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Modular Construction System Evaluation

Pre-Decisional Study

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DISCLAIMER

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EXECUTIVE SUMMARY

PURPOSE AND SCOPE

The purpose of this study is to respond to U.S. Department of Energy (DOE) Technical Direction Letter (TDL) 02-003 (Waisley 2001), which directs Bechtel SAIC Company, LLC (BSC) to complete a design study to recommend repository design options to support receipt and/or emplacement of any or all of the following: commercial spent nuclear fuel (CSNF), high-level radioactive waste (HLW), DOE-managed spent nuclear fuel (DSNF) (including naval spent nuclear fuel [SNF]), and immobilized plutonium (if available), as soon as practicable, but no later than 2010. From the possible design options, a recommended approach will be determined for further evaluation to support the preliminary design of the repository.

This study integrates the results of the repository Design Evolution Study (Rowe 2002) with supporting studies concerning national transportation options (BSC 2002b) and Nevada transportation options (Gehner 2002). The repository Design Evolution Study documents the processes used to reevaluate the design, construction, operation, and cost of the repository in response to TDL 02-003 (Waisley 2001), and to determine possible repository conceptual design options. The transportation studies evaluate the national and Nevada transportation options that support the repository conceptual design options. An evaluation methodology was established, based on Program-level requirements developed for the study in reference BSC 2001a, to allow the repository and system design options to be evaluated on a consistent basis. The transportation options and the design components were integrated into system design implementation options, which were evaluated using receipt and emplacement scenarios. The scenarios tested the ability of the design concept to adapt to changes in funding, waste receipt rate, and Nevada rail transportation availability. The results of the evaluation (in terms of system throughput, cost, and schedule) were then compared to the Program-level requirements, and recommendations for design alternatives, requirements changes, or further evaluation were developed.

ANALYSIS

Seven receipt and emplacement scenarios were developed to evaluate the recommended design concept.

- **Scenario 1 – Mostly Rail, Reference Receipt Rates**

  This scenario assumes that wastes are transported to the repository in accordance with the target schedule in the *Civilian Radioactive Waste Management System Requirements Document* (CRD) (DOE 2001a, Table 1). CSNF selection for transport at utility sites is in accordance with the "youngest fuel first greater than 10 years old" (YFF10) criterion (see Appendix A for definition). Transportation is "mostly rail" (i.e., rail with legal weight truck [LWT] transport only for sites that cannot handle a rail cask). Waste is emplaced as received, with no storage. Emplacement occurs first in the subsurface Panel 1, followed immediately by emplacement in Panel 2 and subsequent panels as needed. Surface facility phases are constructed as needed to meet the receipt rate.

- **Scenario 2 – Mostly Rail, Initial APR/ACR Receipt Rate**

  This scenario assumes the same transportation modes as Scenario 1. The CSNF receipt rate is capped at the maximum rate shown in the Acceptance Priority Ranking/Acceptance Capacity Report (APR/ACR) (DOE 1995a) for 10 years (until 2019). Beginning in 2020, the CSNF receipt rate ramps up to 3,600 metric tons of heavy metal (MTHM)/year to allow the receipt schedule to catch up to the CRD target schedule.

- **Scenario 3 – Mostly Rail, Reference Receipt Rate, Delayed Emplacement**

  This scenario is similar to Scenario 1, except that after the testing area in Panel 1 is filled (approximately 1200 MTHM of CSNF and a proportional amount of defense wastes), no more waste is emplaced until 2020. This simulates a postulated requirement to perform testing on the waste emplaced in the testing area prior to proceeding with further emplacement. During this time (2013-2019), all of the waste received is assumed to be stored on the surface. In addition, construction of subsurface Panels 2-4 is delayed by 8 years. After 2019, waste emplacement resumes, at a CSNF rate 3,600 MTHM/year.

- **Scenario 4 – Mostly Rail, Accelerated Receipt and Emplacement Rate**

  This scenario is similar to Scenario 1, but assumes that the CSNF waste receipt and emplacement rates are increased by 1/3 to a maximum of 4,000 MTHM/year.

- **Scenario 5 – Initial Truck/Heavy Haul, Low Rate**

  This scenario assumes that the Nevada rail line will not be available until 2015; therefore, transportation to the repository during the first 5 years of operation will be by LWT and limited heavy haul (for naval SNF only). The initial CSNF transportation rate is limited to 100 MTHM/year, and the HLW transportation rate is limited to 10 MTHM/year. Naval SNF is assumed to be shipped by heavy haul until 2015. The CSNF receipt rate ramps up to 3,600 MTHM/year after 2014, to allow the receipt to catch up with the CRD target schedule; the defense wastes receipt rates ramp up to the reference rate. Construction of subsurface Panels 2 - 4 is delayed by 3 years.

- **Scenario 6 – Initial Truck/Heavy Haul, High Rate**

  This scenario is similar to Scenario 5, except that the initial (2010-2014) receipt rates for CSNF and defense wastes (except naval SNF) are increased by a factor of four.

- **Scenario 7 – Initial Truck/Heavy Haul, High Rate, 2 Year Rail Delay**

  This scenario is similar to Scenario 6, but assumes that the Nevada rail line will become operational in 2012, instead of 2015.

For each of the receipt and emplacement scenarios, the construction and operation of the modular components of the repository surface facilities were time-phased to match the receipt, aging, and emplacement rates. This was accomplished by matching the capabilities of the modular components to the annual receipt rates.

It should be noted that the preliminary construction schedules developed for the surface and subsurface facilities in the Design Evolution Study (Rowe 2002) result in an initial operation date of December 2010. While this meets the goal of 2010 initial operation, it does not allow for receipt and processing of a significant quantity of waste in calendar year 2010 (certainly not approaching the CRD target level of 400 MTHM CSNF). However, for the purpose of performing the cost analysis, this inconsistency was not considered (i.e., receipt and emplacement rates were assumed to match the values given in Appendix C).

Direct costs for facilities that have changed from the Site Recommendation (SR) design, per this study, were based on unit rates derived from the May 2001 Total System Life Cycle Cost (TSLCC) estimate. For the facilities that are unchanged from the SR design, the direct costs were based on the total direct cost values from the May 2001 TSLCC. The operations and maintenance (O&M) costs were based on the May 2001 TSLCC estimate, adjusted for items included in other parts of the estimate. O&M costs were also adjusted for each scenario to account for variations in receipt and emplacement rates.

Repository indirect costs include engineering, licensing, management support, administration, Payments Equivalent to Taxes (PETT), Benefits (i.e., payments to the state of Nevada and local governments), and Program Integration and Institutional (PI&I) costs. These costs were calculated based on rates from the May 2001 TSLCC. In addition, the contingency factors used in the May 2001 TSLCC were reviewed and increased as necessary to reflect the conceptual nature of the modular design concept.

RESULTS

Table ES-1 summarizes the logistics results for the 7 scenarios, as compared to the May 2001 TSLCC reference case. Note that the Maximum CSNF Storage Capability in Table ES-1 is the amount of storage capability costed in the analysis, not the maximum actually in storage at any one time.

Table ES-1. Logistics Results

Scenario	Total CSNF Accepted, 2010-20 (MTHM)	Total CSNF Emplaced, 2010-20 (MTHM)	Maximum CSNF Storage Capability (MTHM)[1]
TSLCC	25,200	25,200	5,000[1]
1	25,200	25,200	1,400[2]
2	10,000	10,000	1,400[2]
3	25,200	4,800	21,400[2]
4	33,610	33,610	1,400[2]
5	11,250	11,250	1,400[2]
6	12,600	12,600	1,400[2]
7	19,800	19,800	1,400[2]

[1] Pool storage for blending purposes
[2] Comprised of 400 MTHM pool storage, with the remainder in dry storage

Of the 7 scenarios, only scenarios 1, 3, and 4 meet or exceed the May 2001 TSLCC total receipt through 2020, and only scenarios 1 and 4 meet or exceed the May 2001 TSLCC total emplacement through 2020. Scenarios 5 - 7 fail to meet the TSLCC receipt and emplacement totals through 2020 due to the low initial receipt rate caused by delayed Nevada rail construction. Scenario 2 fails to meet the TSLCC total receipt and emplacement due to limiting the receipt rate for the first 10 years to the APR/ACR rate. Scenario 3 meets the TSLCC total receipt through 2020, but fails to meet the TSLCC total emplacement, due to the moratorium on emplacement from 2013-2019.

Table ES-2 shows the total Civilian Radioactive Waste Management System (CRWMS) future costs through 2010 and 2020, as well as the peak annual costs through 2010 for the 7 scenarios and the May 2001 TSLCC.

Table ES-2. CRWMS Future Costs, 2002-2020 (M 2002$)[1]

FY	TSLCC	Scen 1	Scen 2	Scen 3	Scen 4	Scen 5	Scen 6	Scen 7
Total 2002-10	8,970	7,930	7,610	7,470	8,070	6,410	6,950	7,490
Total 2002-20	19,570	21,190	18,640	19,150	22,340	17,960	18,780	20,110
Peak 2002-10	1,630	1,540	1,520	1,290	1,720	1,060	1,370	1,480

[1] Costs rounded to the nearest $10 million

Note that all of the scenarios exhibit lower total costs through 2010 than the May 2001 TSLCC, and all but Scenario 4 exhibit lower peak costs through 2010. Scenarios 1,4, and 7 exhibit higher total costs through 2020 than the May 2001 TSLCC.

Table ES-3 shows the total life cycle cost for receipt and emplacement of 97,800 MTHM for the May 2001 TSLCC and the 7 scenarios.

Table ES-3. Total Life Cycle Cost for 97,800 MTHM Emplacement (B 2002$)

Scenario	Historical Costs	WAST	Nevada Transportation	Repository	PI&I	Total	Delta to May 2001 TSLCC
May 2001 TSLCC[1]	9.0	6.2[2]	0.9	37.5	6.4[3]	60.0	0
1	9.0	5.6	1.0	40.6	**6.8**	**62.9**	**2.9**
2	9.0	5.7	1.0	40.2	**6.0**	**61.9**	**1.9**
3	9.0	5.6	1.0	44.0	**6.8**	**66.3**	**6.3**
4	9.0	5.2	1.0	40.6	**6.8**	**62.6**	**2.5**
5	9.0	6.4	1.0	42.0	**6.2**	**64.6**	**4.6**
6	9.0	6.4	1.0	41.0	**6.2**	**63.5**	**3.4**
7	9.0	6.0	1.0	40.7	**6.8**	**63.4**	**3.4**

[1] For the May 2001 TSLCC, FY 2001 costs have been included in historical costs.

2 Includes $0.5 billion in 180(c) costs which in the TSLCC were included in PI&I
3 Reduced by $0.5 billion in 180(c) costs transferred to WAST

As can be seen from Table ES-3, the life cycle costs for the 7 scenarios are $1.9 to $4.6 billion higher than the May 2001 TSLCC. Repository costs are $2.7 to $4.5 billion higher. However, nearly all of the increase in repository costs result from the difference in assumed contingency factors between the May 2001 TSLCC (~14% for repository costs) and this study. Table ES-4 shows a summary comparison of repository costs without contingency for the 7 scenarios and the TSLCC.

Table ES-4. Repository Base Cost Comparison for 97,800 MTHM Emplacement

Scenario	Repository Cost (B 2002$)	Delta to May 2001 TSLCC
May 2001 TSLCC	31.9	0.0
1	31.5	-0.4
2	31.5	-0.4
3	34.1	2.2
4	31.5	-0.4
5	32.6	0.7
6	31.8	-0.1
7	31.6	-0.3

A detailed reconciliation of the costs for scenario 1 versus the May 2001 TSLCC showed that the principal cost reductions in scenario 1 result from lower repository O&M and design costs.

A parametric assessment of Fee Adequacy was performed for the 7 scenarios analyzed in this study utilizing data from the May 2001 TSLCC model (DOE 2001e), adjusted for the larger repository area. The results of the assessment indicated that there does not appear to be a Fee Adequacy concern with any of the scenarios.

CONCLUSIONS AND RECOMMENDATIONS

The overall conclusion of this study is that the repository design concept recommended for further study in the Design Evolution Study (Rowe 2002) is adaptable and appears to be sufficiently flexible to encompass a variety of receipt rates, emplacement rates, transportation options, and funding profiles. Other conclusions are as follows:

1. Peak and total Program costs during the pre-operations period (through 2010) were reduced by utilizing a phased repository construction concept. Scenario 1, which has receipt and emplacement assumptions similar to those in the May 2001 TSLCC (DOE 2001e), reduced peak Program costs by $90 million (6 percent) and total costs through 2010 by $1.0 billion (12 percent) versus the SR design. Scenario 5 reduced peak costs by $570 million (35 percent) and total costs by $2.6 billion (29 percent), but at the cost of a

substantial reduction in initial receipt capability. Note that without the assumed increase in contingency factors versus the May 2001 TSLCC, the cost differences for all scenarios would have been greater.

2. Repository design and construction costs represent about 24 percent of total Program costs through 2010. Therefore, even though these costs were reduced by almost 50 percent by phased construction in Scenario 1, the net reduction in total cost was only 12 percent.

3. The preliminary construction schedule developed for the Design Evolution Study, while supporting a 2010 operation date, does not support receipt of waste at the CRD target rates in 2010 (400 MTHM of CSNF).

4. Once adjusted for differing contingency factors, estimated total life cycle costs for the 7 implementation scenarios are not significantly different than for the SR design modeled in the May 2001 TSLCC, particularly given the large uncertainties in the cost estimates.

5. The Nuclear Waste Fund (NWF) Fee appears to be adequate for all of the scenarios.

6. The construction schedule developed for the Design Evolution Study identified a number of early construction activities that would improve confidence in meeting an operation date of 2010. Further evaluation is being performed as part of the Critical Decision 1 (CD-1) effort to determine the extent to which early construction activities may be required.

7. Construction and operation of the repository in a phased manner appears to be consistent with the current regulatory requirements in 10 CFR 63.

8. The phased repository construction concept appears to be adaptable to early waste receipt, assuming adequate funding and authorization.

9. The design concept analyzed in this study did not meet the constrained funding criterion of $600 million/year from LA through 2010. Contributing factors were the need to support a rapid ramp-up in waste receipt rate through 2015, and the fact that Balance-of-Plant (BOP) cost phasing was not evaluated. However, given the fact that repository design and construction costs represent about 24 percent of the total Program costs through 2010, it is unlikely that the $600 million/year goal can be met without reductions in Program costs other than design and construction.

10. The analysis of Scenario 3 involved a several-year moratorium on underground construction and emplacement after the filling of the test area in subsurface Panel 1. This required an assumption of either surface storage at the repository for defense wastes, or halting receipt of defense wastes during the emplacement moratorium. For the purposes of this study, it was assumed that surface storage of defense wastes would be employed. If such a feature were to be included in the repository design, storage casks for HLW and DSNF (including naval SNF) would need to be designed and licensed.

11. The cost analyses performed for this design concept were only rough order of magnitude (ROM) estimates, in that there was little or no "bottoms up" cost analysis performed due to lack of design detail and time constraints. Therefore, the life cycle costs generated in this study are useful only for comparative purposes.

The following recommendations were developed from this study:

1. As part of the preliminary design process, further evaluation of the repository design concept and more detailed estimates of BOP facilities' cost and construction schedules will be required to more accurately determine annual costs through 2010.

2. As part of the preliminary design process, further evaluation of the repository construction schedule should be performed to more accurately determine the need for early construction activities and the receipt rate in the early years of operation.

3. As the design is refined further, more comprehensive life cycle cost and Fee Adequacy analyses should be performed, including development of a more detailed O&M cost model.

4. There is a need to evaluate other Program costs (besides repository design and construction), in order to further reduce the funding profile through 2010.

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ACRONYMS AND ABBREVIATIONS

APR/ACR	Acceptance Priority Ranking/Acceptance Capacity Report
BOP	Balance-of-Plant
BSC	Bechtel SAIC Company, LLC
BWR	Boiling Water Reactor
CA	Construction Authorization
CALVIN	CRWMS Analysis and Logistics Visually Interactive Model
CRD	CRWMS Requirements Document
CRWMS	Civilian Radioactive Waste Management System
CSNF	Commercial Spent Nuclear Fuel
DC	Disposal Container
DOE	U.S. Department of Energy
DPC	Dual-Purpose Canister
DSNF	DOE-Managed Spent Nuclear Fuel
DTS	Dry Transfer System
ES&H	Environmental Safety and Health
FB	Finishing Building
FEIS	Final Environmental Impact Statement
FY	Fiscal Year
G&A	General and Administrative
GA	General Atomics
GROA	Geologic Repository Operations Area
HH	Heavy Haul
HLW	High-Level Radioactive Waste
HTOM	High Temperature Operating Mode
IAS	Integrated Acceptance Schedule
INEEL	Idaho National Environmental and Engineering Laboratory
LA	License Application
LWT	Legal Weight Truck
M&O	Management and Operating Contractor
MPC	Multi-Purpose Canister
MRS	Monitored Retrievable Storage
MTHM	Metric Tons of Heavy Metal

ACRONYMS AND ABBREVIATIONS (CONTINUED)

NRC	U.S. Nuclear Regulatory Commission
NDOT	Nevada Department of Transportation
O&M	Operations and Maintenance
OCRWM	Office of Civilian Radioactive Waste Management
OLT	Omni-Directional Lift Transporter
PETT	Payments Equivalent to Taxes
PI&I	Program Integration and Institutional
PWR	Pressurized Water Reactor
QA	Quality Assurance
QC	Quality Control
RIMS	Regulatory, Infrastructure, and Management Support
SNF	Spent Nuclear Fuel
SR	Site Recommendation
SRS	Savannah River Site
SS	Stainless Steel
TDL	Technical Direction Letter
TSLCC	Total System Life Cycle Cost
TWP	Technical Work Plan
WAST	Waste Acceptance, Storage, and Transportation
WHF	Waste Handling Facility
WP	Waste Package
WTF	Waste Transfer Facility
WVDP	West Valley Demonstration Project
YFF10	Youngest Fuel First Greater Than or Equal to 10 Years Old

1. INTRODUCTION

1.1 PURPOSE

The purpose of this study is to respond to U.S. Department of Energy (DOE) Technical Direction Letter (TDL) 02-003 (Waisley 2001), which directs Bechtel SAIC Company, LLC (BSC) to complete a design study to recommend repository design options to support receipt and/or emplacement of any or all of the following: commercial spent nuclear fuel (CSNF), high-level radioactive waste (HLW), DOE-managed spent nuclear fuel (DSNF) (including naval spent nuclear fuel [SNF]), and immobilized plutonium (if available), as soon as practicable, but no later than 2010. From the possible design options, a recommended approach will be determined for further evaluation to support the preliminary design of the repository.

1.2 BACKGROUND

A repository development approach that includes modular repository design and construction may provide significant advantages in meeting Program schedules and provide the flexibility to address Program technical and regulatory issues. In addition, a phased development approach using modular design may reduce the near-term annual costs for repository design and construction. It is possible that annual funding for the Program will be constrained until a repository is constructed and begins operation, thus putting a priority on repository designs that can be constructed under reduced funding levels.

1.3 SCOPE

This study integrates the results of the repository Design Evolution Study (Rowe 2002) with supporting studies concerning national transportation options (BSC 2002b) and Nevada transportation options (Gehner 2002). The repository Design Evolution Study documents the processes used to re-evaluate the design, construction, operation, and cost of the repository in response to TDL 02-003, and to determine possible repository conceptual design options. The transportation studies evaluate the national and Nevada transportation options that support the repository conceptual design options. An evaluation methodology was established, based on Program-level requirements developed for the study in reference BSC 2001a, to allow the repository and system design options to be evaluated on a consistent basis. The transportation options and the design components were integrated into system design implementation options, which were evaluated using 7 receipt and emplacement scenarios. The scenarios tested the ability of the design concept to adapt to changes in funding, waste receipt rate, and Nevada rail transportation availability. The results of the evaluation (in terms of system throughput, cost, and schedule) were then compared to the Program-level requirements, and recommendations for design alternatives, requirements changes, or further evaluation were developed.

This study includes a number of scenarios that are not consistent with the target acceptance rates in the *Civilian Radioactive Waste Management System Requirements Document* (CRD) (DOE 2001a, Table 1) for any of the waste forms planned for disposal in a repository. This does not imply in any way that any changes to the target acceptance rates are being contemplated. The focus of this study is not on evaluating and selecting operating scenarios (including acceptance rates), but rather on creating a system design that is flexible enough to adapt to a wide range of possible future technical, schedule, licensing, and funding constraints. This is based on recognition (confirmed by historical experience) that many factors, such as funding, that could affect the achievability of preferred scenarios, are outside of the Program's control.

1.4 QUALITY ASSURANCE

An Activity Evaluation was performed for this activity in accordance with AP-2.21Q, *Quality Determinations and Planning for Scientific, Engineering, and Regulatory Compliance Activities*, and is attached to the Technical Work Plan (TWP) (BSC 2002a). The Activity Evaluation determined that this study is not quality affecting; however, it was performed and documented using applicable Quality Assurance procedures as guidance, as described in the TWP.

2. ASSUMPTIONS

This section describes the assumptions used in the analysis.

2.1 PROGRAM-LEVEL ASSUMPTIONS

This section summarizes the Program-level assumptions used in the study. These assumptions are taken from the White Paper on Program-level assumptions (BSC 2001a). The rationales for these assumptions are given in BSC 2001a.

2.1.1 Design Approach

A. The study shall focus on flexible modular design options that could support a staged repository development approach.

B. The repository design shall have the flexibility to accommodate early receipt, assuming adequate funding and authorization are available.

C. An initial subsurface performance confirmation and test facility (hereafter called the Demonstration Stage) shall be included as an option.

D. Repository design and operations assumptions shall be bounded by values assumed in the Final Environmental Impact Statement (FEIS).

E. The design shall retain the capability for either a high- or low-temperature post-closure thermal mode.

2.1.2 Waste Receipt

A. The design shall support waste receipt as soon as practicable, but no later than 2010.

B. The repository shall have the initial capability to receive annually at least one waste package (WP) quantity of CSNF and one shipment of naval SNF. Initial receipt of HLW, DSNF (excluding naval SNF), and immobilized plutonium (if available) shall be a goal assuming adequate funding is available.

2.1.3 Waste Emplacement

A. Waste emplacement is decoupled from waste receipt.

B. A high priority goal of the study is to develop a design concept that could allow initial emplacement of some CSNF (plus any or all of the other waste types described in 2.1.2.B, if possible) by 2010, even under the constrained funding assumption in section 2.1.4.

C. The design of the repository will be based on a capacity of 70,000 metric tons of heavy metal (MTHM) (63,000 MTHM CSNF, 7,000 MTHM defense wastes), but shall not preclude receipt and emplacement of up to the maximum waste quantity described in the FEIS.

D. As a minimum, the initial emplacement rate shall support a subsurface testing facility.

2.1.4 Funding Profile and Cost Constraints

The following constrained funding assumptions shall be used:

- A maximum of $400 million/year (Program total) through LA
- A maximum of $600 million/year from LA through 2010

The design shall have the flexibility to ramp up to the target receipt schedule in the current CRD Table 1, assuming additional funding is available. The design shall not preclude the ability to expand receipt rates to levels exceeding the maximum target rate in the CRD.

2.1.5 Limited Work Authorization, Regulatory Changes, and Program Redirection

The design solutions shall not be predicated on the receipt of a Limited Work Authorization (LWA), regulatory changes, or legislative redirection of the Program. The design must be flexible enough to accommodate early construction of non-nuclear portions of the facility outside the Geologic Repository Operations Area (GROA), assuming adequate funding and authorization.

2.1.6 Transportation

A. There will be no requirement for availability of rail transportation prior to start of operations.

B. Repository design solutions shall be integrated with the national transportation system.

2.2 PROJECT-LEVEL ASSUMPTIONS

The design studies that comprise the Design Evaluation Study (Board et al. 2002; Brown 2002; Linden 2002; McDaniel 2002; Silva and Stanley 2002) and the transportation options studies (BSC 2002b; Gehner 2002) contained a number of Project-related assumptions. These assumptions are summarized in the Design Evolution Study Summary (Rowe 2002) and the transportation options studies. Two additional assumptions were made for this study regarding the repository thermal operating mode and CSNF aging:

A. A high-temperature subsurface thermal operating mode (HTOM) was assumed for all scenarios, to be consistent with the Site Recommendation (SR) design reflected in the May 2001 Total Life Cycle Cost estimate (TSLCC) (DOE 2001b).

B. The thermal operating mode was assumed to require 1,000 MTHM of surface aging for CSNF. This allows for a more consistent cost comparison with the SR surface facility design, which included a 5,000 MTHM blending pool.

3. EVALUATION METHODOLOGY

This section describes the evaluation methodology used for the study.

3.1 GENERAL EVALUATION PROCESS

In order to provide as much consistency as possible between the design studies, standard evaluation criteria and a recommended evaluation methodology were developed. This methodology is described in detail in the Design Evolution Study Summary (Rowe 2002, Appendix A). The evaluation criteria used in the design studies were grouped into the following general categories:

- Pre- and Post-Closure Health and Safety (public and workers)
- Flexibility
- Licensability and Regulatory Acceptance
- Receipt/Emplacement Capability
- Schedule
- Cost
- Non-Safety (Programmatic) Risk (e.g., constructability, operability, maintainability)
- Compatibility with Other Design Components
- Public Confidence
- Use of Existing Studies and Analyses

Within these general categories, specific evaluation criteria were identified for each study. The Program-level assumptions provided in the TDL (Waisley 2001) were factored into the specific evaluation criteria, along with project-level assumptions developed for the individual studies. The specific evaluation criteria were then classified as either "needs" (i.e., required to be satisfied), or "wants" (desirable to be satisfied). The design alternatives developed for each study were then evaluated versus the evaluation criteria, to determine the recommended alternative.

3.2 USE OF SCENARIOS IN DESIGN EVALUATION

In this study, the design recommendations from the Design Evolution Study are evaluated for each of the selected operational scenarios. However, many of the evaluation criteria described in the Design Evolution Study Summary (Rowe 2002, Appendix A) are not applicable to this scenario-based analysis. For example, one would not expect any scenario-related differences for postclosure public health and safety. In contrast, one would expect scenario-related effects on criteria such as Schedule, Receipt/Emplacement Capabilities, Cost, and Flexibility.

Therefore, for this study, a subset of the evaluation criteria described above was selected that consists of the Program-level assumptions described in Section 2. The results of the evaluation are described in Section 6.3. In addition, potential licensing issues raised either in the design studies or in this study are discussed in Section 6.4.

4. SUMMARY OF DESIGN STUDIES

This section summarizes the results of the Repository Design Evolution Study (Rowe 2002) and the transportation options studies (BSC 2002b; Gehner 2002) that were performed to provide input to the system analysis.

4.1 TRANSPORTATION OPTIONS STUDIES

This section describes the results of the National Transportation Options study (BSC 2002b) and the Nevada Transportation Options study (Gehner 2002).

4.1.1 National Transportation Options Study

The purpose of this study was to identify and analyze the throughput and costs of national transportation options that will be used as input to the Modular Design Implementation System Evaluation for License Application.

4.1.1.1 Waste Stream

A 70,000 MTHM waste stream was used as the basis for this analysis, consisting of 63,000 MTHM of CSNF and 7,000 MTHM of defense wastes. The CSNF characteristics are shown in Table 1.

Table 1. CSNF Waste Stream Parameters, 63,000 MTHM

	BWR[1]					PWR[2]				
	Age (yrs)	Burnup (GW/MT)	Enrich. (%)	% of Assm	MT/ Assm	Age (yrs)	Burnup (GW/MT)	Enrich. (%)	% of Assm	MT/ Assm
Average	16.5	42	3.7	57.5	0.174	17.1	46	4.3	42.5	0.433
Maximum	56	66	4.8	N/A	N/A	59	71	5.0	N/A	N/A
Minimum	5	0	0.7	N/A	N/A	5	2	0.3	N/A	N/A

[1] BWR = boiling water reactor
[2] PWR = pressurized water reactor
Note: Data taken from reference BSC 2002b, Table 3.

The CSNF selection criterion used in this analysis is "Youngest Fuel First Greater than or Equal to 10 Years Old" (YFF10), which is described in Appendix A. This selection criterion was chosen to maintain consistency with the assumptions used in the waste stream for the May 2001 TSLCC (DOE 2001b). The YFF10 criterion produces a "best estimate" waste stream from a standpoint of transportation cask shipments and CSNF parameters at arrival. For each scenario, the CALVIN Version 3.1 computer code (BSC 2001c) was used to calculate the CSNF accepted and shipped to the repository. The reference annual CSNF acceptance rates are based on the target acceptance rates given in the CRD (DOE 2001a, Table 1).

The defense waste stream modeled in this report was derived from the DOE/EM Integrated Acceptance Schedule (IAS) v1.08 dated June 29, 2001 (Bebee 2001). This draft shipping schedule for DSNF, HLW, and Navy waste has the latest (most accurate) projected inventories and dates of availability.

For the 70,000 MTHM waste stream, the first 4,667 MTHM of HLW and 2,333 MTHM of DSNF from the full waste stream were selected. For purposes of converting the HLW allocation to number of canisters, it was assumed that each HLW canister contains 0.5 MTHM (DOE 1999a, Appendix A). All naval and Idaho National Engineering and Environmental Laboratory (INEEL) DSNF listed in the IAS was included in the 2,333 MTHM allocated to DSNF, to be consistent with the assumption that all DSNF must be removed from INEEL by 2035. No West Valley Demonstration Project (WDVP) HLW was assumed to be in the first 4,667 MTHM of HLW. In addition, for Savannah River (SRS), no HLW canisters containing immobilized Plutonium were assumed to be part of the total SRS HLW canisters.

Tables 2 and 3 describe the HLW and DSNF waste streams for both the full and 70,000 MTHM cases.

Table 2. HLW Waste Stream

Waste Site	Full Waste Stream		70,000 MTHM Waste Stream	
	MHTM[1]	Canisters	MHTM[1]	Canisters
Hanford	6,099.0	12,198	2,706.5	5,413
INEEL	660.5	1,321	232.5	465
Savannah River	2,935.5	5.871	1,728.0	3,456
WVDP	639.9	300	0	0
Total	10,334.9	19,690	4,667	9,334

[1] Assumes 0.5 MTHM per canister for defense wastes, and 2.13 MTHM per canister for West Valley
Note: Data taken from reference BSC 2002b, Table 4

Table 3. DSNF Waste Stream

Waste Site	Canisters	
	Full Waste Stream	70,000 MTHM Waste Stream
Hanford – 15 ft.	344	344
Hanford – MCO	441	351
INEEL – Naval	300	300
INEEL – 10 ft.	984	984
INEEL – 15 ft.	619	619
SRS – 10 ft.	400	400
Total	3,088	2,998

Note: Data taken from reference BSC 2002b, Table 5

4.1.1.2 Transportation Cask Options

This section discussed transportation cask alternatives, including some that are not included in the standard cask fleet assumed in the TSLCC. These alternatives included:

- Legal Weight Truck (LWT) casks for HLW and DSNF
- LWT casks for canistered CSNF

It was concluded that LWT casks could be developed and procured for these waste forms by 2010, although uncertainties exist with regard to costs and certification/procurement schedules.

4.1.1.3 National Transportation Scenarios

A total of 27 transportation scenarios were developed in the study. Of these 27 scenarios, 6 were selected for use in the system-level evaluation. These transportation scenarios are described in Table 4.

Table 4. National Transportation Scenarios Selected for System Evaluation

Scenario	Shipping Mode 2010-14	CSNF Rate (MTHM/yr)		HLW Rate (MTHM/yr) 2010-14	DSNF Rate (Can/yr) 2010-14	CSNF Selection Criterion[4]
		2010-14	2015-			
1B	Mostly Rail	400,600,900,...	900,900,900, 900,900,1800, 2200,2600, 3000,3600...	Reference[3]	Reference[3]	YFF10
3B	Mostly Rail	Reference[2]	Reference[2]	Reference[3]	Reference[3]	YFF10
4A	Mostly Rail	Ref. + 33.3%	4000	Reference[3]	Reference[3]	YFF10
5A	LWT[1]	50,100,...	400,600,1200, 2000,3000, 3600,...	10,20,...	5,7,10,10,16..	YFF10
7A	LWT[1]	200,400,...	400,600,1200, 2000,3000, 3600,...	40,80,...	11,19,22,22,28 ...	YFF10
7D	LWT[1]	200,400[5]	Reference[6]	20,40[5]	11,19,22,22,28 ...	YFF10

[1] LWT mode includes limited heavy haul of naval SNF
[2] Reference CSNF rates are the target rates used in the TSLCC analysis (see Appendix C, Table C-1)
[3] Reference defense rates are the rates defined in the IAS (see Appendix C, Table C-2)
[4] See Appendix A for definition of criteria
[5] 2010 –11 only for Scenario 7D
[6] 2012+ for Scenario 7D

The annual costs developed for these scenarios are given in Appendix B. These costs include a 25 percent contingency for both capital and labor costs.

4.1.2 Nevada Transportation Options Study

This study (Gehner 2002) evaluated a number of scenarios for transporting SNF and HLW, within Nevada, to the repository at Yucca Mountain. These scenarios include use of legal-weight truck (LWT), rail, and limited heavy-haul (HH) transport. The study also addresses infrastructure upgrades.

The first scenario (Option 1) provides rail access to the repository site by 2010, when the surface facilities are ready to receive the waste. The initiation of rail construction for Option 1 would be required by early Fiscal Year (FY) 2007 or about one year prior to repository construction authorization.

The second scenario (Option 2) considers a phased approach to having rail access to the repository by 2015, with limited HH transport of Navy rail casks during the initial five years. This approach addresses constrained funding during repository construction where approximately 95% of the cost to design and construct the railroad is deferred until after 2010. The use of limited HH transport requires an intermodal transfer of the shipping cask from a railcar to a HH transporter at the mainline railroad, a road from the transfer location to an existing highway, and upgrading of the highway between the transfer location and the repository site. This mode of transport also requires a Nevada Department of Transportation (NDOT)-issued heavy-haul permit for each movement of the HH transporter on the highway. Note that costs for a HH transfer station at the repository are included in the surface facilities costs developed in Section 4.2.2.1.

The third scenario (Option 3) delays rail access to the repository until 2012, also with limited HH transport of Navy rail casks during the initial two years. This approach addresses the impact of not starting the branch rail line construction until DOE receives repository construction authorization in 2008. This use of limited HH has the same requirements as identified in Option 2.

Also discussed in this study (Gehner 2002) are three alternatives for a site access road from U.S. 95 to the repository site. The function of the site access road is to support repository construction, operations, and waste receipt. Alternatives 1 and 2 identify a new road approximately 20 miles long that starts from U.S. 95, about one mile west of the Gate 510 entrance road, and proceeds to the repository site along the west side of Forty Mile Wash. The difference between the two alternatives is that Alternative 1 includes an NDOT scope to design and construct an interchange at U.S. 95, whereas Alternative 2 requires that trucks cross the highway. Alternative 3 discusses using the existing Gate 510 entrance and upgrading the existing site roads to accommodate heavy-haul as well as the other site traffic. Alternative 1 was recommended, as it provides the greatest level of safety, a low level of cost and schedule risk, and is likely to be preferred by NDOT. In comparison to the new branch rail line, the site access road is not a major cost driver.

Figures 1 - 3 show the development schedules for the 3 Nevada transportation options. Table 5 summarizes the total costs of the 3 options. Table 6 summarizes the costs of the recommended

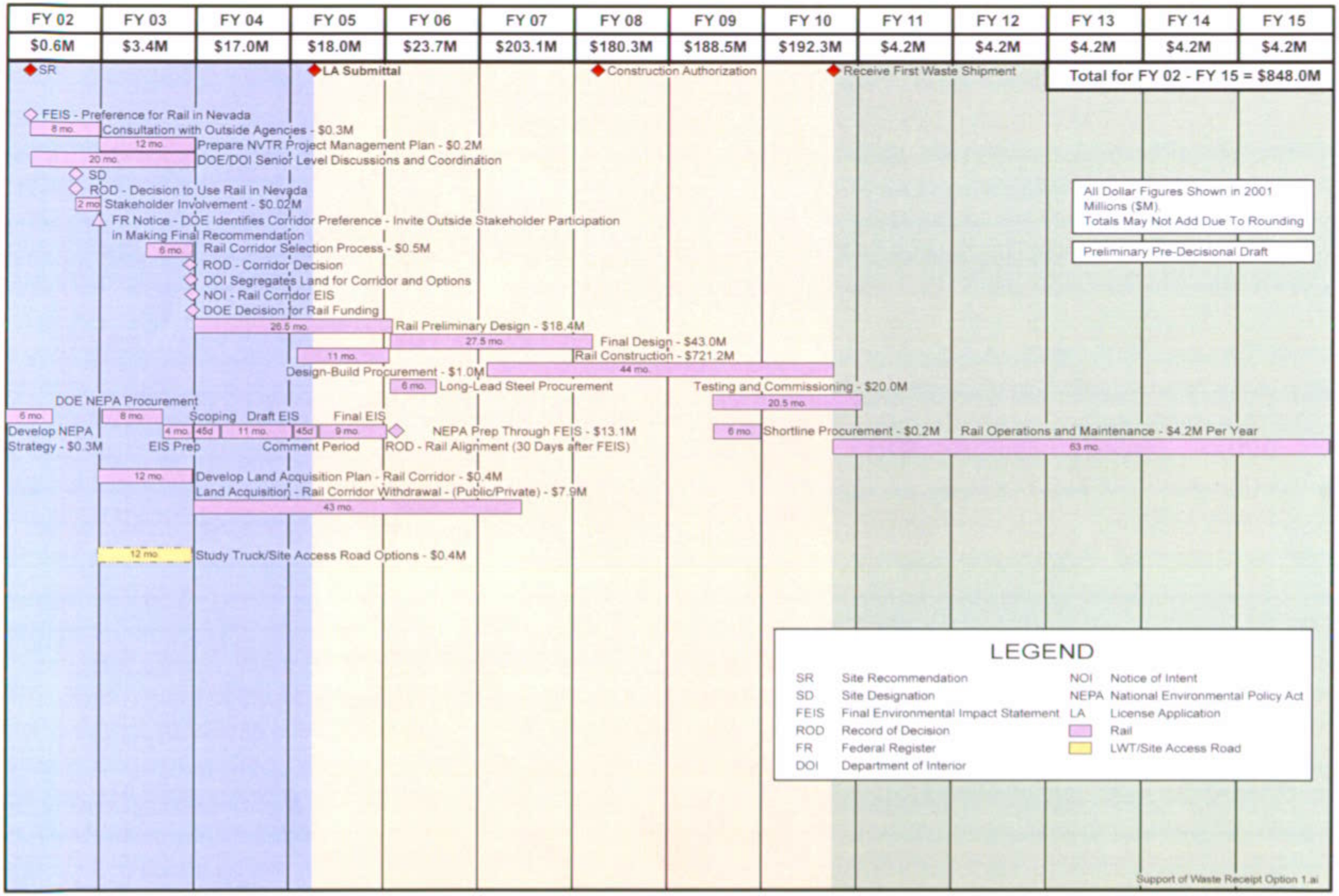

Figure 1. Nevada Transportation Option 1

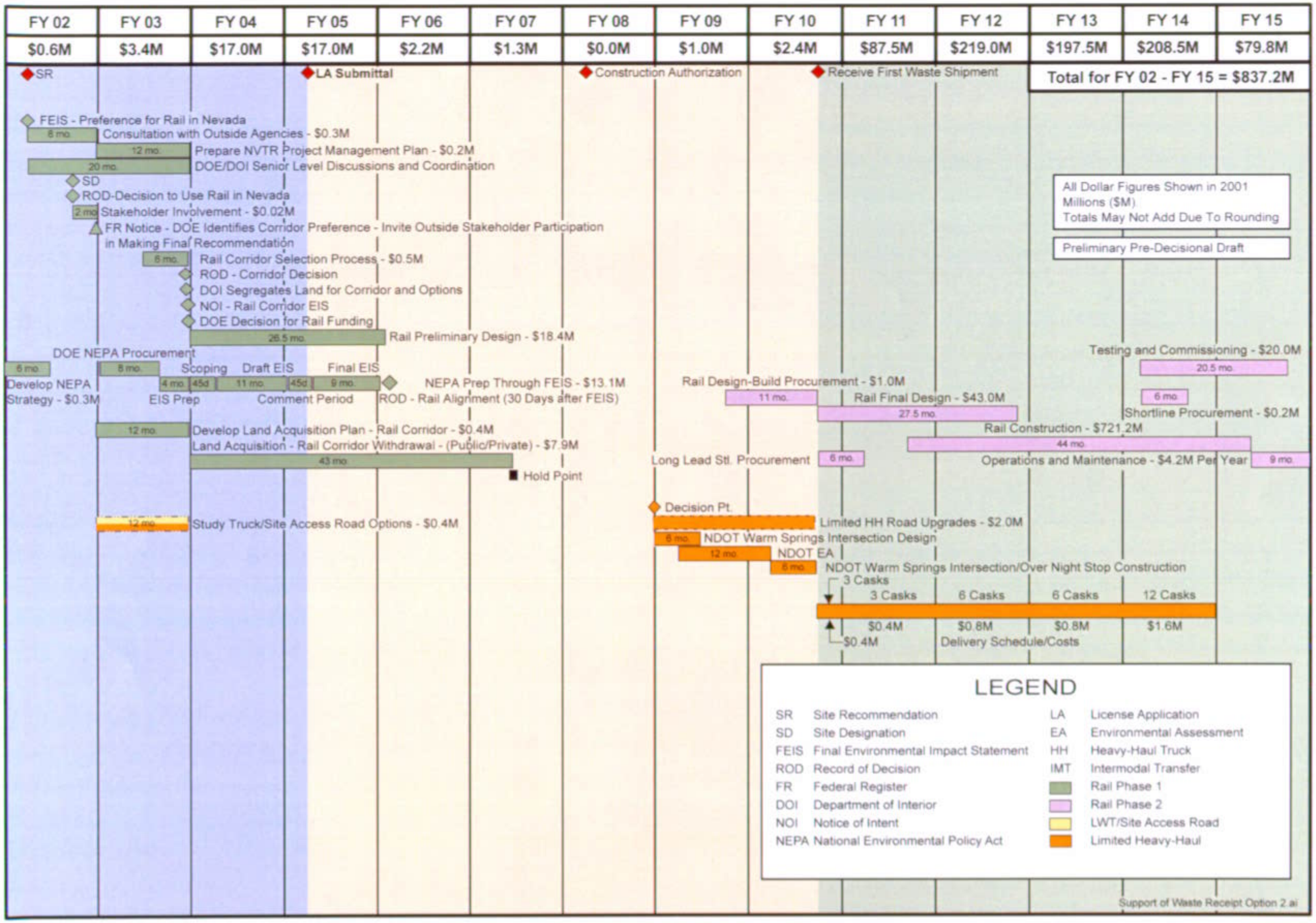

Figure 2. Nevada Transportation Option 2

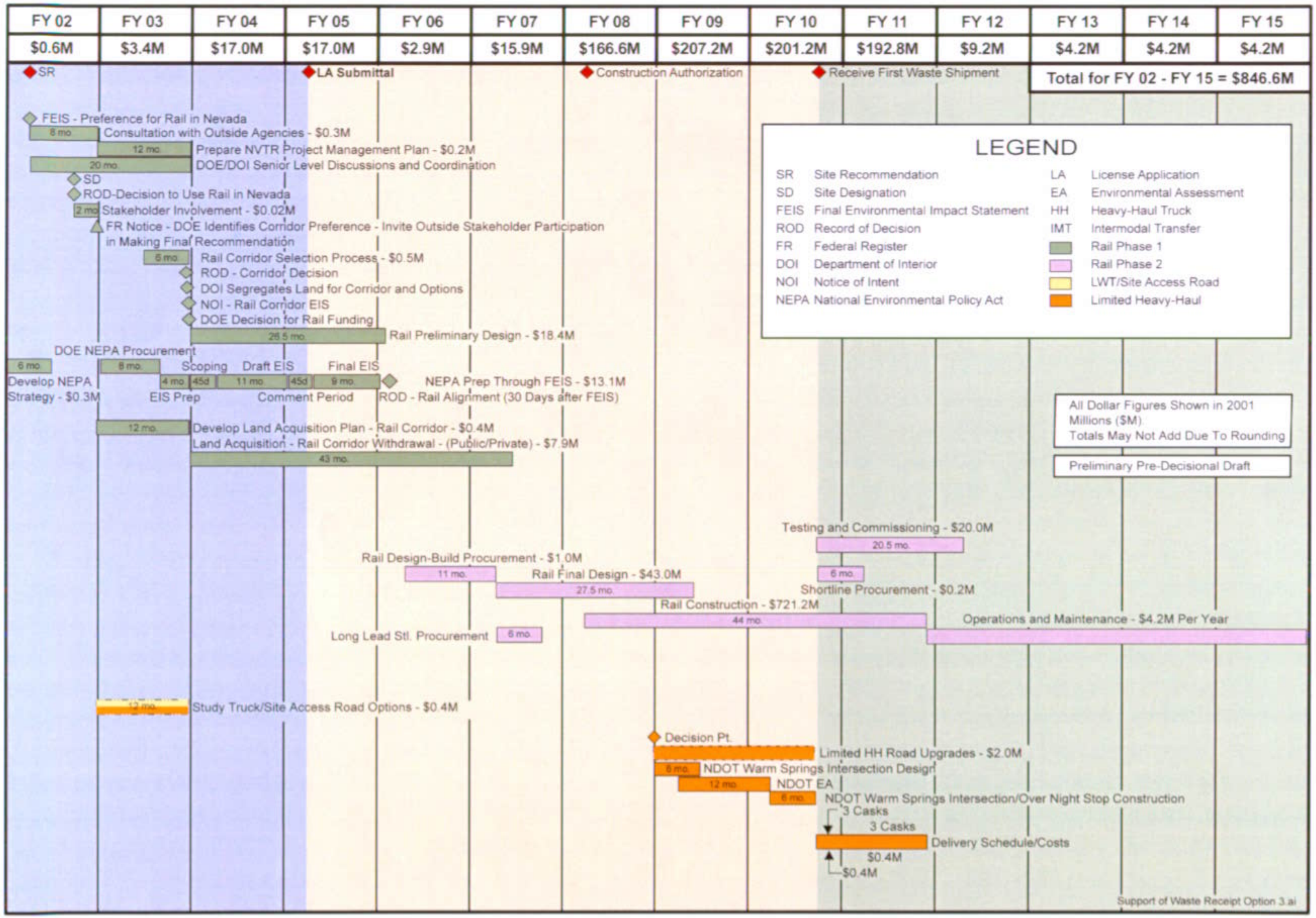

Figure 3. Nevada Transportation Option 3

site access road alternative. Table 7 shows the annual development costs, including the site access road development, for the 3 options. These costs include a 25 percent contingency. Note that the schedules shown in Figures 1 – 3 were developed under the assumption that transportation operations would begin in June 2010 (consistent with the May 2001 TSLCC [DOE 2001b]). Preliminary construction schedules developed for the Design Evolution Study (Rowe 2002) resulted in an initial repository operation date of December 2010 (see Section 5.2). This may result in a small inconsistency in Nevada transportation 2010 costs.

Table 5. Nevada Transportation Options Total Costs

Cost Category	Costs in 2001 Dollars (Millions)[1]		
	Option 1	**Option 2**	**Option 3**
Design, Acquisition, and Construction	826.9	829.0	829.0
Heavy Haul Operations and Maintenance (per cask)	0	0.1	0.1
Rail Operations and Maintenance (per year)	4.2	4.2	4.2

[1] These costs are escalated to 2002 dollars for this analysis using an escalation factor of 1.02
Note: Data taken from reference Gehner 2002, Tables 1 – 3

Table 6. Site Access Road Costs

Cost Component	Cost (M 2001$)[1]
Site Access Road Construction	36.3
U.S. 95 Interchange Construction	13.8
Annual Maintenance (per year)	0.1
Overlay (every 8 Years) (per application)	1.9

[1] These costs are escalated to 2002 dollars for this analysis using an escalation factor of 1.02
Note: Data taken from reference Gehner 2002, Table 5

Table 7. Nevada Transportation Annual Costs (M 2001 $)[1]

Fiscal Year	Option 1	Option 2	Option 3	Site Access Road
2002	0.6	0.6	0.6	0
2003	3.4	3.4	3.4	0
2004	17.0	17.0	17.0	14.3
2005	18.0	17.0	17.0	14.3
2006	23.7	2.2	2.9	14.3
2007	203.1	1.3	15.9	7.2
2008	180.3	0.0	166.6	0.1
2009	188.5	1.0	207.2	0.1
2010	192.3	2.4	201.2	0.1
2011	4.2	87.5	192.8	0.1
2012	4.2	219.0	9.2	0.1

Table 7. Nevada Transportation Annual Costs (M 2001 $)[1] (Continued)

Fiscal Year	Option 1	Option 2	Option 3	Site Access Road
2013	4.2	197.0	4.2	0.1
2014	4.2	208.5	4.2	0.1
2015	4.2	79.8	4.2	1.9[2]
2016+	4.2	4.2	4.2	0.1[1]

[1] These costs are escalated to 2002 dollars for this analysis using an escalation factor of 1.02

[2] 1.9 M every 8 years for road overlay

Note: Data taken from reference Gehner 2002, Tables A-1 to A-4

4.2 REPOSITORY DESIGN EVOLUTION STUDY

This section summarizes the results of the Repository Design Evolution Study (Rowe 2002), including the design component sub-studies (Board et al. 2002; Brown 2002; Linden 2002; McDaniel 2002; Silva and Stanley 2002), and the resulting repository conceptual design options.

4.2.1 Repository Subsurface Design

This section summarizes the results of the repository sub-studies addressing underground layout, in-drift configuration, and WP emplacement.

4.2.1.1 Subsurface Layout

The Underground Layout study (Board et al. 2002) provides the results of a reevaluation of the siting footprint, horizon selection, and underground layout of the proposed repository at the Yucca Mountain Project site.

An examination of the repository horizon selection was performed to determine if there was sufficient justification in altering the current SR horizon selection. It was determined that the current SR horizon selection, with minor modifications to adjust to the new siting footprint, was the best overall alternative.

With the horizon selected, the layout of the SR design was reexamined. It was proposed to alter the design concept to a repository composed of a number of panels that have shorter emplacement drifts, can be constructed more rapidly, and provide flexibility to adjust the repository design over time, as one need not "commit" to development of a large single panel at the earliest stages of construction. This layout additionally provides greater control of separation of the construction and emplacement functions, allows for somewhat simpler forced ventilation control, and facilitates performance confirmation testing within the center of the repository area. Since the layout is constructed in a phased manner over time, it was possible to incorporate a performance confirmation testing area into the overall layout while meeting the 2010 emplacement goal. Within the repository siting footprint it is possible to provide approximately 83,900 m of usable emplacement drift in four panels, which is sufficient to emplace 70,000

MTHM of waste. Additional expansion area consisting of approximately 16,000 m of usable drift length is available in a fifth panel, if necessary.

Figure 4 shows the recommended repository footprint and subsurface layout. Table 8 lists the key design parameters for the subsurface facility.

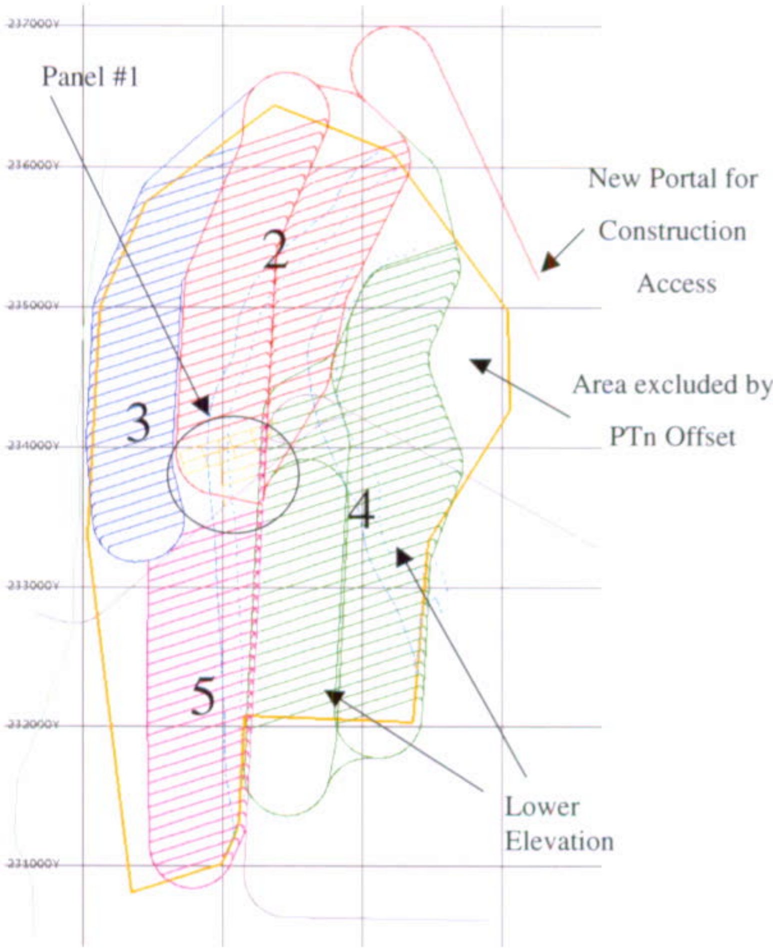

Figure 4. Recommended Modular Subsurface Layout

Table 8. Subsurface Facility Design Parameters

Panel	Usable Emplacement Drift Length (m)[1]	Construction Schedule (Months)[2]	Direct Cost (M 2002$)[3]	Distributables & Field Costs (M 2002$)[3]
1	4,092	35[4]	216	0.6
2	24,229	124	1,117	7.9
3	17,490	105	559	4.1
4	38,074	182	1,342	10.7
5	16,063	~101[5]	618	3.9
Total	99,921			

[1] Taken from reference Board et al. 2002, Table 5 -1
[2] Taken from reference Board et al. 2002, Figures 5-8 and 5-10
[3] Taken from reference Board et al. 2002, Appendix A
[4] 28 months to first emplacement
[5] Estimated based on similarity to Panel 3

Note that the subsurface construction schedule includes assumptions that certain preparatory work outside the GROA is performed prior to issuance of the CA, including offsite and onsite power upgrades and Balance-of-Plant (BOP) construction (Board et al. 2002, Figure 5-7).

It is possible that the first stage of the repository could be used to acquire additional engineering and scientific data. Figure 5 shows a potential configuration that could utilize a portion of Panel 1 to gather engineering and scientific data during the early phases of repository operations. The costs for the Demonstration Stage are included in the Panel 1 costs in Section 4.2.1.1.

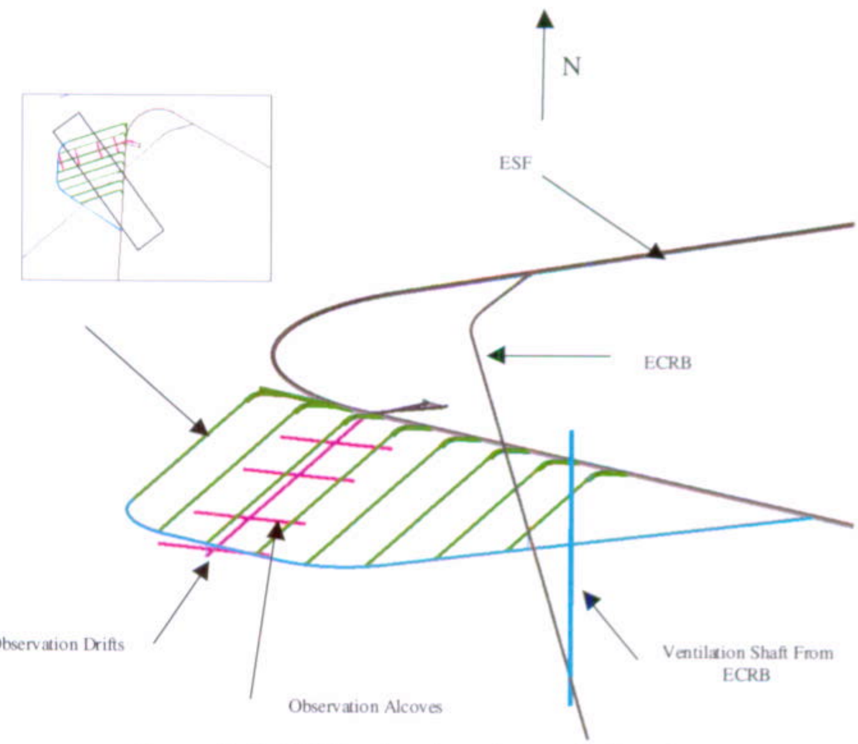

Figure 5. 3-Drift Testing Area Layout in Panel 1

4.2.1.2 In-Drift Configuration

This study (Linden 2002) examined the in-drift configuration for the emplacement drift. The present in-drift configuration consists of a circular opening configuration with an invert composed of carbon steel beams and crushed tuff ballast. The WP is carried into the drift via a rail-mounted gantry and is placed horizontally in the drift on pallets. This evaluation assessed whether the current drift geometry and emplacement drift system components (e.g., invert and emplacement pallets) should be carried forward to license application or whether the current drift geometry should be changed to better satisfy repository requirements and design constraints.

It was recommended that the SR in-drift design configuration be carried forward with a modification to the ground support system. With this recommendation, instead of steel sets being routinely installed within the emplacement drifts, the sets would only be installed on an as-needed basis, with rock bolts and mesh providing the primary ground support function. The SR invert design configuration would be carried forward unchanged. Implementation of this recommendation would not require any changes to project requirements.

Figure 6 (Linden 2002, Figure 26) shows the recommended in-drift configuration, and Table 9 shows the estimated unit costs.

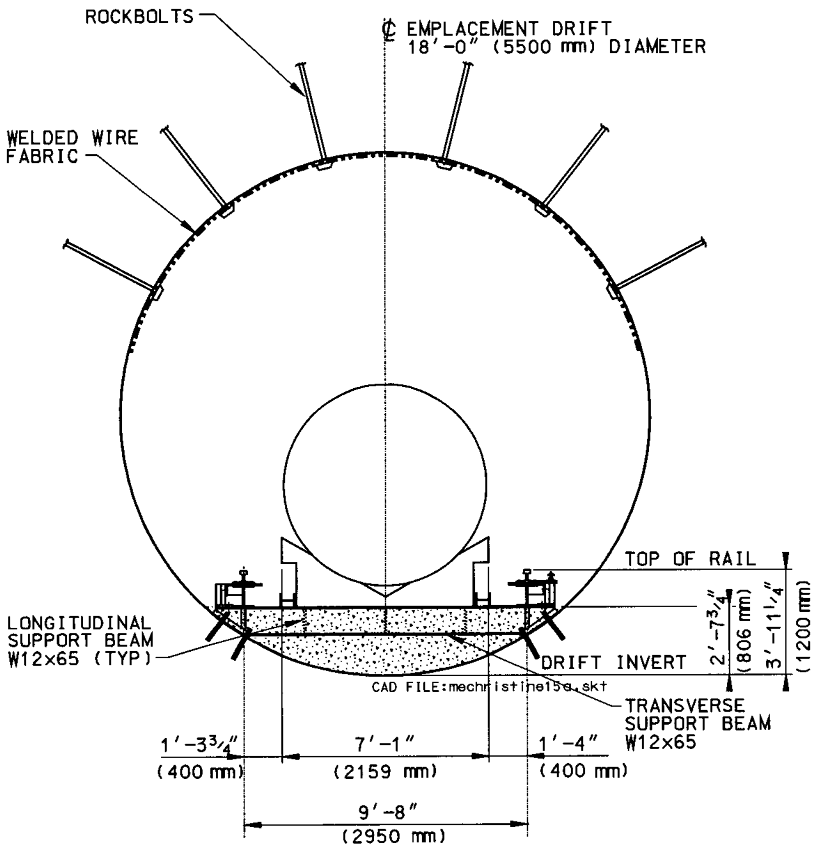

Figure 6. Recommended In-Drift Configuration

Table 9. In-Drift Design Configuration Unit Costs

Item	Unit Cost (2002$)
Excavation, Ground Support, and Invert	$12,357/meter[1]
WP Pallets	$57,000/pallet[2]

[1] Reference: Linden 2002: SR excavation, ground support, and invert ($14,257/m) (Section 7.4.2.3.6.1) minus cost savings for new ground support ($1,900/m) (Section 7.4.3.2.3.1)

2 Reference: Linden 2002, Section 7.4.2.3.6.1

4.2.1.3 Waste Package Emplacement

This study (Silva and Stanley 2002) evaluated significant processes involving waste emplacement and retrieval, known as the Waste Emplacement/Retrieval System. This evaluation effort is a natural progression of the current baseline design for Site Recommendation, exploring fundamental emplacement and retrieval concepts against the current concept in order to refine and improve waste emplacement and retrieval.

The concept that was proposed for recommendation is an omni-directional lift transporter (OLT) for transporting the WPs from the surface Waste Handling Facilities to the subsurface emplacement drift entrance, and a rail-based gantry for handling and emplacing waste within the emplacement drifts.

Figure 7 shows a schematic of the recommended WP emplacement system. Table 10 shows the cost estimate for the OLT-gantry system, based on the 31-year emplacement period in the May 2001 TSLCC, which includes purchase of initial and replacement equipment.

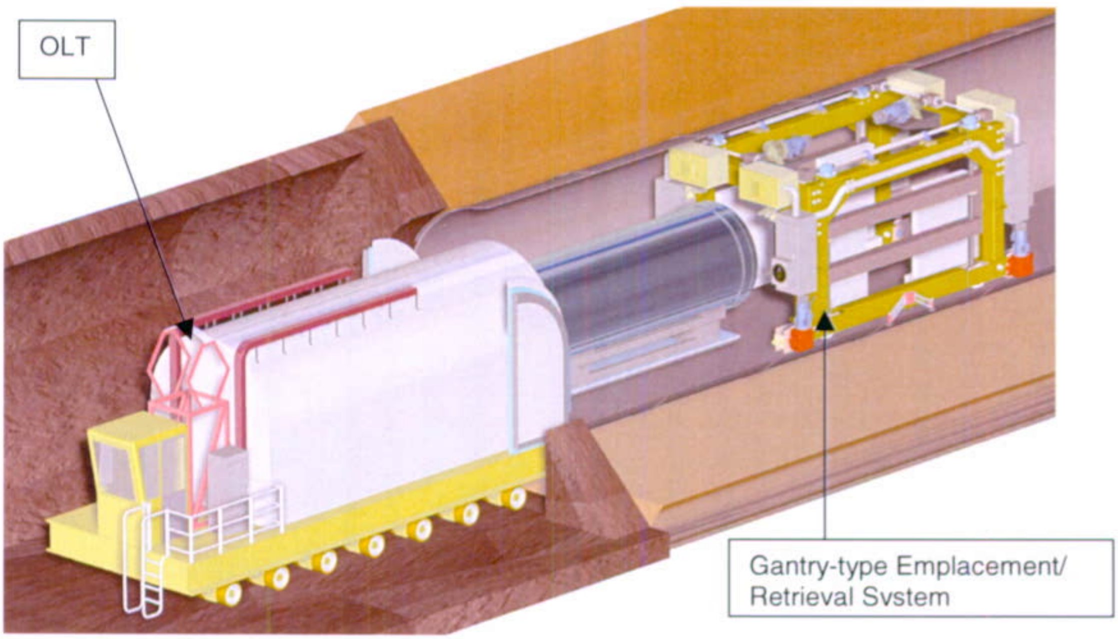

Figure 7. Recommended Waste Package Emplacement System

Table 10. Purchase Cost Summary for OLT Equipment (M 2002$)

	Locomotive[1]	OLT	OLT Shielding	Emplacement Gantry	Gantry Transporter	Personnel Carrier
Initial Cost	$0.41	$3.13	$0.73	$1.40	$0.71	$0.32
Replacement Cost	$0.34	$2.51	$0.029	$1.12	$0.57	$0.25

[1] A locomotive is needed in the OLT design to transport the emplacement gantry on a gantry carrier
Note: these costs were taken from Table 10 of Silva and Stanley 2002, adjusted to 2002 dollars (escalation factor of 1.044), and converted to millions

4.2.2 Surface Facilities

This section summarizes the results of the repository sub-studies addressing waste handling facility (WHF) functions and layout, and storage.

4.2.2.1 Waste Handling Facility

The objective of this study (Brown 2002) was to evaluate and recommend the design and construction approach to be employed by the Yucca Mountain Project Surface Facilities responsible for receiving, processing, and packaging radioactive waste for emplacement. The current concept of constructing one large integrated Waste Handling Building was compared to a phased modular approach, with greater flexibility, improved incorporation of lessons learned, and a lower initial cost profile, but a higher total cost.

Based upon a thorough review of the options available, it was recommended for further study that the surface facilities be constructed in a phased approach consisting of multiple buildings, with the functions of the overall surface facilities distributed amongst them.

In the recommended option, fuel is handled primarily dry, with limited wet capability for off-normal fuel. This is similar to the approach used in La Hague, France. Casks and WPs are moved laterally using an OLT, both between and within buildings to reduce the number of lifts and operations.

Initial construction (Phase 1) would consist of a facility referred to as a "finishing building" (FB), equipped with a small processing line capable of processing bare fuel and canisters and finishing WPs for emplacement. This processing line allows for delayed completion of the primary processing building until after 2010, when significant quantities of material are transported to the site for processing. The processing line would continue to be used for processing bare fuel, canisters or both. Note that the waste transfer system in this building is assumed to utilize a dry transfer system (DTS) similar to the cold demonstration project system developed at INEEL (Brown 2002, Section 3.6).

After completion of the first phase of construction, a wet Waste Transfer Facility (WTF) would be constructed to support processing off-normal fuel and storing assemblies too hot for dry storage (Phase 2). In addition, several support facilities would also be constructed at this time. As proposed, the surface facilities have limited thermal blending inventory storage. This would necessitate either a substantial increase in the pool capacity or a separate aging facility to reduce the overall heat load and provide a blending inventory, and/or a change in the maximum thermal heat limits for the individual WPs.

When additional processing capacity is needed, a dry WTF with finishing capability would be constructed (Phase 3). Other support facilities would in general remain similar to the ones described in the Site Recommendation baseline.

Figure 8 shows the locations of the recommended WHF phases. Tables 11 and 12 show the estimated costs and capacities of the WHF phases. Note that Table 11 does not include costs for the surface aging facility shown in Figure 8; these costs are discussed in Section 4.2.2.2.

Table 11. Surface Facility Construction Costs and Schedules

Facility / Function	**Cost (M 2002$)**[1]	**Schedule (Weeks)**[1]
Phase 0 – Construction That Could be Performed Prior to Construction Authorization (CA)		
Road from North Portal to Interface Point	$6.6	24
Rail from North Portal to Interface Point	$6.6	24
Fill removal	$2.6	10
Subtotal	15.8	
Phase 1 - Construction Necessary to Support Initial Operations (post-CA)		
Half-size FB with processing and two cask preparation areas	$135.4[2]	49
Pit for handling WPs from Aging	$2.5	0 (part of FB)
Cask carrier preparation building with lift beams	$30.8	24
OLTs for shipping casks (2)	$2.0	N/A
OLTs with integral shielding within welding area (2)	$4.0	N/A
Fill emplacement	$4.1	5
Subtotal	$178.8	
Phase 2 - Construction Necessary to Support Long-Term Operations		
Rail staging	$4.4[2]	12
Complete equipment in cask carrier preparation building	$10.3[2]	12
Wet WTF without load-out capability	$115.4	53
Waste treatment building (WTB)	$21.0	45
Empty DC Preparation building	$17.3	24
OLTs for shipping casks (2)	$2.0	N/A
OLTs with integral shielding within welding area (2)	$4.0	N/A
Subtotal	$174.4	
Phase 3 - Construction Necessary to Support Full Scale Operations		
Dry WTF with half-size finishing building Incorporated	$201.1	68
OLTs for shipping casks (4)	$4.0	N/A
OLTs with integral shielding for transfer between WTFs and within welding areas (4)	$8.0	N/A
Shielded above grade corridor between dry WTF and finishing building with processing (100 feet)	$2.4	8
Subtotal	$215.5	
Total	$593.5	

[1] Reference: Brown 2002, Tables 4-1 through 4-4
[2] Costs adjusted from values in Waste Handling Facility Report as a result of review by Cost Estimating Group

Table 12. Surface Facility Modular Capabilities

Phase	Cumulative Throughput (Casks/year)[1]	Cumulative Nominal CSNF Capacity (MTHM/year)[2]
1	365	~400 (truck only) ~1,800 (mostly rail)
2	365	~400 (truck only) ~1,800 (mostly rail)
3	1,100	~4,000

[1] Reference: Brown 2002,Table 3-4 (Option 1)
[2] Estimated from shipment calculations for Transportation scenarios 1B and 7A (see Table 4); includes proportional amount of defense wastes

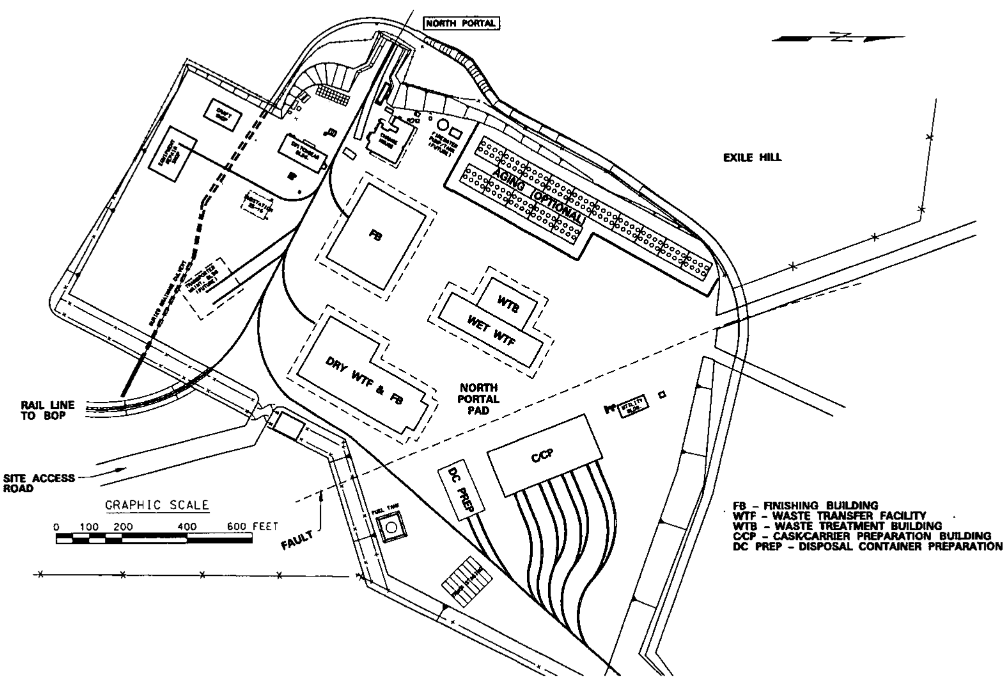

Figure 8. Modular Surface Facilities Layout

4.2.2.2 Aging

The purpose of this study (McDaniel 2002) was to identify options and issues for aging commercial spent nuclear fuel received for disposal at the Yucca Mountain Monitored Geologic Repository. Some early shipments of commercial spent nuclear fuel to the repository may be received with high-heat-output (younger) fuel assemblies that will need to be managed to meet thermal goals for emplacement. The capability to age as much as 40,000 metric tons of heavy metal of commercial spent nuclear fuel would provide more flexibility in the design to manage this younger fuel and to de-couple waste receipt and waste emplacement.

A. Storage Locations

The following storage locations were evaluated:

- Surface storage at four locations near the North Portal
- Subsurface storage in the permanent emplacement drifts and in a new subsurface area

For the purposes of this study, only surface storage locations were considered.

The surface storage sites were chosen based on relatively flat sites located close to the North Portal WHF (see Figure 9). Three sites were identified: north of Exile Hill, Midway Valley, and south along Exile Hill. A fourth storage site in the North Portal Pad area was also included.

The concrete storage pads were sized considering current commercial vendor designs for five different dry storage cask systems and one vertical WP-storage configuration. The storage pads were sized for 5,000 MTHM of storage; this results in 504 storage casks on a 665 ft by 609 ft pad.

The study evaluated storage sites for up to 20,000 MTHM in 5,000 MTHM modules. The Exile Hill and Midway Valley sites could accommodate 20,000 MTHM. The North Portal site is only large enough for 5,000 MTHM. The North Portal Pad site could accommodate about 1,000 MTHM. There is a possibility that as much as 40,000 MTHM of storage may be needed. Further evaluations would be required to determine if the Exile Hill and Midway Valley sites could be expanded beyond 20,000 MTHM of storage.

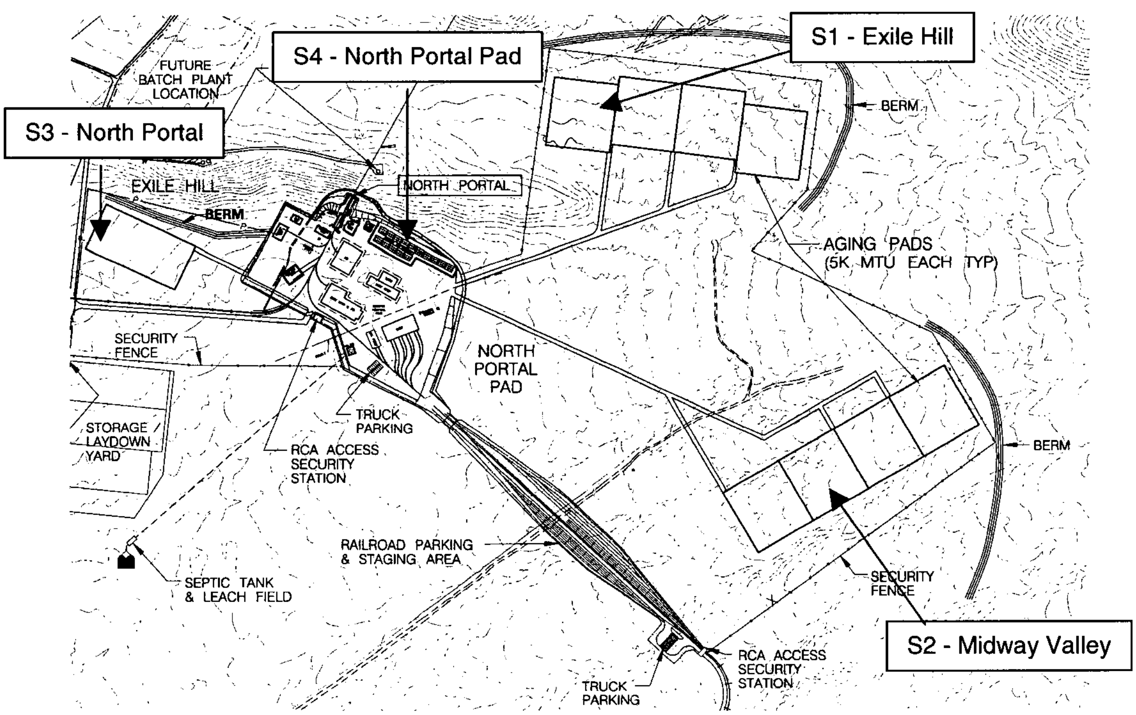

Figure 9. Potential Surface Aging Locations

B. Storage Containers

The following containers for surface storage were evaluated and recommended:

- Dual Purpose Canisters (DPC) – DPCs received at the repository are placed in a storage cask for aging; additionally, uncanistered CSNF could be loaded into a new DPC at the repository for aging.

- Multi-Purpose Canisters (MPC) – MPCs received at the repository are placed in a storage cask for aging, similar to DPCs, but can also be used for disposal using a disposal overpack.

- New disposal canister for uncanistered CSNF – uncanistered CSNF would be placed in a new "storage and disposal" canister for aging; the canister would also be used for disposal.

C. Cost Information

Pricing information for the spent fuel storage equipment was provided by system vendors, fabricators of canisters and casks, and experienced industry consultants. The unit costs shown in Table 13 represent the additional capital costs for the storage container options.

Table 13. Unit Costs for Storage Containers (M 2002$)

Option	Canister/Basket, 10 MTHM	Storage Cask, 10 MTHM	Carrier/Equip, 20,000 MTHM	Unit Capital Cost for Container Surface Aging 1 MTHM
C1 – DPC Vertical	0	0.250	4.0	0.0252
C1 – DPC Horizontal	0	0.150	12.8	0.0156
C2 – MPC Vertical	0	0.250	4.0	0.0252
C2 – MPC Horizontal	0	0.150	12.8	0.0156
C3 – Disposal Canister Vertical	0.450	0.250	4.0	0.0702
C3 – Disposal Canister Horizontal	0.400	0.150	12.8	0.0556

Note: Data taken from McDaniel 2002, Table 2.

Costs were developed for surface storage by estimating material quantities and associated direct costs and field distributable costs. Table 14 lists the resulting unit capital costs for the 4 surface storage locations.

Table 14. Unit Costs for Surface Storage

Option	Direct Cost (M 2002$)	Unit Direct Cost $M per MTHM
S1 – Exile Hill: 5000 MTHM	22.1	0.0044
S1 – Exile Hill: 20,000 MTHM	86.3	0.0043
S2 – Midway Valley: 5,000 MTHM	22.5	0.0045
S2 – Midway Valley: 20,000 MTHM	86.8	0.0043
S3 – North Portal: 5000 MTHM	21.6	0.0043
S4 – North Portal Pad: 1000 MTHM	7.7	0.0075

Note: Data taken from McDaniel 2002, Table 3

D. Unit Cost Assumptions for System Evaluation

The aging study did not recommend a single storage cask design or location. For the purpose of this study, the following cost assumptions were made for aging:

- Commercial DPCs will be used for CSNF aging. This option was selected because of the current lack of licensed commercial MPC designs, and the uncertainties associated with development of a storage and disposal canister for the repository. The cost for storage casks (for CSNF received in DPCs) is assumed to be the average cost of the C1 (vertical) and C2 (horizontal) option storage casks ($0.2M/cask). This reflects the uncertainty as to the storage method that will ultimately be chosen. For CSNF received uncanistered, the average cost of the canister from option C3 ($0.425M) is added to the storage cask cost.

- Storage pads for surface aging are assumed to be constructed in increments as needed. The first storage pad (the North Portal Pad) is assumed to hold 1,000 MTHM; subsequent pads are constructed in 5,000 MTHM increments. The unit cost of the first storage pad is assumed to be $.0075M/MTHM, and the unit cost of subsequent storage pads is assumed to be the 5,000 MTHM value for the Exile Hill/Midway Valley storage areas ($0.0045M/MTHM).

- The aging study did not include storage of defense wastes. If surface storage of defense wastes is required, it is assumed that storage canisters and casks will be developed for WP-sized quantities of defense wastes at a cost similar to those for CSNF. However, it must be noted that no designs currently exist for such storage systems. Naval SNF is assumed to require only a storage cask (similar to a DPC), whereas HLW and DSNF will require a storage system with both an internal basket and a cask (similar to uncanistered CSNF). Unit costs were assumed to be the same as for CSNF systems for "WP – sized" storage containers.

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5. SYSTEM DESIGN IMPLEMENTATION SCENARIOS

This section describes the process for combining the results of the Repository Design Evolution Study with the results of the national and Nevada transportation options studies to produce a series of system design implementation scenarios for further evaluation.

5.1 RECEIPT AND EMPLACEMENT SCENARIOS

This section describes the receipt and emplacement scenarios that will be used to perform the system design implementation evaluations. For all scenarios, the last year of emplacement is assumed to be 2038, which is driven by the receipt rate of defense wastes described in Section 4.1.1. The end of closure is assumed to be 2119, which is consistent with the 100-year preclosure period assumed in the May 2001 TSLCC (DOE 2001e). The nominal receipt, storage, and emplacement rates for the scenarios are given in Appendix C.

5.1.1 Scenario 1 – Mostly Rail, Reference Receipt Rates

This scenario assumes that wastes are transported to the repository in accordance with the target schedule in the CRD (DOE 2001a, Table 1). CSNF selection for transport at utility sites is in accordance with the "youngest fuel first greater than 10 years old" (YFF10) criterion (see Appendix A for definition). Transportation is "mostly rail" (i.e., rail with LWT transport only for sites that cannot handle a rail cask). Waste is emplaced as received, with no storage. Emplacement occurs first in the subsurface Panel 1, followed immediately by emplacement in Panel 2 and subsequent panels as needed. Surface facility phases are constructed as needed to meet the receipt rate.

5.1.2 Scenario 2 – Mostly Rail, Initial APR/ACR Receipt Rate

This scenario assumes the same transportation modes as Scenario 1. The CSNF receipt rate is capped at the maximum rate shown in the Acceptance Priority Ranking/Acceptance Capacity Report (APR/ACR) (DOE 1995a) for 10 years (until 2019). Beginning in 2020, the CSNF receipt rate ramps up to 3,600 MTHM/year to allow the receipt schedule to catch up to the CRD target schedule. Emplacement occurs first in the subsurface Panel 1, followed immediately by emplacement in Panel 2 and subsequent panels, which are constructed as needed. Surface facility phases are constructed as needed to meet the receipt rate.

5.1.3 Scenario 3 – Mostly Rail, Reference Receipt Rate, Delayed Emplacement

This scenario is similar to Scenario 1, except that after the testing area in Panel 1 is filled (approximately 1,200 MTHM of CSNF and a proportional amount of defense wastes), no more waste is emplaced until 2020. This simulates a postulated requirement to perform testing on the waste emplaced in the testing area prior to proceeding with further emplacement. During this time (2013-2019), all of the waste received is assumed to be stored on the surface. In addition, construction of subsurface Panels 2 - 4 is delayed by 8 years, since Panel 2 is not needed for emplacement until 2020. In 2020, waste emplacement resumes at a CSNF rate of 3,600 MTHM/year (and a corresponding defense rate) in order to achieve a last year of emplacement of 2038.

5.1.4 Scenario 4 – Mostly Rail, Accelerated Receipt and Emplacement Rate

This scenario is similar to Scenario 1, but assumes that the CSNF waste receipt and emplacement rates are increased by 1/3 to a maximum of 4,000 MTHM/year. Emplacement occurs first in the subsurface Panel 1, followed immediately by emplacement in Panel 2 and subsequent panels, which are constructed as needed. Surface facility phases are constructed as needed to meet the receipt rate.

5.1.5 Scenario 5 – Initial Truck/Heavy Haul, Low Rate

This scenario assumes that the Nevada rail line will not be available until 2015; therefore, transportation to the repository during the first 5 years of operation will be by Legal Weight Truck (LWT) and limited heavy haul (for naval SNF only). The initial CSNF transportation rate is limited to 100 MT/year and the HLW transportation rate is limited to 10 MTHM/year. Naval SNF is assumed to be shipped by heavy haul until 2015. The CSNF receipt rate ramps up to 3,600 MTHM/year after 2014, to allow the receipt to catch up with the CRD target schedule. The defense wastes receipt rates also ramp up to the reference rate after 2014. Emplacement occurs first in the subsurface Panel 1, followed immediately by emplacement in Panel 2 and subsequent panels, which are constructed as needed. Construction of Panels 2-4 is delayed by 3 years relative to the reference case. Surface facility phases are constructed as needed to meet the receipt rate.

5.1.6 Scenario 6 – Initial Truck/Heavy Haul, High Rate

This scenario is similar to Scenario 5, except that the initial (2010-2014) receipt rates for CSNF and defense wastes (except naval SNF) are increased by a factor of four.

5.1.7 Scenario 7: Initial Truck/Heavy Haul, High Rate, 2 Year Rail Delay

This scenario is similar to Scenario 6, but assumes that the Nevada rail line will become operational in 2012, instead of 2015.

Tables 15 and 16 summarize the characteristics of these scenarios.

Table 15. Receipt and Emplacement Scenarios – CSNF Parameters

Scenario	Description	2010-14 CSNF Receipt Rate (MT/yr)	2015+ CSNF Receipt Rate (MT/yr)	2010-14 National Transportation	2015+ National Transportation	Nevada Transportation	CSNF Emplacement Rate (MT/yr)	Storage Used	CSNF Selection Criterion
1	Mostly Rail, Reference Receipt Rate, YFF10	Reference[1]	Reference[1]	Mostly Rail	Mostly Rail	Option1 (Rail in 2010)	Receipt Rate	No	YFF10
2	Mostly Rail, Initial APR/ACR Receipt Rate	400, 600, 900, 900, 900	900,900,900, 900,900,1800, 2200,2600, 3000, 3600…	Mostly Rail	Mostly Rail	Option 1 (Rail in 2010)	Receipt Rate	No	YFF10
3	Mostly Rail, Reference Receipt Rate, Delayed Emplacement	Reference[1]	Reference[1]	Mostly Rail	Mostly Rail	Option 1 (Rail in 2010)	400, 600, 200, 0 (2014-19), 3,600, …	Yes (2013-19)	YFF10
4	Mostly Rail, Accelerated Receipt and Emplacement	Reference[1] + 33%	Reference[1] + 33% (4,000 max)	Mostly Rail	Mostly Rail	Option 1 (Rail in 2010)	Receipt Rate	No	YFF10
5	Intitial LWT/HH, Low Rate, 5 year Delayed Rail	50,100, 100, 100, 100	400, 600, 1200, 2000, 3000, 3600, …	LWT	Mostly Rail	Option 2 (LWT 2010-14, Rail in 2015)	Receipt Rate	No	YFF10
6	Intitial LWT/HH, High Rate, 5 Year Delayed Rail	200, 400, 400, 400, 400	400, 600, 1200, 2000, 3000, 3600, …	LWT	Mostly Rail	Option 2 (LWT 2010-14, Rail in 2015)	Receipt Rate	No	YFF10
7	Intitial LWT/HH, High Rate, 2 Year Delayed Rail	200, 400 (2010-11)	Reference[1] (2012+)	LWT	Mostly Rail	Option 3 (LWT 2010-11, Rail in 2012)	Receipt Rate	No	YFF10

[1] The Reference rate is the CRD Table 1 (DOE 2001a) target receipt rate used in the May 2001 TSLCC (DOE 2001b)

Table 16. Receipt and Emplacement Scenarios – Defense Wastes Parameters

Scenario	Description	2010-14 Defense Receipt Rate (MT/yr)	2015+ Defense Receipt Rate (MT/yr)	2010-14 National Transportation	2015+ National Transportation	Nevada Transportation	Defense Emplacement Rate	Storage Used
1	Mostly Rail, Reference Receipt Rate, YFF10	Reference[1]	Reference[1]	Rail	Rail	Option 1 (Rail in 2010)	Receipt Rate	No
2	Mostly Rail, Initial APR/ACR Receipt Rate	Reference[1]	Reference[1]	Rail	Rail	Option 1 (Rail in 2010)	Receipt Rate	No
3	Mostly Rail, Reference Receipt Rate, Delayed Emplacement	Reference[1]	Reference[1]	Rail	Rail	Option 1 (Rail in 2010)	Receipt Rate (2010-12), 0 (2013-19), 1.2x Receipt Rate (2020-)	Yes (2013-19)
4	Mostly Rail, Accelerated Receipt and Emplacement	Reference[1]	Reference[1]	Rail	Rail	Option 1 (Rail in 2010)	Receipt Rate	No
5	Intitial LWT/HH, Low Rate, 5 year Delayed Rail	5,10,10,10,10 Naval: Reference Rate[1]	Reference[1]	LWT + HH (naval)	Rail	Option 2 (LWT/HH 2010-14, Rail in 2015)	Receipt Rate	No
6	Intitial LWT/HH, High Rate, 5 Year Delayed Rail	20,40,40, 40,40 Naval: Reference Rate[1]	Reference[1]	LWT + HH (naval)	Rail	Option 2 (LWT/HH 2010-14, Rail in 2015)	Receipt Rate	No
7	Intitial LWT/HH, High Rate, 2 Year Delayed Rail	20,40 (2010-11) Naval: Reference Rate[1]	Reference[1] (2012+)	LWT + HH (naval)	Rail	Option 3 (LWT/HH 2010-11, Rail in 2012)	Receipt Rate	No

[1] The Reference rate is the rate defined in Table 4.

5.2 REPOSITORY DESIGN MODULE TIME-PHASING

For each of the receipt and emplacement scenarios described in Section 5.1, the construction and operation of the modular components of the repository surface facilities described in Section 4 were time-phased to match the receipt, aging, and emplacement rates. This was accomplished by matching the capabilities of the modular components to the annual receipt rates.

5.2.1 Surface Facilities

The Surface Facilities include five elements:

- Phase 0 (Permanent Plant Facilities)
- Phase 1
- Phase 2
- Phase 3
- Balance of Plant & Construction Support

Phase 0 (Permanent Plant Facilities) includes in-plant road, rail & fill removal at the North Portal. The schedule for Phase 0 is the same for all 7 scenarios.

Phase 1 includes North Portal fill, half size finishing building, Cask Carrier Prep Building, and Omni-Directional Lift Transporters. The schedule for Phase 1 is the same for all scenarios. The cost of the following items is excluded from Phase 1: Operator Recruitment & Training; Operating Manuals/Procedures; Operations Readiness Review; and Hot Start-up Testing. It is assumed these costs are picked up elsewhere. These costs are included in O&M costs. Phase 1 is also assumed to include a 1,000 MTHM surface aging facility at the North Portal Pad location (see Figure 9, location S4) for all scenarios.

Phase 2 includes Waste Transfer Facility (wet), Complete Rail Siding, Waste Treatment Building, Empty DC Prep Building, Complete Cask Carrier Prep, and OLTs. The cost of the following items is excluded from Phase 2: Operator Recruitment and Training; Operating Manuals/Procedures; Operations Readiness Review; and Hot Start-up Testing. These costs are included in O&M costs.

Phase 3 includes Dry Waste Transfer Facility, Transfer Corridor, and OLTs. The timing for Phase 3 construction changes such that the facilities are completed prior to the year the waste receipt rate exceeds 365 transportation casks per year. The cost of the following items is excluded from Phase 3: Operator Recruitment and Training; Operating Manuals/Procedures; Operations Readiness Review; Hot Start-up Testing. These costs are included in O&M costs.

Balance of Plant & Construction Support includes all other Surface Facilities included in the May 2001 TSLCC except those facilities identified in Phases 1-3 above. The schedule for these surface facilities is the same for all 7 scenarios. Construction Support ($82.5 million) is accelerated to pre-CA time frame, commencing in FY2006. The schedule for pre-CA Construction Support is the same for all 7 scenarios.

The total CSNF blending storage capacity in the three surface facilities phases consists of 10 canisters plus 144 PWR (or 324 BWR) assemblies in the Phase 3 dry WTF, and 480 PWR (or 1080 BWR) assemblies in the Phase 2 wet WTF (Brown 2002, Sections 3.7.1 and 3.7.2), for a total of approximately 400 MTHM. This is substantially less than the 5,000 MTHM capacity of the blending pool in the SR design. The significant reduction of storage capacity will necessitate either a separate aging facility to reduce overall heat load and provide a blending inventory and/or a change in the thermal heat limits for the individual WPs. A thermal operating strategy for the repository is currently under development. Once this is completed, a detailed analysis should be performed during preliminary design to determine the appropriate amount and type of WHF blending storage. For the purposes of this study, it was assumed that the 1,000 MTHM North Portal Pad aging area described in Section 4.2.2 is also used for WP blending purposes, giving a total blending storage capacity of about 1,400 MTHM. It was assumed that this blending capacity would be sufficient to support a HTOM. The cost of the North Portal Pad aging area was added to Phase 1 for all scenarios, plus 100 storage casks/canisters (about 1,000 MTHM) for all scenarios except Scenario 3 (which already includes significant storage).

The details of the surface facilities phased construction schedule and associated annual costs are contained in an Excel worksheet included in Appendix D.

It should be noted that the preliminary construction schedules developed for the surface facilities in the Design Evolution Study result in an initial operations date of December 2010. While this meets the goal of 2010 initial operation, it does not allow for receipt and processing of a significant quantity of waste in calendar year 2010 (certainly not approaching the CRD target level of 400 MTHM CSNF).

5.2.2 Subsurface Facility

Subsurface facilities include Panels 1-4, South Portal in Panel 1, the new portal in Panel 2, and associated facilities. The schedule for all scenarios except Scenarios 3 and 5 is driven by the estimated advance rate of the tunneling operation, not the waste emplacement rate; the Scenario 3 schedule for Panels 2 - 4 is delayed 8 years to reflect the moratorium on subsurface construction following filling of the initial subsurface test area, and the Scenario 5 schedule is delayed 3 years in response to the low initial waste receipt rate. The details of the subsurface phased construction schedule and associated annual costs are contained in an Excel worksheet included in Appendix D.

The preliminary construction schedules developed for the subsurface Panel 1 in the Design Evolution Study result in an initial operations date of December 2010. While this meets the goal of 2010 initial operation, it does not allow for emplacement of a significant quantity of waste in calendar year 2010 (certainly not approaching the CRD target level of 400 MTHM CSNF). However, this schedule was based on completion of 5 of the 8 drifts in Panel 1 by the end of 2010. The detailed construction schedule for Panel 1 (Board et al. 2002, Figure 5-8) shows that the first 3 drifts (which have about a 1,200 MTHM capacity), are completed by about June 2010. Even allowing time for a readiness review, it is possible that sufficient emplacement drifts for 400 MTHM could be available in 2010.

Table 17 summarizes the operation dates of the surface and subsurface modules for the 7 receipt and emplacement scenarios. Note that in some scenarios (e.g., 1, 3, 4, and 6), Phase 3 of the surface facilities is required to commence operation at the same time as Phase 2. This reflects the need for the additional processing capability in Phase 3 (note that Phase 2 does not include any cask processing capability, but is required for operation of Phase 3).

Table 17. Surface and Subsurface Modules Development

	Year of Initial Operation						
Module	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**
Surface Facilities							
Phase 1	2010	2010	2010	2010	2010	2010	2010
Phase 2	2013	2013	2013	2013	2013	2012	2013
Phase 3	2013	2020	2013	2013	2018	2012	2015
Subsurface Facilities (First Emplacement)							
Panel 1	2010	2010	2010	2010	2010	2010	2010
Panel 2	2012	2012	2020	2012	2015	2012	2012
Panel 3	2018	2018	2026	2018	2021	2018	2018
Panel 4	2024	2024	2032	2024	2027	2024	2024

5.3 REPOSITORY COST ANALYSIS

This section describes how the repository annual costs were developed from the unit cost data and construction schedules. Detailed worksheets showing the annual breakdowns for repository costs are included in Appendix D. The Basis of Estimate for the repository costs are provided in references Board et al. 2002; Linden 2002; Brown 2002; and McDaniel 2002.

5.3.1 General Assumptions

- LA is submitted in December 2004.
- Three year NRC review of LA.
- Ability to begin certain pre-construction activities prior to CA.
- CA received in March 2008.
- Costs derived or taken from the May 2001 TSLCC are escalated from 2000 dollars to 2002 dollars using a factor of 1.044.

- The BSC Detailed Work Plan ("Plan B") is used for the FY 2002 through LA costs. The estimate from LA through start of waste acceptance is based on a level-of-effort staffing plan for each functional organization with the exception of the operations and maintenance (O&M) cost.

- For the purposes of performing the cost analysis, receipt and emplacement rates were assumed to match the values given in Appendix C for each scenario. The inconsistencies between the preliminary construction schedules developed for the repository in the Design Evolution Study and the assumed receipt rates (noted in Section 5.2) were not considered.

5.3.2 Construction Costs

Direct costs for facilities that have changed from the SR design, per this study, are based on unit rates derived from the May 2001 TSLCC cost estimate. For the facilities that are unchanged from the SR design, the direct costs are based on the total direct cost values from the May 2001 TSLCC. The following is a list of adjustments to these direct cost values that account for the new M&O business model and/or experience:

- A productivity factor adjustment is applied to the direct labor cost to account for slower productivity associated with "Q-Listed" facilities.

- A revised factor is applied to the direct cost to allow for the construction contractor's indirect cost (e.g., temporary facilities, supervision, small tools, equipment, supplies, etc.)

- A revised factor is applied to the direct cost to account for the M&O's general and administrative cost (G&A rate). This rate is consistent with the current M&O business model.

- A factor is applied to the direct cost to allow for support services provided by the Nevada Test Site (NTS) during the construction phase of the project.

For Scenario 3, which assumed an 8 year delay in construction of Panels 2-4, an estimate of demobilization and mobilization costs for underground construction was included in the subsurface construction costs.

In order to allow for a direct comparison to the May 2001 TSLCC, WP spacing for all scenarios was assumed to be 0.1 meters, the value used in the TSLCC. Drip shield unit costs were calculated using the continuous drip shield model assumed in the May 2001 TSLCC. Note that the 0.1 meter WP spacing in the TSLCC resulted from a HTOM consistent with the SR surface facilities design (which included a 5,000 MTHM blending pool). The WP spacing that would result from a HTOM using the surface facilities design concept developed in the Design Evolution Study (which includes only about 400 MTHM of blending storage) has not been determined, due to the conceptual nature of the repository design and the current lack of a repository thermal operating strategy. This potential inconsistency was addressed in this study only to the extent that an additional 1,000 MTHM of surface blending storage was included in the cost analysis (see Section 5.2.1). Note that the available drift length in the first 4 subsurface panels is sufficient to accommodate 70,000 MTHM at up to 2 meter WP spacing. Since all 4 panels are assumed to be constructed regardless of the WP spacing, the subsurface construction costs are insensitive to the thermal operating mode. In addition, if the WPs were spaced significantly farther apart than 0.1 meters, a segmented drip shield would be used rather than the continuous drip shield costed in the this study. Therefore, the difference in total drip shield cost should not vary significantly with WP spacing.

The WP unit cost was assumed to be the average WP cost estimated in the May 2001 TSLCC, escalated to 2002 dollars ($0.465M, including the pallet). The number of WPs emplaced each year was estimated from the nominal waste receipt rate by utilizing average assemblies (or canisters) per WP values for PWR CSNF, BWR CSNF, and defense wastes derived from the May 2001 TSLCC waste stream (DOE 2001b, Table B-2). This approximation is accurate to about 0.6 percent, as shown in Table 18.

Table 18. Waste Package Model Results for Scenario 1

Type of WP	May 2001 TSLCC	Scenario 1	Delta (%)
CSNF	9,919	10,000	0.8
HLW	4,422[1]	4,247	-4.0
Naval SNF	300	300	0
Total	14,641[1]	14,547	-0.6

[1] Does not include 127 WPs (635 canisters) of immobilized plutonium included in TSLCC waste stream

5.3.3 Operations and Maintenance Costs

The O&M costs are based on the May 2001 TSLCC estimate, adjusted for items included in other parts of the estimate. For example, Performance Confirmation and Testing and Regulatory, Infrastructure, and Management Support (RIMS)-related costs are included as separate line items, and are not included in this function. The procurement and installation of the drip shields is included in the monitoring phase of the project. O&M costs were also adjusted for each scenario to account for variations in receipt and emplacement rates.

5.3.4 Indirect Costs

- Repository indirect costs include engineering, licensing, management support, administration, Payments Equivalent to Taxes (PETT), Benefits (i.e., payments to the state of Nevada and local governments), and Program Integration and Institutional (PI&I) costs. In the May 2001 TSLCC, engineering, licensing, management support, and administration costs were rolled up into a cost category called RIMS. For this analysis, costs that were included as RIMS are now included in the cost estimate for each functional organization represented by the current M&O (e.g., functional directs, project management, license application, repository design, etc.). Functional directs include project controls, finance, administration, science, engineering, etc.

PETT, Benefits and PI&I costs used in this study were based on costs generated for the May 2001 TSLCC. The TSLCC costs are based on 31 years emplacement and 69 years monitoring (100 years total). These costs were adjusted for the 70,000 MTHM waste stream by deleting 2 years of emplacement period costs and adding 2 years of monitoring period costs. The TSLCC costs were then escalated to 2002 dollars, and the contingency factor was adjusted as described in Section 5.4. Institutional costs (Nuclear Waste Policy Act Section 180[c]) are included in the WAST cost estimate.

5.4 COST CONTINGENCY FACTORS

Contingency factors are typically added to cost estimates to compensate for uncertainties in the cost data and/or the estimating process. For this study, the contingency factors used in the May 2001 TSLCC were reviewed and adjusted as necessary to reflect the conceptual nature of the modular design concept. Based on this review, the contingency factors shown in Table 19 were assumed for this study. Note that contingency factors are assigned only after 2005.

Table 19. Cost Contingency Factors

Cost Element	Contingency Factor (percent)
National Transportation	25.0
Nevada Transportation	25.0
Repository	30.0
Program Management & Integration	19.7
Institutional	30.0

6. EVALUATION OF SYSTEM DESIGN IMPLEMENTATION SCENARIOS

This section describes the results of the evaluation of the system conceptual design implementation scenarios. Logistics results and cost results are presented, plus an evaluation of the results versus the programmatic assumptions listed in Section 2.

6.1 LOGISTICS RESULTS

Table 20 summarizes the logistics results for the 7 scenarios, as compared to the May 2001 TSLCC. Note that the Maximum CSNF Storage Capability in Table 20 is the amount of storage capability costed in the analysis, not the maximum actually in storage at any one time.

Table 20. Logistics Results

Scenario	Total CSNF Accepted, 2010-20 (MTHM)	Total CSNF Emplaced, 2010-20 (MTHM)	Maximum CSNF Storage Capability (MTHM)[1]
TSLCC	25,200	25,200	5,000[1]
1	25,200	25,200	1,400[2]
2	10,000	10,000	1,400[2]
3	25,200	4,800	21,400[2]
4	33,610	33,610	1,400[2]
5	11,250	11,250	1,400[2]
6	12,600	12,600	1,400[2]
7	19,800	19,800	1,400[2]

[1] Pool storage for blending purposes
[2] Comprised of 400 MTHM pool storage, with the remainder in dry storage

Of the 7 scenarios, only scenarios 1, 3, and 4 meet or exceed the May 2001 TSLCC total receipt through 2020, and only scenarios 1 and 4 meet or exceed the May 2001 TSLCC total emplacement through 2020. Scenarios 5-7 fail to meet the TSLCC receipt and emplacement totals through 2020 due to the low initial receipt rate caused by delayed Nevada rail construction. Scenario 2 fails to meet the TSLCC total receipt and emplacement due to limiting the receipt rate for the first 10 years to the APR/ACR rate. Scenario 3 meets the TSLCC total receipt through 2020, but fails to meet the TSLCC total emplacement, due to the moratorium on emplacement from 2013-2019.

6.2 COST RESULTS

6.2.1 Costs for 70,000 MTHM Receipt and Emplacement

Table 21 summarizes the annual CRWMS future costs for the years 2002-2020 for the 7 scenarios, as compared to the May 2001 TSLCC (escalated to 2002 dollars). Table 22 shows the life cycle cost for emplacement of 70,000 MTHM. The historical costs were taken from the May 2001 TSLCC, escalated to 2002 dollars, and adjusted for actual FY 2001 expenditures.

Table 21. Annual CRWMS Future Costs, 2002-2020 (M 2002$)[1]

FY	TSLCC	Scen 1	Scen 2	Scen 3	Scen 4	Scen 5	Scen 6	Scen 7
2002	470	380	380	380	380	380	380	380
2003	530	530	530	530	530	530	530	530
2004	680	640	640	640	640	640	640	640
2005	790	640	640	640	560	630	630	630
2006	780	710	660	710	730	670	670	670
2007	1,460	990	920	990	1,000	710	740	770
2008	1,520	1,090	980	1,040	1,100	790	840	1,010
2009	1,630	1,430	1,340	1,260	1,420	1,010	1,160	1,380
2010	1,120	1,540	1,520	1,290	1,720	1,060	1,370	1,480
2011	890	1,390	1,200	1,250	1,470	1,100	1,350	1,350
2012	960	1,370	1,110	1,210	1,250	1,120	1,200	1,020
2013	1,100	1,200	1,010	1,080	1,290	1,040	1,110	1,150
2014	1,070	1,350	1,050	1,100	1,500	1,000	1,200	1,310
2015	1,110	1,380	1,070	1,090	1,530	900	1,060	1,280
2016	1,130	1,400	1,110	1,050	1,520	1,140	1,090	1,420
2017	1,090	1,400	1,110	1,220	1,520	1,270	1,170	1,420
2018	1,110	1,260	1,120	1,210	1,390	1,290	1,140	1,250
2019	1,080	1,260	1,190	1,220	1,400	1,380	1,220	1,230
2020	1,070	1,250	1,080	1,250	1,400	1,310	1,280	1,200
Total 2002-10	8,970	7,930	7,610	7,470	8,070	6,410	6,950	7,490
Total 2002-20	19,570	21,190	18,640	19,150	22,340	17,960	18,780	20,110
Peak 2002-10	1,630	1,540	1,520	1,290	1,720	1,060	1,370	1,480

[1] Costs rounded to the nearest $10 million

Note that all of the scenarios exhibit lower total costs through 2010 than the May 2001 TSLCC, and all but Scenario 4 exhibit lower peak costs through 2010. Scenarios 1, 4, and 7 exhibit higher total costs through 2020 than the May 2001 TSLCC.

Note that the annual cost results shown in Table 21 assume that the repository can receive and process waste at the rates given in Tables 15 and 16. As discussed in Section 5.2, the preliminary construction schedules developed in the Design Evolution Study, while meeting the goal of initial repository operation in 2010, do not support the receipt of the quantities of waste in 2010 shown in Tables 15 and 16. Therefore, the annual costs shown in Table 21 for 2010 are likely overestimated. However, it is likely that processing rates could be accelerated in the near term such that the total costs through 2020 would not differ significantly from those given in Table 21.

Table 22. Life Cycle Cost for 70,000 MTHM Emplacement (B 2002$)

Scenario	Historical	WAST[1]	Nevada Transportation	Repository	PI&I[2]	Total
1	9.0	5.0	1.0	35.1	6.5	56.6
2	9.0	5.1	1.0	35.1	5.4	55.5
3	9.0	5.0	1.0	37.5	6.5	59.0
4	9.0	5.1	1.0	35.1	6.5	56.6
5	9.0	5.1	0.9	35.1	5.8	56.0
6	9.0	5.1	0.9	35.1	5.8	55.9
7	9.0	5.0	1.0	35.0	6.5	56.5

[1] WAST = Waste Acceptance, Storage, and Transportation
[2] PI&I = Program Integration and Institutional

6.2.2 Total Life Cycle Costs and Fee Adequacy

6.2.2.1 Total Life Cycle Cost Calculation

In order to estimate the impacts of the modular repository design concept on Total System Life Cycle Costs and Fee Adequacy, the results for 70,000 MTHM emplacement were extended to 97,800 MTHM (83,800 CSNF, 14,000 defense), the total waste stream amount in the May 2001 TSLCC. The waste streams for the 7 scenarios were extended by adding additional years of acceptance at the maximum acceptance rate

The costs for the extended years of receipt and/or emplacement were estimated using costs for years with comparable receipt/emplacement rates. The increased amount of drift length required for 97,800 MTHM was accounted for by multiplying the additional WPs generated by the average WP length (including spacing between WPs). Note that at 0.1 meter spacing, the WPs for 97,800 MTHM require about 74,700 meters of emplacement drift length, which is within the total emplacement drift length for Panels 1 – 4 (see Table 8). However, due to the uncertainty about the WP spacing required for a HTOM using the assumed surface facilities design (see Section 5.3.2), it was assumed that Panel 5 is constructed for all 97,800 MTHM scenarios. Additional drip shield costs were calculated from the additional number of WPs, and spread over the closure period. The total pre-closure period was kept the same for all scenarios. Once the adjusted future costs were calculated, the historical costs from the May 2001 TSLCC (adjusted for actual 2001 expenditures) were added to all scenarios. The receipt, storage, and emplacement rates for the 97,800 MTHM waste stream scenarios are given in Appendix C. The detailed cost calculations are included in the summary cost worksheets in Appendix D. Table 23 shows the resulting life cycle costs for the 7 scenarios and the May 2001 TSLCC.

Table 23. Total Life Cycle Cost for 97,800 MTHM Emplacement (B 2002$)

Scenario	Historical Costs	WAST	Nevada Transportation	Repository	PI&I	Total	Delta to May 2001 TSLCC
May 2001 TSLCC[1]	9.0	6.2[2]	0.9	37.5	6.4[3]	60.0	0
1	9.0	5.6	1.0	40.6	**6.8**	**62.9**	**2.9**
2	9.0	5.7	1.0	40.2	**6.0**	**61.9**	**1.9**
3	9.0	5.6	1.0	44.0	**6.8**	**66.3**	**6.3**
4	9.0	5.2	1.0	40.6	**6.8**	**62.6**	**2.5**
5	9.0	6.4	1.0	42.0	**6.2**	**64.6**	**4.6**
6	9.0	6.4	1.0	41.0	**6.2**	**63.5**	**3.4**
7	9.0	6.0	1.0	40.7	**6.8**	**63.4**	**3.4**

[1] For the May 2001 TSLCC, FY 2001 costs have been included in historical costs.
[2] Includes $0.5 billion in 180(c) costs which in the TSLCC were included in PI&I
[3] Reduced by $0.5 billion in 180(c) costs transferred to WAST

As can be seen from Table 23, the life cycle costs for the 7 scenarios are $1.9 to $4.6 billion higher than the May 2001 TSLCC. Repository costs are $2.7 to $4.5 billion higher. However, nearly all of the increase in repository costs result from the difference in assumed contingency factors between the May 2001 TSLCC (~14% for repository costs) and this study. Table 24 shows a summary comparison of repository costs without contingency for the 7 scenarios and the TSLCC.

Table 24. Repository Base Cost Comparison for 97,800 MTHM Emplacement

Scenario	Repository Cost (B 2002$)	Delta to May 2001 TSLCC
May 2001 TSLCC	31.9	0.0
1	31.5	-0.4
2	31.5	-0.4
3	34.1	2.2
4	31.5	-0.4
5	32.6	0.7
6	31.8	-0.1
7	31.6	-0.3

Table 25 shows a reconciliation of the costs for Scenario 1 with the May 2001 TSLCC. In this table, the May 2001 TSLCC costs have been redistributed to match as closely as possible the Scenario 1 cost categories.

Table 25. Scenario 1 and TSLCC Cost Reconciliation

Cost Element	Millions of 2002 Dollars		
	Scenario 1	**May 2001 TSLCC[1]**	**Delta**
Repository			
Project Support[2]	$11,269	$12,845	-$1,576
Construction	$18,516	$17,848	$668
Other[3]	$1,715	$1,215	$501
Contingency	$9,085	$5,957	$3,129
TOTAL YMP – NEVADA	**$40,586**	**$37,865**	**$2,721**
Waste Acceptance and Transportation (WAST)			
Waste Acceptance and National Transportation	$5,597	$6,171	-$574
Nevada Transportation	$968	$877	$92
TOTAL WAST	**$6,565**	**$7,047**	**-$483**
Program Integration and Institutional (PI&I)			
Program Integration	$2,233	$2,334	-$101
Institutional	$3,174	$3,272	-$97
Contingency	$1,343	$915	$427
TOTAL PI&I	$6,750	$6,521	$228
GRAND TOTAL FUTURE COSTS	$53,900	$51,433	$2,467
Historical Costs (1983-2000)	$8,587	$8,587	$0
2001 Costs	$417	$0	$417
TSLCC	**$62,904**	**$60,020**	**$2,884**

[1] Note that TSLCC costs include projected FY2001 costs, so cost deltas for individual categories may be slightly off.

[2] Includes Functional Directs, Design, Repository O&M, Licensing, Performance Assessment, Site Services, Procurement, Construction Management, Special Projects, and USGS

[3] Includes Bechtel Nevada, YMP Program Direction, Set-Asides, and Miscellaneous Adjustments

The principal difference in base repository costs between the May 2001 TSLCC and Scenario 1 is due to lower Project Support costs in Scenario 1 ($1.6 billion). This is due mostly to re-estimation of the support costs included as RIMS costs in the TSLCC. In the "Other" cost category, Scenario 1 costs are $500 million higher than the TSLCC, principally due to higher estimated "set-asides" (fees, etc). The largest cost difference, as discussed above, is in contingency costs.

Other differences between the TSLCC and Scenario 1 costs are in WAST, Nevada transportation, and PI&I. The WAST cost differences ($574 million) mainly reflect the assumption of transport via dedicated trains in Scenario 1, rather than general freight as in the TSLCC. The differences in PI&I costs reflect increased contingency costs, partially balanced by reductions in 2002 – 2005 costs to reflect the Plan B budget.

6.2.2.2 Fee Adequacy Assessment

A parametric assessment of Fee Adequacy was performed for the 7 scenarios analyzed in this study. Costs were split between civilian and defense funding sources utilizing data from the May 2001 TSLCC model (DOE 2001e), adjusted for the larger repository area. The results of the assessment indicated that there does not appear to be a Fee Adequacy concern with any of the scenarios.

6.3 EVALUATION OF RESULTS VERSUS PROGRAMMATIC ASSUMPTIONS

Table 26 shows the summary results of an evaluation of the recommended design concept as implemented by the 7 scenarios analyzed in this study versus the programmatic assumptions described in Section 2. A "green" ranking means that the implementation of the design fully satisfies the programmatic assumption or constraint. A "yellow" ranking means that some elements of the design implementation did not fully satisfy the programmatic assumption, although the overall ranking is acceptable. A "red" ranking means that the implementation of the design does not satisfy the assumption or constraint. A discussion of the areas that received a "yellow" or "red" ranking follows.

Criterion

2.1.3.B A high priority goal of the study is to develop a design concept that could allow initial emplacement of some CSNF (plus any or all of the other waste types described in 3.2.B, if possible) by 2010, even under the constrained funding assumption in section 3.5.

Ranking: Green/Red

Discussion

The design concept evaluated allowed the initial emplacement of all waste types analyzed by 2010 (green). However, the constrained funding limitation was not met (red) (see discussion of Criterion 2.1.4, below).

Table 26. Evaluation of Design Implementation Versus Programmatic Assumptions

Criteria No.	Description	Ranking	Comments
2.1.1. A	The study shall focus on flexible modular design options that could support a staged repository development approach	GREEN	The design of the surface and subsurface facilities is modular – the evaluation of the 8 scenarios shows that these modules can be constructed in a manner that would support a staged repository development approach.
2.1.1.B	The repository design shall have the flexibility to accommodate early receipt, assuming adequate funding and authorization is available.	GREEN	See discussion in Section 6.4.5.
2.1.1.C	An initial subsurface performance confirmation and test facility shall be included as an option.	GREEN	A test facility is included in subsurface Panel 1.
2.1.1.D	Repository design and operations assumptions shall be bounded by values assumed in the Final Environmental Impact Statement (FEIS).	GREEN	No instances were identified in the Design Evolution Study or in the evaluation of the scenarios in this study that exceeded the bounding values in the FEIS.
2.1.1.E	The design shall retain the capability for either a high- or low-temperature post-closure thermal mode.	GREEN	The scenarios evaluated in this report assume 0.1 meter WP spacing and 100 years pre-closure ventilation, which results in a high temperature post-closure thermal mode. However, the subsurface design includes sufficient drift space in the 5 panels to accommodate greater WP spacings, and that, combined with extended ventilation, would support a lower temperature post-closure thermal mode.

Table 26. Evaluation of Modular Design Implementation Versus Programmatic Assumptions (Continued)

Criteria No.	Description	Ranking	Comments
2.1.2.A	The design shall support waste receipt as soon as practicable, but no later than 2010.	GREEN	The construction schedules for surface and subsurface facilities supported beginning of receipt by 2010. All 3 Nevada transportation options supported a 2010 start of operations.
2.1.2.B	The repository shall have the initial capability to receive annually at least one WP quantity of CSNF and one shipment of naval SNF. Initial receipt of HLW, DSNF (excluding naval SNF), and immobilized plutonium (if available) shall be a goal assuming adequate funding is available.	GREEN	The minimum receipt scenario (Scenario 5) received 50 MT of CSNF, 5 MT of HLW , 3 naval SNF canisters, and 2 DSNF canisters.
2.1.3.A	Waste emplacement is decoupled from waste receipt.	GREEN	Scenario 3 demonstrates emplacement rates that differ from the receipt rates.
2.1.3.B	A high priority goal of the study is to develop a design concept that could allow initial emplacement of some CSNF (plus any or all of the other waste types described in 2.1.2.B, if possible) by 2010, even under the constrained funding assumption in section 2.1.4	GREEN / RED	See discussion in text.
2.1.3.C	The design of the repository will be based on a capacity of 70,000 MTHM (63,000 MTHM CNSF, 7,000 MTHM defense wastes), but shall not preclude receipt and emplacement of up to the maximum waste quantity described in the FEIS.	GREEN	The subsurface design concept includes 4 Panels that provide sufficient drift space to accommodate 70,000 MTHM ; a 5th Panel provides additional space to accommodate up to about 100,000 MTHM total at 0.1-meter WP spacing. If additional wastes are to be emplaced such that the drift space in the 5 Panels is exceeded, the design concept does not preclude characterizing additional subsurface areas and constructing emplacement drifts
2.1.3.D	As a minimum, the initial emplacement rate shall support the subsurface testing facility.	GREEN	Scenario 5 , which has the lowest initial emplacement rates, emplaces approximately 100 WPs in the first 4 years; this rate is sufficient to support the testing facility, which conceptually would hold about 90 WPs.

Table 26. Evaluation of Modular Design Implementation Versus Programmatic Assumptions (Continued)

Criteria No.	Description	Ranking	Comments
2.1.4	The following constrained funding assumptions shall be used: - A maximum of $400 million/year (Program total) through LA - A maximum of $600 million/year from LA through 2010 The design shall have the flexibility to ramp up to the target receipt schedule in the current *CRWMS Requirements Document* (CRD) Table 1, assuming additional funding is available. The design shall not preclude the ability to expand receipt rates to levels exceeding the maximum target rate in the CRD	RED	See discussion in text.
2.1.5	The design solutions shall not be predicated on the receipt of a Limited Work Authorization (LWA), regulatory changes, or legislative redirection of the Program. The design must be flexible enough to accommodate early construction of non-nuclear portions of the facility outside the Geologic Repository Operations Area (GROA), assuming adequate funding and authorization.	YELLOW	See discussion in text.
2.1.6.A	There will be no requirement for availability of rail transportation prior to start of operations.	GREEN	Three of the 7 scenarios do not assume that the Nevada rail line is available in 2010.
2.1.6.B	Repository design solutions shall be integrated with the national transportation system.	GREEN	All scenarios use National transportation options that are integrated with the repository design implementation options.

Criterion

2.1.4 The following constrained funding assumptions shall be used:

- A maximum of $400 million/year (Program total) through LA
- A maximum of $600 million/year from LA through 2010

The design shall have the flexibility to ramp up to the target receipt schedule in the current *CRWMS Requirements Document* (CRD) Table 1 (DOE 2001a), assuming additional funding is available. The design shall not preclude the ability to expand receipt rates to levels exceeding the maximum target rate in the CRD.

Ranking: Red

Discussion

The implementation scenarios demonstrated that the design concept has the flexibility to ramp-up to receipt and emplacement rates meeting and in some cases exceeding the CRD target rates by as much as 33 percent. However, the construction schedule developed for the repository design concept does not support initial receipt in 2010 at the target rate in the CRD (400 MTHM CSNF), even though for costing purposes this rate was assumed in several of the scenarios. In addition, the constrained funding assumption was not met in any of the scenarios analyzed. The minimum-capability scenario (Scenario 5) was intended to comply as far as possible with the constrained funding limit. As shown in Table 21, the maximum annual cost prior to 2010 for this scenario was $1.06 billion, which significantly exceeded the $600 million annual goal.

Criterion

2.1.5 The design solutions shall not be predicated on the receipt of a Limited Work Authorization (LWA), regulatory changes, or legislative redirection of the Program. However, the design must be flexible enough to accommodate early construction of non-nuclear portions of the facility outside the Geologic Repository Operations Area (GROA), assuming adequate funding and authorization.

Ranking – Yellow

Discussion

See Section 6.4.3 below.

6.4 LICENSING ISSUES

In addition to the evaluation criteria described in Section 6.3, the design concept and its implementation in this study were examined with respect to licensability. The following licensability issues were identified during the design component sub-studies or the design implementation analysis conducted in this study:

6.4.1 Surface Facilities

The Waste Handling Facility sub-study (Brown 2002, Appendix B) concluded that the recommended option (a dry waste handling facility with a small wet system for off-normal circumstances) involves some licensing risk due to the dry processing of large amounts of bare CSNF assemblies on a continual basis. However, the inclusion of a wet off-normal handling facility ameliorates this risk somewhat. The number of individual handling functions bears heavily on the perceived safety performance of the high throughput process. The NRC reviewers will scrutinize these functions with likely advantage given to the fewer processing steps, as present in the dry system. However, the uncertainties involved in the phased and separated modular design may combine to increase the risk of licensing.

6.4.2 Aging

The aging sub-study (McDaniel 2002) concluded that if Option C3 is selected for aging of CSNF (a new disposable canister that could be stored and then placed directly into a disposal overpack):

- Design and licensing of the disposal canister design would be required, which would parallel the design and licensing of the WPs. This would minimize the number of storage systems that would need to be licensed and deployed.

- The WHF would need to include new process steps for handling, inspecting, and welding the new disposal canisters.

An additional issue arose during the analysis of Scenario 3. If it is assumed that all subsurface construction is halted for several years after the initial test area is filled, waste received between 2013 and 2019 would either need to be stored at the repository, or acceptance would need to be halted during the emplacement moratorium. The aging sub-study did not include an analysis of surface storage for defense wastes. For the purposes of this study, it was assumed that defense wastes could be stored on the surface in "WP-sized" canisters with a concrete overpack (similar in design and cost to DPC storage for CSNF). Such storage systems for defense wastes do not currently exist, and would require development by DOE and licensing by the NRC. If it is decided to provide for storage of defense wastes at the repository, additional work would be required to determine the feasibility and cost of providing for storage.

The issue of whether storage (aging) facilities could be licensed as part of the repository under 10 CFR Part 63 is addressed in Appendix E.

6.4.3 Design Implementation

The preliminary construction schedules from the Design Evolution Study identified a number of early construction activities that would be required to meet a 2010 operations date. Examples of such activities are:

- Safety and infrastructure improvements

- Support of ongoing testing and initiation of additional performance confirmation activities

- Site remediation activities.

Tables 7 and 11 show the activities identified in the Design Evolution Study for the Nevada rail and surface facilities, respectively. The Underground Layout Study (Board et al. 2002, Figure 5-7) also assumes on-site power upgrades and other BOP early construction activities. Further evaluation is being performed as part of the Critical Decision 1 (CD-1) effort to determine the extent to which early construction activities may be required.

6.4.4 Phased Repository Construction

Appendix E contains a detailed discussion of regulatory issues associated with phased construction and operation of the repository.

6.4.5 Early Waste Receipt

The Design Evolution Study Summary (Rowe 2002, Section 7) discussed the adaptability of the phased construction design concept to early receipt of waste (i.e., prior to 2010), assuming adequate funding and authorization are available. Two early receipt options were evaluated, as described below.

Option 1 – Early Receipt and Emplacement

The current LA schedule, along with the NRC review time, will not give the project a CA until March 2008. This would not provide sufficient time to construct the facilities necessary for early waste receipt and emplacement. Thus, any meaningful early receipt and emplacement would require a change to the decision strategy to submit the LA prior to 2004, and an expedited review by the NRC to allow starting construction prior to 2008.

Option 2 – Early Receipt Only

Delay all subsurface work and simply construct a waste storage area at one or more of the potential sites identified in Figure 9. This surface storage would require a change to the Nuclear Waste Policy Act (NWPA) (DOE 1995b). The change would be necessary to remove the prohibitions and limitations that are contained in NWPA sections 135 (a) (1) and (2), and 141 (g), which prevent the storage of waste at Yucca Mountain prior to repository licensing. If such legislative relief were obtained, the NRC would need to conduct a conforming rulemaking to amend 10 CFR 63 to eliminate its corresponding prohibitions.

Even if the current NWPA storage prohibitions were to be removed, the Energy Reorganization Act, Section 202 (3) and (4), requires that DOE storage of commercial reactor spent fuel be licensed by the NRC. Two licensing options are presented:

10 CFR 72 license – 10 CFR 72 is the NRC regulation for storing spent fuel. Originally issued in the early 1980s, this regulation accommodates both dry and wet storage, and stand-alone storage as well as storage at a licensed reactor site. If applied to Yucca Mountain, a specific Part 72 license could be issued to DOE after NRC review. However, if a request for hearing were granted by the Commission, a 10 CFR 2 Subpart G hearing would be held prior to license issuance. Such a hearing would take place if parties were admitted upon successful petition for leave to intervene, and if the assigned Atomic Safety and Licensing Board were to admit at least one contention for litigation. The high likelihood that Nevada and Clark County would petition successfully and participate in a hearing has the potential to introduce the significant schedule uncertainty in this endeavor.

Operate under DOE Orders – This option would require amendment to both the NWPA and the Energy Reorganization Act to allow DOE to receive and store the fuel without the requirement for NRC licensing. We would still need to address the issues concerning NEPA and the fact that 10 CFR 63 does not allow early fuel storage. This option would be counter to recent DOE actions at INEEL, which entail NRC licensing of spent fuel storage, and would likely draw opposition due to the lack of public access to the process.

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7. CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the results of the system design implementation analysis, and lists recommendations for alternative conceptual design solutions and/or changes in Program/Project requirements.

7.1 CONCLUSIONS

The Design Evolution Study (Rowe 2002) examined potential enhancements to the repository design that is presented in the *Yucca Mountain Science and Engineering Report* (S&ER) (DOE 2001c). The study concluded that there are several enhancements that, if implemented, could potentially result in an improved repository design, lower peak costs, and increased flexibility. The design concept used in this study reflects the recommendations of the Design Evolution Study.

This study evaluated the implementation of the modular design concept using 7 receipt and emplacement scenarios. The scenarios tested the ability of the design concept to adapt to changes in funding, waste receipt/emplacement rate, and Nevada rail transportation availability.

The overall conclusion of this study is that the repository design concept recommended for further study in the Design Evolution Study (Rowe 2002) is adaptable and appears to be sufficiently flexible to encompass a variety of receipt rates, emplacement rates, transportation options, and funding profiles. Other conclusions are as follows:

1. Peak and total Program costs during the pre-operations period (through 2010) were reduced by utilizing a phased repository construction concept. Scenario 1, which has receipt and emplacement assumptions similar to those in the May 2001 TSLCC, reduced peak Program costs by $90 million (6 percent) and total costs through 2010 by $1.0 billion (12 percent) versus the SR design. Scenario 5 reduced peak costs by $570 million (35 percent) and total costs by $2.6 billion (29 percent), but at the cost of a substantial reduction in initial receipt capability. Note that without the assumed increase in contingency factors versus the May 2001 TSLCC, the cost differences for all scenarios would have been greater.

2. Repository design and construction costs represent about 24 percent of total Program costs through 2010. Therefore, even though these costs were reduced by almost 50 percent by phased construction in Scenario 1, the net reduction in total costs was only 12 percent.

3. The preliminary construction schedule developed for the Design Evolution Study, while supporting a 2010 operations date, does not support receipt of waste at the CRD target rates in 2010 (400 MTHM of CSNF).

4. Once adjusted for differing contingency factors, estimated total life cycle costs for the 7 implementation scenarios are not significantly different than for the SR design modeled in the May 2001 TSLCC, particularly given the large uncertainties in the cost estimates.

5. The Nuclear Waste Fund Fee appears to be adequate for all of the scenarios.

6. The construction schedule developed for the Design Evolution Study identified a number of early construction activities that would improve confidence in meeting an operation date of 2010. Further evaluation is being performed as part of the Critical Decision 1 (CD-1) effort to more definitively determine the extent to which early construction activities are required.

7. Construction and operation of the repository in a phased manner appears to be consistent with the current regulatory requirements in 10 CFR 63.

8. The phased construction concept appears to be adaptable to early waste receipt, assuming adequate funding and authorization.

9. The design concept analyzed in this study did not meet the constrained funding criterion of $600 million/year from LA through 2010. While this criterion was set somewhat arbitrarily, the minimum cost implementation scenario (Scenario 5) exceeded this goal by over $400 million in 2009. Contributing factors were the need to support a rapid ramp-up in waste receipt rate through 2015, and the fact that BOP cost phasing was not evaluated. However, given the fact that repository design and construction costs represent about 24 percent of the total Program costs through 2010, it is unlikely that the $600 million/year goal can be met without reductions in Program costs other than design and construction.

10. The analysis of Scenario 3 involved a several-year moratorium on underground construction and emplacement after the filling of the test area in subsurface Panel 1. This required an assumption of either surface storage at the repository for defense wastes, or halting receipt of defense wastes during the emplacement moratorium. For the purposes of this study, it was assumed that surface storage of defense wastes would be employed. If such a feature were to be included in the repository design, storage casks for HLW and DSNF (including naval SNF) would need to be designed and licensed.

11. The cost analyses performed for this design concept were only rough order of magnitude (ROM) estimates, in that there was little or no "bottoms up" cost analysis performed due to lack of design detail and time constraints. Therefore, the life cycle costs generated in this study are useful only for comparative purposes.

7.2 RECOMMENDATIONS

The following recommendations were developed as a result of this study:

1. As part of the preliminary design process, further evaluation of the repository design concept and more detailed estimates of BOP facilities' cost and construction schedules will be required to more accurately determine annual costs through 2010.

2. As part of the preliminary design process, further evaluation of the repository construction schedule should be performed to more accurately determine the need for early construction activities and the receipt rate in the early years of operation.

3. As the design is refined further, more comprehensive life cycle cost and Fee Adequacy analyses should be performed, including development of a more detailed operations and maintenance (O&M) cost model.

4. There is a need to evaluate other Program costs (besides repository design and construction), in order to further reduce the funding profile through 2010.

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APPENDIX A
YFF10 CSNF SELECTION CRITERION

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APPENDIX A – YFF10 CSNF SELECTION CRITERION

1. Casks are selected based on priority (from highest to lowest). The highest priority cask usually has the largest capacity (and lowest heat limit) that can be handled at the site. Assemblies are then selected based on the YFF10 method (youngest fuel 10 years old or older selected first) and are tested against the cask limits.

2. Assemblies that pass the cask limit tests are loaded. Assemblies that fail the cask limit test are rejected.

   - If sufficient acceptable assemblies cannot be located in the pool to fill the allocation, assemblies are taken from dry storage.

   - If sufficient acceptable assemblies cannot be located in dry storage, fuel younger than 10 years old will be selected from the pool starting at the minimum acceptable fuel age and working up to 10 years old.

   - If the current cask still cannot be filled, the desired fuel age is reset to 10 years, the next priority cask (usually a smaller, more robust design) is chosen, and the assembly selection/testing is repeated.

   - Once sufficient assemblies have been loaded to fill the allocation, the next pool is selected. Note that if sufficient acceptable assemblies cannot be loaded, the pool's remaining allocation will be deferred to the next year.

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APPENDIX B
TRANSPORTATION SCENARIOS ANNUAL COSTS

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APPENDIX B – TRANSPORTATION SCENARIOS ANNUAL COSTS

This appendix contains the costs developed for the national transportation scenarios that were included in this study. The annual costs are shown in Table B-1 and the total costs are shown in Table B-2. These results were taken from reference BSC 2002b.

Table B-1. Annual Costs for National Transportation Scenarios

Year	Millions of 2001 Dollars					
	1B	3B	4A	5A	7A	7D
2002[1]	2.8	2.8	2.8	2.8	2.8	2.8
2003[1]	8.9	8.9	8.9	5.2	5.2	5.2
2004[1]	15.2	15.2	15.2	5.6	5.6	5.6
2005[1]	13.0	13.0	13.0	8.3	8.3	8.3
2006	17.6	37.9	37.9	18.5	18.5	18.5
2007	13.6	46.6	46.6	14.5	14.5	14.5
2008	48.6	92.2	93.7	31.7	36.1	36.1
2009	78.3	123.9	133.6	45.8	59.0	59.0
2010	144.5	125.9	142.9	36.3	51.8	85.6
2011	137.1	148.6	167.7	47.3	66.2	109.3
2012	145.3	176.9	199.6	59.5	77.5	106.4
2013	145.7	192.8	226.0	99.4	120.6	141.1
2014	131.8	190.5	228.3	120.7	138.2	174.6
2015	132.5	197.6	238.9	128.4	128.2	208.2
2016	129.3	181.0	204.7	146.1	134.0	190.9
2017	142.3	192.3	216.9	175.9	171.4	200.6
2018	140.3	186.5	219.2	199.4	196.8	192.1
2019	164.6	179.1	219.1	201.3	207.3	195.4
2020	159.8	180.9	226.7	216.4	217.7	181.2
2021	183.4	183.4	221.7	212.9	209.1	185.1
2022	188.5	182.2	228.0	213.2	203.9	185.0
2023	204.7	184.5	230.6	207.6	206.2	187.8
2024	200.9	182.9	229.8	207.0	204.7	184.4
2025	211.1	185.2	234.9	210.0	213.6	192.3
2026	199.6	192.8	226.0	213.9	215.4	182.5
2027	199.3	179.8	202.4	214.8	217.8	191.3
2028	185.1	169.7	107.5	217.5	216.3	191.5

Table B-1. Annual Costs for National Transportation Scenarios (Continued)

Year	Millions of 2001 Dollars					
	1B	3B	4A	5A	7A	7D
2029	186.4	170.9	53.6	226.1	226.9	177.9
2030	195.2	171.2	75.5	235.1	224.8	179.0
2031	189.8	173.5	50.5	231.9	219.9	181.4
2032	192.2	169.2	65.8	210.9	202.6	176.6
2033	195.3	142.6	51.8	204.0	202.2	174.6
2034	190.2	60.6	59.4	192.1	178.9	166.9
2035	191.6	55.8	57.3	102.1	85.8	89.8
2036	142.5	43.1	52.8	49.9	52.7	51.3
2037	46.8	40.1	47.0	75.3	64.5	71.4
2038	34.6	39.9	45.6	49.2	32.0	32.0
2039	28.7	5.4	8.3	47.5	39.5	46.3
2040	16.3	0.0	0.0	23.8	22.6	20.1
Total	4,953.3	4,825.6	5,415.8	4,908.0	4,899.3	4,802.7

[1] Note: 2002-2005 costs were not used in the total system cost analysis; current budget numbers were used instead.

APPENDIX C
RECEIPT AND EMPLACEMENT SCENARIOS

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APPENDIX C – RECEIPT AND EMPLACEMENT SCENARIOS

This appendix lists the nominal receipt, storage, and emplacement rates for the scenarios used in this study. Section C.1 gives the data for the 70,000 MTHM waste stream, and Section C.2 shows data as expanded for a 97,800 MTHM waste stream.

C.1 70,000 MTHM WASTE STREAM

Table C-1. Scenario 1 Nominal CSNF Receipt, Storage, and Emplacement Rates

Year	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)
2010	400	0	400
2011	600	0	600
2012	1,200	0	1,200
2013	2,000	0	2,000
2014	3,000	0	3,000
2015-2032	3,000	0	3,000
2033	1,800	0	1,800
Total	63,000	0	63,000

Table C-2. Scenario 1, 2, and 4 Defense Wastes Receipt/Emplacement Rates

Year	HLW (MTHM/year)	Naval SNF (Canisters/Year)	Other DSNF (Canisters/Year)
2010	127.5	3	18
2011	220	3	41
2012	220	6	62
2013	220	6	76
2014	235	12	76
2015	235	14	76
2016	220	14	76
2017	235	14	76
2018	245	14	86
2019	367.5	14	129
2020	357.5	14	130
2021	322.5	14	129
2022	360	14	138

Table C-2. Scenario 1, 2, and 4 Defense Wastes Receipt/Emplacement Rates (Continued)

Year	HLW (MTHM/year)	Naval SNF (Canisters/Year)	Other DSNF (Canisters/Year)
2023	357.5	14	143
2024	370	14	148
2025	377.5	14	151
2026	197	14	153
2027	0	14	152
2028	0	14	105
2029	0	14	105
2030	0	15	105
2031	0	15	50
2032	0	15	66
2033	0	15	116
2034	0	0	103
2035	0	0	66
2036	0	0	49
2037	0	0	49
2038	0	0	24
Total	4667	300	2698

Table C-3. Scenario 2 Nominal CSNF Receipt, Storage, and Emplacement Rates

Year	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)
2010	400	0	400
2011	600	0	600
2012-2019	900	0	900
2020	1,800	0	1,800
2021	2,200	0	2,200
2022	2,600	0	2,600
2023	3,000	0	3,000
2024-2035	3,600	0	3,600
2036	2,000	0	2,000
Total	63,000	0	63,000

Table C-4. Scenario 3 Nominal CSNF Receipt, Storage, and Emplacement Rates

Year	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)
2010	400	0	400
2011	600	0	600
2012	1,200	1,000	200
2013	2,000	2,000	0
2014-2019	3,000	3,000	0
2020-2032	3,000	0	3,600
2033	1,800	0	3,600
2034-36	0	0	3,600
2037	0	0	600
Total	63,000	21,000	63,000

Table C-5. Scenario 3 Nominal Defense Waste Receipt, Storage, and Emplacement Rates

Year	Receipt Rate			Storage Rate			Emplacement Rate		
	HLW (MTHM/ yr)	Naval SNF (Can/yr)	DSNF (Can/yr)	HLW (MTHM/ yr)	Naval SNF (Can/yr)	DSNF (Can/yr)	HLW (MTHM/ yr)	Naval SNF (Can/yr)	DSNF (Can/yr)
2010	97.5	3	18	0.0	0	0	97.5	3	18
2011	190	3	41	0.0	0	0	190.0	3	41
2012	190	6	62	158.3	5	52	31.7	1	10
2013	190	6	76	190.0	6	76	0.0	0	0
2014	205	12	76	205.0	12	76	0.0	0	0
2015	205	14	76	205.0	14	76	0.0	0	0
2016	190	14	76	190.0	14	76	0.0	0	0
2017	205	14	76	205.0	14	76	0.0	0	0
2018	215	14	86	215.0	14	86	0.0	0	0
2019	337.5	14	129	337.5	14	129	0.0	0	0
2020	340	14	130	0.0	0	0	408.0	17	156
2021	322.5	14	129	0.0	0	0	387.0	17	155
2022	360	14	138	0.0	0	0	432.0	17	166
2023	357.5	14	143	0.0	0	0	429.0	17	172
2024	370	14	148	0.0	0	0	444.0	17	178
2025	377.5	14	151	0.0	0	0	453.0	17	181
2026	382.5	14	153	0.0	0	0	459.0	17	184
2027	132	14	152	0.0	0	0	459.0	17	182

Table C-5. Scenario 3 Nominal Defense Waste Receipt, Storage, and Emplacement Rates (Continued)

Year	Receipt Rate			Storage Rate			Emplacement Rate		
	HLW (MTHM/ yr)	Naval SNF (Can/yr)	DSNF (Can/yr)	HLW (MTHM/ yr)	Naval SNF (Can/yr)	DSNF (Can/yr)	HLW (MTHM/ yr)	Naval SNF (Can/yr)	DSNF (Can/yr)
2028	0	14	105	0.0	0	0	459.0	17	126
2029	0	14	105	0.0	0	0	418.0	17	126
2030	0	15	105	0.0	0	0	0.0	18	126
2031	0	15	50	0.0	0	0	0.0	18	60
2032	0	15	66	0.0	0	0	0.0	18	79
2033	0	15	116	0.0	0	0	0.0	18	139
2034	0	0	103	0.0	0	0	0.0	18	124
2035	0	0	66	0.0	0	0	0.0	18	79
2036	0	0	49	0.0	0	0	0.0	15	59
2037	0	0	49	0.0	0	0	0.0	0	59
2038	0	0	24	0.0	0	0	0.0	0	278
Total	4,667.0	300	2,698	1,705.8	93	647	4,667.2	300	2,698

Table C-6. Scenario 4 Nominal CSNF Receipt, Storage, and Emplacement Rates

Year	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)
2010	533	0	533
2011	800	0	800
2012	1,600	0	1,600
2013	2,677	0	2,677
2014-2027	4,000	0	4,000
2028	1,390	0	1,390
Total	63,000	0	63,000

Table C-7. Scenario 5 Nominal Receipt, Storage, and Emplacement Rates

Year	CSNF			Receipt/Emplacement Rate		
	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)	HLW (MTHM/year)	Naval SNF (Canisters/Year)	Other DSNF (Canisters/year)
2010	50	0	50	5	3	2
2011	100	0	100	10	3	4
2012	100	0	100	10	6	4
2013	100	0	100	10	6	4
2014	100	0	100	10	12	4
2015	400	0	400	128	14	18
2016	600	0	600	220	14	41
2017	1,200	0	1,200	220	14	62
2018	2,000	0	2,000	220	14	76
2019	3,000	0	3,000	235	14	76
2020	3,600	0	3,600	235	14	76
2021	3,600	0	3,600	220	14	76
2022	3,600	0	3,600	235	14	76
2023	3,600	0	3,600	248	14	86
2024	3,600	0	3,600	338	14	129
2025	3,600	0	3,600	340	14	130
2026	3,600	0	3,600	323	14	129
2027	3,600	0	3,600	360	14	138
2028	3,600	0	3,600	358	14	143
2029	3,600	0	3,600	370	14	148
2030	3,600	0	3,600	378	15	151
2031	3,600	0	3,600	197	15	186
2032	3,600	0	3,600	0	15	201
2033	3,600	0	3,600	0	15	204
2034	3,600	0	3,600	0	0	191
2035	1,350	0	1,350	0	0	154
2036	0	0	0	0	0	66
2037	0	0	0	0	0	66
2038	0	0	0	0	0	57
Total	63,000	0	63,000	4667	300	2698

Table C-8. Scenario 6 Nominal Receipt, Storage, and Emplacement Rates

Year	CSNF			Receipt/Emplacement Rate		
	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)	HLW (MTHM/yr)	Naval SNF (Canisters/yr)	Other DSNF (Canisters/yr)
2010	200	0	200	20	3	8
2011	400	0	400	40	3	16
2012	400	0	400	40	6	16
2013	400	0	400	40	6	16
2014	400	0	400	40	12	16
2015	400	0	400	127.5	14	18
2016	600	0	600	220	14	41
2017	1,200	0	1,200	220	14	62
2018	2,000	0	2,000	220	14	76
2019	3,000	0	3,000	235	14	76
2020	3,600	0	3,600	235	14	76
2021	3,600	0	3,600	220	14	76
2022	3,600	0	3,600	222.5	14	76
2023	3,600	0	3,600	215	14	86
2024	3,600	0	3,600	337.5	14	129
2025	3,600	0	3,600	340	14	130
2026	3,600	0	3,600	322.5	14	129
2027	3,600	0	3,600	360	14	138
2028	3,600	0	3,600	357.5	14	143
2029	3,600	0	3,600	370	14	148
2030	3,600	0	3,600	347.5	15	151
2031	3,600	0	3,600	137	15	186
2032	3,600	0	3,600	0	15	201
2033	3,600	0	3,600	0	15	204
2034	3,600	0	3,600	0	0	191
2035	0	0	0	0	0	154
2036	0	0	0	0	0	66
2037	0	0	0	0	0	66
2038	0	0	0	0	0	3
Total	63,000	0	63,000	4667	300	2698

Table C-9. Scenario 7 Nominal Receipt, Storage, and Emplacement Rates

Year	CSNF			Receipt/Emplacement Rate		
	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)	HLW (MTHM/yr)	Naval SNF (Canisters/yr)	Other DSNF (Canisters/yr)
2010	200	0	200	20.0	3	8
2011	400	0	400	40.0	3	16
2012	400	0	400	97.5	6	32
2013	600	0	600	190.0	6	52
2014	1200	0	1200	190.0	12	70
2015	2000	0	2000	190.0	14	82
2016	3000	0	3000	205.0	14	79
2017	3000	0	3000	205.0	14	76
2018	3000	0	3000	190.0	14	76
2019	3000	0	3000	205.0	14	76
2020	3000	0	3000	215.0	14	86
2021	3000	0	3000	337.5	14	129
2022	3000	0	3000	340.0	14	130
2023	3000	0	3000	322.5	14	129
2024	3000	0	3000	360.0	14	138
2025	3000	0	3000	357.5	14	143
2026	3000	0	3000	370.0	14	148
2027	3000	0	3000	377.5	14	151
2028	3000	0	3000	358.0	14	153
2029	3000	0	3000	96.5	14	152
2030	3000	0	3000	0	15	155
2031	3000	0	3000	0	15	175
2032	3000	0	3000	0	15	154
2033	3000	0	3000	0	15	66
2034	3000	0	3000	0	0	51
2035	1,200	0	1,200	0	0	49
2036	0	0	0	0	0	49
2037	0	0	0	0	0	49
2038	0	0	0	0	0	24
Total	63,000	0	63,000	4,667	300	2,698

C.2 97,800 MTHM WASTE STREAM

Table C-10. Scenario 1 Nominal CSNF Receipt, Storage, and Emplacement Rates for 97,800 MTHM Waste Stream

Year	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)
2010	400	0	400
2011	600	0	600
2012	1,200	0	1,200
2013	2,000	0	2,000
2014-39	3,000	0	3,000
2040	1600	0	1600
Total	83,800	0	83,800

Table C-11. Scenario 1, 2, and 4 Nominal Defense Waste Receipt and Emplacement Rates for 97,800 MTHM Waste Stream

Year	HLW	DSNF	Naval SNF
	(MTHM/Yr)	(Canisters/Yr)	(Canisters/Yr)
2010	97.5	18	3
2011	190	41	3
2012	190	62	6
2013	190	76	6
2014	205	76	12
2015	205	76	14
2016	190	76	14
2017	205	76	14
2018	215	86	14
2019	337.5	129	14
2020	340	130	14
2021	322.5	129	14
2022	360	138	14
2023	357.5	143	14
2024	370	148	14
2025	452.2	151	14
2026	531.8	153	14
2027	529.3	152	14

Table C-11. Scenario 1, 2, and 4 Nominal Defense Waste Receipt and Emplacement Rates for 97,800 MTHM Waste Stream (Continued)

Year	HLW (MTHM/Yr)	DSNF (Canisters/Yr)	Naval SNF (Canisters/Yr)
2028	531.8	105	14
2029	489.8	105	14
2030	372.5	105	15
2031	372.5	50	15
2032	372.5	66	15
2033	372.5	116	15
2034	372.5	103	0
2035	373	66	0
2036	325	49	0
2037	310	49	0
2038	310	49	0
2039	220.5	49	0
2040	207.5	16	0
2041	207.5	0	0
2042	209	0	0
Total	10334.9	2788	300

Table C-12. Scenario 2 Nominal CSNF Receipt, Storage, and Emplacement Rates for 97,800 MTHM Waste Stream

Year	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)
2010	400	0	400
2011	600	0	600
2012-19	900	0	900
2020	1,800	0	1,800
2021	2,200	0	2,200
2022	2,600	0	2,600
2023	3,000	0	3,000
2024-41	3,600	0	3,600
2042	1,200	0	1,200
Total	83,800	0	83,800

Table C-13. Scenario 3 Nominal CSNF Receipt, Storage, and Emplacement Rates for 97,800 MTHM Waste Stream

Year	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)
2010	400	0	400
2011	600	0	600
2012	1,200	1,000	200
2013	2,000	2,000	0
2014-19	3,000	3,000	0
2020-39	3,000	0	3,600
2040	1,600	0	3,600
2041	0	0	3,600
2042	0	0	3,400
Total	83,800	21,000	83,800

Table C-14. Scenario 3 Nominal Defense Receipt, Storage, and Emplacement Rates for 97,800 MTHM Waste Stream

Year	Receipt Rate			Storage Rate			Emplacement Rate		
	HLW (MTHM/ yr)	Naval SNF (Can/yr)	DSNF (Can/yr)	HLW (MTHM/ yr)	Naval SNF (Can/yr)	DSNF (Can/yr)	HLW (MTHM/ yr)	Naval SNF (Can/yr)	DSNF (Can/yr)
2010	97.5	18	3	0.0	0.0	0.0	97.5	3	18
2011	190	41	3	0.0	0.0	0.0	190.0	3	41
2012	190	62	6	158.3	5.0	52.0	31.7	1	10
2013	190	76	6	190.0	6.0	76.0	0.0	0	0
2014	205	76	12	205.0	12.0	76.0	0.0	0	0
2015	205	76	14	205.0	14.0	76.0	0.0	0	0
2016	190	76	14	190.0	14.0	76.0	0.0	0	0
2017	205	76	14	205.0	14.0	76.0	0.0	0	0
2018	215	86	14	215.0	14.0	86.0	0.0	0	0
2019	337.5	129	14	337.5	14.0	129.0	0.0	0	0
2020	340	130	14	0.0	0.0	0.0	408.0	17	156
2021	322.5	129	14	0.0	0.0	0.0	387.0	17	155
2022	360	138	14	0.0	0.0	0.0	432.0	17	166
2023	357.5	143	14	0.0	0.0	0.0	429.0	17	172
2024	370	148	14	0.0	0.0	0.0	444.0	17	178
2025	452.2	151	14	0.0	0.0	0.0	542.6	17	181

Table C-14. Scenario 3 Nominal Defense Receipt, Storage, and Emplacement Rates for 97,800 MTHM Waste Stream (Continued)

Year	Receipt Rate			Storage Rate			Emplacement Rate		
	HLW (MTHM/yr)	Naval SNF (Can/yr)	DSNF (Can/yr)	HLW (MTHM/yr)	Naval SNF (Can/yr)	DSNF (Can/yr)	HLW (MTHM/yr)	Naval SNF (Can/yr)	DSNF (Can/yr)
2026	531.8	153	14	0.0	0.0	0.0	638.2	17	184
2027	529.3	152	14	0.0	0.0	0.0	635.2	17	182
2028	531.8	105	14	0.0	0.0	0.0	638.2	17	126
2029	489.8	105	14	0.0	0.0	0.0	587.8	17	126
2030	372.5	105	15	0.0	0.0	0.0	447.0	18	126
2031	372.5	50	15	0.0	0.0	0.0	447.0	18	60
2032	372.5	66	15	0.0	0.0	0.0	447.0	18	79
2033	372.5	116	15	0.0	0.0	0.0	447.0	18	139
2034	372.5	103	0	0.0	0.0	0.0	447.0	18	124
2035	373	66	0	0.0	0.0	0.0	447.6	18	79
2036	325	49	0	0.0	0.0	0.0	390.0	15	59
2037	310	49	0	0.0	0.0	0.0	372.0	0	59
2038	310	49	0	0.0	0.0	0.0	372.0	0	59
2039	220.5	49	0	0.0	0.0	0.0	264.6	0	59
2040	207.5	16	0	0.0	0.0	0.0	249.0	0	59
2041	207.5	0	0	0.0	0.0	0.0	249.0	0	59
2042	209	0	0	0.0	0.0	0.0	294.7	0	132
Total	10,334.9	300	2,788	1,705.8	93	647	10,334.9	300	2,788

Table C-15. Scenario 4 Nominal CSNF Receipt, Storage, and Emplacement Rates for 97,800 MTHM Waste Stream

Year	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)
2010	533	0	533
2011	800	0	800
2012	1,600	0	1,600
2013	2,677	0	2,677
2014-32	4,000	0	4,000
2033	2,190	0	2,190
Total	83,800	0	83,800

Table C-16. Scenario 5 Nominal CSNF and Defense Waste Receipt, Storage, and Emplacement Rates for 97,800 MTHM Waste Stream

Year	CSNF			Receipt/Emplacement Rate		
	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)	HLW (MTHM/ yr)	Naval SNF (Canisters/yr)	Other DSNF (Canisters/yr)
2010	50	0	50	10.0	3	2
2011	100	0	100	20.0	3	4
2012	100	0	100	20.0	6	4
2013	100	0	100	20.0	6	4
2014	100	0	100	20.0	12	4
2015	400	0	400	97.5	14	32
2016	600	0	600	190.0	14	52
2017	1,200	0	1,200	190.0	14	70
2018	2,000	0	2,000	190.0	14	82
2019	3,000	0	3,000	205.0	14	79
2020	3,600	0	3,600	205.0	14	76
2021	3,600	0	3,600	190.0	14	76
2022	3,600	0	3,600	205.0	14	76
2023	3,600	0	3,600	215.0	14	86
2024	3,600	0	3,600	337.5	14	129
2025	3,600	0	3,600	340.0	14	130
2026	3,600	0	3,600	322.5	14	129
2027	3,600	0	3,600	360.0	14	138
2028	3,600	0	3,600	357.5	14	143
2029	3,600	0	3,600	370.0	14	148
2030	3,600	0	3,600	452.2	15	151
2031	3,600	0	3,600	531.8	15	186
2032	3,600	0	3,600	529.3	15	201
2033	3,600	0	3,600	531.8	15	204
2034	3,600	0	3,600	489.8	0	208
2035	3,600	0	3,600	372.5	0	162
2036	3,600	0	3,600	372.5	0	49
2037	3,600	0	3,600	372.5	0	49
2038	3,600	0	3,600	372.5	0	49
2039	3,600	0	3,600	372.5	0	49
2040	3,600	0	3,600	373.0	0	16
2041	550	0	550	373.0	0	0

Table C-16. Scenario 5 Nominal CSNF and Defense Waste Receipt, Storage, and Emplacement Rates for 97,800 MTHM Waste Stream (Continued)

Year	CSNF			Receipt/Emplacement Rate		
	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)	HLW (MTHM/ yr)	Naval SNF (Canisters/yr)	Other DSNF (Canisters/yr)
2042	0	0	0	373.0	0	0
2043	0	0	0	373.0	0	0
2044	0	0	0	373.0	0	0
2045	0	0	0	207.5	0	0
Total	83,800	0	83,800	10,334.9	300	2788

Table C-17. Scenario 6 Nominal CSNF and Defense Waste Receipt, Storage, and Emplacement Rates for 97,800 MTHM Waste

Year	CSNF			Receipt/Emplacement Rate		
	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHMyr)	HLW (MTHM/yr)	Naval SNF (Canisters/yr)	Other DSNF (Canisters/yr)
2010	200	0	200	20.0	3	8
2011	400	0	400	40.0	3	16
2012	400	0	400	40.0	6	16
2013	400	0	400	40.0	6	16
2014	400	0	400	40.0	12	16
2015	400	0	400	97.5	14	32
2016	600	0	600	190.0	14	52
2017	1,200	0	1,200	190.0	14	70
2018	2,000	0	2,000	190.0	14	82
2019	3,000	0	3,000	205.0	14	79
2020	3,600	0	3,600	205.0	14	76
2021	3,600	0	3,600	190.0	14	76
2022	3,600	0	3,600	205.0	14	76
2023	3,600	0	3,600	215.0	14	86
2024	3,600	0	3,600	337.5	14	129
2025	3,600	0	3,600	340.0	14	130
2026	3,600	0	3,600	322.5	14	129
2027	3,600	0	3,600	360.0	14	138
2028	3,600	0	3,600	357.5	14	143
2029	3,600	0	3,600	370.0	14	148

Table C-17. Scenario 6 Nominal CSNF and Defense Waste Receipt, Storage, and Emplacement Rates for 97,800 MTHM Waste (Continued)

Year	CSNF			Receipt/Emplacement Rate		
	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)	HLW (MTHM/yr)	Naval SNF (Canisters/yr)	Other DSNF (Canisters/yr)
2030	3,600	0	3,600	452.2	15	151
2031	3,600	0	3,600	531.8	15	186
2032	3,600	0	3,600	529.3	15	201
2033	3,600	0	3,600	531.8	15	204
2034	3,600	0	3,600	489.8	0	179
2035	3,600	0	3,600	372.5	0	137
2036	3,600	0	3,600	372.5	0	49
2037	3,600	0	3,600	372.5	0	49
2038	3,600	0	3,600	372.5	0	49
2039	3,600	0	3,600	372.5	0	49
2040	2,800	0	2800	373.0	0	16
2041	0	0	0	373.0	0	0
2042	0	0	0	373.0	0	0
2043	0	0	0	373.0	0	0
2044	0	0	0	373.0	0	0
2045	0	0	0	117.5	0	0
Total	83,800	0	83,800	10334.9	300	2788

Table C-18. Scenario 7 Nominal CSNF and Defense Waste Receipt, Storage, and Emplacement Rates for 97,800 MTHM Waste Stream

Year	CSNF			Receipt/Emplacement Rate		
	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)	HLW (MTHM/yr)	Naval SNF (Canisters/yr)	Other DSNF (Canisters/yr)
2010	200	0	200	20.0	3	8
2011	400	0	400	40.0	3	16
2012	400	0	400	97.5	6	18
2013	600	0	600	190.0	6	41
2014	1200	0	1200	190.0	12	62
2015	2000	0	2000	190.0	14	76
2016	3000	0	3000	205.0	14	76

Table C-18. Scenario 7 Nominal CSNF and Defense Waste Receipt, Storage, and Emplacement Rates for 97,800 MTHM Waste Stream (Continued)

Year	CSNF			Receipt/Emplacement Rate		
	Receipt Rate (MTHM/yr)	Storage Rate (MTHM/yr)	Emplacement Rate (MTHM/yr)	HLW (MTHM/yr)	Naval SNF (Canisters/yr)	Other DSNF (Canisters/yr)
2017	3000	0	3000	205.0	14	76
2018	3000	0	3000	190.0	14	76
2019	3000	0	3000	205.0	14	76
2020	3000	0	3000	215.0	14	86
2021	3000	0	3000	337.5	14	129
2022	3000	0	3000	340.0	14	130
2023	3000	0	3000	322.5	14	129
2024	3000	0	3000	360.0	14	138
2025	3000	0	3000	357.5	14	143
2026	3000	0	3000	370.0	14	148
2027	3000	0	3000	452.2	14	151
2028	3000	0	3000	531.8	14	153
2029	3000	0	3000	529.3	14	152
2030	3000	0	3000	531.8	15	155
2031	3000	0	3000	489.8	15	175
2032	3000	0	3000	372.5	15	154
2033	3000	0	3000	372.5	15	66
2034	3000	0	3000	372.5	0	51
2035	3000	0	3000	372.5	0	49
2036	3000	0	3000	372.5	0	49
2037	3000	0	3000	373.0	0	49
2038	3000	0	3000	373.0	0	49
2039	3000	0	3000	373.0	0	49
2040	3000	0	3000	373.0	0	16
2041	3000	0	3000	373.0	0	0
2042	1000	0	1000	237.5	0	0
Total	83800	0	83800	10334.9	300.0	2788.0

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APPENDIX D
SUMMARY SYSTEM COST WORKSHEETS

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APPENDIX D – SUMMARY SYSTEM COST WORKSHEETS

The worksheet files listed below contain the summary cost calculations for the 70,000 MTHM and 97,800 MTHM waste streams. These files are included electronically on a compact disk.

File Name	Size (kB)	Date
Design-Alt_Summary-Case1 Rev 0.xls	2,397	8/8/02
Design-Alt_Summary-Case2 Rev 0.xls	2,374	8/8/02
Design-Alt_Summary-Case3A Rev 0.xls	2,384	8/8/02
Design-Alt_Summary-Case4 Rev 0.xls	2,384	8/8/02
Design-Alt_Summary-Case5 Rev 0.xls	2,444	8/8/02
Design-Alt_Summary-Case6 Rev 0.xls	2,368	8/8/02
Design-Alt_Summary-Case7 Rev 0.xls	2,404	8/8/02
Subsurface Construction Rev 0.xls	108	8/2/02
Surface Facilities Detail By Phase Rev 0.xls	33	8/8/02
Cost Results Summary Rev 0.xls	231	8/8/02

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APPENDIX E
ANALYSIS OF STATUTORY AND REGULATORY FLEXIBILITY TO ACCOMMODATE A PHASED APPROACH TO REPOSITORY DEVELOPMENT

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APPENDIX E - ANALYSIS OF STATUTORY AND REGULATORY FLEXIBILITY TO ACCOMMODATE A PHASED APPROACH TO REPOSITORY DEVELOPMENT

Purpose and Assumptions: This analysis addresses questions about the Department of Energy's (DOE's) statutory authority to adopt a phased approach to development of a licensed repository, and the Nuclear Regulatory Commission's (NRC's) administrative discretion to license it.

The purpose of phased repository construction and waste emplacement is assumed here to be to allow DOE, after receiving the required NRC approvals for construction and operation of a full-scale repository, to begin repository operation on a limited scale more quickly than currently contemplated, so that the Department can begin acquiring confirmatory data on pre-closure operations and post-closure compliance as quickly as practicable. This first phase could, for example, be a pilot-scale emplacement of radioactive wastes after appropriately limited underground construction. This would allow an early start on work to confirm the technical bases for the thermal emplacement mode approved in the license. If the initial approved mode were low temperature, the initial phase of repository operation could also provide data to support a license amendment for higher temperature operation by emplacing test quantities of wastes in a high temperature configuration.

Once the initial phase complies with applicable license conditions and specifications, it is assumed to be followed by a step-wise sequence of limited expansions of surface and underground facilities to permit additional underground emplacements under continuing DOE evaluation and NRC oversight. As operational conditions change and NRC permits (e.g., through approval of a license amendment, if necessary), these subsequent emplacements might take place with progressively higher-temperature wastes, or with wastes thermally similar to those initially emplaced but at different rates or spatial densities to produce different peak temperatures in the ambient host rock.

1. Does any provision of the Nuclear Waste Policy Act (NWPA), as amended, prohibit DOE from adopting such a phased approach?

No. The Act specifies limits only on the phasing of facility development for the Program as a whole, not for the phasing of repository operations area development at Yucca Mountain. Section 114(d), for example, prohibits the emplacement of more than 70,000 metric tons of heavy metal (MTHM) of spent fuel or the high-level waste derived from reprocessing an equivalent amount of this material until a second repository begins operation. Section 148(d)(1) of the Act also stipulates that the construction of any monitored retrievable storage (MRS) facility "may not begin until the Commission has issued a license for the construction of a repository." In addition, section 141(g) prohibits MRS construction in any State with a site approved for site characterization, and further specifies that this restriction "shall continue to apply to any site selected for construction as a repository."

Section 141(g) might be interpreted by some as a constraint on the development of more surface storage capacity at Yucca Mountain than would be needed to support planned waste emplacement operations under a phased approach to building and operating a licensed repository. But such a case would have to show that DOE's plans for surface storage as an integral part of a Yucca Mountain repository effectively amount to the development of an MRS. As discussed under Question 2 below, DOE can take prudent measures to manage the phasing of surface and underground components of the repository operations area to make such a case exceedingly difficult.

More important, a close reading of the Act does not support any apparent Congressional intention to constrain the development of pre-emplacement surface storage facilities at a repository site. Subsection 141(g) only forbids construction of an MRS facility "developed pursuant to this section" in Nevada. Expanded lag storage that is an integral part of the surface facilities of a repository is not an MRS developed pursuant to Section 141. Further, the Act does not explicitly define "storage" or "MRS" at all, much less in a way that could be applied to storage at a repository. Thus, there does not appear to be much statutory basis for an objection that lag storage at a repository as an integral part of repository operation is an MRS prohibited by section 141.

Further, as long as Yucca Mountain is being developed as a repository, there can be no question of an inconsistency with the spirit of the Act's prohibition of an MRS in Nevada if the total amount of storage at the repository were limited to the amount of SNF and waste licensed for disposal there. Section 114(d) makes it clear that the intent of the Act is to prohibit imposing more than 70,000 MTHM of waste on any one small area of the country until a second repository is in operation. The last sentence of that subsection specifies that if an MRS is located, or planned to be located, within 50 miles of the first repository,

> "the Commission decision approving the first [repository] application shall prohibit the emplacement of a quantity of spent fuel containing in excess of 70,000 metric tons of heavy metal or a quantity of solidified high-level radioactive waste resulting from the reprocessing of spent fuel in both the repository and monitored retrievable storage facility until such time as a second repository is in operation."

The prohibitions here apply specifically only to emplacement of wastes in an MRS and in the first repository, not to the storage of wastes at the repository to facilitate their emplacement. However, it is clear that temporary surface storage at the repository for up to the total amount approved for disposal in a repository (limited by law to 70,000 MTHM in the initial license) would not violate the intent of these restrictions on an MRS facility in the vicinity of a repository.

A plain reading of all these provisions of the Act suggests that Congress intended to phase the development of the MRS and the first repository only to assure that the Program as a whole remained committed to the ultimate goal of providing safe and sufficient geologic disposal capacity for all the nation's spent fuel and HLW. So long as this commitment remains clear and credible, nothing in the Act would prohibit the phasing of facility construction and waste emplacement operations at Yucca Mountain in a way that would allow some waste received at the repository to be stored for a period before emplacement underground.

Prudence would counsel DOE to propose in its initial license application that NRC authorize construction of a disposal facility that could ultimately accommodate the statutory maximum 70,000 metric tons of waste allowed without a second repository. But the law does not require the Commission to reject a DOE application for less. To the contrary, Section 114(d) of the NWPA as amended specifically provides for NRC review of an application to construct only a part of the repository:

> "The Commission shall consider an application for a construction authorization for all *or part* of a repository in accordance with the laws applicable to such applications." [emphasis added]

The legislative history of this provision documents a clear Congressional intent that the Commission consider a DOE application to construct a repository that is smaller than the maximum allowed. Congress enacted the provision in spite of the fact that the Commission at the time did not support it. In comments submitted on the first comprehensive nuclear waste bill containing this language (H.R. 5016, 97th Congress), the Nuclear Regulatory raised a concern about the bill's requirement to consider an application to license part of a repository:

> "We believe that the provision in Section 8(d) requiring the Commission to consider a license application for part of a repository is ill advised. The Commission believes it presently has authority under the Atomic Energy Act, as amended, to establish requirements for a license application, and we have the discretionary authority to set requirements to cover part or all of a repository. However, in this first-of-a-kind undertaking, we do not think it prudent to legislate this restrictive requirement in advance. We would prefer to look at a complete application from DOE for the entire repository in order to properly evaluate geologic and hydrologic conditions at the site for any potential health and safety problems before issuing a license to emplace waste in all or part of the repository." (Letter from Nunzio J. Palladino, Chairman, NRC, to the Honorable Hamilton Fish, Committee on Science and Technology, U.S. House of Representatives, December 11, 1981. Contained in the House Report on the High-Level Radioactive Waste Management and Policy Act (H.R. 5016), December 15, 1981, Rept. 97-411 Part 1.)

Note that the Commission was objecting here only to a legislative *requirement* that NRC consider an application for part of a repository, not to such consideration *per se*; the Commission argued that it already has the discretion for such consideration under existing law. Note also that the source of the objection appears to be the Commission's preference to see an application covering the entire underground part of the repository, so that the whole geologic disposal system can be evaluated before approving any emplacement. In any case, Congress proceeded to adopt the "all or part of" language despite the Commission's view. The language remained in H.R. 5016 as reported by the Committee on Science and Technology, was incorporated into a consolidated House nuclear waste bill, and was ultimately enacted in Section 114(d) of the NWPA.

2. Do any provisions of NRC's 10 CFR Part 63 repository licensing rule prohibit or otherwise constrain DOE from adopting the phased development approach described above?

There is no clear regulatory bar to the phased implementation of repository development. NRC staff has in fact specifically said just the opposite. Commenting on "Proposed Alternative Strategy for the Department of Energy's Civilian Radioactive Waste Management Program," a 1993 DOE task force report, NRC wrote: "The staff believes that the concept of phased emplacement is permitted under 10 CFR 60." (Robert M. Bernero, Director, Office of Nuclear Material Safety and Safeguards, USNRC, letter to Christopher Kouts, Acting Director, Strategic Planning and International Programs, OCRWM, September 14, 1993, p. 3.) If NRC believed that phased repository development is permitted under Part 60, it is difficult to imagine that phased development would not also be permitted under Part 63, a rule predicated on risk-informed, performance-based regulation.

The only provision of the Part 63 rule that could constrain the implementation of phased repository development is the requirement that underground facility construction be "substantially complete" before NRC may issue a license for DOE to receive and possess waste at the repository. But as a closer reading of this requirement in the context of other NRC requirements will show, even the pre-requisite of "substantially complete" construction is best construed in a way that would permit phased repository construction and phased waste emplacement.

Consistent with the accepted Congressional intent of Section 114(d), the rule does not specify a minimum quantity of spent fuel or high level waste for which the Commission could accept an application to construct a repository. Section 63.42(d) of the rule would simply implement with a universal license condition the law's requirement to phase the development of the first repository to promote development of a second:

> "A license issued under this part includes the provisions set forth in Section 114(d) of the Nuclear Waste Policy Act, as amended, defining the quantity of solidified high-level radioactive waste and spent nuclear fuel , until such time as a second repository is in operation, whether or not these provisions are expressly set forth in the license."

The rule not only does not prohibit DOE from applying to construct a portion of the repository's statutory maximum capacity. It also provides for construction, waste receipt, and waste emplacement schedules that may, within the limits of applicable law and regulation, be somewhat independent of each other. Sec. 63.21(b)(2) on the content of any license application specifically provides that the application include "[p]roposed schedules for construction, receipt of waste, and emplacement of wastes at the proposed geologic repository operations area."

Thus, regardless of the amount of wastes DOE might propose to emplace in any license application, schedules for repository construction and waste receipt and emplacement are implicitly issues for separate consideration in a license review. Whether DOE applies for a license to construct a repository capable of emplacing the full initial 70,000 MHTM waste inventory allowed by law or something less, the schedule for construction of that capacity would remain an issue for separate adjudication, as would the schedules for receipt and emplacement of that inventory.

Part 63 can therefore be presumed to envision the staging of these activities, especially for the purpose of optimizing the safety of repository construction and operation. The start of surface storage facility construction need not await the completion of underground facility construction, for example, nor is DOE required to complete all surface handling and storage facilities before beginning to receive wastes.

Considering the fundamental interdependence of these activities, however, the rule's allowance for NRC consideration of an application to construct only part of a repository does not mean that DOE should expect to put off a review of its plans for the remainder. NRC's comments on the 1981 nuclear waste bill show that it would be concerned about an application for "part of a repository" if DOE did not also explain in detail its plans for eventual development of the entire repository system. It would be difficult for NRC, or any regulator, to determine the conditions needed for safe operation of only one segment of the system without a clear understanding of how that segment would affect the safety of the rest of the system.

It is clear from the regulations that NRC could, if it chose, place conditions on the license limiting the amount that could initially be emplaced. Given the Commission's concerns about the need to review the proposed repository system as a whole, DOE would probably be wise to apply for NRC authorization to build a repository for the full 70,000 MHTM inventory allowed under current law. The application would present the necessary plans, schedules, procedures, and justification for the Department's preferred phasing of capacity development for this inventory. The Commission would then have discretion to impose any other conditions it deemed necessary to control or coordinate the development of facilities for receiving, handling, packaging, storing, and emplacing this quantity of wastes.

As discussed under Question 1 above, the NWPA does provide procedural assurances against the possibility that indefinite long-term storage capacity might be developed at the expense of repository development. But DOE compliance with these statutory restrictions need not interfere with phased development of a repository as long as there is a clear and reasonable relationship between DOE's proposed plans for emplacement and its proposed plans for interim surface storage.

Once DOE submits an application for authorization to construct an underground facility for emplacement, the burden would arguably be on those who would contend that the surface facilities supporting emplacement would effectively constitute an MRS within the meaning of NWPA section 141(g). Prudent proposals in DOE's initial license application could limit the salience of any such claim. First, as noted above, DOE would be well-advised to apply at the outset for conditional authority to construct, in defined phases under NRC oversight, a repository with an ultimate capacity of 70,000 metric tons pending the availability of a second repository. Second, DOE could propose to sequence the construction of surface storage so that it could not exceed a stipulated ratio of storage to emplacement capacity during the first phase of repository construction. This ratio could be adjusted in subsequent phases to provide for proportionally more surface storage capacity with each new increment of disposal capacity, if ongoing evaluations of excavation data confirmed that expanded emplacement could proceed safely and in compliance with long-term performance requirements.

Coordinated build-out of surface and underground facilities can allow for improvements of the system based on experience. While one might not expect to learn much from the construction of surface handling facilities, for example, one could learn quite a bit about the adequacy of the design and ways to improve it during the initial stages of operation. Just as for the underground facilities, one can argue that construction of the surface facilities in stages would allow a shakedown and optimization of waste receipt, handling, and packaging facilities at each stage before construction of subsequent stages. Phasing the scale-up of surface facilities and operations could also provide opportunities for improvements underground. To the extent that it could accommodate lessons learned from excavations for emplacement, staged surface facility development could, for example, permit adjustments in waste package design, construction, loading, or sealing that might enhance confidence in post-closure performance.

Within some rule of reason linking rates of waste acceptance to rates of underground emplacement, the Section 63.21(b)(2) requirement for separate schedules effectively gives the Department the discretion to propose (and the Commission the discretion to require) different initial phasing and independent later adjustment of the schedule for each activity.

To enhance flexibility for these kinds of adjustments, one way to interpret the language permitting an application for "part of a repository" could be to include, with the proposed underground facility design, detailed designs only for the initial surface facilities. This would allow the design of facilities for subsequent operational stages to be deferred until they can be based on actual operating experience supporting underground emplacement. In this approach, the application would present the postclosure safety case for the entire projected disposal inventory, but would focus the application for the surface facilities on the initial stage. The logic would be that because there is little question about DOE's ability to design and ultimately license full-scale surface facilities for waste receipt, handling, packaging, and storage, it is not necessary to prove that point before starting surface operations at small scale. Furthermore, it might be prudent to defer detailed design of large-scale disposal packaging equipment and facilities until the waste package design has been approved in the initial construction authorization, and until DOE has been able to evaluate the cost-effectiveness of potential design refinements based on initial operating experience and further research.

Whatever DOE's rationale for its implementation choices in the initial license application, it is important to keep in mind that flexibility for staged waste receipt, repository construction, and waste emplacement is consistent with the Commission's risk-informed, performance-based (RIPB) approach to the development of the technical criteria for licensing Yucca Mountain. In its rule, the Commission said it sought to "establish a coherent body of risk-informed, performance-based criteria for Yucca Mountain that is compatible with the Commission's overall philosophy of risk-informed, performance-based regulation." It then defined this philosophy as:

> "an approach in which risk insights, engineering analysis and judgment (e.g., defense in depth), and performance history are used to (1) focus attention on the most important activities, (2) establish objective criteria for evaluating performance, (3) develop measurable or calculable parameters for monitoring system and licensee performance, (4) provide flexibility to determine how to meet the established performance criteria in a way that will encourage and reward improved outcomes, and (5) focus on the results as the primary basis for regulatory decision-making." (Federal Register, Volume 64, Number 34 [February 22, 1999], page 8643)

Given such priorities as developing "measurable or calculable parameters for monitoring system performance," providing flexibility to adjust compliance strategies to "encourage and reward improved outcomes," and focusing on "results as the primary basis for regulatory decision-making," it is difficult to see how NRC's risk-informed, performance-based approach could be implemented *without* a phased implementation schedule. With this first-of-a-kind facility, there can be no "results" for NRC's regulatory decision making after construction authorization if there is no phased construction and operation to permit additional data gathering and evaluation before expanding to the next phase.

The Commission's provision for continuing evaluation of lessons learned from construction and operation is even more explicit in Section 63.21's requirement for a discussion of confirmatory research and development in the LA. Under paragraph (21), the SAR must include:

> "An identification of those structures, systems, and components of the geologic repository, both surface and subsurface, which require research and development to confirm the adequacy of design. For structures, systems, and components important to safety and for the engineered and natural barriers important to waste isolation, DOE shall provide a detailed description of the Programs designed to resolve safety questions, including a schedule indicating when these questions would be resolved."

With its requirement for a schedule for the resolution of safety questions needing confirmatory research, this paragraph arguably *presumes* that the Commission's authorization of construction will be contingent on the results of further information gathering. The rule's section on CA conditions also makes this clear. Section 63.32(b) binds the Commission itself to issue the construction authorization with conditions and reporting requirements, in order to provide timely notice of developments that could affect continuing compliance with those conditions:

> "The Commission will incorporate, in the construction authorization, provisions requiring DOE to furnish periodic or special reports regarding:
>
> (1) Progress of construction;

(2) Any data about the site, obtained during construction, that are not within the predicted limits on which the facility design was based;

(3) Any deficiencies, in design and construction, that, if uncorrected, could adversely affect safety at any future time; and

(4) Results of research and development programs being conducted to resolve safety questions."

Subsection (c) of section 63.32 also provides for Commission control over changes in repository design, construction, and implementation procedures approved in the initial construction authorization:

> "The construction authorization for a geologic repository operations area at the Yucca Mountain site will include restrictions on subsequent changes to the features of the geologic repository and the procedures authorized. The restrictions that may be imposed under this paragraph can include measures to prevent adverse effects on the geologic setting as well as measures related to the design and construction of the geologic repository operations area."

The Commission reserved authority to impose functionally similar conditions and controls over its issuance of a license to receive and possess (LTRP) radioactive waste for emplacement. Section 63.43(a) on license specifications provides that:

> "A license issued under this part shall include license conditions derived from the analyses and evaluations included in the application, including amendments made before a license is issued, together with such additional conditions as the Commission finds appropriate."

Note here that conditions on receipt and possession for emplacement are to be derived not only from the analyses and evaluations provided in the license application. They may also derive from DOE "amendments" to the application "made before a license is issued." Because, as will be discussed shortly below, DOE may not even apply for the possession license until after NRC issuance of the construction authorization, the Commission clearly anticipated here that conditions for the license for waste emplacement would build on lessons learned from analyses and evaluations conducted during construction.

As this subsection also makes clear, however, conditions on the license could derive from lessons learned even after DOE's submittal of its initial application to receive and possess wastes for emplacement. The Commission reserves the right here to impose "such additional conditions as [it] finds appropriate" -- including, presumably, those justified by new data and analyses not only from prior construction, but also, after Commission issuance of the initial LTRP, from prior emplacements.

The kinds of license conditions specifically defined in the rule also suggest that the Commission had something very like a phased approach to repository implementation in mind. Subsection 63.43(b) says that license conditions "shall include items in the following categories:

> ...Restrictions as to the amount of waste permitted per unit volume of storage space, considering the physical characteristics of both the waste and the host rock.
>
> Requirements relating to test, calibration, or inspection, to assure that the foregoing restrictions are observed."

These are just the sort of parameters that any pilot-scale waste emplacement operation, and subsequent phases of expanded emplacement, would seek to analyze and evaluate.

The continuing evaluation of Commission-approved licensing conditions against the actual conditions encountered during construction and operation is in fact a key element of the agency's entire approach to repository regulation. Subpart F of Part 63, like Subpart F of the original Part 60 before it, requires DOE to conduct a performance confirmation program from the outset of site characterization to the end of license termination proceedings. The purpose is to "verify the assumptions, data, and analyses that ... permitted construction of the repository." Proposed Section 63.132, for example, requires that:

> "During repository construction and operation, a continuing program of surveillance, measurement, testing, and geologic mapping shall be conducted to ensure that geotechnical and design parameters are confirmed and to ensure that appropriate action is taken to inform the Commission of changes needed in design to accommodate actual field conditions encountered. ... If significant differences exist between the measurements and observations and the original design bases and assumptions, the need for modifications to the design or in construction methods shall be determined and these differences, their significance to repository performance, and the recommended changes reported to the Commission."

To test the approved repository design in time to permit such changes as soon as possible, Section 63.133 of the rule further requires the emplacement of waste packages "as early as practicable" in the "early or developmental stages of construction":

> "(a) During the early or developmental stages of construction, a program for in-situ testing of such features as ... the thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted.
>
> (b) The testing shall be initiated as early as practicable."

Considering that the emplacement of waste packages containing radioactive materials would probably provide more realistic if not more useful data for evaluating repository design, it would be consistent with the intent of this requirement for DOE to apply for a license to receive and possess the needed quantity of wastes as soon as construction of enough of the underground facility has been completed for the safe initiation of testing. Even if that portion of the facility is very small – and a truly risk-informed, performance-based approach would dictate that it be no larger than necessary to produce the needed safety information as soon as possible -- Section 63.133 could reasonably be construed as requiring the completion of such an area as a first priority for the initiation of waste package testing under radiologically hot operating conditions "as early as practicable."

It should also be clear that with performance confirmation and other requirements for continuing safety evaluations and risk-informed readjustments, a phased approach to repository construction and operation would be compatible with an initial license for either hot or cool operation. In either case, testing would be required during initial operations to demonstrate or confirm the acceptability of the preferred thermal mode. But even if the initial license were for operation at a cooler temperature, DOE would likely want to perform the tests needed to support a subsequent application to amend the license for hotter operation. Preclosure considerations, such as a shorter operating period to minimize cumulative exposures from surface facilities, favor higher temperature repository operation, so that if postclosure uncertainties can be favorably resolved, there would be an incentive to switch to a hotter mode.

Even if the initial license were for hot operation, though, any subsequent failure of performance confirmation testing to re-confirm the basis for that license need not preclude a switch to cooler operation. The rule would also permit an initial phase of primarily cool operation even if the initial license allowed hot operation. The first stage of operation could involve emplacement of cooler waste in a low-temperature configuration, with only small quantities of hot waste emplaced for test purposes to confirm or demonstrate the basis for hot operation. In this way, little would have to be undone if the results of testing failed to support hot operation.

Because the results of confirmatory testing for either operating mode would determine the ability to operate hot after the initial testing period, the kinds of tests required for either the hotter or cooler mode would probably be much the same. Thus, deferring large-scale emplacement until after the thermal operating mode has been firmly established would reduce the impacts of a change from the mode initially approved.

Taken together, all of the above-cited selections from the rule make it difficult to argue that the Commission did not anticipate and expressly provide for empirically warranted changes in repository construction and operation to improve safety after issuance of the initial CA. Indeed, it would be difficult for the Commission to defend this rule as risk-informed and performance-based if it did not specifically provide for such changes as DOE acquires new information and insights building and operating this first-of-a-kind facility.

On a more historical note, it is also worth considering that at the time Part 60 was developed, NRC expected that the data available at the license application stage would be obtained from less than $100 million of research in an underground test facility comprising about 1000 feet of drift. Today, the cross drift alone that connects the main excavations at Yucca Mountain is longer than that. Clearly, far more data are available today – representing the amount and quality of information that NRC, when Part 60 was written, would have expected to be obtained only after the CA, during the initial construction of the repository. DOE has since gone well beyond that modest effort. By 1993, it was planning a 6-year delay between the CA and the OL to construct a large surface facility and substantial underground emplacement area before starting disposal. Significantly, the previously cited DOE task force report on this plan argued that the Department should include in its application for a construction authorization a proposal to begin emplacement in a small test facility.

This context puts into a different and more accommodating light the Section 63.41(a) requirement that construction of the repository operations area be "substantially complete" before NRC can issue a license amendment to receive and possess radioactive materials. Under this paragraph, the Commission may issue such a license on finding that, among other things:

> "Construction of the geologic repository operations area has been substantially completed in conformity with the application as amended, the provisions of the Atomic Energy Act, and the rules and regulations of the Commission. Construction may be deemed to be substantially complete for the purposes of this paragraph if the construction of:
>
> > (1) Surface and interconnecting structures, systems, and components; and
> >
> > (2) Any underground storage space required for initial operation, are substantially complete."

There is a long-standing principle of jurisprudence under which, faced with apparently contradictory statutory mandates, courts should try to construe the law in a way that will permit the implementation of both requirements to the extent possible. If the provision for substantially completed construction here were construed to require DOE to construct all the facilities necessary to dispose of 70,000 metric tons equivalent before NRC could license the receipt and possession of any waste at Yucca Mountain, it would effectively render the rule's provisions for learning from implementation experience invalid. Compliance with the Commission's requirements for confirmatory testing and evaluation during construction, for example, would be operationally meaningless if the underground facility, having been substantially completed, could not be modified in any significant way to take advantage of lessons learned from waste emplacement

The same reasoning applies to the NRC requirement for completion of surface facilities as well. If DOE were required to build all the capacity needed for full-scale acceptance and emplacement before any wastes could be received, compliance with Part 63 requirements for performance confirmation, and for periodic evaluation of the continuing validity of facility license conditions, would be pointless for remedial purposes. DOE would be unable to use its experience with early waste handling and packaging to improve subsequent surface facility designs for safer pre-closure operation or better post-closure performance. For both surface and subsurface facilities, such a stringent interpretation of "substantially complete" construction would allow DOE and NRC limited recourse to meaningful engineering remedies if post-CA confirmatory studies brought unanticipated safety issues or potentially adverse post-closure performance trends to light. It would be difficult to show that this was what Congress intended or the Commission desires, particularly in light of NRC's stated commitment to RIPB principles.

Fortunately, an alternative reading of this paragraph is not only possible, but persuasive. Section 63.41(a)(2) requires that the construction of underground storage space be substantially completed only for the space "required for initial operation." This implicitly envisions that the construction of underground storage space for emplacements *after* initial operation could be deferred under a phased approach to such emplacements.

Note also that under this paragraph, all the construction in question must be completed "in conformity with the application as amended ...." This signals a Commission expectation that DOE could propose and NRC could approve amendments to the original application for construction authorization as both agencies continue gathering and evaluating data from construction. It also suggests that, if DOE's application for the initial license amendment for waste receipt and possession provided for a small "initial operation" followed by expanded emplacement operations as results from the initial operation confirm its performance, "substantially complete" construction of only this small initial operation would enable NRC to approve receipt and possession "in conformity with the application." In any case, given its commitment to risk-informed, performance-based regulation, NRC will probably not want to impose conditions on any license amendment for waste receipt and possession in a way that would foreclose continuing data gathering and evaluation from construction as well as waste emplacement. The Commission would more likely want to regulate in a way that would permit both construction and emplacement to proceed "in conformity" with any license amendments the Commission may subsequently approve for either.

This reading of the Commission's requirement for "substantially complete" construction at least avoids an outcome that would render meaningful compliance with the other Commission requirements cited here all but impossible. Phased repository development is a prerequisite for optimizing ambient temperatures after initial operation, and a more literal interpretation of the requirement would preserve this option while still assuring that all the construction necessary to support initial repository operation would be "substantially complete." The narrower reading would also be most consistent with the Commission's risk-informed performance-based regulatory philosophy. Without the regulatory latitude for a phased completion of the construction authorized, it is difficult to see how future waste emplacement operations could be regulated to "provide flexibility to determine how to meet the established performance criteria in a way that will encourage and reward improved outcomes."

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT 1. QA: N/A

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