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ENTERED

JUN 11 1991

Ms. Judith M. Espinosa, Secretary
New Mexico Environment Department
P.O. Box 26110
Santa Fe, NM 87502

Dear Ms. Espinosa:

Enclosed for your information is the draft report, "Strategy for the Waste Isolation Pilot Plant Test Phase," Revision 0, April 1, 1991. DOE requests that draft reports not be released into the public domain until they are finalized.

If you have any questions or comments regarding this matter, please contact Jerry Carr of my staff.

Sincerely,

Arlen Hunt
Project Manager

report in magazine file for

Enclosure

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STRATEGY FOR THE WASTE ISOLATION PILOT PLANT TEST PHASE

REVIEW DRAFT

April 1, 1991

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1. INTRODUCTION

1.1 The Purpose and scope of this document

The purpose of this document is to provide the project participants, interested parties, and decision makers with an understanding of the logic, objectives and interfaces of the Test Phase activities.

This document presents the high-level strategy for the Test Phase of the Waste Isolation Pilot Plant (WIPP) project, as summarized in Figure 1. It describes the performance assessment that will be conducted to determine compliance with the key Environmental Protection Agency (EPA) regulations, the program of tests that will be conducted to provide the basis for a determination of compliance, and the process by which the U. S. Department of Energy (DOE) will decide whether transuranic (TRU) radioactive wastes can be emplaced in the WIPP for permanent disposal. It includes the key assumptions under which the strategy was developed and plans, consisting of time phased activities, for the principal activities to be conducted during this phase.

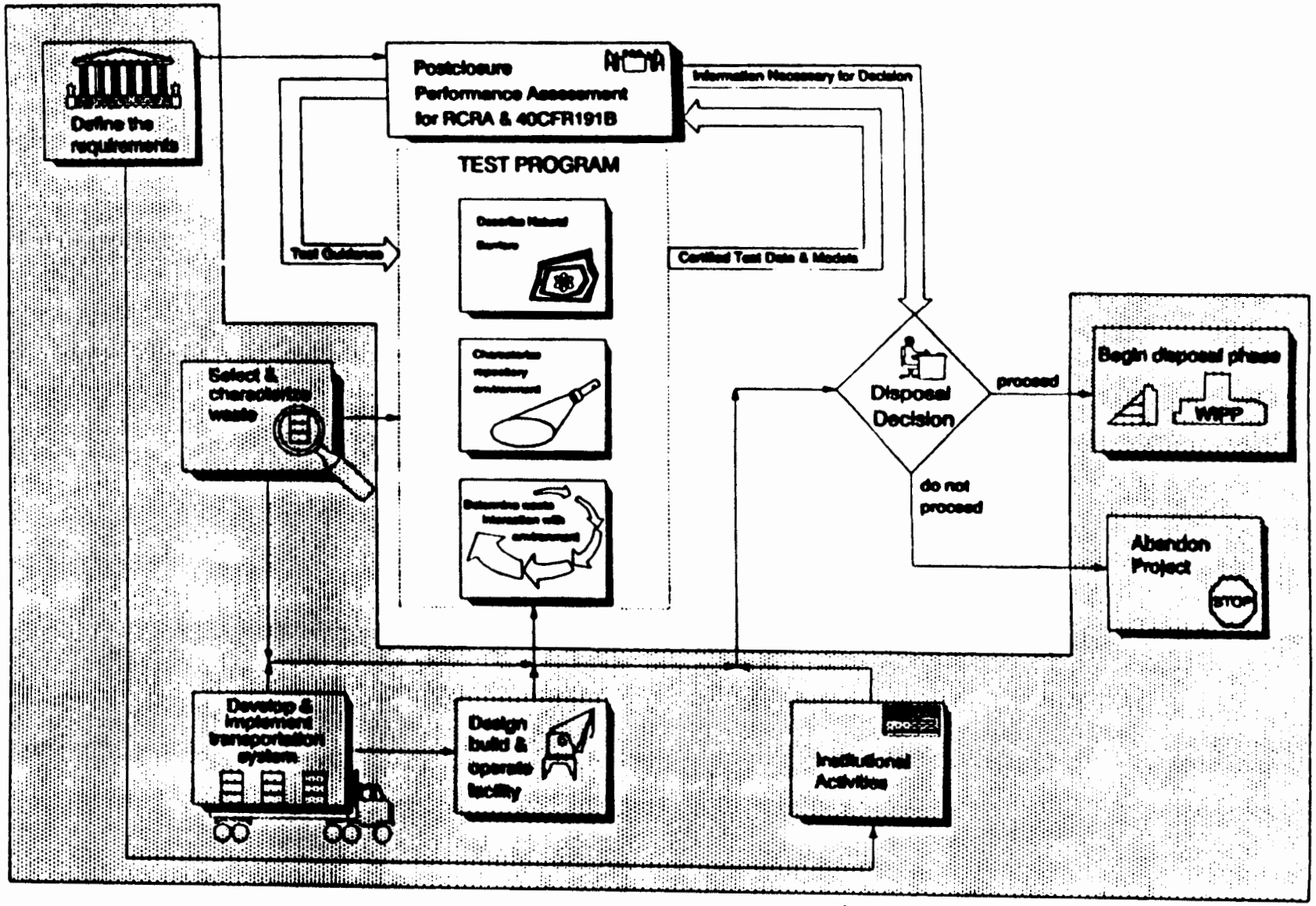
This document does not discuss the shaded items shown in Figure 1. All of these activities, especially the institutional-related activities, are necessary to support the disposal decision. A comprehensive discussion of the multitude of activities that are involved in the WIPP project are not provided in this document. Furthermore, this document does not address the operational safety of the WIPP or the DOE's strategy for complying with other Federal and State environmental regulations; these issues are addressed in other documents (DOE, 1990a and 1990b, respectively).

A list of the key documents that exist or will be developed during performance assessment, the test program, and the decision process can be found in Appendix A.

1.2 Background

Purpose of the WIPP. The DOE was authorized and funded by the Congress to provide a facility for demonstrating the safe disposal of TRU radioactive wastes produced by national-defense activities. This facility, called the WIPP, has been developed in southeastern New Mexico. It is an underground facility excavated more than 2000 feet below the surface in a bedded-salt formation. If compliance with applicable regulations can be demonstrated using information from the Test Phase, the WIPP will be used to provide permanent disposal for the TRU wastes.

Development in phases. The TRU wastes will remain radioactive for many thousands of years, and some of the wastes contain chemicals considered to be hazardous by the EPA. To preclude premature decisions and to ensure that adequate information exists to support the commitment of resources to developing a facility that must remain safe both in the near term



Notes:
1) Shaded portion not emphasized in this document.
2) Arrows show major interactions, not necessarily time flow.

Figure 1. The WIPP Program

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and over the thousands of years needed for waste isolation, the DOE decided to develop the facility in several phases. The process began with a siting phase during which several sites were evaluated and a preferred site was selected, extensive surface-based testing was conducted to evaluate the suitability of the site, a repository appropriate to the conditions of the site was designed, and analyses were conducted to determine the safety of the WIPP facility. This phase ended with the publication of an environmental impact statement in 1980 and a decision to proceed with the next phase-site and preliminary design validation, during which two shafts were constructed, an underground testing area was excavated, and various experiments were conducted. The validation was followed by further collection of data about the site and the construction of the WIPP. The surface facilities needed to start receiving waste were built and considerable underground excavation was completed, including rooms for further experimentation and some rooms for permanent waste emplacement. The WIPP is now in the Test Phase and is poised to initiate in-situ experiments with TRU wastes as a key part of the Test Phase. The goal of the Test Phase is to develop the basis by which a determination of regulatory compliance can be made. The Test Phase will end when a decision is made to begin disposal operations in the WIPP or to abandon the project if it cannot be demonstrated that compliance can be achieved.

The key regulations governing the WIPP. In 1985, after the validation program was completed and WIPP construction was begun, the EPA issued environmental standards for the disposal of radioactive transuranic waste as Part 191 of Title 40 of the Code of Federal Regulations (40 CFR Part 191). And in 1986, the EPA issued a notice that the hazardous elements in TRU wastes are subject to the land-disposal requirements of the Resource Conservation and Recovery Act (RCRA) as amended by the Hazardous and Solid Waste Amendments of 1984. In 1987, the EPA's standards for long-term disposal (Subpart B of 40 CFR Part 191) were vacated and remanded to the EPA for revision. The DOE has agreed with the State of New Mexico that, until the revised standards are issued, it will proceed with its long-term performance assessment planning as if the 1985 standards were still in effect.

The next steps in the WIPP project. The DOE has conducted extensive studies of the site and the performance of the repository, and has not identified any attributes that would disqualify it as a potential repository. Additional information is needed to better define the mechanisms of repository behavior and reduce the uncertainties in current predictions. For example, concerns have been raised about the possibility that gas generated underground in the WIPP could, over the long term, build up to unacceptable pressures, leading to possible releases of radioactive or chemically hazardous materials into the environment. The DOE has made a commitment that no waste will be permanently emplaced in the WIPP until compliance with the EPA regulations has been determined. To make these determinations and to address the uncertainties about the long-term safety of the WIPP, the DOE is now conducting the Test Phase. The strategy for test-phase is the subject of this document.

2. THE TEST PHASE

2.1 Focus and principal activities

The Test Phase consists of three major elements: performance assessment, the test program, and the decision process. Its principal focus is the performance assessments needed to evaluate compliance with the requirements of EPA regulations for long-term waste isolation and the collection of the data needed for these assessments. The basic logic for the Test Phase is shown in Figure 2.

Performance assessment. Performance assessment, described in more detail in Section 3, will include developing the approach to determining compliance, conducting the analyses necessary to evaluate compliance, and documenting the results. The assessments will be made in an iterative process in which analyses will be refined as more data from the test program become available. The results of these iterative assessments will be evaluated to specify how the test program should proceed, including any changes that are deemed necessary. Performance assessment will evaluate engineered alternatives to the existing waste and the facility configuration in the event alternatives are required for compliance.

The collection of data for performance assessments has been under way since the site-evaluation studies begun in 1975; it has been conducted through field tests at the site, studies performed in the WIPP underground excavations, and laboratory experiments. However, no tests with TRU waste have been conducted to study the behavior of the waste and its interactions with the repository conditions. The performance assessments conducted to date have used assumed waste properties and bounding assumptions about waste-interaction mechanisms and parameters, and their results have uncertainties that can be reduced by testing with TRU waste.

Test program. To collect the data needed to reduce uncertainties in performance assessments, the DOE plans to conduct a test program consisting of underground tests with TRU waste, laboratory tests, and other investigations. This program, as described in Section 4, considers three principal activities:

- Collecting additional information about the natural barriers at the site.
- Characterizing the underground WIPP environment.
- Studying the interactions of waste with the underground WIPP environment.

Decision process. The decision process will consist of all the activities necessary to document compliance (or non-compliance) with applicable regulations, to complete the necessary institutional interactions, and to prepare a determination of compliance.

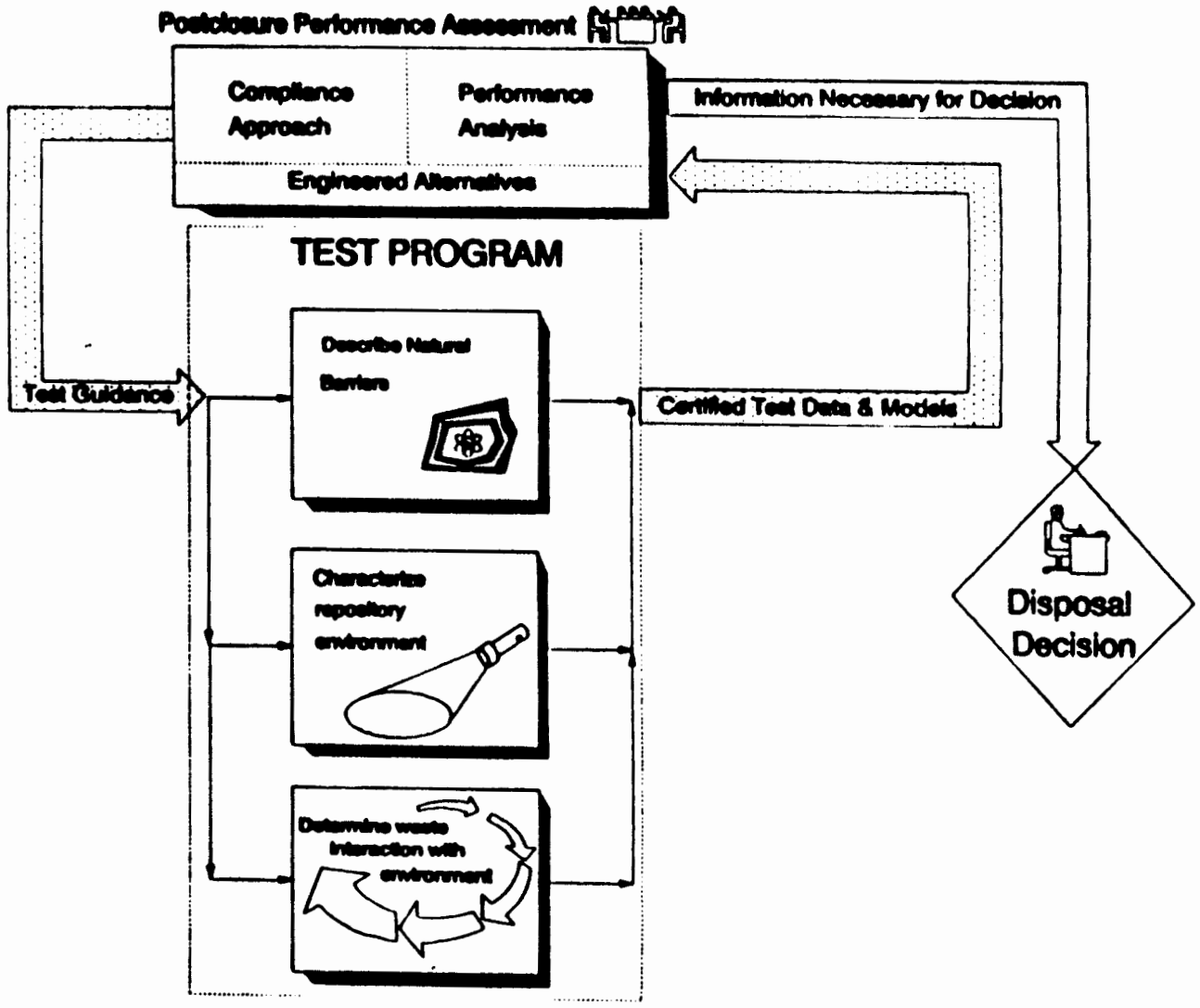

Figure 2. WIPP Test Phase

2.2 Plans for using waste

To conduct the underground tests, the DOE plans to emplace TRU waste in WIPP underground excavations. All tests with waste will be conducted in accordance with the conditions imposed by the EPA in its decision, announced in the *Federal Register* on November 14, 1990 (EPA, 1990), to grant the DOE's petition for a "no-migration variance." The conditions specify, among other things, that all waste emplaced in the WIPP for the tests is to be fully retrievable and the testing period is limited to a maximum of 10 years and waste emplacement is limited to one percent of WIPP's design capacity (or 8,500 drums). The amount of waste used will be kept to the minimum quantities needed for the purposes of the test phase.

At the beginning of the program, the tests will use contact-handled TRU waste as it currently exists. The existing TRU waste has been classified into 15 categories (e.g., metal wastes, combustible wastes, cemented inorganic particles, solidified organic liquids). In later stages, alternative waste forms, (wastes modified by various engineering methods) will also be studied if needed.

Although two types of TRU waste (contact-handled and remotely handled TRU wastes) will eventually be emplaced in the WIPP if disposal operations are allowed to begin, only contact-handled TRU waste needs to be used in the tests. Contact-handled waste represents most (97 percent by volume) of the TRU waste and when packaged in drums or boxes can be safely handled because it emits very little penetrating radiation. It is assumed that no operations demonstration, pilot room-scale tests, or tests with remotely handled TRU waste are necessary before the disposal decision. The need, feasibility, and extent of any operations demonstration or pilot room-scale tests are under DOE evaluation.

2.3 Timing

The general timing of the activities in the Test Phase is shown in Figure 3. The program will be conducted in what are anticipated to be annual cycles of interaction between testing and performance assessment. During each of these annual cycles, the results of testing will provide models and input data for performance assessment. Performance assessment, in turn, will provide the basis for guidance from the DOE in its annual direction to the test program and TRU waste management program. The DOE will specify, on the basis of performance assessments, what additional data are needed to support compliance determinations and by determining, through sensitivity studies, which parameters are most important to performance. Based on current understanding of the site facility and waste form performance, DOE anticipates conducting five Test/performance assessment interactive cycles as shown in Figure 3

Figure 3 shows a nominal completion date for the final performance assessment of 1996. It is possible that completion of this analysis could occur as early as 1993 if a revised Subpart B of 40 CFR Part 191 is promulgated in a timely manner and regulatory compliance is determined with sufficient confidence; conversely, the test program may need to be extended to include additional tests for confirmation purposes. Therefore it should be emphasized that regulatory compliance could occur several years before the nominal expected date; activities to support the decision process should be in place by 1993.

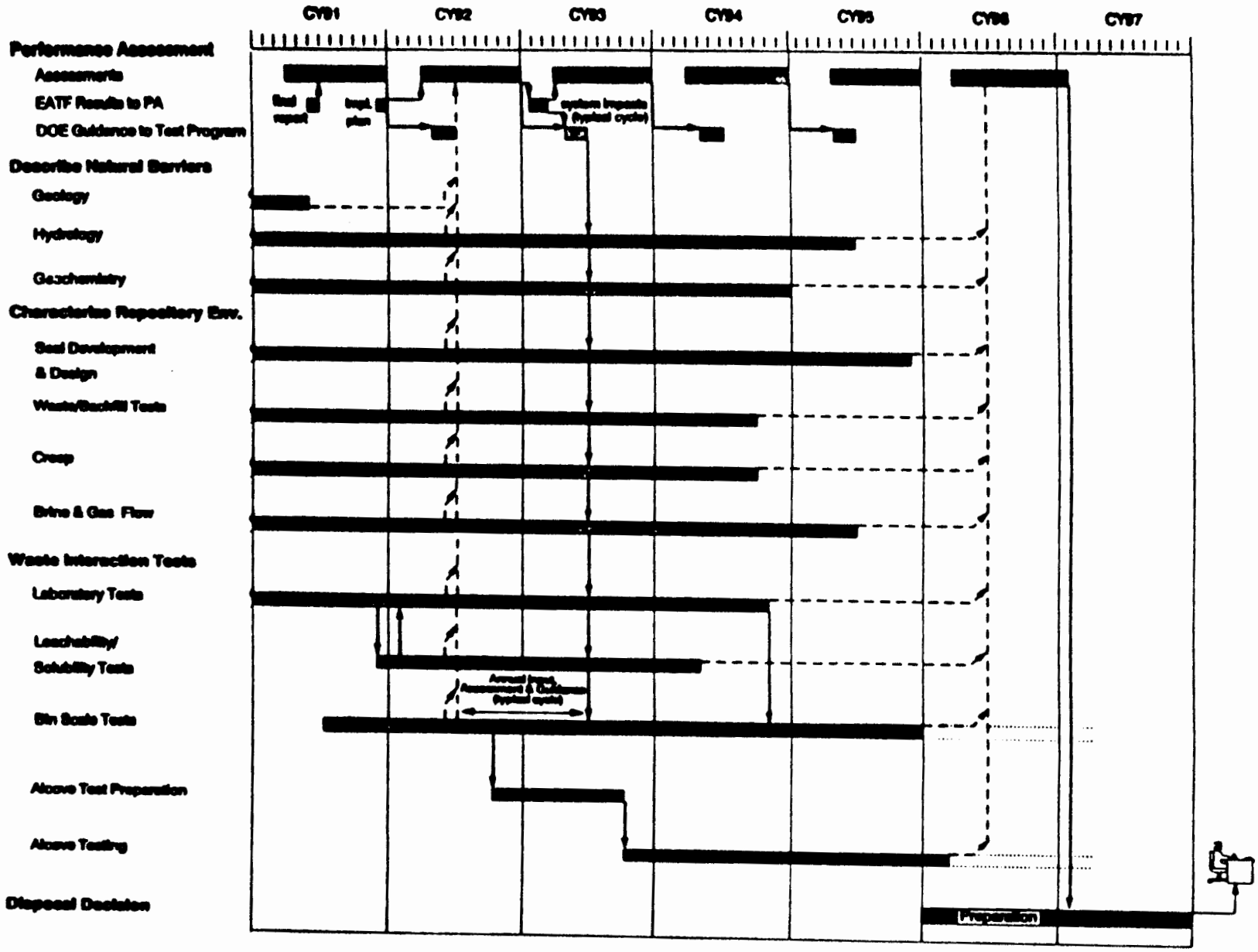

Figure 3. Time-Phased Activities for WIPP Test Phase

2.4 Assumptions

The key assumptions on which the strategy for the Test Phase is based are as follows:

- The reference design for the WIPP is the design described in the Final Safety Analysis Report (DOE, 1990a).
- The basis for assessing compliance with the TRU-waste disposal standards is the 1985 version of Subpart B of 40 CFR Part 191 until revised standards are promulgated.
- The revised standards promulgated by the EPA as Subpart B of 40 CFR Part 191 will not be significantly different from the remanded standards and hence will not require a radically different approach to the determination of compliance.
- The evaluation performed by the independent review group to determine compliance will not require an approach different from the one currently guiding the program.
- Waste generator sites and the transportation system are adequately prepared to support the test program.
- Funding for the current fiscal year (1991) and fiscal year 1992 is based on the President's budget; funding for later years is based on program requirements.
- Bin-scale tests will be performed at WIPP.
- Initiation of bin-scale tests is based on the Secretary's Decision Plan (Revision 7).
- There will be no tests with Remote Handled waste.
- Data collection may continue beyond the decision to dispose to confirm previous compliance evaluations.

2.5 Milestones

Some important milestones associated with the WIPP Test Phase are listed in Table 1. These milestones support the time-phased activities presented in this document for the Test Phase and may change based on how the Test Program progresses.

Table 1. Milestones for the WIPP Test Phase

Activity	Date (Calendar Year)
Start bin tests at the WIPP	Third Quarter 1991
Establish location or locations for leachability and solubility tests	First Quarter 1992
Start leachability and solubility tests	Second Quarter 1992
Complete large-scale seal design for test alcoves	First Quarter 1993
Subpart B of 40 CFR 191 Repromulgated issue (expected date)	Second Quarter 1993
Start waste emplacement for alcove tests	Third Quarter 1993
Decide on engineered alternatives (earliest expected date)	Second Quarter 1994
Complete leachability and solubility tests	Fourth Quarter 1994
Complete collection of data from alcove tests	First Quarter 1996
Complete final performance assessments for RCRA and Subpart B of 40 CFR Part 191	Fourth Quarter 1996*
Decide on permanent disposal in the WIPP	Fourth Quarter 1997**

* Final Performance Assessment may be completed as early as 1993
** A decision on permanent disposal in the WIPP may be made as early as 1995

2.6 Uncertainties in strategy

The schedules presented in this strategy are meant to show time phasing of activities and should be considered estimates, because it is not clear at present how much time will be needed to complete various prerequisite activities. These include: characterizing the wastes to be used in testing sufficiently to satisfy the RCRA; providing sufficient quantities of engineered alternative waste forms; designing, constructing, and testing seals for the alcove tests; and the time needed to collect suitable and sufficient data from tests. These and other uncertainties will be evaluated and contingencies will be identified as appropriate in follow-on long-term strategy planning by the project.

3. PERFORMANCE ASSESSMENT

Performance assessments will be conducted for the WIPP to evaluate compliance with the EPA regulations for the long-term disposal of TRU wastes (Subpart B of 40 CFR Part 191) and the long-term disposal of wastes containing hazardous elements (RCRA-related regulations). Performance assessment is a set of activities that will allow the DOE to predict whether the repository system, its subsystems, and its components will meet the requirements for safety after the permanent closure of the repository. It is an iterative process of comparing the site-specific performance goals of repository systems, subsystems, and components with calculated performance predictions, using increasingly more detailed site-specific data and design information.

Conceptual and numerical models are being developed to assess the performance of the repository system, its subsystems, and, in some instances, key components determined to be important to safety or waste isolation. These models will be exercised to define uncertainties and provide further guidance to the test program for data acquisition, the refinement of performance goals, and design changes.

3.1 Regulatory requirements

The EPA regulations in the vacated and remanded Subpart B of 40 CFR Part 191 limit the cumulative releases of radioactive materials to the "accessible" environment for 10,000 years after the WIPP has been closed. The DOE will have to determine that this requirement can be met not only under the conditions expected to occur at the site for 10,000 years after closure but also under disturbed conditions, such as inadvertent human intrusion. The EPA standards also specify limits for the annual radiation dose that can be delivered to individual members of the public and ground-water protection requirements for 1,000 years after closure under undisturbed conditions.

The EPA regulations that are related to the RCRA as amended specify restrictions on the land disposal of hazardous elements. Land disposal is to be permitted only if it can be predicted, to a reasonable degree of certainty, that the hazardous chemicals will not migrate from the disposal unit for as long as the wastes remain hazardous. The no-migration prediction must include an analysis performed to identify and quantify any aspects of the prediction that contribute significantly to uncertainty. This analysis must include an evaluation of reasonable future events, including earthquakes.

3.2 Approach to the determination of compliance

Compliance with Subpart B of 40 CFR Part 191. Preliminary evaluations of repository performance for compliance with Subpart B of 40 CFR Part 191 have been conducted and reported (DOE, 1990b). They were based on data collected at the site since 1975 and used an approach similar to that reported earlier (DOE, 1980).

More recently, a formal process for evaluating compliance with the quantitative requirements of Subpart B of 40 CFR Part 191 has been established and documented (Marietta et al., 1989). Basically, the approach consists of identifying the processes and events that might affect the long-term waste-isolation capability of the WIPP; developing scenarios that describe how these processes and events could affect the long-term isolation capability of the WIPP; and estimating the cumulative releases of radionuclides caused by all significant processes and events. The estimates are based on models that describe the flow of gases and liquids in the rocks under and around the waste rooms of the WIPP. These models reflect both the theoretical understanding and experimental data concerning the processes and events that may be experienced by the disposal system at the site. The results of the modeling exercises are given as probabilities of exceeding the EPA's cumulative-release limits. Part of the performance-assessment process is the conduct of sensitivity analyses to determine the relative importance of parameters used in the calculations. The DOE will develop documentation that establish criteria for acceptability of results of performance assessments and of the test program to be used in evaluating compliance.

The information needed to assess performance has been tabulated and is summarized in Table 2. The various activities in the test program will provide the information in the form of data sets consisting of specific parameters to be used in performance assessments and as certified models for analyses. To be certified, models must be subjected to sufficient verification and validation as well as quality assurance. A representative data set for all the information in Table 2 was developed to support recent performance assessments. This representative data set must now be supplemented and confirmed by the test program. Sensitivity studies indicate that the critical parameters needed are the transport characteristics in the rock units overlying the repository (primarily retardation in the Rustler Formation); local radionuclide geochemistry in the waste rooms (primarily the solubility of uranium, neptunium, thorium, plutonium, radium, and lead in WIPP brine); gas generation and migration rates; the closure and compaction state of the waste rooms, which affects the stability and permeability of the wastes; and the characteristics that describe the injection of material into a borehole and drill string penetrating the waste rooms (human intrusion).

Significant progress has been made in evaluating compliance with Subpart B of 40 CFR Part 191. The critical scenarios have been identified, including those associated with human intrusion. These scenarios are related to mining potash resources near the repository and drilling into waste rooms, with a subsequent connection to potentially pressurized brine reservoirs in the Castile Formation beneath the repository.

A preliminary performance assessment was recently completed (Bertram-Howery et al., 1990), and its results suggest that compliance with Subpart B of 40 CFR Part 191 can be achieved. However, sufficient uncertainty exists in the data and models that predictions of compliance are premature at present. The collection of additional data to reduce these uncertainties will be one of the principal objectives of the test program.

Table 2. Primary Information Needed for WIPP 40 CFR 191 Performance Assessment

Radionuclide Transport in Overlying Units
Hydrogeology
Transport Characteristics
Climate and Recharge Impacts on Hydrology
Gas and Brine Flow in Salado and Castile Formations
Hydrogeology
Gas Flow Characteristics
Brine Pocket Characteristics
Waste Panel
Closure and Compaction of Room Contents
Radionuclide Inventory
Hazardous Component Inventory
Gas Generation
Gas Dissipation
Local Radionuclide Geochemistry
Human Intrusion Characteristics
Disturbed Zone Characteristics and Behavior
Seal System
Drifts and Panels
Shafts

Compliance with RCRA-related regulations. The approach to evaluating compliance with the RCRA-related regulations will be based on the evaluation performed to obtain the no-migration determination from the EPA. Further evaluations will be consistent with the same basic models and computer codes used for Subpart B of 40 CFR Part 191. Criteria will be developed by DOE and used to ensure that the methodology is consistent with, and meets the requirements of, the regulations. Investigations during the Test Phase will be directed at providing more-specific estimates of hazardous-component source terms by examining waste compositions and further characterizing existing waste.

3.3 Strategy for evaluating compliance

Cyclical approach. As shown in Figure 4, the performance-assessment process, including the test program described in Section 4, will be conducted in what are anticipated to be annual cycles. In each cycle, data from the test program will be used to update scenarios, as well as conceptual and numerical models, the models will be exercised to evaluate compliance. Guidance to the test program will be provided by specifying information needs and associated

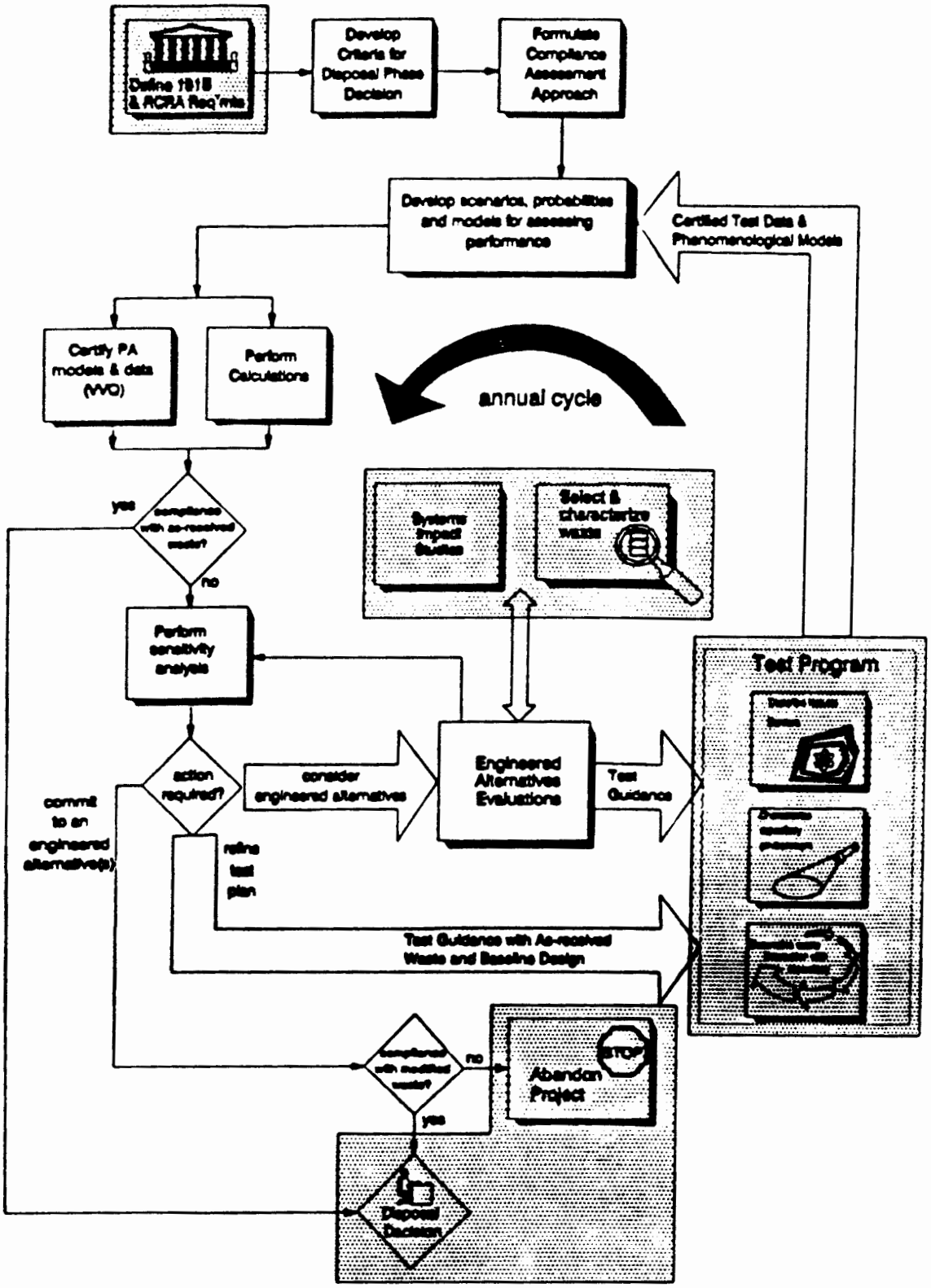

Figure 4. Post-closure Performance Assessment

parameters and include guidance to the TRU waste management program such as recommended changes in waste forms or containers and/or additional technology development/demonstration requirements, as appropriate. If at the end of any cycle the results of this process show, at a sufficient level of confidence, that compliance is achieved, then the DOE will begin the decision process described in Section 5. If the results show that the level of confidence is insufficient because of uncertainties associated with the calculations, then the next cycle will start.

Engineered alternatives. In each cycle, if compliance cannot be demonstrated with existing waste forms, the results of sensitivity studies will be examined to determine the proper guidance for the test program. In addition to specific modifications of the tests, potential engineered measures that may be used to achieve a higher level of confidence in compliance will be tested and evaluated. These measures include modifications of the waste forms and of the facility configuration, such as changes in the materials to be used for backfilling the repository after waste has been emplaced.

The performance assessments performed to date have been based on the current design of the repository and waste characteristics assumed to be representative of the existing TRU wastes. Existing, largely unprocessed TRU wastes, designated level I wastes, will also be used in the initial cycles of the testing-and-assessment process that constitutes the Test Phase described in this document. The level I wastes consist of a variety of waste forms classified into 15 different categories, including, for example, solidified organic laboratory wastes, combustible wastes, and metals.

The DOE plans to conduct tests with the engineered alternatives and to assess the performance of the repository under these modified conditions to determine whether implementation of engineered alternatives is necessary to demonstrate compliance. System studies to assess impacts to the balance of the TRU waste management system will also be conducted by DOE (outside of WIPP) in a parallel manner, so that the disposal decision can be made based on a total system evaluation.

To be prepared for these studies, the DOE established in 1989 the Engineered Alternatives Task Force (EATF) to identify and select various modifications, analyze their relative effectiveness, and evaluate the feasibility of implementing the alternatives that seem most promising. The EATF will issue a report that explains the methods it used and describes the relative effectiveness of selected alternatives in relation to the existing waste forms and the existing repository design. Impacts on TRU-waste generators have also been considered in a preliminary fashion.

The EATF identified a number of waste-form modifications that have been classified into two levels. Level II consists of wastes that have been treated to reduce the rate of, but not the potential for, gas generation. An example of treatment is shredding waste and solidifying in concrete. Level III consists of wastes that have been treated to eliminate the potential for gas generation, such as incineration.

The DOE plans to use the results obtained by the EATF in assessing the performance of the repository with engineered wastes. The project will develop an implementation plan to identify/select the modification candidates to be tested during the test program. Once the initial cycles of testing with level I (existing) wastes have been initiated, tests with the identified level II wastes will begin shortly thereafter. The performance-assessment cycle will continue to refine tests and engineered modifications until either compliance can be demonstrated or it becomes clear that compliance cannot be cost effectively demonstrated. The anticipated timing of performance-assessment activities is shown in Figure 5.

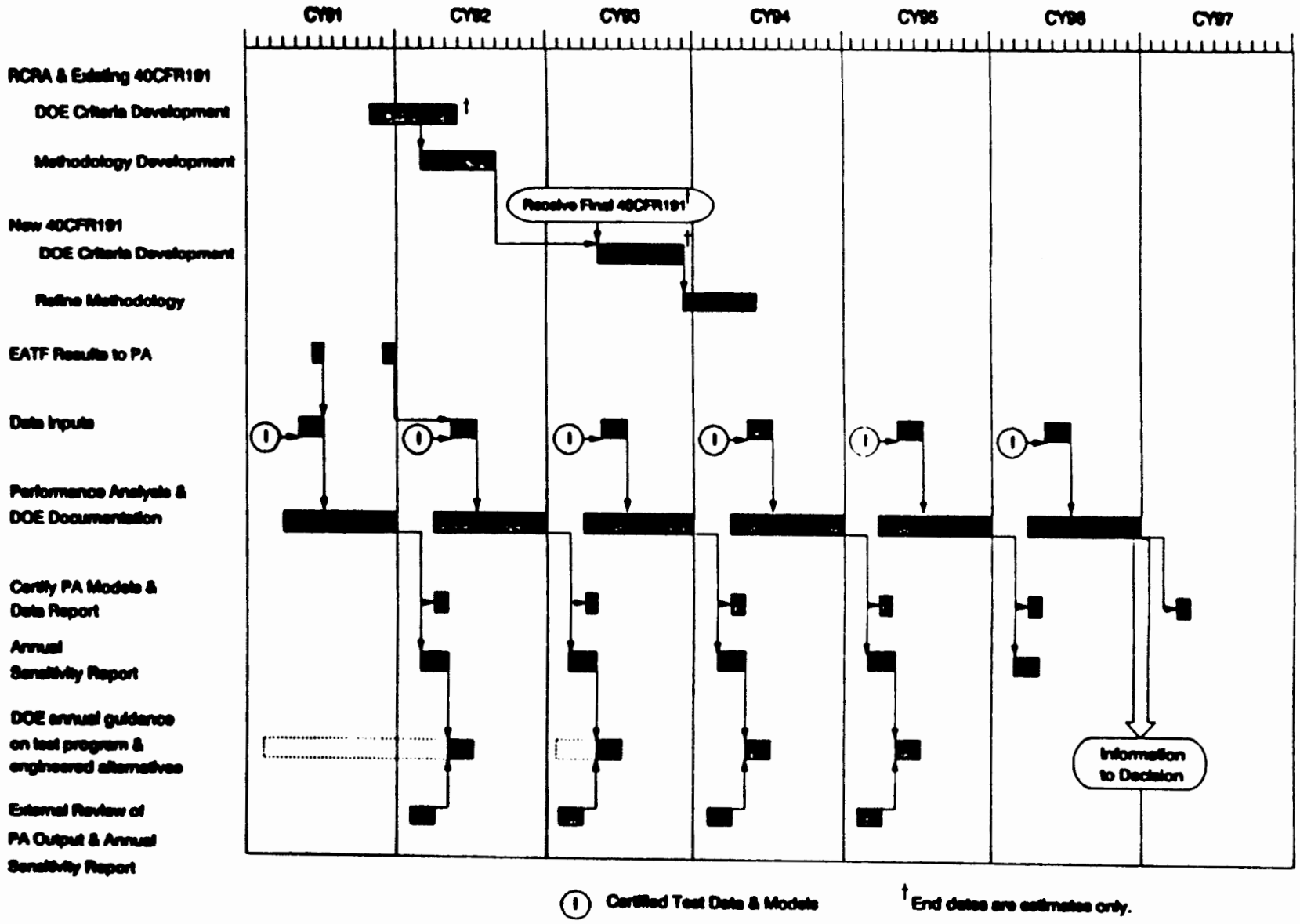

Figure 5. Performance Assessment Time-Phased Activities

4. THE TEST PROGRAM

As mentioned in Section 2, the test program consists of activities directed at (1) describing the natural barriers that can provide long-term isolation at the WIPP site, (2) characterizing the environment expected to prevail in the WIPP underground after waste emplacement and into the distant future, and (3) determining the interactions of the waste with the underground environment. The various tests performed in each of these categories are briefly described below.

The principal purpose of the test program is to provide necessary and sufficient information to support a credible and defensible prediction of repository performance over the next 10,000 years. This includes reducing or defining uncertainties in the available information about the site and the behavior of the rock units at the site; providing input data for performance assessments; collecting data needed for predicting the future behavior of the waste in the underground repository; and developing, verifying, and validating models to be used in performance assessment and design. All data and models from the test program will be subjected to a formal process of quality assurance. The scope of the test program and the general rationale for the tests have been developed and documented (DOE, 1990; Bertram-Howery et al., 1989). The relationship of the various testing activities is shown in Figure 6, and the anticipated timing of the principal activities is shown in Figures 7, 8, and 9.

4.1 Describing the natural barriers

There are multiple natural barriers at the WIPP site that would contribute to safe isolation over the long term. The first barriers are the bedded salt and anhydrite units of the Salado Formation, which is the host rock for the WIPP underground repository; these units do not admit the flow of ground water, which is the principal natural mechanism for transporting any radionuclides released from the waste. Other barriers lie above the repository; they consist of multiple rock units, only a few of which admit the flow of ground water. The Rustler Formation, which lies just above the Salado, supports such a flow, but at a very low velocity-about one meter per year. Even if radionuclides were transported through these barriers-for example, as a result of human intrusion-it is anticipated that their migration toward the environment would be blocked or significantly retarded by hydrologic or geochemical processes in the rock units through which they would pass.

Extensive studies of the geologic, hydrologic, and geochemical conditions at the site have been performed since the start of site characterization in 1975. Since 1978, the data collected in these studies have been used to model, at increasing levels of refinement, the performance of the natural barriers. These studies are being extended to provide detailed data for performance assessments and to reduce or define the uncertainties associated with the currently available data.

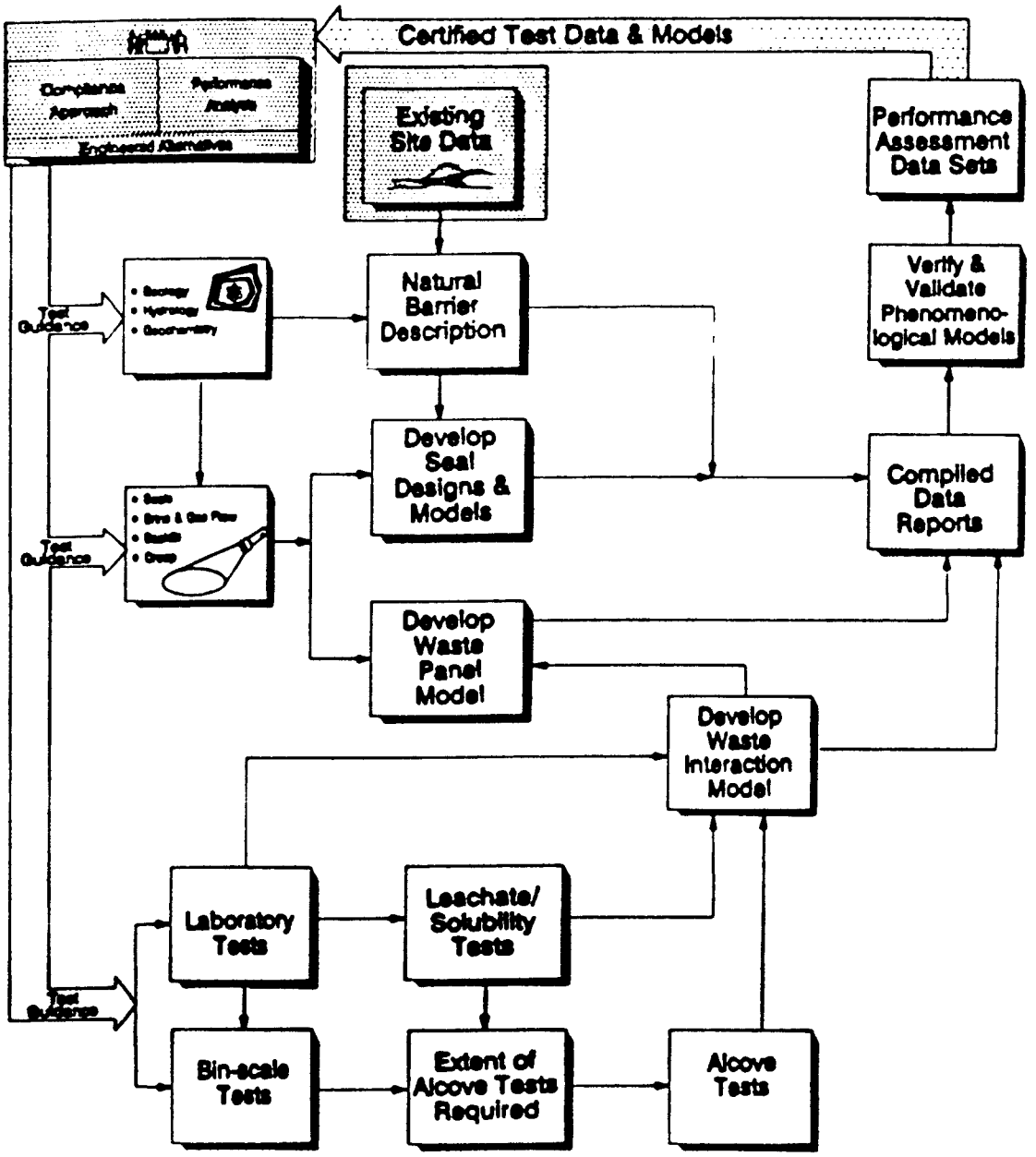

Figure 6. WIPP Test Program

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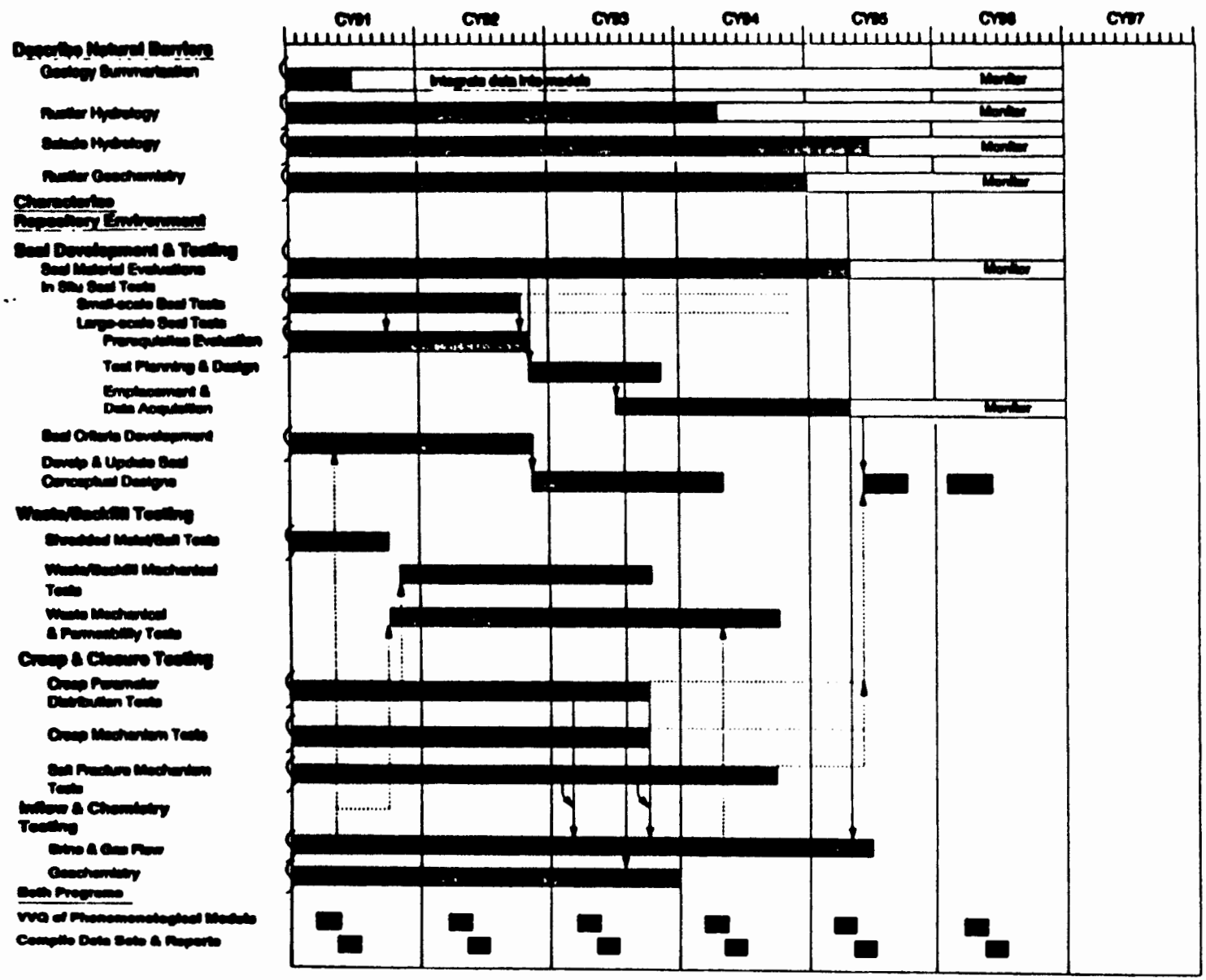

Figure 7. Describe Natural Barriers and Characterize Repository Environment Time-Phased Activities

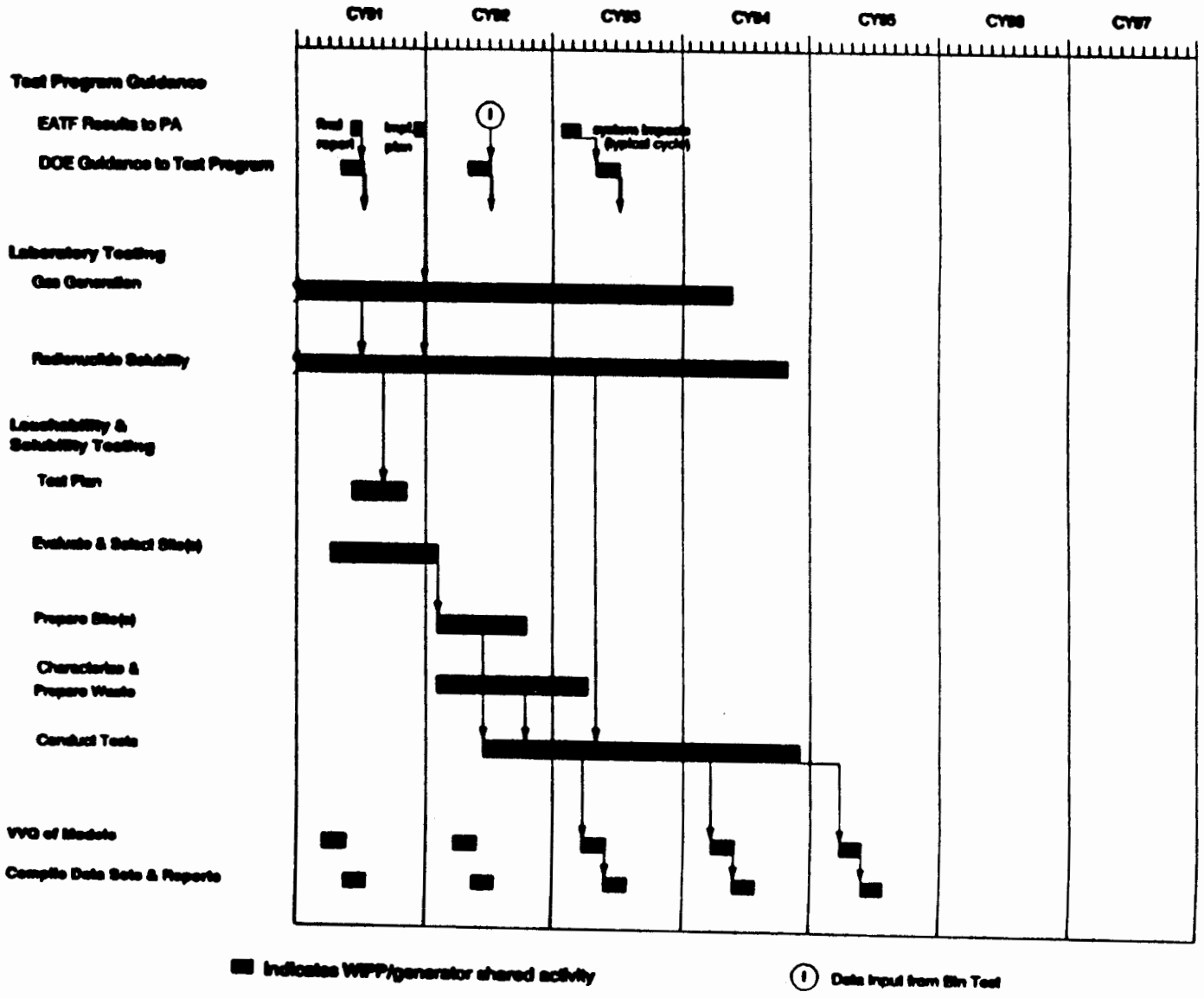

Figure 8. Laboratory, Leachability and Solubility Testing

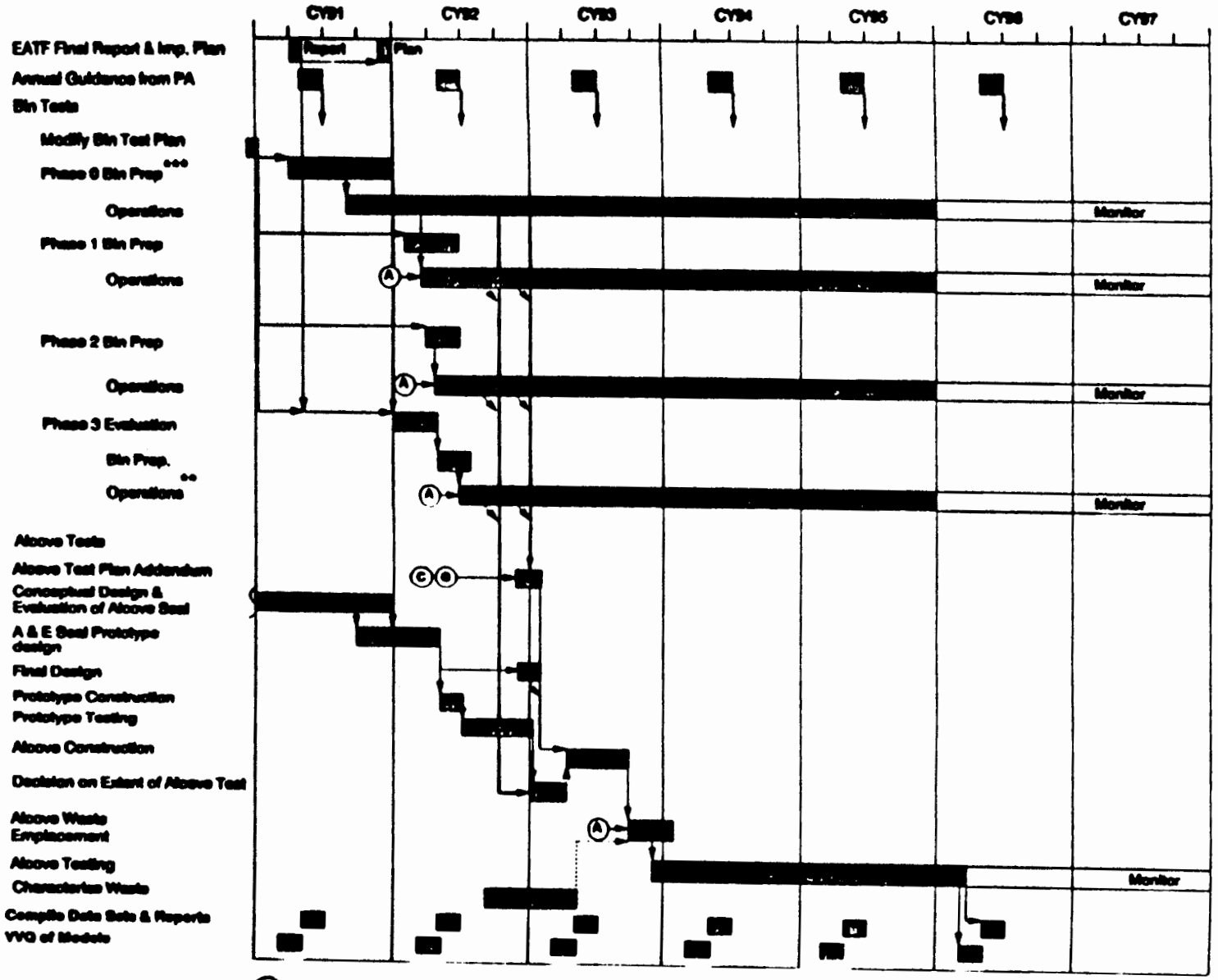

Figure 9. Bin-Scale and Alcove Tests

The investigations of natural barriers will be focused on understanding the travel of radionuclides through or past the various barriers. This requires a detailed knowledge of the various rock formations (geology), groundwater flow (hydrology), and the mechanisms for blocking or retarding the transport of radionuclides (geochemistry). The specific information needs that will be supplied by these studies to performance assessment are shown in Table 2, and the anticipated timing for each category of testing is shown in Figure 7.

4.1.1 *Geology*

The geologic tests have been directed at expanding the information available about existing rock formations near the repository and the perturbations that could result from future changes in climate. Particular emphasis has been given to quantifying variations in the physical and chemical properties of the various rock units.

Because the information base on WIPP geology is extensive, these tests are scheduled to end in 1991. They will, however, be extended if the information collected is insufficient for performance assessment.

4.1.2 *Hydrology*

The hydrologic studies will focus on two rock units: the Salado Formation and the above-lying Rustler Formation. For the Salado Formation, they will include development of models for coupled two-phase (liquid and gas) flows; these models will take into account the forces (lithostatic and gas pressures) that would tend to drive in opposite directions any brine that might occur in the repository. Studies of the dominant physical and chemical processes active in the undisturbed portion of the Salado Formation will also be conducted.

The hydrologic studies of the Rustler and surrounding formations will be directed at developing defensible models of the mechanisms involved in fluid flow and radionuclide transport from above the repository to the accessible environment. Both transient and steady-state conditions will be included in the modeling.

Data will also be collected on conditions that are potentially unfavorable, such as the presence above and below the repository of anhydrite beds that are more permeable to brine and gas than the salt.

4.1.3 *Geochemistry*

The flow path for the transport of radionuclides to the environment would be the Culebra Member of the Rustler Formation. The geochemistry tests will therefore focus on the processes (e.g., adsorption, precipitation, ion exchange, and diffusion into dead-end fractures) that would block or retard such transport. A transport model that accounts for variation in geochemical characteristics is being developed. Finally, uncertainty in key parameters will be assessed.

4.2 Characterizing the repository environment

Tests and studies in this category will address two phenomena important to long-term performance: salt creep and brine inflow. Processes related to these phenomena can profoundly affect the progression of events and perhaps long-term repository performance. For example, if the pressure in the repository remains low for a sufficient time, lithostatic pressure behind the surrounding salt can squeeze brine into the rooms. The gases that would be generated by brine interactions with the waste may, for example, interfere with creep-induced closure. On the other hand, if gas generation is sufficiently rapid, it would prevent or retard brine inflow, lowering the attendant gas-evolution potential, but perhaps driving away from the repository hazardous gases that had been contained in the waste. Because of uncertainties in the progression of such events and uncertainties related to the engineering of the repository, the DOE has identified a series of tests to characterize the repository environment. As shown in Figure 7, all of these tests are already under way.

Another objective of the repository-environment studies is to obtain information needed for developing two types of engineered barriers for the WIPP: backfill for all underground excavations and long-term seals that would be installed at the openings of the room panels, tunnels, and shafts.

4.2.1 *Studies of creep closure*

The tendency of salt to creep in response to pressure is a phenomenon essential to long-term performance. This creep flow will eventually heal fractures induced by mining, close up the underground openings, consolidate the backfill, and entomb the waste by crushing it and the backfill into a compact mass. An accurate model of this time-dependent phenomenon is necessary for a defensible performance assessment, and this requires a detailed understanding of fracture generation, fracture healing, and creep flow. In addition, it is important to learn whether there is a scale effect for creep and to study the behavior of the anhydrite beds that lie above and below the salt bed of the repository because the response of anhydrite to pressure gradients is different from that of salt.

Fracture generation, fracture healing, and creep flow will be studied in laboratory and in-situ tests. The results of these tests will be used in assessing performance, in designing seals, and in selecting materials for backfill. To study creep in three dimensions, which is important in seal design and evaluation, the tests will use large thin-walled cylinders of salt under shear and thick-walled cylinders under controlled stress gradients.

4.2.2 *Studies of brine and gas flow and geochemistry*

Both brine and gas flows are important to performance. Brine constitutes about 0.5 percent by weight of the salt at the WIPP horizon, and of particular interest is intergranular brine, which was trapped between grains of salt. The excavation of an opening allows this brine to move toward the lower pressures in the excavation. The brine appears today on tunnel walls as moisture that quickly evaporates in the dry underground air, but moisture builds up in

some closed holes, and it would likewise accumulate in the WIPP disposal rooms when they are closed. If sufficient quantities of brine come in contact with the waste, the containers may corrode and generate gases.

The studies of brine and gas flow will address the rates, total potentials, and variabilities of flow. They will include variabilities due to differences in the scale of excavations and the presence of anhydrite layers above and below the WIPP excavations. Large-scale data on brine inflow will be obtained from the experiments in the "brine inflow" room (Nowak, 1990).

The geochemistry studies will examine the composition of the brines, their variability, and their interactions with candidate backfill materials. The results will be used in assessing performance and developing performance criteria for seals.

4.2.3 *Studies of backfill consolidation and waste compaction*

One of the engineered barriers that will be used if waste is disposed of in the WIPP is backfilling around waste containers with crushed salt or other crushed materials. The backfill will consolidate with time and may include additives like bentonite, which would sorb brine and various radionuclides. Thus, in addition to hastening the closure of the underground openings and helping to entomb the waste in a compact mass, backfill may inhibit the inflow of brine and retard the transport of materials from the waste.

Laboratory studies will be conducted to (1) determine the characteristics of Backfill; (2) determine whether backfill additives would remove gas or prevent its production in the presence or absence of free brine, and (3) quantify their effects on the chemical conditions in the repository. Since bentonite and similar additives swell when absorbing liquids, the studies will also address mechanical parameters like creep-closure rates and shear strength. The results will be used in performance assessment and in selecting materials for backfill. The backfill studies will be complemented by laboratory studies of waste-container collapse to determine rates and final states of compaction.

4.2.4 *Development and design of long-term seals*

Long-term seals will serve two functions: blocking the connection established by the WIPP shafts between the host rock (the Salado Formation) and the overlying aquifers and isolating waste rooms, panels of rooms, and shafts within the Salado Formation. The guiding assumption is that the seals in the Salado need serve only until the salt has become completely reconsolidated and permeability is thereby reduced. Since this interval is expected to be much longer than the time allotted for the test program, but not long enough to fully demonstrate the design, a phased approach to materials selection and seal design will be used that will culminate before the WIPP is prepared for permanent closure. Small-scale seal material and design tests

under way now will progress to large-scale emplacement demonstrations for both shaft and drift seals before the decision process begins. Seal-material evaluations and the results of in-situ tests will be used to develop criteria for seal performance and a detailed conceptual design.

4.3 Waste-Interaction tests

Besides the data collected from studies of natural barriers and the repository environment, performance assessment requires information that can be obtained only from tests with radionuclides, whether in real or simulated wastes. The needed information includes data on the generation of gases, which can interfere with room closure and may drive hazardous elements in the waste beyond acceptable boundaries, and information on waste leachability by, and solubility in, brine. The uncertainties in the currently available information on some of these waste characteristics are too great for defensible performance assessments.

The tests designed to provide information on waste interactions are divided into early laboratory tests and follow-on, more-definitive tests of each phenomenon. The follow-on tests will use real waste. The gas-generation tests are to be conducted in the WIPP underground in specially designed bins. As the bin tests progress, their results will be evaluated to determine to what extent additional tests should be conducted in underground rooms (or alcoves) to provide a more realistic environment.

4.3.1 *Laboratory tests*

The laboratory studies have several objectives. They will quantify the production of hydrogen by anoxic corrosion of metals under various moisture conditions and they will quantify the effects of microbial degradation of the nonradioactive constituents of TRU waste. Laboratory tests will be used to determine the effects of radiolysis on the bioavailability of plastics and rubbers, and investigate the effects of waste compaction on gas generation by radiolysis. They will also quantify the effectiveness and chemical effects of proposed backfill additives to remove gas or prevent its production. If necessary the tests will investigate biodegradation of volatile organic compounds (VOCs) and material compatibility of soluble and volatile hazardous components with backfill components (e.g., bentonite) and cementitious seal components (e.g., salt-based grout).

These tests are performed in a laboratory away from the WIPP. Tests to collect data on gas generation began early in 1990, and tests of radionuclide solubility began several months later. As shown in Figure 8, the current plan is to end these tests in 1994.

Because of their early start and scope, and the controlled nature of laboratory testing, these tests are expected to provide guidance for the bin tests and tests of solubility and leachability. They are also expected to aid in the quantitative and qualitative interpretation of bin-test results.

4.3.2 *Tests of leachability and solubility*

Predictions of the chemical behavior of radionuclides in WIPP brines are necessary to determine the source term (i.e., the quantities of the important radionuclides in the WIPP inventory that will be mobilized for possible transport to the accessible environment) and the scenario-dependent rates at which these radionuclides will be mobilized. Because most plausible release scenarios involve advective or diffusive transport of radionuclides dissolved or suspended in aqueous fluids, the radionuclide source term ideally comprises (1) the product of the equilibrium or steady-state concentrations of radionuclides in brines that could enter WIPP disposal rooms after they are filled and sealed and the volumes of these brines, and (2) the rates at which these concentrations are attained and these volumes accumulate. The Leachability and Solubility tests will determine how processes distribute radionuclides between brines and solids in the repository.

These tests will be conducted with real contact-handled TRU waste at site(s) yet to be selected. Based on laboratory testing results, the scope of these tests will be identified by mid-1991 and DOE will then determine the location(s) of the tests. The site(s) will be selected and testing plans completed early in 1992. The tests are expected to be completed within 2 years as shown in Figure 8. DOE is examining the possibility of accelerating the initiation of these critical tests.

4.3.3 *Bin tests*

Bin tests will be conducted with real contact-handled TRU waste in the WIPP underground testing areas. Their principal objective is to provide data on gas evolution from the waste under realistic repository conditions, and hence most of these tests will reproduce the oxygen-free environment that is expected to occur in the repository as time passes. The waste contains various materials from which gases can evolve; they include cellulosic materials, plastics, rubber materials, and other organic materials; corroding steels, aluminum, and noncorroding metals; solid inorganic materials; inorganic sludges; and cements. The tests will examine various mechanisms for gas generation over the long term. Among them are the evolution of hydrogen from the corrosion of metals; the evolution of hydrogen and oxygen through the radiolysis of brine or water in the waste; and the evolution of carbon dioxide, methane, nitrogen, and hydrogen sulfide from the bacterial decomposition of organic materials.

Test objectives

The current suite of tests is designed to provide a statistically representative evaluation of the rates and the total potential production of gases for evaluating compliance with 40 CFR Part 191. It is not expected, however, to provide representative information about hazardous waste across the total DOE inventory, although some data gathered in the bins, such as the evolution of volatile organic compounds, will be relevant to the evaluation of compliance with RCRA requirements (Lappin et al., 1991). The results of the bin tests will provide the DOE with additional data to predict gas generation for the entire inventory of the TRU wastes expected to be disposed of in the WIPP.

Test phases

The bin tests will be conducted in four phases. The first phase (phase 0) will be a limited set of experiments designed to gather preliminary experimental data on the existing TRU waste (level I waste). The results from this phase will be used to design the remainder of the bin tests.

The results of phase 0 will be initial gas-generation rates under dry conditions and variabilities for each waste category. The variability of these results will determine how many replicate bins for each waste category will be needed in subsequent test phases.

Phase 1 testing will evaluate many of the same waste types as phase 0 but will include brine, salt, and backfill in the bins to more closely simulate the postclosure repository environment.

Phase 2 testing will examine the effects of modifying the wastes by adding "getters" for carbon dioxide or supercompacting the waste. Both wet and dry conditions will be simulated in the bins.

Phase 3 testing (if needed) will focus on engineered modifications of the existing waste forms. The bins will contain both wet and dry wastes.

Quantities and sources of waste

In total, the DOE expects to use nearly 150 bins corresponding to nearly 1,000 drum-volume-equivalents of contact-handled TRU waste.

It is assumed that the majority of the waste for the bin tests will be taken from the drums at the Rocky Flats Plant or the Idaho National Engineering Laboratory. To be acceptable, the waste must be certified to meet the WIPP waste-acceptance criteria. Waste from other sites may be needed to support these tests depending on the outcome of the EATF report, subsequent implementation plan, and early test results.

Timing

As shown in Figure 9, phase 0 testing can begin as soon as all prerequisites in accordance with the Secretary's Decision Plan, including bin preparation and WIPP facility readiness for the Test Phase are complete. Phase 1 can begin after 6 months of data collection in Phase 0 on the same waste categories. Phases 2 can also begin after 6 months of data are available from phase 0 and can therefore be performed in parallel with phase 1. Figure 9 shows phases 1, 2, and 3 beginning within a few months of each other, but the actual schedule will depend on the availability of waste that can be shipped to the WIPP.

4.3.4 *Alcove tests*

An important result of the bin tests will be a determination that sufficient information about gas generation and hazardous materials in TRU waste exists. From this the DOE will decide to what extent alcove tests will be conducted. These tests would use real TRU waste in the containers (drums or standard waste boxes) that would be used for disposal. The tests would be conducted in specially prepared alcoves-large rooms somewhat smaller than those that would be used for actual waste disposal. The primary basis for this decision will be the need for a more representative environment and more information from a larger sample of TRU wastes in the WIPP environment. An essential part of this information will be data on the potential for the evolution of volatile organic compounds from the waste.

Rationale

The need for alcove tests is predicated on the current belief that for confidence in performance assessments maximum assurance is required about the evolution of gas quantities and species over the long term. This assurance is best provided by a combination of laboratory, bin, and alcove tests. Only the alcove tests, however, will be "totally" representative of wastes and conditions in the WIPP. If engineered alternatives other than those currently planned (supercompaction and engineered backfill) are identified and selected for further evaluation, they will be incorporated into the alcove tests. The alcoves will be used to verify that predictions from the smaller scale, more-selective laboratory and bin tests are satisfactory for the assessment of long-term performance. The alcove tests, unlike the bin tests, would allow a direct determination of the source term for volatile organic compounds, should that information become necessary to support a no-migration determination. The alcove tests will allow the interaction of all evolved gases with each other and with the disposal-room environment-an objective that can be attained only to a limited degree in the bin tests.

Description of tests

The alcove tests will replicate, as closely as possible, the environment expected to be present in the WIPP over the long term and will use enough waste to be fully representative of the repository. All drums will be fully vented through carbon filters designed to limit the emission of volatile organic compounds and to control particulate discharges while allowing gases to diffuse into the atmosphere of the alcove. Brine will be added to some of the containers; quantities will be sufficiently small that there will be no hazard of contaminating the facility by leakage.

A representative waste quantity would be about 1,050 drum equivalents per alcove, and the wastes would be selected to be typical of wastes from all expected sources. This waste quantity has been used to size the alcove rooms. The plan calls for five waste alcoves and one empty alcove as a control to determine conditions in a sealed room unaffected by waste. One waste alcove will be filled with drums as they currently exist at the storage sites. Two alcoves, which will not be backfilled, will be filled with waste drums to which the selected backfill mix and

expected brine quantity have been added. One of these alcoves will employ unaltered waste forms, and one will use compacted waste from the Rocky Flats supercompactor. The remaining two alcoves differ from these last two alcoves only in the fact that the selected backfill material will also be placed in the alcove, over the drums, to most fully replicate the disposal configuration. Because retrieval must still be ensured, compaction of the salt by the room walls for the duration of the test will be prevented by isolating the backfill from the walls with standoff bulkheads.

All alcoves will be sealed to allow repository conditions to be simulated. Since anoxic conditions are expected early in the sealed repository, this condition will be established by inert-gas purging and scavenging oxygen to speed attainment of the required test condition. The sealing will also allow evolved-gas concentrations to build up and ensure optimum conditions for detection and permit the use of tracer gases. Parameters to be measured in the alcoves will be room closure, gas pressure, temperatures, and alcove gas composition as a function of time. This strategy assumes that two to three years will be required to develop enough information to determine useful rates of gas evolution, and the tests will be designed for a nominal life of five years. However, the actual extent of the alcove tests will be made in "Decision on extent of Alcove Test" shown on Figure 9.

A prerequisite to implementing alcove tests is assurance that an adequate alcove seal can be emplaced. The design of the seals will be tested before emplacing waste and conducting the alcove tests. If an adequate seal cannot be demonstrated, it may be necessary to consider expanding the scope of the bin tests to obtain essential data expected from alcove tests.

5. THE DECISION PROCESS

The decision process will involve all the activities necessary to document compliance with the applicable regulations, to complete the necessary institutional interactions, and to prepare a summary statement and recommendation for the Secretary of Energy upon which a final determination of compliance can be based following an external review. Documentation will be needed for compliance with the EPA regulations in Subpart B of 40 CFR 191 and the regulations related to the RCRA. Another supplemental EIS will be prepared to assess environmental impacts in accordance with NEPA. Compliance with other applicable Federal and State regulations will also be documented. All of these documents will be reviewed by the cognizant DOE organizations (e.g., the Office of the Assistant Secretary for the Environment, Safety and Health) whose concurrence is needed. The purpose of the review will be to ensure that the documentation is adequate and appropriate to support the determination of compliance, to obtain the necessary permits and approvals, and to comply with DOE orders. The necessary permits and approvals are identified in the Final Supplemental Environmental Impact Statement (DOE, 1990b). The principal activities to be conducted during the decision process are shown in Figure 10.

After review and concurrence by the cognizant DOE organizations, the determination of compliance with the EPA's regulations for long-term disposal in Subpart B of 40 CFR Part 191 will be reviewed by an independent review group. Comments resulting from this review will be addressed prior to the Secretary's final decision on the Disposal Phase (The DOE has agreed with the State of New Mexico that compliance with Subpart A of 40 CFR Part 191, the standards for the operational period, will be determined and documented before any waste is received at the WIPP.)

The documentation of compliance with the RCRA regulations is presented in two separate documents. One will be a petition to the EPA to grant a no-migration variance in accordance with the provisions of 40 CFR Part 268. This petition will be reviewed by the EPA. If the EPA deems the documentation of compliance to be adequate, it will grant a no-migration variance under conditions to be enforced by the EPA. The other document an application to the State of New Mexico for an RCRA permit under Part B. (For the test phase, the WIPP has received an RCRA permit under Part A as an "interim-status" facility subject to the requirements of 40 CFR Part 265.) The Part B permit is significantly broader than a no-migration finding, since it will impose the applicable technical and general facility standards of 40 CFR Part 264 and the requirements of 40 CFR Part 270. The State permit will be issued under State procedures, which include public notice, comment, and an opportunity for a public hearing. The conditions of this permit will be enforced by the State.

The DOE will take all necessary steps to meet the requirements of the National Environmental Policy Act (NEPA) and to comply with applicable DOE orders. The DOE will also conduct various institutional activities, prepare and issue the necessary notices, and perform the planning necessary for the disposal phase, including a readiness review to determine that waste acceptance for permanent disposal can begin at the WIPP.

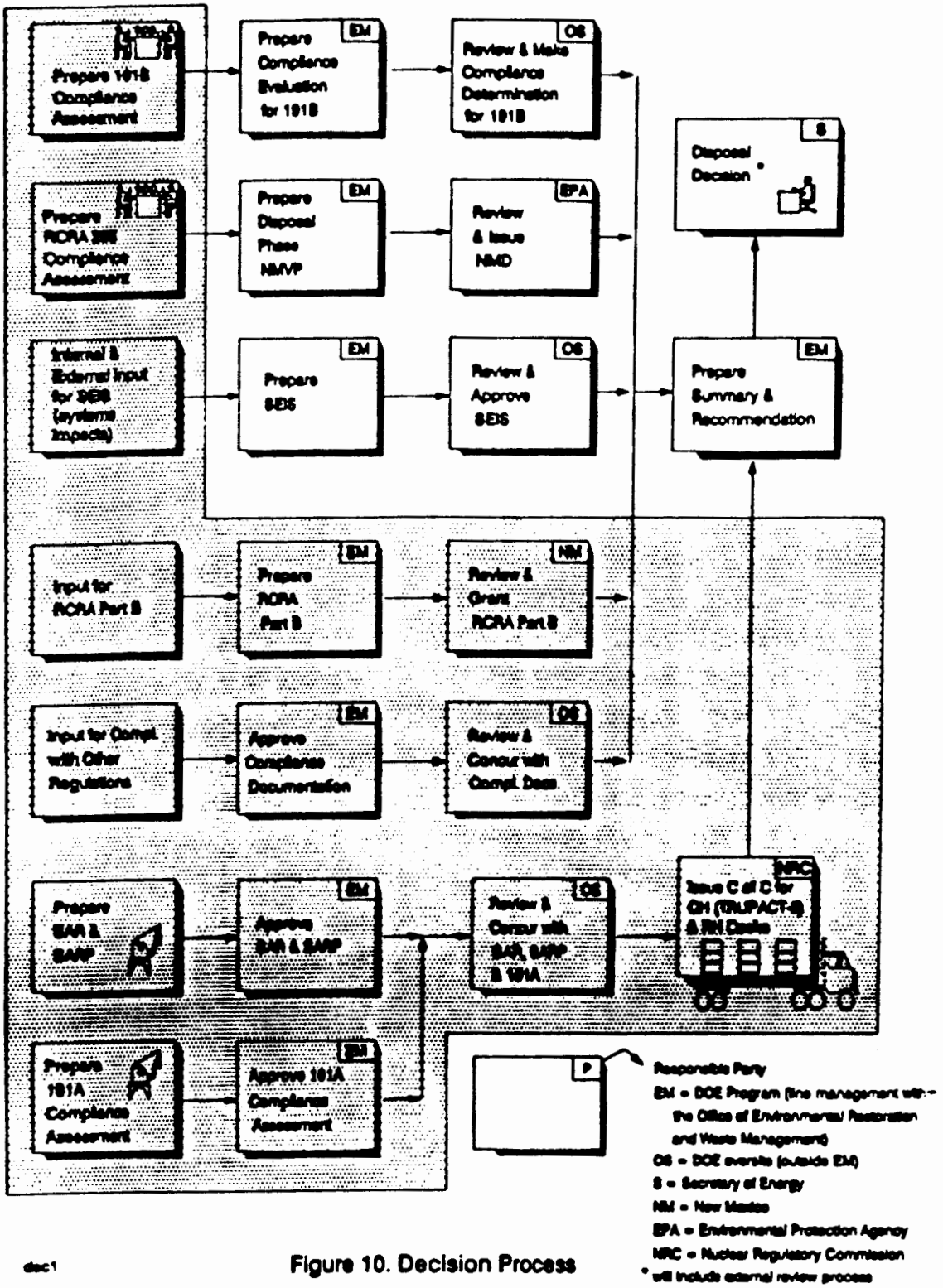

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Figure 10. Decision Process

In accordance with the NEPA, the DOE will issue another supplemental environmental impact statement (SEIS). This document will analyze the potential short- and long-term impacts of TRU-waste disposal in the WIPP based on data collected during the Test Phase and assessment of impacts. Some of the analyses in the SEIS will be based on the results of the performance assessments discussed in Section 3, but the sources of input for the SEIS will not be limited to the test-phase activities described in this document: input will also be provided by various other ongoing WIPP programs, such as the environmental monitoring program. The SEIS will be issued first as a draft for public comment and revised to reflect the comments before it is issued as the final SEIS. Public hearings will be held as part of this process.

In addition, the DOE will update as needed the WIPP Final Safety Analysis Report (FSAR). The FSAR, prepared in accordance with DOE Order 5481.1B, is a systematic analysis of the potential hazards associated with WIPP operations. The DOE will also update as appropriate other documentation related to the operation of the WIPP or to waste transportation; this includes the safety analysis report for packaging (SARP), which has been prepared for the TRUPACT II containers in which the waste will be shipped.

Once the process of documentation and review (both internal and external) has been completed, the DOE will prepare an internal summary report for the Secretary of Energy. This report will include a recommendation as to whether waste disposal at the WIPP should begin. Given a determination of compliance with the applicable regulations and a favorable record of decision on the new SEIS, and a favorable readiness review, the Secretary will decide whether the WIPP should begin receiving TRU waste for permanent disposal. The time required to prepare the documentation and to complete the various other activities mentioned above is estimated to be between 12 and 24 months.

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