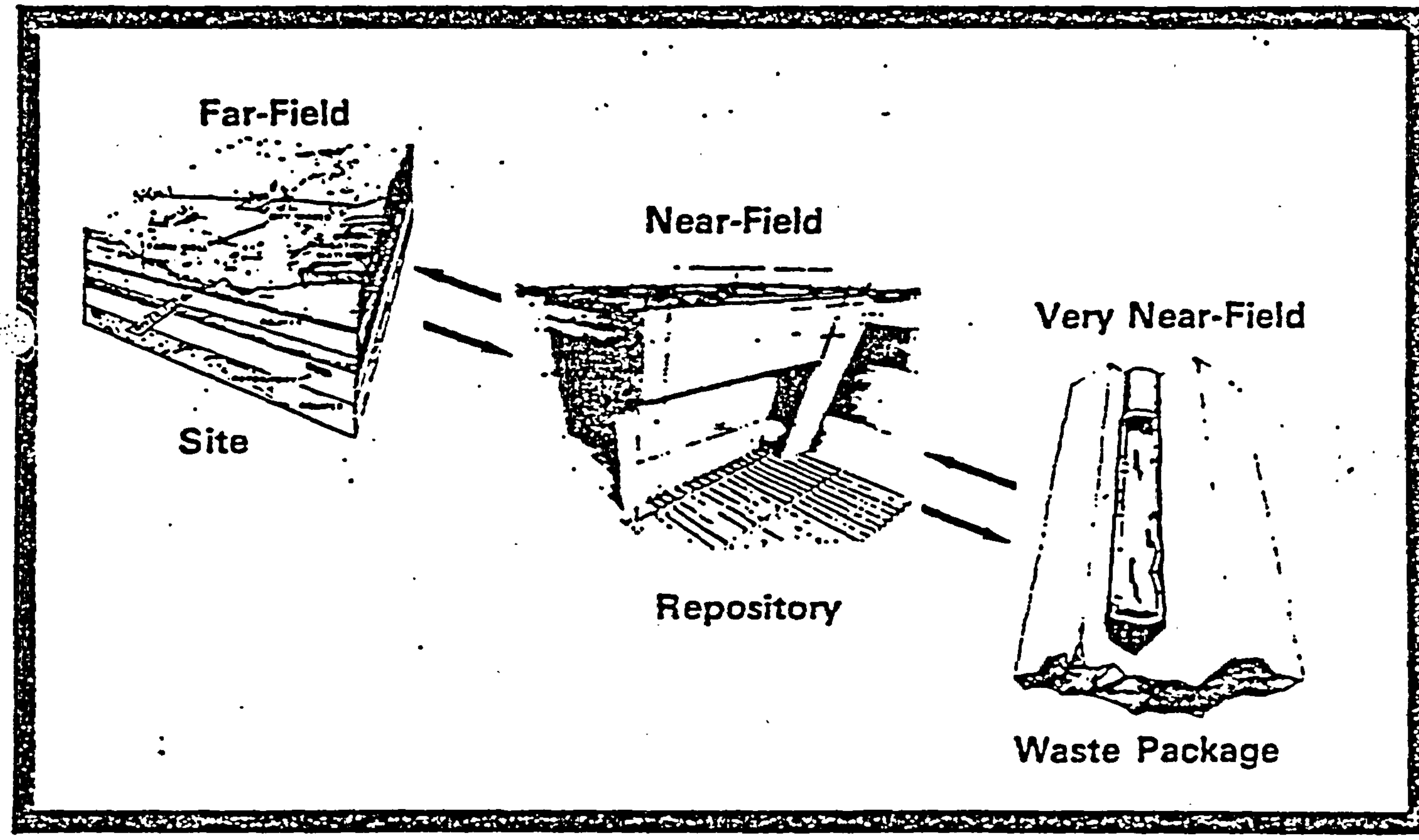
- POSTCLOSURE ASSESSMENTS
  - RADIOLOGICAL
  - FOR LONG-TERM PROCESSES AND SHORT-DURATION EVENTS
  - FOR PUBLIC HEALTH AND SAFETY

FY 83 PERFORMANCE ASSESSMENT SUBCONTRACTORS

NAME	SCOPE OF WORK
INTERA ENVIRONMENTAL CONSULTANTS	PA METHODOLOGY IMPROVEMENTS, VALIDATION AND DOCUMENTATION SENSITIVITY AND UNCERTAINTY METH. DEVELOPMENT ENGINEERING SYSTEMS PERFORMANCE ASSESSMENT SITE PERFORMANCE ASSESSMENT
OAK RIDGE NATIONAL LABORATORY	DEMONSTRATION OF ADJOINT UNCERTAINTY ANALYSIS TECHNIQUES
PACIFIC NORTHWEST LABORATORY	GEOSTATISTICAL UNCERTAINTY ANALYSIS BASELINING AND BENCHMARKING SALT SITE CODES
BATTELLE COLUMBUS LABORATORIES	TECHNICAL ASSISTANCE ON ADJOINT UNCERTAINTY ANALYSIS TECHNIQUES COMPUTER PROGRAMMING ASSISTANCE

ONWI

Preliminary Performance Assessment Plan for a Nuclear Waste Repository in Salt

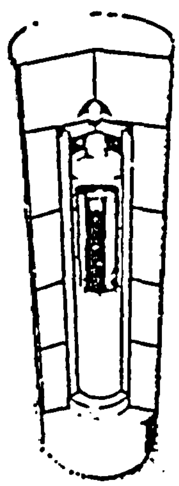


Performance Assessment Department
Office of Nuclear Waste Isolation
Battelle Project Management Division
Columbus, Ohio

TO BE ISSUED IN FY 83

Performance
Assessment Measures

- Effective Confinement Period Provided by Structures and Barriers
- Annual Radionuclide Transport Release Rates Not to Exceed One Part in 100,000 in Undeground Facility After 1,000 Years



Detailed Individual Process Analyses for Waste Package Performance Assessment

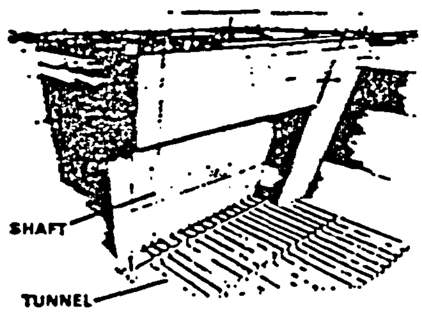
- Waste Package Thermal Boundary Analyses
- Temperature Analyses Within Waste Package Components
- Waste Package Thermomechanical Stress Boundary Analyses
- Stress and Strain in Various Components of Waste Package
- Geochemical Reactions Affecting the Waste Package
- Corrosion of Metallic Canister and Overpack Fluid Flow in the Vicinity of the Waste Package
  - Brine Migration
  - Convective Currents
  - Others
- Radionuclide Leach Rate From Waste Form and Release Rate From the Waste Package

Detailed Individual Process Analyses for Waste Package Performance Assessment

Performance Assessment Plan

Radionuclides Release

Taking Into Account the Effects of Heat, Mechanical Stress, and Chemical Reactions Within Engineering System, Host Rock and Site Should Provide Adequate Isolation for at Least 10,000 Years with Acceptable Isolation Beyond that Time



Artist's Concept of a Geologic Repository

Proposed Analyses for Repository Subsystem Performance Assessment

2.1 Assessment of Thermal Environment

2.2 Thermomechanical Response in the Repository Regime

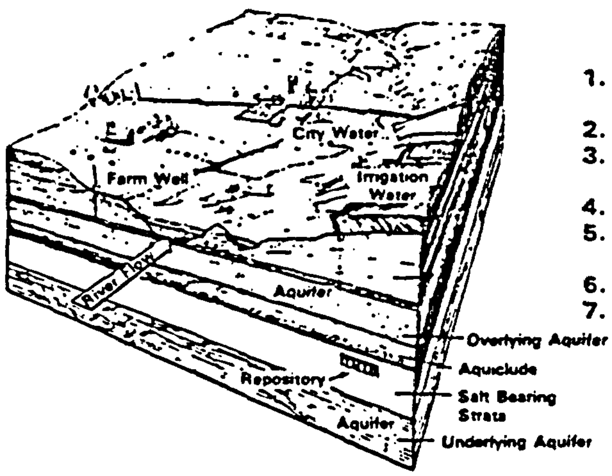
2.3 Fluid Flow Conditions in the Repository Regime

2.4 Geochemical Reactions Affecting Radionuclide Transport in the Repository Regime

2.5 Radionuclide Transport Within Repository Regime

Proposed Analysis for Repository Subsystem Performance Assessment

Analyses Proposed for Site Subsystem Assessment



1. Site Data Compilation, Evaluation and Geostatistical Analyses
2. Ground-Water Flow Rate and Hydrologic Budget
3. Geochemical Reactions Affecting Radionuclide Transport in Site Domains
4. Radionuclide Transport from Repository Boundary to Biosphere
5. Radiation Doses to Human Through Various Environmental Pathways
6. Long-Term Natural Processes and Events
7. Evaluation of Potential Human Interference

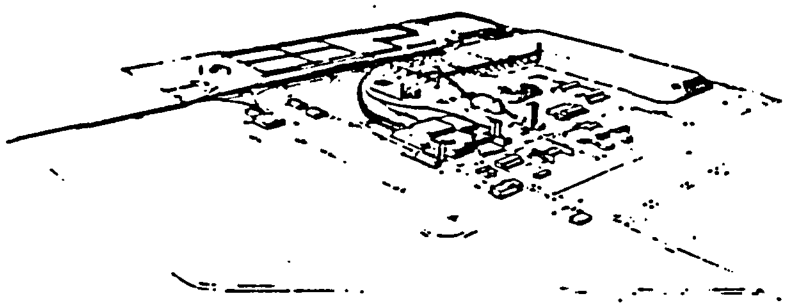
Performance Measures

Ground-Water and Radionuclide Travel Times and Rates From Repository to Accessible Environment

Analyses Proposed for Site Subsystem Assessment

Performance Measures

1. Occupational Exposures
2. Maximum Exposed Individual and Population



Normal Operations

1 Occupational Radiological Exposures From Normal Operations

2 Maximum Exposed Individual and Population (Environmental) Radiological Doses From Normal Operations

Accidents

3 Occupational Radiological Exposures From Accidents

4 Maximum Radiological Exposed Individual and Population (Environmental) Doses From Accidents

Operational Phase Radiological Safety Performance Assessment Plan

COMPUTER TAPES AND DOCUMENTATION*

TRANSMITTED TO

USNRC (JAMES A. SHIELDS)

ON 4/30/81

PATHS

VTT

FE3DGW

MMT

PABLM

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* THE SELECTION PROCESS WAS NOT COMPLETED AT TIME OF TRANSMITTAL. PATHS AND VTT ARE NOT NOW INCLUDED IN THE SUITE OF CODES OF INTEREST IN THE SALT PROGRAM.

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COMPUTER CODE DOCUMENTATION
REPORTS EXPECTED BACK
FROM PRINTERS IN APRIL 1983

DACRIN	ONWI-431
DOT	ONWI-420
FFSM	ONWI-436
FTRANS	ONWI-426
GEOTHER	ONWI-434
GETOUT	ONWI-433
GSM	ONWI-447
MATLOC	ONWI-421
MMT	ONWI-432
NETFLO	ONWI-425
PABLM	ONWI-446
PHREEQE	ONWI-435
SALT4	ONWI-429
STAFAN	ONWI-427
STFLO	ONWI-428
SWENT	ONWI-457
UTAH2	ONWI-430
VERTPAK-1	ONWI-451
VISCOT	ONWI-437
WAPPA	ONWI-452

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OTHER REPORTS ON GENERIC SALT SITE AND SYSTEM PERFORMANCE ASSESSMENT METHODOLOGY APPLICATIONS

JAN 1980	PNL-2782	TEST CASE RELEASE CONSEQUENCE ANALYSIS FOR A SPENT FUEL REPOSITORY IN BEDDED SALT
DEC 1980	PNL-3356	AN ANALYSIS ON THE USE OF ENGINEERED BARRIERS FOR GEOLOGIC ISOLATION OF SPENT FUEL IN A REFERENCE SALT SITE REPOSITORY
DEC 1980	PNL-3548	SUMMARY OF FOUR RELEASE CONSEQUENCE ANALYSES FOR HYPOTHETICAL NUCLEAR WASTE REPOSITORIES IN SALT AND GRANITE
JUN 1981	ONWI-320(1)	PRELIMINARY EVALUATION OF SOLUTION-MINING INTRUSION INTO A SALT DOME REPOSITORY
AUG 1981	PNL-3530	A REFERENCE ANALYSIS ON THE USE OF ENGINEERED BARRIERS FOR ISOLATION OF SPENT NUCLEAR FUEL IN GRANITE AND SALT

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METHODOLOGY APPLICATIONS, CONT'D

JUN 1982	PNL-2955	REFERENCE SITE INITIAL ASSESSMENT FOR A SALT DOME REPOSITORY
SEP 1982	PNL-4129	A TECHNOLOGY DEMONSTRATION: GEOSTATISTICAL AND HYDROLOGIC ANALYSIS OF SALT AREAS
FEB 1983	ONWI-286	ENGINEERED COMPONENTS FOR RADIOACTIVE WASTE ISOLATION SYSTEMS--ARE THEY TECHNICALLY JUSTIFIED?

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NPO/ONWI SCR PROGRAM

R. W. WUNDERLICH

M. A. GLORA

ONWI

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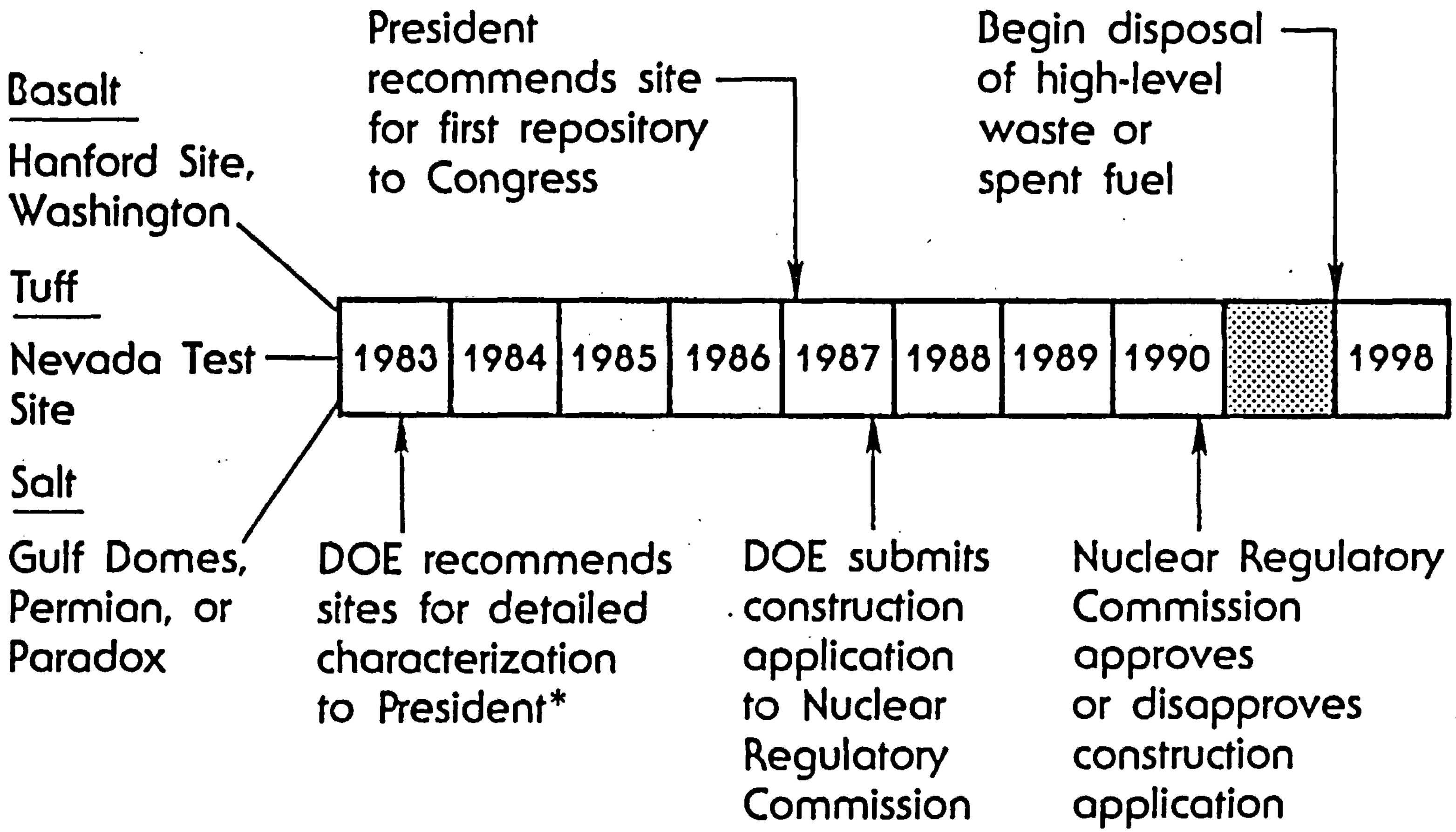
NPO/ONWI SCR PROGRAM

- WASTE LEGISLATION
- SCHEDULES
- SITING GUIDELINES

RW/NPO:4/20/83

Schedule for First Repository



Steps in Selecting the First Repository Site

- DOE develops guidelines for recommending sites—draft guidelines issued 2/7/83.
- DOE nominates at least 5 sites as suitable for characterization.
- DOE prepares environmental assessments for 5 sites.
- DOE recommends to the President at least 3 of the 5 sites for detailed site characterization and prepares site characterization plans.
- DOE characterizes at least 3 sites, including construction of exploratory shafts.
- DOE prepares environmental impact statement and site characterization report as part of site recommendation.
- DOE recommends at least one site from those characterized to the President.
- The President recommends repository site to Congress by 3/31/87.*
- DOE applies to Nuclear Regulatory Commission (NRC) for repository construction authorization.
- The NRC makes decision on first license application by 6/30/90.*
- Repository operation begins by 1/31/98.

REPOSITORY SCHEDULE

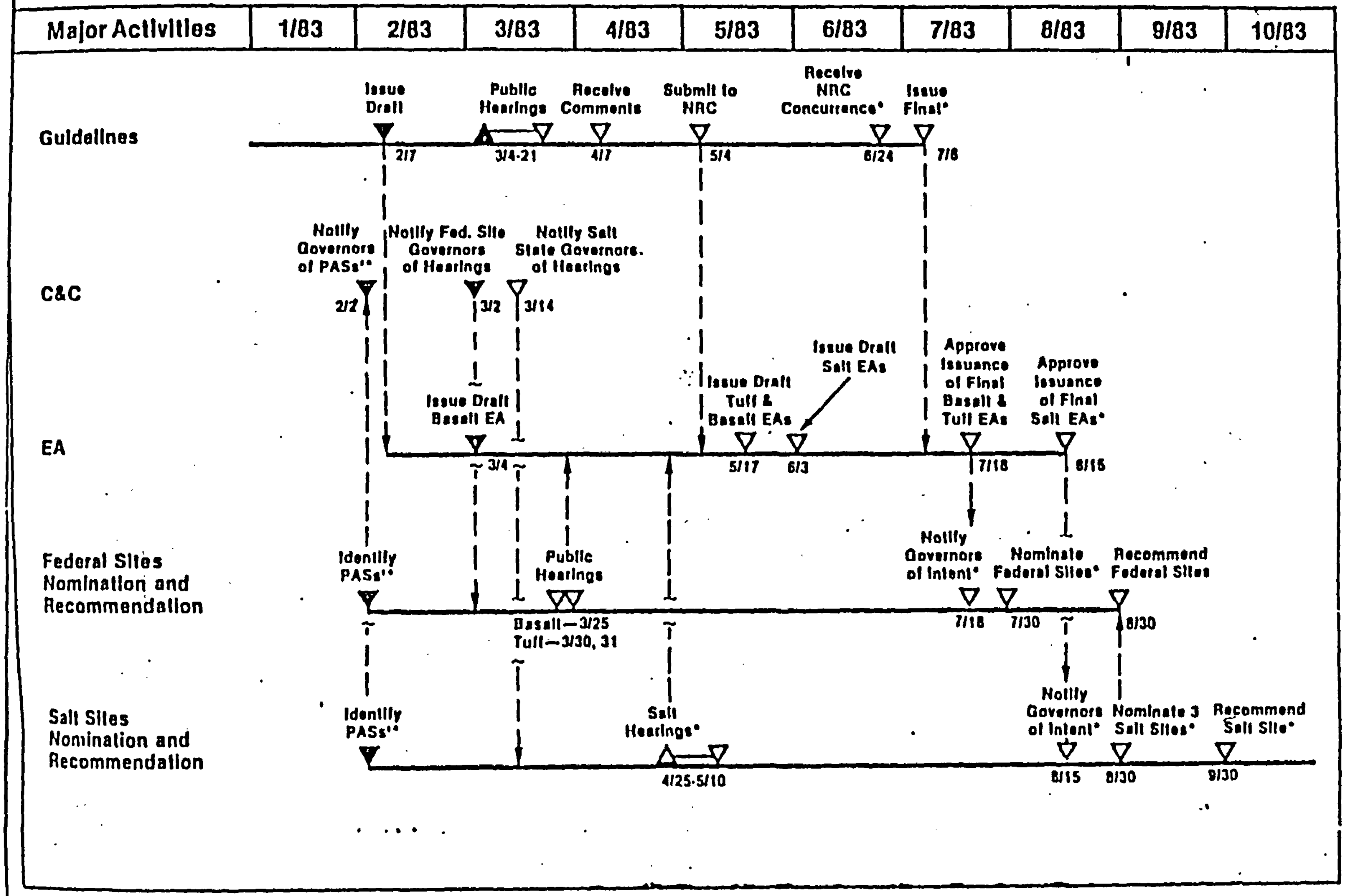
PHASE I - LEGISLATION ENACTMENT TO NOMINATION

PHASE II - NOMINATION TO EXPLORATORY SHAFT BREAK-OUT

PHASE III - EXPLORATORY SHAFT BREAK-OUT TO REPOSITORY SITE SELECTION

RW/NPO:4/20/83 .

PHASE I
FIRST REPOSITORY—RECOMMENDATION FOR CHARACTERIZATION



April 4, 1983

△ — Start

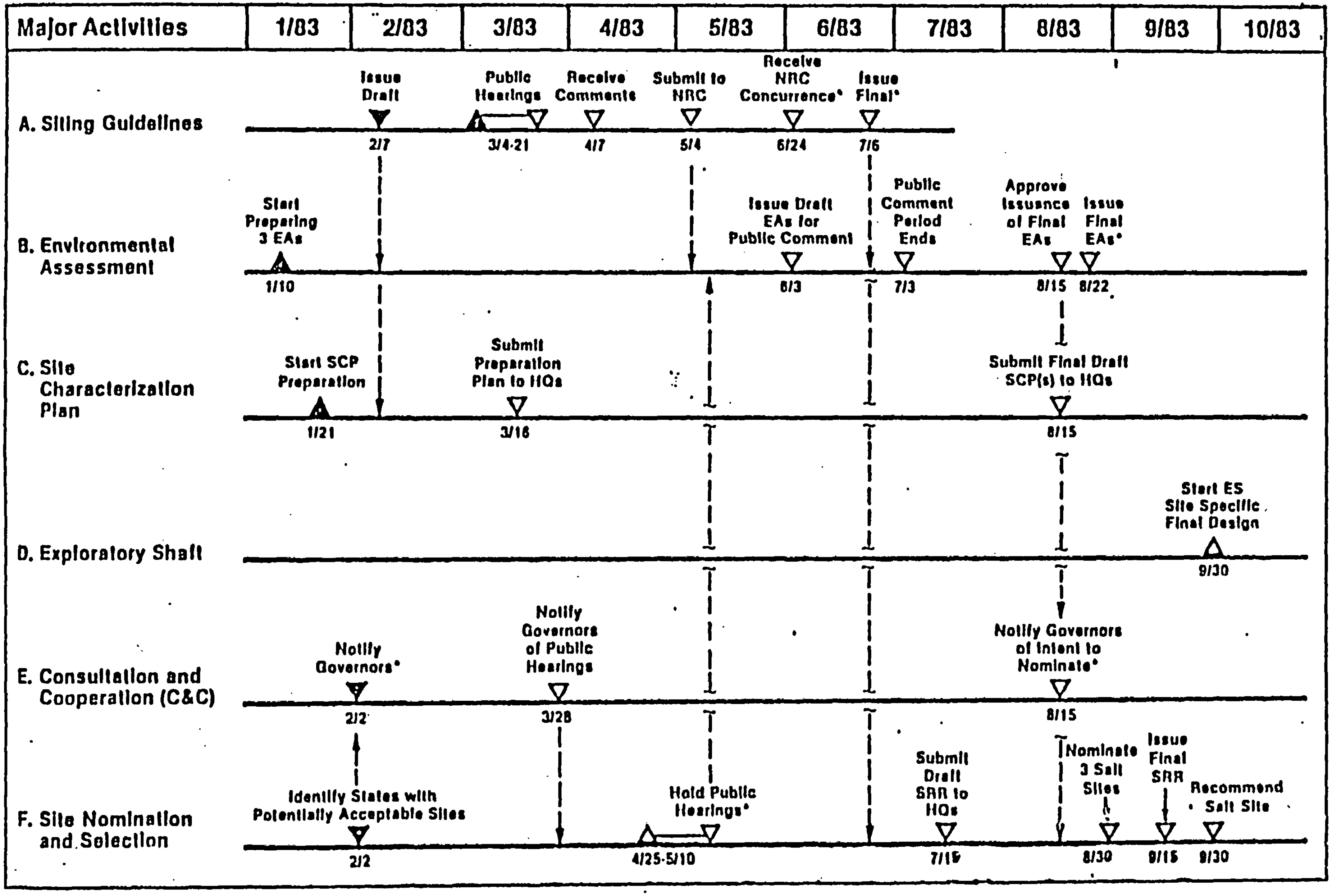
▽ — Complete

* — Statutory Requirement

▼ — Actual

'Potentially Acceptable Sites (PAS)

PHASE I
SALT—LEVEL I



April 4, 1983

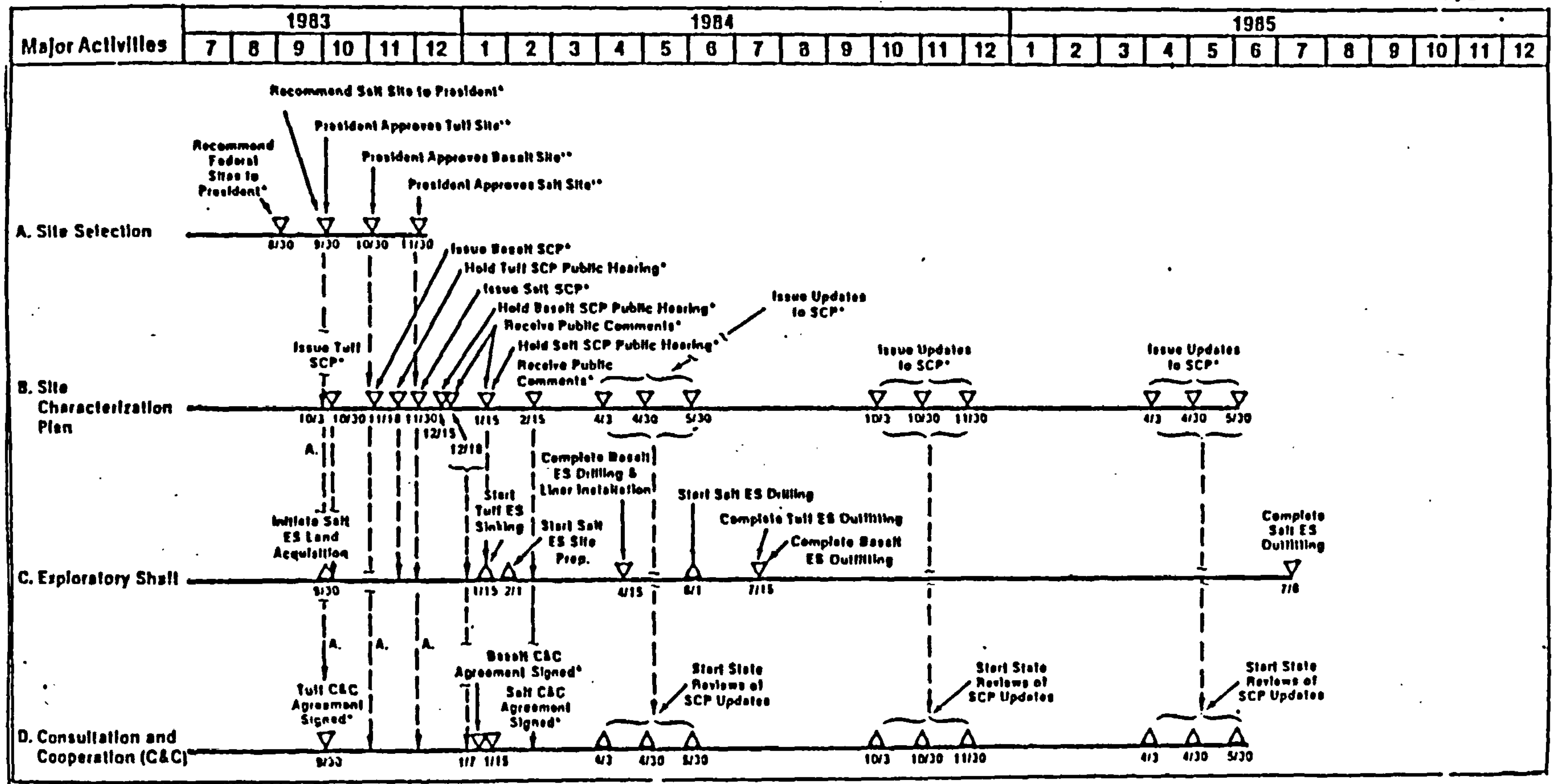
△ — Start

▽ — Complete

* — Statutory Requirement

▼ — Actual

PHASE II
FIRST REPOSITORY—COMPLETION OF EXPLORATORY SHAFTS



April 4, 1983

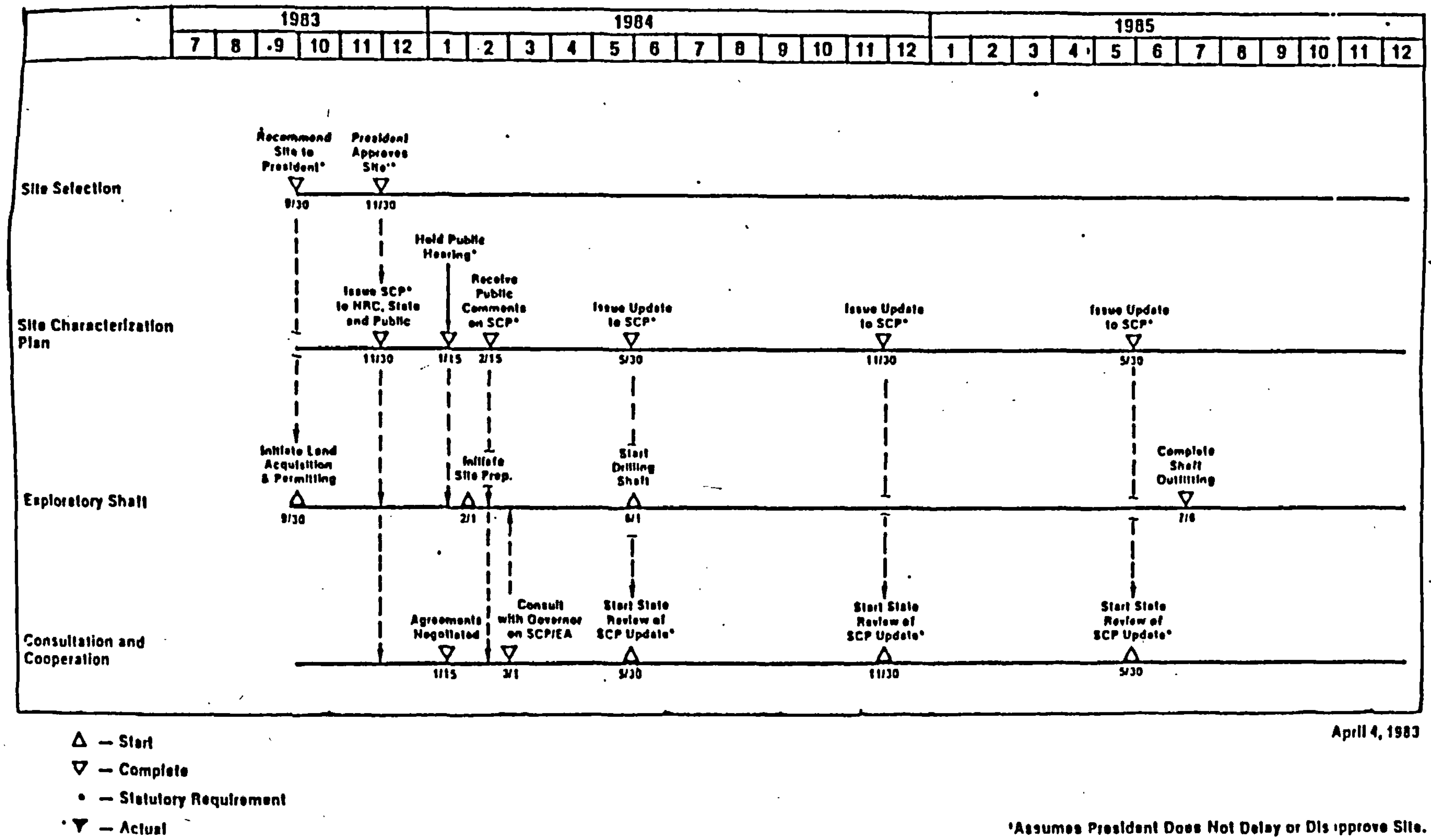
Δ — Start

∇ — Complete

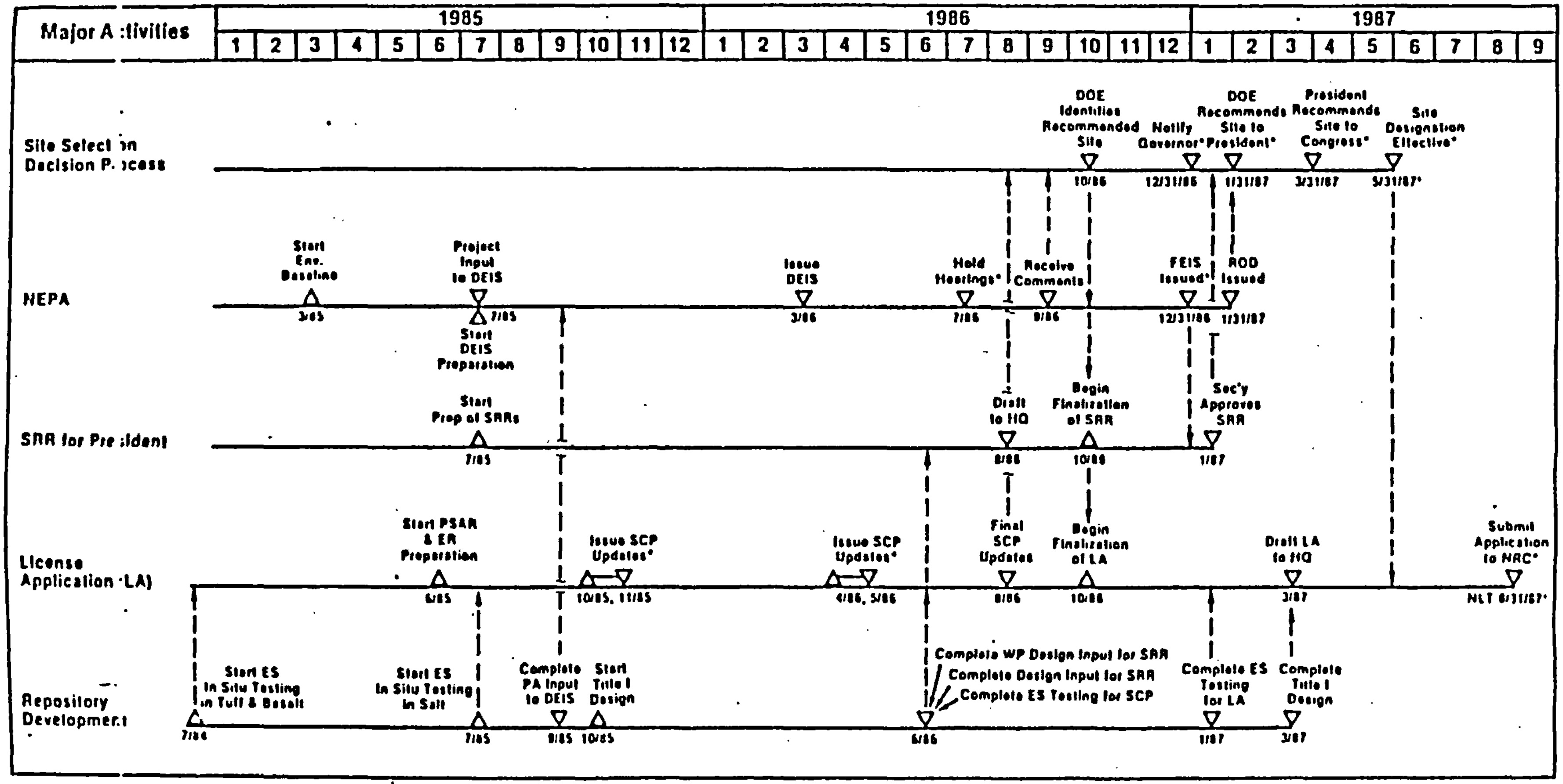
• — Statutory Requirement

*Assumes President Does Not Delay or Disapprove Site.

PHASE II
SALT—LEVEL I



PHASE III
FIRST REPOSITORY—SITE SELECTION AND SUBMISSION OF LA



△ — Start

▽ — Complete

• — Statutory Requirement

▼ — Actual

April 4, 1983

*Assumes No State Objection

ONWI/NPO SCR/SCP PROGRAM

REGULATORY GUIDE 4.17

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ONWI/NPO SCR/SCP STRATEGY

- SCR REPRESENTS LEGISLATED SITE CHARACTERIZATON PLAN WHEN SUPPLEMENTED
  - DECONTAMINATION AND DECOMMISSIONING
- MAXIMUM USE OF REFERENCES TO BE MADE TO ADDRESS NWPA REQUIREMENTS
  - EA'S
  - TOPICAL REPORTS
  - PROGRAMMATIC REPORTS
- REGULATORY GUIDE 4.17 FORMAT
  - USE OF APPENDICES (TYPICAL DECONTAMINATION AND RESTORATION, PERFORMANCE ASSESSMENT PLAN)

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SCR/NWPA COMPARISON

NWPA
SEC. 113(B)(1)

		SCR SECTIONS
(A) (i)	A DESCRIPTION OF CANDIDATE SITE	3.0 - 7.0
(ii)	A DESCRIPTION OF SUCH SITE CHARACTERIZATION ACTIVITIES INCLUDING THE FOLLOWING:	10.3 - 10.5
	• THE EXTENT OF PLANNED EXCAVATIONS	10.3 - 10.5
	• PLANS FOR ANY ON SITE TESTING WITH RADIOACTIVE OR NONRADIOACTIVE MATERIAL	10.3 - 10.5
	• PLANS FOR ANY INVESTIGATION ACTIVITIES THAT MAY AFFECT THE CAPABILITY OF SUCH CANDIDATE SITE TO ISOLATE HIGH-LEVEL RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL, AND	10.3 - 10.5
	• PLANS TO CONTROL ANY ADVERSE, SAFETY-RELATED IMPACTS FROM SUCH SITE CHARACTERIZATION ACTIVITIES.	9.5
(iii)	PLANS FOR THE DECONTAMINATION AND DECOMMISSIONING OF SUCH SITE, AND FOR THE MITIGATION OF ANY SIGNIFICANT ADVERSE ENVIRONMENTAL IMPACTS CAUSED BY SITE CHARACTERIZATION ACTIVITIES, IF IT IS DETERMINED UNSUITABLE FOR APPLICATION FOR A CONSTRUCTION AUTHORIZATION FOR A REPOSITORY	APP.

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SCR/NWPA COMPARISON, CONTINUED

		SCR SECTIONS
(iv)	CRITERIA TO BE USED TO DETERMINE THE SUITABILITY OF SUCH CANDIDATE SITE FOR THE LOCATION OF A REPOSITORY DEVELOPED PURSUANT TO SECTION 112(a)	2.5
(v)	ANY OTHER INFORMATION REQUIRED BY THE COMMISSION	RG 4.17
(B)	A DESCRIPTION OF THE POSSIBLE FORM OR PACKAGING FOR THE HIGH-LEVEL RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL TO BE EMPLACED IN SUCH REPOSITORY, A DESCRIPTION, TO THE EXTENT PRACTICABLE, OF THE RELATIONSHIP BETWEEN SUCH WASTE FORM, OR PACKAGING AND THE GEOLOGIC MEDIUM, OF SUCH SITE, AND A DESCRIPTION OF THE ACTIVITIES BEING CONDUCTED BY THE SECRETARY WITH RESPECT TO SUCH POSSIBLE WASTE FORM OR PACKAGING OR SUCH RELATIONSHIP, AND	9.0
(C)	A CONCEPTUAL REPOSITORY DESIGN THAT TAKES INTO ACCOUNT LIKELY SITE SPECIFIC REQUIREMENTS.	8.0