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Viability Assessment of a Repository at Yucca Mountain

Costs to Construct and Operate the Repository

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Viability Assessment of a Repository at Yucca Mountain

Volume 5: Costs to Construct and Operate the Repository

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ACRONYMS

AEC	U.S. Atomic Energy Commission
ASTM	American Society for Testing and Materials
CFR	*Code of Federal Regulations*
CRWMS	Civilian Radioactive Waste Management System
DOE	U.S. Department of Energy
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
LA	License Application
M&O	Management and Operating Contractor
NRC	Nuclear Regulatory Commission
OCRWM	Office of Civilian Radioactive Waste Management
TSPA	Total System Performance Assessment
USGS	U.S. Geological Survey
VA	Viability Assessment
YMP	Yucca Mountain Site Characterization Project
YMSCO	Yucca Mountain Site Characterization Office

Measurements

Btu	British thermal unit
cm	centimeter
Eh	redox potential
ft	foot
gal	gallon
g	gram
in.	inch
kg	kilogram
km	kilometer
kPa	kilopascal
kV	kilovolt
kVA	kilovolt-ampere
kWh	kilowatt-hour

lin ft	linear feet
m	meter
mL	milliliter
mm	millimeter
MPa	megapascal
MTHM	metric tons of heavy metal
MTU	metric tons of uranium
MVA	megavolt-ampere
nm	nanometer
pH	hydrogen-ion concentration notation
ppm	parts per million
ppmv	parts per million by volume
psi	pounds per square inch
wt	weight

OVERVIEW

PURPOSE

This Monitored Geologic Repository-Viability Assessment (VA) cost estimate was mandated by the U.S. Congress in the 1997 Energy and Water Development Appropriations Act. That Act states in part:

> "....the Secretary shall provide to the President and to the Congress a viability assessment of the Yucca Mountain site. The viability assessment shall include:
>
> (1) the preliminary design concept for the critical elements for the repository and waste package;
>
> (2) a total system performance assessment, based upon the design concept and the scientific data and analysis available by September 30, 1998, describing the probable behavior of the repository in the Yucca Mountain geological setting relative to the overall system performance standards;
>
> (3) a plan and cost estimate for the remaining work required to complete a license application; and
>
> (4) an estimate of the costs to construct and operate the repository in accordance with the design concept."

The cost estimate in Volume 5 was created in compliance with the fourth item mandated in the 1997 Act. It provides the costs to construct and operate a repository using the information available for the design concept and supported by the data and analysis specified in Volumes 2 and 3. The purpose of the Monitored Geologic Repository-VA cost estimate further serves as a major component of the Total System Life Cycle Cost estimate, published as *Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program* (DOE 1998c), for the entire U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM) program.

As discussed in Section 1.6 of Volume 1, OCRWM implements the federal policy for permanent disposal of high-level radioactive waste and spent nuclear fuel. The OCRWM program includes planning of transportation systems for spent nuclear fuel and high-level radioactive waste, possible interim storage of spent nuclear fuel, development of acceptance criteria for waste forms destined for geologic disposal, and development of a monitored geologic repository.

SCOPE

This volume presents a management summary of the cost estimate to complete the design, and to license, construct, operate, monitor, close, and decommission a Monitored Geologic Repository at Yucca Mountain in Nevada. This volume summarizes the scope, estimating methodologies, and assumptions used in development of the Monitored Geologic Repository-VA cost estimate. It identifies the key features necessary to understand the summary costs presented herein. This cost summary derives from a larger body of documented cost analysis.

The scope of the VA is based primarily on the reference design for the repository and waste package described in Volume 2 and on the *Performance Confirmation Plan* (CRWMS M&O 1997). These documents, like the VA estimate itself, draw upon extensive documented sources. Not all portions of the VA reference design are at the same level of completeness. In assigning resources, highest priority has been given to advancing the design of the repository features important to radiological safety and those for which no prior Nuclear Regulatory Commission (NRC) design or licensing precedent exists. Consequently, different estimating methodologies were used, depending on current design maturity, stage of development of related programs, and development of concepts of operation for the repository. As the design matures, the cost estimate can be refined.

The approaches to estimating and cost analysis used in this volume are the same as those used for large-scale design, construction, and long-term operations projects. To arrive at the VA cost, Yucca Mountain Site Characterization Project

(YMP) requirements were identified and a hierarchy of cost elements was defined. Project phases were defined; construction, operations, and contracting strategies were established; assumptions were formulated; appropriate cost estimating methodologies were selected; and cost estimates were developed and rolled up to the summary level provided in this document.

Volume 5 is organized to reflect this structured approach to cost estimation and contains the following sections:

Section 1, Cost Elements. This section briefly defines the components of each major repository cost element.

Section 2, Project Phases. This section presents the definition, as used in the estimate, of five project phases (Licensing, Pre-emplacement Construction, Emplacement Operations, Monitoring, and Closure and Decommissioning) and the schedule dates for each phase. It also contains major milestone dates and a bar chart schedule.

Section 3, Major Assumptions. This section identifies key high-level assumptions for the cost estimate basis. Additional detailed assumptions are included in the appendices.

Section 4, Integrated Cost Summary. This section presents a high-level roll-up of the VA costs resulting from the estimating work. The tables and figures contained in this section were compiled from the more detailed cost estimates in the appendices.

Section 5, References. This section identifies the references that support this cost volume.

Appendices. For each major repository cost element, Appendices B-F presents additional information on the scope of cost elements, identifies methodologies used to develop the cost estimates, lists underlying cost assumptions, and tabulates summary results. Appendix A contains a glossary to assist the reader in understanding the terminology in Volume 5. Appendix G presents costs associated with three VA design options, as described in Volume 2. These costs are provided for information and are not compiled into the integrated cost summary.

VIABILITY ASSESSMENT AND TOTAL SYSTEM LIFE CYCLE COSTS

The Monitored Geologic Repository-VA cost estimate is a detailed, point-in-time estimate of the costs to design, construct, operate, monitor, close, and decommission a radioactive waste disposal facility at Yucca Mountain based on the current VA reference design. Only those costs associated with construction and operation of the repository, as described in Volumes 1–3 and prescribed in the 1997 Energy and Water Development Appropriations Act, are presented in the Monitored Geologic Repository-VA cost estimate.

DOE recognized that the Monitored Geologic Repository-VA cost estimate, while responsive to the requirements of the Appropriations Act, does not address the total system life cycle cost for the program. To address this issue, the *Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program* (DOE 1998c) was prepared concurrently with the Monitored Geologic Repository-VA cost estimate and serves as a companion document. The Total System Life Cycle Cost estimate provides a total cost picture for use in financial planning, policy making, and assessing the adequacy of the fees paid by commercial reactors for storage and final disposition of spent nuclear fuel. The Total System Life Cycle Cost estimate is consistent with the Monitored Geologic Repository-VA cost estimate but covers the total system cost from inception in 1983 through closure and decommissioning in 2116. Figure O-1 depicts the salient differences between the two estimates.

It is important to recognize the interrelationships among these areas of cost. The following points highlight significant differences:

- The Monitored Geologic Repository-VA cost estimate represents the design, construction, operation, and monitoring of a repository encompassing the statutorily mandated limit of 70,000 MTHM of waste inventory. This estimate accounts for costs

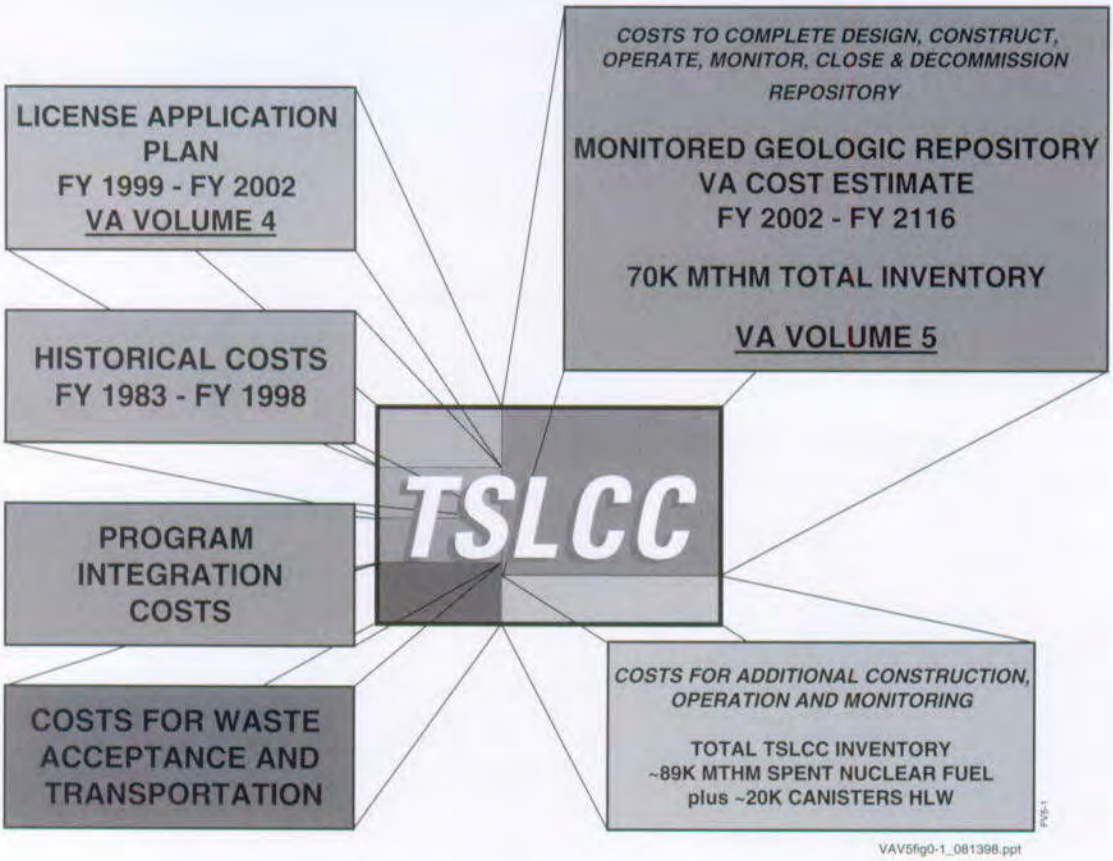

Figure O-1. Components of the Total System Life Cycle Cost Estimate

beginning with the submission of a license application (LA) in March 2002 up to and including closure and decommissioning of the facility in fiscal year 2116. This body of costs is fully discussed within this volume. A full description of the repository and this inventory is addressed in Volume 2.

- The additional costs are associated with residual inventory above 70,000 MTHM. The Total System Life Cycle Cost includes an additional 23,300 MTHM of commercial spent nuclear fuel, 237 MTHM of DOE spent nuclear fuel, and approximately 12,000 canisters of high-level radioactive waste.

- Volume 4 describes the remaining efforts and costs necessary to assemble and submit an LA acceptable to NRC. These costs are not reflected in Volume 5 but are included within the Total System Life Cycle Cost. These cost elements within Volume 4 were developed in a different format from those in Volume 5. This is because the work in the LA concludes site characterization while the work after the LA involves a design, procurement, construction, and operation program.

- Historical costs (fiscal years 1983–1998) are included within the Total System Life Cycle Cost.

- Costs associated with the transportation of inventories to be permanently emplaced at the repository are included within the Total System Life Cycle Cost. Transportation costs include relocation of inventories to the repository site and the costs associated with capital expenses to provide the transportation infrastructure in Nevada. Neither of

these costs is included in the Monitored geologic Repository-VA cost estimate.

- OCRWM program level costs necessary to manage the entire portfolio of efforts delineated above are included within the Total System Life Cycle Cost.

- Additional costs addressed in the Total System Life Cycle Cost are payment-equal-to-taxes, financial and technical assistance, quality assurance, federal salaries, and other benefit costs as defined in the Nuclear Waste Policy Act, as amended (Nuclear Waste Policy Act of 1982).

Additional details and specific information addressing each of these elements are provided within the Total System Life Cycle Cost document. The Monitored Geologic Repository-VA cost estimate reflects fiscal year 1998 dollars. The Total System Life Cycle Cost and the draft environmental impact statement (EIS) will also be reported in 1998 dollars. The LA costs in Volume 4 are depicted in year of expenditure dollars.

The costs reported in this volume represent a preliminary estimate based on the design approach described in Volume 2 and the assumptions concerning development and operation of the system specified in Volume 5. Alternative designs and approaches for implementing the repository system have been and will continue to be analyzed. These analyses show several ways for the program to proceed on schedule with various cash flow profiles, including lower yearly funding requirements. Alternative implementation options include early acceptance of waste, varying receipt rates, modular construction of the surface and underground repository facilities, varying amounts of spent nuclear fuel in lag storage, and an approach to transportation with lower initial capital investment than the rail branch to the Yucca Mountain site assumed in current plans. Although these options can lower near-term repository cash flow profiles, they generally increase the Total System Life Cycle Cost and vary costs to utilities for storage at their sites, depending on the rates of acceptance at the repository.

COST SUMMARY

The cost to design, license, construct, operate, monitor, close, and decommission the repository at Yucca Mountain is estimated to be $18.7 billion in constant 1998 dollars. The capital costs for design, licensing, and construction are $10.6 billion; operations and maintenance costs are $8.1 billion. The $18.7 billion would be expended in the following project phases:

Licensing (March 2002–February 2005)	$ 0.8 billion
Pre-Emplacement Construction (March 2005–February 2010)	$ 2.9 billion
Emplacement Operations (March 2010–September 2033)	$ 11.1 billion
Monitoring (October 2033–February 2110)	$ 3.5 billion
Closure and Decommissioning (March 2110–September 2116)	$ 0.4 billion

INDEPENDENT ASSESSMENT OF THE MONITORED GEOLOGIC REPOSITORY–VIABILITY ASSESSMENT COST ESTIMATE

Through its Office of Field Management, DOE engaged the services of a worldwide engineering and construction company to perform an independent review of the Monitored Geologic Repository-VA cost estimate. Overall, the review team found the majority of the cost estimate to be well done, given the assumptions associated with the reference design. In some areas, refinements of the cost estimate were necessary. Generally, justification for the finalized estimated costs was found to be consistent and appropriate for the project period, resulting in a credible representation of the project.

This review was managed by the DOE Office of Field Management and its contractor, independently of OCRWM. The independent assessment was a multistep process begun in October 1997 with review of the cost estimating assumptions. Following that review, the five major cost elements

of the repository estimate—Surface; Subsurface; Waste Package; Performance Confirmation; and Regulatory, Infrastructure, and Management Support—were evaluated from January through June 1998. During the review process, the review team had unfettered access to OCWRM and YMP information and personnel.

The major activities of the cost estimate review included the following:

- Kick-Off Meetings—Meetings were held at project offices to present design, cost estimate, and related YMP documents. These meetings also included formal presentations to the review team as well as opportunities to investigate the data and ask questions of key personnel.

- Cost Estimate Reviews—YMP information, estimate backup data, bases of estimate, and scope documentation were reviewed in project offices and the contractor's home office. The review included evaluation of large cost drivers as well as details in the assumptions, methodologies, and estimating practices for major cost elements and sub-elements. The review team's approach followed standard industry practices and included considerable review of cost estimate details, including the following:

  - Reviewing the unit prices, productivity, and labor rates for reasonableness.

  - Comparing the costs against existing databases, commercial norms, and other DOE projects.

  - Checking the estimate against design drawings, specifications, etc., to determine whether there were any omissions.

  - Verifying consistency with the base assumptions.

  - Comparing the work scopes of the five cost elements for proper integration and to assess any potentials of overlap or omissions. Additionally, YMP management, design, construction management, and other similar support activities were compared against typical levels from similar projects. During this period of review, daily and weekly telephone conference calls and periodic follow-up meetings provided the review team with necessary information.

- Preparation of Draft Reports—Draft or preliminary assessment reports were completed for each cost element of the Monitored Geologic Repository-VA cost estimate. These draft reports summarized the review team's evaluation process, the cost items being evaluated, and any observations or findings. A summary of the technical scope of each activity was also provided in these reports.

- Summary Report—The summary report provides a top-level summary of the independent review team's assessment of the Monitored Geologic Repository-VA cost estimate. It lists key observations from and suggestions on each of the five draft reports. The report also presents the Yucca Mountain Site Characterization Office (YMSCO) responses to and resolution status of the suggestions and observations.

YMP evaluated all concerns and findings identified by the review team during the course of the assessment. Where additional responses or activities were necessary to address review team concerns, action plans were developed and issues were tracked until completion. When necessary, estimates were reconciled and revisited with the review team to ensure closure consistent with their expectations. All but a few minor items were resolved with the review team; resultant changes to the cost estimate have been incorporated into the cost figures contained in this volume. On July 27, 1998, the external review team published a final draft summary report for the Monitored Geologic Repository-VA cost estimate (DOE 1998a).

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1. COST ELEMENTS

The Monitored Geologic Repository-VA cost estimate is structured around cost elements established through detailed analysis of project requirements in five major areas. To understand the summaries, it is necessary to understand what the cost elements contain. This section briefly defines the major project cost elements by listing subelements and their scope of work. Additional information on cost elements is provided in the appendices, which further describe cost element scope of work, methodologies used to develop the cost estimates, assumptions, and a summary of results.

1.1 SURFACE FACILITIES

The work required to design, construct, operate, maintain, and decommission the surface facilities consists of the following cost subelements:

- **Field Costs** consists of four subelements: Site Preparation and Transportation, Site Support Systems, Waste Handling Structures, and North Portal Support Structures. Field Costs include costs to prepare the site and construct all major facilities for receipt, handling, and packaging of waste for emplacement, as well as the preparation of site-generated, low-level radioactive waste for disposition. In addition, costs are included to construct sitewide systems such as roads and an onsite rail system and systems for water, sewage, electricity, fuel oil, fencing, communication, and environmental monitoring.

- **Startup and Training Activities** is associated with the activation and startup of surface facilities at the North Portal and other sitewide systems such as water supply and environmental monitoring. The hiring and training of operations staff, construction inspection, operational readiness reviews, and integration testing are also included.

- **Emplacement Activities** includes all activities related to the operation and maintenance of the surface facilities at the North Portal, and other sitewide systems such as roads, water supply, and environmental monitoring.

- **Monitoring Activities** includes the costs associated with operating and maintaining equipment and facilities to support the performance confirmation program. The initial monitoring phase includes costs to mothball the surface facility equipment to ensure readiness if waste package retrieval is necessary.

- **Decommissioning Activities** includes the costs for permanently decommissioning and dismantling surface facilities at the North Portal; returning the site to a more natural condition; disposing of resulting debris; and erecting barriers to human intrusion.

- **Design** costs provide engineering design, construction inspection, and facility configuration management and controls, starting with submittal of the LA through completion of construction at the North Portal. This cost element also provides for designing sitewide systems such as roads, water supply, and environmental monitoring.

- **Offsite Power** is a cost element that includes the design, installation, and construction of new electrical transmission lines and power distribution equipment necessary to bring sufficient electricity supply to the repository to support construction and operations.

Appendix B presents more information on these cost elements.

1.2 SUBSURFACE FACILITIES

The work required to design, construct, operate, maintain, close, and decommission the subsurface facilities includes the following cost subelements:

- **Access Excavation and Construction** includes the excavation and completion of access drifts, excavation of the assembly/disassembly chamber for the tunnel boring machine, and construction of ventilation barriers.

- **Emplacement Drift Excavation** represents activities to excavate and complete emplacement drifts, emplacement drift turnouts, and the ventilation shafts connecting emplacement drifts to the Main Exhaust drift.

- **Excavated Material Handling** includes removing excavated material from the subsurface to the surface from the tunnel boring machine and roadheader excavation equipment.

- **Support System Facilities** covers the costs to operate portal support, batch plant, precast yard, and development-side subsurface utilities; surface support facilities; and operation of the repository development-side ventilation system.

- **Subsurface Emplacement Operations** includes underground transportation and emplacement of waste packages and the operation and maintenance of subsurface emplacement-side utilities and ventilation systems.

- **Decommissioning Activities** includes placing seals in access mains, performance confirmation drifts, and ventilation shafts. It also provides for decommissioning, demolishing, and removing surface support facilities.

- **Ventilation Shafts** includes costs to excavate, finish, and complete the development and emplacement ventilation shafts.

- **Subsurface Management and Integration** provides for management and integration of architectural and engineering services and configuration management control of construction specifications and drawings. It also includes the cost to organize, coordinate, plan, schedule, direct, and inspect construction activities.

- **South Portal Facilities** includes costs to construct and operate surface support facilities at the South Portal.

- **Early Testing and Development** covers the development and testing of mockup prototype equipment for waste package transport and emplacement equipment.

Appendix C presents more information on these cost elements.

1.3 WASTE PACKAGE

The work required to fabricate the disposal containers to be emplaced in the repository includes the following cost subelements:

- **Commercial Spent Nuclear Fuel Containers** covers the costs to fabricate disposal containers for boiling-water reactor and pressurized-water reactor assemblies.

- **Defense High-Level Radioactive Waste Containers** provides for fabrication of disposal containers for immobilized, defense high-level radioactive waste.

- **DOE Spent Nuclear Fuel Containers** includes the costs for fabrication of disposal containers for DOE spent nuclear fuel, including naval spent nuclear fuel.

- **Waste Package Supports** provides for fabrication of the supports on which the waste packages rest.

- **Design** includes the costs for the design and procurement of the disposal containers and waste package supports.

Appendix D presents more information on these cost elements.

1.4 PERFORMANCE CONFIRMATION

A performance confirmation program is required by NRC regulations to ensure that waste packages and the subsurface repository function in accordance with license requirements. Work within the

scope of the performance confirmation program includes the following cost subelements:

- **Site Testing** includes subsurface geologic mapping and sampling, surface-based saturated and unsaturated zone hydrologic testing, underground fault zone hydrologic testing, sample testing, thermal testing, and general surface-based testing.

- **Repository Testing** covers in situ seal testing, design testing, near-field testing, and monitoring of hydrocarbons remaining in the repository.

- **Waste Package Testing** provides for conducting offsite laboratory testing of waste package materials and waste forms, in situ waste package monitoring, and testing of recovered waste package material specimens.

- **Repository Subsurface Support Facilities** maintains subsurface test facilities, equipment, and the integrated network of systems needed to directly monitor emplacement drift environment. It also provides for monitoring the geologic, hydrologic, and geochemical conditions adjacent to the emplacement drifts, as well as the conditions surrounding the repository block.

- **Evaluation and Reporting** provides for collection of performance confirmation program data, updating and running total system performance assessment (TSPA) models, interpreting results, refining models, and updating regulatory reports and licensing documents, as required.

Appendix E presents more information on these cost elements.

1.5 REGULATORY, INFRASTRUCTURE, AND MANAGEMENT SUPPORT

This cost element consists of several repository support services not included in other cost estimates. These support services include the following activities:

- **Regulatory** includes all costs associated with regulatory support for NRC licensing reviews; development, review, and distribution of the LA update; technical data management; total system performance analyses supporting licensing reviews; and license application updates during waste emplacement, monitoring, and closure phases of the repository.

- **Preconstruction Authorization Site Services** includes all costs of providing support for the operations and maintenance of the site test facilities as necessary to support site characterization and performance confirmation testing from 2002 to 2005.

- **Environment, Safety, and Health** includes all costs associated with the National Environmental Policy Act (1969) coordination and compliance including support for NRC adoption of the EIS, coordination and support for development of the LA update, and support for EIS supplements, if necessary. This cost element also includes development and management of a repository operations emergency response plan and safety and health programs for the protection of the worker and the public. After 2010, the cost for these activities is contained in the Surface cost estimate.

- **Infrastructure** includes costs associated with information management, institutional and external affairs, administrative support services, and project planning and control.

- **Training** provides a YMP training program between 2002–2007 that meets the quality assurance, safety and health, and other DOE-mandated program requirements. After 2007, these activities are included in the Surface cost estimate.

- **Set Asides** are costs associated with furnishing direct support to DOE operations and other support programs not specifically covered in other cost elements. These activities include administrative support services,

information management, security services, management and technical services, telecommunications services, and telecommunications video support services.

- **Monitoring Technical Assistance** provides technical support during the monitoring phase from 2034 to 2110. Activities include failure and root cause analysis, modification support, performance confirmation oversight, and document maintenance.

- **Overhead and Fee** includes costs for DOE contractor overhead and fee. Costs incurred from subcontractors are included in the elements where the burden is incurred.

Appendix F presents more information on these cost elements.

2. PROJECT PHASES

The time encompassed by the Monitored Geologic Repository-VA cost estimate extends from the year 2002 through 2116. During this period, the project will evolve through five distinctly different activity phases. Understanding these project phases and the work that will be accomplished during each is vitally important to understanding the cost estimate. Section 2 defines the project phases and effective dates of each phase, lists key milestone dates, and presents a bar chart of scheduled activities. The cost estimate assumes that activities will be conducted within the scheduled time frames. Delays or other deviations from the schedule will impact costs.

2.1 PROJECT PHASE DESCRIPTIONS

2.1.1 Licensing Phase (March 2002–February 2005)

The estimate for this phase includes all costs related to completing repository and waste package designs. Costs to support the LA and respond to issues related to the EIS are included. The estimate also contains the costs to develop test requirements for facility operating systems and the monitoring systems that will confirm repository performance.

2.1.2 Pre-Emplacement Construction Phase (March 2005–February 2010)

The Pre-Emplacement Construction Phase will start after NRC authorizes construction. The estimate for this phase includes all capital and operating costs to construct surface and subsurface facilities within the radiologically controlled area. The underground area will include, as a minimum, sufficient development to begin emplacing waste packages in February 2010. Costs include expenses for additional design and licensing work, personnel training, prototype testing, development of operations and maintenance procedures, repository startup operations, and establishing baseline parameters for confirming repository performance. The initial procurement of disposal containers must take place during this phase to support emplacement operations.

2.1.3 Emplacement Operations Phase (March 2010–September 2033)

The Emplacement Operations Phase begins after NRC issues a license amendment for the repository to receive and possess waste. The major cost elements for this phase pertain to repository operations for accepting the waste and to procurement, handling, and emplacement of waste packages. Also included are capital and operating costs for continued underground construction, startup activities, and the cost of tests and analyses required to confirm repository performance.

2.1.4 Monitoring Phase (October 2033–February 2110)

The Monitoring Phase includes capital and operating costs to decontaminate and mothball most of the surface facility structures and systems. Cost elements will include expenses for maintaining the facilities in standby status and providing sufficient maintenance to retrieve waste packages, if necessary. Costs associated with ventilation and inspection of the underground access and main drifts will continue, as will performance confirmation and required security functions.

2.1.5 Closure and Decommissioning Phase (March 2110–September 2116)

The Closure and Decommissioning Phase includes operating and capital costs for demolishing the repository surface infrastructure; constructing barriers to preclude human intrusion; backfilling the access shafts, ramps, and boreholes; and restoring the site to a condition that does not require human support.

2.2 SCHEDULE

The following key milestones form the basis for the Monitored Geologic Repository-VA cost estimate.

Submit license application for construction authorization	March 2002
Start repository construction	March 2005

Submit license amendment to receive and possess waste	September 2008
Start waste emplacement	March 2010
Submit license amendment to close repository	September 2107
Start repository closure	March 2110
Complete repository closure	September 2116

Figure 2-1 is a bar chart schedule of major activities. The activities are organized by major cost elements.

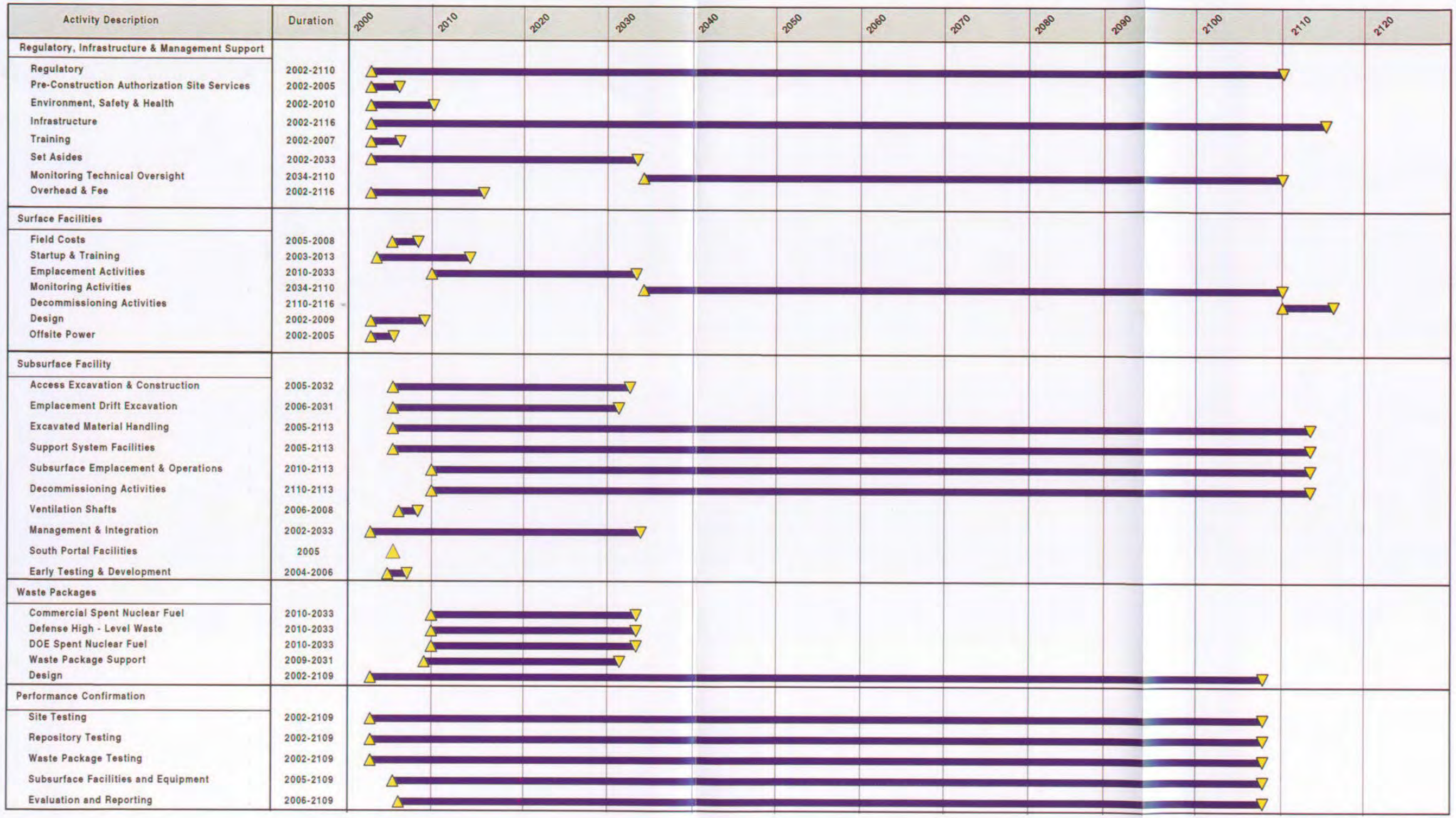

Figure 2-1. Monitored Geologic Repository-VA Cost Estimate Activity Description Schedule

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3. MAJOR ASSUMPTIONS

To develop the Monitored Geologic Repository-VA cost estimate, key assumptions that affect the cost estimate were made about the overall project and repository. Assumptions specific to individual cost elements were also used in formulating the overall estimate. These assumptions relate to the reference design described in Volume 2. Cost element assumptions included in the respective appendices further define and clarify the cost estimates contained therein. Major assumptions follow:

- All estimated costs are given in constant 1998 dollars.

- There will be no collocated interim storage facility at the repository.

- There are no costs included for expanding the capacity of the repository beyond the 70,000 MTHM mandated for the VA. For the VA, waste allocation is as follows:

  - 63,000 MTHM commercial spent nuclear fuel

  - 640 MTHM-equivalent commercial high-level radioactive waste

  - 4,027 MTHM-equivalent defense high-level radioactive waste

  - 2,333 MTHM DOE spent nuclear fuel, including naval spent nuclear fuel

- The repository will be designed to ensure that it can be functional and kept open for at least 100 years after initial waste emplacement. It is assumed that the repository will be closed in 2110 and decommissioned by 2116.

- The repository will be designed to support retrieval operations. If future waste retrieval is directed, a 10-year period will be required to allow activation of the retrieval infrastructure. However, costs associated with retrieval operations are not included in the VA.

- Repository design, construction, emplacement of waste, monitoring, and closure and decommissioning activities will be conducted under a quality assurance program as described in the current quality assurance requirements and description document (DOE 1998b).

- No backfill will be used in the emplacement drifts. All other drifts, shafts, boreholes, and ramps will be backfilled and sealed during the closure and decommissioning phase.

- There are three additional repository design options under consideration: emplacement drift backfill, ceramic-coated waste packages, and long-life drip shields. These options are not part of the VA reference design, and costs associated with their implementation are not included in the VA cost summaries in this volume. The design options are described and rough-order-of-magnitude costs are provided in Appendix G.

- There is no requirement for additional site characterization or collection of additional design data in potential repository expansion areas.

- Preconstruction site test facilities, including the Change House, Switchgear Building, Substation 25-16, and the sanitary sewer system, will become part of the final repository layout. The facilities will be upgraded as required.

- DOE will own and control land, water rights, and subsurface rights. After a site recommendation is submitted to Congress and final congressional action is taken, DOE will formally dedicate the land for constructing a repository.

- Substantially complete construction of repository facilities is required for the initial receipt and emplacement of spent nuclear

fuel and high-level radioactive waste. Substantially complete construction is defined as completion of the surface facilities and sufficient construction of emplacement drifts to safely handle and emplace the initial waste packages.

- All spent nuclear fuel and high-level radioactive waste will be shipped directly to the repository.

- Cost impacts resulting from possible schedule delays or other actions beyond the control of YMP are not included. The schedule milestones in Section 2.2 must be met for the Monitored Geologic Repository-VA cost estimate to be valid.

- Current cost-sharing and support arrangements with the Nevada Test Site will continue.

Additional assumptions are included in the summary cost estimates presented in Appendices B, C, D, E, and F.

4. INTEGRATED COST SUMMARY

4.1 OVERVIEW

This section combines the individual cost element summaries in the appendices into a summary-level, total repository cost estimate. The total repository costs are listed by the major cost elements and project phases. The cost figures are displayed in tables and graphs.

The cost to complete the design and to license, construct, operate, monitor, decommission, and close the repository at Yucca Mountain is estimated to be $18.7 billion in constant value 1998 dollars. The capital costs for design, licensing, and construction are $10.6 billion, while the operations and maintenance costs are $8.1 billion.

The following sections contain tables and figures that further define the overall repository cost estimate. Dollar amounts are summary figures derived from detailed calculations. Some minor differences or variations in the figures may occur due to effects from computational rounding of the numbers.

4.2 REPOSITORY COST SUMMARY

The $18.7 billion total repository cost breakdown by cost element, including all phases, in rounded dollars, is:

Surface Facilities	$ 5.4 billion
Subsurface Facilities	$ 5.0 billion
Waste Package	$ 4.0 billion
Performance Confirmation	$ 2.1 billion
Regulatory, Infrastructure, and Management Support	$ 2.2 billion
Total	$ 18.7 billion

The total cost for the VA broken out during the five phases, including all cost elements of the repository, in rounded dollars, is:

Licensing (March 2002—February 2005)	$ 0.8 billion
Pre-Emplacement Construction (March 2005—February 2010)	$ 2.9 billion
Emplacement Operations (March 2010—September 2033	$ 11.1 billion
Monitoring (October 2033—February 2110)	$ 3.5 billion
Closure and Decommissioning (March 2110—September 2116)	$ 0.4 billion
Total	$ 18.7 billion

Table 4-1 and Figures 4-1 and 4-2 also present the $18.7 billion total repository cost summary by cost element and phase, respectively.

4.3 REPOSITORY ANNUAL COST DISTRIBUTION

The data in Table 4-2 are the basis for the total repository annual cost distribution represented in the bar graph in Figure 4-3 . Annual peaks as high as $700 million will occur during the Pre-Emplacement Construction Phase. If such cost peaks prove prohibitive, alternative procurement and construction strategies might be necessary to create a more level cost structure. For example, certain non-

Table 4-1. Repository Cost Summary (1998 $ in Millions)

Phase	Phase Total	Surface Facilities	Subsurface Facilities	Waste Packages	Performance Confirmation	Regulatory, Infrastructure & Management Support
Licensing	752.3	145.5	92.2	38.5	123.4	352.7
Pre-Emplacement Construction	2,913.5	1,179.5	933.0	52.0	245.9	503.1
Emplacement Operations	11,166.4	3,112.0	2,602.8	3,948.0	750.4	753.4
Monitoring	3,513.6	862.4	1,199.0	20.2	941.6	490.5
Closure and Decommissioning	369.9	129.3	175.6	0.0	0.0	65.0
Grand Total	**18,715.8**	**5,428.7**	**5,002.5**	**4,058.6**	**2,061.3**	**2,164.6**

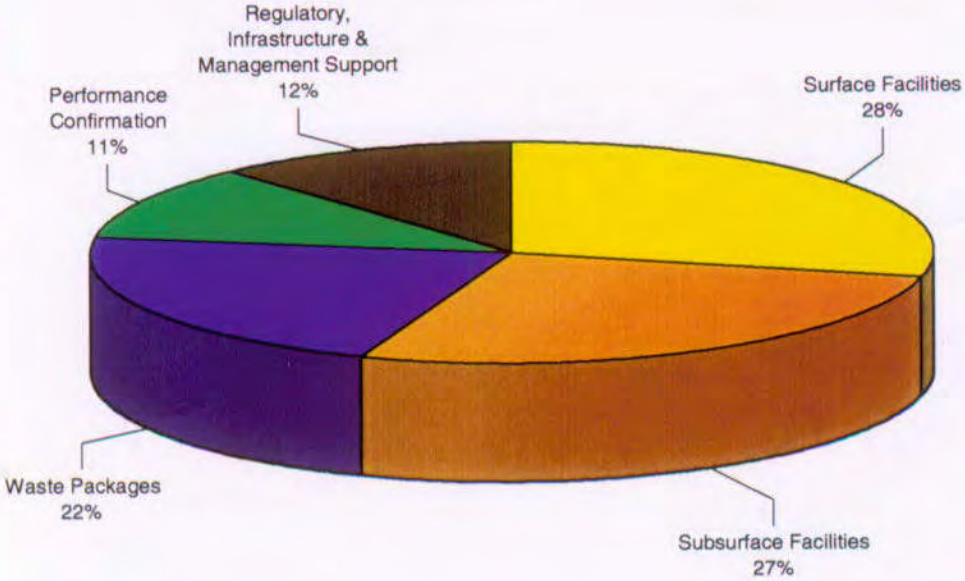


Figure 4-1. Repository Cost Summary by Cost Element

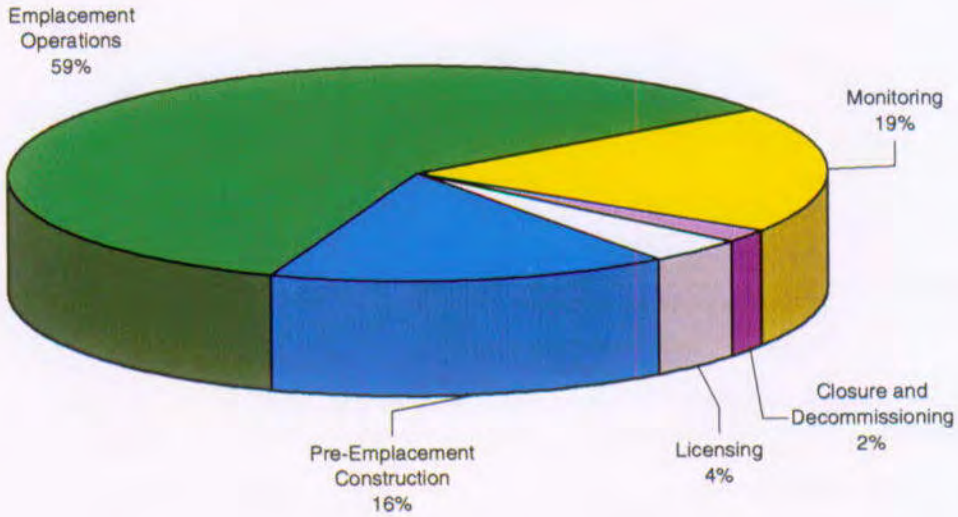


Figure 4-2. Repository Cost Summary by Phase

Table 4-2. Repository Annual Cost Distribution (1998 $ in Millions)

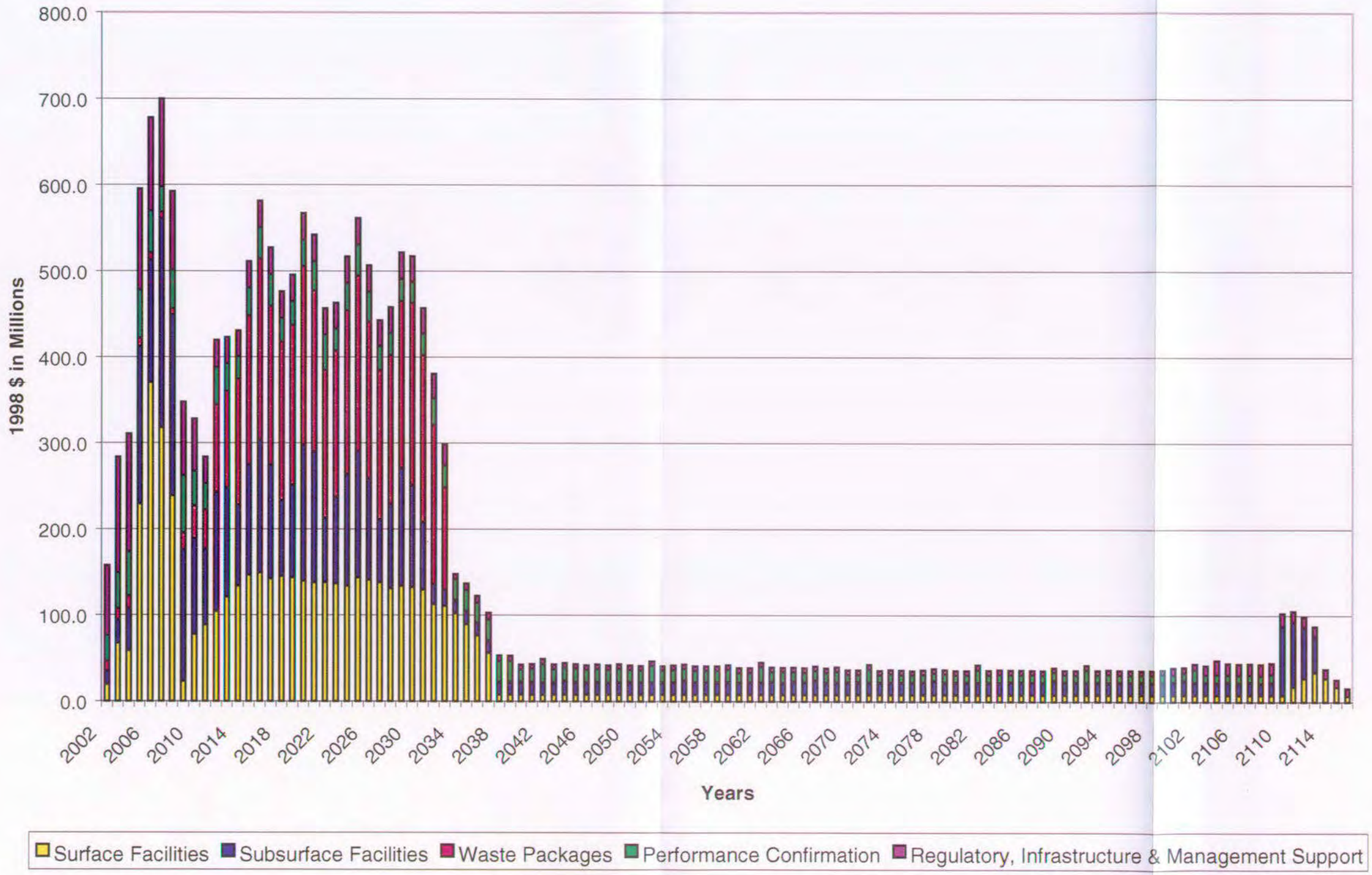
Year	Yearly Total	Surface Facilities	Subsurface Facilities	Waste Packages	Performance Confirmation	Regulatory, Infrastructure & Management Support
2002*	157.8	19.4	15.7	11.1	30.2	81.4
2003	283.8	67.4	27.2	13.1	41.6	134.5
2004	310.6	58.8	49.3	14.2	51.5	136.9
2005	595.3	229.4	183.3	9.6	56.0	116.9
2006	678.1	370.5	142.7	8.1	48.8	107.9
2007	700.0	317.9	243.0	7.7	29.1	102.1
2008	592.4	238.7	210.7	7.2	44.8	90.9
2009	347.8	23.0	153.1	19.4	67.1	85.1
2010	328.0	77.5	111.7	38.2	40.2	60.4
2011	283.9	88.8	88.6	45.1	30.7	30.8
2012	419.8	104.3	138.6	102.0	43.7	31.2
2013	422.8	121.2	126.8	112.3	32.4	30.1
2014	430.6	133.9	94.8	146.3	26.0	29.7
2015	511.2	146.5	128.7	173.0	32.3	30.7
2016	581.6	149.4	154.6	210.7	35.9	31.0
2017	527.1	142.3	132.5	184.5	37.0	30.8
2018	476.2	145.1	88.4	184.6	27.3	30.8
2019	495.7	143.7	107.8	185.9	27.5	30.8
2020	567.0	139.5	158.8	207.7	30.0	31.0
2021	542.2	138.1	152.0	187.4	33.9	30.8
2022	456.6	138.1	74.8	172.1	41.0	30.7
2023	463.0	136.7	100.6	170.4	25.5	29.8
2024	516.9	133.9	130.4	189.8	32.0	30.7
2025	561.6	143.7	146.9	204.2	35.9	30.9
2026	506.6	140.9	118.3	182.2	34.5	30.7
2027	442.7	138.1	73.0	174.1	27.7	29.7
2028	457.9	131.0	98.0	173.5	25.7	29.6
2029	521.4	133.9	137.0	194.0	26.0	30.5
2030	517.4	132.4	118.9	212.0	24.3	29.8
2031	456.9	129.6	78.7	193.9	25.1	29.5
2032	380.8	112.7	23.6	185.2	30.7	28.5
2033	298.7	110.7	19.2	118.8	25.1	25.0
2034	147.5	102.1	14.9	0.3	24.2	6.0
2035	136.7	89.3	15.0	0.3	24.4	7.8
2036	122.3	76.6	14.2	0.3	23.5	7.8
2037	102.7	56.0	14.4	0.3	24.4	7.8
2038	53.2	7.4	14.8	0.3	23.5	7.3
2039	52.9	7.4	14.7	0.3	24.6	6.0
2040	42.4	7.4	14.9	0.3	14.4	5.5
2041	43.2	7.4	14.8	0.3	15.2	5.5
2042	49.1	7.4	14.3	0.3	21.2	6.0
2043	42.8	7.4	14.4	0.3	15.2	5.5
2044	44.4	7.4	16.6	0.3	14.7	5.5
2045	43.2	7.4	14.8	0.3	15.2	5.5
2046	41.9	7.4	14.4	0.3	14.4	5.5
2047	42.9	7.4	14.6	0.3	15.2	5.5
2048	41.8	7.4	14.3	0.3	14.4	5.5
2049	43.2	7.4	14.6	0.3	15.5	5.5
2050	41.8	7.4	14.9	0.3	13.8	5.5
2051	41.2	7.4	14.5	0.3	13.8	5.3
2052	46.7	7.4	14.0	0.3	19.7	5.3
2053	40.7	7.4	14.6	0.3	13.2	5.3
2054	41.6	7.4	14.4	0.3	14.3	5.3
2055	43.0	7.4	16.9	0.3	13.2	5.3
2056	40.6	7.4	14.5	0.3	13.2	5.3
2057	40.7	7.4	14.6	0.3	13.2	5.3
2058	40.6	7.4	14.5	0.3	13.2	5.3
2059	41.9	7.4	14.7	0.3	14.3	5.3
2060	38.6	7.4	14.3	0.3	11.4	5.3
2061	38.6	7.4	14.5	0.3	11.3	5.3

Table 4-2. Repository Annual Cost Distribution (Continued)

Year	Yearly Total	Surface Facilities	Subsurface Facilities	Waste Packages	Performance Confirmation	Regulatory, Infrastructure & Management Support
2062	45.2	7.4	14.6	0.3	17.8	5.3
2063	39.4	7.4	15.2	0.3	11.3	5.3
2064	39.3	7.4	14.0	0.3	12.4	5.3
2065	39.6	7.4	15.4	0.3	11.3	5.3
2066	38.7	7.4	14.6	0.3	11.3	5.3
2067	40.8	7.4	16.7	0.3	11.3	5.3
2068	38.4	7.4	14.2	0.3	11.3	5.3
2069	39.7	7.4	14.4	0.3	12.3	5.3
2070	36.3	7.4	14.8	0.3	8.6	5.3
2071	36.3	7.4	14.8	0.3	8.6	5.3
2072	42.5	7.4	14.3	0.3	15.3	5.3
2073	35.9	7.4	14.5	0.3	8.6	5.3
2074	37.1	7.4	14.5	0.3	9.7	5.3
2075	36.1	7.4	14.6	0.3	8.6	5.3
2076	35.6	7.4	14.1	0.3	8.6	5.3
2077	36.3	7.4	14.8	0.3	8.6	5.3
2078	38.1	7.4	16.6	0.3	8.6	5.3
2079	37.0	7.4	14.5	0.3	9.7	5.3
2080	35.9	7.4	14.5	0.3	8.6	5.3
2081	35.9	7.4	14.4	0.3	8.6	5.3
2082	42.3	7.4	14.3	0.3	15.1	5.3
2083	36.1	7.4	14.6	0.3	8.6	5.3
2084	36.8	7.4	14.3	0.3	9.7	5.3
2085	36.5	7.4	15.0	0.3	8.6	5.3
2086	36.3	7.4	14.8	0.3	8.6	5.3
2087	36.2	7.4	14.7	0.3	8.6	5.3
2088	35.7	7.4	14.2	0.3	8.6	5.3
2089	39.4	7.4	16.8	0.3	9.7	5.3
2090	36.2	7.4	14.7	0.3	8.6	5.3
2091	36.0	7.4	14.5	0.3	8.6	5.3
2092	42.2	7.4	14.2	0.3	15.1	5.3
2093	36.1	7.4	14.7	0.3	8.6	5.3
2094	36.9	7.4	14.3	0.3	9.7	5.3
2095	36.1	7.4	14.6	0.3	8.6	5.3
2096	36.0	7.4	14.5	0.3	8.6	5.3
2097	35.9	7.4	14.4	0.3	8.6	5.3
2098	36.0	7.4	14.5	0.3	8.6	5.3
2099	37.0	7.4	14.4	0.3	9.7	5.3
2100	39.3	7.4	14.8	0.3	8.6	8.2
2101	39.8	7.4	16.8	0.3	8.8	6.5
2102	43.7	7.4	14.5	0.3	15.1	6.5
2103	41.7	7.4	14.7	0.3	8.6	10.9
2104	47.8	7.4	14.3	0.3	9.7	16.2
2105	44.2	7.4	14.8	0.3	8.6	13.2
2106	43.8	7.4	14.4	0.3	8.6	13.2
2107	44.1	7.4	14.7	0.3	8.6	13.2
2108	43.4	7.4	14.0	0.3	8.6	13.1
2109	44.9	7.4	14.5	0.3	9.7	13.1
2110	103.0	7.4	80.6	0.0	0.0	15.0
2111	105.2	17.0	75.5	0.0	0.0	12.7
2112	98.4	27.2	58.9	0.0	0.0	12.2
2113	87.4	34.0	41.2	0.0	0.0	12.2
2114	37.9	27.2	0.0	0.0	0.0	10.7
2115	25.6	17.0	0.0	0.0	0.0	8.6
2116	15.4	6.8	0.0	0.0	0.0	8.6
Total	**18,715.8**	**5,428.7**	**5,002.5**	**4,058.6**	**2,061.3**	**2,164.6**

*Costs in year 2002 represent partial year (7 months).

Note: These cost estimates reflect DOE's best estimates, given the scope of the work identified and planned schedule of required activities. Future budget requests for the program have yet to be established, and, in any event, will be determined through the annual executive and congressional budget process.



Note: These cost estimates reflect DOE's best estimates, given the scope of the work identified and planned schedule of required activities. Future budget requests for the program have yet to be established, and, in any event, will be determined through the annual executive and congressional budget process.

Figure 4-3. Repository Annual Cost Distribution

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nuclear-related construction could proceed that would not require prior NRC approval.

During the Emplacement Operations Phase, annual costs range from approximately $300 million to $567 million. This large fluctuation is caused primarily by the varying schedule for completing additional subsurface emplacement drifts and the associated procurement of waste package supports.

Costs during the Monitoring Phase level off at approximately $40 million/year, with periodic increases during every 10th year for procuring new remote monitoring equipment.

During the Closure and Decommissioning Phase, annual costs will rise to approximately $100 million as construction and demolition activities begin again.

4.4 REPOSITORY CAPITAL AND OPERATING AND MAINTENANCE COST SUMMARY

Table 4-3 and Figure 4-4 show the allocation and distribution of capital and operating and maintenance expenses among the major cost elements over the project phases. Substantial capital requirements are evident during the Licensing and Pre-Emplacement Construction Phases. During the Emplacement Operations Phase, substantial capital requirements continue for the Subsurface and Waste Package cost elements. Subsurface costs continue to include excavating and completing emplacement drifts, while Waste Package costs include procuring the disposal containers necessary to emplace waste packages. Surface operation and maintenance costs increase considerably due to operation of the Waste Handling Building; the bulk of the labor required to operate the repository is in this cost element. The financial demands of operations and maintenance during the Monitoring Phase are considerable because of the number of years involved. Capital costs begin again in 2110 when decommissioning of the entire repository commences.

4.5 COST ESTIMATE CONTINGENCY

Contingency is an integral part of the cost estimate. During preparation of the Monitored Geologic Repository-VA cost estimates, contingencies were developed to cover costs that may result from incomplete design, unforeseen and unpredictable conditions, or uncertainties that could possibly affect cost. For example, an estimate that is prepared with conceptual scope and minimum pricing information would require a higher contingency allowance.

Before an appropriate contingency amount was added to the cost element(s), the degree of uncertainty inherent in each component of the estimate was determined. Figure 4-5 provides an example

Table 4-3. Repository Capital and Operating and Maintenance Costs
(1998 $ in Millions)

Phase	Phase Total	Surface Facilities		Subsurface Facilities		Waste Packages		Performance Confirmation		Regulatory, Infrastructure & Management Support	
		Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Licensing	752.3	132.2	13.4	92.2	0.0	38.5	0.0	106.3	17.1	352.7	0.0
Pre-Emplacement Construction	2,913.5	1,075.5	104.1	933.0	0.0	52.0	0.0	191.4	54.5	503.1	0.0
Emplacement Operations	11,166.4	0.0	3,112.0	2,350.3	252.5	3,948.0	0.0	182.7	567.6	36.3	717.0
Monitoring	3,513.6	0.0	862.4	130.5	1,068.5	0.0	20.2	55.4	886.2	6.1	484.3
Closure and Decommissioning	369.9	129.3	0.0	172.3	3.3	0.0	0.0	0.0	0.0	65.0	0.0
Grand Total	**18,715.8**	**1,337.0**	**4,091.8**	**3,678.3**	**1,324.2**	**4,038.4**	**20.2**	**535.9**	**1,525.4**	**963.2**	**1,201.4**

O&M–Operating and maintenance

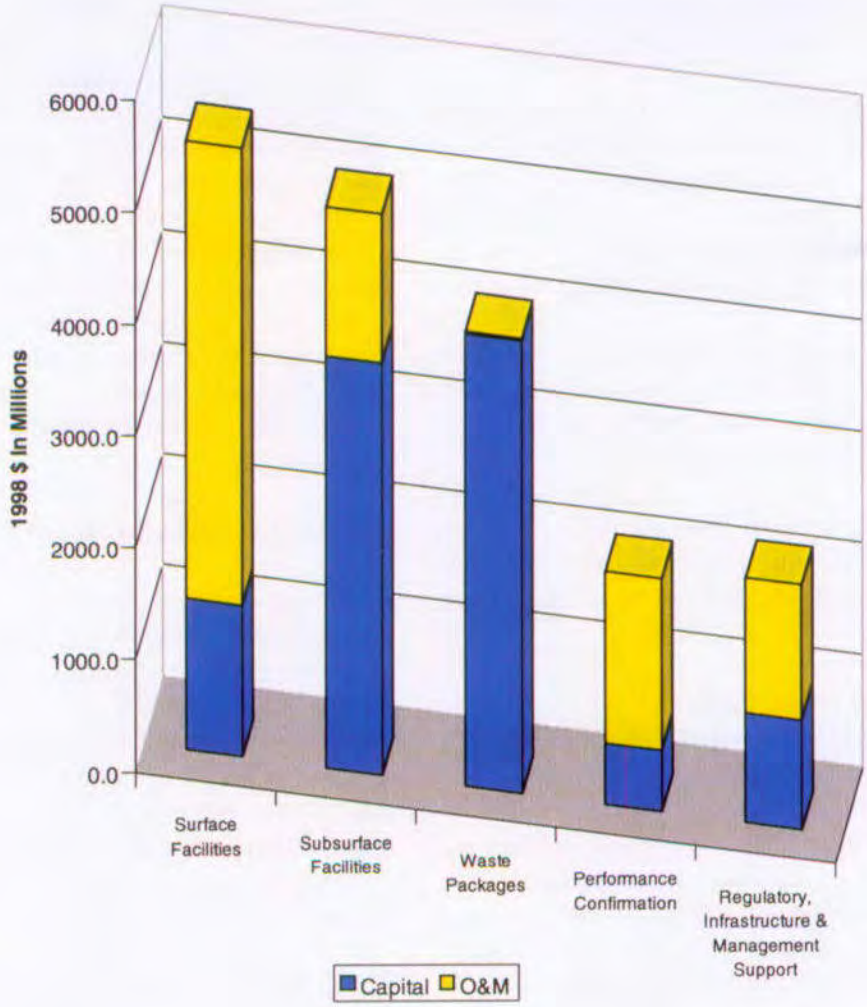

Figure 4-4. Repository Capital and Operating and Maintenance Cost

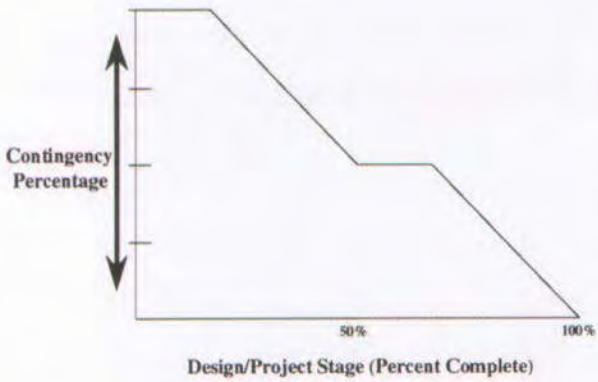

Figure 4-5. Contingency Application Guide - Example

of how much contingency would be applied to an estimate, given a particular level of maturation in the design, concept, or activity. Professional cost estimators use these common contingency-determination processes to mitigate potential uncertainties.

The addition of contingency to the base cost estimates within each cost element was not intended to cover sweeping or major changes to the VA design as described in Volume 2. Rather, contingency is included in the estimates to account for reasonably expected variances in bases and events affecting the current VA scope and related operational concepts.

The approach and use of contingency for the VA estimate is consistent with and follows the principles and practices of the American Association of Cost Engineers. Additionally, the principles and application of contingencies in preparation of the Monitored Geologic Repository-VA cost estimates were reviewed during the independent cost assessment.

With respect to contingencies in the Monitored Geologic Repository-VA cost estimate, Figure 4-6 shows the overall distribution of contingency by cost elements over the life of the repository.

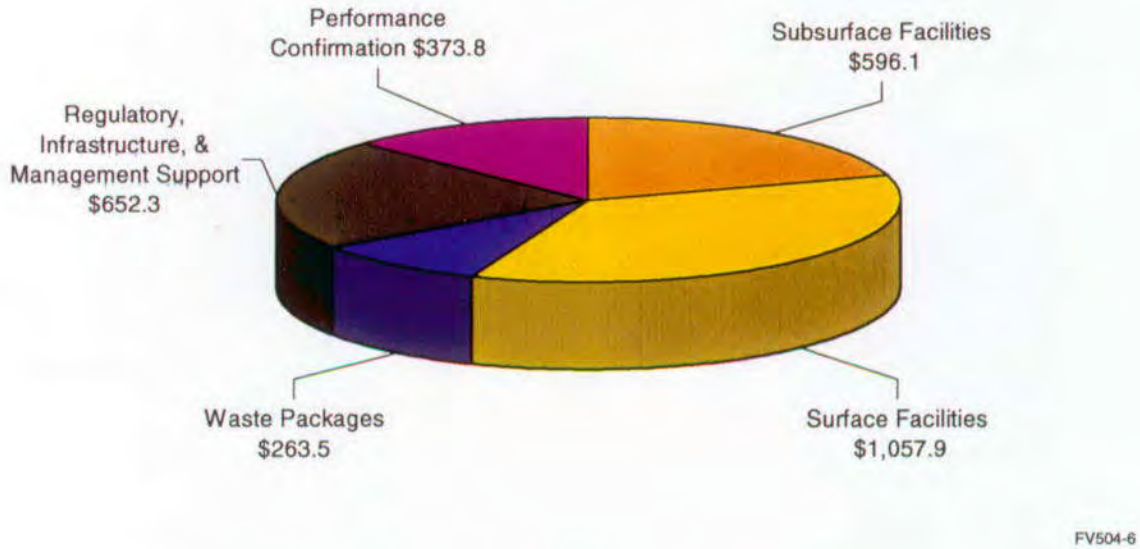

Figure 4-6. Contingency Distribution by Cost Element (1998 $ in Millions)

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5. REFERENCES

The numbers at the end of each reference are Office of Civilian Radioactive Waste Management document accession numbers. See the inside front cover of this document for whom to contact regarding more information.

5.1 DOCUMENTS CITED

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DOE (U.S. Department of Energy) 1998a. *Independent Cost Assessment Summary Report, Mined Geologic Repository Viability Assessment*. Washington, D.C.: DOE Field Management Division FM-20. 238625.

DOE 1998b. *Quality Assurance Requirements and Description for the Civilian Radioactive Waste Management Program*. DOE/RW-0333P, Rev. 08. Las Vegas, Nevada: DOE Yucca Mountain Site Characterization Office. MOL.19980601.0022.

DOE 1998c. *Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program*. DOE/RW-0510. Washington, D.C.: DOE Office of Civilian Radioactive Waste Management. HQO.19980901.0001.

Means, R.S. 1998. *Heavy Construction Cost Data*. 12th Annual Ed. Kingston, Massachusetts: RS Means, Inc., Publishers. 104089.

5.2 STANDARDS AND REGULATIONS

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48 CFR (*Code of Federal Regulations*) 915. Federal Acquisition Regulations System: Contracting by Negotiation. 238615.

48 CFR 970. Federal Acquisition Regulations System: DOE Management and Operating Contracts. 238616.

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DOE Order 6430.1A, Section 1630-1.1. General Design Criteria, Load Requirements. 226693.

Energy and Water Development Appropriations Act, 1997. Public Law 104-206, 104th Congress. 238115.

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National Environmental Policy Act of 1969. 42 U.S.C. § 4321. 222754.

Nuclear Waste Policy Act of 1982. 42 U.S.C. §10101 et seq. 211264.

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APPENDIX A

GLOSSARY

APPENDIX A

GLOSSARY

Many of the definitions in this glossary are Yucca Mountain Site Characterization Project specific.

Alcoves	Small excavations (rooms) off the main tunnel of a repository, which are used for scientific study or for installing equipment.
Assembly Transfer System	System in the Waste Handling Building to transfer uncanistered spent nuclear fuel assemblies from the shipping casks to disposal containers.
Autotransformer	An electronic component used to transfer electric energy.
Backfill	(1) The general fill that is placed in the excavated areas of the underground facility. Backfill for the repository will be tuff. (2) The material or process used to refill an excavation.
Batch Plant	A facility where the components of concrete are mixed.
Biota	The animal and plant life in the region of the proposed repository.
Bottom-Up Estimating Method	A method of estimating characterized by a thorough detailed analysis of all tasks, components, processes, and assemblies. Costing for each task, subtask, step, and function is required to accomplish an operation or produce a deliverable. The quantities and unit prices associated with labor, material, equipment, and overhead for each task, subtask, step, or function are then extended to arrive at a total price.
Canister Transfer System	System in the Waste Handling Building to transfer canisters containing radioactive waste from the shipping casks to the disposal containers.
Capital Costs	The cost of equipment, materials, labor, and other expenses required to construct and decommission the repository.
Carrier/Cask Handling System	System in the Waste Handling Building that unloads the casks from the carriers and transfers the casks to either the assembly transfer system or the canister transfer system. The system also receives empty casks from the assembly and canister transfer systems and nondisposable canister overpacks from the assembly transfer system, and loads them onto carriers for transfer to the Carrier Preparation Building.
Contractor's Bond	A financial guarantee purchased by a contractor from a third party to assure contractor performance.
Coupled Processes	Interacting thermal, hydrologic, mechanical, chemical, and biological processes.
Craft Labor	Workers possessing certain manual or mechanical skills.

CRWMS (Civilian Radioactive Waste Management System)	The composite of the sites and all facilities, systems, equipment, materials, information, activities, and personnel required to perform those activities necessary to manage radioactive waste disposal.
Decommission	To remove from service a facility in which nuclear materials are handled. This usually involves decontaminating said facility so that it may be dismantled or dedicated to other purposes.
Decontamination	A process that removes, destroys, or neutralizes chemical, biological, or radiological contamination from a person, object, or area.
Disposal Container	The vessel consisting of the barrier materials and internal components in which the canistered or uncanistered waste form is placed. The filled, sealed, and tested disposal container is referred to as the waste package.
Disposal Container Handling System	System in the Waste Handling Building that prepares empty disposal containers for loading, receives full disposal containers from the assembly and canister transfer systems, welds and inspects the containers, and transfers them to the waste emplacement system. The system also receives and handles retrieved waste packages from the subsurface and disposal containers that are defective, and routes them to the waste package remediation system.
Drift	From mining terminology, a horizontal underground passage. The nearly horizontal underground passageways from the shaft(s) to the alcoves and rooms. Includes excavations for emplacement (emplacement drifts) and access (access mains).
Drip Shield	A sheet of impermeable material placed above the waste package to prevent seepage water from directly contacting the waste packages.
Dual-Purpose Canister	A containment vessel specially designed to store and transport commercial spent nuclear fuel.
Elastic Modulus	The ratio of the stress in a body to the corresponding strain.
Emplacement	The placement and positioning of canisters of spent nuclear fuel or high-level radioactive waste in prepared positions within a repository.
Engineered Barrier System	The waste packages and the underground facility. These are the human-designed, or engineered, components of the disposal system and the waste package.
Expert Opinion Method	An estimating method of gathering experts in areas such as engineering, manufacturing, procurement, and testing to "brainstorm" estimates. Estimating by expert opinion is usually used only on a new concept with little or no definition and is marked by decisions based solely on individual judgment and similar experience.

Exploratory Studies Facility	An underground laboratory at Yucca Mountain that includes a 7.9-km (4.9-mile) main loop (tunnel), a 2.8-km (1.75-mile) cross drift, and a research alcove system constructed for performing underground studies during site characterization. The data collected will contribute toward determining the suitability of the Yucca Mountain site as a repository, and some or all of the facility eventually will be incorporated into the proposed repository.
Gantry	A movable crane carried on a four-legged portal frame that runs along rails.
Geochemistry	The study of the abundance of the elements and atomic species (isotopes) in the earth. Geochemistry, or geochemical study, looks at systems related to chemicals arising from natural rock, soil, soil processes such as microbe activity, and gases, especially as they interact with man-made materials from the repository system. In the broad sense, all parts of geology that involve chemical changes.
Geophysical Logging	Continuous recording versus depth of a characteristic of the formations penetrated by a drillhole.
Graveyard Shift	Late-night work shift generally starting at midnight and ending at 8 a.m.
Historical Estimating Method	Estimates using this method are based on documented historical resources, data, and information. The historical data source that supports the estimate, such as actual resource usage from a previous estimate, is identified in the item description. The estimate is then compared to any stated changes in design or operating conditions, and uses adjustment factors to account for complexity, technical or physical differences.
Hydrology	(1) The study of water characteristics, especially the movement of water. (2) The study of water, involving aspects of geology, oceanography, and meteorology.
In Situ	In its natural position or place. The phrase distinguishes in-place experiments, conducted in the field or underground facility, from those conducted in the laboratory.
In-Fillings	Material that separates the adjacent rock walls of a discontinuity and may be weaker than the parent rock.
Infiltration	The process of water entering the soil at the ground surface and the ensuing movement downward when the water input at the soil surface is adequate. Infiltration becomes percolation when water has moved below the depth at which it can be removed (to return to the atmosphere) by evaporation or evapotranspiration.

Lagging	Steel structures erected to prevent cave-ins inside the emplacement drifts.
Lateral Extent	The range or distance over which the stratigraphic unit extends to the side.
Low-Level Radioactive Waste	Radioactive waste that is not classified as high-level radioactive waste, transuranic waste, or byproduct tailings containing uranium or thorium from processed ore. Usually generated by hospitals, research laboratories, and certain industries.
Mineralogy	The science of minerals that deals with their crystallography and their physical and chemical properties in general, their classification, and the ways of finding and distinguishing them.
Muck	Material excavated from a mine or geologic repository.
N Stamp	A certification granted by the American Society of Mechanical Engineers (ASME) that a structure meets all applicable ASME requirements.
Near-Field	The region where the adjacent natural geohydrologic system has been significantly impacted by the excavation of the repository and the emplacement of waste.
Operations and Maintenance Costs	The costs to operate the repository and perform maintenance as needed.
Overcoring	The drilling of a relatively larger diameter core, encompassing a pre-existing, smaller diameter.
Out Years	Government fiscal years beyond the current year for which expenditures are being planned.
Overcoring	The drilling of a relatively larger diameter core, encompassing a pre-existing, smaller diameter hole.
Overhead	Those general charges or expenses that do not belong exclusively to any particular part of the work (taxes, insurance, lighting, accounting and other office expenses, depreciation, etc.).
Panel	A piece of steel bolted onto steel sets to keep rock from falling into the emplacement drifts.
Parametric Estimate	Estimating method using statistical relationships between historical costs and other program variables such as system physical or performance characteristics, contractor output measures, and manpower loading.
Percolation Flux	Volumetric percolation rate per unit area. The flux that passes below the root zone of plants and is no longer susceptible to removal back into the atmosphere by evapotranspiration.

Piezometer	An instrument for measuring pressure.
Precast Yard	Area where the precast concrete products, such as lining segments and inverts, are fabricated and stored until they are placed into service.
Psychrometer	A type of thermometer whose bulb is covered with a cotton wick saturated in water used to measure the dryness of the surrounding air. A wet bulb thermometer.
"Q" Drawing	A detailed drawing that meets certain YMP quality assurance requirements (DOE 1998b).
Radiologically Controlled Area	An area of the surface repository enclosed by security fences, control gates, lighting, and detection systems. This area includes the facilities and transportation systems required to receive and ship rail and truck waste shipments, prepare shipping casks for handling, and load waste forms into disposal containers for underground emplacement. It also includes the facility and systems required to treat and package site-generated, low-level radioactive waste for offsite disposal.
Radionuclide	Radioactive type of atom with an unstable nucleus that spontaneously decays, usually emitting ionizing radiation in the process. Radioactive elements characterized by their atomic mass and number.
Remediation	Action taken to permanently remedy a release or threatened release of a hazardous substance into the environment, instead of or in addition to removal. To prevent or minimize the release of hazardous substances so that they do not migrate to cause substantial danger to present or future public health or welfare or the environment.
Repository Horizon	The near horizontal plane within the host rock where the location of the proposed repository is planned.
RIMS	Regulatory, Infrastructure, and Management Support.
Roadheader	An underground excavating machine that uses either a transverse or in-line cutter head for specialty excavations, such as small chambers, when specially shaped openings that cannot be dug by the tunnel-boring machine are required.
Rough-Order-of-Magnitude	This type of estimate is prepared to furnish an idea of the cost of a unit, system, plant, or facility. Often used for broad-brush screening, sifting, and selection of concepts that precede deeper interest in a particular project. Usually, these estimates use the information available from cost references, cost factors, cost index ratios, and generalized percentages.

Roundtable Cost Estimate	A cost estimate created from the interaction of functional experts on a given project. Representatives of functional areas, such as engineering, environmental, manufacturing, purchasing, contracts, etc., may be brought together to develop project costs based on experience and knowledge of market conditions. The estimate developed by this approach is usually completed in the absence of detailed drawings or bills of material and with very limited information concerning specifications.
Saturated Zone	The region below the water table where rock pores and fractures are completely saturated with groundwater.
Sensitivity Analysis	An analytic or numerical technique for examining the effects of varying specified parameters when a model run is performed. A sensitivity study shows the effects that changes in parameters have on model outcomes and can illustrate which parameters have a greater impact on the predicted behavior of the system being modeled. Also called sensitivity analysis because it shows the sensitivity of the consequences (such as radionuclide release) to uncertain parameters (such as infiltration rate that results from precipitation).
Shrink Fit	Method of assembly of waste packages in which the outer barrier is heated to expand so that the inner barrier can be slid into it. The outer barrier is then cooled so that it shrinks to fit tightly over the inner barrier.
Site Characterization	Activities, whether in the laboratory or in the field, undertaken to establish the geologic conditions and the ranges of the parameters of a candidate site relevant to the location of a repository. These activities include borings, surface excavations, excavations of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing needed to evaluate the suitability of a candidate site for the location of a repository, but do not include preliminary borings and geophysical testing needed to assess whether site characterization should be undertaken.
Stakeholder	An individual or organization having an important, ongoing interest in the service and service quality of the Office of Civilian Radioactive Waste Management.
Standard Industry Practice	This practice is based on estimating using published or well-accepted standards and price guides. The estimator references the title, publication date, and table or page number of the estimating handbook or guide. Adjustments for location, quantity, productivity, job conditions, or other project conditions or requirements may be made, if documented.
Steel Set	A curved steel beam or rib used for ground support in the Main Drift and some of the emplacement drifts.

Stratigraphy	The branch of geology that deals with the definition and interpretation of rock strata, the conditions of their formation, character, arrangement, sequence, age, distribution, and especially their correlation by the use of fossils and other means of identification.
Subsistence Allowance	Money given to a workman at a remote location as compensation for additional transportation expenses.
Swing Shift	Work shift that generally starts at 4 p.m. and ends at midnight.
Tectonics	Geologic forms or effects created by deformation of the earth's crust. Earthquakes not caused by volcanic activity or gravity initiated movements such as landslides.
Unsaturated Zone	The zone of soil or rock below the ground surface and above the water table in which the pore spaces contain water, air, and other gases. Also called the vadose zone.
Vendor Quote/Catalog Estimate	This type of estimate is based on a bid, quotation, catalog item, or purchase order from one or more vendors. When the item is a quotation, the estimate cites the source and date of the quotation and whether it is a competitive or single-source bid. When the item is from a catalog, the estimate cites the source catalog's name and date and the item reference. When the quote or catalog is not current, the text cites the escalation factor used to adjust for present value.
Viscosity	The flow resistance of a material such as the plug material used in the performance confirmation program.
Waste Package	A loaded, sealed, and tested disposal container.
Witness Specimen	Test specimens placed alongside the test subject (such as a waste package) so that they will witness the same conditions as the test subject. The specimens will be removed for analysis to evaluate the performance of the test subject.
Work Packages	A collection of cost elements assembled into a task that can be accomplished by a given trade.

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APPENDIX B

SURFACE FACILITIES

APPENDIX B

SURFACE FACILITIES

This appendix presents the cost estimate for construction, operation, and decommissioning of surface facilities at the repository. The cost estimate is based on the VA reference design presented in Volume 2, Section 4.1.

For each cost element defined in Section 1.1 of Volume 5, this appendix defines the scope on a summary level, identifies the methodologies used to develop the cost estimate as well as the assumptions on which the estimate is based, and presents summary results.

The summary results are presented as tables and figures that show estimates by cost element and project phase. In addition, annual cost distributions, as well as capital, operating, and maintenance costs, are provided (see Section B.4).

The scope for the Surface Facilities cost elements includes the following major elements: Field Costs, Startup and Training Costs, Emplacement Activities, Monitoring Activities, Decommissioning, Design, and Offsite Power. None of these cost elements includes the following items. The Monitored Geologic Repository-VA cost estimates that cover these costs are shown in parentheses.

- Subsurface operations at the South Portal and shaft access areas (Subsurface)
- Environmental monitoring wells (Performance Confirmation)
- Offsite facilities and design support: systems engineering, technical publications, regulatory compliance, project management and controls, project engineering, environmental programs, information resources management, and facilities services (Regulatory, Infrastructure, and Management Support)
- Waste package fabrication (Waste Package)
- Offsite transportation, land acquisition, institutional benefits, Nevada Test Site infrastructure, and quality assurance support (Total System Life Cycle Cost)

B.1 SCOPE OF MAJOR COST ELEMENTS

B.1.1 Field Costs

This element includes all costs to prepare the site and construct surface facilities at the North Portal operations area, which includes major facilities for receiving, handling, and packaging waste for emplacement in the repository. The element also includes construction of sitewide systems such as roads and water supply. Costs include direct field costs, such as direct labor, materials, equipment costs and subcontract costs; and indirect field costs, such as equipment rental, contractor overhead and profit, insurance, temporary construction, worker transportation, subsistence expenses, and subcontract fees. Construction management cost is included in the Design cost element, while construction costs associated with the offsite power and communications are included in the Offsite Power cost element.

Field Costs are broken out into the subelements described in sections that follow.

B.1.1.1 Site Preparation and Transportation

This includes demolition and/or upgrading of nonpermanent structures that are part of the Exploratory Studies Facility; site grading; and construction of onsite rail systems, roads, paving, parking facilities, and flood control systems (e.g., bridges and culverts). The site will cover approximately 100 acres (North Portal operations area) and will include about 27,000 lin ft of rail lines and 65,000 lin ft of roads.

B.1.1.2 Site Support Systems

This includes construction of the systems that support the entire site: the sewage system near the South Portal; water systems (e.g., well, fire, potable, cooling, chilled, hot, and deionized); electrical power systems; cabling to support monitoring, control, and communication; security fencing systems; environmental monitoring equipment; and fuel-oil supply. Costs for the portions of the sys-

tems that extend into the facilities are included with those facilities.

B.1.1.3 Waste Handling Structures

This includes construction costs for buildings within the radiologically controlled area and the systems and components located within them:

- Waste Handling Building. This multistory, 460,000-ft^2 building provides the structure, controlled areas, and access required to house and operate waste handling systems, protect personnel, and maintain radiological confinement. The Waste Handling Building facility areas house the following:
  - Primary waste handling systems: carrier/cask handling system, assembly transfer system, canister transfer system, disposal container handling system, and waste package remediation system
  - Primary support areas: waste handling operations center, contaminated equipment transfer and maintenance, decontamination, low-level radioactive waste management, operating galleries, local material storage
  - Pool support areas
  - Facility support areas: radiation protection, security access, laboratories, change facilities, administration, and uncontaminated equipment maintenance
  - Heating, ventilation, and air conditioning equipment areas
  - Building support areas: rooms for fire protection, electrical, and communication equipment
- Waste Treatment Building. This 80,000-ft^2 building houses the radiological waste handling system that collects and prepares for disposition low-level radioactive waste generated onsite.
- Carrier Preparation Building. This 20,000-ft^2 building houses the material handling system required to prepare incoming carrier and cask configurations for unloading at the Waste Handling Building and for offsite shipment. At this facility, shipping cask impact limiters and personnel radiation shields are removed or installed.
- Transporter Maintenance Building. This building houses equipment and tools necessary to maintain the waste package transporters.
- North Portal Airlock Building. This building covers the North Portal area and maintains the air pressure on the emplacement side below atmospheric pressure for radiological control in the unlikely event of a radiological discharge during the Emplacement Operations Phase.

B.1.1.4 North Portal Support Structures (Balance of Plant)

This includes construction costs for the following buildings in the North Portal operations area outside the radiologically controlled area, and the systems and components located within them: administration facilities, security stations, medical center, fire station, central warehouse, central shops, motor pool, mockup building, utility building, and visitor center. These structures have a combined floor area of about 200,000 ft^2.

B.1.2 Startup and Training

This element includes all costs to activate and start up the surface facilities at the North Portal operations area and sitewide systems such as water supply and environmental monitoring. Startup and Training includes the costs for hiring and training operations staff, inspecting construction, conducting operational readiness reviews, and integration testing.

These costs are incurred until the surface facilities and systems have ramped up to full capacity, which is defined as waste acceptance at the rate of

3,000 MTHM/year. During the startup period, approximately 1,000 employees would receive more than a million hours of training.

B.1.3 Emplacement Activities

This element includes all costs to operate and maintain the surface facilities at the North Portal operations area and the sitewide systems such as roads, water supply, and environmental monitoring. Emplacement Activities costs include operations and maintenance labor; utilities; replacement of maintenance materials and equipment; offsite services (disposal of low-level radioactive waste generated onsite, dual-purpose container dispositioning, employee transportation); and consumables such as low-level radioactive waste packaging materials, chemicals, inert gases (nitrogen and helium), office supplies, and janitorial supplies.

This element covers labor hours for all repository staff working in or dispatched from the North Portal operations area surface facilities. This includes waste handling operations personnel and support personnel (e.g., administration, training, security, logistics, environmental protection, computer services, food services, and motor pool and visitor center operations). This element does not include subsurface emplacement operations staff that may be dispatched from the surface facilities.

B.1.4 Monitoring Activities

This element covers the cost of the following surface facility activities at the North Portal Operations area: supporting operations and maintenance associated with the performance confirmation program, decontaminating and mothballing the facilities, and maintaining security at the site.

Initial monitoring operations are expected to include decontamination of surface nuclear facilities, lock-down of facilities, and shutdown and preservation of electrical, mechanical, and hydraulic systems. Decontamination will take approximately 3.5 years and will entail decontaminating about 160,000 ft^2 of operations area. The balance of the monitoring phase requires only minimal operations and a small support staff of about 70.

Monitoring Activities costs include labor for operations and maintenance, utilities (power and liquid fuels), maintenance materials, offsite services (e.g., low-level radioactive waste disposal and employee transportation), and consumables (e.g., low-level radioactive waste packaging materials, chemicals, process gases, office supplies, and janitorial supplies). This element includes labor costs for all repository support staff working in or dispatched from the North Portal operations area surface facilities (e.g., administration, security, fire protection, minor maintenance, utility operations, and computer services).

B.1.5 Decommissioning Activities

This element includes all costs to permanently decommission and dismantle the surface facilities at the North Portal operations area; return the site to a more natural condition, if required; dispose of the resulting debris; and erect barriers to human intrusion. Final decontamination of the facilities within the radiologically controlled area includes scraping concrete, removing steel linings and contaminated equipment, and by demolition.

B.1.6 Design

This element includes all costs for engineering, design, and inspection from submittal of the LA in 2002 through completion of the surface facilities construction in 2008. It also includes construction management and the balance of the procurement.

The element does not include the costs for quality assurance, technical publications, regulatory (licensing), project management, project engineering, environmental programs, information resources management, and facilities services. These costs are included in the Regulatory, Infrastructure, and Management Support cost estimate (see Appendix F) except for quality assurance, which is in the Total System Life Cycle Cost estimate.

B.1.7 Offsite Power

This element includes all costs to build a 230-kV line from the Northwest Switching Station to Jackass Flats Substation; it is anticipated that a new 230-kV switchyard adjacent to Jackass Flats Substation will be constructed. A 230-kV line from Pahrump Substation to Lathrop Wells Substation will be built, including a 230-kV loop from Lathrop Wells Substation to the repository, and from the repository to Jackass Flats Substation. Line voltage will be upgraded to 230-kV from Pecos Substation to the Northwest Switching station. This arrangement will serve the repository directly from the public utilities and be entirely independent of the Nevada Test Site.

Such an arrangement will provide an independent 230-kV system with firm capacity in excess of that which may be needed. The system will not require an autotransformer. The repository would be completely independent of the Nevada Test Site and would have the most reliable system, using mostly new equipment and introducing no autotransformer to reduce the reliability.

B.2 ESTIMATING METHODOLOGIES

Estimating methodologies used for each Surface Facilities cost element are explained in sections that follow, and the methodology used to establish contingency rates is summarized.

B.2.1 Field Costs

This estimate is structured into construction accounts for site and architectural work, including costs for concrete, steel, equipment, piping, electrical, paint, insulation, and systems for control and communications.

Labor, material, equipment purchase, and subcontractor costs are direct field costs. Direct labor hours and direct cost for materials and equipment were estimated separately. Productivity factors and crew sizes were established based on commercially available cost information and from general knowledge of project estimators and engineers. The labor cost was estimated using the labor rates and foreman-to-worker ratios from existing Nevada Test Site labor agreements.

Indirect costs were added to the direct field costs. Indirect costs include contractors' overhead, profit equipment rentals, bonding, temporary construction, bus transportation. and subsistence allowance. These indirect costs were based upon experience derived from prior similar projects and were expressed as a percentage of the direct costs.

The estimating methodology for the Waste Handling and Waste Treatment Buildings was as follows:

- The main components were estimated by creating material lists from the design drawings and related documents. The quantities for some of the smaller components, such as piping and instrumentation, were parametrically estimated based on the main components of the building.

- The prices for materials and equipment, such as concrete and bridge cranes, were taken from commercially available cost databases and historical cost data available to YMP. The prices for some specialty equipment were obtained from vendor telephone quotes.

- The use of subcontractors was assumed for the specialty components of this building, principally for the instrument and control systems.

Field Costs for remaining facilities, such as the Carrier Preparation Building, administration building, fire station, utility building, and security stations, were estimated on the basis of the square footages of these buildings. Unit construction costs were taken from Means and other sources (Means 1998). Costs for some specialty equipment were estimated separately and added as appropriate.

B.2.2 Startup and Training

The following methodologies were used to estimate these costs:

- Labor costs for training were determined by estimating the hours of student and instructor time required multiplied by average labor rates. Student hours were estimated from staffing projections and the number of hours of training time per student for a dozen different training categories. Instructor hours were a percentage of the total student hours.

- The labor costs to develop plans and procedures were determined by estimating the number of systems requiring plans and procedures and the development hours required per system, multiplied by average labor rates.

- The cost for vehicles was established from a price list.

- The cost for furnishings was estimated from a price list for a workstation and the number of workstations.

- The spare parts cost was estimated as a percentage of the annual maintenance materials cost during emplacement operations.

- The cost for operating supplies was estimated as a percentage of the labor costs.

- Maintenance material costs were estimated as percentages of the direct field cost construction account without contingency and excluding site preparation work.

- Utility costs were based on estimates of power and fuel-oil usage and unit rates.

B.2.3 Emplacement Activities

The following methodologies were used to estimate these costs:

- The labor costs were estimated by developing a conceptual staffing plan, which includes about 200 specific jobs, broken down by building and function. The staffing plan applied to steady-state operations and reflected the business practices associated with nuclear operations (i.e., productive hours are reduced due to changing clothes, training, and equipment downtime). The number of full-time-equivalent employees was estimated from the staffing plan by assuming job coverage is needed when vital employees are unavailable due to vacations, sick days, or training. Average labor rates were then applied to each labor category to calculate the labor cost per year.

- The labor cost variations that will occur over the emplacement phase were reflected in the estimate. This was done by developing an algorithm that related annual cask-receipt quantities to the number of waste handling workers and, indirectly, the level of support staff. This resulted in an average emplacement staffing level that was 92 percent of the peak-year staffing level.

B.2.4 Monitoring Activities

Monitoring Activities was divided into two time periods, decontamination and standby. The following methodologies were used to estimate these costs:

- Decontamination costs, incurred immediately following the Emplacement Operations Phase, represent about a third of the total monitoring operations costs. The annual costs for labor, utilities, and employee transportation were estimated as a percentage of the costs during an average year of the phase. This yearly cost was multiplied by 3.5 to reach the total for the full 3.5-year decontamination effort.

- Standby costs represent the other two-thirds of the monitoring operations costs and were estimated based on a conceptual staffing plan using average labor rates. This cost was multiplied by the number of years in the standby period to reach the total labor estimate for the entire period. The costs for consumables and employee transportation were estimated as a percentage of the labor costs during this period; the costs for maintenance materials and utilities were estimated as a percentage of their annual costs during emplacement.

B.2.5 Decommissioning Activities

The following methodologies were used to estimate these costs:

- Costs for final decontamination and removal of surface facilities were estimated as a percentage of the construction cost, with a higher percentage used for the facilities in the radiologically controlled area.

- The cost of the permanent barriers was estimated using the quantity of materials taken from conceptual design figures; prices for materials and labor hours were taken from existing cost databases; productivity factors and crew sizes were established; labor costs were estimated and applied; and indirect costs were added as a percentage of the direct costs.

B.2.6 Design

The following methodologies were used to estimate these costs:

- Total engineering design and construction inspection costs were estimated as a percentage of Field Costs, with the percentage varying by complexity of the construction.

- Construction management costs were estimated as a percentage of Field Costs.

B.2.7 Offsite Power

The estimating methodologies used to develop the offsite power estimate were the expert opinion and parametric method.

B.2.8 Contingency Rates

A contingency rate was calculated for each cost element from data provided by project engineers and estimators. The engineers considered how the magnitude of the design (e.g., structures, systems, components, staffing, and utility rates) could reasonably change from the current basis. Their consensus was expressed as a percentage increase or decrease from the reference design confidence levels.

The cost estimators also considered how sensitive each element would be to changes in the selection of estimating methodologies, assumptions, and cost data. Their consensus was also expressed as a percentage increase or decrease from the base estimate (i.e., without contingency).

As a result, the following contingency factors were developed for each elements:

Cost Element	Contingency
Field Costs	34 percent
Startup and Training	20 percent
Emplacement Activities	14 percent
Monitoring Activities	42 percent
Decommissioning	33 percent
Design	23 percent

B.3 COST ESTIMATING ASSUMPTIONS

The assumptions used as a basis for the surface facilities cost estimates are presented in the sections that follow.

B.3.1 General

Following are general assumptions:

- All costs are reported in constant 1998 dollars, that is, future costs do not include escalation.

- Employee transportation costs are based on $550/day per bus, 47 full-time employees per bus, and 240 trips to the site annually.

- Construction staff working swing and graveyard shifts work 7 hours a day and are paid for 8 hours.

- Labor rates for operations are fully burdened and include the gross salary to the employee plus all other costs to the employer (e.g., contribution to Social Security, unemployment insurance, comprehensive general liability, workers compensation, state unemployment insurance, subsistence allowance, and costs arising from the employer's benefit package).

- Operations staff work 1,840 hours annually, including training hours. All employees require 8 hours of general employee training. Nuclear workers annually require an additional 112 hours of training, and any staff that perform safety functions require an additional 32 hours of training.

- Operations staff working the swing and graveyard shifts are paid 6 and 12.5 percent more than day shift workers, respectively.

- The cost of operating supplies is 8 percent of the operations and labor cost and includes materials such as decontamination and water-treating chemicals, inerting gases, offices supplies, and janitorial supplies.

- Annual maintenance materials costs are estimated as percentages of the nonlabor portion of the direct field costs without contingency (i.e., equipment, materials, and half the subcontract costs). The percentages, by construction account, are as follows: 14 percent for site vehicles, 8.5 percent for Waste Handling Building equipment, 5 percent for control systems and paint, 3.5 percent for non-Waste Handling Building equipment, 1.5 percent for architectural, and 1 percent for piping, electrical, and insulation. Maintenance materials costs are not included for the site preparation work and concrete accounts.

- The cost of purchased utilities is as follows: $0.07/kWh for electrical power; $1.31/gal for fuel oil or gasoline. Water will be supplied from onsite wells.

B.3.2 Field Costs (Construction)

Following are Field Cost assumptions:

- Construction and startup will be completed in 5 years, beginning March 1, 2005. Construction of all facilities will be completed 14 months before emplacement.

- Construction labor rates are based on craft rate data from the Nevada Test Site's 1997–2002 labor agreements.

- Construction crews consist of one foreman and five craft workers; 75 percent of the foreman's hours are spent on direct construction activities with the balance on supervision.

- Indirect field cost is estimated from direct field cost data (i.e., costs for labor, materials, equipment, and subcontracts), as the sum of the following:

  - Equipment rental at $3.44 per field labor man-hour

  - Construction contractor's overhead at 25 percent of direct field cost, less subcontract costs, plus equipment rental

  - Subcontractors' fee at 5 percent of the subcontract cost

  - Construction contractor's profit at 5 percent of the sum of direct field cost, equipment rental, contractor's overhead, and subcontractor's fee, less subcontract costs

- Construction contractor's bond at 2 percent of the sum of the direct field cost, equipment rental, contractor's overhead, subcontractor's fee, and contractor's profit

- Temporary construction at 1 percent of direct field cost

- All permanent equipment is purchased by the contractor and therefore subject to the contractor's overhead, profit, and bond; no equipment is furnished by DOE.

B.3.3 Startup and Training

Following are assumptions for Startup and Training:

- Startup begins 3.4 years before the end of construction with the writing of plans and procedures. Startup continues until December 1, 2014, when surface facilities and systems have ramped up to a full emplacement rate of 3,000 MTHM of commercial spent nuclear fuel and up to 700 canisters of other waste.

- All new staff require training before performing work responsibilities. The average months of training required are shown here. The instructor-to-student ratio averages about 20 to 1.

  - Nineteen months for operators handling waste or performing maintenance on fuel-handling pools or in transfer cells

  - Fifteen months for operators conducting waste treatment, operating cranes, or having significant safety oversight responsibility

  - Six months for utility system operators

  - Five months for cask handlers or personnel performing security, fire protection, or medical response functions

  - Four months for rail and truck-carrier handlers and maintenance personnel for non-radioactive systems

  - One and one-half months for general support personnel within the radiologically controlled area

  - One month for general support personnel outside the radiologically controlled area

- The cost to develop training plans and operations, maintenance, and test procedures is estimated as an average of 750 man-hours per system or subsystem. The number of systems and subsystems identified for the surface facilities is 166.

- The number of man-years required to operate the surface facilities after construction and before emplacement is approximately half the number of full-time-equivalent employees required at the beginning of emplacement.

- The cost of the initial spare parts is estimated as 50 percent of the maintenance materials cost for an average emplacement year.

- Relocation costs for new hires averages $5,000 per full-time-equivalent.

- Total utility costs required to operate the surface facilities after construction and before emplacement is estimated as two times the utility costs incurred during an emplacement year.

B.3.4 Emplacement Activities

Following are assumptions for Emplacement Activities:

- Emplacement operations span 23.6 years, beginning March 2, 2010, ramping up to full capacity by December 1, 2014, and ending September 30, 2033.

- Waste handling, security, and associated support operations are planned for three

shifts per day, 7 days per week. Other operations are planned for a single shift and 5 days per week.

- Annual maintenance materials costs are estimated as percentages of the nonlabor portion of the direct field costs without contingency (i.e., equipment, materials, and half the subcontract costs). The percentages, by construction account, are as follows: 14 percent for site vehicles, 8.5 percent for Waste Handling Building equipment, 5 percent for control systems and paint, 3.5 percent for non-Waste Handling Building equipment, 1.5 percent for architectural, and 1 percent for piping, electrical, and insulation. Maintenance materials costs are not included for the site preparation work and concrete accounts.

- The transportation and disposal cost for low-level radioactive waste generated in the course of operations is $10.50/ft^3, a figure expected to be consistent with disposal cost at the Nevada Test Site. The cost for the materials needed to perform onsite packaging of low-level radioactive waste (e.g., drums and cement) averages $25/ft^3 of low-level radioactive waste.

- Transportation and disposal/recycle of empty dual-purpose canisters averages $5,000 per canister.

B.3.5 Monitoring Activities

Following are assumptions for Monitoring Activities:

- Monitoring operations span about 76 years, beginning October 2034 and ending February 2110. The capability to retrieve the emplaced waste is maintained for 100 years following the start of emplacement.

- During the Monitoring Phase, surface facilities are decontaminated; then, all operations cease, except for security, fire protection, and minor support for performance-confirmation operations.

- After the Emplacement Operations Phase, facilities within the radiologically controlled area are thoroughly decontaminated and the systems are shut down. These operations take 3.5 years. The average annual cost during this period for labor, utilities, and employee transportation is estimated at 75 percent of the same costs during one emplacement year.

- Transportation and disposal costs for low-level radioactive waste generated during the decontamination period are $10.50/ft^3. The cost for the materials needed to perform onsite packaging of this waste (e.g., drums and cement) averages $25/ft^3 of waste.

- Annual utility costs during the standby period are estimated as 5 percent of the utility costs incurred during an emplacement year.

- Annual maintenance materials costs are estimated as percentages of the same costs during an emplacement year, 10 percent for the decontamination period, and 1 percent for the monitoring period.

B.3.6 Decommissioning Activities

Following are assumptions for Decommissioning Activities:

- Decommissioning begins 100 years after the start of emplacement operations and is completed in 6 years.

- The total cost of decommissioning and site reclamation is 15 percent of the construction cost, without contingency, for facilities within the radiologically controlled area and 10 percent for other facilities. This includes design planning activities as well as field activities. Additional costs are included for design and construction of barriers to human intrusion.

- Cost estimates for erecting the barriers use assumptions similar to those used to estimate costs for Field Costs and Design.

B.3.7 Design

Following are Design assumptions:

- Design activities continue from fiscal year 1998 through the construction period, up to January 1, 2009. Costs incurred before March 2002 are addressed in Volume 4.

- Construction management costs are estimated as 8 percent of total direct and indirect field costs, without contingency.

- Engineering design and construction inspection costs cover design to support the VA, the site recommendation, and the LA; procurement and construction design; and design support for construction. Total engineering design and inspection costs, estimated as a percentage of total field costs, without contingency, are 19 percent for the Waste Treatment Building, 23 percent for the balance of Waste Handling Structures, 15 percent for conventional support facilities, and 17 percent for nonconventional support facilities.

- Design costs to support construction estimated as a percentage of total Field Costs, without contingency, are 7.5 percent for facilities within the radiologically controlled area and 3.5 percent for other facilities.

B.3.8 Offsite Power

Following are assumptions for Offsite Power:

- Power will be purchased from an available offsite utility company rather than obtained from onsite generating stations.

- Electrical service quality and reliability will conform to IEEE 493 (IEEE 1990) to ensure that load requirements are met (DOE Order 6430.1A, Section 1630-1.1.

- An overall power factor of not less than 85 percent will be achieved.

- Surface electrical loads will remain relatively constant during the Emplacement Operations Phase.

- A loop-type system with firm capacity will be required to comply with present agreements with the public utilities. Firm capacity is defined as the amount of power that will be always available, even under abnormal conditions.

B.4 ESTIMATE SUMMARY

Costs to construct Surface Facilities during the Pre-Emplacement Construction Phase peak at approximately $370 million in 2006 as the Waste Handling Building, Waste Treatment Building, Carrier Preparation Building, and the balance-of-plant are constructed. Costs during the Emplacement Operations Phase remain relatively level at an average of approximately $140 million/year to support operations and maintenance of the surface facilities. Costs during the Monitoring Phase following decontamination remain level at approximately $7 million/year for security, fire protection, and support to performance confirmation. Finally, costs during the Closure and Decommissioning Phase peak at approximately $34 million in 2113 and then decrease as surface facilities are dismantled, the site is restored, and barriers to human intrusion are erected.

Table B-1 and Figures B-1a and B-1b show the Surface Facility cost summary. Table B-2 and Figure B-2 show the Surface Facility annual cost distribution. Table B-3 and Figure B-3 show Surface Facility capital and operating and maintenance costs. Dollar amounts are summary figures derived from detailed calculations. Some minor differences or variations in the figures may occur due to effects from computational rounding of the numbers.

Table B-1. Surface Facility Cost Summary
(1998 $ in Millions)

Phase	Phase Totals	Field Cost	Startup & Training	Emplacement Activities	Monitoring Activities	Decom-missioning Activities	Design	Offsite Utilities
Licensing	145.5	0.0	13.4	0.0	0.0	0.0	85.1	47.1
Pre-Emplacement Construction	1,179.5	960.3	104.1	0.0	0.0	0.0	110.3	4.9
Emplacement Operations	3,112.0	0.0	45.2	3,047.6	19.1	0.0	0.0	0.0
Monitoring	862.4	0.0	0.0	0.0	862.4	0.0	0.0	0.0
Closure and Decommissioning	129.3	0.0	0.0	0.0	0.0	129.3	0.0	0.0
Grand Total	**5,428.7**	**960.3**	**162.6**	**3,047.6**	**881.5**	**129.3**	**195.4**	**52.0**

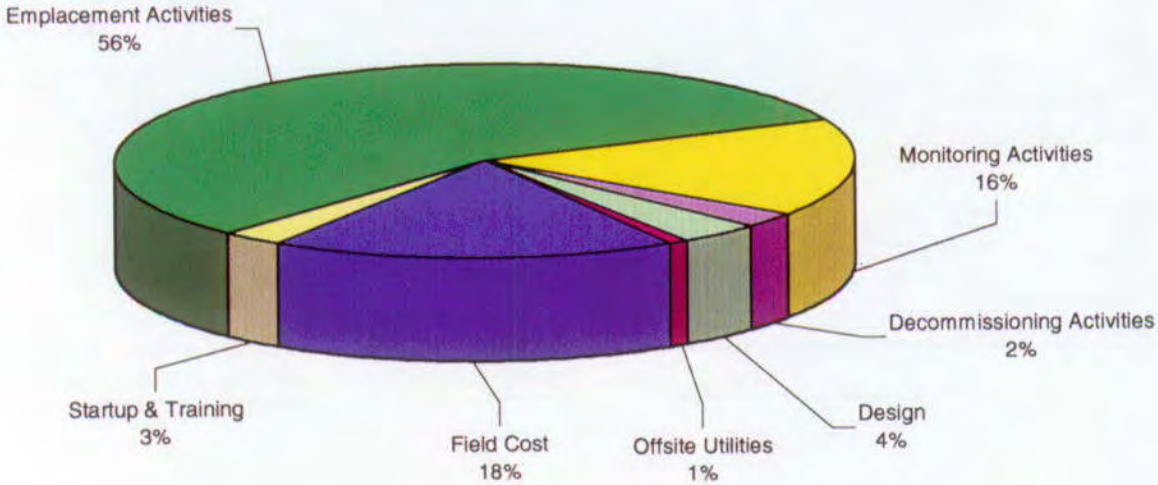

Figure B-1a. Surface Facility Percent of Total Cost by Cost Element

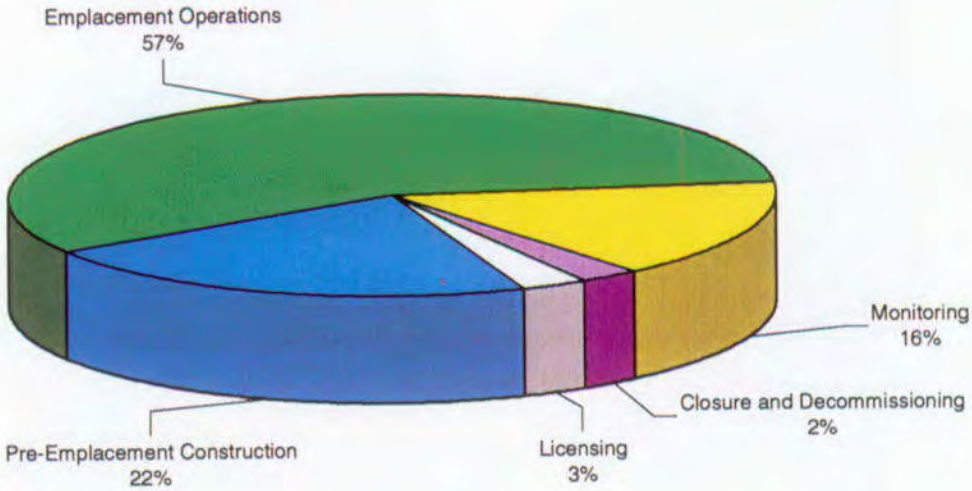

Figure B-1b. Surface Facility Percent of Total Cost by Phase

Table B-2. Surface Facility Annual Cost Distribution
(1998 $ in Millions)

Year	Yearly Totals	Field Cost	Startup & Training	Emplace-ment Activities	Monitoring Activities	Decom-missioning Activities	Design	Offsite Utilities
2002*	19.4	0.0	0.0	0.0	0.0	0.0	16.8	2.6
2003	67.4	0.0	6.7	0.0	0.0	0.0	37.3	23.4
2004	58.8	0.0	6.7	0.0	0.0	0.0	31.0	21.1
2005	229.4	187.0	9.2	0.0	0.0	0.0	28.3	4.9
2006	370.5	323.2	15.2	0.0	0.0	0.0	32.1	0.0
2007	317.9	268.7	25.1	0.0	0.0	0.0	24.1	0.0
2008	238.7	181.4	31.6	0.0	0.0	0.0	25.7	0.0
2009	23.0	0.0	23.0	0.0	0.0	0.0	0.0	0.0
2010	77.5	0.0	11.3	66.2	0.0	0.0	0.0	0.0
2011	88.8	0.0	11.3	77.5	0.0	0.0	0.0	0.0
2012	104.3	0.0	11.3	93.0	0.0	0.0	0.0	0.0
2013	121.2	0.0	11.3	109.9	0.0	0.0	0.0	0.0
2014	133.9	0.0	0.0	133.9	0.0	0.0	0.0	0.0
2015	146.5	0.0	0.0	146.5	0.0	0.0	0.0	0.0
2016	149.4	0.0	0.0	149.4	0.0	0.0	0.0	0.0
2017	142.3	0.0	0.0	142.3	0.0	0.0	0.0	0.0
2018	145.1	0.0	0.0	145.1	0.0	0.0	0.0	0.0
2019	143.7	0.0	0.0	143.7	0.0	0.0	0.0	0.0
2020	139.5	0.0	0.0	139.5	0.0	0.0	0.0	0.0
2021	138.1	0.0	0.0	138.1	0.0	0.0	0.0	0.0
2022	138.1	0.0	0.0	138.1	0.0	0.0	0.0	0.0
2023	136.7	0.0	0.0	136.7	0.0	0.0	0.0	0.0
2024	133.9	0.0	0.0	133.9	0.0	0.0	0.0	0.0
2025	143.7	0.0	0.0	143.7	0.0	0.0	0.0	0.0
2026	140.9	0.0	0.0	140.9	0.0	0.0	0.0	0.0
2027	138.1	0.0	0.0	138.1	0.0	0.0	0.0	0.0
2028	131.0	0.0	0.0	131.0	0.0	0.0	0.0	0.0
2029	133.9	0.0	0.0	133.9	0.0	0.0	0.0	0.0
2030	132.4	0.0	0.0	132.4	0.0	0.0	0.0	0.0
2031	129.6	0.0	0.0	129.6	0.0	0.0	0.0	0.0
2032	112.7	0.0	0.0	112.7	0.0	0.0	0.0	0.0
2033	110.7	0.0	0.0	91.6	19.1	0.0	0.0	0.0
2034	102.1	0.0	0.0	0.0	102.1	0.0	0.0	0.0
2035	89.3	0.0	0.0	0.0	89.3	0.0	0.0	0.0
2036	76.6	0.0	0.0	0.0	76.6	0.0	0.0	0.0
2037	56.0	0.0	0.0	0.0	56.0	0.0	0.0	0.0
2038	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2039	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2040	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2041	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2042	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2043	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2044	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2045	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2046	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2047	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2048	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2049	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2050	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2051	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2052	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2053	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2054	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2055	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2056	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2057	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2058	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2059	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2060	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2061	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0

Table B-2. Surface Facility Annual Cost Distribution (Continued)
(1998 $ in Millions)

Year	Yearly Totals	Field Cost	Startup & Training	Emplace-ment Activities	Monitoring Activities	Decom-missioning Activities	Design	Offsite Utilities
2062	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2063	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2064	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2065	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2066	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2067	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2068	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2069	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2070	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2071	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2072	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2073	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2074	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2075	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2076	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2077	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2078	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2079	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2080	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2081	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2082	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2083	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2084	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2085	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2086	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2087	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2088	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2089	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2090	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2091	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2092	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2093	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2094	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2095	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2096	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2097	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2098	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2099	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2100	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2101	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2102	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2103	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2104	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2105	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2106	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2107	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2108	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2109	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2110	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0
2111	17.0	0.0	0.0	0.0	0.0	17.0	0.0	0.0
2112	27.2	0.0	0.0	0.0	0.0	27.2	0.0	0.0
2113	34.0	0.0	0.0	0.0	0.0	34.0	0.0	0.0
2114	27.2	0.0	0.0	0.0	0.0	27.2	0.0	0.0
2115	17.0	0.0	0.0	0.0	0.0	17.0	0.0	0.0
2116	6.8	0.0	0.0	0.0	0.0	6.8	0.0	0.0
Total	**5,428.7**	**960.3**	**162.6**	**3,047.6**	**881.5**	**129.3**	**195.4**	**52.0**

* Costs for the year 2002 are for 7 months.

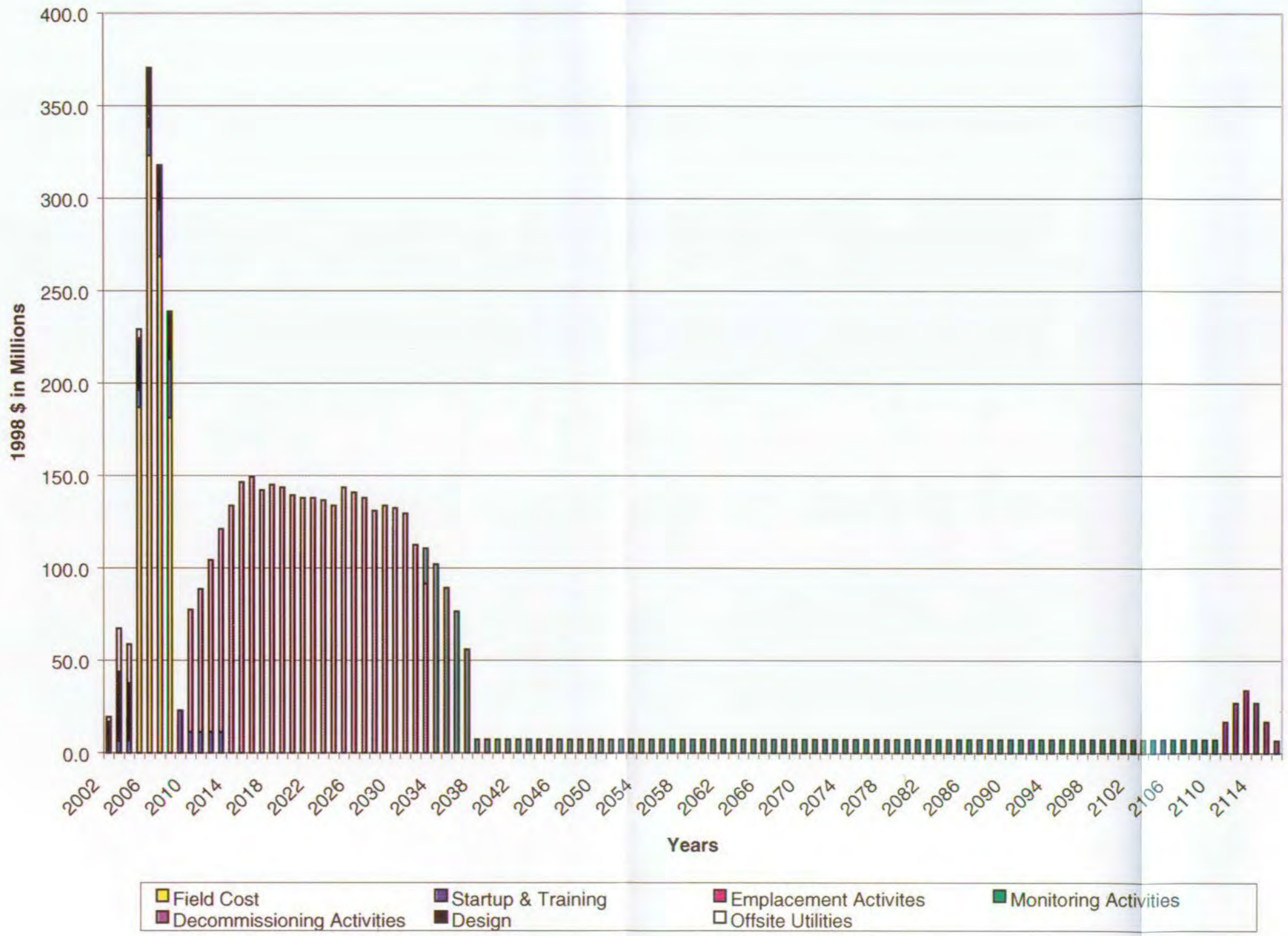

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Figure B-2. Surface Facility Annual Cost Distribution

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Table B-3. Surface Facility Capital and Operating and Maintenance Costs

Phase	Surface Facilities Totals		Field Cost		Startup & Training		Emplacement Activities	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Licensing	132.2	13.4	0.0	0.0	0.0	13.4	0	0.0
Pre-Emplacement Construction	1,075.5	104.1	960.3	0.0	0.0	104.1	0.0	0.0
Emplacement Operations	0.0	3,112.0	0.0	0.0	0.0	45.2	0.0	3,047.6
Monitoring	0.0	862.4	0.0	0.0	0.0	0.0	0.0	0.0
Closure and Decommissioning	129.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total	**1,337.0**	**4,091.8**	**960.3**	**0.0**	**0.0**	**162.6**	**0.0**	**3,047.6**

Phase	Monitoring		Decommissioning Activities		Design		Offsite Utilities	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Licensing	0.0	0.0	0.0	0.0	85.1	0.0	47.1	0.0
Pre-Emplacement Construction	0.0	0.0	0.0	0.0	110.3	0.0	4.9	0.0
Emplacement Operations	0.0	19.1	0.0	0.0	0.0	0.0	0.0	0.0
Monitoring	0.0	881.5	0.0	0.0	0.0	0.0		
Closure and Decommissioning	0.0	0.0	129.3	0.0	0.0	0.0	0.0	0.0
Grand Total	**0.0**	**881.5**	**129.3**	**0.0**	**195.4**	**0.0**	**52.0**	**0.0**

O&M–Operating and Maintenance

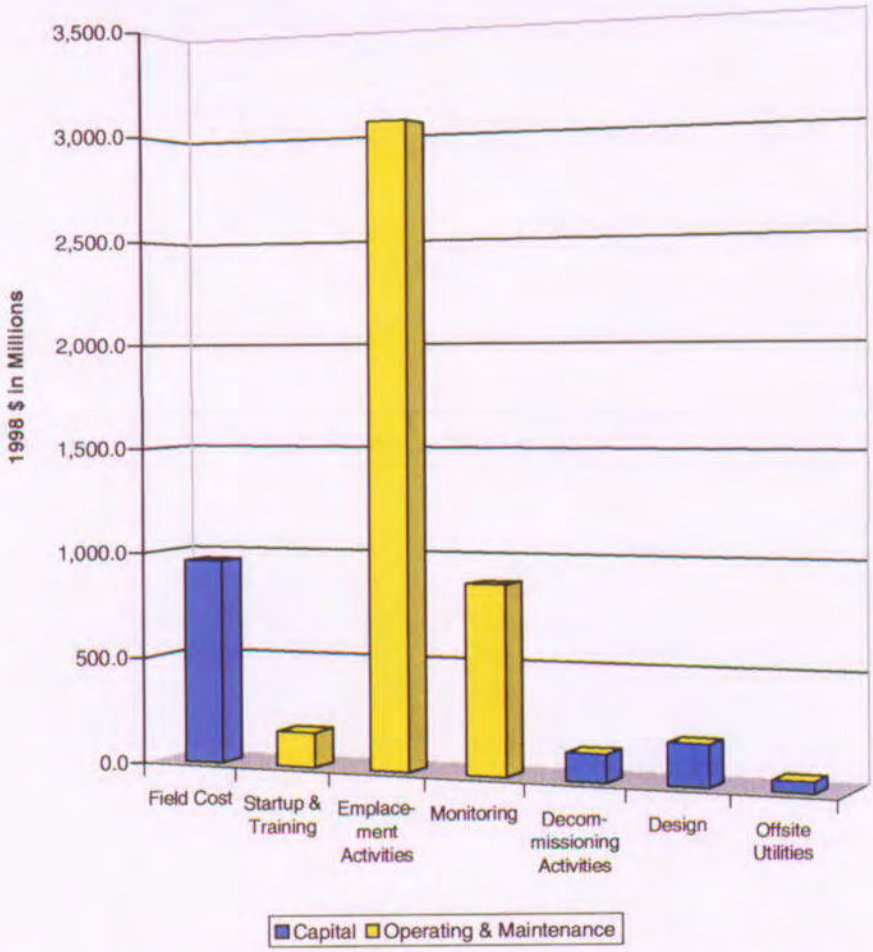

Figure B-3. Surface Facility Capital and Operating and Maintenance Cost Summary

APPENDIX C

SUBSURFACE FACILITIES

APPENDIX C

SUBSURFACE FACILITIES

This appendix presents the cost estimate for construction and operation of subsurface facilities at the repository. The cost estimate is based on the reference design for the repository that is presented in Volume 2, Section 4.2.

For each cost element defined in Section 1.2 of Volume 5, this appendix defines scope on a summary level, identifies the methodologies used to develop the cost estimate, identifies assumptions that the estimate rests on, and presents summary results.

The summary results are presented as tables and figures that show cost estimates by cost element and project phase. In addition, annual cost distributions, as well as capital, operating, and maintenance costs, are provided (see Section C.4).

C.1 SCOPE OF MAJOR COST ELEMENTS

The scope of major cost elements is presented below.

C.1.1 Access Excavation and Construction

This element includes all costs to excavate, line, and complete access drifts: the Exhaust Main, North Ramp Extension, South Ramp Extension, North Main, West Main, and East Main North Extension. The drifts are 7.62 m (25 ft) in diameter and total approximately 15 km (9 miles). This cost element also includes excavation of several assembly and disassembly chambers for the tunnel boring machine and construction of ventilation barriers. The cost for three cross-block exploratory drifts is also included here.

C.1.2 Emplacement Drift Excavation

This element includes all costs to excavate and complete the emplacement drifts. This includes 102 emplacement drifts totaling approximately 121 km (75 miles) in length. The emplacement drifts would be excavated with a tunnel boring machine 5.5 m (18 ft) in diameter. This cost element also includes the excavation and completion of emplacement drift turnouts and ventilation raises that connect the emplacement drifts to the Exhaust Main drift. This includes grouting of precast concrete segments and placement of steel sets and panel linings in the emplacement drifts. This item also includes installation of emplacement drift closure doors, gantry rails, emplacement drift electrical system, and emplacement drift communication and control system.

C.1.3 Excavated Material Handling

This element includes all costs for the removal of all excavated material from subsurface to the surface for the tunnel boring machines and roadheader excavation methods.

C.1.4 Support System Facilities

This element includes all operations costs for the portal support, batch plant, precast yard, and development-side subsurface utilities and surface support facilities. It also includes operation of the development-side ventilation system.

C.1.5 Subsurface Emplacement Operations

This element includes all costs for the transport and emplacement of approximately 10,500 waste packages. This includes all activities starting with the remotely controlled loading of waste packages within the Waste Handling Building onto a reusable rail car and ending with placement of the waste package onto the waste package support by the gantry. It also includes operation and maintenance of subsurface emplacement-side utilities and ventilation system.

C.1.6 Decommissioning Activities

This element includes all costs for the placement of backfill and seals in the Access Main and performance confirmation drifts and ventilation shafts during the closure phase. It also includes the decommissioning, demolition, and removal of surface support facilities.

C.1.7 Ventilation Shafts

This element includes all costs to excavate, line, and finish the development and emplacement ventilation shafts. The development shaft has an excavated diameter of 6.7 m (22 ft) and a depth of 342 m (1,120 ft). The emplacement shaft has an excavated diameter of 6.7 m (22 ft) and a depth of 417 m (1,370 ft).

C.1.8 Subsurface Management and Integration

This element includes all costs for architectural and engineering design services for the development and configuration management control of construction specifications and drawings. In addition, this element includes all costs for construction management services for organizing, coordinating, planning, scheduling, directing, and inspecting construction activities.

C.1.9 South Portal Facilities

This element includes all costs to construct and operate surface support facilities at the South Portal: a warehouse, change house, offices for construction and security, weight scale, maintenance shops, utilities, and the precasting yard and batch plant.

C.1.10 Early Testing and Development

This element includes all costs for development and testing of mockup prototype waste package transport and emplacement equipment. Equipment includes the waste package transporter, transport locomotive, emplacement gantry, and loading/unloading mechanism.

C.2 ESTIMATING METHODOLOGIES

C.2.1 Contracting

Previous cost estimates for the subsurface repository were based on the assumption that a single contractor would do the majority of the work with a long-term contract. The underground construction and operations cost estimate for the VA used an estimating assumption that a single service contractor would provide the common onsite services and utilities integrated with short-term, fixed-priced contractors for specific products or work packages. The results of these estimates were merged into a single large spreadsheet.

The following sections describe the responsibilities of the service contractor and the scope of fixed-price contracts included in the estimate. Descriptions of the long-term-cost estimating system and the short-term-construction computer-aided estimating system are also included.

C.2.2 Description of the Long-Term Estimating System Model

A single long-term service contract was assumed for operation and maintenance of utilities and facilities that support the underground operations.

The service contractor will operate and maintain the muck (mined rock) conveyor system from the point where the muck is loaded onto the conveyor in the subsurface repository to its placement on the surface muck storage pile. The service contractor will also be responsible for installation of the underground belt system from the pickup point to the portal. Portal support, which involves warehousing and loading supplies on railcars for shipment underground, will be provided by the service contractor.

The service contractor also will operate and maintain the following systems:

- Ventilation system, including the surface-based main fan systems and the subsurface ducts and fans located in the main drifts
- Subsurface transportation systems
- Subsurface utilities
- Concrete batch plant used to mix concrete products
- Precast concrete operations
- System to transport and emplace waste packages in emplacement drifts

- Subsurface monitoring and control systems
- Surface facilities such as the change house, shops, and offices
- Site roads, pad areas, and drainage facilities

The subsurface emplacement and operation costs were developed using a long-term-operation estimating system. The assumptions used in implementing this estimating system are listed in Section C.3 of this appendix.

Developing cost estimates for long-term operations requires an approach that is different from that used for short-term construction projects; the estimator needs a system that allows the development of cash flows. The estimate format must allow for calculation of annual operating expenses, as well as initial procurement and replacement costs for the plant and equipment. The estimating system must also allow the estimator to extract resource summaries for use in the EIS.

To organize the cost estimate and track the large volume of information that must be processed, the estimators used a system comprising a series of interactive spreadsheets. These spreadsheets initially were developed to produce estimates for contract mining operations. The spreadsheets also have been used to estimate costs for several major feasibility studies. The system creates a cost center for each major element of the operating costs for subsurface facility operations. It also prepares related purchase and replacement cost schedules.

Eighteen interactive spreadsheets were used in the system as follows:

- A labor spreadsheet computed craft labor costs per shift using the project labor agreements and statutory payroll taxes and insurance. The shift costs incorporated the union operating rules with the estimated shift time requirements.
- An equipment-operating cost spreadsheet tabulated and analyzed the equipment operating costs for use in the estimate. The equipment costs were developed using published sources and the estimator's experience.
- A materials spreadsheet tabulated permanent material costs and freight costs. The costs used were based on published sources, telephone contacts, and historical project cost data.
- A supplies spreadsheet tabulated the costs of supplies and freight. The costs used were based on published sources, telephone contacts, and historical project cost data.
- A "sequence" spreadsheet developed an operating schedule for each cost center. The production rates and delay times were based on the estimator's and designer's best judgment.
- A "takeoff" spreadsheet tabulated labor shifts, equipment operating hours, consumable supply quantities, and permanent material quantities.
- A "crew" spreadsheet combined the takeoff spreadsheet with the cost elements to produce an annual operating cost.
- A summary spreadsheet imported data from the crew spreadsheet. This spreadsheet provided two additional columns: one for direct input of capital costs for equipment and one for the direct input of subcontract costs. This spreadsheet also allows the addition of percentage markups.
- A spreadsheet tabulated and summarized the equipment operating hours by type of equipment by year.
- A "replace" spreadsheet computed the replacement schedule for a single piece of capital equipment.
- A spreadsheet tabulated output from the various "replace" spreadsheets and provided a unified equipment purchase and replacement schedule.

- A "purchase" spreadsheet was used to develop a purchase and replacement cost schedule for capital equipment.

- A labor summary spreadsheet tabulated a schedule of direct operating shifts per year by labor classification, using the labor sheet index codes.

These spreadsheets were developed as a series of small modules that build into a final summary. The use of small, linked modules allows the estimator and designer to check their work as they build the estimate.

C.2.3 Description of the Fixed-Price Contract Estimating System

Fixed-price contracts were assumed for constructing and equipping various portions of the subsurface facility and closing and decommissioning the subsurface repository.

The South Portal fixed-price contract comprises the site work and construction at the South Portal. It includes grading and moving earth to and from the necessary construction pads; constructing office, shop, and warehouse space; installing the overland conveyor to carry mined rock from the portal to the muck pile; and building the electrical substation and switch gear.

The fixed-price contract for initial underground construction includes the upgrade of existing ramps and the main drift of the Exploratory Studies Facility; excavation and completion of the perimeter main drifts; construction of all operational alcoves; and excavation of the following:

- Three cross-block exploratory drifts that will be used to define the limits of the useful repository area

- Emplacement drifts numbers 1-10

- Ventilation raises for 10 emplacement drifts and cross-block exploratory drifts

Drifts to be used for performance confirmation monitoring were included as part of this work package, but the costs are found in the performance confirmation estimate.

The fixed-price contract for initial electrical and mechanical underground construction includes the electrical and mechanical work associated with the access excavation and construction and the emplacement drift excavation.

The fixed-priced contract for ventilation shafts covers excavating, completing, and equipping the emplacement exhaust shaft and the development intake shaft.

The fixed-priced contract for emplacement drift construction includes excavating and completing the remaining emplacement drifts. This also includes construction of the turnouts, or small starter drifts used by the tunnel boring machine to start boring, and the ventilation raises for those drifts.

The fixed-price contract for decommissioning includes all functions needed to close and decommission the subsurface facilities. This includes removing nonpermanent subsurface fixtures, backfilling the main drifts, and filling and sealing the two shafts and two ramps. It also includes dismantling the South Portal surface facilities.

The computer-aided estimating system was used to develop estimates for short-term work items that would fit a fixed-price construction contract for subsurface facilities. It uses a series of resource tables to provide the costs for labor, equipment operating and ownership costs, material, and supply costs. Cost data were taken from the long-term-operations estimating system, with adjustments as needed. The fixed-price contract estimates generated by the computer-aided estimating system were then fed into the long-term estimating model described in Section C.2.2 to produce a summary of costs as shown in Section C.4.

C.2.4 Contingency Rates

A contingency was developed for each type of work. Estimators and design engineers determined how each type of work could reasonably change

from the current basis. This determination was expressed as a percentage increase from the base cost. This allowance is to cover unforeseen events, not major changes in design.

The following are composite contingencies from the subsurface estimate:

Cost Estimate	Contingency
Access Excavation & Construction	17 percent
Emplacement Drift Excavation	17 percent
Excavated Material Handling	15 percent
Support Systems Facilities	15 percent
Subsurface Emplacement Operations	15 percent
Decommissioning Activities	19 percent
Ventilation Shafts	15 percent
South Portal Activities	15 percent

This approach provides a high level of confidence in the estimate.

C.3 COST ESTIMATING ASSUMPTIONS

The cost estimate for subsurface facilities is based on a number of assumptions encompassing labor, materials, and construction.

C.3.1 Common Assumptions

For the labor required to construct and operate the repository, craft labor rates are based on existing labor agreements between the construction unions and the Nevada Test Site Management and Operating Contractor (M&O).

To calculate payroll taxes and insurance, 1998 rates were used.

Estimates for materials and supplies include freight allowance.

Employee transportation costs assume that all employees travel to work by bus, each bus transports 47 employees, and each bus costs $550/day.

The daily advance rate for a 7.62-m (25-ft) -diameter main drift is 354 m/day (115 ft/day). Excavation proceeds during three shifts per day with a 4-hour maintenance period during day shifts. Temporary ground support is installed in conjunction with excavation, with permanent cast-in-place lining installed later. Muck is hauled directly from the tunnel boring machine to the main conveyor.

C.3.2 Emplacement Drift Excavation

The daily advance rate of 30 m (98 ft) will be similar for all tunnel boring machines excavating the drifts of 5.5-m (18-ft) diameter. Excavation proceeds during three shifts per day with a 4-hour maintenance period during day shifts. Permanent ground support is installed in conjunction with the excavation operation. Muck is hauled by railcar to a main conveyor loading station.

The estimated penetration rate of roadheader is 15 m^3 per cutting hour, 45 m^3 per shift. For small roadheaders for utility and performance confirmation alcoves, the estimated rate is 10 m^3 per cutting hour. Both of these rates are based on 3 hours of cutting per shift, with the balance of the shift reserved for ground support, maintenance, and positioning.

It is estimated to take 6 days to construct pilot holes and back reams for vent raises and 3 days to cast the concrete lining.

C.3.3 Subsurface Emplacement Operations

An average of 2.2 waste packages will be moved each day. Initially, the schedule requires less than one package per day, so a single crew will work one shift per day. A second shift, plus additional help at the plant, will be added as the number of packages increases.

Emplacement operations span approximately 24 years, beginning March 2010 and ending September 2033. Operations will increase to full

rate (3,000 MTHM commercial spent nuclear fuel plus 700 canisters of other wastes per year) by March 2014. After the initial ramp-up, emplacement operations are generally steady over the entire emplacement period.

C.3.4 Ventilation Shafts

To compute progress of this work, the following production rates were used. Boring the pilot hole was estimated at 55 m/day (180 ft/day). Enlarging the hole was estimated at 18 m/day (59 ft/day). The final downreaming operation was estimated at 3 m/day (10 ft/day). A permanent cast-in-place concrete lining was installed concurrent with the downreaming operation.

C.4 ESTIMATE SUMMARY

Construction and operations costs of the Subsurface Facilities during the Pre-Emplacement Construction Phase peak at approximately $243 million in 2007 as the West Main, Exhaust Main, North and South Access Mains, and the first series of emplacement drifts are completed. Costs during the Emplacement Operations Phase are on a 5-year cycle with costs ranging from approximately $73 million to approximately $159 million, as new emplacement drifts are periodically excavated and completed for additional waste emplacement concurrent with waste storage. Costs during the Monitoring Phase remain level at approximately $15 million/year for subsurface facility maintenance and support of performance confirmation. And finally, costs during the Closure and Decommissioning Phase peak in the first year, 2106, at approximately $81 million and then decrease as seals are placed on the access drifts and ventilation shafts are backfilled.

Table C-1 and Figures C-1a and C-1b summarize Subsurface Facility costs. Table C-2 and Figure C-2 show the Subsurface Facility annual cost distribution. Table C-3 and Figure C-3 show Subsurface Facility capital and operating and maintenance costs. Dollar amounts are summary figures derived from detailed calculations. Some minor differences or variations in the figures may occur due to effects from computational rounding of the numbers.

Table C-1. Subsurface Facility Cost Summary
(1998 $ in Millions)

Phase	Phase Totals	Access Excavation & Construction	Emplacement Drift Excavation	Excavated Material Handling	Support Systems Facilities	Subsurface Emplacement Operations
Licensing	92.2	0.0	0.0	0.0	0.0	0.0
Pre-Emplacement Construction	933.0	386.7	104.1	73.4	80.2	0.0
Emplacement Operations	2,602.8	176.2	1,217.1	316.2	360.0	202.9
Monitoring	1,199.0	0.0	0.0	257.7	314.6	580.4
Closure and Decommissioning	175.6	0.0	0.0	9.8	53.5	2.2
Grand Total	**5,002.5**	**562.9**	**1,321.3**	**657.2**	**808.4**	**785.4**

Phase	Decom-missioning Activities	Ventilation Shafts	Subsurface Management & Integration	South Portal Facilities	Early Testing & Development
Licensing	0.0	0.0	85.6	0.0	6.6
Pre-Emplacement Construction	0.0	69.9	156.0	43.8	18.8
Emplacement Operations	0.0	0.0	330.3	0.0	0.0
Monitoring	31.4	0.0	14.8	0.0	0.0
Closure and Decommissioning	77.9	0.0	32.2	0.0	0.0
Grand Total	**109.3**	**69.9**	**619.0**	**43.8**	**25.4**

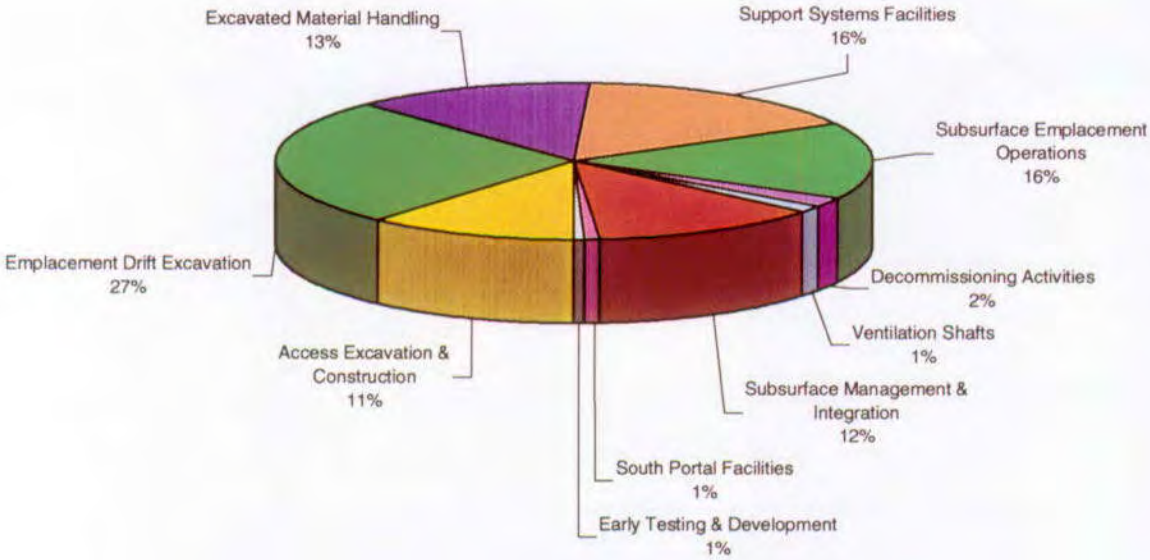

Figure C-1a. Subsurface Facility Percent of Total Cost by Cost Element

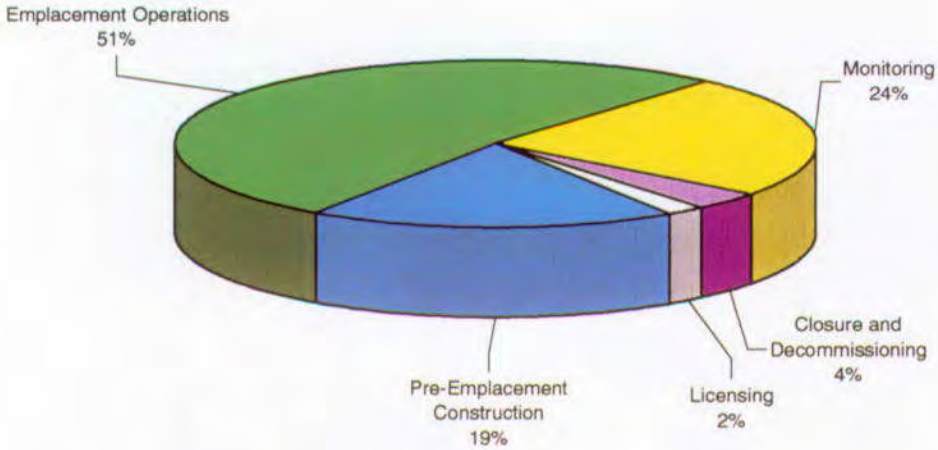

Figure C-1b. Subsurface Facility Percent of Total Cost by Project Phase

Table C-2. Subsurface Facility Annual Cost Distribution (1998 $ in Millions)

Year	Yearly Totals	Access Excavation & Construction	Emplacement Drift Excavation	Excavated Material Handling	Support Systems Facilities	Subsurface Emplacement Operations	Decommissioning Activities	Ventilation Shafts	Subsurface Management & Integration	South Portal Activities	Early Testing & Development
2002 *	15.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.7	0.0	0.0
2003	27.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.2	0.0	0.0
2004	49.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.7	0.0	6.6
2005	183.3	38.8	0.0	34.7	14.3	0.0	0.0	0.0	37.8	43.8	14.0
2006	142.7	56.3	7.1	10.4	17.4	0.0	0.0	9.5	37.3	0.0	4.8
2007	243.0	105.0	48.4	10.1	17.5	0.0	0.0	35.0	27.0	0.0	0.0
2008	210.7	102.8	31.2	8.9	15.4	0.0	0.0	25.4	27.0	0.0	0.0
2009	153.1	83.8	17.5	9.3	15.6	0.0	0.0	0.0	27.0	0.0	0.0
2010	111.7	0.0	14.6	57.3	15.9	5.7	0.0	0.0	18.2	0.0	0.0
2011	88.6	0.0	41.5	11.4	15.4	6.6	0.0	0.0	13.7	0.0	0.0
2012	138.6	6.2	82.4	9.8	15.4	6.7	0.0	0.0	18.2	0.0	0.0
2013	126.8	15.8	57.9	11.8	16.2	6.9	0.0	0.0	18.2	0.0	0.0
2014	94.8	0.0	47.1	11.7	16.7	7.2	0.0	0.0	12.0	0.0	0.0
2015	128.7	5.0	65.9	14.6	16.8	8.3	0.0	0.0	18.2	0.0	0.0
2016	154.6	17.8	79.4	12.0	18.1	8.3	0.0	0.0	18.9	0.0	0.0
2017	132.5	17.1	62.0	10.5	16.3	8.4	0.0	0.0	18.2	0.0	0.0
2018	88.4	0.0	42.9	11.4	15.9	8.7	0.0	0.0	9.5	0.0	0.0
2019	107.8	0.0	57.2	12.1	16.3	8.4	0.0	0.0	13.7	0.0	0.0
2020	158.8	10.1	89.6	13.5	18.0	8.8	0.0	0.0	18.9	0.0	0.0
2021	152.0	26.9	60.4	21.0	16.1	8.8	0.0	0.0	18.9	0.0	0.0
2022	74.8	0.0	29.3	10.3	16.6	9.1	0.0	0.0	9.5	0.0	0.0
2023	100.6	0.0	54.6	11.3	16.1	8.8	0.0	0.0	9.8	0.0	0.0
2024	130.4	7.8	70.6	12.3	16.2	8.8	0.0	0.0	14.6	0.0	0.0
2025	146.9	9.2	77.5	14.8	18.1	9.1	0.0	0.0	18.2	0.0	0.0
2026	118.3	11.8	55.1	11.0	17.3	9.4	0.0	0.0	13.7	0.0	0.0
2027	73.0	0.0	29.2	11.1	15.0	9.1	0.0	0.0	8.6	0.0	0.0
2028	98.0	0.0	51.2	10.8	16.5	9.2	0.0	0.0	10.3	0.0	0.0
2029	137.0	8.1	72.1	11.6	17.9	9.2	0.0	0.0	18.2	0.0	0.0
2030	118.9	10.0	61.6	8.1	11.9	9.8	0.0	0.0	17.7	0.0	0.0
2031	78.7	29.6	15.3	6.1	9.2	9.5	0.0	0.0	9.0	0.0	0.0
2032	23.6	0.7	0.0	6.9	4.3	9.5	0.0	0.0	2.2	0.0	0.0
2033	19.2	0.0	0.0	4.7	4.0	8.4	0.0	0.0	2.2	0.0	0.0
2034	14.9	0.0	0.0	3.0	3.8	8.1	0.0	0.0	0.0	0.0	0.0
2035	15.0	0.0	0.0	3.6	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2036	14.2	0.0	0.0	2.8	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2037	14.4	0.0	0.0	3.0	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2038	14.8	0.0	0.0	3.1	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2039	14.7	0.0	0.0	3.3	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2040	14.9	0.0	0.0	3.5	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2041	14.8	0.0	0.0	3.4	3.8	7.6	0.0	0.0	0.0	0.0	0.0

Table C-2. Subsurface Facility Annual Cost Distribution (Continued)
(1998 $ in Millions)

Year	Yearly Totals	Access Excavation & Construction	Emplacement Drift Excavation	Excavated Material Handling	Support Systems Facilities	Subsurface Emplacement Operations	Decommissioning Activities	Ventilation Shafts	Subsurface Management & Integration	South Portal Activities	Early Testing & Development
2042	14.3	0.0	0.0	2.6	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2043	14.4	0.0	0.0	3.0	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2044	16.6	0.0	0.0	5.2	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2045	14.8	0.0	0.0	3.4	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2046	14.4	0.0	0.0	2.7	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2047	14.6	0.0	0.0	3.2	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2048	14.3	0.0	0.0	2.9	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2049	14.6	0.0	0.0	3.2	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2050	14.9	0.0	0.0	3.2	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2051	14.5	0.0	0.0	3.1	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2052	14.0	0.0	0.0	2.6	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2053	14.6	0.0	0.0	3.2	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2054	14.4	0.0	0.0	2.7	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2055	16.9	0.0	0.0	5.5	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2056	14.5	0.0	0.0	3.1	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2057	14.6	0.0	0.0	3.2	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2058	14.5	0.0	0.0	2.8	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2059	14.7	0.0	0.0	3.3	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2060	14.3	0.0	0.0	2.9	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2061	14.5	0.0	0.0	3.1	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2062	14.6	0.0	0.0	2.9	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2063	15.2	0.0	0.0	3.8	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2064	14.0	0.0	0.0	2.6	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2065	15.4	0.0	0.0	4.0	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2066	14.6	0.0	0.0	2.9	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2067	16.7	0.0	0.0	5.3	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2068	14.2	0.0	0.0	2.8	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2069	14.4	0.0	0.0	3.0	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2070	14.8	0.0	0.0	3.1	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2071	14.8	0.0	0.0	3.4	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2072	14.3	0.0	0.0	2.9	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2073	14.5	0.0	0.0	3.1	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2074	14.5	0.0	0.0	2.8	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2075	14.6	0.0	0.0	3.2	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2076	14.1	0.0	0.0	2.7	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2077	14.8	0.0	0.0	3.4	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2078	16.6	0.0	0.0	4.9	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2079	14.5	0.0	0.0	3.1	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2080	14.5	0.0	0.0	3.1	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2081	14.4	0.0	0.0	3.0	3.8	7.6	0.0	0.0	0.0	0.0	0.0

Table C-2. Subsurface Facility Annual Cost Distribution (Continued)
(1998 $ in Millions)

Year	Yearly Totals	Access Excavation & Construction	Emplacement Drift Excavation	Excavated Material Handling	Support Systems Facilities	Subsurface Emplacement Operations	Decommissioning Activities	Ventilation Shafts	Subsurface Management & Integration	South Portal Activities	Early Testing & Development
2082	14.3	0.0	0.0	2.6	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2083	14.6	0.0	0.0	3.2	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2084	14.3	0.0	0.0	2.9	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2085	15.0	0.0	0.0	3.6	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2086	14.8	0.0	0.0	3.2	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2087	14.7	0.0	0.0	3.3	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2088	14.2	0.0	0.0	2.8	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2089	16.8	0.0	0.0	5.4	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2090	14.7	0.0	0.0	3.1	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2091	14.5	0.0	0.0	3.1	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2092	14.2	0.0	0.0	2.8	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2093	14.7	0.0	0.0	3.3	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2094	14.3	0.0	0.0	2.6	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2095	14.6	0.0	0.0	3.2	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2096	14.5	0.0	0.0	3.1	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2097	14.4	0.0	0.0	3.0	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2098	14.5	0.0	0.0	2.8	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2099	14.4	0.0	0.0	3.0	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2100	14.8	0.0	0.0	3.4	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2101	16.8	0.0	0.0	5.4	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2102	14.5	0.0	0.0	2.8	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2103	14.7	0.0	0.0	3.3	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2104	14.3	0.0	0.0	2.9	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2105	14.8	0.0	0.0	3.4	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2106	14.4	0.0	0.0	2.7	3.8	7.8	0.0	0.0	0.0	0.0	0.0
2107	14.7	0.0	0.0	3.3	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2108	14.0	0.0	0.0	2.6	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2109	14.5	0.0	0.0	3.1	3.8	7.6	0.0	0.0	0.0	0.0	0.0
2110	80.6	0.0	0.0	11.3	22.2	0.9	31.4	0.0	14.8	0.0	0.0
2111	75.5	0.0	0.0	3.8	21.3	0.9	35.7	0.0	13.9	0.0	0.0
2112	58.9	0.0	0.0	3.3	20.8	0.9	23.2	0.0	10.8	0.0	0.0
2113	41.2	0.0	0.0	2.8	11.4	0.4	19.0	0.0	7.6	0.0	0.0
2114	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2115	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2116	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**5,002.5**	**562.9**	**1,321.3**	**657.2**	**808.4**	**785.4**	**109.3**	**69.9**	**619.0**	**43.8**	**25.4**

* Costs for the year 2002 are for 7 months.

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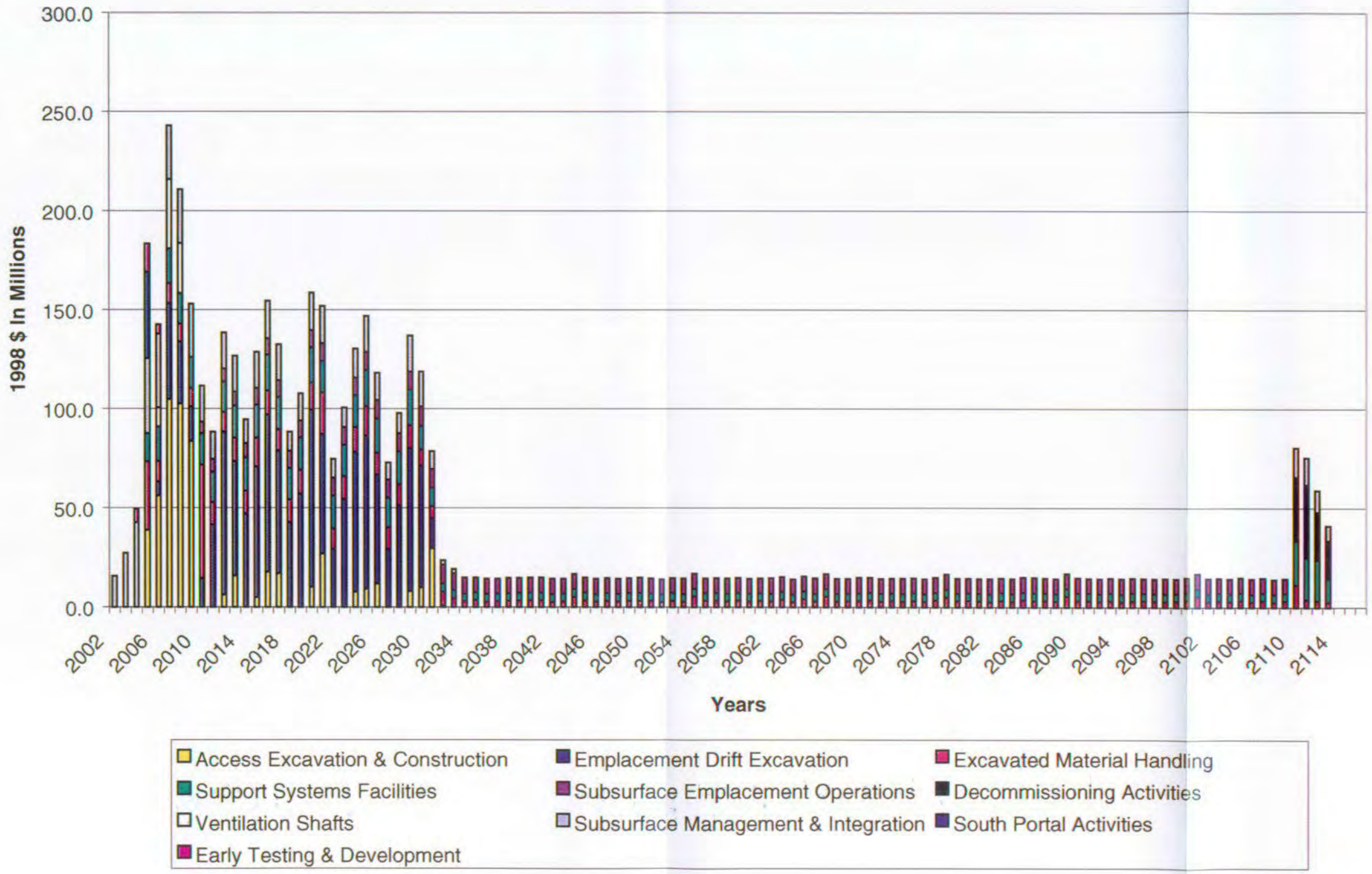

Figure C-2.Subsurface Facility Annual Cost Distribution

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Table C-3. Subsurface Facility Capital and Operating and Maintenance Costs
(1998 $ in Millions)

Phase	Subsurface Facilities Totals		Access Excavation & Construction		Emplacement Drift Excavation		Excavated Material Handling		Support Systems Facilities		Subsurface Emplacement Operations	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Licensing	92.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pre-Emplacement Construction	933.0	0.0	386.7	0.0	104.1	0.0	73.4	0.0	80.2	0.0	0.0	0.0
Emplacement Operations	2,350.3	252.5	176.2	0.0	1,217.1	0.0	266.6	49.6	360.0	0.0	0.0	202.9
Monitoring	130.5	1,068.5	0.0	0.0	0.0	0.0	62.3	195.4	22.2	292.5	0.0	580.4
Closure and Decommissioning	172.3	3.3	0.0	0.0	0.0	0.0	9.3	0.5	53.5	0.0	0.0	2.2
Grand Total	**3,678.3**	**1,324.2**	**562.9**	**0.0**	**1,321.3**	**0.0**	**411.7**	**245.4**	**515.9**	**292.5**	**0.0**	**785.4**

Phase	Decom-missioning Activities		Ventilation Shafts		Subsurface Management & Integration		South Portal Facilities		Early Testing & Development	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Licensing	0.0	0.0	0.0	0.0	85.6	0.0	0.0	0.0	6.6	0.0
Pre-Emplacement Construction	0.0	0.0	69.9	0.0	156.0	0.0	43.8	0.0	18.8	0.0
Emplacement Operations	0.0	0.0	0.0	0.0	330.3	0.0	0.0	0.0	0.0	0.0
Monitoring	31.4	0.0	0.0	0.0	14.5	0.2	0.0	0.0	0.0	0.0
Closure and Decommissioning	77.9	0.0	0.0	0.0	31.6	0.6	0.0	0.0	0.0	0.0
Grand Total	**109.3**	**0.0**	**69.9**	**0.0**	**618.1**	**0.8**	**43.8**	**0.0**	**25.4**	**0.0**

O&M–Operating and maintenance

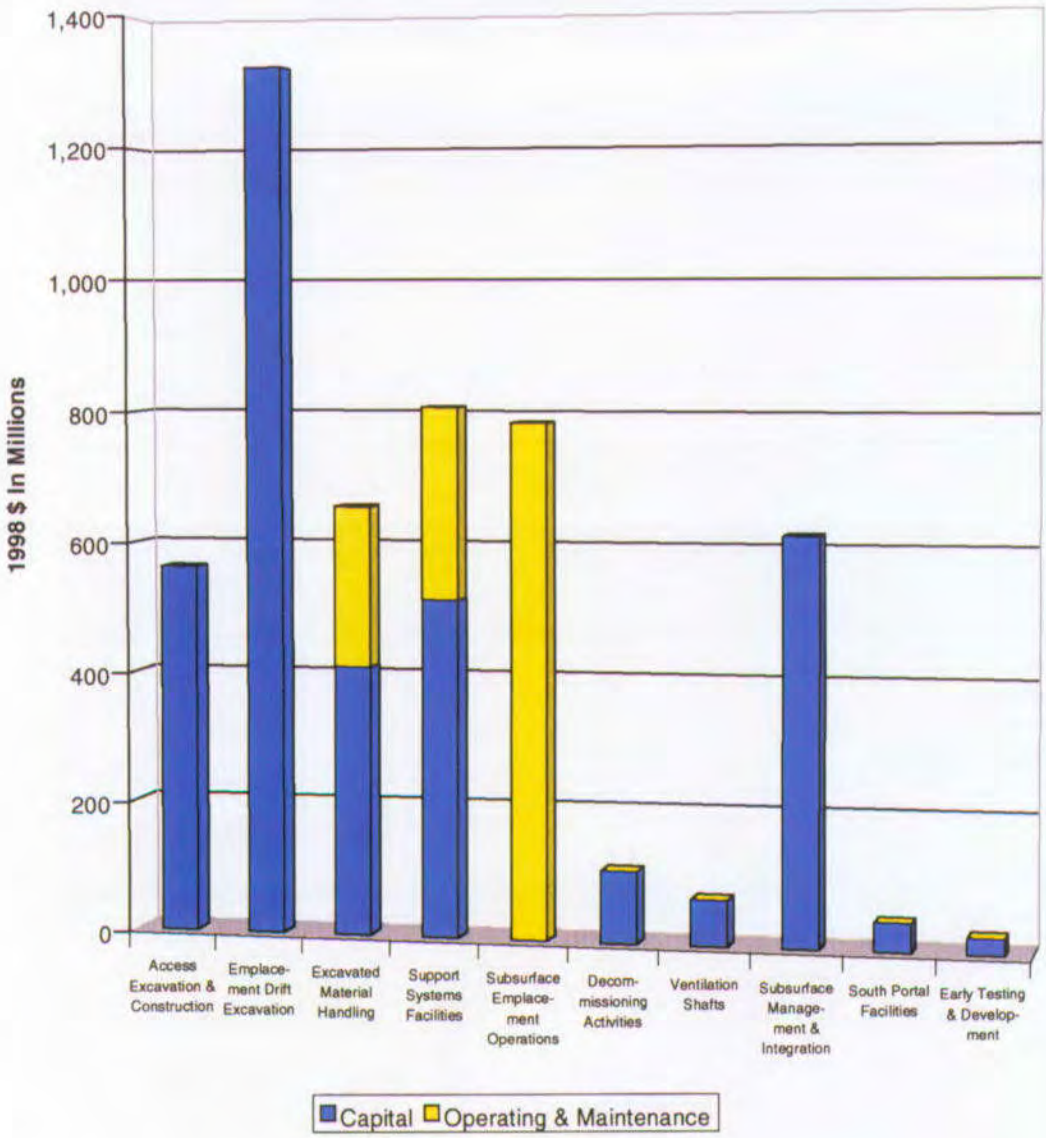

Figure C-3. Subsurface Facility Capital and Operating and Maintenance Costs

APPENDIX D

WASTE PACKAGE

APPENDIX D
WASTE PACKAGE

This appendix presents the cost estimate for completing the designs and fabricating waste packages used to dispose of waste at the Yucca Mountain repository. The cost estimate is based on the reference design for the waste package, which is presented in Volume 2, Section 5. The quantities of waste packages required, by type, are given in *Basis for the VA and TSLCC Cost Estimate Operations Waste Stream* (CRWMS M&O 1998b).

Each major cost element is defined in Section 1.3 of Volume 5. This appendix defines the scope on a summary level, identifies the methodologies used to develop the cost estimate as well as key assumptions on which the estimates are based, and presents summary results.

The summary results are presented as tables and figures that show cost estimates by cost element and project phase. In addition, annual cost distributions, as well as capital, operating, and maintenance costs, are provided (see Section D.4).

D.1 SCOPE OF MAJOR COST ELEMENTS

Waste package scope requirements are based on 12 designs intended to capture the presently identified spent nuclear fuel and defense high-level radioactive waste. Waste package designs are given in Table D-1.

D.1.1 Commercial Spent Nuclear Fuel Waste Packages

There are two basic types of waste packages for disposing of commercial spent nuclear fuel: one to hold boiling-water reactor assemblies and one to hold pressurized-water reactor assemblies. These basic types are subdivided further as follows: one type holds 44 boiling-water reactor assemblies, another type holds 24 boiling-water reactor assemblies, a third type holds 21 pressurized-water reactor assemblies, and the fourth holds 12 pressurized-water reactor assemblies. This element includes the cost to fabricate and ship the waste packages to the Waste Handling Building.

Table D-1. Waste Package Unit Quantities and Costs

Waste Package Type	Quantity of Assumed Waste Packages (*)	Unit Cost	Total (1998 $ in Millions)
21 PWR-No Absorber Plates	1,369	305,000	417.5
21 PWR-No Absorber Plates, with Absorber Rods	169	432,000	73.0
21 PWR-Absorber Plates	2,641	381,000	1,006.2
12 PWR-No Absorber Plates	394	238,000	93.9
12 PWR-No Absorber Plates, South Texas Long	179	306,000	54.8
44 BWR-No Absorber Plates	773	287,000	221.9
44 BWR-Absorber Plates	2,024	451,000	912.8
24 PWR-Thick Absorber Plates	93	333,000	31.0
5 Defense High-Level Waste-Co Disposal-Short	1,261	251,000	316.5
5 Defense High-Level Waste-Co Disposal-Long	405	327,000	132.5
Navy Fuel-Canistered Fuel	285	357,000	101.7
DOE Spent Nuclear Fuel-Miscellaneous	907	319,000	289.3
Total Quantity	**10,500**		**3,651.1**

PWR–Pressurized-water reactor

BWR–Boiling-water reactor

*CRWMS M&O 1998b. *Basis for the VA and TSLCC Cost Estimate Operations Waste Stream.* A00000000-01717-17001-00002 REV 00. Vienna, Virginia: CRWMS M&O. MOV.19980622.0021.

D.1.2 Defense High-Level Radioactive Waste Packages

This elcment includes the cost to fabricate and ship waste packages for immobilized defense high-level radioactive waste to the Waste Handling Building.

D.1.3 DOE Spent Nuclear Fuel Waste Packages

This element includes the cost to fabricate and ship waste packages for DOE spent nuclear fuel containers to the Waste Handling Building.

D.1.4 Waste Package Supports

This element includes the cost to fabricate waste package supports.

D.1.5 Waste Package Design

This element covers design and procurement costs. The tasks associated with the design costs include developing drawings and technical specifications for fabrication and, if necessary, changing those designs as a result of testing. The procurement costs cover the following tasks: integrating scope, cost, and fabrication information with the project baseline; coordinating information with the fabricators; and procuring and testing the prototypes. Also included are the costs to set up and test the remote welding and nondestructive examination systems.

D.2 ESTIMATING METHODS

D.2.1 Waste Package

The waste package estimate used the bottom-up method to derive the cost. By this method, the scope of work was quantified and divided into tasks, subtasks, steps, and functions required to complete the design and to produce the deliverables. The quantities and unit prices associated with each task, subtask, step, or function were extended to arrive at the cost.

The estimate was developed using manufacturing plans. Hours were estimated for each fabrication operation, and a labor rate was applied to these hours to create the labor input. To determine material costs, estimators first determine the weight of material for each component using spreadsheets and drawings, where available. To ascertain the weight of each material, the quotes were obtained from materials vendors and these were used to establish a cost per pound. This unit material cost was applied to the component weights derived from spreadsheets to establish the total materials cost. Weld-material weights were calculated, and a cost per pound was established from vendors.

The labor, material, and equipment data were entered into a spreadsheet model, and the total cost was established. The total cost includes fabrication, quality assurance, profits, transportation, and other costs consisting of administration, temporary office facilities, equipment, etc., to obtain a realistic figure.

D.2.2 Waste Package Supports

The costs for waste package supports were based on design engineering sketches and were estimated using a bottom-up method. Because only a highly conceptual design exists, the costs are "rough-order-of-magnitude" estimates.

D.2.3 Contingency Rates

A contingency rate of 20 percent was applied to the entire estimate. This rate is a composite of higher and lower rates for the individual waste package types. Preliminary design work has been done on five waste package types. Only conceptual sketches support the cost estimate for nine waste package types and the waste package supports.

D.3 ESTIMATING ASSUMPTIONS

The following assumptions were made during development of the waste package cost estimate.

D.3.1 General Assumptions

- Estimates are based on conceptual designs.
- The outer barrier is Carbon Steel A516 Grade 70.

- The interior barrier is nickel-base alloy ASTM B 575 N06022 (Alloy 22).

- The waste package will be fabricated and inspected in accordance with the American Society of Mechanical Engineers Code, Sections III and VIII (ASME 1992a; 1992b). It will not be N stamped because it is not a pressure vessel.

- The method of assembly will be "shrink fit."

- Borated stainless steel plates will be used for criticality control as noted.

- The uncanistered spent nuclear fuel basket tubes will be Carbon Steel A516, Grade 55 or 70.

- The outer barrier thickness is 0.10 m (3.94 in.) and the inner barrier thickness is 0.02 m (0.79 in.).

- Complete manufacturing processes and assumptions are as noted in the *Waste Package Fabrication Process Report* (CRWMS M&O 1998a).

D.3.2 Commercial Spent Nuclear Fuel Waste Packages

D.3.2.1 44 Boiling-Water Reactor Assemblies with Neutron Absorber Plates

A drawing exists for this design and was used in conjunction with spreadsheet calculations and engineering sketches to develop the estimate.

D.3.2.2 44 Boiling-Water Reactor Assemblies with No Absorber Plates

No drawings exist for this design. Sufficient analysis of this design has not been completed and, as a result, "Q" drawings cannot be produced. Spreadsheet calculations and engineering sketches were used to develop the estimate.

D.3.2.3 21 Pressurized-Water Reactor Assemblies with Absorber Plates

A drawing exists for this waste package design. Spreadsheet calculations and engineering sketches were used in the estimate.

D.3.2.4 21 Pressurized-Water Reactor Assemblies with No Absorber Plates

No drawings exist for this design. Sufficient analysis of this design has not been completed and, as a result, "Q" drawings cannot be produced. Spreadsheet calculations and engineering sketches were used.

D.3.2.5 21 Pressurized-Water Reactor Assemblies with Control Rods

No drawings exist for this design. Sufficient analysis of this design has not been completed and, as a result, "Q" drawings cannot be produced. Spreadsheet calculations and engineering sketches were used in the estimate. Control rod cost is based on an estimate from a qualified vendor.

D.3.2.6 24 Boiling-Water Reactor Assemblies

No drawings exist for this design. Sufficient analysis of this design has not been completed and, as a result, "Q" drawings cannot be produced. Spreadsheet calculations and engineering sketches were used to develop the estimate.

D.3.2.7 12 Pressurized-Water Reactor Assemblies with No Absorber Plates

A drawing exists for this design. It was used in conjunction with spreadsheet calculations to develop the estimate.

D.3.2.8 12 Pressurized-Water Reactor Assemblies South Texas Long Design with Absorber Plates

No drawings exist for this design. Sufficient analysis of this design has not been completed and, as a result, "Q" drawings cannot be produced. Spreadsheet calculations and engineering sketches were

used to develop the estimate. Cost numbers were used from the design for 12 Pressurized-Water Reactor assemblies with no absorber plates, and a ratio was used to obtain material costs. The cost for the borated stainless steel plates was added.

D.3.3 Defense High-Level Radioactive Waste Packages

D.3.3.1 5 Defense High-Level Radioactive Waste, Long

No drawings exist for this design. Sufficient analysis of this design has not been completed and, as a result, "Q" drawings cannot be produced. Spreadsheet calculations and engineering sketches were used to develop the estimate.

D.3.3.2 5 Defense High-Level Radioactive Waste, Short

A drawing exists for this design, and it was used in conjunction with spreadsheet calculations to develop the estimate.

D.3.4 DOE Spent Nuclear Fuel Waste Packages

No drawings exist for this design. Sufficient analysis of this design has not been completed and, as a result, "Q" drawings cannot be produced. Spreadsheet calculations and engineering sketches were used to develop the estimate.

D.3.5 U.S. Navy Canistered Fuel Waste Package

No drawings exist for this design. Sufficient analysis of this design has not been completed and, as a result, "Q" drawings cannot be produced. Spreadsheet calculations and engineering sketches were used to develop the estimate. There are a total of 300 naval spent nuclear fuel packages to be emplaced. The Monitored Geologic Repository-VA cost estimate included 285 packages through the year 2033. The final 15 are emplaced in 2034; their cost is contained in the Total System Life Cycle Cost estimate.

D.3.6 Waste Package Supports

No drawing exists for this design. A conceptual engineering sketch and hand calculations were used to develop the estimate.

D.4 ESTIMATE SUMMARY

During the Licensing Phase, all costs are associated with waste package design. These costs range from $11 million to $14 million/year. In the Pre-Emplacement Construction Phase, total annual costs range from $7 million to $9 million. In 2009, a large number of waste package supports will be purchased, raising the total costs for that year to $19 million.

The major annual costs during the Emplacement Operations Phase come from waste package fabrication and emplacement; these costs are expected to be about $180 million/year. During this phase, the total annual cost periodically increases to over $200 million as a result of periodic purchases of waste package supports.

Costs during the Monitoring Phase remain level at roughly $300,000 a year to support material corrosion performance confirmation. No costs are incurred during the Closure and Decommissioning Phase.

Table D-1 shows waste package unit quantities and costs. Table D-2 and Figure D-1 show waste package annual costs. Table D-3 and Figure D-2 show the waste package capital and operating and maintenance costs summary. Dollar amounts are summary figures derived from detailed calculations. Some minor differences or variations in the figures may occur due to effects from computational rounding of the numbers.

Table D-2. Waste Package Annual Fabrication Costs
(1998 $ in Millions)

Year	Yearly Totals	Commercial Spent Nuclear Fuel Containers	Defense High-Level Waste Containers	DOE Spent Nuclear Fuel Containers	Design	Waste Package Supports
2002*	11.1	0.0	0.0	0.0	11.1	0.0
2003	13.1	0.0	0.0	0.0	13.1	0.0
2004	14.2	0.0	0.0	0.0	14.2	0.0
2005	9.6	0.0	0.0	0.0	9.6	0.0
2006	8.1	0.0	0.0	0.0	8.1	0.0
2007	7.7	0.0	0.0	0.0	7.7	0.0
2008	7.2	0.0	0.0	0.0	7.2	0.0
2009	19.4	0.0	0.0	0.0	7.2	12.3
2010	38.2	24.4	7.5	0.4	5.9	0.0
2011	45.1	34.9	7.5	0.4	2.3	0.0
2012	102.0	57.7	7.5	1.1	3.9	31.9
2013	112.3	93.1	7.5	2.1	2.3	7.4
2014	146.3	133.6	7.5	2.9	2.3	0.0
2015	173.0	132.8	17.8	12.8	2.3	7.4
2016	210.7	136.5	18.8	18.9	2.1	34.3
2017	184.5	133.0	23.2	16.4	2.1	9.8
2018	184.6	131.8	22.9	27.9	2.1	0.0
2019	185.9	131.3	23.2	21.9	2.1	7.4
2020	207.7	129.8	21.3	22.6	2.1	31.9
2021	187.4	132.9	21.6	23.5	2.0	7.4
2022	172.1	132.0	21.3	16.8	2.0	0.0
2023	170.4	130.3	21.3	16.8	2.0	0.0
2024	189.8	133.4	21.3	18.4	2.0	14.7
2025	204.2	131.5	21.3	20.0	2.0	29.4
2026	182.2	132.4	20.0	20.7	1.9	7.4
2027	174.1	132.0	20.0	20.3	1.9	0.0
2028	173.5	131.3	20.0	20.3	1.9	0.0
2029	194.0	131.6	25.2	20.7	1.9	14.7
2030	212.0	134.2	25.2	21.3	1.9	29.4
2031	193.9	132.6	25.2	24.5	1.9	9.8
2032	185.2	134.2	25.3	23.9	1.9	0.0
2033	118.8	83.8	16.6	16.5	1.9	0.0
2034	0.3	0.0	0.0	0.0	0.3	0.0
2035	0.3	0.0	0.0	0.0	0.3	0.0
2036	0.3	0.0	0.0	0.0	0.3	0.0
2037	0.3	0.0	0.0	0.0	0.3	0.0
2038	0.3	0.0	0.0	0.0	0.3	0.0
2039	0.3	0.0	0.0	0.0	0.3	0.0
2040	0.3	0.0	0.0	0.0	0.3	0.0
2041	0.3	0.0	0.0	0.0	0.3	0.0
2042	0.3	0.0	0.0	0.0	0.3	0.0
2043	0.3	0.0	0.0	0.0	0.3	0.0
2044	0.3	0.0	0.0	0.0	0.3	0.0
2045	0.3	0.0	0.0	0.0	0.3	0.0
2046	0.3	0.0	0.0	0.0	0.3	0.0
2047	0.3	0.0	0.0	0.0	0.3	0.0
2048	0.3	0.0	0.0	0.0	0.3	0.0
2049	0.3	0.0	0.0	0.0	0.3	0.0
2050	0.3	0.0	0.0	0.0	0.3	0.0
2051	0.3	0.0	0.0	0.0	0.3	0.0
2052	0.3	0.0	0.0	0.0	0.3	0.0
2053	0.3	0.0	0.0	0.0	0.3	0.0
2054	0.3	0.0	0.0	0.0	0.3	0.0
2055	0.3	0.0	0.0	0.0	0.3	0.0
2056	0.3	0.0	0.0	0.0	0.3	0.0
2057	0.3	0.0	0.0	0.0	0.3	0.0
2058	0.3	0.0	0.0	0.0	0.3	0.0
2059	0.3	0.0	0.0	0.0	0.3	0.0
2060	0.3	0.0	0.0	0.0	0.3	0.0
2061	0.3	0.0	0.0	0.0	0.3	0.0

Table D-2. Waste Package Annual Fabrication Costs (Continued)
(1998 $ in Millions)

Year	Yearly Totals	Commercial Spent Nuclear Fuel Containers	Defense High-Level Waste Containers	DOE Spent Nuclear Fuel Containers	Design	Waste Package Supports
2062	0.3	0.0	0.0	0.0	0.3	0.0
2063	0.3	0.0	0.0	0.0	0.3	0.0
2064	0.3	0.0	0.0	0.0	0.3	0.0
2065	0.3	0.0	0.0	0.0	0.3	0.0
2066	0.3	0.0	0.0	0.0	0.3	0.0
2067	0.3	0.0	0.0	0.0	0.3	0.0
2068	0.3	0.0	0.0	0.0	0.3	0.0
2069	0.3	0.0	0.0	0.0	0.3	0.0
2070	0.3	0.0	0.0	0.0	0.3	0.0
2071	0.3	0.0	0.0	0.0	0.3	0.0
2072	0.3	0.0	0.0	0.0	0.3	0.0
2073	0.3	0.0	0.0	0.0	0.3	0.0
2074	0.3	0.0	0.0	0.0	0.3	0.0
2075	0.3	0.0	0.0	0.0	0.3	0.0
2076	0.3	0.0	0.0	0.0	0.3	0.0
2077	0.3	0.0	0.0	0.0	0.3	0.0
2078	0.3	0.0	0.0	0.0	0.3	0.0
2079	0.3	0.0	0.0	0.0	0.3	0.0
2080	0.3	0.0	0.0	0.0	0.3	0.0
2081	0.3	0.0	0.0	0.0	0.3	0.0
2082	0.3	0.0	0.0	0.0	0.3	0.0
2083	0.3	0.0	0.0	0.0	0.3	0.0
2084	0.3	0.0	0.0	0.0	0.3	0.0
2085	0.3	0.0	0.0	0.0	0.3	0.0
2086	0.3	0.0	0.0	0.0	0.3	0.0
2087	0.3	0.0	0.0	0.0	0.3	0.0
2088	0.3	0.0	0.0	0.0	0.3	0.0
2089	0.3	0.0	0.0	0.0	0.3	0.0
2090	0.3	0.0	0.0	0.0	0.3	0.0
2091	0.3	0.0	0.0	0.0	0.3	0.0
2092	0.3	0.0	0.0	0.0	0.3	0.0
2093	0.3	0.0	0.0	0.0	0.3	0.0
2094	0.3	0.0	0.0	0.0	0.3	0.0
2095	0.3	0.0	0.0	0.0	0.3	0.0
2096	0.3	0.0	0.0	0.0	0.3	0.0
2097	0.3	0.0	0.0	0.0	0.3	0.0
2098	0.3	0.0	0.0	0.0	0.3	0.0
2099	0.3	0.0	0.0	0.0	0.3	0.0
2100	0.3	0.0	0.0	0.0	0.3	0.0
2101	0.3	0.0	0.0	0.0	0.3	0.0
2102	0.3	0.0	0.0	0.0	0.3	0.0
2103	0.3	0.0	0.0	0.0	0.3	0.0
2104	0.3	0.0	0.0	0.0	0.3	0.0
2105	0.3	0.0	0.0	0.0	0.3	0.0
2106	0.3	0.0	0.0	0.0	0.3	0.0
2107	0.3	0.0	0.0	0.0	0.3	0.0
2108	0.3	0.0	0.0	0.0	0.3	0.0
2109	0.3	0.0	0.0	0.0	0.3	0.0
2110	0.0	0.0	0.0	0.0	0.0	0.0
2111	0.0	0.0	0.0	0.0	0.0	0.0
2112	0.0	0.0	0.0	0.0	0.0	0.0
2113	0.0	0.0	0.0	0.0	0.0	0.0
2114	0.0	0.0	0.0	0.0	0.0	0.0
2115	0.0	0.0	0.0	0.0	0.0	0.0
2116	0.0	0.0	0.0	0.0	0.0	0.0
Total	**4,058.6**	**2,811.1**	**448.9**	**391.1**	**152.7**	**254.8**

*Costs in the year 2002 are for 7 months.

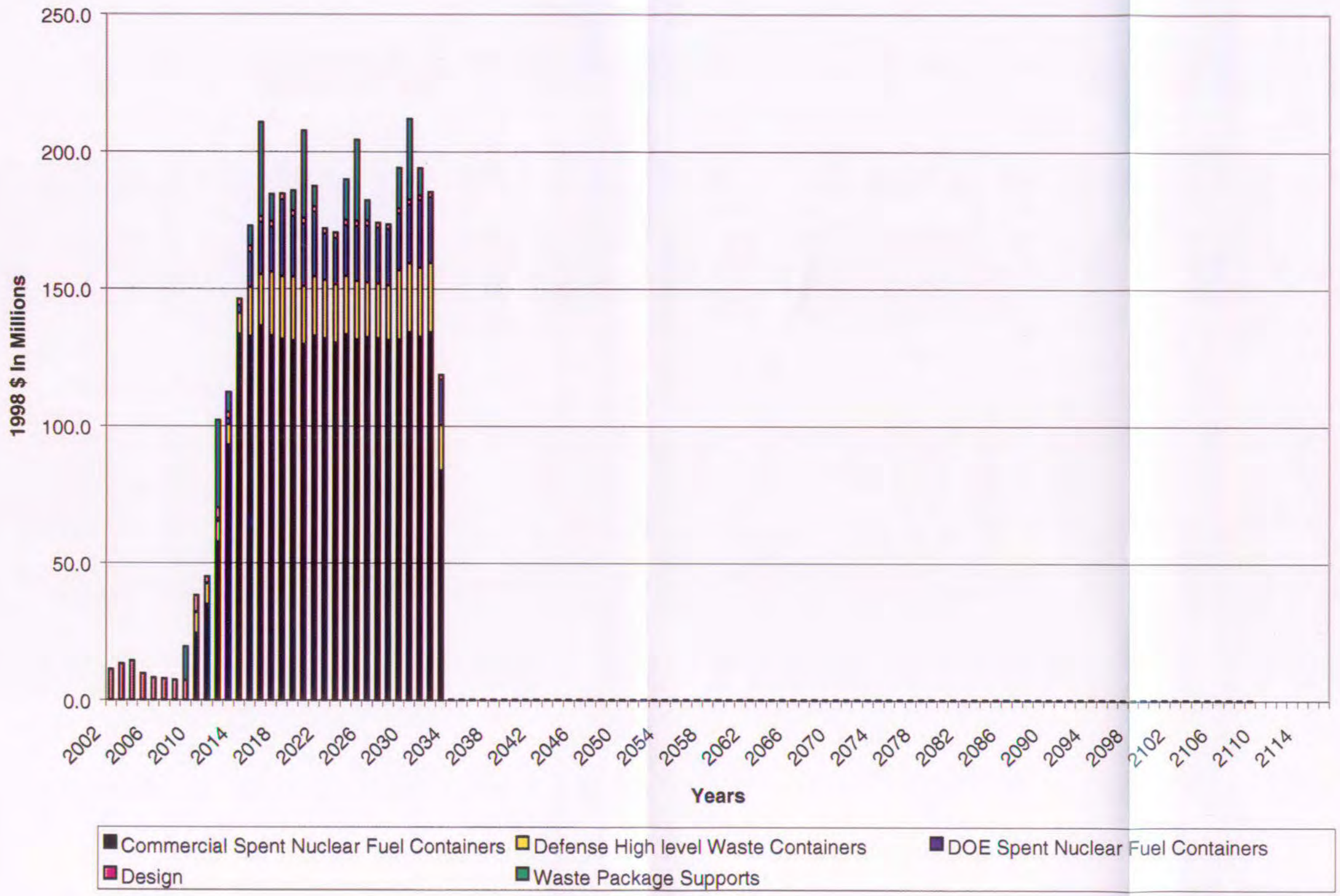

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Figure D-1.Waste Package Annual Fabrication Cost Distribution

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Table D-3. Waste Package Capital and Operating and Maintenance Costs Summary
(1998 $ in Millions)

Phase	Waste Packages Totals		Commercial Spent Nuclear Fuel		Defense High-Level Waste		DOE Spent Nuclear Fuel		Waste Package Design		Waste Package Supports	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Licensing	38.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.5	0.0	0.0	0.0
Pre-Emplacement Construction	52.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.8	0.0	12.3	0.0
Emplacement Operations	3,948.0	0.0	2,811.1	0.0	448.9	0.0	391.1	0.0	54.3	0.0	242.6	0.0
Monitoring	0.0	20.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.2	0.0	0.0
Closure and Decommissioning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total	**4,038.4**	**20.2**	**2,811.1**	**0.0**	**448.9**	**0.0**	**391.1**	**0.0**	**132.5**	**20.2**	**254.8**	**0.0**

O&M–Operating and maintenance

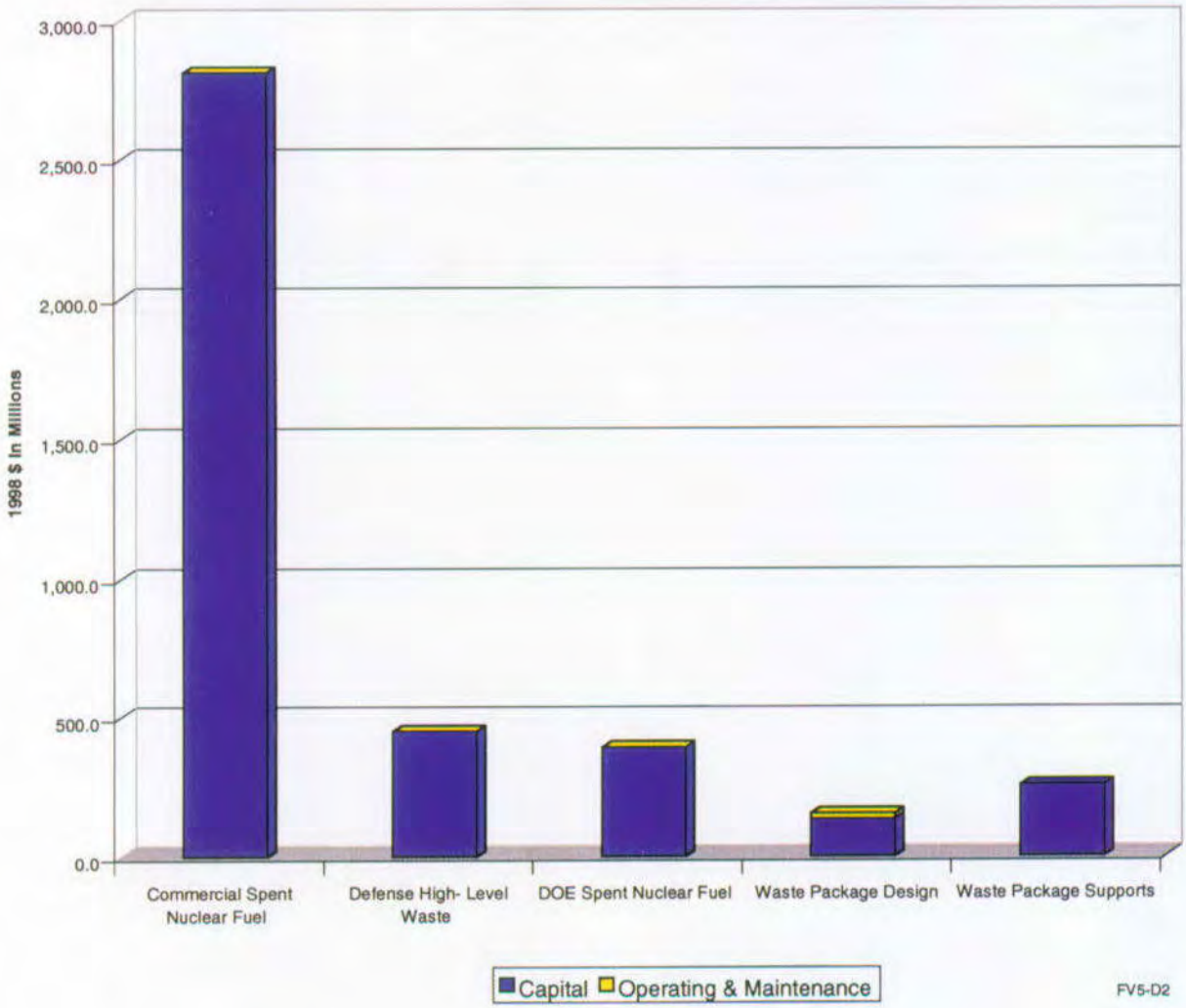

Figure D-2. Waste Package Capital and Operating and Maintenance Costs Summary (1998 $ in Millions)

APPENDIX E

PERFORMANCE CONFIRMATION

APPENDIX E

PERFORMANCE CONFIRMATION

This appendix presents the cost estimate for the performance confirmation program that would monitor repository system performance. The cost estimate is based on the *Performance Confirmation Plan* (CRWMS M&O 1997), which defines performance confirmation parameters and describes concepts for measuring, monitoring, observing, and testing them. It also describes the types of activities and equipment necessary to acquire data for monitoring performance.

NRC regulations require a performance confirmation program. Although DOE is still developing this program, and issues resolved during the upcoming licensing proceedings could affect it, the scope is discussed in this appendix in some detail. This was required to compile the performance confirmation cost estimate. The principal factors affecting postclosure performance are discussed in Volume 3.

For each cost element defined in Volume 5, Section 1.4, this appendix defines scope on a summary level, identifies the methodologies used to develop the cost estimate as well as the assumptions on which the estimate is based, and presents summary results.

The summary results are presented as tables and figures that show estimates by cost element and project phase. In addition, annual cost distributions, as well as capital, operating, and maintenance costs, are provided (see Section E.4).

E.1 SCOPE OF MAJOR COST ELEMENTS

E.1.1 Site Testing

This element includes all costs for subsurface geologic mapping and sampling, surface-based hydrologic instrumentation and monitoring, underground fault zone hydrologic testing, sample testing, full-scale thermal instrumentation and testing, and general surface-based testing.

Subsurface mapping and sampling would provide information on stratigraphy, lateral extent, depth, thickness, rock type, mineralogy and fracture density, and on characteristics of major fracture sets and faults such as location, width, length, aperture, orientation, displacement, and mineralogy of infillings. Offsite laboratory analyses of samples taken from the site would confirm subsurface conditions for parameters related to rock hydrologic properties. If unanticipated geologic conditions were encountered, issues related to percolation flux through the repository horizon could be addressed, as needed.

Hydrologic instrumentation and monitoring in surface-based boreholes would provide information on rock and water temperature, gas pressure, moisture content, and in situ fluid potential derived from thermocouple psychrometer measurements of temperature and relative humidity.

Subsurface fault zone hydrologic testing would provide information on rock and water temperature, and on rock mass permeability, gas pressure, moisture content, and in situ fluid potential.

Thermal testing and monitoring would provide information on rock and water temperature; rock mass permeability and deformation; gas pressure; moisture content; relative humidity; water chemistry; and in situ rock stress from subsurface testing, monitoring, and sampling.

General site testing and monitoring would include infiltration investigations, seismic instrumentation and monitoring, sample management, and monitoring of ground elevation changes. Also included would be the monitoring of regulatory compliance.

E.1.2 Repository Testing

This element includes all costs associated with in situ seal testing for ramp, shaft, and borehole applications; in situ design testing; near-field testing; and laboratory testing for hydrocarbons remaining in the repository. In situ testing of seal designs and materials could require multiple test locations.

E.1.3 Waste Package Testing

This element includes all costs associated with offsite laboratory testing of waste package materials and waste forms, in situ waste package monitoring, and testing of recovered waste package material specimens. The key parameters affecting waste package performance to be measured in laboratory testing include those associated with oxidation and aqueous corrosion. All corrosion degradation modes identified as important to either the outer or inner barrier of the waste package would be measured in long-term laboratory corrosion tests. Oxidation and corrosion products would be characterized. Waste package in situ monitoring would include monitoring a variety of parameters in the subsurface excavations and surrounding rocks, including gaseous radionuclides, whose presence would indicate an early waste package failure; container surface temperature; and humidity.

Several methods would be used to determine how waste package materials were behaving in the actual emplacement drift environment. Specimens, mostly container materials, would be placed in various locations within the repository to cover a reasonable range of expected geological and geochemical variations. Dummy waste packages would be placed within the emplacement drifts. The key parameters monitored would be corrosion and other degradation characteristics of each waste package barrier. These include the dry oxidation rate and the different phenomena occurring in humid atmospheres and under aqueous conditions, such as threshold humidity level, humid-air general corrosion rate, aqueous general corrosion rate, pitting corrosion characteristics in humid air and in aqueous conditions, and microbial corrosion characteristics. If examination of recovered specimens revealed unanticipated conditions, testing and measurements would be conducted by withdrawing a dummy waste package and examining it either in the surface facility or at an offsite laboratory.

Waste package material testing could involve the recovery of actual waste packages for inspection and testing purposes. Because such recovery and testing is extremely costly, it would be used only as a contingency; that is, should a breached, damaged, or malfunctioning waste package be detected, it would be retrieved and brought back to the surface facility for repair or repackaging, as appropriate.

E.1.4 Subsurface Facilities and Equipment

This element includes all costs associated with subsurface test facilities and support concepts, which would consist of an integrated network of systems to directly monitor the emplacement drift environment; monitor the geologic, hydrologic, and geochemical conditions adjacent to the emplacement drifts; and monitor conditions surrounding the repository block. A number of different support facilities would be needed to do this. The parameter to be monitored and the equipment needed to do so would dictate the type and location of the support facility.

Subsurface support facilities would include observation drifts and alcoves near the emplacement area, remotely operated systems for emplacement drift monitoring, monitoring equipment in the exhaust ventilation system, and recovery of actual waste packages, as a contingency. Observation drifts would provide access for thermal monitoring of areas altered by heat emitted by waste packages. Remote observation and inspection of emplacement drifts would include visual, thermal, and radiological monitoring. Because radiation levels and temperatures in the emplacement drifts probably would be relatively high, remote observation would be necessary. A remotely operated visual inspection system would obtain records of waste package surfaces, drift inverts and walls, ground support systems, and drift collapse and rockfalls in the drifts following waste emplacement.

A remotely operated thermal inspection system would measure waste package surface temperature, temperature on the emplacement drift wall, and drift air temperature following waste emplacement. Remote radiological inspection would monitor radiation levels in the emplacement drifts following waste emplacement to detect potential waste package failure and radionuclide release. Ventilation drift monitoring would provide observations of the incoming and outgoing conditions in the emplacement drift air, including

temperature, relative humidity, and presence of gaseous radionuclides.

E.1.5 Evaluating and Reporting

Data collected during the performance confirmation program would be used to update the models that evaluate total system performance, as needed. Results of monitoring and analysis could confirm the system-predicted response. If actual conditions differed from those predicted, the results could support further evaluations of the impact of those conditions on long-term performance of the repository system.

Modeling results also would enable analysts to evaluate the predictive capability of TSPA models and to refine them, as appropriate. Consequently, TSPA modeling would be a continuing task, as needed, during the performance confirmation program. Data collected from monitoring also could be used to update regulatory reports and licensing documents, as required.

E.2 ESTIMATING METHODOLOGIES

E.2.1 Site Testing

For this element, two cost estimating methodologies were used: bottom-up and roundtable. Bottom-up was used where monitoring methods were well defined and mature enough to identify discrete elements of labor, equipment, and material. The detailed bottom-up estimate was prepared using test requirements and supplemented with assumptions as the basis for determining cost estimates. Roundtable was used where monitoring methods were conceptually defined or where the equipment or method requires further development. The roundtable estimate was prepared using costs and requirements for other test elements as the basis for roughly estimating labor, equipment, and material costs.

E.2.2 Repository Testing

For this element, two cost estimating methodologies were used: bottom-up and roundtable. Bottom-up was used were monitoring methods were well defined and mature enough to identify discrete elements of labor, equipment, and material. The detailed bottom-up estimate was prepared using the test requirements and supplemented with assumptions as the basis for determining cost estimates. Roundtable was used where monitoring methods were conceptually defined or where the equipment or method requires further development. The roundtable estimate was prepared using costs and requirements for other test elements as the basis for roughly estimating labor, equipment, and material costs.

E.2.3 Waste Package Testing

For this element, a roundtable estimate was prepared using costs and requirements from current activities as the basis for roughly estimating labor, equipment, and material costs.

E.2.4 Subsurface Facilities and Equipment

For this element, a detailed bottom-up estimate was prepared using facility and equipment requirements supplemented with assumptions as the basis for estimating labor, equipment, and material costs.

E.2.5 Evaluation and Reporting

For this element, a roundtable estimate was prepared using costs and requirements from current activities as the basis for roughly estimating labor, equipment, and material costs.

E.2.6 Contingency Rates

Estimators calculated the following contingency rate for each cost element:

Cost Element	Contingency Rate
Site Testing	22 percent
Repository Testing	22 percent
Waste Package Testing	9 percent
Subsurface Facilities and Equipment	15 percent
Evaluation and Reporting	18 percent

The differences in the contingency rates reflect the degree of maturity of the performance confirmation program and the information available for the activities contained in each cost element.

E.3 ESTIMATING ASSUMPTIONS

This section describes general and specific assumptions used to develop the estimate. High-level assumptions that apply to all major cost elements are discussed in Section 3.

E.3.1 Site Testing

To develop cost estimates, this major cost element was divided into six subelements: Subsurface Geologic Mapping and Sampling, Surface-Based Hydrology, Underground Fault Zone Hydrology, Sample Testing, Full-Scale Thermal Instrumentation and Testing, and General Site Monitoring and Testing. Assumptions were then defined for each subelement.

E.3.1.1 Subsurface Geologic Mapping and Sampling

Five hundred core samples will be taken.

Ten percent of the emplacement drifts will be mapped. The total tunnel length to be mapped will be 50,550 m (165,800 ft), based on the sum of the perimeter main drifts; 12,000 m (39,400 ft) of emplacement drifts; three cross-block access drifts; and five observation drifts, turnouts, and test alcoves.

Single-pass geological observations will be made and recorded in the construction of all emplacement drifts and tunnels.

E.3.1.2 Surface-Based Borehole Hydrology

Five new boreholes with an average depth of 760 m (2,490 ft) will be drilled using a reverse-air-circulation drill rig.

Instrumentation for unsaturated zone and saturated zone monitoring will be combined in each borehole.

E.3.1.3 Underground Fault Zone Hydrology

One underground fault zone test site will be established.

The testing site will have one 30-m (100-ft) geothermal borehole and three 15-m (50-ft) boreholes.

E.3.1.4 Sample Testing

Three initial baseline microbial samples will be taken immediately after excavation to ensure establishment of baseline microbial population; 43 additional baseline samples will be taken from 2006 to 2027.

Five additional samples will be taken every 5 years from 2029 to 2109 to establish changes in the biota due to human activity.

A total of 169 samples from the mapped drifts will be analyzed for apparent age of minerals. Samples will be collected at 300-m (980-ft) intervals within tunnels. This sample density is a gross average and will vary locally within the repository.

To determine the age of pore fluids, 189 samples will be tested for Chlorine-36 levels from 2005 to 2027. An additional 589 samples will be tested from 2010 to 2109.

A total of 97 samples will be tested for stable isotopes, radiogenic isotopes, and major ions.

E.3.1.5 Full-Scale Thermal Instrumentation and Testing Assumptions

Five observation drifts will be required and five areas will be instrumented. Each area extends from 100 to 200 m (330 to 660 ft). Within each area, three to six emplacement drifts will be monitored.

Instrumentation holes will be drilled from within 20 alcoves (approximately 10 m, or 30 ft, in length) for each monitoring area, including alcoves along each observation drift and along the Exhaust Main or Perimeter drifts.

Each alcove will contain 14–16 boreholes with an average depth of 100 m (330 ft).

Approximately 17,000 sensors will be installed in boreholes.

E.3.1.6 General Site Monitoring and Testing

Twenty stations for monitoring ground elevation changes will be located on the surface directly above emplacement drifts.

Monitoring will continue from 2006 through January 2110.

Infiltration monitoring will be conducted in existing surface-based boreholes and within existing alcoves and niches in the Exploratory Studies Facility and repository.

Infiltration observations and measurements will be performed in 3 alcoves and 20 surface-based boreholes.

Seismic monitoring will be conducted at 10 existing surface seismic stations and 2 new underground alcove seismic testing sites.

Only 2 percent of all borehole core will yield samples that require storage. This core quantity equates to about 1,050 m (3,440 ft), primarily from full-scale thermal monitoring boreholes.

All stored samples consist of rock core, no water samples will be stored.

E.3.2 Repository Testing

To develop cost estimates, this major cost element was divided into the following subelements: Seal Testing, Design Testing, Near-Field Testing, and Monitoring of Hydrocarbons Remaining in the Repository.

E.3.2.1 Seal Testing

Two surface-based borehole seal test sites will be required.

Each site will require a pad measuring approximately 20 by 40 m (70 by 130 ft).

Twelve vertical 4-in.-diameter boreholes will be drilled at each test site to an average depth of approximately 9 m (30 ft).

Overcoring will be required to retrieve plug samples at different times.

Laboratory testing of plug material will include strength, elastic modulus, permeability, moisture content, and chemical analyses (degradation).

Field tests of samples of plug material will include viscosity, set time, and density.

Field testing of cured plugs will include air or water permeability, geophysical logging.

Two underground seals testing sites will be required.

Costs associated with full-scale seals testing will be incurred during the normal sealing operations.

E.3.2.2 Design Testing

One in situ testing location will be required.

The mockup waste package will consist of a canister containing heaters.

Testing will simulate final design features for post-closure performance and environments.

E.3.2.3 Near-Field Testing

The testing program will consist of large-scale physical model testing and small-scale testing of component samples.

In situ monitoring of the engineered barrier system components and the waste package environment will use temperature, humidity, and chemistry sensors, piezometers, and strain gauges. Remote-controlled cameras (included in other cost categories) will be used for visual inspection.

Engineered barrier system components and materials to be tested will include waste package supports, grout, invert materials, precast concrete lining, and steel ribs and lagging.

Twenty-five samples per year of 5 materials used in the engineered barrier system will be analyzed over a 5-year period, for a total of 625 samples

between 2005 and 2009. In addition, 10 samples per year of 5 materials will be analyzed over a 20-year period, for a total of 1,000 samples between 2010 and 2029.

To assess the chemical alteration of steel and concrete materials, 125 samples of each material type will be tested from 2005 to 2027, followed by 310 samples for each type from 2010 to 2109.

One hundred twenty-five samples will be analyzed for chemical composition/alteration of concrete from 2005 to 2027.

E.3.2.4 Monitoring of Hydrocarbons Remaining in the Repository

One hundred rock samples will be analyzed for the presence of hydrocarbons.

E.3.3 Waste Package Testing

To develop cost estimates, this major cost element was divided into the following subelements: Offsite Laboratory Testing, In Situ Monitoring and Data Analysis, Dummy Waste Package Testing, and Waste Package Material Specimen Testing.

E.3.3.1 Offsite Laboratory Testing

National laboratories currently participating will continue their participation. Pacific Northwest National Laboratory and Argonne National Laboratory have the facilities needed to test radioactive materials. Lawrence Livermore National Laboratory has an operational long-term corrosion test facility that has been funded by the project. A future trade study is planned to assess the cost-effectiveness of onsite versus offsite laboratory testing.

The staff conducting offsite laboratory testing will be located at each laboratory and in Las Vegas. The Las Vegas staff will manage, plan, and integrate TSPA modeling efforts.

E.3.3.2 In Situ Monitoring and Data Analysis

A remotely operated vehicle will take videos and collect data from the in situ monitors. These data and videos will be available to Lawrence Livermore National Laboratory and the YMP Las Vegas management group for analysis through electronic data transmission.

E.3.3.3 Dummy Waste Package Testing

Ten dummy waste packages will be randomly selected from the fabrication stream. Witness specimens will be placed with the dummy waste packages. After emplacement, the dummy waste packages will be removed if the witness specimens indicate an area of concern or a deviation occurs.

E.3.3.4 Waste Package Material Specimen Testing

A total of 7,680 witness specimens will be placed near waste packages to subject them to the same environmental conditions as waste packages, including dummy waste packages.

E.3.4 Repository Subsurface Support Facilities

To develop cost estimates, this major cost element was divided into two subelements: Permanent Observation Drifts and Test Alcoves, and Remotely Operated Vehicles.

E.3.4.1 Permanent Observation Drifts and Test Alcoves

A 5.5-m (18-ft) -diameter tunnel boring machine will be used to construct the Permanent Observation Drifts; it will progress at the rate of 30 m/day (100 ft/day).

Roadheaders will be used to construct turnouts, alcoves, and other small lead-in and tunnel connectors, as well as small launch chambers for the tunnel boring machine, assembly and disassembly chambers, etc.

E.3.4.2 Remotely Operated Vehicles

One remote-inspection gantry and a spare will be purchased every 10 years because of changes in technology.

E.3.5 Evaluating and Reporting

To develop cost estimates, this major cost element was divided into the following subelements: Technical Data Analysis and Management, and Post-LA Predictions and Periodic TSPAs.

E.3.5.1 Technical Data Analysis and Management

A full-time core staff will provide continuity during the monitoring of the repository. Participation from outside organizations will be minimal.The core staff will consist of the minimum number of people needed to input monitoring data into the technical database.

E.3.5.2 Post-License Application Predictions and Periodic Total System Performance Assessments

After waste emplacement starts, performance assessments will be conducted every 5 years. This will be frequent enough to keep a core staff usefully employed, with half their time spent updating models to reflect advances in hardware, software, and modeling capabilities.

A full-time core staff will provide continuity from one TSPA to the next. The size of that staff will be based on the minimum number of disciplines needed to run TSPA models and modify them as needed. Staff involvement with NRC is expected to peak with submittal of the LA and the LA update.

The issues of climate, tectonics, erosion, volcanism, and human intrusion will be resolved during licensing. However, expertise in these areas may be needed periodically; it will be provided through subcontracts with consultants for the first 10 years.

All criticality issues will be resolved in the first 10 years.

E.4 ESTIMATE SUMMARY

Performance confirmation costs during the Licensing Phase increase from approximately $30 million in 2002 to $56 million in 2005 for TSPA analysis in support of the NRC licensing review. Costs during the Pre-Emplacement Construction Phase range from $29 million to $67 million as equipment is purchased and installed. Emplacement Operations costs are generally on a 5-year cycle, ranging from approximately $24 million to approximately $44 million. This cycle results from the completion of new emplacement drifts and performance confirmation facilities and the emplacement of materials and instrumentation throughout the subsurface environment. Costs during the Monitoring Phase remain relatively level, decreasing slightly over time, with an average of approximately $9 million/year to support sample and data collection, analysis of the material and data, and reporting. Peaks in the costs are estimated every 10 years as remotely operated inspection vehicles are replaced. No performance confirmation costs are incurred during the Closure and Decommissioning Phase.

Table E-1 and Figures E-1a and E-1b show performance confirmation costs summaries. Table E-2 and Figure E-2 show performance confirmation annual cost distribution. Table E-3 and Figure E-3 show performance confirmation capital and operating and maintenance costs. Dollar amounts are summary figures derived from detailed calculations. Some minor differences or variations in the figures may occur due to effects from computational rounding of the numbers.

Table E-1. Performance Confirmation Costs Summary
(1998 $ in Millions)

Phase	Phase Totals	Site Testing	Repository Testing	Waste Package Testing	Subsurface Facilities and Equipment	Evaluation and Reporting
Licensing	123.4	93.1	9.3	21.0	0.0	0.0
Pre-Emplacement Construction	245.9	101.3	29.1	32.3	69.1	14.2
Emplacement Operations	750.4	445.7	46.0	68.9	78.7	111.0
Monitoring	941.6	382.6	62.9	100.2	190.9	205.0
Closure and Decommissioning	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total	**2,061.3**	**1,022.8**	**147.3**	**222.3**	**338.7**	**330.2**

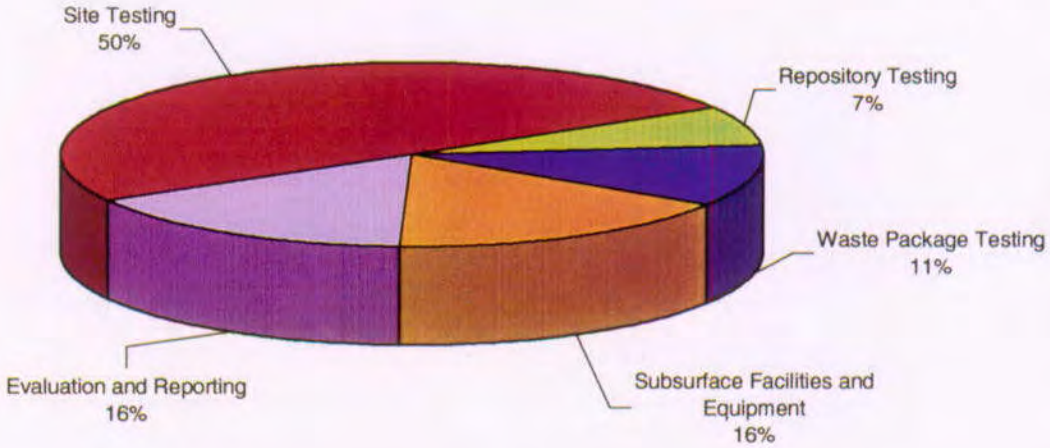

Figure E-1a. Performance Confirmation Percent of Total Cost by Cost Element

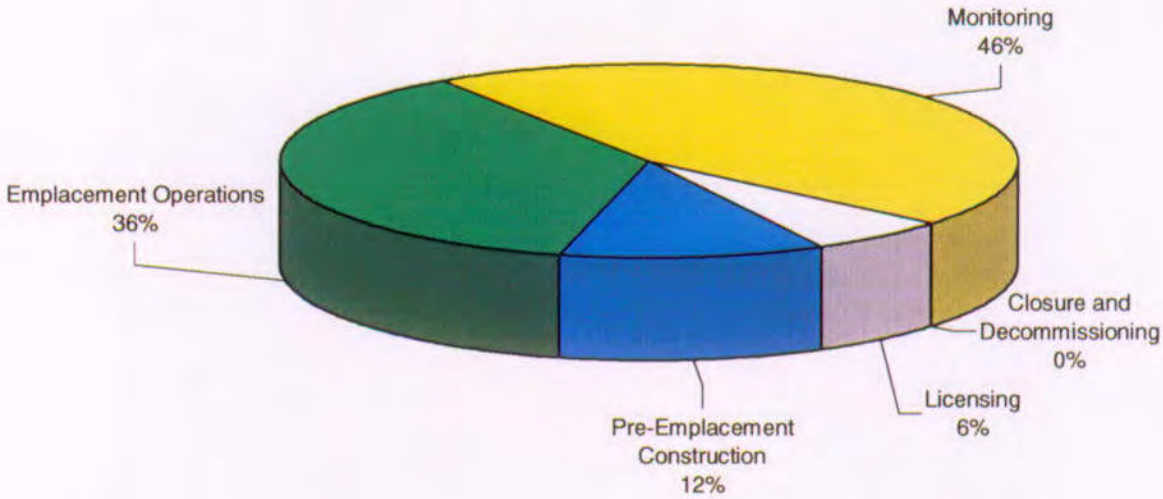

Figure E-1b. Performance Confirmation Percent of Total Cost by Phase

Table E-2. Performance Confirmation Annual Cost Distribution
(1998 $ in Millions)

Year	Yearly Totals	Site Testing	Repository Testing	Waste Package Testing	Subsurface Facilities and Equipment	Evaluation and Reporting
2002 *	30.2	18.9	2.6	8.7	0.0	0.0
2003	41.6	32.0	3.3	6.3	0.0	0.0
2004	51.5	42.2	3.4	6.0	0.0	0.0
2005	56.0	38.8	7.8	7.3	2.1	0.0
2006	48.8	16.9	7.6	6.0	17.0	1.4
2007	29.1	13.0	3.6	6.2	4.0	2.3
2008	44.8	17.0	5.3	6.4	11.8	4.3
2009	67.1	15.5	4.8	6.3	34.3	6.2
2010	40.2	9.7	4.3	4.6	16.2	5.4
2011	30.7	16.5	4.3	4.6	0.0	5.4
2012	43.7	20.1	4.1	4.5	9.6	5.4
2013	32.4	19.0	1.7	4.5	1.9	5.4
2014	26.0	12.0	1.7	5.1	1.9	5.4
2015	32.3	18.7	1.7	4.6	1.9	5.4
2016	35.9	22.4	1.7	4.6	1.9	5.4
2017	37.0	23.4	1.7	4.6	1.9	5.4
2018	27.3	14.2	1.7	4.1	1.9	5.4
2019	27.5	14.2	1.7	4.4	1.9	5.4
2020	30.0	20.8	1.6	1.7	1.9	4.1
2021	33.9	24.6	1.7	1.7	1.9	4.1
2022	41.0	25.3	1.6	1.7	8.4	4.1
2023	25.5	16.2	1.7	1.7	1.9	4.1
2024	32.0	22.8	1.6	1.7	1.9	4.1
2025	35.9	26.6	1.7	1.7	1.9	4.1
2026	34.5	25.3	1.6	1.7	1.9	4.1
2027	27.7	18.4	1.6	1.7	1.9	4.1
2028	25.7	16.6	1.5	1.7	1.9	4.1
2029	26.0	16.7	1.6	1.7	1.9	4.1
2030	24.3	15.2	1.4	1.7	1.9	4.1
2031	25.1	16.0	1.4	1.7	1.9	4.1
2032	30.7	15.2	1.4	1.7	8.4	4.1
2033	25.1	16.0	1.4	1.7	1.9	4.1
2034	24.2	15.1	1.5	1.7	1.9	4.1
2035	24.4	15.7	1.4	1.7	1.9	3.6
2036	23.5	14.9	1.4	1.7	1.9	3.6
2037	24.4	15.7	1.4	1.7	1.9	3.6
2038	23.5	14.9	1.4	1.7	1.9	3.6
2039	24.6	15.9	1.5	1.7	1.9	3.6
2040	14.4	5.8	1.4	1.7	1.9	3.6
2041	15.2	6.6	1.4	1.7	1.9	3.6
2042	21.2	5.8	1.4	1.7	8.7	3.6
2043	15.2	6.6	1.4	1.7	1.9	3.6
2044	14.7	6.0	1.5	1.7	1.9	3.6
2045	15.2	6.6	1.4	1.7	1.9	3.6
2046	14.4	5.8	1.4	1.7	1.9	3.6
2047	15.2	6.6	1.4	1.7	1.9	3.6
2048	14.4	5.8	1.4	1.7	1.9	3.6
2049	15.5	6.8	1.5	1.7	1.9	3.6
2050	13.8	5.4	1.2	1.7	1.9	3.6
2051	13.8	5.4	1.2	1.7	1.9	3.6
2052	19.7	5.4	0.6	1.7	8.4	3.6
2053	13.2	5.4	0.6	1.7	1.9	3.6
2054	14.3	6.4	0.7	1.7	1.9	3.6
2055	13.2	5.4	0.6	1.7	1.9	3.6
2056	13.2	5.4	0.6	1.7	1.9	3.6
2057	13.2	5.4	0.6	1.7	1.9	3.6
2058	13.2	5.4	0.6	1.7	1.9	3.6
2059	14.3	6.4	0.7	1.7	1.9	3.6
2060	11.4	5.4	0.6	1.1	2.0	2.2
2061	11.3	5.4	0.6	1.1	1.9	2.2

Table E-2. Performance Confirmation Annual Cost Distribution
(1998 $ in Millions) (Continued)

Year	Yearly Totals	Site Testing	Repository Testing	Waste Package Testing	Subsurface Facilities and Equipment	Evaluation and Reporting
2062	17.8	5.4	0.6	1.1	8.4	2.2
2063	11.3	5.4	0.6	1.1	1.9	2.2
2064	12.4	6.4	0.7	1.1	1.9	2.2
2065	11.3	5.4	0.6	1.1	1.9	2.2
2066	11.3	5.4	0.6	1.1	1.9	2.2
2067	11.3	5.4	0.6	1.1	1.9	2.2
2068	11.3	5.4	0.6	1.1	1.9	2.2
2069	12.3	6.4	0.7	1.1	1.9	2.2
2070	8.6	2.7	0.6	1.1	1.9	2.2
2071	8.6	2.7	0.6	1.1	1.9	2.2
2072	15.3	2.7	0.6	1.1	8.7	2.2
2073	8.6	2.7	0.6	1.1	1.9	2.2
2074	9.7	3.7	0.7	1.1	1.9	2.2
2075	8.6	2.7	0.6	1.1	1.9	2.2
2076	8.6	2.7	0.6	1.1	1.9	2.2
2077	8.6	2.7	0.6	1.1	1.9	2.2
2078	8.6	2.7	0.6	1.1	1.9	2.2
2079	9.7	3.7	0.7	1.1	1.9	2.2
2080	8.6	2.7	0.6	1.1	1.9	2.2
2081	8.6	2.7	0.6	1.1	1.9	2.2
2082	15.1	2.7	0.6	1.1	8.4	2.2
2083	8.6	2.7	0.6	1.1	1.9	2.2
2084	9.7	3.7	0.7	1.1	1.9	2.2
2085	8.6	2.7	0.6	1.1	1.9	2.2
2086	8.6	2.7	0.6	1.1	1.9	2.2
2087	8.6	2.7	0.6	1.1	1.9	2.2
2088	8.6	2.7	0.6	1.1	1.9	2.2
2089	9.7	3.7	0.7	1.1	1.9	2.2
2090	8.6	2.7	0.6	1.1	1.9	2.2
2091	8.6	2.7	0.6	1.1	1.9	2.2
2092	15.1	2.7	0.6	1.1	8.4	2.2
2093	8.6	2.7	0.6	1.1	1.9	2.2
2094	9.7	3.7	0.7	1.1	1.9	2.2
2095	8.6	2.7	0.6	1.1	1.9	2.2
2096	8.6	2.7	0.6	1.1	1.9	2.2
2097	8.6	2.7	0.6	1.1	1.9	2.2
2098	8.6	2.7	0.6	1.1	1.9	2.2
2099	9.7	3.7	0.7	1.1	1.9	2.2
2100	8.6	2.7	0.6	1.1	1.9	2.2
2101	8.8	2.7	0.6	1.1	2.2	2.2
2102	15.1	2.7	0.6	1.1	8.4	2.2
2103	8.6	2.7	0.6	1.1	1.9	2.2
2104	9.7	3.7	0.7	1.1	1.9	2.2
2105	8.6	2.7	0.6	1.1	1.9	2.2
2106	8.6	2.7	0.6	1.1	1.9	2.2
2107	8.6	2.7	0.6	1.1	1.9	2.2
2108	8.6	2.7	0.6	1.1	1.9	2.2
2109	9.7	3.7	0.7	1.1	1.9	2.2
2110	0.0	0.0	0.0	0.0	0.0	0.0
2111	0.0	0.0	0.0	0.0	0.0	0.0
2112	0.0	0.0	0.0	0.0	0.0	0.0
2113	0.0	0.0	0.0	0.0	0.0	0.0
2114	0.0	0.0	0.0	0.0	0.0	0.0
2115	0.0	0.0	0.0	0.0	0.0	0.0
2116	0.0	0.0	0.0	0.0	0.0	0.0
Total	**2,061.3**	**1,022.8**	**147.3**	**222.3**	**338.7**	**330.2**

*Costs for the year 2002 are for 7 months.

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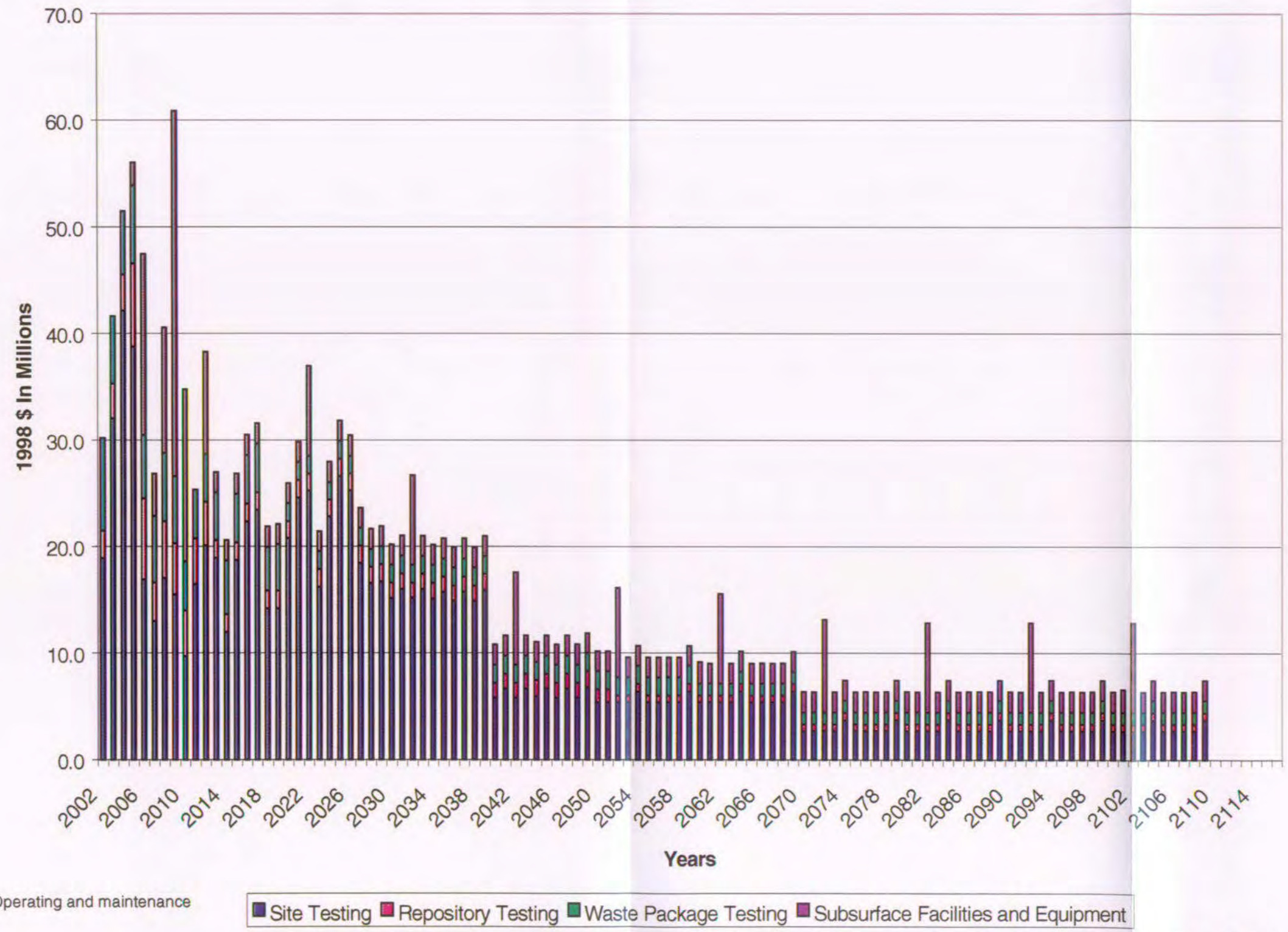

O&M–Operating and maintenance

Figure E-2. Performance Confirmation Annual Cost Distribution

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Table E-3. Performance Confirmation Capital and Operating and Maintenance Cost
(1998 $ in Millions)

Phase	Performance Confirmation Totals		Site Testing		Repository Testing		Waste Package Testing		Repository Subsurface and Support Facilities		Evaluation and Reporting	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Licensing	106.3	17.1	93.1	0.0	9.3	0.0	3.9	17.1	0.0	0.0	0.0	0.0
Pre-Emplacement Construction	191.4	54.5	95.9	5.4	20.0	9.1	6.3	25.9	69.1	0.0	0.0	14.2
Emplacement Operations	182.7	567.6	134.8	311.0	2.5	43.5	7.5	61.4	38.0	40.8	0.0	111.0
Monitoring	55.4	886.2	0.0	382.6	0.0	62.9	8.4	91.8	47.1	143.8	0.0	205.0
Closure and Decommissioning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total	**535.9**	**1,525.4**	**323.8**	**699.0**	**31.8**	**115.5**	**26.1**	**196.2**	**154.2**	**184.6**	**0.0**	**330.2**

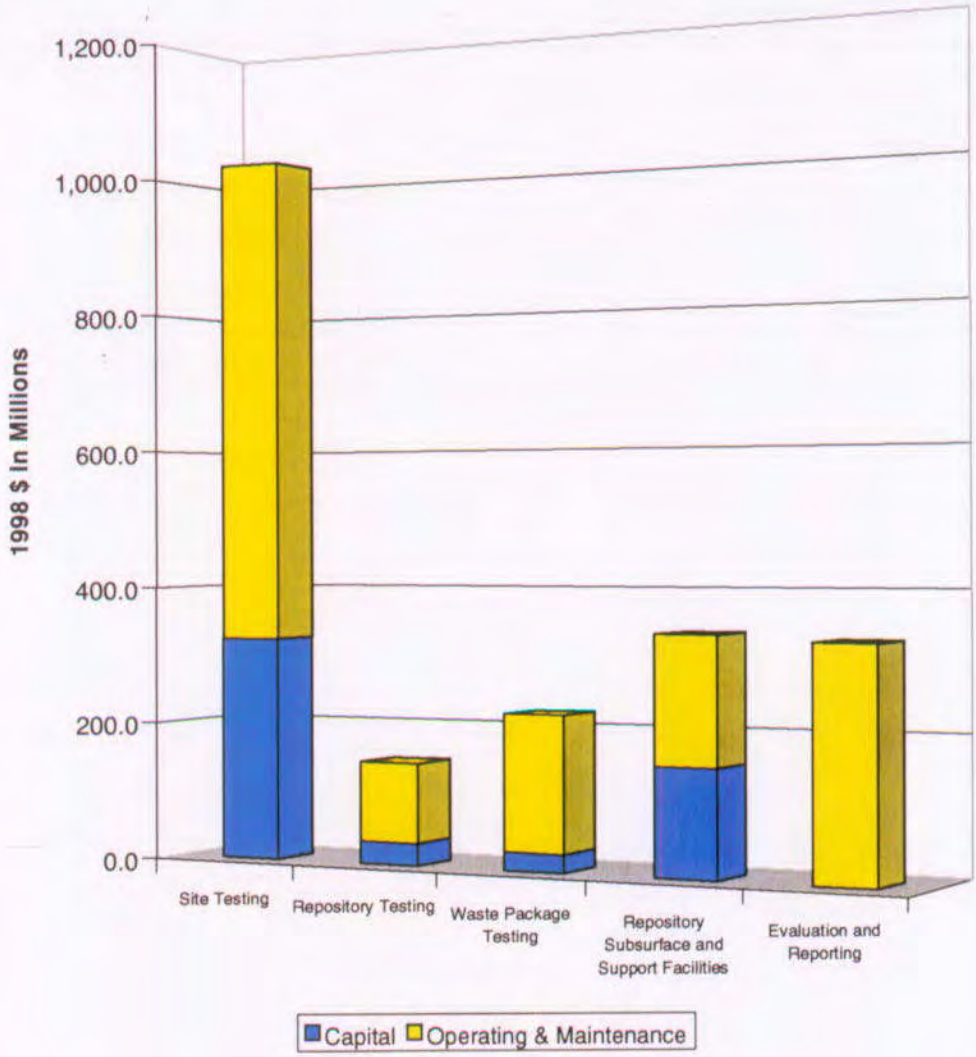

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Figure E-3. Performance Confirmation Capital and Operating and Maintenance Costs

APPENDIX F

REGULATORY, INFRASTRUCTURE, AND MANAGEMENT SUPPORT

APPENDIX F

REGULATORY, INFRASTRUCTURE, AND MANAGEMENT SUPPORT

This appendix presents the cost estimate for regulatory, infrastructure, and management support for the repository at Yucca Mountain.

For each cost element defined in Volume 5, Section 1.5, this appendix further defines the scope, describes the methodologies used to develop the cost estimate, identifies underlying assumptions, and presents summary cost results.

These summary results are presented as tables and figures that show cost estimates by cost element and project phase. In addition, annual cost distributions, as well as capital, operating, and maintenance costs, are provided (see Section F.4).

F.1 SCOPE OF MAJOR COST ELEMENTS

F.1.1 Regulatory

This element includes all costs associated with the following: regulatory support for NRC licensing reviews; development, review, and distribution of the LA update; technical data management; total system performance analyses to support licensing reviews; and license application updates during waste emplacement, monitoring, and closure phases of the repository.

F.1.1.1 Licensing

This subelement includes all costs associated with regulatory support provided for the NRC licensing review, licensing hearings, issuance of the safety evaluation report, and approval of the construction quality assurance program. Included are costs for the development, review, reproduction, and distribution of the LA update as required by NRC during its review for construction authorization. Support is also provided for NRC review of preoperational test results and development of the technical specifications issued by NRC with the license to receive and possess waste.

This support includes responding to technical issues raised during NRC reviews and to any other issues regarding license application and subsequent issuance of the safety evaluation report. Responses will be developed in consultation with the cognizant technical organizations and communicated to NRC in writing or verbally, as required.

This cost element also includes costs for responding to comments and technical issues raised during DOE reviews performed in accordance with the quality assurance program.

F.1.1.2 Technical Data Management

This subelement includes all costs to comply with the regulations regarding management of the technical data management systems. LA design requirements and technical information will be compiled, maintained, and distributed as necessary to support NRC licensing evaluations, license application updates, final procurement, construction design, and performance confirmation activities. Reference and technical information will be compiled and maintained for easy retrieval on an automated technical data tracking system. Summarized and interpretive data will be compiled in a reference information database. An Internet-based information system will be linked to the YMP Intranet.

F.1.1.3 Total System Performance Assessment

This subelement includes all costs associated with the TSPA analyses that will support the NRC licensing review, LA update, and EIS.

For review of the LA for construction authorization, performance assessment management and staff will prepare and present materials; address questions and concerns; and when required, provide follow-up information to address comments. This effort will refine, revise, and expand the TSPA review criteria and issues list, based on review results of the TSPA for the LA, feedback from the TSPA peer review team, results of expert elicitation, and comments from NRC, Nuclear Waste Technical Review Board, or other oversight bodies. The analyses performed will include changes to

repository or engineered barrier system designs and additional data from site characterization and/or design activities. This cost element will cover any of these activities required to respond to comments from DOE and NRC for the LA update.

The performance assessment organization will support providing any required EIS supplement to NRC. This includes additional TSPA analyses required by the EIS.

F.1.1.4 Regulatory Out Years

This cost subelement includes all costs associated with the development, reproduction, and distribution of license application updates. The requirements for an update could be initiated by any of the following:

- Changes to the site description
- Changes in the design or operation of the facility
- Changes in waste characteristics
- Material testing
- Performance confirmation
- Regulatory compliance requirements during the waste emplacement, monitoring, and closure phases of the repository

This cost subelement includes all interactions with NRC regarding enforcement of technical specifications, regulatory interpretations, and any other issues that may arise as a result of normal, off-normal, or accident conditions. Included are the coordination and oversight of any procedural modifications, nuclear material accountability, safeguards and security updates, and radioactive-waste handling issues that are highlighted by either NRC or the licensee. This element also covers the efforts to coordinate and develop the license amendment to close and decommission the facility, including interactions with NRC on removal of institutional controls, maintenance of the postclosure boundary and marker system, verification and validation of test data, performance confirmation data, and postclosure monitoring plans and procedures.

F.1.2 Preconstruction Authorization Site Services

F.1.2.1 Operate and Maintain Preconstruction Site Test Facilities

This cost subelement includes all costs of providing support for the operations and maintenance of site test facilities supporting remaining site characterization and performance confirmation testing from 2002 to 2005. After 2005, the surface estimate contains the costs for those activities that remain. A full description of these test facilities can be found in Volume 4, Section 5.

This cost element includes the following services:

- Management of all site test facilities
- Organization, development, and review of budgets, schedules, annual plans, progress reports, subcontractor change requests, and variance analysis reports
- Performance of preconstruction site test facility operations and maintenance program, access controls, and access transportation
- Provision and maintenance of the electric power delivery system for the test facilities
- General janitorial services, fuel and fueling services, and trash removal services for the site test facilities
- Warehousing and material-handling services
- Testing and construction support, rental equipment, bond, and insurance coverage for the site test facilities
- Maintenance of mobile equipment, buildings and structures, and ground support for the site test facilities

- Testing and maintenance of the repository ventilation system

- Procurement and maintenance of mine rescue and safety equipment

F.1.2.2 Site Logistical Support

This subelement includes all costs of providing support for the operations and maintenance of site services from 2002 to 2005. For the period after 2005, the costs for these services are contained in the Surface estimate. The following services will be provided:

- General support services for Monitored Geologic Repository's field activities

- Information for site operational decisions regarding construction support, facility allocation, and budgeting

- General administrative support to Monitored Geologic Repository employees assigned to Area 25 of the Nevada Test Site

- Development, implementation, and maintenance of field operating instructions

- General facility coordination, planning, and oversight support for the Monitored Geologic Repository team members, tenant managers, and tenants

- YMP facilities input to the operations and maintenance system for the areas of general facility maintenance; infrastructure renovation and repair coordination; building and facility interface; maintenance and repair prioritization; condition assessments; general support facility operations concepts; space planning and allocation; administration of service subcontracts; and coordination of environment, safety and health requirements for facilities, roads, and grounds

- Maintenance, upgrading, and operation of the technical field support systems (Geographic Information System, Global Positioning System, Visual Archive Retrieval System, Maximo Server, and the Condition Assessment Information System) for operational requirements in Area 25 and surrounding areas

- Conducting public outreach programs, including tours and other field activities

- Visitor safety training

- Administration of motor pool assets (pickups, sedans, carryalls, crew cabs, trailers, and vans) for YMP participants

- Administration of the YMP field radio pool and radio and battery maintenance and replacement for the Nevada Test Site

- Field operation instructions for activities and monitoring of project radio communications

- Administration of an accumulation area for hazardous materials and battery disposal

- Maintenance and distribution of general field safety equipment, including fire extinguishers, first aid kits, hard hats, water, ice, and other safety equipment

- Maintenance of respirators issued in coordination with field safety and industrial hygiene personnel

- Public open house and general tour logistics, including bus requirements, schedules, and provision of safety gear to support visitors, scientists, managers, and dignitaries

- General field control and coordination services for Area 25 at the Nevada Test Site

- In-field accountability of YMP personnel and visitors, and visitor control, incident reporting, security coordination, and badging for Monitored Geologic Repository employees at all Nevada locations

- Site property removal

- Participation in development of the YMP emergency management plan
- Implementation of project emergency management activities, including evacuation coordination and drills
- Management of the incident report system including filing and updating occurrence and reporting system reports, tracking for compliance to corrective measures, and maintaining the program authority file
- Reports, and maintenance of files of visits by foreign nationals

F.1.3 Environment, Safety, and Health

This element includes all costs to comply with National Environmental Policy Act including support for NRC adoption of the EIS, coordination and support for development of the LA update, and support for EIS supplements, if necessary. This element provides ongoing support for core environmental safety and health programs such as environmental compliance, state and federal permit compliance, land access and withdrawal, management of hazardous and nonhazardous waste minimization programs, environmental monitoring (e.g., air quality, meteorological, radiological), monitoring work areas for potential hazards, development and implementation of worker safety and health programs, habitat reclamation, and resolution of emerging environmental safety and health issues. This element also includes development and management of a repository operations emergency response plan for protection of workers and the public.

F.1.4 Infrastructure

This element includes costs associated with information management, institutional and external affairs, administrative support services, and project planning and control.

F.1.4.1 Information Management

This cost subelement covers an information management program, which includes the following areas: information technology, telecommunications, and program information management.

Information Technology. The information technology costs cover information and database systems management, network and server operations, user support, planning, compliance, and information security. This subelement includes all tasks associated with the requirements analysis; systems definition; and software application development, testing, implementation, and maintenance. Information technology covers management of project data, including the data dictionary with standardized and normalized data definitions; assurance of the integrity of commercial databases; and systems administration of database management systems on host computers supporting developer and end-user requirements, including any necessary software or hardware upgrades.

Information technology also includes all tasks associated with technical support for desktop computing at local and remote locations and shared operation of a help desk.

Telecommunications. Telecommunications costs cover technical management of all aspects of telecommunications planning, design, implementation, operation, and maintenance. Telecommunications includes all tasks associated with the specification, acquisition, management, operation, and maintenance of Wide Area Networks, Metropolitan Area Networks, and Local Area Networks.

Program Information Management. This cost subelement covers all services related to records management by operating a centralized records processing facility with responsibility for receipt, review, protection, storage, indexing, scanning, tracking, retrieving, and dispositioning of all program records. It includes graphic services and publications support for the entire YMP, including the creation of presentations, presentation archives, graphics posters, technical drawings and schematics, and color and black and white design. Photographic services provided to the general YMP community include photography, image editing, and photographic reprints of existing materials.

Program information management also supports DOE through technical publications management by performing functions related to the creation and maintenance of plans, procedures, technical requirements documents, and *Quality Assurance Requirements and Description* (DOE 1998b).

F.1.4.2 Institutional and External Affairs

This cost subelement covers the administration of an institutional and external affairs program from 2002 to 2010 in three areas: intergovernmental relations, public outreach, and information product development.

Intergovernmental Relations. This subelement includes the coordination of the stakeholder program, including legislative and intergovernmental activities. This program supports and coordinates all YMP interactions with national, state, local, and tribal government entities; regulatory agencies; public interest groups; the Nevada business community; other stakeholders; and the public.

Public Outreach. This subelement covers the cost of a comprehensive public outreach program to promote public interest in and understanding of issues related to the disposal of spent nuclear fuel and high-level radioactive waste via tours of Yucca Mountain; exhibits at community and technical conferences and events; creation of a speakers bureau; operation of science centers in Las Vegas, Pahrump, and Beatty; and creation of an information and inquiry response program, including a toll-free information line and YMP World Wide Web site on the Internet.

Public outreach develops educational programs for the general public and for area schools and colleges. These programs are designed to assist the public in making informed decisions about Yucca Mountain-related issues. Activities under this cost element include responding to public inquiries and information requests by conducting research, as needed, and preparing and tracking responses. Managing and operating the DOE publications and distribution center, toll-free telephone numbers, and the YMP Web site to disseminate public information are also included.

Information Product Development. Costs for the following activities are covered under this subelement: developing, updating, and acquiring audiovisuals, publications, models, commercial print and electronic media announcements, science centers, and exhibits.

F.1.4.3 Administrative Support Services

This subelement includes the cost of facility and equipment management support, office equipment rental and lease, and motor pool operations. Costs for the DOE safeguards and security program are also included here.

F.1.4.4 Project Planning and Control

Project planning and control activities include project management, integrated planning, scheduling, and cost engineering from 2002 to 2010. From 2010 to 2033, cost subelements are provided for project planning and control. However, staffing levels for this phase of the project are based on prior project control support requirements with adjustments to reflect the status of engineering, science, and licensing. Laboratory management has been eliminated.

The cost elements for 2034–2110 included in the estimate for the Monitoring Phase further reduce operations support and provide no construction support.

The Closure and Decommissioning Phase of the project from 2110 to 2116 will require an increase in the staffing of project controls to support construction and dismantling. Staffing is assumed to be less than that required for the original construction. Project control will provide planning, cost control, and budgets for the closure construction. The staffing levels include preparation of final reports and analysis required for decommissioning.

Project Management. The following activities are covered by this cost subelement: coordinating, planning, and reporting progress on tunneling and other operations. It also includes construction contractor project control and the project control activities of teammates at Los Alamos National Laboratory, Lawrence Berkeley Laboratory,

Lawrence Livermore National Laboratory, and Sandia National Laboratories.

Integrated Planning. This subelement covers the costs of coordinating and managing development of the baseline plan that defines an integrated approach for achieving the technical, schedule, and cost goals of YMP in accordance with DOE guidance. This subelement includes costs supporting preparation of change requests to revise project-level cost and technical baselines as required, and to provide analyses to support periodic management reviews, directors' program reviews, and other activities requiring integrated planning and analyses.

Scheduling. This subelement includes costs to develop and maintain an integrated project schedule by planning, collecting, and reporting schedule data for all participant activities. It also includes costs for providing project information that identifies deviations and trends from approved plans and schedules. Recurring costs associated with coordination, receipt, review, and integration of participant schedule data; schedule summarization; and Gantt chart production are also included.

Cost Engineering. These costs cover development and maintenance of integrated estimates, cost baselines, and contract change requests. These activities ensure standardization of cost estimates and assist in development of cost and schedule risk analyses. Included are costs to prepare monthly analyses of project cost and schedule trends and to coordinate with schedulers and project control administration to ensure consistency of project control data from estimate baselining through cost and schedule tracking. Costs for providing cost engineering and estimating support to develop and update capital and operating cost estimates for the Total System Life Cycle Costs are also included. Costs to assist in updating and/or developing other program-level cost components are also covered here. Finally, costs associated with providing expert technical advice in the functional areas of cost and schedule analysis, trend analysis, financial reporting, and exception management, as well as costs to support various management meetings and special requests fall under this subelement.

F.1.5 Training

The costs for a YMP training program during 2002–2007 that meets quality assurance, safety and health, and other DOE-mandated program requirements are included in this cost element. The program includes development and implementation of a systematic approach to training from analyzing needs; designing, developing, implementing, and evaluating courses and programs; and creating instructional materials, overseeing vendors, and selecting delivery methods.

The YMP training program includes development and implementation of training classes for the following topics:

- Environmental, radiation protection, and safety and health
- Quality assurance and work processes
- Configuration management
- Operations and maintenance
- Conduct of operations
- Emergency management
- Computer software

Additional training activities include maintaining the training and qualification records for project personnel and providing training status tracking and notification; providing registration and logistics support for all training classes; and supporting audits, assessments, investigations, committees, and work groups pertaining to project training.

By August 2007, all YMP training function costs will transition to the repository Surface Facilities cost element. This includes all training associated with conduct of operations and related to operations and maintenance.

F.1.6 Set Asides

Set Asides are costs associated with furnishing direct support to DOE operations and other support

programs not specifically covered in other cost elements. These support activities include administrative support services, information management, security services, management and technical services, telecommunications services, and telecommunications video support services.

F.1.7 Monitoring Technical Oversight

This cost element includes all costs associated with providing technical support during the Monitoring Phase from 2034 to 2110. Support activities include failure and root cause analysis, modification support, performance confirmation oversight, and document maintenance.

F.1.8 Overhead and Fee

This element includes costs for DOE contractor overhead and fee. Costs incurred from subcontractors are included in the elements where the burden is incurred. The Overhead category includes technical management, contracting officer's technical representative, business management, human resources, and financial analysis. It also includes the following Las Vegas elements: space and facilities, administrative services, training, publications, property, and technical information center.

Fee calculation is based on a cost-plus-incentive-fee contract. Fee schedules as represented in 48 CFR 915 and 48 CFR 970 are the basis for calculating the fixed-fee portion of the total fee. Based on the unique activities of each project phase, the qualifying categories, and the factoring schedule in the DOE document, factors were applied to each fee base by phase to derive the total fee amounts for each year of the project.

F.2 ESTIMATING METHODOLOGIES

F.2.1 Estimating Techniques

Bottom-up estimating was combined with historical and order-of-magnitude estimating methodologies to develop the Regulatory, Infrastructure, and Management Support cost estimate. Tasks associated with the scope of work were assigned staffing profiles to determine the individual resource cost requirements. The staffing levels also were compared to the balance of the project using a percentage of the total project approach.

Staffing levels during the Emplacement Phase were estimated by using order-of-magnitude methodology and professional judgment derived from previous experience gained at nuclear power stations and industrial construction projects.

F.2.2 Contingency Rates

A contingency rate was determined for each major cost element. The rate was determined by assessing the magnitude of uncertainty as evaluated by cost engineers and other contributors to the estimate. They considered the firmness of the cost element scope definitions, the impact of other project elements, and the phase in which the costs were to be incurred. Generally, as phases progressed further out in time, the contingency value was increased to account for the greater degree of uncertainty and the higher potential for unforeseen events.

Composite contingency rates by major cost element are given below:

Cost Element	Contingency Rate
Regulatory	17%
Pre-Construction Authorization Site Services	9%
Environment, Safety & Health	9%
Infrastructure	15%
Training	9%
Set Asides	16%
Monitoring Technical Support	20%
Overhead and Fee	4%

F.3 COST ESTIMATING ASSUMPTIONS

F.3.1 General Assumptions

- All dollars are constant 1998 dollars.
- Current cost sharing and support arrangements with Nevada Test Site will continue.

F.3.2 Regulatory

Continued emphasis of TSPA studies, testing, and sensitivity analyses to support regulatory activities will be required on the following process models: unsaturated zone hydrology, saturated zone hydrology, unsaturated zone and saturated zone transport, thermal hydrology, waste package degradation, coupled process models, and waste form mobilization.

Interaction with NRC on licensing amendments to possess and emplace waste will be performed.

F.3.3 Preconstruction Authorization Site Services

Operation and maintenance costs for underground preconstruction site test facilities are covered in the Regulatory, Infrastructure, and Management Support estimate for 2002–2005, after which Subsurface estimates pick up the costs.

Site logistical surface facility support is covered in the Regulatory, Infrastructure, and Management Support estimate for 2002–2005, after which Surface estimates assume the scope and budget.

F.3.4 Environment, Safety, and Health

No substantial change in the proposed action or significant new information is assumed that could cause significant environmental impacts requiring a separate EIS. Estimates include costs associated with development of analysis for an EIS supplement, if necessary.

The current number of radiation safety technicians will be maintained through construction.

For the Regulatory, Infrastructure, and Management Support estimate, Environment, Safety, and Health work activities occur only in the 2002–2010 phase. After February 2010, costs associated with these activities are included in estimates for operation of Surface facilities.

F.3.5 Infrastructure

An Internet-based system will be developed to support the licensing process. The system will be phased out in 2010.

Hardware and software upgrades are assumed to occur every 36 months, with one-third of the upgrade occurring each year.

The Surface estimate includes personnel to manage the visitor center for 2011–2033.

No information management support is being provided to Performance Confirmation in the areas of technical data management or performance assessment. For these areas, Performance Confirmation is providing its own support at the Nevada Test Site.

F.3.6 Training

Training of operators is excluded from the training estimate. Costs for initial and update training of operators are included in the Surface facility operations cost estimate.

F.3.7 Set Asides

The current level of support to DOE by the management technical support contractor is assumed to continue through fiscal year 2033.

F.3.8 Overhead and Fee

Overhead costs and fee are included in this estimate as a function of all project elements.

F.4 ESTIMATE SUMMARY

Regulatory, Infrastructure, and Management Support costs will vary considerably according to the activities performed in the different phases.

Regulatory, Infrastructure, and Management Support costs increase from approximately $81 million in 2002 to peak at $137 million in 2004 for supporting the NRC licensing review, preparing Environment, Safety, and Health programs, establishing the Infrastructure, operating the site facilities, and providing Set Aside support.

Costs steadily decrease from $117 million in 2005 to $60 million in 2010 as the surface facilities and initial subsurface emplacement drifts are completed. The Surface cost estimate absorbs the costs of operating site services, Environment, Safety, and Health programs and training during Pre-Emplacement Construction Phase.

Costs level at approximately $30 million/year after the facilities startup period in 2010, with the majority of the Regulatory, Infrastructure, and Management Support costs being Set Asides and Overhead and Fee.

Costs remain level at approximately $5 million/year from 2034 to 2100. Regulatory, Infrastructure, and Management Support picks up the cost for monitoring technical support services during this phase.

Costs start to increase in 2100 as preparations are begun to prepare a license amendment to close and decommission the repository. The costs peak at $15 million in 2110 when heavy NRC interaction on the license amendment is anticipated. Costs decrease to $9 million in 2116 with most of that being incurred to support the remaining infrastructure.

Table F-1 and Figures F-1a and F-1b show the Regulatory, Infrastructure, and Management Support cost summary by cost element and project phase. Table F-2 and Figure F-2 show the annual cost distribution. Table F-3 and Figure F-3 show capital and operating and maintenance cost summaries. Dollar amounts are summary figures derived from detailed calculations. Some minor differences or variations in the figures may occur due to effects from computational rounding of the numbers.

Table F-1. Regulatory, Infrastructure, and Management Support Cost Summary
(1998 $ in Millions)

Phase	Phase Totals	Regulatory	Pre-CA Site Services	Environment, Safety, & Health	Infrastructure	Training	Set Asides	Monitoring Technical Support	Overhead & Fee
Licensing	352.7	49.5	67.0	42.6	71.2	8.3	43.5	0.0	70.7
Pre-Emplacement Construction	503.1	68.0	10.8	89.3	110.3	8.1	84.1	0.0	132.4
Emplacement Operations	753.4	86.4	0.0	7.4	161.1	0.0	228.6	0.0	269.8
Monitoring	490.5	169.2	0.0	0.0	127.2	0.0	0.0	88.6	105.4
Closure and Decommissioning	65.0	29.6	0.0	0.0	31.2	0.0	0.0	0.0	4.1
Grand Total	**2,164.6**	**402.7**	**77.8**	**139.4**	**501.1**	**16.4**	**356.1**	**88.6**	**582.5**

CA–construction authorization

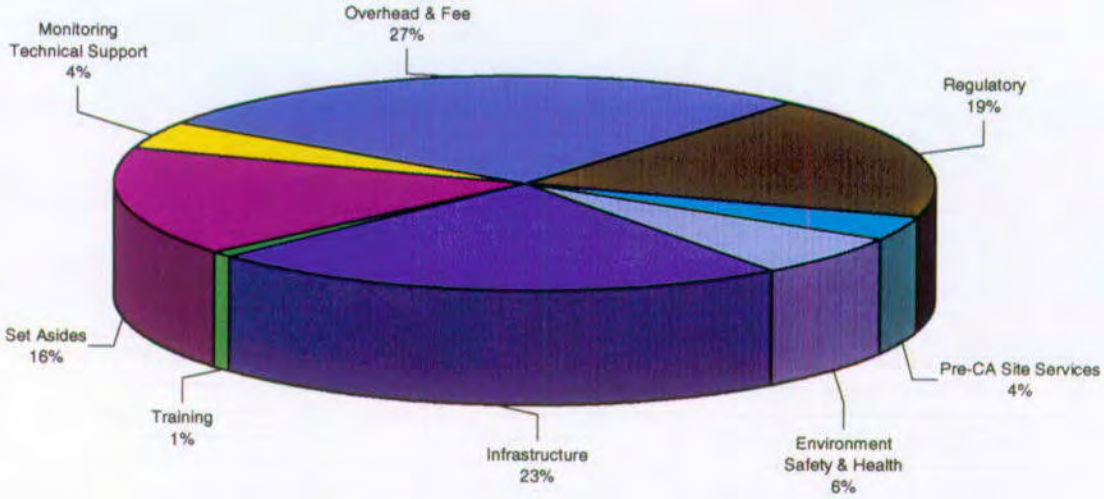

Figure F-1a. Regulatory, Infrastructure, and Management Support Percent of Total Cost by Cost Element

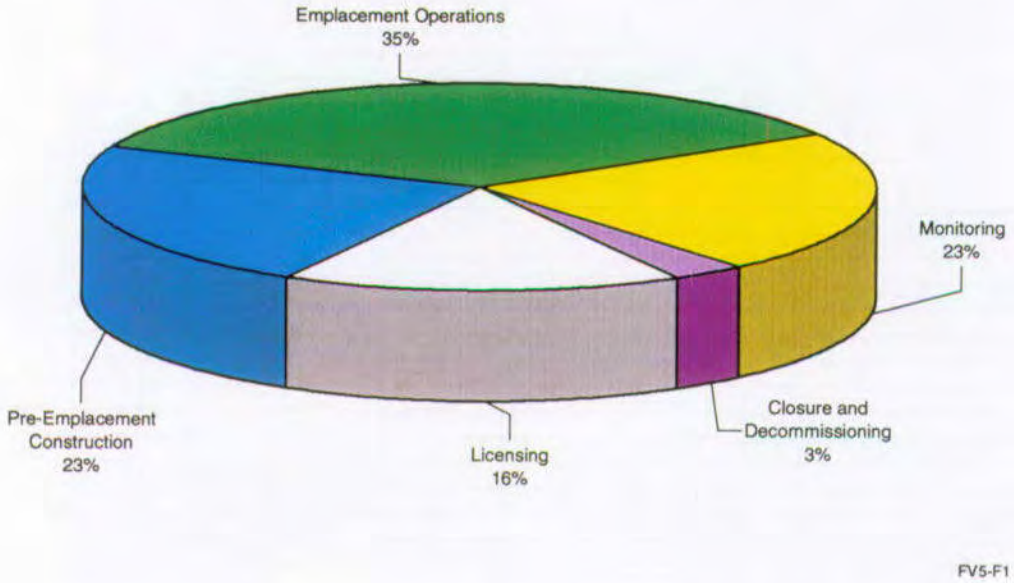

Figure F-1b. Regulatory, Infrastructure, and Management Support Percent of Total Cost by Project Phase

Table F-2. Regulatory, Infrastructure, and Management Support Annual Cost Distribution
(1998 $ in Millions)

Year	Yearly Totals	Regulatory	Pre-CA Site Services	Environment, Safety, & Health	Infrastructure	Training	Set Asides	Monitoring Technical Support	Overhead & Fee
2002*	81.4	11.0	15.1	9.6	16.1	1.9	9.8	0.0	17.8
2003	134.5	17.3	25.9	17.2	27.6	3.2	16.8	0.0	26.4
2004	136.9	21.1	25.9	15.8	27.6	3.2	16.8	0.0	26.4
2005	116.9	17.6	10.8	18.7	24.1	3.0	16.8	0.0	26.0
2006	107.9	19.7	0.0	20.6	21.6	2.8	16.8	0.0	26.5
2007	102.1	16.0	0.0	18.8	21.6	2.3	16.8	0.0	26.7
2008	90.9	9.0	0.0	16.4	21.6	0.0	16.8	0.0	27.2
2009	85.1	5.8	0.0	14.9	21.6	0.0	16.8	0.0	26.0
2010	60.4	5.3	0.0	7.4	12.8	0.0	13.8	0.0	21.1
2011	30.8	3.7	0.0	0.0	6.5	0.0	9.3	0.0	11.3
2012	31.2	3.7	0.0	0.0	6.5	0.0	9.3	0.0	11.7
2013	30.1	3.7	0.0	0.0	6.5	0.0	9.3	0.0	10.6
2014	29.7	3.7	0.0	0.0	6.5	0.0	9.3	0.0	10.2
2015	30.7	3.7	0.0	0.0	6.5	0.0	9.3	0.0	11.2
2016	31.0	3.7	0.0	0.0	6.5	0.0	9.3	0.0	11.6
2017	30.8	3.7	0.0	0.0	6.5	0.0	9.3	0.0	11.3
2018	30.8	3.7	0.0	0.0	6.5	0.0	9.3	0.0	11.3
2019	30.8	3.7	0.0	0.0	6.5	0.0	9.3	0.0	11.3
2020	31.0	3.7	0.0	0.0	6.5	0.0	9.3	0.0	11.5
2021	30.8	3.7	0.0	0.0	6.5	0.0	9.3	0.0	11.3
2022	30.7	3.7	0.0	0.0	6.5	0.0	9.3	0.0	11.2
2023	29.8	3.7	0.0	0.0	6.5	0.0	9.3	0.0	10.3
2024	30.7	3.7	0.0	0.0	6.4	0.0	9.3	0.0	11.3
2025	30.9	3.7	0.0	0.0	6.4	0.0	9.3	0.0	11.5
2026	30.7	3.7	0.0	0.0	6.4	0.0	9.3	0.0	11.3
2027	29.7	3.7	0.0	0.0	6.4	0.0	9.3	0.0	10.4
2028	29.6	3.7	0.0	0.0	6.4	0.0	9.3	0.0	10.2
2029	30.5	3.7	0.0	0.0	6.4	0.0	9.3	0.0	11.1
2030	29.8	3.7	0.0	0.0	6.4	0.0	9.3	0.0	10.4
2031	29.5	3.7	0.0	0.0	6.4	0.0	9.3	0.0	10.1
2032	28.5	2.9	0.0	0.0	6.4	0.0	9.3	0.0	9.9
2033	25.0	1.4	0.0	0.0	6.4	0.0	9.3	0.0	7.8
2034	6.0	1.7	0.0	0.0	1.3	0.0	0.0	1.2	1.8
2035	7.8	1.7	0.0	0.0	1.3	0.0	0.0	1.2	3.5
2036	7.8	1.7	0.0	0.0	1.3	0.0	0.0	1.2	3.5
2037	7.8	1.7	0.0	0.0	1.3	0.0	0.0	1.2	3.5
2038	7.3	1.7	0.0	0.0	1.3	0.0	0.0	1.2	3.0
2039	6.0	1.7	0.0	0.0	1.3	0.0	0.0	1.2	1.8
2040	5.5	1.7	0.0	0.0	1.3	0.0	0.0	1.2	1.2
2041	5.5	1.7	0.0	0.0	1.3	0.0	0.0	1.2	1.2
2042	6.0	1.7	0.0	0.0	1.3	0.0	0.0	1.2	1.8
2043	5.5	1.7	0.0	0.0	1.3	0.0	0.0	1.2	1.2
2044	5.5	1.7	0.0	0.0	1.3	0.0	0.0	1.2	1.2
2045	5.5	1.7	0.0	0.0	1.3	0.0	0.0	1.2	1.2
2046	5.5	1.7	0.0	0.0	1.3	0.0	0.0	1.2	1.2
2047	5.5	1.7	0.0	0.0	1.3	0.0	0.0	1.2	1.2
2048	5.5	1.7	0.0	0.0	1.3	0.0	0.0	1.2	1.2
2049	5.5	1.7	0.0	0.0	1.3	0.0	0.0	1.2	1.2
2050	5.5	1.7	0.0	0.0	1.3	0.0	0.0	1.2	1.2
2051	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2052	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2053	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2054	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2055	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2056	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2057	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2058	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2059	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2060	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2061	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2

Table F-2. Regulatory, Infrastructure, and Management Support Annual Cost Distribution (1998 $ in Millions) (Continued)

Year	Yearly Totals	Regulatory	Pre-CA Site Services	Environment, Safety, & Health	Infrastructure	Training	Set Asides	Monitoring Technical Support	Overhead & Fee
2062	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2063	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2064	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2065	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2066	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2067	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2068	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2069	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2070	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2071	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2072	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2073	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2074	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2075	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2076	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2077	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2078	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2079	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2080	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2081	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2082	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2083	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2084	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2085	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2086	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2087	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2088	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2089	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2090	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2091	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2092	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2093	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2094	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2095	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2096	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2097	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2098	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2099	5.3	1.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2100	8.2	4.7	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2101	6.5	2.9	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2102	6.5	2.9	0.0	0.0	1.2	0.0	0.0	1.2	1.2
2103	10.9	2.9	0.0	0.0	5.6	0.0	0.0	1.2	1.2
2104	16.2	8.2	0.0	0.0	5.6	0.0	0.0	1.2	1.2
2105	13.2	5.3	0.0	0.0	5.6	0.0	0.0	1.2	1.2
2106	13.2	5.3	0.0	0.0	5.6	0.0	0.0	1.2	1.2
2107	13.2	5.3	0.0	0.0	5.6	0.0	0.0	1.2	1.2
2108	13.1	5.3	0.0	0.0	5.5	0.0	0.0	1.2	1.2
2109	13.1	5.3	0.0	0.0	5.5	0.0	0.0	1.2	1.2
2110	15.0	7.9	0.0	0.0	5.5	0.0	0.0	0.5	1.2
2111	12.7	6.2	0.0	0.0	5.2	0.0	0.0	0.0	1.2
2112	12.2	6.2	0.0	0.0	5.2	0.0	0.0	0.0	0.8
2113	12.2	6.2	0.0	0.0	5.2	0.0	0.0	0.0	0.8
2114	10.7	4.9	0.0	0.0	5.2	0.0	0.0	0.0	0.6
2115	8.6	3.0	0.0	0.0	5.2	0.0	0.0	0.0	0.3
2116	8.6	3.0	0.0	0.0	5.2	0.0	0.0	0.0	0.3
Total	**2,164.6**	**402.7**	**77.8**	**139.4**	**501.1**	**16.4**	**356.1**	**88.6**	**582.5**

CA–construction authorization
*Costs for the year 2002 are for 7 months.

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CA—construction authorization

Note: Costs in the year 2002 are for 7 months.

Figure F-2. Regulatory, Infrastructure, and Management Support Annual Cost Distribution

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Table F-3. Regulatory, Infrastructure, and Management Support Capital and Operating and Maintenance Cost Summary (1998 $ in Millions)

Phase	RIMS Totals		Regulatory		Pre-CA Site Services		Environment, Safety, & Health		Infrastructure	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Licensing	352.7	0.0	49.5	0.0	67.0	0.0	42.6	0.0	71.2	0.0
Pre-Emplacement Construction	503.1	0.0	68.0	0.0	10.8	0.0	89.3	0.0	110.3	0.0
Emplacement Operations	36.3	717.0	3.1	83.3	0.0	0.0	7.4	0.0	9.0	152.1
Monitoring	6.1	484.3	2.6	166.6	0.0	0.0	0.0	0.0	3.0	124.2
Closure and Decommissioning	65.0	0.0	29.6	0.0	0.0	0.0	0.0	0.0	31.2	0.0
Grand Total	**963.2**	**1201.4**	**152.8**	**249.9**	**77.8**	**0.0**	**139.4**	**0.0**	**224.8**	**276.3**

Phase	Training		Set Asides		Monitoring Technical Support		Overhead & Fee	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Licensing	8.3	0.0	43.5	0.0	0.0	0.0	70.7	0.0
Pre-Emplacement Construction	8.1	0.0	84.1	0.0	0.0	0.0	132.4	0.0
Emplacement Operations	0.0	0.0	8.4	220.2	0.0	0.0	8.3	261.5
Monitoring	0.0	0.0	0.0	0.0	0.0	88.6	0.5	104.9
Closure and Decommissioning	0.0	0.0	0.0	0.0	0.0	0.0	4.1	0.0
Grand Total	**16.4**	**0.0**	**136.0**	**220.2**	**0.0**	**88.6**	**216.2**	**366.4**

CA–Construction authorization

RIMS–Regulatory, Infrastructure, and Management support

O&M–Operating and maintenance

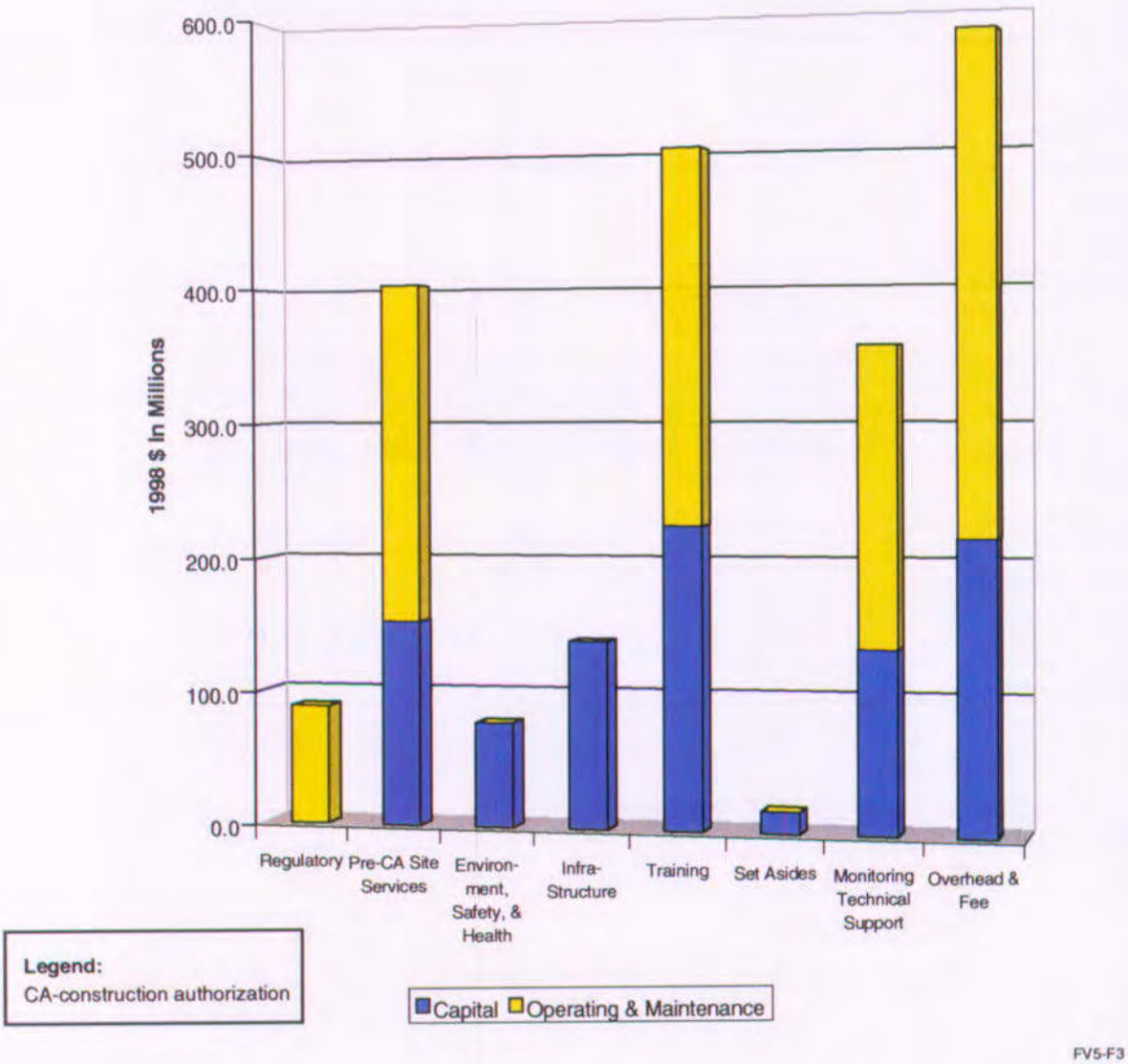

Figure F-3. Regulatory, Infrastructure, and Management Support Capital and Operating and Maintenance Cost Summary

APPENDIX G

ENGINEERED BARRIER SYSTEM DESIGN OPTIONS

APPENDIX G

ENGINEERED BARRIER SYSTEM DESIGN OPTIONS

Several potential engineered barrier system design options are being evaluated to extend waste package life. The design options under consideration include the following:

- Emplacement drift backfill
- Drip shields with backfill
- Ceramic-coated waste packages with backfill

Each option cost estimate is described in the sections that follow. Detailed Design descriptions are contained in Volume 2, Section 5.3. The costs are preliminary rough-order-of-magnitude estimates because the designs have not progressed beyond the conceptual stage. If further evaluations indicate one or more options should be incorporated into the repository reference design, these options will be further developed and included in the LA.

G.1 EMPLACEMENT DRIFT BACKFILL

G.1.1 Description

One option under consideration is to backfill the emplacement drifts with tuff or other material. This material would be placed around and over the waste packages to a depth of approximately 2 ft. Because of heat and radiation, the backfill operation would be performed by remotely operated machinery. This emplacement drift backfill option is also integral to the success of the design options described in Sections G.2 and G.3.

G.1.2 Cost Estimate

Following is the cost estimate for emplacement drift backfill:

Backfill material	$ 91 million
Emplacement	$269 million
Total design option cost	$360 million

G.2 DRIP SHIELDS

G.2.1 Description

A drip shield is a piece of highly corrosive-resistant material placed over a waste package to prevent water from dripping directly on the outer surface. Investigations into appropriate materials to use for drip shields are under way. This option will be combined with emplacement drift backfill, presented in Section G.1. The backfill would be used to protect the drip shield as well as the waste package.

G.2.2 Cost Estimate

Following is the cost estimate for drip shields plus emplacement drift backfill:

Drip shield manufacture	$360 million
Emplacement	$ 51 million
Backfill	$360 million
Total design option cost	$771 million

G.3 CERAMIC-COATED WASTE PACKAGES

G.3.1 Description

The use of a protective, ceramic oxide coating on the waste package, from materials such as magnesium aluminate spinel, aluminum oxide, or titanium dioxide, is being investigated to extend waste package life. These materials are melted or partially melted and applied as a spray to the outside of the waste package.

G.3.2 Cost Estimate

Following is the cost estimate for ceramic-coated waste packages plus emplacement drift backfill:

Coating 10,500 waste packages	$263 million
Coating top welds in surface facility	$110 million
Backfill	$360 million
Total design option cost	$733 million

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Viability Assessment of a Repository at Yucca Mountain