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**Civilian Radioactive Waste Management System
Management & Operating Contractor**

Retrievability Strategy Report

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April 1997

Prepared for:

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**Civilian Radioactive Waste Management System
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Retrievability Strategy Report

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PREFACE

Section 122 of the *Nuclear Waste Policy Act* requires that a repository be “designed and constructed to permit retrieval of any spent fuel placed in such repository, during an appropriate period of operation of the facility,” for one of these reasons:

- To protect “public health and safety, or the environment”
- To permit “the recovery of the economically valuable contents of such spent fuel.”

The Act also requires the Secretary to specify an appropriate period of retrievability at the time of the design of a repository. The Secretary has not yet defined any such period. However, the Nuclear Regulatory Commission, in the Code of Federal Regulations Title 10 Part 60.111, requires the design of a geologic repository operations area to allow the retrieval of any or all waste “on a reasonable schedule starting at any time up to 50 years after waste operations are initiated....” NRC describes a “reasonable schedule” as one that would permit retrieval in about the same time as it took to construct the repository and emplace the waste.

Based on the existing conceptual repository and waste package design and analysis, the Yucca Mountain Project described retrieval operations under normal and abnormal conditions in the 1988 *Site Characterization Plan (SCP)* document. In 1991, under the same design assumptions, the Project issued a *Retrieval Strategy Report for a Potential High-Level Nuclear Waste Repository*. Both the conceptual design of the waste package and the emplacement methods have since changed significantly.

This report presents the results of a study to determine whether and to what degree these design and other changes require a revision of the retrieval strategy and, if they do, to recommend a revised strategy. The aim of such a revised strategy was to inform decision makers on how to proceed with design to allow retrievability. In particular, the strategy was to describe the process by which retrieval would be executed and to contain sufficient details, recommended design alternatives, and the technical rationale to:

- Support the development of the *License Application*
- Provide a technical basis for each retrievability design requirement in the FY 97 *Retrieval Design & Operation Report for the Viability Assessment*.

As part of the study, a thorough literature search was conducted and the relevant strategy and other technical documents were evaluated. A compliance and licensing assessment was also developed to determine the level of detail required for the retrieval section of the *License Application*.

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EXECUTIVE SUMMARY

KEY FINDINGS

Need for a Revised Strategy. Major changes in repository and waste package concepts have occurred since the 1988 *Site Characterization Plan*. Current design calls for far larger and heavier unshielded waste packages, for the emplacement of fewer packages, and for in-drift emplacement. As a result, past retrieval strategies are, in some respects, no longer valid and a revised strategy is required to reflect these changes.

Preserving the Retrieval Option. The Nuclear Regulatory Commission and the Department of Energy documents on retrieval generally require that the repository be designed so that retrieval is a practical option, that retrieval is not so expensive, difficult, or dangerous that the option is foreclosed. NUREG-0804 states the the agencies also "foresee no situation where protection of public health and safety would require the waste to be removed very rapidly." (NRC1983)

These documents also make a clear and sharp distinction between retrieval and all other kinds of removal and movements of waste that occur during the period during which waste is emplaced. Retrieval would occur only as a result of a top policy decision by the Department of Energy and the Nuclear Regulatory Commission to protect public health and safety or the environment, or to recover resources from the spent fuel. It is expected to take years, perhaps decades, to accomplish and may be very difficult. All other movements or recovery of waste for any other reason will occur as part of normal repository operations, and will not be governed by the regulations and requirements for retrieval as defined by the *Nuclear Waste Policy Act* and by the Nuclear Regulatory Commission. However, the capability developed to conduct those operations safely and efficiently even under adverse conditions will also be used to perform any retrieval operations. Current plans for use of very large unshielded waste packages, which must be moved and emplaced remotely, may require the repository design to include a robust ground support system to assure safe and easy access to packages and drifts throughout the operational period. Any operations required for retrieval would take advantage of this same system and features. This report identifies design requirements derived from the proposed retrieval strategy that are in addition to those requirements already established for the operational period of the repository.

Retrieval under the Current Design. Over a range of seven scenarios, both normal and abnormal, retrieval remains possible within the current mined geologic disposal system conceptual design. The strategy outlined in this report describes, in the level of detail consistent with current design details, how to retrieve waste in each of the seven scenarios with the current Mined Geologic Disposal System design. No equipment beyond that required for current operational plans will be required.

Expected Retrieval Environment. The main features of the repository that could affect the expected retrieval environment include seismicity, geomechanics (rockfall), water in-flow, temperature and radiation levels. An evaluation of these features shows that:

- The likelihood of emplacement-drift-damaging seismic ground motion or fault displacement during the preclosure design lifetime is minimal.

The considerable uncertainties about the behavior of the rock under high thermal loads are driving the design to a robust ground support system to support construction, operations, and performance confirmation activities. This system should allow retrieval using standard emplacement equipment, but performance uncertainties should be resolved as quickly as possible through the drift scale test and monitoring early in the performance confirmation stage.

- There is little likelihood that normal water percolation, a rising water table, perched water, could cause enough water to enter the repository during the preclosure period to impede normal operations or retrieval.
- The repository is being designed to accommodate high radiation and temperatures from the waste packages. No additional features are required to allow retrieval even 50 or more years after emplacement starts, when the temperature in the drifts will be near its peak and radiation levels will still require shielding.

The Retrieval Period. The retrieval period extends from the time the order to retrieve is given to the time all waste to be retrieved is on the surface. Retrieval planning at the beginning of the period will take an estimated 10 years. The time required for actual retrieval depends on the number of waste packages to be retrieved and whether the conditions of retrieval are normal or abnormal. Under normal conditions, the expected retrieval rate is 1,000 packages per year, requiring about 10 years to retrieve the entire waste package inventory. The entire waste inventory could be retrieved in about 5 years. Abnormal conditions would slow the retrieval rate. However, retrieving the waste packages at about two per day results in meeting the retrieval time.

Assuming an expected planning period of 10 years, the elapsed time from the order to accomplish full retrieval until the last package is on the surface would be 34 years, conforming to 10 CFR Part 60 guidance. The time to retrieve the entire inventory if the drifts have been backfilled has not been calculated. This retrieval schedule would most likely go well beyond both the 24 years cited for abnormal retrieval and the time described in 10 CFR Part 60 guidance as "...about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes," currently estimated at 34 years.

Equipment Development and Prototype Testing. The operational equipment (handling equipment, locomotives, transporter and gantry) being designed to handle the large unshielded waste packages currently contemplated should work well for both normal emplacement and retrieval operations. However, to allow waste package movement for operational purposes under abnormal conditions (such as rock fall or failed power or rail systems), some special equipment will be required. Proof-of-principle and prototype testing of any specialized equipment designed to handle waste packages in abnormal conditions or to recover them from an accident should be performed before the license to receive and possess waste and the start of waste emplacement. The need and extent of these tests to support planned operations will be determined by a test and evaluation analysis. Proof-of-principle testing will only be required if no supplier performance data exist for the expected conditions. Since this equipment will also serve for retrieval under abnormal conditions, the retrievability requirements do not impose additional needs for equipment development and testing beyond those required for preclosure operations.

Compliance and Licensing Needs. To determine the information on retrieval needed for developing the *Licensing Application (LA)*, the Draft Regulatory Guide 3003 on the format and content for the license application was examined and a list of 21 questions developed that this study should attempt to address. Table 8-2 indicates the sections of this report that either answer these questions or suggest how the information required to answer them can be developed.

RECOMMENDED RETRIEVAL STRATEGY

The recommended strategy incorporates most of the features of the earlier strategy from the *Site Characterization Plan*. However, the proposed strategy recognizes that under the current design concept the requirements for "proof of principle" and prototype tests conducted to show that retrieval will be possible will be met by tests. These tests are required to assure that, during the operational period, waste packages can be reached and moved under both normal and abnormal conditions. The strategy includes steps to assure that land for storage and transportation rights of way that could be needed for retrieval will be available until repository closure. The strategy also makes clear that detailed design and construction requirements for retrieval should be deferred until the time of retrieval so they can be based on the actual conditions that will be encountered.

The key elements of the recommended strategy, which are described in detail in Section 8, are:

- *Maximize use of equipment, facilities, and procedures designed for repository operation.*

Tie retrieval as closely as possible to the emplacement method, using the same systems and equipment and following the same steps in reverse order, to avoid the need for development and testing of specialized equipment required only for retrieval. To the maximum extent possible, use the existing repository surface and subsurface facilities for retrieval. At the end of repository loading, decontaminate and mothball the waste handling building for possible reuse during retrieval. To adapt to actual retrieval conditions most effectively, defer design and construction of any additional facilities required for retrieval operations, such as additional shafts, until the time of retrieval.

- *Add flexibility for easy retrieval*

Provide access for retrieval into each emplacement drift from the east and west main drifts. Design the waste package so that remotely-operated specialized equipment can be used to retrieve the package from either end under abnormal conditions such as rockfall.

- *Preserve the option of continued use of the repository*

Design the repository to allow concurrent emplacement and retrieval of waste packages. Develop approaches for partial retrieval, such as all the packages in a particular area, or only certain types of packages. Ensure that, for partial retrieval in which continued use of the repository is contemplated, the design, methods and the equipment used do not adversely affect waste isolation.

- *Make initial provisions for storage and transportation of retrieved waste.*

Size and locate on a plot plan, before the license application, a site for a temporary surface storage facility that has the flexibility to store the entire planned waste inventory of the repository. Further evaluate the site for storage suitability before the license to receive and possess waste and reserve the site and any needed transportation rights-of-way until repository closure, but defer the design and construction of the facility until the time of retrieval.

- Each emplacement drift shall require retrieval capabilities from the East Main and the West Main for maximum flexibility.
- For partial retrieval, the design, methods used for retrieval, and the equipment shall not negatively affect isolation.
- If additional facilities are required to support retrieval operations, such as additional shafts, or additional support equipment, the design and construction will be accomplished at the time of retrieval to better assess actual retrieval conditions.
- The waste package design will provide a means to allow remotely-operated, specialized equipment to retrieve a waste package under abnormal conditions such as a rockfall.
- The need for proof-of-principle testing for systems and components required to function in a hostile environment will not be required, if supplier performance data exists for the conditions expected to encounter.
- There is no basis for specifying the location of waste packages in the emplacement drifts to make retrieval easier.
- If a branch rail line is built from a mainline railroad to Yucca Mountain, the land withdrawal or right-of-way obtained shall extend until permanent closure of the repository.

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1. INTRODUCTION

1.1 BACKGROUND

In 1982, the *Nuclear Waste Policy Act* (NWPAA) was enacted "to provide for the development of repositories, for the disposal of high-level radioactive waste and spent nuclear fuel, to establish a program of research, development, and demonstration regarding the disposal of high-level radioactive waste and spent nuclear fuel, and for other purposes" (NWPAA 1982). Section 122 of the *Nuclear Waste Policy Act, as Amended* states, "any repository constructed on a site approved under this subtitle (42 U.S.C. 10131 et seq.) shall be designed and constructed to permit the retrieval of any spent nuclear fuel placed in such repository, during an appropriate period of operation of the facility, for any reason pertaining to the public health and safety, or the environment, or for the purpose of permitting the recovery of the economically valuable contents of such spent fuel" (NWPAA 1987, p. 25). Since the enactment of the NWPAA, Title 10 of the Code of Federal Regulations Part 60 (10 CFR Part 60), *Disposal of High-Level Radioactive Wastes in Geologic Repositories*, has been prepared by the Nuclear Regulatory Commission (NRC) to serve as a key, top-level requirements document.

As an added measure of assurance, this regulation includes the requirement to maintain the option of retrieving emplaced high-level nuclear waste (HLW) or spent nuclear fuel (SNF). Therefore, the repository design and waste package design must include retrieval as a planned contingency.

Shortly after the enactment of the NWPAA, the Department of Energy (DOE) tasked Sandia National Laboratories (SNL) to produce a retrievability strategy for compliance demonstration. This strategy considered vertical and long horizontal boreholes for the emplacement of waste packages (SNL 1986).

Sandia National Laboratories produced the *Site Characterization Plan Conceptual Design Report* (SCP-CDR). Volume 4, Appendix J entitled, "Waste Retrieval", describes retrieval operations under normal and abnormal conditions based on the conceptual design and preliminary analyses (SNL 1987). This strategy report was followed by another retrieval strategy document entitled, *Retrieval Strategy Report for a Potential High-Level Nuclear Waste Repository* (SNL, 1991). This document is based on the SCP-CDR. At that time, the waste package concept involved a smaller waste package, three pressurized-water reactor (PWR) and four boiling-water reactor (BWR) fuel assemblies per waste package, with an alternative configuration of ten BWR fuel assemblies, and the emplacement panel designs covered vertical and horizontal boreholes.

Over the past ten years, the repository and waste package concepts have changed to larger waste packages and in-drift emplacement. These changes necessitate a reassessment of the retrieval strategy for Yucca Mountain.

1.2 PURPOSE

The purpose of this retrievability strategy report is to identify a flexible strategy to ensure that retrieval can be accomplished, to identify the possible retrieval options, given a wide variety of input

parameters, and to discuss the recommended retrieval process with regard to the repository and waste package designs that are currently in the conceptual stage. As the MGDS design progresses, the retrieval strategy will be revised accordingly. As a result this document will be revised accordingly.

1.2.1 Study Objectives

The objectives of this systems study are to produce a retrievability strategy consisting of a step-by-step process of how retrieval would be executed (a) to support licensing in the development of the *License Application*, and (b) to provide a technical basis for each design requirement developed for retrievability, in support of the design activity for FY 97 *Retrieval Design and Operation* report in support of Viability Assessment. The intent of this integrated systems study is to support decisions on how to proceed with design with respect to retrievability, regarding the extent to which the repository/waste package designs should accommodate the retrieval option.

1.2.2 Scope

The scope of the retrievability strategy report includes the following functions:

- Evaluate prior work on retrievability and assess what areas if any are still applicable to the current design. (Section 3)
- Perform a regulatory/licensing assessment to determine information needs and level of detail necessary for compliance with NRC requirements. (Section 4)
- Identify events or conditions that could lead to a decision to retrieve. (Section 5)
- Identify the potential retrieval environment. (Section 6, 7.3)
- Determine to what extent the MGDS design should accommodate the retrievability requirement now, as opposed to delaying the implementation of designs to accommodate retrieval until the time of retrieval, if required. (Section 8)
- Develop retrieval scenarios that include alternate storage and associated times required for retrieval. (Section 7)

1.2.3 Study Approach

Figure 1-1 shows the flow of tasks that have been performed in the conduct of this study.

Figure 1-1. Flow of Tasks Performed for Study

1.3 REPORT ORGANIZATION

This document provides a report of a recommended retrieval strategy and associated design requirements and recommendations. The report is organized as follows:

- **Cover Pages**—These pages contain the complete title, document identifier, Work Breakdown Structure (WBS) number, Site Characterization Program Baseline (SCPB) identification number, quality assurance designator, and the signatures and dates for the individuals who prepare, approve and concur with the approval of the document.
- **Executive Summary**—This section provides a top-level description and the study findings and recommendations.
- **Introduction**—Section 1 provides the objectives, scope, background, study approach, and the organization of the report.
- **Requirements, Inputs, and Assumptions**—Section 2 lists all the requirements, inputs, and assumptions used in the development of the report. It also addresses the quality assurance procedures used in the development and review of the document.
- **Assessment of Past Retrieval Positions**—Section 3 identifies the process used in screening documents from the Record Information System (RIS) and the assessment of these documents for applicable information in this report.
- **Compliance and Licensing Assessment**—Section 4 identifies the level of detail and content that is specified by the NRC in Draft Regulatory Guide 3003. This guide has been summarized in the form of questions and the conclusion section shows a matrix where the report addresses each question. Some questions have been deferred to other activities that will provide the answer prior to developing the License Application.
- **Conditions Requiring Retrieval**—Section 5 discusses the two reasons as stated in the NWSA, (1) public health and safety or the environment, and (2) resource recovery. This section also addresses the fact that there is a category that is not retrieval, but rather is considered waste package movement. Four areas have been identified to cover the category of waste package movement.
- **Expected Retrieval Environment**—Section 6 discusses the expected environment at the end of the retrieval period, 50 years from the start of emplacement. The parameters identified are seismic, geomechanical, water-inflow, radiation levels, temperature, and waste package conditions.
- **Retrieval Scenario Development**—Section 7 discusses the process flow for retrieval, using a logic diagram tool to show the performance functions and those events that could challenge the function of retrieving waste. Seven retrieval scenarios, each with different retrieval parameter combinations have been developed to explain how retrieval operations

would be conducted, and to address the concern of maintaining retrievability of the repository.

- **Conclusion**—Section 8 contains summary of the study results, conclusions, recommended design requirements, and recommendations.
- **References**—Section 9 provides a listing of the references used throughout the document.
- **Appendix A**—Acronyms and Abbreviations
- **Appendix B**—Glossary

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2. REQUIREMENTS AND INPUTS

2.1 REQUIREMENTS

The requirements relevant to this study were obtained from the *Mined Geologic Disposal System Requirements Document* (CRWMS M&O 1997b); *The Nuclear Waste Policy Act, As Amended* (NWPAA 1987); 10 CFR Part 60, *Disposal of High-Level Radioactive Waste In Geologic Repositories* (10 CFR Part 60 1996); 10 CFR Part 20, *Standards for Protection Against Radiation* (10 CFR Part 20 1996); and the *Controlled Design Assumptions Document* (CRWMS M&O 1996d).

2.1.1 Controlled Design Assumptions Document

The following key assumptions on retrieval and retrievability have been taken from the *Controlled Design Assumptions Document*.

Key 010, Subsurface Waste Package Transport

Rail transport will be used for subsurface transport of waste packages.

Key 011, Horizontal In-Drift Emplacement

Waste packages will be emplaced in-drift in a horizontal mode.

Key 013, No Human Entry in Emplacement Drifts Containing Waste Packages

No human entry is planned in emplacement drifts while waste packages are present. The waste emplacement/retrieval equipment may use robotics and/or remote control features to perform operations and monitoring within the emplacement drifts. Under off-normal conditions, human entry will be considered if protection to the workers can be provided.

Key 031, Waste Package Shielding

Waste package containment barriers will provide sufficient shielding for protection of waste package materials from radiation enhanced corrosion.

Individual waste packages will not provide any additional shielding for personnel protection.

Additional shielding for personnel protection will be provided on the subsurface transporter and in surface and subsurface facilities.

Key 037, Expected Waste Package Lifetime

Mean waste package lifetime will be well in excess of 1000 years.

Key 038, Waste Packages Breached at 1000 years

The fraction of waste packages breached at 1000 years shall be less than 1 percent.

Key 046, Backfill in Emplacement Drifts

Backfill in emplacement drifts is not required. However, the repository design should not preclude the use of emplacement drift backfill at the end of the preclosure period. The specifications for the emplacement drift envelope to accommodate are: 1) level single layer backfill (quartz sand, crushed tuff, or other material of similar favorable thermohydrologic properties), and 2) waste packages should initially be covered with at least 0.6 meters of material.

Key 047, Surface Facilities Location

The proposed repository waste handling and administrative surface facilities will be located adjacent to the north portal. Flood considerations for locating surface facilities are included in Assumption TDS 008. Administrative facilities will be located east of the nuclear facilities.

Key 055, Retrieval Demonstration

Proof-of-principle demonstrations of waste package retrieval will be conducted following license application.

Key 058, Transportation Mode/Route Within Nevada

Spent nuclear fuel (SNF) and high-level waste (HLW) arriving in Nevada on mainline commercial rail lines, will be transported to the repository via rail. The rail routes being considered are described in the *Nevada Potential Repository Preliminary Transportation Strategy - Study 2* (CRWMS M&O 1995c). For costing purposes, a straight cost average of the four routes will be used: 1) Caliente - base route; 2) Carlin - Monitor Valley via Ralston; 3) Valley Modified- via Indian Hills; and 4) Jean - Wilson Pass Option via Stewart Valley.

The Caliente Route is the baseline route for the Life Cycle Cost Estimate.

Key 064, Seismic Design Criteria

The seismic design of repository SSCs (structures, systems, and components) important to (radiological) safety (including surface facilities, subsurface facilities, and waste packages) shall be based on the methodology presented in Reference 1. Seismic design shall include design for vibratory ground motion and fault displacement.

Preliminary values corresponding to Frequency-Category-1 (mean annual exceedance probability of 0.001) and Frequency-Category-2 (mean annual exceedance probability of 0.0001) for the following parameters shall be based on Reference 2.

- Peak acceleration (Table 1, Reference 2)
- Peak velocity (Table 1, Reference 2)

- Factors for reduction of ground motion with depth (Table 3, Reference 2)
- Response spectra (Appendix C, Reference 2)

REFERENCES

Reference 1: Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain, Topical Report YMP/TR-003-NP, Rev. 1, DRAFT A, August 1996 (in DOE review).

Reference 2: *Seismic Design Inputs for the Exploratory Studies Facility at Yucca Mountain* (CRWMS M&O 1994a).

Key 065, Retrieval Design

MGDS design for retrieval will be performed when, and if, retrieval of the waste packages is directed.

Key 066, Gantry Emplacement and Pedestal Support

Waste packages will be placed center in-drift, on pedestals, using gantry emplacement.

Key 067, Emplacement Drift Ventilation

Emplacement drift ventilation will be maintained at a low, controlled volume for monitoring purposes.

Key 068, Use of North Ramp for Waste Transport

The north ramp will be used for waste transport.

Key 070, Excavated Opening Diameters

The following diameters are assumed for underground openings.

<u>Underground Opening</u>	<u>Diameter (m)</u>
Ramps	7.62
Shafts	6.1 (finished inside diameter)
Access/Service Main	7.62
Central Exhaust Main	7.62
Emplacement Drift	TBD

Key 072, Repository Subsurface Layout

The current subsurface repository layout contains the following features:

- Long parallel emplacement drifts
- Only upper emplacement block (no lower emplacement block)
- In-drift waste package emplacement
- Central exhaust main below emplacement drifts

- Two shafts and two ramps
- One upper block perimeter/access drift

2.1.2 Mined Geologic Disposal System Requirement Document

- Section 2.5.G
Because of uncertainty about the start time for retrieval operations, transportation requirements and architecture will not be maintained for post-retrieval waste transport capability [CRD 2.4.J]
- Section 3.2.G
Waste packages will be designed so that there shall be no more than one percent of the waste packages breached in 1000 years. [CRD 3.4.B]
- Section 3.2.H
The MGDS shall be designed to support repository construction for the 6 years prior to waste emplacement, to support initiation of retrieval at any time up to 50 years after waste emplacement operations have begun, to support retrieval operations for up to 34 years, and to support closure operations for up to 10 years. (TBV6) [CRD 3.2.3]
- Section 3.2.I
The MGDS shall have a mass loading of 80-100 MTU per acre, primarily in the TSw2 geologic unit within the primary area. [CRD3.2.1A] [CRD 3.4.A]
- Section 3.2.J
The MGDS shall have the capacity to retrieve all emplaced disposal containers in 34 years. (TBV7) [CRD 3.1.1.C]
- Section 3.3.I
The MGDS design shall retain the option of using emplacement drift backfill until the license amendment to close the repository has been approved by the NRC. [CRD 3.1.1.C]

2.1.3 The Nuclear Waste Policy Act, As Amended, 1987, Sec. 121, and 122

The basis for maintaining the waste retrievability option is stated in the *Nuclear Waste Policy Act, As Amended*:

Sec. 121. (a) Environmental Protection Agency Standards - not later than 1 year after the date of the enactment of this Act [enacted Jan. 7, 1983], the Administrator, pursuant to authority under other provisions of law, shall, by rule, promulgate generally applicable standards for protection of the general environment from offsite releases from radioactive material in repositories.

- (b) Commission requirements and criteria.
- (B) Such criteria shall provide for the use of a system of multiple barriers in the design of the repository and shall include such restrictions on the retrievability of the solidified high-level radioactive waste and spent fuel emplaced in the repository as the Commission deems appropriate.

Sec. 122. Notwithstanding any other provision of this subtitle, any repository constructed on a site approved under this subtitle shall be designed and constructed to permit the retrieval of any spent nuclear fuel placed in such repository, during an appropriate period of operation of the facility, for any reason pertaining to the public health and safety, or the environment, or for the purpose of permitting the recovery of the economically valuable contents of such spent fuel. The Secretary shall specify the appropriate period of retrievability with respect to any repository at the time of design of such repository, and such aspect of such repository shall be subject to approval or disapproval by the Commission as part of the construction authorization process under subsections (b) through (d) of section 114.

2.1.4 10 CFR Part 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories

Several sections of 10 CFR Part 60, *Disposal of High-Level Radioactive Wastes in Geologic Repositories* contain references to waste retrieval and retrievability. These references follow:

Section 60.2, Definition

Retrieval means the act of intentionally removing radioactive waste from the underground location at which the waste had been previously emplaced for disposal.

Section 60.21, Content of application

(c) The Safety Analysis Report shall include:

(12) A description of plans for retrieval and alternate storage of the radioactive wastes should the geologic repository prove to be unsuitable for disposal of radioactive wastes.

Section 60.46, Particular activities requiring license amendment

(a) Unless expressly authorized in the license, an amendment of the license shall be required with respect to any of the following activities:

(1) Any action which would make emplaced high-level radioactive waste irretrievable or which would substantially increase the difficulty of retrieving such emplaced waste.

Section 60.102, *Concepts*

(d) Stages in the licensing process. There are several stages in the licensing process. The site characterization stage, though begun before submission of a license application, may result in consequences requiring evaluation in the license review. The construction stage would follow, after issuance of a construction authorization. A period of operations follows the issuance of a license by the Commission. The period of operations includes the time during which emplacement of wastes occurs; any subsequent period before permanent closure during which the emplaced wastes are retrievable; and permanent closure, which includes sealing of shafts. Permanent closure represents the end of active human intervention with respect to the engineered barrier system.

Section 60.111, *Performance of the geologic repository operations area through permanent closure*

(b) Retrievability of waste. (1) The geologic repository operations area shall be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and, thereafter, until the completion of a performance confirmation program and Commission review of the information obtained from such a program. To satisfy this objective, the geologic repository operations area shall be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission. This different time period may be established on a case-by-case basis consistent with the emplacement schedule and the planned performance confirmation program. (2) This requirement shall not preclude decisions by the Commission to allow backfilling part or all of, or permanent closure of, the geologic repository operations area prior to the end of the period of design for retrievability. (3) For purposes of this paragraph, a reasonable schedule for retrieval is one that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes.

Section 60.131, *General design criteria for the geologic repository operations area*

(b) Protection against design basis events. The structures, systems, and components important to safety shall be designed so that they will perform their necessary safety functions, assuming occurrence of design basis events.

(b) Structures, systems, and components important to safety

(6) Inspection, testing, and maintenance. The structures, systems, and components important to safety shall be designed to permit periodic inspection, testing, and maintenance, as necessary, to ensure their continued functioning and readiness.

(7) Criticality control. All systems for processing, transporting, handling, storage, retrieval, emplacement, and isolation of radioactive waste shall be designed to ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. Each system shall be designed for criticality safety under normal and accident conditions. The calculated effective multiplication factor (k_{eff}) must be (Section 3.2.I) sufficiently below unity to show at least a 5% margin, after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.

Section 60.132, *Additional design criteria for surface facilities in the geologic repository operations area.*

(a) Facilities for receipt and retrieval of waste. Surface facilities in the geologic repository operations area shall be designed to allow safe handling and storage of wastes at the geologic repository operations area, whether these wastes are on the surface before emplacement or as a result of retrieval from the underground facility.

Section 60.133, *Additional design criteria for the underground facility*

(c) Retrieval of waste. The underground facility shall be designed to permit retrieval of waste in accordance with the performance objectives of § 60.111.

(e) Underground openings. (1) Openings in the underground facility shall be designed so that operations can be carried out safely and the retrievability option maintained.

Section 60.135, *Criteria for the waste package and its components.*

(b) Specific criteria for HLW package design

(3) Handling. Waste packages shall be designed to maintain waste containment during transportation, emplacement, and retrieval.

(4) Unique identification. A label or other means of identification shall be provided for each waste package. The identification shall not impair the integrity of the waste package and shall be applied in such a way that the information shall be legible at least to the end of the period of retrievability. Each waste package identification shall be consistent with the waste package's permanent written records.

2.2 QUALITY ASSURANCE

A Quality Assurance Procedure, QAP-2-0 activity evaluation of the retrievability strategy has been conducted. This evaluation concluded that this study is subject to the *Quality Assurance Requirements and Description* (QARD) requirements. There are no applicable determination of importance evaluations in accordance with Nevada Line Procedure, NLP-2-0, *Determination of Importance Evaluations*. This study does provide recommended requirements for inclusion in the

Mined Geologic Disposal System Requirements Document. The appropriate quality assurance procedure, QAP-3-5, *Development of Technical Documents*, in particular, will be used in the preparation, review, approval, and, if necessary will be used in the revision of the report. Accordingly, the *Technical Document Preparation Plan* for this document was developed, issued, and utilized to guide the preparation of this document.

2.3 INPUTS AND ASSUMPTIONS

This section identifies the inputs and assumptions used in developing the report, acknowledges if the inputs are qualified or unqualified, and identifies the section or sections in which the input was used. Although, specific assumptions have been identified in this section, additional assumptions have been used for the development of retrieval scenarios in Section.7. Table 2-1 shows inputs used in the development of this report.

A partial list of assumptions that have been used in this document are listed below; for a complete list see Table 2-1:

- **Assumptions from NUREG-0804, *Staff Analysis of Public Comments on Proposed Rule 10 CFR Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories"* (NRC 1983)**

Retrievability Period--The design must also ensure that the option is preserved long enough to permit a decision to permanently close the repository to take any corrective actions shown to be necessary by the verification and monitoring program. Since some of the assumptions and issues that will need to be verified and resolved by the monitoring program may not be identified until the underground facility is excavated, it is not possible to specify prior to construction the complete content of the verification program or how long it will take. We expect the verification program to evolve throughout the operating lifetime of the repository.

Further rationale by the NRC staff--...the option to retrieve should be preserved for the time necessary to emplace all of the waste, complete a performance confirmation program, arrive at a decision as to whether retrieval must be undertaken, and execute retrieval, if found to be necessary. The design for retrievability should encompass all of these considerations. If retrieval is deemed necessary, a planning period is clearly required, and this requires identification of foreseen tasks and the estimated time line prior to retrieval.

Table 2-1. Inputs Used in Development of Report

Inputs	Input Classification (Qualified or Unqualified)	Section(s) of Report Input Used	Impact of Data on Outputs
Project Planning Schedule, YMP-CM-0015, Rev. 11	Unqualified ¹	8.0	No impact on study findings
Waste Quantity & Throughput Study Report, B00000000-0717-5705-00059, REV 00, March 1997	Qualified (QAP-3-5)	2.0, 7.0, 8.0	Time to emplace impacted time to retrieve number of waste packages to retrieve
Preliminary MGDS Hazards Analysis, September 1996, B00000000-17171-0200-00130, REV 00	Qualified (QAP-3-9)	6.0, 7.0	Used to identify internal and external events
DOE Position on Retrieval and Retrieval for a Geological Repository, DOE 1986	Qualified ¹ (NRC Review & Comment)	Ex. Sum., 3.0, 8.0	Supported requirements and recommendations and recommended strategy
Site Characterization Plan (SCP), DOE/RW-0199, December 1998	Qualified (Peer Review)	Ex. Sum., 3.0, 8.0	Used as point of departure from current strategy
Engineered Barrier System Performance Requirements Systems Study Report, B00000000-17171-5705-000001, REV 01, November 1996	Qualified (QAP-3-5)	7.0, 8.0	Contingency to add backfill if required through preclosure period
MGDS Design-Viability Assessment (in-process)	Unqualified ¹	7.0, 8.0	Provided a basis to state how retrieval would be accomplished; used in scenario development
Retrieval Strategy Report for a High-Level Waste Repository, SAND87-2777, 1991	Unqualified ¹	Ex. Sum., 3.0, 8.0	Used to support recommendations
NUREG-0804 Staff Analysis of Public Comments on Proposed Rule 10 CFR Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories" 1983	Qualified	2.0, 7.0, 8.0	Used to support recommended requirements and recommendations
Retrievability Period Systems Study Report, 1994, B00000000-01717-5705-00017, REV 00	Unqualified ¹	3.0, 8.0	Used for schedule durations
Retrieval Conditions Evaluation Report, BCA000000-01717-5705-00003, REV 00, September 1995	Qualified (QAP-3-5)	6.0, 7.0	Used for ground support and radiation levels
Advanced Conceptual Design Report, March 1996	Unqualified ¹	7.0	Used in scenario development
Draft NRC Regulatory Guide, 3003 Format and Content for the License Application for the High-Level Waste Repository	Unqualified ¹	4.0, 7.0, 8.0	Used to create license assessment content and level of detail for this report
Design Analysis-Emplacement Scale Thermal Evaluations of Large and Small WP Designs, 1995 (B00000000-01717-0200-00009 REV 00)	Qualified (QAP-3-9)	6.0, 7.0	Used to ground support stability-supports ability to retrieve from emplacement drift-addresses expected conditions

Table 2-1. Inputs Used in Development of Report (continued)

Inputs	Input Classification (Qualified or Unqualified)	Section(s) of Report Input Used	Impact of Data on Outputs
The Nuclear Waste Policy Act; as amended DOE/RW-043B, March 1994, Sections 121 and 122	Qualified	5.0, Ex. Summary, 7.0	Addresses scenario development -reasons why retrievability is reviewed. Supports development of process flow diagram.
Controlled Design Assumption Document B00000000-01717-4600-0032, REV 4, October 1996			
Key 010	Unqualified ¹	7.0	No impact - scenario development
Key 011	Unqualified ¹	7.0	No impact - scenario development
Key 013	Unqualified ¹	7.0	Controlled scenario development-remote operations and equipment
Key 031	Unqualified ¹	6.2.6, 7.0	Supports waste package expected condition
Key 037	Unqualified ¹	6.2.6, 7.0	Supports waste package expected condition
Key 038	Unqualified ¹	6.2.6, 7.0	Supports waste package expected condition
Key 046	Unqualified ¹	7.0	Scenario 7 developed for defense in depth and output for Figure 8-1
Key 047	Unqualified ¹	7.0	Supports retrieval scenarios-surface facilities
Key 055	Unqualified ¹	8.0	Did not endorse-see recommendation
Key 058	Unqualified ¹	8.0	Supports land withdrawn recommendation
Key 064	Unqualified ¹	6.2.1	Supported seismic evaluation-rockfalls have been addressed
Key 065	Unqualified ¹	8.1.2.2	Supports recommendation
Key 066	Unqualified ¹	7.0	Supports retrieval scenario development. No impact on outcome
Key 067	Unqualified ¹	7.0	Supports retrieval scenario development. No impact on outcome.
Key 068	Unqualified ¹	7.0	Supports retrieval scenario development. No impact on outcome.

Table 2-1. Inputs Used in Development of Report (continued)

Inputs	Input Classification (Qualified or Unqualified)	Section(s) of Report Input Used	Impact of Data on Outputs
Key 070	Unqualified ¹	7.0	Supports retrieval scenario development. No impact on outcome.
Key 072	Unqualified ¹	7.0	Supports retrieval scenario development. No impact on outcome.
Code of Federal Regulations, 10 CFR Part 60, December 1996			
Section 60.2	Qualified	3.0, 5.0, 6.0, 7.0, Glossary	Used definitions in glossary
Section 60.21	Qualified	4.0, 7.0	Supported temporary storage recommended requirement
Section 60.46	Qualified	4.0, 5.0, 7.0	Licensing assessment
Section 60.102	Qualified	8.0	Supported licensing assessment
Section 60.111	Qualified	7.0, 8.0	50 year retrievability period of retrieval schedule
Section 60.131	Qualified	7.7.15	Supports waste package constraint for storage capability
Section 60.132	Qualified	7.0	Supports need for temporary storage contingency
Section 60.133	Qualified	7.0	Used in development of retrieval scenarios
Section 60.135	Qualified	6.2.6, 7.0	Supports waste package containment for retrieval

Table 2-1. Inputs Used in Development of Report (continued)

Inputs	Input Classification (Qualified or Unqualified)	Section(s) of Report Input Used	Impact of Data on Outputs
MGDS RD, April 1997, Revision 3 B00000000-01717-1708-0008*			
Section 2.5.G	Qualified	7.0	Used in potential scenario development and land withdrawn recommendation
Section 3.2.G	Qualified	7.7.3	Used in scenario-breached waste package
Section 3.2.H	Unqualified ¹	7.0, 8.0	This report substantiated this requirement by providing a basis
Section 3.2.I	Qualified	6.2.4, 7.0	Used for scenario development and expected retrieval environment
Section 3.2.J	Unqualified ¹	7.0, 8.0	This report substantiated this requirement by providing a basis
Section 3.3.I	Qualified	7.7.7, 8.0	Used for scenario 7 development and schedule development
NUREG-1318, Technical Position on Items and Activities in the High-Level Waste Geologic Repository Program Subject to Quality Assurance Requirements, April 1988 (Sections 4.2.(d), 5.2.(d))	Qualified	7.0, 8.0	Supports recommended strategy
NUREG/CR-3489	Qualified (Peer Review)	3, Table 3-1	Document assessed and determined not applicable to this report
SAND84-2242	Qualified (Peer Review)	3, Table 3-1	Document assessed and determined to be duplicative of SCP
NUREG/CR-5385	Qualified (Peer Review)	3, Table 3-1	Document assessed and determined not applicable to this report

Table 2-1. Inputs Used in Development of Report (continued)

Inputs	Input Classification (Qualified or Unqualified)	Section(s) of Report Input Used	Impact of Data on Outputs
SAND87-2777	Qualified (Peer Review)	3, Table 3-1	Document assessed and determined to be duplicate to DOE Position 1986
SCP-CDR SAND84-2641 (SNL 1987)	Qualified (Peer Review)	3, Table 3-1	Document assessed and determined to be duplicative of SCP
Nevada Potential Repository Preliminary Transportation Strategy Study 2	Unqualified ¹	7.0, 8.0	Used for developing position on land withdrawal until repository closure
Assumption A	Unqualified ¹	7.0	Used for development of preparation period for retrieval schedules
Assumption B	Unqualified ¹	7.0	Output for Figure 7-1.

¹This input has been identified as unqualified. The portions of this input which were used to arrive at the outputs of this report have no direct impact to outputs associated with nuclear safety or waste isolation; therefore, outputs using this input are considered qualified.

*This document was developed and reviewed under Quality Assurance Procedure, QAP-3-5 and was approved on April 10, 1997. The document has been submitted to YMSCO for acceptance and for Level II baseline control.

Performance Confirmation Program Modifications--...common sense dictates that the option to modify or to initiate a new phase of a performance confirmation program late in the operational phase should be maintained to be able to respond to variability in the host rock or to technological developments which lead to engineering changes. The capacity to keep the repository open for 10 to 15 years after the operational phase if needed is therefore advisable.

Retrieval Schedule--...we consider a reasonable schedule (retrieval) to be one in which the waste could be retrieved in the same overall time that the repository was constructed and wastes were emplaced...if, as a result of years of data collection and analysis, a decision is made that the site or design is not adequate to isolate the wastes for the long term, corrective actions could be taken. These actions could be performed over a period of years or decades without imminent health and safety hazard.

Subsurface Design--...we do not want the underground facility design to be such that retrieval would be so expensive or difficult or entail such high occupational exposures that the option is foreclosed and needed corrective actions could not be taken...Design of the repository for retrievability of the waste assures that it will remain practical to take corrective actions should they become necessary.

Subsurface Maintenance--Maintaining the option to retrieve the wastes does not entail keeping the mined areas open, although DOE may choose to do so in some geologic media...Tradeoff between keeping the rooms (emplacement drifts) open and ventilated, backfilling, and areal heat densities are design options that the DOE must consider in meeting this requirement.

Accelerated Retrieval Schedule--We can foresee no situation where protection of the public health and safety would require the waste to be removed very rapidly.

- **Assumption from NUREG 1318, *Technical Position on Items and Activities in the High-Level Waste Geologic Repository Program Subject to Quality Assurance*, Sections 4.2 (d) and 5.2 (d):**

In the event that retrieval is necessary, DOE should, at that time, analyze the proposed retrieval process to identify additional items that are important to safety. These additional items should also be covered under the Subpart G Quality Assurance (QA) Program. If retrieval is found to be necessary, analysis of retrieval operations need to be conducted by DOE, at that time, to identify Q-List items.

- **Assumption A**

If the order to retrieve has been given by the Department of Energy (DOE) and has received concurrence by the NRC prior to retrieval, a planning period is required. This planning period is part of the total time to retrieve waste (see Section 7).

- **Assumption B**

For retrieval schedule development, activities beyond the point at which waste is at the surface are not within the scope of the MGDS. See Figure 7-1.

- **Assumption from Table 2-2**

Table 2-2 shows Commercial Spent Nuclear Fuel (CSNF) and High-Level Waste/Defense Spent Nuclear Fuel (HLW/DSNF) (Co-disposal) Combined Waste Stream-Summary. Derived from *Waste Quantity, Mix and Throughput Study Report* (CRWMS M&O 1997a).

Table 2-2. Baseline Commercial Spent Nuclear Fuel (CSNF) and High-Level Waste/Defense Spent Nuclear Fuel (HLW/DSNF) (Co-disposal) Combined Waste Stream-Summary. (CRWMS M&O 1997b)

Disposal Containers								
Year	BWR 44	BWR 24	PWR 21	PWR 12	PWR ST	HLW	DSNF	Total
2010	14	0	21	2	0	0	1	38
2011	37	0	36	2	0	0	1	76
2012	58	0	75	9	7	0	3	152
2013	75	0	132	23	15	0	6	251
2014	133	0	202	30	0	0	8	373
2015	123	0	206	22	12	100	40	503
2016	137	0	191	32	8	100	56	524
2017	122	0	198	32	15	95	33	495
2018	135	0	189	31	12	95	65	527
2019	123	0	195	35	13	95	49	510
2020	130	0	194	36	8	95	50	513
2021	128	5	193	29	8	95	50	508
2022	117	15	195	38	11	95	31	502
2023	123	1	204	25	9	95	31	488
2024	127	8	196	26	10	95	36	498
2025	150	12	179	26	10	95	41	513
2026	188	2	191	0	0	95	35	511
2027	164	1	204	0	0	95	31	495
2028	152	1	203	0	0	95	31	482
2029	137	1	212	0	0	95	51	496
2030	139	2	222	0	0	95	58	516
2031	116	1	233	0	0	94	58	502
2032	116	0	230	0	14	25	71	456
2033	82	0	138	0	3	14	47	284
2034								0
2035								0
2036								0
2037								0
2038								0
2039								0
2040								0
2041								0
Total	2826	49	4239	398	155	1663	883	10213
Mean**	135	4	202	30	11	96	46	502
Median**	129	2	197	31	10	95	49	503
Std Dev**	19	5	14	5	2	2	13	16
Min	14	0	21	0	0	0	1	38
Max	188	15	233	38	15	100	71	527

*These are included in arrivals, but not in the waste packages numbers

**Years before 2015 and rampdowns of categories have been excluded

3. ASSESSMENT OF PAST RETRIEVAL POSITIONS

3.1 DOCUMENTS REVIEWED

The purpose of researching existing documents pertaining to retrievability was to verify that all previously developed retrieval strategies and plans were considered for this latest effort, especially in light of the evolving design of the repository and the waste package.

The Record Information System was searched looking for either "retrieve" or retrievability". This search revealed 131 documents that contained either "retrieve" or "retrievability". This list was reduced to 8 for final consideration in the report.

Figure 3-1 shows the criteria used in the selection of documents for further assessment. Based on the selection criteria process, the following documents, listed chronologically, have been reviewed:

- *Assessment of Retrieval Alternatives for the Geological Disposal of Nuclear Waste*, NUREG/CR-3489, (NRC, 1984)
- *DOE Position on Retrievability and Retrieval for a Geologic Repository*, 1986 (DOE 1986)
- *Retrievability: Strategy for Compliance Demonstration*, SAND84-2242, 1986 (SNL 1986)
- *Site Characterization Plan Conceptual Design Report (SCP-CDR)*, 1987 (SNL 1987)
- *Site Characterization Plan (SCP)*, (OCRWM 1988)
- *Stability of Disposal Rooms During Waste Retrieval*, NUREG/CR-5335, (NRC, 1989)
- *Retrieval Strategy Report*, SAND87-2777, (SNL, 1991a)
- *Retrievability Period Systems Study Report*, 1994 (CRWMS M&O 1994b)

Figure 3-2 provides a document interaction chart of documents dealing with retrievability. The following sections contain a brief description of the reviewed document along with extracts pertinent to the license assessment questions (see Section 4).

3.1.1 Assessment of Retrieval Alternatives for the Geological Disposal of Nuclear Waste (1984)

This report identifies retrieval concerns, which include identifying and locating breached canisters; technology for removing back fill/rock fall by semi-remote, or remote methods; adequacy of ground support system; and adequate ventilation system for personnel and equipment. Major concepts and issues addressed include:

Figure 3-1. Criteria Used in Selection of Documents for Further Assessment

*Work complete in 1984, not issued until 1986

**Work was complete in 1987, not issued until 1991

Figure 3-2. Document Interaction Chart for Retrievability

- The primary method for high-level nuclear waste disposal being placement of canistered high-level wastes in stable, geologic formations deep underground. This method consists of the construction of mined repositories in the geologic formations to store the canisters in boreholes drilled either into the floor or sidewalls of horizontal underground rooms.
- The assessment of alternatives for retrieval of canistered waste packages under varying operational modes, ranging from re-mining for retrieval of an emplaced package to retrieval of several emplaced packages under difficult and severe conditions and environments.
- The review and identification of the range of alternative repository design and operational/retrieval modes. As assessment of the technologies upon which the alternative operational/retrieval modes are based, and the degree to which each relies upon extensions or transfers of these technologies.

The major objective of the report was to allow the Nuclear Regulatory Commission (NRC) to identify, early in the design process, approaches to retrievability that could ultimately prove to be unsatisfactory from a licensing standpoint, as well as to identify sound technical approaches. The concerns and conclusions from this report were to be used by designers and others to provide for the option of waste retrieval and for assessing alternatives to retrieval concepts for the next phases of repository design and pre-licensing processes. However, the design has now evolved to the point where the alternatives presented are no longer valid.

3.1.2 DOE Position on Retrievability and Retrieval for a Geologic Repository (1986)

This document identifies early, pre-SCP (OCRWM 1988) aspects of the DOE position on retrievability (DOE 1986):

- The repository must be designed, constructed, and operated so that, during any time within the established limits, it is possible to retrieve any or all of the emplaced waste.
- The capacity to retrieve the waste, if necessary, must include all waste, regardless of container size or shape, temperature, radiation level, or age.
- The capacity to retrieve must extend to all areas of the repository in which waste is emplaced.
- No act, whether by design or circumstance, shall preclude the possibility of, or the opportunity for, retrieval for the reasons given in this statement of position.
- Retrieval concepts, methods, and nonstandard equipment necessary for the retrieval of any or all of the emplaced waste must be designed and engineered prior to license application, to ensure that the retrieval method will successfully operate and function under adverse underground conditions.
- Retrieval concepts, methods, and nonstandard equipment necessary for the retrieval of any or all of the emplaced waste must be fabricated for mock-up tests during a proof-of-principle demonstration period prior to license application and must be further developed

and tested , as needed, under selected repository conditions during the review of the license application and repository construction.

The DOE position on retrievability identifies the need for proof-of-concept and prototype equipment development. This position paper is identified in other documents which were reviewed for this study. The documents and sections containing these similar requirements are identified below:

- *Site Characterization Plan*, 1988, Volume III, Section 6.2.9.3
- *Site Characterization Plan Conceptual Design Report*, 1987, Volume I, Section 3.2.1

Section 3.5 of the *1986 DOE Position on Retrievability and Retrieval for a Geologic Repository* reads in part as follows:

Retrieval concepts , methods, and nonstandard equipment necessary for the retrieval of any or all of the emplaced waste shall be: (1) designed and engineered, before license application, so that the retrieval method will successfully operate and function under a range of adverse underground conditions; (2) fabricated for mock-up tests during a proof-of-principal demonstration period before the license application; and (3) further developed and tested , if needed, under selected repository conditions during the review of the license application and repository construction. The purpose of these three activities related to the design and demonstration of the retrieval capability is to show that no irretrievable steps will be taken when actual nuclear waste is emplaced underground. Therefore it shall be necessary to substantiate the fact that the retrieval method and equipment can and will operate in the intended and requisite manner.

NOTE: This demonstration of equipment and methods for retrieval while not desirable from a cost and schedule view is required. The retrieval equipment for normal emplacement and normal retrieval will be functionally verified as part of the repository design process. The equipment used to retrieve from abnormal conditions will need to have proof-of principal demonstration before license application with prototype equipment development completed during the license application review period and actual repository construction.

3.1.3 Nevada Nuclear Waste Storage Investigations Project Retrievability: Strategy for Compliance Demonstration (1986)

This document defines the strategy for demonstrating compliance with the retrievability requirement. It includes regulatory requirements, repository and equipment designs, expected conditions, and scenario development methods. The emplacement and retrieval system assumes a repository design consisting of vertical and horizontal emplacement in waste packages smaller than those in the present design. The vertical emplacement concept involves emplacing a single high-level radioactive waste package into a vertical borehole drilled into the floor of the emplacement drift. The horizontal emplacement concept involves emplacing up to 34 waste packages into horizontal boreholes up to 200 m long that are drilled into the sides of the emplacement drifts. The small waste package limits the amount of waste placed in each container. Also, the system provides shielding via crushed tuff shield plug, which allows access to the emplacement drifts for maintenance or for other emplacement operations.

The waste package is transported to the repository horizon via a rubber-tired transporter, which provides the shielding and the subsystems necessary to rotate the waste package to the vertical or to translate to the side for horizontal emplacement in the bore hole. The transporter subsystem, which includes the transporter, auxiliary equipment, and the emplacement dolly, is used for both vertical and horizontal emplacement, as well as retrieval should it be necessary. The retrieval process was envisioned to be the reverse of the emplacement process with three tests to determine if the retrieval would be normal or if some adverse condition had occurred over time which would necessitate additional equipment and procedures. These tests were: (1) assessment of the drift condition, (2) assessment of the bore hole, and (3) during the actual waste package removal assess if some abnormal condition could occur that would effect the removal process.

NOTE: The repository design configuration has changed (OCRWM 1996). The vertical and horizontal emplacement concepts studied in this paper are no longer under consideration. The vertical emplacement concept involved implanting a single high-level radioactive waste package into a vertical borehole drilled into the floor of the emplacement drift. The waste package was then either covered with crushed tuff or a shielded plug. In the horizontal mode up to 34 waste packages would be placed into horizontal boreholes up to 200 m long that are drilled into the sides of the emplacement drifts. The transporter subsystem which includes the transporter, auxiliary equipment, and the emplacement dolly is used for both vertical and horizontal emplacement and retrieval should that option be necessary.

3.1.4 Site Characterization Plan Conceptual Design Report (1987)

This report describes the 1986 repository design as it has evolved from studies conducted since the preparation of the *Nevada Nuclear Waste Storage Investigations Project Preliminary Repository Concepts Report* in 1983. That preliminary concept proposed a repository constructed in a single stage, including a single waste handling building to receive and process spent fuel and high-level waste.

The design described in the *Site Characterization Plan Conceptual Design Report* (SCP-CDR) (SNL 1987) consists of the concurrent construction of two waste handling buildings, the first of which is designed to receive 400 metric tons of uranium (MTU)/year over a three-year period, during which time construction of a full-capacity waste handling building is completed. The repository is designed to receive, prepare, and permit emplacement of the equivalent of 70,000 metric tons of heavy metal, commonly expressed as MTU.

Waste consists of small packages, which are emplaced in vertical and horizontal bore holes underground above the water table and beneath Yucca Mountain. The repository is not backfilled during the preclosure period; ramps and drifts are designed for long-term stability. The retrieval period is 50 years, followed by as many as 34 years of actual retrieval operations.

3.1.5 Site Characterization Plan (1988)

The position on retrievability defined in the 1988 *Site Characterization Plan* (SCP) (OCRWM 1988) assumes a retrievability period of 50 years which was specified in 10 CFR Part 60.111(b). This position requires no special site data for surface storage and no backfill during the preclosure period. As a result of 10 CFR Part 60, the repository must be designed, constructed, operated and maintained to ensure retrieval capability of the emplaced waste. This requirement leads to impacts

on repository design and on the duration of planned operations. Retrieval-related considerations include the selection of the waste emplacement mode, the selection of materials for rock-support systems, and the maintenance requirements for the ramps, shafts, and drifts.

Three important points regarding retrievability are as follows:

- Retrievability is a performance issue which necessitates numerous design constraints.
- Retrieval is considered to be complete when the waste reaches the surface. Temporary storage at the surface and offsite transport after retrieval are not addressed in the SCP since it is unlikely that these activities will require additional site data.
- Since the decision to retrieve will be made as a result of performance confirmation activities or of a DOE decision to recover resources, retrieval is limited to activities intended to maintain the retrieval option and to retrieve the waste.

3.1.6 Stability of Disposal Rooms During Waste Retrieval (1989)

This report addresses structural stability of disposal rooms in a geological repository. It presents the results of a numerical analysis to determine the stability of waste disposal rooms for vertical and horizontal emplacement in boreholes during the period of waste retrieval. Convective cooling of the disposal rooms in preparation for waste retrieval is included in the analysis. Thermal results illustrating the heat transfer response of the rock adjacent to the disposal rooms is presented. Also, mechanical results illustrating the predicted distribution of stress, joint slip, and room deformations for the investigated period of time are documented.

The report assumes that waste retrieval starts 50 years after the initial emplacement of the waste, and that access to and retrieval of the waste containers takes place through the disposal rooms, which are not backfilled. The time frame for retrieval is 50 years, followed by as many as 34 years of actual waste retrieval.

3.1.7 Retrieval Strategy Report for a High-Level Nuclear Waste Repository (1991)

This 1987 report describes a strategy for retrieval of emplaced waste at the potential Yucca Mountain repository in Nevada (SNL 1991a). It includes descriptions of repository and equipment designs; the operations during waste emplacement, post-emplacement, and retrieval; and expected repository conditions (normal and abnormal). Retrieval-related regulations are presented and discussed as a basis for evaluating the design and operations plans. Specifically, the report describes the following:

- Emplacement system
- Repository
- Ventilation system
- Underground repository development and emplacement operations
- Retrieval requirements and design criteria
- Post-emplacement operations
- Repository conditions for retrieval
- Retrieval demonstrations.

The report concludes with discussions of retrieval strategy implementation, which includes determining required equipment and operations demonstrations as well as plans for future work.

NOTE: Since the publication of this report, MGDS design changes have been made (CRWMS M&O, 1996e). The concept of disposal rooms or drifts with vertical or horizontal bore holes and small waste canisters has been replaced with large service drifts and smaller emplacement drifts with center-mounted, large, waste canisters.

3.1.8 Retrieval Period Systems Study Report (1994)

The report summarizes the requirements by legislation and by NRC regulations to provide the capability to retrieve waste for some time after initial emplacement of waste in a geologic repository. Specifically, 10 CFR 60.111(b) requires that the repository "be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated".

The objective of this study (CRWMS M&O 1994b) is to evaluate different retrieval capability time periods in terms of potential advantages and disadvantages and to provide a recommendation regarding the appropriate period to maintain the retrieval option.

Potential performance advantages related to extending the retrievability period include increased confidence in system performance predictions, the ability to recover valuable natural resources contained in the spent nuclear fuel (SNF), and increased public confidence in the repository to isolate waste. These performance advantages must be evaluated against the potential disadvantages of extending the retrievability period.

Three time periods are considered are 50, 100, and 200 years. The 50-year period has been selected because it represents the current NRC position. 100-year period has been included because it is the Proposed Program Approach presented by the DOE to Congress. The 200-year period has been chosen because it sufficiently reflects impacts associated with longer time periods. Each period has been evaluated against repository design options, including thermal loadings, variations to the in-drift emplacement mode and shielded versus unshielded waste packages. The report also evaluates safety, off-normal conditions, schedule, non-technical impacts, retrieval scenarios, retrieval systems, and provides cost analysis of design alternatives. Finally, the report addresses a variation of the caretaker program that has been considered for the extended periods.

The study recommends the retention of the planned 50-year retrievability period rather than an extension to 100 or 200 years since 50 years is sufficient for performance confirmation, is least costly, and entails the least risk. Evaluation of public confidence showed that public debate is based on accessibility for the retrieval of the waste versus preservation of choices for future generations. A second issue is based on the lack of a basic understanding of the performance of the functions of the repository. A third issue is confidence in the capability of man-made systems versus natural systems to isolate waste. Although the need for resource recovery in the future is not well known and therefore exhibits no preference, assumptions can be made regarding equipment replacement scenarios and the nature of the performance confirmation program to allow for extended retrieval periods without incurring significant cost or risk penalties.

3.2 SYNOPSIS OF DOCUMENT REVIEW

As mandated in 10 CFR 60.111(b), the NRC retains the retrievability option until the correction of a performance confirmation program and commission review of the information obtained from such a program. All of the reviewed studies support this requirement. Analysis reveals that the retrievability concept is the ultimate backup position for regulators and the DOE in that, should either the engineered barriers or natural barriers fail, removing the waste and returning it to the surface provides maximum protection of public health and safety, or the environment. Also, the DOE retains the option of recovery of potentially valuable natural resources from the spent nuclear fuel.

In several of the reviewed reports, issues such as proof-of-principle demonstration prior to license application and prototype equipment development during the construction period are major issues because of impacts to cost and schedule. Handling equipment, the locomotives (commercially available), transporter (unique design), and the gantry (unique design), are being designed for large unshielded waste packages. These pieces of equipment will work after mock-up development and training cycles for normal emplacement and normal retrieval operations. For abnormal conditions of retrieval, such as rockfall, failed power system, or failed rail system, special equipment must be designed, constructed, and proven to function under simulated conditions before emplacement of waste. Demonstration of prototype equipment which will be required for abnormal operations will remove any doubt that waste retrieval will be an option if and when it may be required. The equipment that will be required for recovery from abnormal conditions during emplacement operations will also provide for the needs of retrieval, even under adverse conditions, as abnormal emplacement events would require the same equipment.

The current repository design uses large unshielded waste packages, (which may weigh as much as 65.9 mt), containing a large quantity of spent fuel and causing a relatively high heat load, and therefore large thermal stresses on the host rock (CRWMS M&O 1996g). These stresses combined with operational access and performance confirmation requirements are driving the repository design towards a robust ground support system. The need for robust ground support is primarily for operational considerations and not retrievability. (See Section 6.)

3.3 EXISTING STUDY APPLICABILITY CHART

Table 3-1 lists the key points from each of the past studies reviewed and answers the question whether these key points are still applicable given the present repository and waste package design criteria, i.e. large waste package placed in long horizontal drifts on pedestals and not backfilled.

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Table 3-1. Existing Study Applicability Chart

Existing Retrieval Document	Applicable		Existing Retrieval Document	Applicable	
	Yes	No		Yes	No
ASSESSMENT OF RETRIEVAL ALTERNATIVES FOR THE GEOLOGICAL DISPOSAL OF NUCLEAR WASTE, NUREG/CR-3489			SITE CHARACTERIZATION PLAN, 1988		
First Tuff Concept: vertical bore holes, backfilling at permanent closure, rooms open and ventilated.		X	Design waste emplacement envelope to allow access to the waste package throughout the retrievability period for normal and credible abnormal conditions.	X	
Second Tuff Concept: vertical bore holes, backfilling at permanent closure, rooms bulkheaded with only leakage air allowed to enter.		X	Assess the condition of the emplacement envelope and waste package prior to removal as (required)	X	
Third Tuff Concept: vertical bore holes, immediate backfilling and bulkheading, no ventilation in backfilled rooms.		X	Perform corrective actions as required.	X	
Fourth Tuff Concept: horizontal bore holes, backfilling at permanent closure, rooms open and ventilated.		X	Design the waste package and the transporter with the option to remove the waste for normal and credible abnormal conditions.	X	
Fifth Tuff Concept: horizontal bore holes, backfilling at permanent closure, rooms bulkheaded with only leakage air allowed to enter.		X	Verify conditions of equipment and waste package.	X	
Sixth Tuff Concept: horizontal bore holes, immediate backfilling and bulkheading, no ventilation in backfilled rooms.		X	Verify operator training.	X	
DOE POSITION ON RETRIEVABILITY AND RETRIEVAL FOR A GEOLOGIC REPOSITORY, 1986			Develop Site and design data to support retrievability.	X	
Persons responsible for the design and construction of a repository shall bear in mind at all times that the function of the repository is to provide containment and isolation of the waste.	X		Determine that retrieval requirements can be met using reasonably available technology.	X	
The method of retrieval planned for the repository shall anticipate and identify all credible malfunctions or accidents to the emplacement, the engineered barriers, and the host rock that could affect retrievability.	X		STABILITY OF DISPOSAL ROOMS DURING WASTE RETRIEVAL, NUREG/CR-5335, 1989		
The method of retrieval shall be designed to operate, if required, under abnormal conditions such as loss of containment through mechanical breach, disoriented emplacement boreholes (emplacement drifts), sudden water inflow, release of radionuclides or other circumstances that could affect the safety and mechanical removal of the emplaced waste.	X		From the results of the analysis a set of conclusions can be made which apply to both disposal rooms (i.e., vertical or horizontal waste emplacement) investigated, unless specifically stated otherwise.		X
The waste package shall be designed and fabricated to allow retrieval of the waste from the emplacement configuration.	X		No new fractures are created from excessive shear stresses in the rock around the disposal room as a result of room excavation, 50 years of thermomechanical rock response, or 120 days of convective cooling in preparation for waste retrieval. Fracturing may occur around the boreholes, but this could not be examined in this study.		X
The physical act of retrieval shall be designed to minimize occupational health and safety hazards due to radiation exposure.	X		Slip along pre-existing vertical joints in the rock is predicted around the disposal room as a result of room excavation.		X
The design of all methods of retrieval shall be based on and employ levels of technology determined to be reasonably available at the time of license application.	X		Fifty (50) years of thermomechanical rock response has little effect on the development of joint slip beyond that predicted from room excavation alone.		X
The design of the retrieval method and retrieval equipment for the repository shall anticipate the deterioration and ambient emplacement conditions by the time retrieval may become necessary.	X		Assuming that the rock can be classified as "fair to good" according to the geomechanical classification system, only light ground support such as rockbolts, wire mesh, or shotcrete is estimated to be necessary to maintain rock stability.		X
The ventilation of the underground facilities shall be designed and constructed for all construction and operation demands, including mining, emplacement, retrieval and performance confirmation testing.	X		After 50 years, the maximum predicted rock surface temperature of the disposal room for horizontal waste emplacement is 60° C, which exceeds the allowable maximum of 50° C according to the design criterion.		X
The facilities that must provide additional ventilation air needed for retrieval need not be constructed when the repository is constructed.	X		The maximum predicted deformation of the disposal room is of the order of 0.005 m, which is substantially below the maximum of 0.152 m, according to the design criterion.		X
The design and layout of the repository operations area, surface and underground, shall be planned so as not to preclude the possibility of constructing facilities for temporary storage at a later time, if needed.	X		The radius of curvature of the axis of the horizontal borehole is significantly larger than the minimum of 34 m allowed by the design criterion.		X
Retrieval concepts, methods, and nonstandard equipment necessary for the retrieval of any or all of the emplaced waste shall be: (1) designed and engineered, before license application, so that the retrieval method will successfully operate and function under a range of adverse underground conditions; (2) fabricated for mock-up tests during a proof-of-principle demonstration period before the license application; and (3) further developed and tested if needed, under selected repository conditions during the review of the license application and repository construction.		X	RETRIEVAL STRATEGY REPORT FOR A HIGH-LEVEL NUCLEAR WASTE REPOSITORY, SAND87-2777, 1991		
The repository design submitted at the time of license application shall identify the specific means by which retrieval can be accomplished under a wide range of circumstances.	X		The inclusion of the waste retrieval capability shall not affect or unnecessarily complicate the repository design such that the primary function of the repository, containment and isolation of waste, is compromised.	X	
The planned method of retrieval shall include an analysis of retrieval methods that can be called upon to function under normal and abnormal geotechnical conditions.	X		The retrieval method shall anticipate both normal and abnormal conditions.	X	
The design shall specify the sequence of retrieval events e.g., Rock cooling followed by re-mining, followed by waste container verification, etc.	X		The design of the waste container shall consider the potential need for waste retrieval.	X	
The planning and design of a retrieval method may require nonstandard mechanical equipment that is not currently available or in use under similar circumstances, therefore a proof-of-principal demonstration is required.	X		The design of the retrieval method shall minimize occupational health and safety hazards.	X	
The proof-of-principal demonstration shall be completed and documented before license application is made to the NRC.		X	The design for waste retrieval capability shall employ levels of technology that are determined to be reasonably available at the time of license application.	X	
A period of time after license application (LA), before and during construction of the repository, will be available to construct and demonstrate the equipment and methods which more closely resemble those designed for use at a time when retrievability may be necessary.	X		The design for waste retrieval capability shall anticipate the potential for deterioration and degradation of geotechnical conditions.	X	
In the event partial retrieval is required, the method selected for retrieval must not adversely affect or disturb the adjacent areas of the repository and their natural or engineered barriers.	X		Additional ventilation requirements for retrieval will be designed at the same time as the repository.	X	
The placement of backfill material before the permanent closure of the repository is an option available to the repository operations manager, with appropriate approval.	X		Additional ventilation facilities and equipment for retrieval need not be constructed at the time of repository construction.	X	
No ongoing monitoring of individual waste packages shall be required for the maintenance of the retrieval capability over and above that required for performance confirmation as identified in 10 CFR Part 60.	X		The design of the repository operations area will not preclude the ability to construct temporary storage facilities at a later time if needed.	X	
The repository shall not be operated or maintained in a manner such that any areas of the repository become permanently inaccessible during the period of retrievability if those areas of the repository are necessary for the retrieval of any or all of the emplaced waste.	X		Retrieval concepts, methods, and nonstandard equipment will be: (a) Designed before license application to function under both normal and abnormal conditions; (b) Tested in mock-up environments during proof-of-principal demonstrations; and (c) Tested further under selected repository conditions during prototypical equipment development (if needed).		X
NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS PROJECT RETRIEVABILITY: STRATEGY FOR COMPLIANCE DEMONSTRATION, SAND84-2242			Proof-of-principal demonstrations will be completed and documented before submission of the license application to the NRC.		X
Develop facility designs which allow for retrieval of emplaced waste.	X		Prototypical equipment development may continue, if needed, until the license to receive and possess is granted by the NRC.	X	
Develop equipment designs that ensure waste-retrieval capability.	X		RETRIEVABILITY PERIOD SYSTEMS STUDY REPORT, 1994		
Demonstrate the ability of the equipment to perform waste-retrieval operations.	X		50 year retrievability period is sufficient for the performance confirmation program, least costly, and provides for the least safety risk.	X	
Develop operational activities in support of compliance demonstration.	X				
Develop scenarios for retrieval under standard and adverse conditions.	X				
Conduct on going supportive studies.	X				
Develop and conduct a quality assurance program.	X				
SITE CHARACTERIZATION PLAN CONCEPTUAL DESIGN REPORT SCP-CDR, 1987					
Describes normal and off-normal retrieval conditions. Normal conditions include continued usability of the drifts, ramps, and ventilation system, and acceptable air quality, radiation levels, and borehole and container conditions. Off-normal conditions have a lower probability of occurrence than do normal conditions and will likely necessitate the use of nonstandard equipment and procedures.	X				
Because retrieval operations are a planned contingency, the facilities and equipment needed to accomplish full retrieval will not be constructed during initial construction of the repository.	X				
The repository is being designed so that the retrievability requirement will not compromise the safety of the repository or its ability to isolate the waste.	X				
The design will include the capability of retrieval under off-normal conditions and will be based on technology that is reasonably available at the time of licensing.	X				
Facilities and equipment needed for retrieval, will be verified by a proof-of-principle demonstration before license application and with phototype equipment development the later stages of design and construction.		X			

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4. COMPLIANCE AND LICENSING ASSESSMENT

Based upon Nuclear Regulatory Commission (NRC) guidance contained in Draft Regulatory Guide 3003, *Format and Content for the License Application for the High-Level Waste Repository*, the following 21 questions were derived to be answered, to the extent possible, by this study. These questions have provided guidance in determining the required level of detail necessary for developing the License Application. Subsequent sections of this report will address these questions.

4.1 DESIGN

1. How is the Geological Repository Operations Area (GROA) designed to preserve the option of waste retrieval throughout the emplacement period and, thereafter, until the completion of a performance confirmation program and NRC review of the information obtained from such a program?
2. What are the design bases and details of the retrieval plans and procedures to locate, access, retrieve, and transport waste packages through the underground facility and up the ramp to the appropriate surface facilities? Include a general description of plans for retrieval and an alternative storage site in the case that Yucca Mountain were found to be unsuitable.
3. What provisions are provided for retrieval for the portions of the underground facility, such as the openings and backfill materials, that are considered parts of the engineered barrier system?
4. Can the waste be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement is initiated?
5. What is the capability for retrieval for the backfill materials used in the emplacement drifts and other drifts such as mains or submains?
6. How do the ventilation systems provide air cooling for retrieval operations?
7. What are the ground support systems and the ventilation system requirements, including the drift wall temperature, drift air temperatures before cooling, capacity of refrigeration plant, quantity of air needed, and number of cooling days needed before personnel and retrieval machinery can enter?
8. How do the excavation and ground support systems respond under thermal loading and retrieval conditions?
9. Does the Hot Cell (waste-handling system, buildings, and equipment) have special features, systems, or special handling techniques that are important to waste retrieval operations?

10. How do the instrumentation and control systems monitor and control the behavior of equipment or systems important to retrievability?
11. How does the retrieval system include shielding and what is the sequence of retrieval operations under normal and off-normal conditions? Include the impact of categories 1 and 2 Design Basis Events (DBEs) during retrievability.
12. What is the basis for and analysis of the approaches used to identify structures, systems, and components important to retrievability?
13. What structures, systems, and components in the underground facility (including shafts and ramps) have been identified as important to retrievability?

4.2 RADIOLOGICAL

14. What are the radiological designs of the surface and underground physical facilities in the GROA that will permit safe handling and storage of radioactive wastes during retrieval? Include the radiological safety features in the design that show compliance with 10 CFR Part 20.
15. What are the radiological safety features in the designs for retrieval that provide ALARA design considerations?
16. What are the projected concentrations and the expected estimated intakes of radionuclides to workers in restricted areas until permanent closure as a result of retrieval?
17. What are the measures to be taken to maintain the radiological safety of workers in the underground facility, including measures to be taken to minimize potential levels of radioactive contamination, during retrieval for normal operations, anticipated operational occurrences, and accident conditions?
18. What are the projected radiation exposures to workers and to members of the public from retrieval during normal operations, anticipated operational occurrences, and accident conditions that are expected to prevail until permanent closure?

4.3 CRITICALITY

19. How do all systems for retrieval of radioactive waste ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety?

4.4 MAINTENANCE

20. What are the maintenance plans and schedules for all surface facilities, shafts and ramps, and underground facilities important to retrievability?

4.5 PROCEDURE DEVELOPMENT

21. What are the operating controls and limits for a repository important to retrievability?

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5. CONDITIONS REQUIRING RETRIEVAL

The issue of retrievability is addressed in sections 121 and 122 of the *Nuclear Waste Policy Act (NWPA)*, as Amended (NWPA 1987). Section 121 requires the Nuclear Regulatory Commission (NRC) to issue technical criteria providing for use of a system of multiple barriers in the design of the repository and such restrictions on the retrievability of waste as NRC deems appropriate. Section 122 allows the Department of Energy (DOE) to retrieve waste due to any reason pertaining to public health and safety or the environment or for the purpose of permitting the recovery of the economically valuable contents of the spent fuel. The period of retrievability is specified by the DOE at the time of design of the repository which is subject to approval or disapproval by the NRC as part of the construction authorization process.

The NRC adapted the system of multiple barriers by adopting the defense-in-depth approach of prescribing minimum performance standards for each of the major elements of the repository as reflected in the subsystem performance requirements in 10 CFR Part 60.113. Since the performance of the repository is based on a system of multiple barriers that includes both engineered and natural barriers, diminished performance of a natural barrier will not by itself cause the repository to fail to meet the overall system performance objective. In 10 CFR Part 60.113(b), the NRC has provided a requirement which allows flexibility to the applicant by permitting adjustment, on a case-by-case basis of the performance objectives related to a different radionuclide release rate or pre-waste emplacement ground water travel time. Any changes to these regulations will be considered and included in future retrieval studies.

The NRC or the DOE can order the permanent retrieval of any or all of the emplaced waste for reasons related to (1) public health and safety and the environment, ordered by the DOE with the concurrence of the NRC, or (2) the recovery of resources, ordered by DOE. Removal for any other reason, whether temporary or permanent, is not subject to the conditions, criteria, and requirements defined for retrieval in NRC regulations. All other operations in which the emplaced waste is moved, relocated, or transported to another area of the repository for reasons other than those stated above are the responsibility of normal repository operations. In any case, initiation of retrieval is an extraordinary event incurring great cost and effort.

5.1 PUBLIC HEALTH AND SAFETY AND THE ENVIRONMENT

The single reason the NRC may require the retrieval of some or all of the emplaced waste is evidence that the health and safety of the public will otherwise be adversely affected by the emplaced waste (10 CFR Part 60, *Statements of Consideration, Retrievability*, 1996). If the NRC decides that the geologic repository isolation system as planned and implemented will not meet the performance standard and objectives governing the disposal of the waste, it has the authority to require retrieval. The 1986 DOE position on retrievability considers the requirement of retrieval "... for any reason pertaining to...the environment..." (the Nuclear Waste Policy Act of 1982, Section 122) to be one and the same with public health and safety. The effects on the environment would be the same as the effects on public health and safety.

5.2 RESOURCE RECOVERY AND ECONOMICS

The permanent disposal of spent nuclear fuel (SNF) will prevent access to the potentially useful isotopes and metals of potential strategic or energy value contained in the SNF. If the DOE elects to recover any or all of the waste inventory prior to permanent closure, this recovery will be accomplished under DOE authority. Such action would be taken in full compliance with the *Nuclear Waste Policy Act, as Amended* and 10 CFR Part 60.

5.3 DISTINCTION BETWEEN WASTE PACKAGE MOVEMENT AND RETRIEVAL

The 10 CFR Part 60, *Statements of Consideration*, stated that some commenters on the proposed regulation suggested that the regulation specify the conditions requiring initiation of retrieval operations. The NRC countered that such provisions are not needed in the regulation; retrieval is required if the NRC no longer has reasonable assurance that the overall system performance objective is being met, a situation that could exist for various reasons. The NRC intends to retain the flexibility to take into account all relevant factors; the agency requires the ability to maintain its discretion, which would be limited by specifying in advance the particular circumstances necessitating waste retrieval.

As mentioned in Section 3, the *DOE Position on Retrievability and Retrieval for a Geologic Repository* (DOE 1986) identified a distinction between retrieval and waste package movement, and identified categories that are not considered to be retrieval categories. The following list identifies the distinction between waste package movement and retrieval categories.

5.3.1 Reasons for Waste Package Movement (Controlled by Repository Operations)

The reasons for waste package movement are as follows:

- Thermal Loading Balance
- Emplacement Drift Maintenance
- Performance Confirmation (Waste Package Sampling)
- Process/Material Deficiency (Waste Package Rework-Corrective Action)

5.3.2 Reasons for Retrieval (Mandated by Nuclear Waste Policy Act, as Amended)

The reasons for retrieval are as follows:

- Recovery of Resources (SNF Only)
- Public Health, Safety, and Environment
 - Failure of Total System Performance
 - Poor Performance of the Engineered Barrier (Waste Package)

6. EXPECTED RETRIEVAL ENVIRONMENT

This section discusses the different repository subsurface environments in order to develop the conditions under which retrieval may have to be performed. These conditions can be categorized as either normal or abnormal. Normal conditions are considered to be those conditions under which the retrieval process can be performed using standard equipment and procedures, essentially the same equipment used for waste emplacement. Abnormal conditions are considered to be those conditions under which the retrieval process must be performed using nonstandard equipment and processes.

6.1 NORMAL RETRIEVAL ENVIRONMENT

A normal retrieval environment can be characterized in terms of the condition of the systems, structures and components (SSCs) which make up the subsurface facility and the expected temperature and radiation levels in the emplacement drifts. Under a normal retrieval environment, all SSCs are capable of performing their intended functions such as providing waste confinement, ground support, ventilation, and equipment access to the emplaced waste. Air quality, drift temperatures, and radiation levels are within the design limits of the standard equipment planned for a normal retrieval.

Retrieval under a normal environment can occur for a number of reasons, all of which have resulted in no impacts to the SSCs or the conditions under which they must perform their functions during the period of retrievability.

6.2 ABNORMAL RETRIEVAL ENVIRONMENT

An abnormal retrieval environment results from the presence of one or more abnormal conditions prior to initiation of retrieval. These abnormal conditions can be the result of an external event or an unpredicted process occurring in a natural or engineered barrier which can impact the ability to perform a normal retrieval. Specialized equipment will be required to handle the specific abnormality in order to retrieve the waste. Events and resultant abnormal conditions are discussed in the following sections and will be addressed in more detail in Section 7. Section 7 also identifies the types of design basis events which may occur during retrieval under both a normal or abnormal retrieval environment.

6.2.1 Seismic Activity

Seismic activity could cause emplacement drift or access drift rock fall, infrastructure damage and impede retrievability.

However, the likelihood of emplacement-drift-damage by seismic ground motion or fault displacement during the proposed 100-year, preclosure design lifetime of the emplacement drifts is minimal, based on *Seismic Design Inputs for the Exploratory Studies Facility at Yucca Mountain* (CRWMS M&O 1994a). The 1994 study recommends that fault displacement not be considered in the design of the Exploratory Studies Facility (ESF) because of low faulting recurrence rates.

The largest and most active fault that will be crossed by a repository underground opening is the Bow Ridge fault, which is crossed by the north ramp. Total displacement per event on the Bow Ridge fault is estimated to range from 11 to 28 cm, and the annual probability of surface faulting is estimated at 1×10^{-4} to 1×10^{-5} per year, as much as approximately one chance in a hundred of a modest faulting event in the north ramp during the preclosure period. The north ramp crosses the Bow Ridge fault near the north portal, far from the proposed waste emplacement area.

The south ramp and main access drift will also intersect the Ghost Dance fault. Current evidence is equivocal as to whether the Ghost Dance fault was active in the Quaternary Period, the period within the last 2 million years. Based on an elicitation of interpretations by Geomatrix Consultants (1993), the aggregate assessment of the likelihood that the Ghost Dance is an active fault is 0.44, the most likely range of displacement values per event is from 0.5 to 4 cm, and the annual probability of a surface-rupturing event ranges from 1.0×10^{-5} to 3.3×10^{-6} (CRWMS M&O 1994a). Even at the higher end of this range of probabilities, the probability of not seeing a surface-rupturing event in 150 years is 99.85 percent, assuming a Poisson temporal occurrence distribution. Furthermore, completed trenching studies suggest that the Ghost Dance fault has had little, if any, displacement during the Quaternary (USGS 1996). Consequently, it is expected that current studies will show a result of a smaller aggregate estimated probability that the fault is active and a lower faulting hazard estimate. In any case, no waste is planned for emplacement across the Ghost Dance fault.

The probability of faulting in waste-emplacement areas west of the Ghost Dance fault is even less. The small, secondary faults in the waste emplacement area may not have moved during the Quaternary, but the presence or absence of Quaternary activity cannot be demonstrated for most of them. Assuming that these faults are active, the small amount of cumulative displacement in the Tiva Canyon Member suggests that single-event displacements would be on the order of 1 cm or less (CRWMS M&O 1994a). The annual probability of an event occurring on one of these secondary faults likely is less than the probability of an event on the Ghost Dance fault since secondary faulting would probably not occur every time there is primary faulting. The probability of secondary faulting might, therefore, be in the range of 5×10^{-6} to 1×10^{-6} (CRWMS M&O 1994a). The higher end of this probability range corresponds to a probability of 99.92 percent of non-occurrence in 150 years. Probabilistic ground motion hazard has been summarized in Table 6-1.

Table 6-1. Estimated Probabilistic Ground Motion Hazard

Hazard Level--Annual Probability of Being Exceeded	2×10^{-3}	1×10^{-3}	5×10^{-4}	1×10^{-4}
Peak Horizontal Acceleration (g)	0.19	0.27	0.37	0.66
Peak Horizontal Velocity (cm/s)	11	16	23	45

The *Seismic Design Inputs for the Exploratory Studies Facility at Yucca Mountain* states that vertical ground motions should be assumed to be equal to horizontal ground motions at an exceedance probability of 2×10^{-3} , and that an assessment of vertical motions at lower probabilities was not made (CRWMS M&O 1994a). However, vertical and horizontal peak ground motion values can be assumed to be also equal at the lower probabilities.

The above ground motion values are defined at the ground surface and must be reduced for application at depth. Based on conservative analyses, Table 6-2 shows the following reduction factors recommended (CRWMS M&O1994a).

Table 6-2. Reduction Factors for Above Ground Motion Values

Depth (m)	Peak Velocity (cm/s)		Peak Acceleration (g)	
	Horizontal	Vertical	Horizontal	Vertical
0-100	1.00	1.00	1.00	1.00
100-200	0.70	0.80	0.60	0.70
200-400	0.60	0.70	0.50	0.60
>400	0.55	0.60	0.50	0.50

6.2.2 Ground Support

Determination of drift closure, rock mass yield, and joint displacement, have been addressed in M&O documents: *Thermomechanical Analyses* and *Repository Ground Control Evaluation*. Results of these studies, which focused mainly on emplacement drift design and considerations for pillar stability, subsidence, and loads on ground support elements, provide a basis for a preliminary assessment of probable ground behavior and ground support conditions during retrieval. Other studies are in progress that address preclosure near field emplacement drift environments and maintenance requirements for ground support systems. The impacts of ground conditions on retrieval have been addressed in the M&O document: *Retrieval Conditions Evaluation*, (M&O 1995c). This report assessed the subsurface conditions likely to be present at the time when retrieval could be required and concluded the following:

- With proper ground support, ground conditions will remain stable during the retrievability period
- Permanent emplacement drift fixtures, including ground support, should be in usable condition
- Non-emplacement subsurface areas, maintained as necessary, are able to support retrieval operations.

6.2.2.1 Normal Ground Behavior

Anticipated ground behavior for unsupported openings prior to thermal loading is primarily characterized by relatively shallow loosening of rock at the crown and possible slabbing at the sidewalls. High thermal loading generates high horizontal stress, which may result in spalling and slabbing at the crown and invert, but overall the depth of disturbance of the rock mass around the opening is relatively shallow. Required support loads, i.e., internal pressure provided by ground

support to counteract loosening and rock fall, are expected to be low to moderate (CRWMS M&O 1995c).

6.2.2.2 Abnormal Ground Conditions

It is assumed that emplacement drifts will be stabilized by appropriate ground reinforcement or treatment prior to emplacement of waste packages. Also, some level of maintenance is expected to be conducted following emplacement to sustain ground conditions. However, where adequate support is not present in the drift, mainly because the support system has deteriorated, progressive rock fall and raveling may take place. In these cases a modified, self-stabilizing shape would eventually result. For example, a typical altered drift cross section in jointed rock is that of a pointed arch, often approximated as a triangle. Material from such a failed area could block the drift, depending on local rock characteristics. Highly fractured areas, such as might occur in a fault zone, could result in a greater amount of fallen material (CRWMS M&O 1995c).

In addition, the following groundwater conditions could aggravate ground control and complicate retrieval:

- Persistent seepage of groundwater, perched source, percolation through fault zone, other
- Introduced water from other parts of repository due to failed distribution system or fire fighting (although emplacement drifts are protected from gravity in-flow by the repository configuration)(CRWMS M&O 1995c).

6.2.2.3 Retrieval Issues with Respect to Ground Support

The requirements for durability for ground support systems imposed by the current *Mined Geologic Disposal System Requirements Document* (CRWMS M&O 1997b) can be met by implementing a robust design with reasonably available technology. The option to maintain the ability to retrieve emplaced waste while mandated by 10 CFR Part 60 does not drive repository ground support design but is addressed incidentally by virtue of satisfying the requirements imposed by the issues of waste isolation, repository constructability, ground support durability/demands for normal and systematic waste emplacement and the need to complete performance confirmation.

With any ground support system, even a robust system, some amount of deterioration of the support system and rock fall may occur. The potential for limited opening maintenance is anticipated in the repository system. Maintenance should be defined to include the potential for remediation of limited ground support failure that could be required to allow retrieval. Life cycle cost analysis should be performed to assess the tradeoffs inherent in the selection of ground support systems for robustness and the costs associated with normal and remedial maintenance of support systems. These studies should establish goals for ground support performance which define allowable limits for remedial maintenance that would be required to implement retrieval based on the ground support options under consideration.

Ground support must be capable of withstanding cooldown from 200°C to 50°C in 30 days. Based on Figure 6-1 and to sustain the retrieval rate in 10 CFR Part 60.111(b). The equipment to be used cannot operate continuously in temperatures in excess of 50°C.

6.2.3 Water In-Flow

The issue is addressed of water in-flow in the emplacement drifts under natural and thermally driven scenarios. Water table rise, perched water, current percolation flux, thermally driven refluxing of condensate and the influence of climate change are considered.

6.2.3.1 Water Table Rise

Although there is evidence for past water table rise of less than 100 m, a numerical model simulated a water table rise up to 130 m when the precipitation was doubled (USGS, 1984). Although small increases in precipitation are possible during the retrievability period, it is unlikely that major changes will occur in the near future. The most likely scenario for transient water table rise is due to tectonic events. In an analysis of the potential for transient water table rise due to tectonics the National Academy of Sciences (1992) concluded that seismic events would produce less than a 20 m rise in the water table. In the fracture coating analysis, evidence suggests that the potential repository horizon has never been saturated (USGS, 1996). Therefore, water table rise into the potential repository horizon is highly unlikely.

6.2.3.2 Perched Water

Since the potential repository horizon is well fractured and has no underlying restrictive unit, natural perched water bodies are unlikely to be encountered.

6.2.3.3 Current Percolation Flux

Recent analysis suggests that percolation flux through the repository horizon may be on the order of 5 to 10 mm/yr on average with some areas exceeding 10 mm/yr (USGS 1996; LBL 1996). Fluxes of these magnitudes will influence the development of a dryout zone around the waste canisters. Differential dryout could cause some areas of the potential repository to receive higher fluxes by redistributing natural percolation and refluxing of water from the near field environment.

6.2.3.4 Thermally Driven Refluxing

Several scenarios evaluated thermally driven refluxing of condensate removed from around the waste package by heat generation. Under sub-boiling conditions, fluxes are estimated to be on the order of 1mm/yr of liquid flux which is considerably lower than estimates of current flux (LLNL 1993). In waste emplacement areas subject to lower heating due to local variations in waste inventory, thermally driven refluxing of condensate may occur and locally increase the percolation flux. (CRWMS M&O 1996g). However, even if such increases occur, they are not expected to be larger, on average, than the ambient expected flow and thus should not be of consequence to the underground waste retrieval operations.

Figure 6-1. Temperature Vs. Time After Emplacement

6.2.4 Temperatures in Emplacement Drifts

The main drifts in the repository are the east main, west main, north and south and exhaust mains. For thermal loading of 83 MTU/acre, the emplacement drift wall temperature will increase to approximately 160°C at 50 years and then start to decline. For thermal loading of 100 MTU/acre, the emplacement drift wall temperature will increase to approximately 180°C and then start to decline (see Figure 6-1).

The model results do not consider the cooling effect of ventilation air in the main drifts. In fact, ventilation is expected to be maintained in main drifts through the entire preclosure period, and a significant amount of heat could be removed by the ventilation air flow, which would significantly reduce the temperature of the main drift wall.

6.2.5 Radiation Levels

Waste packages are a source of radiation in the emplacement drifts. Three types of waste packages, containing multi-purpose container (MPC), defense high-level waste (DHLW), and uncanistered fuel (UCF) may be disposed of within the repository. Each waste package is a similar disposal overpack consisting of two metallic barriers that offer limited radiation shielding. Radiation levels at the surface of a 21 PWR UCF waste package as a function of time are shown in Figure 6-2 (CRWMS M&O 1995c).

The distance between the end of the last waste package emplaced in the drift and the drift entrance is assumed to be 32 meters. Also assumed is a straight drift entrance with a diameter of 5.5 meters. The types of radiation sources within each of the three types of waste packages include actinides, fission products, and activation products. These, in turn, result in direct gamma (photon) radiation from decay, photons resulting from "bremmsstrahlung" radiation, neutrons from interactions, as well as photons from interactions. The combined result of these sources is a mixed neutron-photon radiation field surrounding each waste package. Due to the decay half-life of the more significant sources, this radiation field is expected to decrease somewhat over the projected retrieval period (CRWMS M&O 1995c).

As shown in Figure 6-2, the total absorbed dose rate at the surface of a pressurized-water reactor (PWR) UCF waste package ranges from about 20 rem/hr at 10 years after emplacement to about 1.5 rem/hr at the end of the 100-year emplacement period (CRWMS M&O 1995c). Other estimates based on limiting condition at the start of emplacement show the average dose rate of a PWR MPC waste package to be 30 rem/hr at the package surface. This value may be used to calculate the average dose rate at the drift entrance by assuming a simple point source dispersion. Based upon a distance of 32 meters between the end of the last package and the drift entrance, the dose rate is attenuated by a factor of about $1/(32)^2$, equaling a value of approximately 31 mr/hr. Allowing for some scattering of additional radiation from drift sidewalls, a conservative value for the average drift entrance radiation field is estimated to be about three times the dose rate at the last package or less than 100 mr/hr (CRWMS M&O 1995c).

21 PWR UCF SURFACE DOSE RATE AS A FUNCTION OF TIME

Figure 6-2. WP Surface Dose Rate as a Function of Time

6.2.6 Waste Package Conditions

The condition of the waste packages after normal deterioration and accelerated deterioration can be caused by either normal or by abnormal conditions or performance.

The design of the waste packages is considered to be sufficiently robust that essentially no deterioration is anticipated during the first 100-year period (CRWMS M&O 1995c). Failure of the waste package will most likely occur in the form of holes created by localized corrosion (pitting) of the container materials. Through-wall pitting will not occur for at least 1000 years. For the purposes of assessing retrievability, the waste packages can be assumed to retain initial design performance characteristics (CRWMS M&O 1995a).

The only plausible event that could affect the behavior of the waste package during the course of the first 100 years is the impact of a large rock falling from the roof of the drift. The mass of a rock that could result in a breach of a waste package has been estimated for various waste package configurations. For example, an initial analysis shows that the rock mass for the 21 PWR MPC-based waste package is 33,100 kg (CRWMS M&O 1995c). A later analysis shows the mass for a 21 PWR uncanistered waste package design to be 38,000 kg (CRWMS M&O 1996f). It is considered that rocks of this size are unlikely during the retrieval period, since the potential for such an occurrence also depends on significant deterioration of the ground support system. The robust design of the waste packages prevents abnormal performance of the package within the first 100 year time period. For the purposes of assessing retrievability, the initial design performance characteristics of the waste package should be used (CRWMS M&O 1995c).

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7. RETRIEVAL SCENARIO DEVELOPMENT

The development of retrieval scenarios is based on the interaction among the retrieval process, the reasons for retrieval, the expected retrieval environment, and the internal/external events that could reasonably be expected to challenge successful retrieval.

7.1 RETRIEVAL PROCESS

Figure 7-1 contains the process flow for retrieval. The portions of the process that are not relevant to the scope of this study are shaded. The process flow "reads" from left to right with subsurface activities primarily on the left and surface activities primarily on the right.

The process flow was developed from the inputs from Section 2, Requirements, and Inputs, and from Section 5, Reasons Requiring Retrieval. In particular, the first four activities are from NUREG-0804 and from the SCP as noted on Figure 7-1. Activities to the right of "Transport Waste Package to Surface" consist of four main branches determined by the reasons for retrieval discussed in Section 5 (engineered barrier failure, resource recovery or total system performance failure). The branches of Figure 7-1 are labeled accordingly.

To link the process with individual scenarios, it is useful to group the process activities into categories of surface or subsurface impacts.

The surface impacts are shown in the logic diagrams as either "Hot Cell/Waste Package Handling" or "Temporary Storage." The rationale for these groupings is described in the remainder of this section.

Surface activities consist of the following:

- Redesign waste package
- Remove/replace waste in package (Hot Cell)
- Return waste package to emplacement drift
- Place waste package in transportation overpack
- Remove/replace fuel - place in transportation cask (Hot Cell)
- Provide temporary storage.

In this case only activities 2 through 6 are applicable to scenario development because the activity redesign of the waste package is not impacted by internal/external events; the waste package itself is.

The activities can be grouped into Handling or Storage, item 6 being the only storage activity. Therefore, on the logic diagrams, the retrieval process is linked to the scenarios as "Hot Cell/Waste Package Handling" or "Temporary Storage".

Subsurface activities consist of the following:

- Plan for retrieval
- Access waste package
- Remove waste package from the drift
- Transport waste package to the surface
- Return waste package to emplacement drift

Only activities 2 through 5 are applicable to scenario development because planning for retrieval is not physically impacted by internal or external events. Activities 2, 3, and 4 are "removal" activities; Activity 5 is a "return" activity. Since return activities are the reverse of removal activities, the impact of internal/external events on equipment is identical under normal conditions, because the equipment used for return and removal activities is identical. Under these conditions no combinations of internal and external events are unique to retrievability. During scenario development, only those events unique to retrieval are developed as removal and replacement activities underneath "Subsurface Impacts".

7.2 REASONS FOR RETRIEVAL

Table 7-1 defines the use of logic symbols used in figures 7-2 through 7-6. Figure 7-2, showing reasons for retrieval, is a logical extension of the discussion in Section 5. The two highest level reasons for retrieval are (a) public health and safety and (b) resource recovery. In Section 5, public health and safety consists of total system performance failure and poor performance of the engineered barrier. It is conceivable, however, that a partial natural barrier failure not resulting in total system performance failure could exist such as water inflow into a limited area. Therefore, a barrier failure is characterized as either a natural barrier failure or as an engineered barrier failure, resulting in the four categories of waste package retrieval. Each category is linked to a specific logic diagram as shown in figures 7-3 through 7-6 and each figure is linked to one or more scenarios.

7.3 EXPECTED RETRIEVAL ENVIRONMENT

Section 6 addresses difficulties involved with retrieval due to failure of the natural or engineered barrier or due to recovery of valuable elements from the spent nuclear fuel. Predicted retrieval conditions, based on the Mined Geologic Disposal System (MGDS) advanced conceptual design (ACD) development are outlined.

Seismic activity, rockfalls, water inflow, and additional repository operating parameters such as drift temperatures, radiation levels, and waste package conditions are discussed in some detail. Although Section 6 is a major contributor to the characterization of each scenario, the impact of performance must also be taken into account. The impact of the expected retrieval environment as well as the effect of internal and external events on retrieval equipment is incorporated in the logic diagrams of this section.

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Figure 7-1. Process Flow Diagram for Retrieval

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Table 7-1. Logic Symbol Definitions

Symbol	Name	Definition
Basic Event	A basic initiating event requiring no further development.
Conditioning Event	Specific conditions or restrictions that apply to any logic gate (used primarily with Inhibit Gate below)
Undeveloped Event	An event which is not further developed either because it is of insufficient consequence or because information is unavailable.
Intermediate Event, functional areas or reason for retrieval	An event that occurs because of one or more antecedent causes acting through logic gates.
AND Gate	Output occurs if all of the inputs occur.
OR Gate	Output occurs if at least one of the inputs occur.
Inhibit Gate	Output occurs if the (single) input occurs in the presence of an enabling condition (the enabling condition is represented by a Conditioning Event drawn to the right of the gate).
Transfer In	Indicates that the diagram is developed further at the occurrence of the corresponding Transfer Out symbol.
	Transfer Out	Indicates that this portion of the diagram must be attached at the corresponding Transfer In from branch of the diagram.
Transfer In/Out	Indicates that this portion of the diagram must be attached where the dashed line terminates (signified by an arrow). This symbol is used to tie identical portions of the diagram together on the same page and is used as an alternative to the triangle transfer in and transfer out.

Figure 7-2. Conditions Requiring Retrieval

* Due to internal or external events

Figure 7-3. Scenario Development for Total System Performance Failure

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* Due to internal or external events

Figure 7-4. Scenario Development for Resource Recovery

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* Due to internal or external events
(All require special handling due to waste package breach)

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Figure 7-5. Scenario Development for Engineered Barrier Failure

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Figure 7 δ. Scenario Development for Natural Barrier Failure

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7.4 INTERNAL AND EXTERNAL EVENTS

The *Preliminary Hazards Analysis* (PHA) (CRWMS M&O 1996c) identified several potential internal events that are included in one of the following groups that apply during the emplacement period.

- I1. Drops, including slapdowns (S,SS)
- I2. Collisions, including a waste package rolling off the transport (S,SS)
- I3. Derailment (SS)
- I4. Flooding from sources within the system design (S)
- I5. Fire (S,SS)
- I6. Thermal from sources within the system design, including welding burnthrough (S)
- I7. Rockfall/steel set fall (SS).

The PHA also identified 22 potential external events that apply during preclosure. The 22 candidate external events are;

- E1. Aircraft Crash (S)
- E2. Debris avalanching (S)
- E3. Dissolution (SS)
- E4. Extreme wind (S)
- E5. Extreme weather fluctuations (S)
- E6. Fire range (S)
- E7. Flooding through storm or river diversion (S)
- E8. Inadvertent future intrusions (S)
- E9. Intentional future intrusions (S)
- E10. Landslide (S)
- E11. Lightning (S)
- E12. Loss of offsite/power (S)
- E13. Industrial-activity induced accident (S)
- E14. Military-activity induced accident (S)
- E15. Rainstorm (S)
- E16. Sandstorm (S)
- E17. Seismic activity, earthquake (S,SS)
- E18. Seismic activity, subsurface fault displacement (S,SS)
- E19. Seismic activity, surface fault displacement (S,SS)
- E20. Static fracturing (SS)
- E21. Tornado (S)
- E22. Volcanism, ash fall (S)

Note: S = Surface, SS = Subsurface

Since, under normal conditions, retrieval would be the reverse of emplacement then the same processes and equipment would be used and the same hazards would apply. As design matures and more detail is available from the *Waste Package Retrieval Equipment Report* (under development), a new hazards analysis will be conducted to determine if new processes or equipment *unique to retrieval* introduces any new hazards.

The seven internal event categories can be subdivided based upon whether they apply to surface, subsurface activities or both. Only I4-"Flooding from sources within the system design" and I6-"Thermal from sources within the system design, including welding burnthrough" have been excluded from subsurface consideration based on current stages of design development. Derailment (I3) and rockfall/steel set fall (I7) are unique to subsurface. All others (I1- Drops, I2-Collisions, including a waste package rolling off the transporter, I5-Fire) apply to both surface and subsurface.

These seven internal event groups are used as basic events in the logic diagrams of figures 7-3, 7-4, 7-5, and 7-6.

The 22 external events have also been categorized as surface or subsurface and incorporated into figures 7-3, 7-4, 7-5, and 7-6. However, since the design basis events (DBEs) analyses have not been completed, the groupings have been simplified to include internal and external events as follows:

- Derails—The derailment event remains the same but is included in the logic diagram as a "diamond" (i.e., underdeveloped event, contingent on completion of DBEs).
- Collisions—Collisions include drops and slapdowns and are also shown as "diamonds" on the logic diagrams.
- Ceases to operate—Includes internal events I4, I5, and I6 as well as external events E1, E2, E4, E5, E6, operate-E8, E9, E10, E11, E12, E13, E14, E16, E21, and E22. These are shown as diamonds on the logic diagrams.
- Rockfall/steel Set Fall—Included as rock fall in figures 7-5 and 7-6.
- Improper Operation—This event includes any internal or external event which although not necessarily safety related none-the-less might impede the retrieval process.
- Dissolution, Flooding, Rainstorms, and Seismic activity—These events are denoted as "basic events" (encircled in Figure 7-5, Rainstorms, and 7-6, Seismic Activity)

7.5 LOGIC DIAGRAM METHOD

The logic diagrams represent a logic model of the process of a facility and those events that could challenge the successful completion of the process. In the case of retrievability, the diagram provides a logical link among the retrieval process, the reasons for retrieval, the expected retrieval environment, and the internal/external events that could reasonably be expected to challenge

successful retrieval. The scenarios in this section are the result of the determination of the combinations of events and processes unique to retrieval. Examples of combinations of events and processes not unique to retrieval are those in common with emplacement. Scenarios common to emplacement, as well as requirements derived from those scenarios, are not within the scope of this report.

Logic diagrams often use the same logic symbols or fault tree diagrams. In fact, fault trees are special cases of logic diagrams and fault trees and event trees can be developed from logic diagrams. The primary difference between logic diagram and fault trees is that logic diagrams often contain areas or locations rather than explicit "most undesired event" as is the case with fault tree top events.

These symbols and definitions are taken from *The Fault Tree Handbook* (NUREG-0492) with slight modifications to intermediate event definitions and transfer in/out symbols.

7.6 RETRIEVAL SCENARIO LOGIC DIAGRAMS

The logic diagrams are organized by reasons requiring retrieval, and scenario as shown in Figure 7-2. Each scenario is developed separately in figures 7-3 through 7-6. Each figure begins with the appropriate reason for retrieval from Figure 7-2 and the attribute that distinguishes one scenario from another. In Figure 7-3, three scenarios are developed from total system performance failure whereas in Figure 7-4, there is a one-to-one correspondence. Resource recovery is a stand alone scenario.

In each figure, the scenario is characterized by surface and subsurface impacts of the events identified in Section 7.2.1. It is not necessary to provide a higher level of detail for subsurface because the impacts can be determined directly. The surface impacts, however, depend on the process and location provided by Figure 7-1. The lowest level of the logic diagram is the internal and/or external event. If the internal/external event on the diagram is enclosed in a diamond, the event will eventually receive further development in DBE analyses. If the event does not require further development, it is enclosed by a circle and is called a basic event. Even if the diamond shaped undeveloped events will eventually be analyzed further, there is sufficient information to characterize the scenarios at this point.

It should be noted that during retrieval under either normal or abnormal conditions, DBEs may occur much the same as they could occur during emplacement operations. The resultant scenarios depend on both the abnormal conditions listed above and the design basis events which may occur during the retrieval phase. Each scenario will be addressed to ensure that retrievability has not been precluded. DBE analysis will be performed to determine the probability and consequence of bounding scenarios selected from those defined herein.

7.7 RETRIEVAL SCENARIOS

This section contains summary level descriptions of the retrieval process for seven different potential scenarios. The conditions in the subsurface at the time of the start of retrieval may be "normal" or "abnormal." Normal retrieval conditions imply the following:

- The emplacement drift ground support is intact, with no rock fall in the drift.
- The drift infrastructure (i.e.; the rails, invert, conductor bar, and any in-drift communication cable), is intact and operable.
- The peak temperature of the tunnel walls is at, or below, 200°C.
- The radiation dose rate is considerably in excess of the safe level for human entry.
- The waste packages are intact, unbreached, and in their original emplacement positions.

In contrast, "abnormal" conditions include any other set of conditions outside the normal conditions. Rock falls, water in-flows, failed infrastructure, and breached waste packages are examples of abnormal conditions.

The seven scenarios to be discussed are summarized in Table 7-2. For each scenario, the following information is provided:

- The reason retrieval has been ordered.
- The retrieval condition (normal or abnormal); if abnormal, the specific abnormal condition is stated.
- The time period during which retrieval was ordered (Emplacement period or Caretaker period).
- The waste package population to be retrieved (all packages, or some subset).
- Content of the retrieved packages, defense high-level waste (DHLW), DOE spent nuclear fuel (SNF), or commercial spent nuclear fuel (CSNF).
- The disposition of the retrieved waste (re-emplaced, stored on site, taken off-site, etc.).

The descriptions of retrieval operations contained in this section are at a summary level of detail. Design analyses such as the *Waste Package Retrieval Equipment Report* (in process) intended to better define these activities are not yet complete. The intent in this section is to provide a description of how various operations might be undertaken, but not to fully define the sequences of steps nor to describe fully the equipment involved.

7.7.1 Scenario 1

This scenario, summarized in Table 7-3, involves retrieval of all waste packages under normal conditions. Retrieval assumes the use, to the extent possible, of the same systems and equipment that were used during emplacement operations. Specialized equipment is not required because conditions in the emplacement drifts are normal. This scenario does not consider the ability to preserve the site for long term waste isolation, since the site will be decommissioned.

Table 7-2. Summary of Retrieval Scenarios

Scenario Number	Reason for Retrieval	Retrieval Conditions	Time period Retrieval Initiated	Waste Package Population	Waste Package Content	Disposition of Retrieved Waste
1	Public Health & Safety (Total System Performance Failure)	Normal	During Caretaker Period, 50 Years from Emplacement Start Date	Full Retrieval	SNF/ DHLW	Onsite Storage/Transport to Offsite Location
2	(Resource Recovery)	Normal	During Emplacement Period	Partial Retrieval	SNF	Recovery/Return to Repository
3	Public Health & Safety (Poor Waste Package Performance)	Abnormal (WP Mechanical Breach-Radiation Release)	During Emplacement Period	Partial Retrieval	SNF/ DHLW	Repackage Waste/ Return to Repository
4	Public Health & Safety (Limited Emplacement Area Unsuitable)	Abnormal (Water Inflow-Limited Area)	During Caretaker Period	Partial Retrieval (Greater than 120)	SNF/ DHLW	Onsite Storage/Return to New Location in Repository
5	Public Health & Safety (Poor WP Performance)	Abnormal (Exceeds Expected Emplacement Drift Temps.)	During Caretaker Period	Partial Retrieval	SNF/ DHLW	Onsite Storage/Return to Repository
6	Public Health & Safety (Total System Performance Failure)	Abnormal (Rockfall)	During Caretaker Period	Full Retrieval	SNF/ DHLW	Onsite Storage/ Transport Offsite
7	Public health & Safety (Total System Performance Failure)	Abnormal (Backfill)	During Operations and during Closure	Full Retrieval	SNF/ DHLW	Onsite Storage/ Transport Offsite

7.7.1.1 Retrieval Timeline

Figure 7-7 shows the preparation period for retrieval Scenario 1. See Section 7.8 and Figure 7-15 for retrieval rate and duration.

Table 7-3. Scenario 1

Title	Retrieval Parameters
Retrieval Reason	Public Health & Safety (Total System Performance Failure)
Retrieval Conditions	Normal
Retrieval Initiation Time Period	During Caretaker Period, 50 Years from Emplacement Start
Waste Package Population	Full Retrieval
Waste Package Contents	Spent Nuclear Fuel/Defense High-level Waste
Retrieved Waste Disposal	Onsite Storage/Transport to Offsite Defined Location

Task	Duration (Years)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. New Program Funding ¹																				
2. Strategic Planning ¹																				
3. Environmental Impact Statement ⁴																				
4. Tasks																				
A. Design																				
Onsite Storage																				
- Waste Handling Building (WHB)																				
- Option 1-Transportation Ovrpk																				
- Option 2-WHB Modifications																				
- Option 3-New WHB																				
- Transportation Cask ²																				
B. Procurement																				
- Construction Contracts																				
- Long Lead Items																				
C. Construction																				
- WHB Modifications																				
- New WHB																				
- Onsite Storage Pad ³																				
- Transportation Cask																				
D. System Operations Test																				

¹Order to retrieve includes new program funding and strategic planning

²Use existing transportation cask design

³Pad construction rate tied into retrieval rate

⁴Includes time required for Licensing

Figure 7-7. Preparation Period for Retrieval - Scenario 1

7.7.1.2 Ventilation Considerations

As time goes on, the temperature of the emplacement drifts increases (see Figure 6-1). Increased temperatures (up to 200°C) and equipment operating limitations (50 to 60°C), dictate the need for cooling of the emplacement drifts.

The ventilation system designed for emplacement operations is designed with sufficient capacity to support cooling for as many as two retrieval operations. Retrieval involves a period of sustained high volume air flow through an emplacement drift for cooling, 60 m³/sec for a period of 3 weeks to cool an average drift (CRWMS M&O1996e, Vol. II, p. 8-283) followed by a reduced continuous flow during the actual waste package recovery phase. Two retrieval operations could be supported by sequencing the operations such that only one drift requires cooling at any particular time.

7.7.1.3 Package Recovery

From Emplacement Location to Main Drift by Gantry—Figure 7-8 shows the waste package gantry. During emplacement operations, several gantries may be utilized in multiple drifts to allow more even distribution of waste heat and fissile material. The gantries and other supporting equipment will function until the end of the emplacement period, and will support requirements for waste package movement, including corrective action for material or fabrication discrepancies, performance confirmation sampling, thermal loading balance, and emplacement drift repairs. This same equipment will be available for retrieval, if required. After the beginning of emplacement operations, replacement of gantries is expected on a regular schedule. Additional equipment may be ordered to allow increased productivity or to replace equipment which has reached the end of its useful life.

From Main Drift to Surface in Shielded Transporter—Waste emplacement requires the use of two sets of transport equipment, 4 locomotives and 2 transporters, over a 24-year emplacement period, assuming one shift per day. As with gantries and supporting equipment, a regular replacement cycle will be established. This equipment will be available for operational waste package movements, including corrective action for material or fabrication discrepancies, performance confirmation sampling, thermal loading balance, and emplacement drift repairs, as well as for retrieval operations, if required.

One set of transport equipment is used to support each retrieval operation. A retrieval operation consists of a single emplacement drift cooled to allow equipment access, a gantry with its supporting equipment, a shielded transporter and two locomotives. Two such operations could be supported by the subsurface facilities without significant re-fit. Only minor interference is expected between the two operations. Each operation should be able to recover two waste packages per shift. If two operations are conducted on a two-shift per day basis, the 11,000-package inventory (CDA, Key 003) will be recovered in six to seven years. This assumes available facilities for accepting, storing, and/or transporting transport the waste when it has been retrieved to the surface.

Offsite Transportation—The significance of this transportation segment is to ensure capability and flexibility to ship offsite by means of one of these options. The following modes of transportation are being considered to transport waste to the site:

- Rail shipments across country using the mainline rail system to a newly constructed branch line in Nevada

Figure 7-8. The Waste Package Gantry (In Development)

- Rail shipments across country using the mainline rail system to an intermodal transfer facility where transportation casks will be transferred to heavy haul truck for transport to the repository
- Legal weight trucks do not have heavy haul capability transporting waste. If the heavy haul mode is selected, a branch rail line will not be present at the time of retrieval. Legal weight truck capability will be possible on the public highway system. However, if a branch rail line were built for transporting waste to the repository, it may be a factor in retrieval.

Dependent upon the selected corridor, from the existing main line rail the cost of maintaining a branch rail line ranges from \$200,000-300,000 per year (CRWMS M&O 1996e). An option is to not provide way maintenance, but rather to ensure that the land withdrawal agreements or memorandums of understanding are in effect to maintain this option, if it is required.

7.7.1.4 Onsite Surface Storage

This scenario assumes that the geologic site is not suitable for long-term waste isolation, and that a decision is required for the disposition of the waste. The options involve locating candidate repository sites, characterizing one or more sites, and choosing the preferred site for the new repository. A different means of disposal such as one that is not in a geologic medium might also be chosen.

One storage option is retrieving all of the waste, transporting it to an onsite storage pad, and placing each waste package in a concrete silo for shielding purposes. It is assumed that during the strategic planning period for retrieval, there is a planning group to address the final disposition of the waste, including the method of disposal or recovery. This process will require more time than the repository-readiness activities. If there is no driver to retrieve the waste from the repository until a destination has been determined, and if the entire infrastructure is ready for offsite shipment, onsite storage may not be required. In that case, it is reasonable to keep the waste packages in the emplacement drifts until another repository has been chosen or other means of disposal have been determined.

Since retrieval is a planned contingency, this storage facility is treated as an "if required" facility. No preliminary design or construction is required during the repository design phase, although the obtaining of land withdrawal rights sufficient for storage of all the waste packages is required. Since land availability is not a factor on the Nevada Test Site (NTS), it is not logical to reserve a storage pad for storing only part of the waste. The determination of the size of this pad and the suitable location is required prior to License Application.

7.7.1.5 Criticality Consideration

The robust waste package design should inherently provide and maintain criticality control during onsite surface storage and retrieval operations. Analyses of the reference waste package design shows sufficiency in meeting 10 CFR Part 60.131(h) requirements under dry (intact) and wet (breached) conditions (CRWMS M&O 1996e). Prior to receiving regulatory licensing to start

retrieval operations, analyses of design basis events specific to retrieval operations and storage will be required. These analyses must ensure that a criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety.

7.7.1.6 Waste Handling Facilities

The repository surface facilities will be used to repackage for shipment offsite. Two options may be possible, retaining the fuel in the waste packages or repackaging the waste.

Option 1 - Retaining Fuel in Waste Packages with Overpack

Option 1 consists of retaining fuel in the waste packages and providing a suitable transportation overpack, which is licensable by the NRC. However, it is questionable whether a waste package with transportation overpack can provide sufficient shielding and yet be structurally adequate to allow shipment. If this option is possible, it eliminates bare-fuel handling.

Retaining the waste in the waste packages and providing transportation impact limiters and auxiliary neutron shielding allows transport of the waste packages by rail, thereby avoiding repackaging and reducing radioactive waste at the Yucca Mountain site. The transportation package will require NRC certification. The possibilities include using the waste package as a transport package or placing the waste package in a transportation overpack. If the waste package serves as a transport container, the ends of the waste package must have extra length in the form of a ring of material, which could be used for impact limiter attachments. The waste-package shell must also have sufficient thickness to withstand the rigors of transportation hypothetical-drop accidents. Since the steel of the waste package may not have sufficient ductility at low temperatures to allow transport in the winter months, a transportation overpack may be necessary. The outside diameter of the pressurized-water reactor (PWR) and the boiling-water reactor (BWR) SNF waste packages is currently less than 1.7 meters, which allows the addition of a transportation overpack to satisfy railcar dimensional limits. The outer diameter of the DHLW waste package is sufficiently large, approximately 2 meters, to preclude the addition of an overpack. The construction materials of all waste packages and the internal basket structures are acceptable materials for transport, with the possible exception of the stainless steel/boron material used for criticality control in PWR and BWR waste packages. These packages will require additional effort to gain approval for transport.

The packaging facility must consist of a transfer unit with the capability for adding the transportation overpack for additional strength and shielding. The overpack could be added at the emplacement drift, instead of using the conventional emplacement shielded transporter vehicle, transporting to the surface, and adding the transportation pack to the waste package. In either case, impact limiters would be installed at the surface for transportation. However, choosing this option may cause a problem in the ability to safely store on a surface storage pad. This option reduces the extent of waste handling facilities on the surface such as the waste handling building which is designed for emplacement.

Option 2 - Designing a New Fleet of Transportation Casks

The options regarding surface waste-handling capabilities to support this retrieval scenario range from remodeling an existing waste-handling building to constructing a new waste handling building for maximum efficiency.

Option 2a, Remodeling—A robust concrete building is required for radiological protection, including shielding and ventilation controls for emplacement operations. For emplacement operations, this building will function with minimum upgrades or remodeling. However, for retrieval operations, at a minimum, the building requires substantial remodeling including new utilities such as power, heating, ventilation, and air conditioning, water, compressed air, and safety systems. This assumes that the building has been "mothballed" after the completion of emplacement operations. Q-listed structures, systems and components (SSCs) would have to be inspected, tested and repaired or replaced before the facilities would be put back into operation.

This facility requires the capability of performing all the functions required for emplacement in addition to the capability of removing the lids from the waste packages to access the SNF and DHLW for repackaging in a transportation cask.

Option 2b, New Construction—The construction of a new building is the ideal option for maximum safety and efficiency. Although the initial cost is substantial, it is cost efficient in terms of unpackaging and repackaging thousands of retrieved waste packages for offsite shipment.

7.7.1.7 Site Support Facilities

Since buildings have a typical design life of 40 years, most of these structures housing record keeping, administration, maintenance, safety monitoring, and medical, would require substantial remodeling and re-equipping for extended lives. Therefore, since the retrieval time period could be lengthy (approximately 30 years), the most likely option is to plan for new construction.

7.7.2 Scenario 2

This scenario, summarized in Table 7-4, involves the retrieval of only the waste packages containing valuable fissile materials such as uranium and plutonium. This retrieval scenario requires a recovery process involving chemical extraction to separate the isotopes from unwanted elements.

Table 7-4. Scenario 2

Title	Retrieval Parameters
Retrieval Reason	Resource Recovery
Retrieval Conditions	Normal
Retrieval Initiation Time Period	During Emplacement Period
Waste Package Population	Partial Retrieval
Waste Package Contents	Spent Nuclear Fuel
Retrieved Waste Disposal	Return to Repository or Determined Location

7.7.2.1 Retrieval Timeline

Figure 7-9 shows the tasks and corresponding durations for Scenario 2.

Task	Duration (Years)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. New Program Funding ¹																				
2. Strategic Planning ¹																				
3. Environmental Impact Statement ⁴																				
4. Tasks																				
A. Design																				
Onsite Storage																				
- Waste Handling Building (WHB) ²																				
- WHB Modifications																				
B. Procurement																				
- Construction Contracts																				
- Long Lead Items																				
C. Construction																				
- Modifications																				
- Onsite Storage Pad (if REQ'D) ³																				
D. System Operations Test																				

¹Order to retrieve includes new program funding and strategic planning

²Use existing Building

³Surface storage facility construction concurrent with retrieval operations

⁴Includes time required for Licensing

Figure 7-9. Preparation Period for Retrieval - Scenario 2

7.7.2.2 Ventilation Considerations

Retrieval in this scenario starts during the emplacement period. One option is to continue emplacement operations according to the schedule during a one-shift operation and to retrieve the selected waste packages for resource recovery during a shift that does not interfere with emplacement operations. The ventilation system must have the capability of supporting this option, and should not be more taxing than the ventilation of two simultaneous retrieval operations previously discussed. Considerable planning and sequencing of equipment and personnel would be needed to ensure that simultaneous emplacement and retrieval operations could be efficiently executed.

Another option includes retrieval of waste without concurrent emplacement. This decision may depend upon the amount of waste being selected for retrieval. If recovery of all SNF containers, estimated at 70 percent of the total inventory, is planned, the operation will be significant. Normal retrieval without concurrent emplacement has been discussed in Scenario 1. Ventilation for Scenario 2 without concurrent emplacement is essentially the same as that in Scenario 1.

The development operations, excavation and equipping of emplacement drifts, could continue unimpeded by the emplacement and/or retrieval operations, since the development operation has its own ventilation system and its own dedicated access ramp and shaft.

7.7.2.3 Transport Capabilities

From Emplacement Location to Main Drift by Gantry—If retrieval occurs on one shift and emplacement on another shift, the same equipment will be utilized. Emplacement operations will fill the repository operation from north to south, but partial retrieval could be executed in any sequence. The only limiting factor is that, once a drift is cooled, all packages desired from that drift should be recovered before moving on to another drift. This would minimize the number of cooling-heating cycles to which the ground support system is subjected.

From Main Drift to Surface—This transport function is standard for all scenarios, utilizing two sets of equipment, including 4 locomotives and 2 transporters.

Surface Transportation—This scenario contains two options for surface transportation needs. The first option assumes that the preferred method is rail (see Section 2.1.1, Key 058), since the previous method of transport was by rail. The first option assumes that an offsite reprocessing plant has been built for reprocessing the SNF.

The second option assumes that a decision has been made to reprocess the SNF onsite near the location of the repository. The second option requires a surface rail line spur to this new reprocessing plant. The location of this plant is not necessary for License Application and does not affect the repository design or land withdrawal activities.

Offsite Transportation—If the decision is to reprocess onsite near the repository, offsite transportation is not necessary. If the decision is to reprocess offsite, or at a minimum, off the Nevada Test Site, offsite transportation capabilities are needed. Like Scenario 1, the three options are rail, heavy haul to a main rail line, or legal weight trucks. Since this scenario occurs during the emplacement period, if a branch rail line has been built, it will be fully operational and maintained. Heavy haul routes on both public highways and onsite can accommodate the heavy haul option.

7.7.2.4 Onsite Surface Storage

Resource recovery of the fissile materials includes the options to reprocess offsite or onsite. The need for surface storage changes with the selected reprocessing option.

7.7.2.5 Extraction of Actinides

This includes retrieval of waste packages with commercial SNF content and waste packages with DOE SNF high-level waste. For waste packages with SNF contents, fuel handling may or may not be necessary if the NRC permits the shipping of waste packages with a transportation overpack. The alternative would require opening the waste packages, removing the SNF, and repackaging in a licensed transportation cask. For waste packages containing both DOE SNF and DHLW, fuel

handling capabilities are required for removing the lids, handling the fuel, and repackaging both types of waste. Onsite storage may be required for retrieving and re-emplacing the DHLW canisters in new waste packages.

Although retrieval for recovery of resources occurs during the emplacement period when the waste handling building is fully functional, some building modifications are required. These modifications include an area for lid removal and repackaging to accommodate waste packages with SNF and DHLW. The waste flow from the SNF will be transported directly to the newly designed and constructed reprocessing plant.

The utilization of onsite surface storage facilities for onsite recovery is required due to the necessity for minimizing waste package movements. In addition, the waste package retrieval rate would have to match the rate of recovery. Since the storage option requires shielded concrete silos and a storage pad, a determination of the added value of the storage option needs a cost benefit analysis.

7.7.2.6 Waste Handling Facilities

Because of substantial differences between offsite processing and onsite processing, waste-handling requirements involve substantial differences. Onsite processing requires a new facility. Therefore, since the waste handling building is fully operational, there may be an advantage to segregating SNF from DHLW in this facility, repackaging the DHLW and removing the DOE SNF, and returning the DHLW to the repository. This segregation requires modifications for the opening of waste packages. An additional need for repackaging would be for replacement of the reprocessing waste in the repository as HLW or the determined final destination. Without co-disposal, it is preferable to perform all functions in the new recovery facility, thereby minimizing waste package movements and fuel handling.

7.7.2.7 Site Support Facilities

Since emplacement operations are in process during retrieval for recovery, the facilities will be functional. A required function of either the site support facilities or a new reprocessing facility is the handling and decontamination of the open waste packages and lids. Since the quantity in pounds of waste package steel may be significant, the storage, handling, and transportation functions associated with this material may require either a modified or a special work area. This area is for decontamination and the potential cutting of the waste package cylinder into smaller pieces for ease in handling and shipping. However, the functions discussed in this scenario do not impact design requirements for the site support facilities.

7.7.3 Scenario 3

This scenario, summarized in Table 7-5, consists of a partial retrieval during the emplacement period. Unknown factors include the number of waste packages requiring retrieval (less than 100 percent), and, the more important assumption, the number of breached waste packages. One possibility is one or more waste packages leaking gasses, which have been detected by the ventilation monitoring system or remote monitoring gantry. This would indicate that the waste

Table 7-5. Scenario 3

Title	Retrieval Parameters
Retrieval Reason	Public Health & Safety (Poor Waste Package Performance)
Retrieval Conditions	Abnormal (WP Mechanical Breach-Radiation Release)
Retrieval Initiation Time Period	During Emplacement
Waste Package Population	Partial Retrieval
Waste Package Contents	Spent Nuclear Fuel/Defense High-level Waste
Retrieved Waste Disposal	Repackage Waste/Return to Repository

package is structurally sound, thereby allowing movement without additional support. However, a waste package could be also be substantially damaged. This could require special equipment to engage, lift and transport the package. For defense in depth purposes, this option has been added.

7.7.3.1 Retrieval Timeline

Figure 7-10 shows the tasks and corresponding durations for Scenario 3.

Task	Duration (Years)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. New Program Funding ¹																				
2. Strategic Planning ¹																				
3. Tasks																				
A. Design																				
- WHB Modifications																				
B. Procurement																				
- Construction Contracts																				
- Long Lead Items																				
C. Construction																				
- Waste Package Fabrication																				
- WHB Modifications																				
D. System Operations Test																				

¹Order to retrieve includes new program funding and strategic planning

Figure 7-10. Preparation Period for Retrieval - Scenario 3

7.7.3.2 Ventilation Considerations

The scenario involves two breached waste package possibilities:

- A "pinhole" breach with leaking gas (less severe)

- A general failure of the waste package with contamination released from the package into the emplacement drift (more severe).

To assess the emplacement drift situation, remotely operated equipment is dispatched to the drift. If the drift infrastructure is intact, as it would likely be in the pinhole case, significant data can be acquired. The severe damage case may or may not be amenable to the acquisition of remotely acquired data. The nature of the cause of the waste package damage may also preclude data acquisition (i.e; a rockfall large enough to cause significant damage to a waste package would also likely preclude normal gantry access to the drift.)

In either case, the same ventilation system is used. An auxiliary filtration unit with associated ductwork is installed in the main exhaust at the bottom of the ventilation raise associated with the drift containing the leaking package. This arrangement allows the drift to be cooled as previously described, but limits the movement of contamination from the drift. A booster fan supplies the pressure required to move the large cooling quantity through the filtration system. The airflow quantity is reduced after the cooldown period, but the airstream is filtered for the duration of the retrieval operation in that emplacement drift.

7.7.3.3 Transport Capabilities

From Emplacement Drift to Main Drift by Gantry (Pinhole Breach)—After cooldown, the gantry enters the emplacement drift in the normal manner. Because it is inserted at the intake end of the drift, there is little danger of significant contamination escaping from the drift while the doors are open. As with normal retrieval operations, all packages are removed in order from the one nearest the door to the one nearest the exhaust end of the drift. Packages are engaged and moved to the transporter normally. When the transporter doors and drift doors are closed, a scan is made for external contamination. Decontamination of the gantry and its support equipment, as well as the transporter, may be required following completion of the operation.

Severe Damage Case—Undamaged packages between the drift entrance and the damaged package would be recovered as described in the pinhole case. The severely damaged package is handled as follows. Fill material, such as tunnel boring machine (TBM) muck, is transported to the emplacement drift entrance and systematically dumped and spread to create a temporary roadbed in the drift. The fill is extended to the point where the toe of the fill is adjacent to the damaged package. One concept which is under consideration for recovery of a package which cannot be engaged by the normal gantry is to attach a grapple to one of the skirt holes in the package, and to pull the package onto a roller-mounted inclined steel deck. When the package is fully on the deck, the "inclined plane hauler" transports the package to the drift entrance. The package is transferred, in the east or west main, to a transporter modified to prevent contamination release. This transfer process requires a ramp and platform. The inclined plane hauler will move up the ramp, the roller-mounted steel deck will be off-loaded onto the platform, and the hauler will withdraw. A shielded transporter, similar to the normal emplacement and retrieval transporter, although with some modifications, self-loads the package and roller-mounted deck, and is then taken to the surface by standard locomotives. The deck is decontaminated, if needed, and returned to service. This type of event (a severely structurally damaged waste package) is so unlikely that, if it were to occur, it would

be dealt with on an individual case basis. For example, special equipment and procedures may be developed specifically for that single event. Retrieval using the fill method described would result in a large volume of potentially contaminated fill which would require removal, packaging and disposal.

From Main Drift to Surface—Compensation is required to handle the “severe damage” scenario, such as covering and possibly, unshielded transport. It may be most expedient, and safest, to forego the transfer of the damaged package into a shielded transport vehicle, and instead move it to the surface under controlled conditions in an unshielded configuration. The equipment will likely require decontamination following the movement of the breached package.

Offsite Transportation—Offsite transportation is not required in this scenario. The shipment from the waste package fabricator (new WP design) to the repository is required, assuming the fabrication takes place offsite. Therefore, these empty waste package loads may be over the legal weight limits (80,000 GVW for legal weight truck) and require heavy haul truck, or overweight truck, or rail, if a branch line exists.

7.7.3.4 Onsite Surface Storage

The need for surface storage does not lend itself to the breached waste package scenario. The goal for retrieving this type of waste package is to transport directly from an emplacement drift to a facility that has waste handling capability (hot cell/fuel transfer capability), and is not stored on the surface for any period of time.

In addition to abnormal retrieval conditions, the reason for retrieval is the substandard performance of the waste package. As the new waste packages are shipped to the repository, retrieval operations would start. There is no supporting rationale for onsite storage of retrieved waste packages. After the SNF or DHLW has been removed from the retrieved waste packages and placed in the new material, new design waste package, there is no reason why they would not be immediately emplaced in the repository, unless there were interference or capacity problems with the continuing normal emplacement operations.

7.7.3.5 Waste Handling Facilities

Since this scenario takes place during the emplacement period, the waste handling building functions as the place for packaging fuel in waste packages. If emplacement operations were to continue as scheduled, and the decision were made to retrieve the limited population of waste packages without the emplacement schedule being interrupted, this could be a big challenge. Emplacement operations would probably be placed on hold long enough to retrieve the waste packages constructed of the specific material before resuming emplacement operations. This option may be totally different if the waste package population were large, such as thousands of waste packages. A new waste handling building may be necessary to accommodate this large volume, or retrieval may be deferred until all waste packages were emplaced, instead of interrupting the emplacement schedule.

7.7.3.6 Site Support Facilities

There is little to no impact in the site support facilities to support the retrieval operations during the emplacement time period. However, if the waste package retrieval population is large, and the emplacement operations continue, it could be necessary for added maintenance facilities, and added facilities dealing with the scrapped waste packages (decon and material preparation for shipment offsite).

7.7.4 Scenario 4

This scenario, summarized in Table 7-6, is unique in that it deals with limited water inflow. The cause may be abnormal meteorological conditions (episodic flow), or by migration of in situ water mobilized by the heat of the emplaced waste inventory. Water would likely appear in cooler areas of the facility, such as mains, or any other drifts where ventilation is maintained throughout the preclosure period. Though unlikely, it is possible that flow could enter a heated emplacement drift by focusing flow in a fractured, locally high permeability zone, and "overpowering" the waste heat output at that point in the drift. While this is a remote possibility, this scenario has been developed to determine how the MGDS design would retrieve under these abnormal conditions. (See Section 6.2.3)

Table 7-6. Scenario 4

Title	Retrieval Parameters
Retrieval Reason	Public Health & Safety (Limited Emplacement Area Unsuitable)
Retrieval Conditions	Abnormal (Water Inflow-Limited Area)
Retrieval Initiation Time Period	During Caretaker Period
Waste Package Population	Partial (Greater than 240)
Waste Package Contents	Spent Nuclear Fuel/Defense High-level Waste
Retrieved Waste Disposal	Onsite Storage/Return to New Location in Repository

The current repository design has two parking drifts that are vacant for various purposes, including emplacement drift repair, that could accommodate up to 240 waste packages. It is assumed that this is insufficient to take care of the larger population affected by this problem.

7.7.4.1 Retrieval Timeline

Figure 7-11 shows the tasks and durations for Scenario 4.

7.7.4.2 Ventilation Capabilities

This scenario does not make any special demands on the ventilation system not covered by other scenarios. However, the result of cooling via ventilation can have a dramatic impact in removing water.

The generally arid condition of the intake air stream and the large flow quantity required to cool the emplacement drift have the potential to remove significant amounts of water by evaporation. The evaporation process also results in significant heat removal in addition to that provided by the increase in dry bulb temperature of the cooling air.

Task	Duration (Years)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. New Program Funding ¹																				
2. Strategic Planning ¹																				
3. Environmental Impact Statement ¹																				
4. Tasks																				
A. Design																				
Onsite Storage																				
B. Procurement																				
- Construction Contracts																				
- Long Lead Items																				
C. Construction																				
- Surface Storage ²																				

¹Order to retrieve includes new program funding and strategic planning

²Surface storage facility construction concurrent with retrieval operations

³Includes time required for Licensing

Figure 7-11. Preparation Period for Retrieval - Scenario 4

The repository is arranged so that water will drain by gravity from emplacement drifts into the east and west mains. The mains in turn, have a consistent slope toward the north which allows flowing water to be captured either in sumps at the entrance of each emplacement drift, or in the main drifts.

This scenario does not assume a breached waste package. However, if contamination were detected in water flowing from an emplacement drift, the water would be impounded temporarily in the immediate area, pumped into a tank car, and removed to the surface. There it could be handled in a similar manner to other site-generated wastes from the surface waste handling processes.

7.7.4.3 Transport Capabilities

From Emplacement Location to Main Drift by Gantry—In the emplacement drift configuration the invert is arranged so that the gantry rails and conductor bar are well above the low point of the emplacement drift. Water seeks the lowest point, which in this case is the center of the drift below the waste packages. The presence of small amounts of water on the invert of the emplacement drifts does not present a major operational problem. The normal retrieval process, incorporating the emplacement gantry, would be utilized for this scenario.

From Main Drift to Surface—Waste package transport from the emplacement drift to the surface is accomplished under normal conditions.

7.7.4.4 Onsite Storage

The need for onsite storage may be required, depending on the population of waste packages. The preferred option is to remove the waste packages from the emplacement drifts in question, and to relocate them to a subsurface parking drift(s). This option eliminates the need to design and construct a storage pad, surface rail spur, and concrete silos for shielding each of the waste packages.

It is anticipated that the requirement to maintain the ability to retrieve a waste package during the caretaker period for performance confirmation sampling (if required) is available. Also, the ability for operations to perform waste package movements for emplacement drift repair, or thermal loading balance still exists. Therefore, the ability to retrieve is readily available.

7.7.4.5 Waste Handling Facilities

There is no requirement in this scenario to handle waste.

7.7.4.6 Site Support Facilities

Since this scenario occurs during the caretaker period, some of the facilities and equipment used for emplacement may no longer be available. Although this scenario assumes partial retrieval, the impact could be substantial for the surface facilities. In the most severe case, where a large number of waste packages must be relocated within the repository, additional emplacement drifts may be required. Site support includes additional maintenance, procurement tasks, and additional administrative support.

7.7.5 Scenario 5

This scenario, summarized in Table 7-7, is similar to Scenario 3, which assumes poor waste package performance. If, after emplacement, the waste-package material is determined to be inadequate, a new material will be selected and will necessitate repackaging. Abnormal conditions consist of higher emplacement drift temperatures and the period of retrieval is during the caretaker period.

Table 7-7. Scenario 5

Title	Retrieval Parameters
Retrieval Reason	Public Health & Safety (Poor Waste Package Performance)
Retrieval Conditions	Abnormal (Exceeded Expected Emplacement Drift Temps.)
Retrieval Initiation Time Period	During Caretaker Period
Waste Package Population	Partial Retrieval
Waste Package Contents	Spent Nuclear Fuel/Defense High-level Waste
Disposal of Retrieved Waste	Onsite Storage/Return to Repository

This assumption is that, due to extreme emplacement drift temperatures, the in-drift infrastructure fails, and the waste cannot be recovered in the normal manner. This scenario applies to nearly any situation in which the in-drift infrastructure is inoperable, regardless of cause. The most likely situation is that in which the rail system and/or conductor bar or communications system is inoperable, preventing the operation of the emplacement gantry. This condition would be discovered by an attempt to send the remote inspection gantry into the drift for a routine performance confirmation check. It may also be inferred from elevated exhaust air temperature in the exhaust monitoring system. A check of the continuity of the rail and conductor bar system could also show abnormal conditions. The drift is assumed to be essentially intact (no caving). However, there is a remote possibility that the rockfall could restrict airflow. The retrieval approach associated with rockfall restricting airflow is not discussed in this scenario but receives in depth discussion in scenario 6 (Section 7.7.6.2).

7.7.5.1 Retrieval Timeline

Figure 7-12 shows the tasks and durations for Scenario 5.

Task	Duration (Years)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. New Program Funding ¹																				
2. Strategic Planning ¹																				
3. Environmental Impact Statement ²																				
4. Tasks																				
A. Design																				
New Waste Package																				
On Site Storage Pad																				
New WHB																				
B. Procurement																				
- Construction Contracts																				
- Long Lead Items																				
C. Construction																				
- Waste Package Fabrication																				
- New WHB																				
- On Site Storage Pad ²																				
D. System Operations Test																				

¹Order to retrieve includes new program funding and strategic planning

²Surface storage facility construction concurrent with retrieval operations

³Includes time required for Licensing

Figure 7-12. Preparation Period for Retrieval - Scenario 4

7.7.5.2 Ventilation Capabilities

As in normal retrieval, the drift is cooled by re-establishing ventilation. Because there has been limited or no reconnaissance, the only information about the drift conditions is obtained from exhaust air sampling and from visual examination from the drift entrance. Temperatures above those

expected under normal conditions could require a longer cooling period, but should not present a major problem to the ventilation system. Unheated "dilution" airflow would be supplied in the exhaust main to moderate the temperature of the air passing through the emplacement drift in order to prevent unworkable conditions in the exhaust main.

7.7.5.3 Transportation Capabilities

From Emplacement Location to Main Drift—A problem of this type may preclude the use of the normal gantry process for waste package recovery. A secondary plan, utilizing a set of specialized equipment specifically for abnormal retrieval operations will be employed to address this situation. This alternative retrieval concept is described earlier in Scenario 3.

Package recovery could be accomplished by an "inclined plane hauler" which backs up to the end of the fill and extends a boom, which attaches a grapple to one of the three holes in the skirt of the waste package. The grapple is attached to a cable and winch. The hauler winches the package up the steel deck of the inclined plane. When the package is fully on the deck, the inclined plane hauler moves out of the emplacement drift and down the ramp into the main drift. The package is transferred, in the east or west main, to a transporter. This process requires a ramp and platform as described in Scenario 3. The process is repeated for each waste package in the drift. The fill material is extended after each waste package is retrieved. This is an approach that will require significant remediation of the drift; if it is to be re-used. This method is not likely to be widely employed. The use of video should allow this operation to be carried out by personnel in an area removed from the immediate vicinity of the activity. Alternatively, shielded operator stations could be utilized on equipment to allow manned operation. All waste packages recovered in this manner will probably require replacement due to the external damage (scratches and possible skirt deformation) from the winching operation. Replacement will require transporting these packages to the surface for repackaging. A decision would be made on a package-by-package basis as to whether the damage is significant enough to affect long term performance, and thus warrant replacement.

From Main Drift to Surface—This portion of transportation of waste packages is by use of the normal two locomotive and waste package transporter. The options, depending on the number of waste packages and on the damage to the waste packages, are as follows: The first option assumes that the number of waste packages involved are minimal (1 drift approximately 60 waste packages). This option allows the utilization of one of the four parking drifts in the repository until waste handling facilities become available. If the population were greater than one drift, a surface storage facility is an option to store on the surface for some time, until a waste handling building can be built or the existing one can be remodeled. The other option is to transport directly to the waste handling facility.

7.7.5.4 Onsite Surface Storage

The surface storage facility accommodates the damaged waste packages. Therefore, each waste package must be shielded with concrete or concrete casks.

7.7.5.5 Waste Handling Facilities

Since this scenario takes place during the caretaker period, the waste handling building has completed 24 years of emplacement operations, and has been decontaminated, and has been "mothballed". Another possibility is that the waste handling building has been decontaminated and demolished upon the completion of emplacement operations, with only the multi-purpose hot cell in operation to support waste package sampling until closure.

7.7.5.6 Site Support Facilities

Since this retrieval occurs during the caretaker period, the buildings are aging (more than 30 years). There may be a combination of new and remodeled buildings for this retrieval scenario.

7.7.6 Scenario 6

This scenario, summarized in Table 7-8, is for the same reason as Scenario 1, and involves the retrieval of all the waste packages; however, it is assumed to take place during the caretaker period rather than during the emplacement period. Scenario 1 is essentially the reverse of emplacement; this scenario is included to describe how retrieval would occur under rockfall conditions (abnormal conditions). (See Section 6.2.2)

Table 7-8. Scenario 6

Title	Retrieval Parameters
Retrieval Reason	Public Health & Safety (Total System Performance Failure)
Retrieval Conditions	Abnormal (Rockfall)
Retrieval Initiation Time Period	During Caretaker Period
Waste Package Population	Full Retrieval
Waste Package Contents	Spent Nuclear Fuel/Defense High-level Waste
Retrieved Waste Disposal	Site Storage/Transport Offsite

In this scenario, one or more drifts have experienced rockfalls, making the normal retrieval operations impossible for the affected drifts. Some portion of the affected drifts may be retrievable in the normal manner, depending on the location of the fall and its effects on the drift infrastructure. If the currently anticipated ground support system of expanded pre-cast segmental concrete lining is employed in the emplacement drifts, a rockfall in an emplacement drift is very unlikely. Other ground support systems being evaluated are steel sets and lagging, and cast-in-place concrete. All three systems are robust, and falls of ground are considered unlikely, but not impossible, with each system.

The retrieval of waste packages not affected by rockfall is accomplished in the normal manner. This operation could proceed in parallel with the retrieval operation involving drifts with rockfall. Although, minor interference is anticipated, operations could be continue essentially simultaneously.

7.7.6.1 Retrieval Timeline

Figure 7-13 shows the tasks and durations for Scenario 6.

7.7.6.2 Ventilation Considerations

Of the two possibilities regarding rockfall, the more likely one is that the rockfall would not completely block the drift. Therefore, ventilating air can be passed through the drift to cool it down. If the obstruction is large, but not complete, it may be necessary to install a temporary ventilation duct and booster fan at the bottom of the exhaust raise to move the required cooling quantity through the drift. The second possibility is that the drift may be fallen tightly enough to essentially preclude airflow through the fall area. Although this is highly unlikely, it is possible; therefore, both eventualities have been considered.

Task	Duration (Years)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. New Program Funding ¹																				
2. Strategic Planning ¹																				
3. Environmental Impact Statement ⁴																				
4. Tasks																				
A. Design																				
Onsite Storage																				
- Waste Handling Building (WHB)																				
- Option 1-Transportation Ovrpk																				
- Option 2-WHB Modifications																				
- Option 3-New WHB																				
- Transportation Cask ²																				
B. Procurement																				
- Construction Contracts																				
- Long Lead Items																				
C. Construction																				
- Transportation Cask																				
- WHB Modifications																				
- New WHB																				
- Onsite Storage Pad ³																				
D. System Operations Test																				

¹Order to retrieve includes new program funding and strategic planning

²Use existing transportation cask design

³Surface storage facility construction concurrent with retrieval operations

⁴Includes time required for Licensing

Figure 7-13. Preparation Period for Retrieval - Scenario 6

7.7.6.2 Ventilation Considerations

Of the two possibilities regarding rockfall, the more likely one is that the rockfall would not completely block the drift. Therefore, ventilating air can be passed through the drift to cool it down. If the obstruction is large, but not complete, it may be necessary to install a temporary ventilation

duct and booster fan at the bottom of the exhaust raise to move the required cooling quantity through the drift. The second possibility is that the drift may be fallen tightly enough to essentially preclude airflow through the fall area. Although this is highly unlikely, it is possible; therefore, both eventualities have been considered.

If there is still electrical continuity of the rails and conductor bar, the remotely operated performance confirmation unit will be deployed to examine the drift. The location and the extent of the rockfall will be recorded, and a specific approach for retrieval will be developed for that drift. Though extremely unlikely, it is possible for the drift to fall so tightly that little or no air can pass through. The following discussion describes a method that could be used to deal with this eventuality.

The cooling process is started after the air sampling is performed to detect contamination. This scenario does not involve breached waste packages; however, if there were breached waste packages present and contamination were detected, the filtration arrangement described in Scenario 3 will be employed to help reduce the spread of the contaminants during the operations. Frequent filter changes would be required because of the dust generated during the recovery activities.

The drift immediately adjacent to a drift containing a tight fall would be cooled and retrieved in the normal manner. When it is safe for workers to enter, a short excavation is made, using either drill and blast or roadheader from the emptied drift through the pillar between drifts so that the two drifts are connected at a point near the fall, but between the fall and the drift entrance. Air flow can then be established into the caved drift entrance to the fall area, through the "crosscut" between the drifts, and on to the main exhaust via the adjacent undamaged drift. All packages between the entrance and fall will be recovered either by gantry or using the fill/inclined plane method. As work progresses on the removal of the fall, the airway will be re-established from the fall to the exhaust, and the remainder of the drift can be then be cooled and retrieved.

7.7.6.3 Transport Capabilities

From Emplacement Location to Main Drift by Gantry—When the cooldown (blast cooling) is complete, the packages between the drift entrance and rockfall can be recovered in the normal manner as long as the rail and conductor bar are intact up to the fall. If they are not, the fill/inclined plane hauler method described in Scenario 3 is used to recover all the waste packages up to the fall. If the rail and conductor bar are intact, the gantry is used for these packages. Once the fall is reached, the fill method and inclined plane hauler are used. The fill process is used to create a temporary road bed from the entrance to the fall. A crawler-mounted utility vehicle (similar to a backhoe) fitted with a boom-mounted hydraulic hammer is used to break up large pieces of concrete liner and fallen rock so that the material can be pushed aside or loaded out. If a package is immediately under the fall, the broken material must either be removed or pushed away until the package can be engaged as previously described above. The skirt may be deformed due to the fall, but it should still be possible to engage at least one of the three holes with the grapple. The package is removed using the "inclined plane hauler" once sufficient material has been moved. When the waste package is removed from the emplacement drift, the remaining rock and concrete from the fall can become part of the roadway fill to the next package. This process continues until the end of the fall area is reached. After several more packages beyond the fall are removed, shadow shields can

be placed to allow workers to repair the ground support in the fall area for stability for workers and equipment.

Another tool which may be utilized on the boom of the utility crawler unit is a large hydraulic shear. This tool can be used to cut steel tangled in a pile of fallen rock. Rebar or steel sets (if used) can be reduced in size by the shearing device. All abnormal retrieval equipment discussed is very preliminary, and much work remains for equipment definition.

From Main Drift to Surface—This transport function is performed with normal transport equipment consisting of two locomotives and the shielded transporter with waste package. A transfer (described earlier) is necessary from the inclined plane hauler to the transporter. Alternatively, the inclined plane hauler can take the package, unshielded, to the surface. As these types of off-normal scenarios are extremely unlikely, it is probable that each will be individually planned and executed with special equipment.

Offsite Transportation—This operation is the same as that discussed in Scenario 1, except that this scenario occurs during the caretaker period rather than the emplacement period. The time after emplacement may be in the range of 30 to 50 years.

7.7.6.4 Onsite Storage

This scenario assumes that the geologic site is not suitable for returning waste to the repository after retrieval. The need for retrieving the waste packages faster from the emplacement drifts is not likely, but may be required. If external events, such as earthquakes, have caused ground support failures, there may be an advantage to removing waste packages faster to avoid further complications to retrieval, and the need for specialized equipment to access the waste packages. The earliest waste package movement is estimated at 12 years from the time retrieval is ordered. Retrieving waste packages before this time may be possible by accelerating tasks, if the retrieval conditions were becoming more difficult with time. It is possible to construct a pad and concrete silos for shielding in much less time than that required to design and construct new or remodeled facilities for handling the waste for off-site transport. Additional explanation similar to this scenario is contained in Scenario 1.

7.7.6.5 Waste Handling Facilities

Since this retrieval scenario occurs place during the caretaker period. The waste handling building can be refurbished with new utilities and equipment, assuming the building shell is still structurally sound.

An alternative to this option is to assume that a new building will be constructed with the built-in capability to open waste packages, if required, prior to loading SNF and DHLW waste in transportation casks. If, however, it is possible to ship waste packages with an overpack as discussed in Scenario 1, there is no need for a waste handling facility.

7.7.6.6 Site Support Facilities

This would be a major impact to the surface facilities regardless of whether retrieval operations started during the early or late part of the caretaker period. Major refurbishment and/or replacement are required to support full retrieval operations, regardless if waste packages can be shipped without fuel handling. Areas of impact include any construction such as on-site storage pad, and additional maintenance required on retrieval equipment and utilities supporting retrieval, such as communications, power, water, ventilation, and life safety systems.

If the decision were made to remove the waste from waste packages and transport in transportation casks, a significant amount of decontamination of waste packages is required.

7.7.7 Scenario 7

This scenario summarized in Table 7-9, though highly unlikely, is conceivable. The current repository design basis regarding backfill is stated in Controlled Design Assumption Key 046. Backfill in emplacement drifts is not required. However, the repository design should not preclude the use of emplacement drift backfill at the end of the preclosure period. The specifications for the

Table 7-9. Scenario 7

Title	Retrieval Parameters
Retrieval Reason	Public Health & Safety (Total System Performance Failure)
Retrieval Conditions	Abnormal (Backfill)
Retrieval Initiation Time Period	During Closure
Waste Package Population	Full Retrieval
Waste Package Contents	Spent Nuclear Fuel/Defense High-level Waste
Retrieved Waste Disposal	Storage Onsite/Transport Offsite to Defined Location

emplacement drift envelope to accommodate are: 1) level single layer backfill (quartz sand, crushed tuff, or other material of similar favorable thermohydrologic properties), and 2) waste packages should initially be covered with at least 0.6 meters of material. This scenario involves the placement of backfill in emplacement drifts followed by a decision to retrieve. The facility has not been completely de-commissioned, but all or part of the emplacement drifts have been backfilled by the time the decision is made.

7.7.7.1 Retrieval Timeline

Figure 7-14 shows the tasks and durations for Scenario 7.

Task	Duration (Years)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. New Program Funding ¹																				
2. Strategic Planning ¹																				
3. Environmental Impact Statement ⁴																				
4. Tasks																				
A. Design																				
Onsite Storage																				
- Waste Handling Building (WHB)																				
- Option 1-Transportation Ovrpk																				
- Option 2-WHB Modifications																				
- Option 3-New WHB																				
- Transportation Cask ²																				
B. Procurement																				
- Construction Contracts																				
- Long Lead Items																				
C. Construction																				
- WHB Modifications																				
- New WHB																				
- Onsite Storage Pad ³																				
D. System Operations Test																				

¹Order to retrieve includes new program funding and strategic planning

²Use existing transportation cask design

³Surface storage facility construction concurrent with retrieval operations

⁴Includes time required for Licensing

Figure 7-14. Preparation Period for Retrieval - Scenario 7

7.7.7.2 Ventilation Considerations

The drifts have previously been cooled to allow backfill placement, but begin to reheat after completion of backfill and ventilation stoppage. The backfill acts as an insulating layer and absorbs much of the waste package heat output. Water inflow is assumed to preclude backfill removal by pneumatic concepts; however, the water is assumed not to flow from the drift as the large amount of granular backfill tends to hold the water. The waste heat also tends to drive most of the liquid water to vapor. The temperature around the waste package could be in excess of 200°C. A breached package is assumed. The breach is assumed to be only a crack, with the package essentially structurally intact. (If it had been severely damaged prior to backfill, the damage would have been discovered in the process of backfilling the emplacement drift. After backfilling, there is no plausible way to severely damage a waste package).

Ventilation must be re-established through the drift. It is important to note that the backfilling operation will not result in complete blockage of the drift. The upper area of the drift would remain open. A temporary fan and filtration system at the bottom of the exhaust raise supplement the flow induced by the main ventilation system, and allow potentially contaminated airborne dust to be captured. The retrieval operation is very dusty in those areas not affected by the water inflow and the filtration system would require constant attention and frequent maintenance. Only a relatively small portion of the top of the drift cross-section is available to carry air because of the backfill.

Cooling of the drift is impeded, and a long period of time is needed to cool the backfill. The retrieval operation is undertaken with portions of the backfill still very hot. The equipment operates in air no hotter than 50°C, but may have to handle hot backfill material.

7.7.7.3 Transport Capabilities

Abnormal Retrieval from Emplacement Drift—The concept described for retrieval from drifts in which the rails and/or power supply have failed is utilized in this scenario. Beginning at the drift entrance, backfill material is loaded by one of several methods. A backhoe arrangement, load-haul-dump, or gathering arm apron loader and shuttle car can be used to pick up backfill material and move it to the drift entrance. This equipment may be operated by personnel in shielded operator's cabs, remotely operated by suitably protected personnel in the vicinity, or by video from a remote location. Because there is a breached waste package in the drift, the recovered material is handled as though it were contaminated. It is loaded in rail cars, covered, and hauled to the surface. It is dumped and covered in a surface holding area. In this area, it is tested for contamination, and, if contaminated, loaded into drums and disposed of as contaminated soil.

A roadbed is built of fill as the backfill is removed. The backfill forms this roadbed if it is of suitable character. As packages are encountered, the backfill removal equipment is pulled out, and the packages are engaged and pulled onto the inclined plane hauler arrangement. All packages are handled as though breached, because they may have surface contamination. They would be covered and taken to a surface facility. The packages are only partially uncovered, and are pulled from under the remaining backfill. A sequential cycle of backfill removal and package engagement/removal is performed.

A rock fall could be encountered at some point. The previous description indicates that ventilation can be established, meaning the fall had not completely blocked the flow path. If the path were totally blocked, the process for bypassing a blocked drift must be implemented. The size of the fallen rock would be reduced by the hydraulic breaker. The broken material would be loaded out with the backfill and treated as though contaminated. The process of backfill removal and package recovery would be repeated until the drift was cleared.

From Main Drift to Surface—As with the other unlikely scenarios, each event will be separately evaluated. A transfer from the hauler to a shielded transporter is one option, while movement to the surface on the hauler is another. The overall situation, including the relative risks of contamination spread and personnel exposure, must be evaluated.

Offsite This task is similar to Scenario 6, which includes retrieval of the entire population of waste packages being retrieved during the closure period. The need still exists for maintaining flexibility in the mode of transportation offsite by rail, heavy haul truck, and legal weight truck.

7.7.7.4 Onsite Surface Storage

The need for onsite storage due to a significant external event may prompt retrieval activities. The duration of storage would be until another repository site were determined suitable and a new

repository built, or a new method for disposal identified and approved. In this scenario, the need for surface storage is paramount.

7.7.7.5 Waste Handling Facilities

Since backfill operations are in process, the assumption is that there is a backfill crew working to close the repository, and that the demolition of the surface facilities may have started. It is assumed that the waste handling building may be the last building to be demolished, due to the sound structural design of the building shell.

7.7.7.6 Site Support Facilities

If backfill operations constitute the major function at the site during this period, with some decommissioning/demolition work, a sufficient building complex to support retrieval operations may not exist. Due to the age of the facilities that were built concurrently with the waste handling building (60 years plus), it is likely that the facilities will not support a long retrieval period, and will require complete rebuilding.

7.8 RETRIEVAL RATE

It is assumed that waste retrieval under normal conditions can be accomplished at the same rate as waste emplacement (2 wp/8 hours) (CRWMS M&O 1997a) but 2 waste retrieval shifts can be accommodated versus 1 shift for emplacement.

The time required to retrieve is dependent on the number of waste packages planned for retrieval (see Table 2.2), and whether conditions are normal or abnormal conditions. If conditions are normal, the expected retrieval rate for a single suite of equipment is 4 per 16 hours, 20 per week, 1,000 per year, or approximately 10 years to retrieve the entire waste package inventory. If a need is identified to retrieve at a faster rate, this number can be doubled, by adding a second suite of equipment, to 8 in 16 hours, 40 per week, 2,000 per year, or approximately 5 years for the entire emplaced waste inventory. Under abnormal conditions (see Section 6), an engineering judgement has been made that constrains retrieval to an average of 2 waste packages in 16 hours, that would require the use of specialized equipment. In this case, all waste packages are assumed to have constraints (although this situation is unlikely), but nevertheless the assumption has been used to determine the retrieval duration. Under these abnormal conditions, the retrieval rate is much slower, 2 waste packages in 16 hours, 10 per week, or 500 per year, or approximately 20 years to retrieve. This rate may require more than one suite of equipment if conditions are extremely adverse. Figure 7-15 shows the retrieval rate from the emplacement location to surface storage.

Retrieval Options	Duration (Years)																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Abnormal Retrieval ¹ (100% of WP)																								
Retrieve WP ² Surface (100% Normal Conditions)																								
Retrieval or WP ³ to Surface Using Both North Ramp & South Ramp (100% Normal Conditions)																								

¹Assume 2 sets of Gentries & Locomotives - 2/day, 10/week, 500/year (2-shift-basis).
²Assumes 2 sets of Gentries & Locomotives - 4/day, 20/week, 1000/year (2-shift basis).
³Assumes 4 sets of Gentries & Locomotives - 8/day, 40/week, 2000/year (2-shift basis).

Figure 7-15. Retrieval Duration from Emplacement Location to Surface Storage

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8. CONCLUSION

8.1 SUMMARY

This report concludes that over a range of different input parameters, retrieval remains possible with the current Mined Geologic Disposal System (MGDS) design¹. The retrieval strategy contained in this report represents the "how" to retrieve from both normal and abnormal retrieval conditions. The seven scenarios in this report have summarized the retrieval process that would be used with the current MGDS conceptual design. Each step in the process has been addressed to the level of detail consistent with the current levels of the design. In some cases, more details were provided to obtain a better understanding of the retrieval process for each scenario. Figure 8-1 shows the schedule beginning after emplacement. Figure 8-1 includes the planning period, the repository preparation period, per the Project Planning Schedule, and the retrieval schedule based on this study.

The evaluation of past retrieval strategies has produced findings that indicate some of the areas are no longer valid since the repository and waste package concepts have changed since the publication of the *Site Characterization Plan* (SCP) in 1988. These changes are primarily due to a larger, more robust, heavier waste package design; fewer waste packages to emplace, a change in emplacement method from horizontal or vertical borehole emplacement to in-drift emplacement, as well as additional information from the site characterization program.

Based on a compliance and license assessment, the summary of the draft regulatory guide 3003, *Format and Content for the License Application for the High-Level Waste Repository*, the list of questions have been addressed to the extent possible to provide assistance in the development of the *License Application*. Further guidance has been used to direct the study research to those documents that the NRC views as valid in regard to retrievability.

The reasons have been identified that would prompt retrieval, based on the *Nuclear Waste Policy Act, as Amended* and on 10 CFR Part 60, and a distinction has been made between "waste package movement" and "retrieval". This distinction provides a more detailed breakdown than the 1986 *DOE Position on Retrievability and Retrieval for a Geologic Repository*.

The evaluations of the expected retrieval environment findings indicate that the likelihood of emplacement drift damage from seismic ground motion or fault displacement during the pre-closure period is small. The probability is one-chance-in-a-hundred of a modest fault occurring in the north ramp area, and the probability of faulting in the waste-emplacement areas is even less.

The probability of rockfalls has been addressed, and the evaluation has produced findings that indicate that there are data gaps. The intent is to verify that, for most of the expected ground support conditions and loads, the drifts are stable and can be supported with conventional ground support. Although site specific rock mass data have been collected from the ESF, it is not possible to define a single set of parameters that describe the rock mass, or the variation of the parameters throughout the site. Ground support design accommodates thermal loading, but ground support performance data has not yet been acquired. Thermal expansion and modulus are not well defined.

¹Based on VA MGDS Design in process

The issue of water being present, if retrieval is required, has been evaluated in terms of water table rise, perched water, current percolation flux, and future climate change. This evaluation concluded that the possibility of a water table rise has been discounted by the National Academy of Science (1992); perched water is very unlikely to be encountered; percolation flux will likely not be redistributed during the preclosure period to cause water inflow in the emplacement drifts; and future climate change is not an issue for the preclosure period.

Other repository operating parameters had been identified and evaluated prior to the development of the retrieval scenarios. These parameters include temperature and radiation levels that drive the need to cool emplacement drifts prior to retrieving waste packages, as well as the need for remotely-operated equipment to retrieve waste packages under normal and abnormal conditions.

A process flow diagram was developed to show the logical task sequence and relationships of operational and support activities that must be accomplished by the system. This process flow diagram was linked to logic diagrams, which represent a logic model of performance activities and those events that could challenge the successful completion of retrieval. This diagram has been used as the basis for developing the seven retrieval scenarios in determining the combinations of events and functions unique to retrieval.

The parameters used to create each scenario are as follows:

- Reason for retrieval
- Retrieval conditions
- Time period retrieval initiated
- Waste package population
- Waste package content
- Disposition of retrieved waste.

Table 8-1 shows a summary of the retrieval scenarios. Each scenario was evaluated for the estimated time in years required to retrieve the waste packages. The timeline for the full retrieval scenarios was estimated from 7 to 12 years. The scenarios contain alternate means of retrieving waste packages that provide additional possibilities on methods of retrieval.

8.1.1 Licensing Assessment Matrix

Table 8-2 lists the section numbers that contain the responses to the questions in Section 4, which address licensing issues that can be answered as a result of this study. For the questions that could not be addressed, recommended resolution actions are identified.

Integrated Retrieval Schedule

- NOTES**
- A. Based on Project Summary Schedule Reference Project Cost and Schedule Baseline, YMP-CM-0015, Rev. 11. FY2003 and beyond - not in current baseline
 - B. Recommendations from this report
 - C. Based on M&O Waste Quantity Mix and Throughput Study Report - 1997 B000000000-01717-5705-00059, Rev. 00
 - D. Based on M&O Waste Quantity Mix and Throughput Study Report-with one year additional (estimated) for QC verification of records - March 1997 B000000000-01717-5705-00059, Rev. 00
 - E. Based on MGDS System Requirements Document - April 1997 B000000000-01717-1708-00008, Rev. 3
 - F. Based on Retrieval Period Systems Study Report - September 1994 and Findings from this report B000000000-01717-5705-00017, Rev. 00
 - G. December 1988 SCP 4-10 year closure - DOE/RW/0199
 - H. Retrieval shown 50 years from start of emplacement

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Table 8-1. Summary of Retrieval Scenarios

Scenario Number	Reason for Retrieval	Retrieval Conditions	Time period Retrieval Initiated	Waste Package Population	Waste Package Content	Disposition of Retrieved Waste
1	Public Health & Safety (Total System Performance Failure)	Normal	During Caretaker Period, 50 Years from Emplacement Start Date	Full Retrieval	SNF/ DHOW	Onsite Storage/Transport to Offsite Location
2	(Resource Recovery)	Normal	During Emplacement Period	Partial Retrieval	SNF	Recovery/Return to Repository
3	Public Health & Safety (Poor Waste Package Performance)	Abnormal (WP Mechanical Breach-Radiation Release)	During Emplacement Period	Partial Retrieval	SNF/ DHOW	Repackage Waste/ Return to Repository
4	Public Health & Safety (Limited Emplacement Area Unsuitable)	Abnormal (Water Inflow-Limited Area)	During Caretaker Period	Partial Retrieval (Greater than 120)	SNF/ DHOW	Onsite Storage/Return to New Location in Repository
5	Public Health & Safety (Poor WP Performance)	Abnormal (Exceeds Expected Emplacement Drift Temps.)	During Caretaker Period	Partial Retrieval	SNF/ DHOW	Onsite Storage/Return to Repository
6	Public Health & Safety (Total System Performance Failure)	Abnormal (Rockfall)	During Caretaker Period	Full Retrieval	SNF/ DHOW	Onsite Storage/ Transport Offsite
7	Public health & Safety (Total System Performance Failure)	Abnormal (Backfill)	During Operations and during Closure	Full Retrieval	SNF/ DHOW	Onsite Storage/ Transport Offsite

8.1.2 Retrieval Strategy Comparison

Table 8-3 shows the comparison of the SCP strategy and the recommended retrieval strategy.

8.1.3 Summary of Key Changes

Overall, the proposed strategy incorporates most of the features of the earlier strategy from the SCP.

- The proposed strategy recognizes that under the current repository design and operational concept, the requirements for “proof-of-principle” and prototype tests to show that retrieval will be possible will be met by the tests required to assure that waste packages can be accessed and moved under normal and abnormal conditions during the operational period. No additional tests are contemplated.
- The proposed strategy includes steps to ensure that land for storage and transportation rights of way that could be needed in the event of retrieval will be available until repository closure.

8.2 RECOMMENDED RETRIEVAL DESIGN REQUIREMENTS

8.2.1 Recommended Retrieval Design Requirements

1. The Mined Geologic Disposal System (MGDS) shall have the capability to allow retrieval or movement of the emplaced waste packages from either end of an emplacement drift.

Rationale: To maximize flexibility in accessing waste packages for repository operations or accommodate retrieval under abnormal conditions, such as a rockfall.

Note: If a rockfall or damage to trackage occurs, normal retrieval equipment (gantry used for emplacement) cannot be used for those waste packages beyond the damaged track or rockfall. Specialized equipment would be required to access the waste packages at the area of damage and the remainder of waste packages in the emplacement drift. With the current concept-track extending the full length, east main to west main, over the main exhaust drift below the repository horizon, it is possible to access the remaining waste packages beyond the damaged area using normal emplacement equipment.

Applicable Study Sections: 7.7.6, 7.7.6.2, 7.7.6.3

2. The MGDS shall have the capability to emplace and retrieve waste packages concurrently from shift to shift (i.e., emplace on day shift, retrieve on the back shift or vice versa).

Table 8-2. Matrix of Answers to Licensing Questions

Questions	Answer/Location
Design	
1. How is the Geologic Repository Operations Area (GROA) designed to preserve the option of waste retrieval throughout the emplacement period and, thereafter, until the completion of a performance confirmation program and NRC review of the information obtained from such a program?	Sect 7.7.1 thru Sect 7.7.7
2. What are the design bases and details of the retrieval plans and procedures to locate, access, retrieve, and transport waste packages through the underground facility and up the ramp to the appropriate surface facilities? Include a general description of plans for retrieval and an alternative storage site in the case that Yucca Mountain were found to be unsuitable.	Sect 7.7.1 thru Sect 7.7.7
3. What provisions are provided for retrieval for the portions of the underground facility such as the openings and backfill materials, that are considered part of the engineered barrier system?	Sect 7.7.1 thru Sect 7.7.7
4. Can the waste be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement is initiated?	Sect 7.7.1 thru Sect 7.7.7
5. What is the capability for retrieval for the backfill materials used in the emplacement drifts and other drifts such as mains, or submains.	Sect 7.7.7
6. How do the ventilation systems provide air cooling for retrieval operations?	Sect 7.7.1.2, 7.7.2.2, 7.3.2, 7.7.4.2, 7.7.5.2, 7.7.6.2, 7.7.7.2
7. What are the ground support systems and the ventilation system requirements, including the drift wall temperature, drift air temperatures before cooling, capacity of refrigeration plant, quantity of air needed, and number of cooling days needed before personnel and retrieval machinery can enter?	Sect 6
8. How do the excavation and ground support systems respond under thermal loading and retrieval conditions?	Sect 6 thru Sect 7.7
9. Does the Hot Cell (waste-handling system, buildings, and equipment) have special features, systems, or special handling techniques that are important to waste retrieval operations?	Sect 7.7.1 thru Sect 7.7.7
10. How does the instrumentation and control systems monitor and control the behavior of equipment or systems important to retrievability?	Sect 7.7.1 thru Sect 7.7.7
11. How does the retrieval system include shielding and what is the sequence of retrieval operations under normal and off-normal conditions? Include the impact of category 1 and 2 Design Basis Events (DBEs) during retrievability.	Sect 7.7.1 thru Sect 7.7.7
12. What is the basis for, and analysis of, the approaches used to identify structures, systems, and components important to retrievability?	See footnote ²
13. What structures, systems, and components in the underground facility (including shafts and ramps) have been identified as important to retrievability?	See footnote ²
Radiological	
14. What are the radiological designs of the surface and underground physical facilities in the GROA that will permit safe handling and storage of radioactive wastes during retrieval? Include the radiological safety features in the design that show compliance with 10 CFR 20.	Sect 7.7.1 thru Sect 7.7.7
15. What are the radiological safety features in the designs for retrieval that provide ALARA design considerations?	Sect 7.7.1 thru Sect 7.7.7 with remote operations
16. What are the projected concentrations and the estimated intakes of radionuclides to workers in restricted areas until permanent closure expected as a result of retrieval?	Resolve with additional studies. See footnote ¹
17. What are the measures to be taken to maintain the radiological safety of workers in the underground facility, (including the measures to be taken to minimize potential levels of radioactive contamination, during retrieval for normal operations, anticipated operational occurrences, and accident conditions?	Sect 7.7.1 thru Sect 7.7.7
18. What are the projected radiation exposures to workers and to members of the public from retrieval during normal operations, anticipated operational occurrences, and accident conditions that are expected to prevail until permanent closure?	See footnote ¹
Criticality	
19. How do all systems for retrieval of radioactive waste ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety?	Sect. 7.7.1.5
Maintenance	
20. What are the maintenance plans and schedules for all surface facilities, shafts and ramps, and underground facilities important to retrievability?	Sect 7.7.1 thru Sect 7.7.7
Procurement Development	
21. What are the operating controls and limits for a repository that are important to retrievability?	Sect 7.7.1 through Sect 7.2.7

¹ This retrieval-related question will be answered in the License Application, and is not addressed in this Strategy Report.
² This is being addressed in the MGDS Systems, Structures and Components (SSCs) definition list document (in process)

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Table 8-3. Comparison of Recommended Retrieval Strategy and SCP Strategy

SCP Strategy	Recommended Strategy
No equivalent.	To the maximum extent possible, all design and construction requirements related to retrieval shall be deferred until the time to retrieve, to allow actual retrieval conditions to dictate retrieval requirements.
No equivalent.	To the extent possible, the retrieval strategy shall be tied to the method used for emplacement.
To build an acceptable level of confidence that retrieval is possible, proof-of-principle demonstrations (component testing) must be documented and completed before license application. Those components that may have some degree of performance uncertainty will be tested to provide reasonable assurance that the planned retrieval method will function under abnormal conditions.	<p>To build an acceptable level of confidence that retrieval is possible, proof-of-principle demonstrations must be completed and documented before license to receive and possess waste.¹ Those components for which adequate demonstration cannot be provided through supplier performance data will be identified by a Test and Evaluation analysis and tested to provide reasonable assurance that the planned retrieval method will function under abnormal conditions.</p> <p>Under the current repository design and operational concept, the need for "proof-of-principle" data and tests for retrieval methods and equipment will be met by the data and tests required to show that access to and movement of waste packages will be assured during the operational period. No demonstration for retrieval is required.</p>
Prototype equipment (non-standard) development and testing will be designed, prior to receiving the license to receive and possess waste, to demonstrate the ability to operate under a range of adverse underground conditions.	<p>Prototypes of specialized (non-standard) equipment required for retrieval under abnormal conditions will be developed and tested prior to receipt of the license to receive and possess waste to demonstrate the ability to operate under a range of adverse underground conditions.</p> <p>Under the current repository design and operational concept, the need for prototype equipment development and testing for retrieval will be met by the prototype tests required to show that access to and movement of waste packages will be assured under abnormal conditions during the operational period.</p>
No equivalent requirement	A temporary storage facility that has the flexibility to store all of the emplaced waste planned for the repository will be sized and located on a plot plan, prior to license application. Further evaluation of this site will be conducted prior to the license to receive and possess waste. This site will be reserved throughout the pre closure period through repository closure. The design and construction of this facility is deferred until the time of retrieval, if required.
No equivalent requirement	Land withdrawn, or right-of-ways necessary for utilities or transportation corridors, shall be reserved until repository closure.
To the maximum extent possible, the retrieval system shall use the repository surface, subsurface facilities, and equipment in existence at the time of retrieval.	To the maximum extent possible, the retrieval system shall use the repository surface, subsurface facilities, and equipment in existence at the time of retrieval.

Table 8-3. Comparison of Recommended Retrieval Strategy and SCP Strategy (Continued)

SCP Strategy	Recommended Strategy
Reasons for removing emplaced waste packages for purposes other than retrieval (per NWPA), such as performance confirmation inspection, redistribution of inventory for ventilation purposes, relocation or transported to another area of the repository (surface or underground) shall be the responsibility of the repository operations, and shall not be considered or governed by any regulations, or requirements for retrieval.	Reasons for removing emplaced waste packages for purposes other than retrieval (per NWPA), such as performance confirmation inspection, redistribution of inventory for ventilation purposes, relocation or transported to another area of the repository (surface or underground) shall be the responsibility of the repository operations, and shall not be considered or governed by any regulations, or requirements for retrieval.
All ventilation facilities, systems, and components for retrieval shall be planned and designed at the same time as the repository.	No clear equivalent
DOE anticipates that there will be a lengthy period of preparation prior to retrieving. The retrieval time will be dependent of the number of waste packages, the degree of difficulty, and the amount of preretrieval construction necessary. The health and safety of repository personnel and the public is to be considered preeminent over the time necessary to retrieve, per 10 CFR Part 60.111(b)(3) that points out retrieval should be on a reasonable schedule which approximates the time necessary to construct the repository and emplace the waste.	No equivalent

¹The 1994 and the 1996 revision of the Civilian Radioactive Waste Management Program Plan modifies the DOE position for development of the MGDS, consistent with Congressional budget direction. As part of the descoping of activities from the SCP, the requirement for proof-of-principle prior to License Application was restated in the *DOE Program Plan* (OCRWM 1996) as "the License Application design ... will describe designs in enough detail to demonstrate reporting safety and enable compliance reviews by the Nuclear Regulatory Commission." Since demonstration can be shown in several ways this statement implies that the proof-of-principle testing can be deferred to the post License Application timeframe.

Rationale: If the reason for retrieval is waste package replacement, or resource recovery, in order to stay within a reasonable overall schedule, and avoid the need for subsurface or surface storage facilities, this continuous retrieval/emplacement could occur if necessary. See Figure 7-1, Process Flow Diagram for Retrieval, which illustrates the return of the waste package to the repository, when retrieval is conducted for engineered barrier enhancements.

Applicable Study Sections: 7.1, Figure 7-1, 7.7.7.6

3. The Waste Handling Building shall be decontaminated to below the levels that require health physics support after emplacement operations are complete and preserved until repository closure.

Rationale: Although retrieval is considered to be a remote possibility, this building is designed with massive concrete walls to provide shielding and maintain exposure to ALARA during work handling operation. Leaving the building shell should not add any additional cost, and preserves an option for other uses for operations or retrieval if required.

Applicable Study Sections: 7.7.1.6, 7.7.2.6, 7.7.3.5, 7.7.5.5, 7.7.6.4.

4. The MGDS design shall include the size and location of temporary storage facilities for retrieval and shall have the capability to store all the emplaced waste. The facility shall not be designed or constructed in parallel with the repository design, but shall be documented as to the size and preliminary location within the GROA prior to license application. Prior to receiving the license to receive and possess waste, this site shall be characterized based on established criteria for suitability or provide confidence by analysis that the site is suitable for temporary storage.

Rationale: The design and layout of the repository operations area shall be planned so as not to preclude the possibility of constructing facilities for temporary storage at a later time, if needed. The basis for this constraint is derived from 10 CFR Part 60.132(a).

Applicable Study Section: 1986 DOE Position, 3.4, 7.7.1.4, 7.7.3.4, 7.7.4.4, 7.7.5.4, 7.7.6.4, 7.7.7.4.

5. The ventilation system must be capable of cooling one emplacement drift from 200°C max to 50°C max in 30 days. Ground support must be capable of withstanding this cooldown rate. The temperature cited is that of the airflow as it enters the emplacement exhaust.

Rationale: In order to meet 10 CFR 60.111(b) it must be possible to retrieve a drift in about the same time as it took to emplace the waste.

8.2.2 Verification of Existing MGDS Requirements

1. The *MGDS Requirements Document* 3.2.H states the MGDS shall be designed to support repository construction for the 6 years prior to waste emplacement, to support initiation of retrieval at any time up to 50 years after waste emplacement operations have begun, to support retrieval operations for up to 34 years, and to support closure operations for up to 10 years. (TBV6)[CRD 3.2.3]

Rationale: The 10 year planning period prior to retrieval is supported in Section 7 of this report-planning schedules for each scenario, and the *Retrievability Period Systems Study Report* (CRWMS M&O 1994b) and the 24 years for retrieval reverts to the 24 years to emplace, based on 24 year schedule down in the RDRD. This relates to 10 CFR Part 60.111(b)(3)... "about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes." The current repository construction is currently scheduled for 6 years, but a conservative estimate has been made not to be overly restrictive.

Applicable Study Sections: Table 2-2, Figures 7-7, 7-9, 7-10, 7-11, 7-12, 7-13 and 7-14.

2. The MGDS Requirements Document 3.2.J states: The MGDS shall have the capability to retrieve all emplaced disposal containers in 34 years (TBV7)[CRD 3.1.1.C]

Rationale: The 10 year planning period prior to retrieval is supported in Section 7 of this report-planning schedules for each scenario, and the *Retrievability Period Systems Study Report* (CRWMS M&O 1994b) and the 24 years for retrieval reverts to the 24 years to emplace, based on 24 year schedule shown in the *Repository Design Requirements Document*. This relates to 10 CFR Part 60.111(b)(3)... "about the same time as that devoted to construction of the geologic repository operations are and the emplacement of wastes." The current repository construction is currently scheduled for 6 years, but a conservative estimate has been made not to be overly restrictive.

Applicable Study Sections: Table 2-2, Figures 7-7, 7-9, 7-10, 7-11, 7-12, 7-13 and 7-14.

8.3 RECOMMENDATIONS

1. The suggested design requirements are candidate requirements for inclusion in the next revision of the appropriate requirements document. Where necessary clarification of suggested requirements will be implemented during the revision of the process.

Recommended Design Requirement from Section 8.2	TBV to be withdrawn	Assumption in CDA to be withdrawn
8.2.1.1	TBV none	none
8.2.1.2	TBV none	none
8.2.1.3	TBV none	none
8.3.1.4	TBV none	Key 061
8.2.1.5	TBV none	none
8.2.2.1	TBV 6	Key 055
8.2.2.2	TBV 7	none

2. The next revision to the *MGDS Functional Analysis Document* should use the process flow diagram (Figure 7-1) and supporting information contained in this report, as input to the functional analysis for the retrieval functions.
3. Prior to receiving a license amendment to receive and possess waste, a test and evaluation requirements analysis, conducted as part of the Test and Evaluation Plan, should consider proof-of-principle demonstrations for repository emplacement equipment that support waste retrieval.
4. Prior to receiving a license amendment to receive and possess waste, a test and evaluation requirements analysis, conducted as part of the Test and Evaluation Plan, should consider

prototype equipment development and demonstration for repository operations that support waste retrieval.

5. The MGDS design analysis should evaluate the need to provide waste package movements for operational purposes, addressing areas of thermal loading balance, performance confirmation sampling and inspection, emplacement drift ground support maintenance, and corrective action from waste package fabrication or material defects.
6. Incorporate data on ground support response from the Drift Scale Tests into the drift design methodology. Although, a minimal amount of data will be available to affect the Viability Assessment, data may be essential for License Application.
7. A licensing evaluation should be conducted to determine the necessity to retrieve all or any damaged waste packages, if the postclosure performance objectives can be met by leaving them in the repository. This may be a desirable conclusion for conditions of highly difficult or dangerous retrieval.
8. A CRWMS M&O study should consider in part whether partial retrieval may upset the expected thermal regime by decreasing near-field temperatures and thus reducing the dry-out period of the potential repository; i.e., the remaining waste packages would be exposed to moisture earlier than with a full repository. This may result in worse postclosure waste isolation performance than leaving damaged waste packages in the repository. Partial retrieval, however, could be offset by replacing the retrieved waste packages with new waste packages, resulting in the full 70,000 MTU inventory at the repository closure. Relocating waste packages within the repository, including re-emplacing retrieved and rehabilitated waste packages in different locations from their original emplacement locations, may improve postclosure waste isolation performance. This effect could result from balancing locally varying thermal effects to account for varying rock thermal and hydrological properties.
9. The *Mined Geologic Disposal Systems Requirements Document* should be revised to reflect the potential reasons for waste package movement that may be required by repository operations during the preclosure period (per Section 5), and address the need to maintain access and emplacement drift infrastructure after a partial retrieval to not preclude the use of emplacement drift backfill at the end of the preclosure period, per the conclusions from the 1997 *Engineered Barrier System Performance Requirements Systems Study Report*. Also for purposes of the performance confirmation program, per 10 CFR Part 60.111(b)(1)...until the completion of a performance confirmation program and Commission review of the information obtained from such a program. Currently CDA Key 061 addresses performance confirmation requirements for underground opening access for data acquisition.
10. Future land withdrawal or right-of-way transactions involving the need for utilities or transportation corridors should extend until the completion of repository closure.

11. Based on recommended strategy Section 8.1.2.2 of the Controlled Design Assumption Key 065 should be withdrawn.
12. Surface waste handling facilities, "Q" listed structures, systems, and components would have to be inspected, tested and repaired or replaced before the facilities would be put back into operations.

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APPENDIX A
ACRONYMS AND ABBREVIATIONS

APPENDIX A ACRONYMS AND ABBREVIATIONS

ACD	Advanced Conceptual Design
ALARA	As Low As Reasonably Achievable
BCP	Baseline Change Proposal
BWR	Boiling-Water Reactor
CFR	Code of Federal Regulations
CHLW	Commercial High-level Radioactive Waste
CSNF	Commercial Spent Nuclear Fuel
DBE	Design Basis Event
deg	Degree
DHLW	Defense High-Level Radioactive Waste
DOE	Department of Energy
DPC	Dual Purpose Canister
EA	Environmental Assessment
EBDRD	Engineered Barrier Design Requirements Document
ESF	Exploratory Studies Facility
FY	Fiscal Year
GROA	Geologic Repository Operations Area
HLW	High-Level Radioactive Waste
LLNL	Lawrence Livermore National Laboratories
LLW	Low-Level Radioactive Waste
LWR	Thermal Light-Water-Cooled Reactor
m	Meter
MGDS	Mined Geologic Disposal System
MPa	Megapascals (unit of confining pressure)
MPC	Multi-Purpose Container
MTHM	Metric Tons of Heavy Metal
MTU	Metric Tons of Uranium
NCAR	National Center for Atmospheric Research
NRC	Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
NNWSI	Nevada Nuclear Waste Storage Investigations
PHA	Preliminary Hazards Analysis
Q-LIST	List of Systems, Structures and Components Important to Safety
PWR	Pressurized-Water Reactor
RH	Relative Humidity
RIG	Remote Inspection Gantry
SCP	Site Characterization Plan
SCPB	Site Characterization Program Baseline
SCP-CDR	Site Characterization Plan Conceptual Design Report
SAT	Single Heater Test
SNF	Spent Nuclear Fuel
SNL	Sandia National Laboratories
SSCs	Structures, Systems, and Components
TBM	Tunnel Boring Machine

UCF	Uncanistered Fuel
WBS	Work Breakdown Structure
WHB	Waste Handling Building
WP	Waste Package
YMP	Yucca Mountain Project

APPENDIX B
GLOSSARY

GLOSSARY

Abnormal Condition: Unplanned event or condition that adversely affects, potentially affects or indicates degradation in the safety, security, environmental or health protection performance or operation of a facility.

Abnormal Retrieval Condition: A condition where the normal emplacement equipment cannot function in reverse for retrieval. This would most likely be an unexpected natural event such as displacement (due to a seismic event) or loss of the rail/power system.

Acceptance: The process by which the CRWMS will take title to and physical possession of SNF or HLW from the Purchaser/Producer/Custodian. Conceptually, acceptance is accomplished by execution of the Accept and Transport Waste functions. Specifically, acceptance is the planning, preparation, and completion of the documentation necessary to transfer title. Any actual handling of the SNF and HLW related to their transfer is accomplished by other CRWMS elements: primarily the Waste Acceptance and Transportation element and/or the Purchaser/Producer/Custodian (CRWMS M&O 1997b).

Actinides: A set of 14 radioactive heavy metals, from thorium to lawrencium in the periodic chart of elements (OCRWM 1996).

As Low As Reasonably Achievable (ALARA): An approach to radiological control to manage and control exposures (individual and collective) to the work force and to the general public at levels as low as is reasonably, taking into account social, technical economic, practical and public policy considerations. As used in this Manual, ALARA is not a dose limit but a process that has the objective of attaining doses as far below the applicable controlling limits as is reasonably achievable (DOE 10 CFR Part 20, 1996)

Barrier: Any material or structure that prevents or substantially delays the movements of water or radionuclides (OCRWM 1990).

Canister: The structure surrounding the waste form (e.g., HLW immobilized in borosilicate glass) that facilitates handling, storage, transportation, and/or disposal. A canister is a metal receptacle with the following purpose: (1) for solidified HLW, its purpose is a pour mold and, (2) for SNF, it may provide structural support for intact SNF, loose rods, nonfuel components, or it may provide confinement of radionuclides (CRWMS M&O 1997b).

Caretaker Phase: This phase begins when all the waste has been emplaced and includes safeguarding the waste, maintaining surface and subsurface facilities, protecting the retrieval option, gathering data to support predictions of the MGDS performance, and preparing an application to amend the MGDS license for permanent closure. This phase will be terminated by a direction to retrieve the waste or an authorization to close the MGDS (CRWMS M&O 1997b).

NOTE: Retrieval may be initiated during either the Operations or the Caretaker phases because of system performance issues or desire to recover resources. Retrieval will become a stand-alone phase, if initiated.

Category 1 Design Basis Events: Those natural and human-induced events that are reasonably likely to occur regularly, moderately frequently, or one or more times before permanent closure of the geologic repository operations area (10 CFR Part 60 1996).

Category 2 Design Basis Events: Other natural and man-induced events that are considered unlikely, but sufficiently credible to warrant consideration, taking into account the potential for significant radiological impacts on public health and safety (10 CFR Part 60 1996).

Civilian Radioactive Waste Management System (CRWMS): The composite of sites, facilities, systems, equipment, materials, information, activities, and personnel required to perform those activities necessary to manage spent nuclear fuel and high-level radioactive waste disposal (CRWMS M&O 1997b).

Closure Phase: This phase includes closing and sealing the subsurface facilities; decontaminating, decommissioning, and removing the surface facilities; creating institutional barriers; and returning the site to as natural a condition as required by the NRC (CRWMS M&O 1997b).

Co-Disposal of SNF and DHLW: Locating of SNF and DHLW in the same waste package (WP) and then depositing the WP in an emplacement drift within the repository.

Commercial High-Level Radioactive Waste (CHLW): The high-level radioactive waste, as defined by NWPA 42 USC 10101(12), resulting from reprocessing spent nuclear fuel in a commercial facility (CRWMS M&O 1997b).

Commercial Spent Nuclear Fuel: SNF, of domestic origin, that was generated in a civilian nuclear power reactor, and includes (1) intact, non-defective fuel assemblies; (2) failed fuel assemblies in canisters; (3) fuel assemblies in canisters; (4) consolidated fuel rods in canisters; (5) nonfuel components inserted in PWR fuel assemblies, including, but not limited to, control rod assemblies, burnable poison assemblies, thimble plug assemblies, neutron source assemblies, and instrumentation assemblies; (6) fuel channels attached to BWR fuel assemblies; and (7) nonfuel components and structural parts of assemblies in canisters. (As defined in 10 CFR 961.11.) (CRWMS M&O 1997b).

Construction Phase: This phase includes construction and equipping of surface facilities, refurbishing ESF openings, continued excavation and equipping of subsurface facilities, gathering data to support predictions of the MGDS performance, fabrication of disposal containers, demonstration of some MGDS operations, and updating the application for a license to receive and possess waste. Approximately 10 percent of the emplacement drifts will be completed in this phase (CRWMS M&O 1997b).

Container: The component of the waste package that is placed around the waste form or the canistered waste form (CRWMS M&O 1997b).

Corrective Action: Measures taken to rectify conditions adverse to quality and, where necessary, to preclude repetition (OCRWM 1997).

Credible Abnormal Retrieval Condition: Retrieval operations that occur subsequently to natural and human-induced events that are reasonably likely to occur regularly, moderately frequently, or one or more times before permanent closure of the geologic repository operations area.

Credible Event or Credible Accident: An event or accident scenario which needs to be considered in the design of a geologic repository (OCRWM 1990).

Criticality Control: The suite of measures taken to maintain nuclear fuel, including spent nuclear fuel, in a subcritical condition during storage, transportation and disposal, so that no self-sustaining nuclear chain reaction can occur. Subcriticality is assured by loading spent fuel in specific configurations that meet certain requirements related to fuel age, enrichment, and reduction in nuclear fuel reactivity through burnup (OCRWM 1996).

Defense High-level Radioactive Waste (DHLW): The high-level radioactive waste, as defined by NWPA 42 USC 10101(12), resulting from reprocessing spent nuclear fuel in a defense facility (CRWMS M&O 1997b).

Design Basis Events (DBE): Those natural and human-induced events that are reasonably likely to occur regularly, moderately frequently, or one or more times before permanent closure of the geologic repository operations area; and other natural and man-induced events that are considered unlikely, but sufficiently credible to warrant consideration, taking into account the potential for significant radiological impacts on public health and safety (10 CFR Part 60, 1996).

Design Input: Those criteria, parameters, bases, or other design requirements upon which design output documents are based (OCRWM 1997).

Design Output: Drawings, specifications, and other documents resulting from the translation of design input requirements of items (OCRWM 1997).

Disposal: The isolation of radioactive wastes from the accessible environment. (As defined in 10 CFR 60.2) Disposal means the emplacement of high-level radioactive waste, spent nuclear fuel, or other highly radioactive material in a repository with no foreseeable intent of recovery, whether or not such emplacement permits the recovery of such waste. (As defined in 10 CFR 961.11 and NWPA 42 USC 10101(9).) (CRWMS M&O 1997b).

DOE: The U.S. Department of Energy or its duly authorized representatives (10 CFR Part 60 1996).

DOE-owned Spent Nuclear Fuel (DOE SNF): SNF that is currently managed by DOE, and includes fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated. DOE SNF includes, but is not limited to, production reactor fuel, research reactor fuel, naval fuel, and some fuel from commercial power reactors (CRWMS M&O 1997b).

Emplacement Drift Backfill: Material added to enhance the waste isolation capability of the engineered barrier. Initial studies indicate that 0.6 meters of backfill would be required over the waste packages (CRWMS M&O 1997b).

Engineered Barrier System: The waste packages and the underground facility (10 CFR Part 60 1996).

Fault Tree Analysis: A method used to examine the various ways in which a system designed to perform a safety function can fail. Each system identified in the event tree is examined to determine how failures of components within that system could cause the failure of the entire system (OCRWM 1990).

Function: A primary statement of purpose; it defines what a system or subsystem must accomplish to meet the system mission (CRWMS M&O 1997b).

Geologic Repository: A system that is intended to be used for, or may be used for, the disposal of radioactive wastes in excavated geologic media. A geologic repository includes: (1) the geologic repository operations area, and (2) the portion of the geologic setting that provides isolation of the radioactive waste. (As defined in 10 CFR 60.2) (CRWMS M&O 1997b).

Geologic Repository Operations Area (GROA): A high-level radioactive waste facility that is part of a geologic repository, including both surface and subsurface areas, where waste handling activities are conducted. (As defined in 10 CFR 60.2) (CRWMS M&O 1997b).

Ground Support: The system (rock bolt with wire mesh, steel set, cast or precast concrete sections) used to line the main and emplacement drifts to minimize rock or earth from falling into the repository tunnels (drifts).

High-level Radioactive Waste (HLW): (1) The highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and (2) other highly radioactive material that the Nuclear Regulatory Commission, consistent with existing law, determines by rule requires permanent isolation. The CRWMS will only accept solidified HLW. For the purposes of this document, HLW is vitrified borosilicate glass cast in a stainless steel canister. (As defined in NHPA 42 USC 10101(12), 10 CFR 72.3, 10 CFR 960.2, 10 CFR 961.11. (Note that the 10 CFR 60 definition of HLW includes SNF. See definitions of commercial HLW and defense HLW.)) (CRWMS M&O 1997b).

Infrastructure: The basic facilities, services, and installations needed for the functioning of a community or society, such as transportation and communication systems (DICTIONARY) Specifically for this document it includes the surface and subsurface facilities such as the service drifts, the emplacement drifts, transporters, electrical power supplies and all of the waste handling buildings and administrative facilities.

Infrastructure Damage: Damage to those items specifically identified as facility infrastructure such as mentioned in the definition above.

Isolation: Inhibiting the transport of radioactive material so that amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits (10 CFR Part 60 1996).

License Application: A document submitted to the Nuclear Regulatory Commission containing general information and a safety analysis for either a geologic repository or an interim storage facility. A license is required to receive, possess and dispose of spent nuclear fuel and high-level radioactive waste (OCRWM 1996).

Logic Diagram: A logic model of the interaction among the process flow, reasons for the process, environment encountered by the process, and the internal and external events that could reasonably be expected to challenge successful completion of the process.

Metric Ton(s) of (Initial) Uranium (MTU): As used in this document, refers to the quantity of Uranium initially loaded into a reactor, or metric ton(s) of heavy metal as used in NWPA, or equivalent (CRWMS M&O 1997b).

Mock-Up-Test: Operation of full-sized models or prototypes of the retrieval equipment in near actual environment to substantiate the ability to successfully operate and function under a range of adverse underground conditions.

Natural Barrier: The physical, mechanical, chemical, and hydrologic characteristics of the geologic environment that individually and collectively act to minimize or preclude radionuclide transport.

Normal Condition: Those repository conditions that would normally be expected during the emplacement period and therefore allow normal emplacement and retrieval operations. An example would be that the emplacement drifts are free of debris and all systems such as power, rails, transporters, door operators and lighting are functioning.

Normal Retrieval Condition: Retrieval operations where the repository is in a normal condition status.

Nuclear Waste Policy Act (42 USC 10101 et seq.): The Federal statute enacted in 1982 that established the Office of Civilian Radioactive Waste Management and defined its mission to develop a Federal system for the management and geologic disposal of commercial spent nuclear fuel and other high-level radioactive wastes, as appropriate. The Act also specified other Federal responsibilities for nuclear waste management, established the Nuclear Waste Fund to cover the cost of geologic disposal, authorized interim storage until a repository is available, and defined interactions between Federal agencies and the states, local governments, and Indian tribes. (OCRWM 1996).

Nuclear Waste Policy Amendments Act of 1987 (42 USC 10101 et seq.): The legislation which amended the Nuclear Waste Policy Act to limit repository site characterization activities to Yucca Mountain, Nevada; to establish the Office of the Nuclear Waste Negotiator to seek a State or Indian tribe willing to host a repository or monitored retrievable storage facility; to create the Nuclear Waste Technical Review Board; and to increase State and local government participation in the waste management program (OCRWM 1996).

Off-Site/Offsite: Physically not in an area managed by DOE where access can be limited for any reason. The site boundary encompasses Controlled Areas. For purposes of this report the site can be considered the GROA.

On Site: Physically in an area managed by DOE where access can be limited for any reason. The site boundary encompasses Controlled Areas. For purposes of this report the site can be considered the GROA.

Operation Phase: This phase includes receiving the waste, preparing disposal containers, emplacing loaded disposal containers in the MGDS, gathering data to support predictions of MGDS performance, providing security and safeguards for the nuclear materials at the MGDS, and completing the excavation of emplacement drifts (CRWMS M&O 1997b).

NOTE: Retrieval may be initiated during either the Operations or the Caretaker phases because of system performance issues or desire to recover resources. Retrieval will become a stand-alone phase, if initiated.

Performance Assessment: Any analysis that predicts the behavior of a system or a component of a system under a given set of constant or transient conditions (OCRWM 1996).

Performance Confirmation: The program of tests, experiments and analyses which is conducted to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that the performance objectives for the period after permanent closure will be met (OCRWM 1997).

Permanent Closure: Final backfilling of the underground facility and the sealing of shafts and boreholes (10 CFR Part 60 1996).

Preclosure: The period of time before and during the closure of the geologic repository (OCRWM 1996).

Preliminary Hazard Analysis (PHA): This method has been structured to key on energy transfer processes associated with a given structure/system/component (S/S/C). Once sources of energy have been identified, the ways in which uncontrolled (or possibly even controlled) energy could interact adversely with other S/S/C/s are examined. To help identify these potential hazards, a generic list of threats is used as a guide.

Process Flow Diagram: An orderly (time dependent) sequence of activities required to achieve a specific objective. Any event that changes or interrupts the flow (order of the sequence of activities either prevents the objective from being achieved) or degrades the effectiveness of the process.

Proof-of-Principle: A demonstrated anticipated operation of significant components of non-standard equipment. Proof-of-principle can be achieved by reviewing supplier test data showing anticipated component performance. If such data is not available test and evaluation analysis are necessary to specify the required testing.

Q-List: Two lists (one for Mined Geologic Disposal System and one for Waste, Acceptance, Storage, and Transportation) controlled by the DOE, consisting of permanent items determined by analysis or direct inclusion (i.e., conservatively concluded by DOE to be important at MGDS,

without conducting an analysis, prior to the implementation of this procedure) to be subject to mandatory quality assurance requirements (QAP-2-3).

Quality List (Q-List): A list of structures, systems, and components that have been determined to be important to safety and engineered barriers that have been determined to be important to waste isolation (OCRWM 1990).

Records Information System (RIS): A computerized index, search, and retrieval system for records management on the Project (OCRWM 1990).

Recovery of Actinides: The act of recovering the actinides from the spent nuclear fuel by a given process such as chemical extraction.

Recovery of Resources: To procure usable substances, such as metal from unusable substances such as ore or waste (DICTIONARY).

Recovery of Waste Packages: The physical movement of a waste package from one location to another. This could be as simple as moving a waste package within a drift to another drift or transporting the waste package to the surface and then into the waste handling building.

Repository: Is synonymous with geologic repository (CRWMS M&O 1997b).

Repository Operations Management: The DOE manager responsible for the day to day operation of the repository.

Restricted Area: Any area access to which is controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials. Restricted area shall not include any areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area (10-CFR-60).

Retrievability: The capability that is provided by the repository system--by means of design approaches, construction methods, and operational procedures--to allow retrieval to be performed (DOE 1986)

Retrieval: The act of intentionally removing radioactive waste from the underground locations at which the waste had been previously emplaced for disposal (10 CFR Part 60 1996).

Retrieval Scenario: A description of the methods for retrieval under various conditions of the repository, and retrieval equipment. The scenarios take waste packages to the surface under a variety of normal and abnormal situations.

Shipment: The movement of the properly prepared (loaded, unloaded, or empty) cask from one site to another and all associated regulatory activities (CRWMS M&O 1997b).

Site Characterization: The program of exploration and research both in the laboratory and the field that is undertaken to establish the geologic conditions and the ranges of parameters of a particular site that are relevant to the implementing documents (OCRWM 1997).

Spent Nuclear Fuel (SNF): Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing. (As defined in NWPA 42 USC 10101(23)) SNF consists of commercial SNF and DOE-owned SNF. (CRWMS M&O 1997b).

To Be Verified (TBV): Term used to identify information that is unqualified, preliminary, or that needs to be reevaluated (CRWMS M&O 1997b).

Transportation Cask: A container for shipping spent nuclear fuel and/or high-level radioactive waste that meets all applicable regulatory requirements (CRWMS M&O 1997b).

Unqualified Data: Data developed prior to the implementation of an NRC approved quality assurance program that meets Office of Civilian Radioactive Waste Management requirements or data developed outside an approved NRC Quality Assurance Program such as by oil companies, universities, or data published in technical or scientific publications. Unqualified data does not include information accepted by the scientific and engineering community as established fact (OCRWM 1997).

Viability Assessment: The Program's assessment of the prospects for geologic disposal at the yucca Mountain site, based on repository and waste package designs, a total system performance assessment, a license application plan, and repository cost and schedule estimates (OCRWM 1996).

Waste Package: The waste form and any containers, shielding, packing, and other absorbent materials immediately surrounding an individual waste container. (As defined in 10 CFR 60.2) (CRWMS M&O 1997b).

Waste Package Movement: All other efforts to remove, extract, or relocate any portion of the emplaced waste during the preclosure lifetime of the repository will be done for reasons unrelated to the reasons mandating retrieval. The removal of emplaced waste for performance confirmation, inspection, analysis, or any other purpose not directly related to public health and safety (and the environment) will not be considered retrieval and will not be governed by the requirements set forth here (DOE 1986).

Yucca Mountain Project (Project): The Project was established by the U.S. Department of Energy, Nevada Operations Office, to carry out planned and systematic actions to determine the suitability of the Yucca Mountain Site (OCRWM 1990).

10 CFR Part 60: The Nuclear Regulatory Commission regulation, titled "Disposal of High-Level Radioactive Wastes in Geologic Repositories," that sets forth technical requirements governing development of a permanent geologic repository for spent nuclear fuel and high-level radioactive waste. The regulation also includes the oversight and licensing duties of the Nuclear Regulatory Commission (OCRWM 1996).

P&S Account - 1.2.1.5 M&O
P&S Account Title - Special Studies
PWBS Element Number - 1.2.1.5
PWBS Element Title - Special Studies

Baseline Start - 01-oct-1995
Baseline Finish - 27-jul-1999

	Prior	FY1997	FY1998	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	Future	At Complete
Annual Budget	1730	927	0	0	0	0	0	0	0	0	0	0	2657

Statement of Work

The following work shall be controlled in accordance with approved implementing procedures identified on the current OCRWM-accepted Requirements Traceability Network Matrix.

This account is responsible for conducting and documenting project studies that support the FY97 SRA/Design activities. Specifically, the project studies within this summary account support functional analysis, criteria development, and design synthesis, all of which are activities that support the FY98 Viability Assessment. As a formal decision tool, project studies are used to solve complex problems affecting multiple portions of the MGDS and provide documented rationale for decisions. Project studies are equally important for establishing preferred system configurations. Each of the studies in the following summary accounts will contain a 4 week (maximum) research phase in which a literature search of previous work similar to that being proposed will be examined in order to validate the need for the current activity. If the need can not be validated then the study will be stopped. If the study is approved to continue beyond the research phase interim status reviews will be held with the DOE. For all the studies in this summary account, with the exception of the Performance Confirmation Follow-on work, these reviews will occur at the end of the research phase, at the study midpoint, and at the study completion. The Performance Confirmation Follow-on work will schedule reviews at the end of the research period and on a quarterly basis thereafter.

Summary Account TR15FB1

1. Waste Isolation Requirements

Attachment 1 (Interim Postclosure Standard) of the FY97 Planning guidance provides a standard to be used "...as a planning basis for evaluating the postclosure performance of the repository until a new EPA standard is promulgated". The standard is a 10,000 year peak dose standard measured against critical groups living about 30km down gradient from Yucca Mountain. The standard also states that: Engineering measures that have potential for significantly reducing the peak dose, and could be implemented at reasonable cost, will be evaluated for possible inclusion in the reference design. The objective of this study will be to provide specific thresholds for determining a significant reduction in peak dose and for determining a reasonable cost for such a reduction. The study will identify each of the design elements contributing to long term waste isolation. The extent of contribution to long term waste isolation and the cost of that contribution will also be determined. The contribution and related cost will then be compared to the thresholds developed earlier in the study.

2. MGDS Seals Study

Develop requirements for seals in the repository ramps and shafts and in the boreholes resulting from surface based testing. Determine the role the seals must play in establishing compliance with 10CFR60 with respect to waste isolation and to returning the site back to its natural condition. Also, the study will determine the approach for meeting state and county regulations related to abandoned boreholes and the function the seals must play in meeting those requirements.

3. Performance Confirmation Follow-On Work

Supplement Performance Confirmation Program requirements important to repository design identified in the FY 96 Performance Confirmation Study with the remainder of the performance confirmation requirements. Establish the required contents of a reference performance confirmation baseline and develop a draft baseline. Develop Revision 0 of the Performance Confirmation program plan utilizing the draft plan developed in FY96 as a starting point.

4. Waste Generated Study

Determine the potential amounts of and preferred disposal options for hazardous, mixed, and low-level wastes generated by the repository, for canistered fuel and for uncanistered fuel waste streams. The study will include an evaluation of packaging options available for each disposal option considered. The study will also evaluate the options of packaging and disposing of the LLW on-site vs. packaging, transporting, and disposing of the LLW at an offsite location. The study will also provide a basis for TSLCC estimates related to LLW generation and disposal. Given the uncertainty of the location of LLW disposal sites in the extended future, the offsite disposal option will be evaluated utilizing a generic LLW disposal site with waste acceptance requirements similar to LLW disposal sites operating today.

5. Waste Package Size Study

TR15 Special Studies (continued)

Provide a technical basis for the selection of waste package sizes used for the VA and LA designs. Consider how the waste package size(s) influences handling designs, viable emplacement modes, criticality control design, shielding design, near field thermal effects, surface facility design, cost, and design for recovery from off-normal events. The study will consider packaging options for outlier fuel assemblies, alternative DHLW waste package capacities, and alternative packaging options for the DOE/SNF.

Summary Account TR15FB2

6. Waste Quantity, Mix, and Throughput Study

The objective of this study will be to develop a consistent approach for utilizing waste stream assumptions for surface, subsurface, and waste package design and to provide a technical basis for that approach. This study will build on the FY96 program studies related to waste stream characteristics (i.e. RSA/ISF/Repository Interface Contingency Study and Design Analysis Scenarios). The study will assure that items important to surface facility design and operation, as well as subsurface design and operation and waste package design, will be sufficiently specified to support design. These items will include the distribution of transportation cask sizes, the number of shipments received at the repository per year, the number of canistered vs. barefuel shipments, and the number of disposal containers (i.e. their capacities for each fuel type). In addition temporary storage requirements driven by thermal loading requirements and/or surges in the shipment rate will also be addressed. The study will also address the impact, in terms of cost, generated waste, etc., of the assumption provided in item 4 of the FY97 planning guidance enclosure 3 (supplemental technical guidance) which provides the guidance to "Utilize a modular design with redundant process trains capable of accommodating both 100% uncanistered fuel and also 75% uncanistered/25% canistered fuel".

Summary Account TR15FB3

7. Retrievability Study

Develop the technical rationale for a decision regarding the design approach to be used for complying with the 10CFR60 requirements related to retrievability. The NRC regulation requires that the Geologic Repository Operations Area "... be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and, thereafter, until completion of a performance confirmation program and commission review of the information obtained from such a program". Options available for potentially satisfying this requirement range from one extreme of developing a design that allows retrieval, if necessary, but does not include features that facilitate the retrieval to the opposite extreme of including features in the design that facilitate retrieval and, in fact, build the retrieval capability into the repository at the time of repository development. This activity will make recommendations regarding the extent to which the repository/waste package designs should accommodate the retrieval option, develop requirements associated with the time required for retrieval, and identify the potential conditions requiring retrieval. This study will also develop and evaluate potential scenarios concerning the final disposition of the retrieved waste. At the completion of each study, a baseline change request or document action request based on the study recommendations will be created and submitted, if appropriate. For those studies completed prior to the end of FY97 support to the DOE review of the study reports will be provided as necessary. For the studies scheduled for completion at the end of FY97, work scope for support to the DOE Document review is included in the FY98 Summary Account TR15GB1, System Study Support to SRA/Design. This WBS is also responsible for activities such as providing transportation-related support to NEPA and addressing technical and programmatic issues associated with the transportation of SNF and DHLW within the state of Nevada. Quarterly status reviews will be held with the DOE on the activities associated with these responsibilities. These activities are contained in the following summary account.

Summary Account TR15FB4

1) Nevada Transportation NEPA Support

This activity will 1) provide support to the NEPA core group that will develop criteria to be used for identifying rail alignments (i.e. potential locations for the track bed and track) within previously identified corridors (i.e. general stretches of land, 5 to 10 miles wide, within which the rail alignments could be placed); and 2) Identify a feasible rail corridor originating in Caliente and traversing the Nellis Air Force Range en route to Yucca Mountain.

2) Transportation Rapid Response

Address technical and programmatic issues associated with transportation of SNF and DHLW within the state of Nevada. Provide coordinated responses to program or project level transportation related inquiries. This activity is also required to support the coordination of intergovernmental activities with various state, local, and national government entities being conducted by Institutional and External Affairs. Provide input for all WBS 1.2.1.5 activities and deliverables to the Monthly System Status Review described in P&S account 1.2.1.1.

TR15 Special Studies (continued)

DELIVERABLES

Deliv ID	Description/Completion Criteria	Due Date
SE050BM3	<p>Performance Confirmation Report</p> <p>Criteria - The FY 97 Performance Confirmation Study Report should supplement the Performance Confirmation Program requirements identified in the FY 96 Performance Confirmation study with the remaining performance confirmation requirements. This report should establish the required contents of a reference performance confirmation baseline and provide a draft version of that baseline. Development of a performance confirmation program plan, containing a performance confirmation program description, should be included in this study report. A QAP-3-5 and an M&O management review of the report must be completed prior to delivery to the DOE.</p>	30-sep-1997
SE200M3	<p>Complete Throughput Study</p> <p>Criteria - The study report should contain a recommendation, with a technical basis, for a consistent approach for utilization of waste stream assumption for surface, subsurface, and waste package design. The study should assure that items important to repository design and operation will be sufficiently specified to support repository design. Temporary storage requirements driven by thermal loading requirements and/or surges in the shipment rate should also be addressed. A QAP-3-5 and an M&O management review of the report must be completed prior to delivery of the report to the DOE.</p>	31-mar-1997
SE436M3	<p>Waste Generated Study Report</p> <p>Criteria - The Waste Generated Study Report should contain the estimates made of the potential amounts of Low Level Waste (LLW), hazardous waste, and mixed waste generated by the repository, for both canisterized as well as uncanisterized fuel waste streams. An examination of the options for disposal of this waste should include both on-site and off-site disposal options. The study should include an evaluation of packaging alternatives of the waste for either shipment off-site or disposal on-site. A QAP-3-5 and an M&O management review of the report must be completed prior to delivery of this report to the DOE.</p>	30-sep-1997
SE440M3	<p>Waste Isolation Req'mt Study Report</p> <p>Criteria - The study report will address an approach for providing thresholds for determining a significant reduction in peak dose and for determining a reasonable cost for such a reduction. The report will also contain an evaluation of the contribution to waste isolation made by each of the major elements of the repository system. Finally, the report will address the cost associated with each of the major elements considered. A QAP-3-5 and an M&O management review of the report must be completed prior to delivery of the report to the DOE.</p>	01-apr-1997
SE456M3	<p>Rail Corridor Evaluation Report</p> <p>Criteria - The Rail Corridor Evaluation Report will identify a feasible corridor less than five miles wide, originating in the Caliente area with an option to start at Crestline, and traverse the NAFR and NTS lands to Yucca Mountain. The report will evaluate alternative corridors in areas where there may be an impact to operations, private land, future planned projects, or known environmental impacts. An M&O technical and programmatic review of the report must be completed prior to delivery of the report to the DOE.</p>	30-apr-1997

TR15 Special Studies (continued)

DELIVERABLES

Deliv ID	Description/Completion Criteria	Due Date
SE460M3	Waste Package Size Study Report Criteria - The Waste Package Size Study Report will develop a technical basis for the selection of appropriate waste package sizes. The evaluation will include considerations of repository cost, schedule, and risk. This report will evaluate the potential advantages to the overall system, rather than elements of the system, when comparing one waste package size to another. A QAP-3-5 and an M&O management review of the report must be completed prior to delivery of the report to the DOE.	30-sep-1997
SE502M3	Retrievability Study - VA Rpt. Criteria - This report should contain a technical rationale for a decision regarding the design approach to be used for complying with the 10CFR60 requirements related to retrievability. The report should also contain recommendations regarding the extent to which the repository/waste package designs should accommodate the retrieval option, develop requirements associated with the time required for retrieval, and identify the potential conditions requiring retrieval. This study will also develop and evaluate potential scenarios concerning the final disposition of the retrieved waste. A QAP-3-5 and an M&O management review of the report must be completed prior to delivery of the report to the DOE.	30-apr-1997
SE506M3	Seals Study Report Criteria - The MGDS Seals Study Report will evaluate the need for seals in the repository and in the boreholes resulting from surface-based testing. The regulatory requirements relative to seals should be considered. An evaluation will be made of an approach for closing the repository and leaving no new preferential pathways for radionuclide transport as a result of repository construction and operation or surface-based testing. A QAP-3-5 and an M&O management review of the report must be completed prior to its delivery to the DOE.	30-may-1997

Approvals

PHIL GSHNER
Preparer - print name

4/30/97
Date

Technical Reviewer - print name

Date

QA Reviewer - print name

Date

Phil Gshner
Preparer - signature

Technical Reviewer - signature

QA Reviewer - signature