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Vol. 2

Draft
Environmental Impact Statement
on 10 CFR Part 61 "Licensing Requirements for Land Disposal of Radioactive Waste"

Main Report

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards

September 1981

U.S. NUCLEAR REGULATORY COMMISSION
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OFFERED by: Applicant/Licensee (Intervenor) PC/NIRS
NRC Staff Other
IDENTIFIED on 10/24/05 Witness/(Panel) LES Disposal
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List of Preparers

The overall responsibility for the preparation of this draft environmental impact statement was assigned to the Low-Level Waste Licensing Branch, Division of Waste Management, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission. The statement was prepared with technical assistance from the firm of Dames and Moore, White Plains, New York.

Nuclear Regulatory Commission Staff

Preparers

R. Dale Smith, Chief
Low-Level Waste Licensing Branch

Paul H. Lohaus
Part 61 Task Leader

G. W. Roles
Part 61 EIS Project Manager

Kitty S. Dragonette

Mary Jo Seeman

Martin S. Weinstein

Contributors

Charles W. Bishop
Timothy C. Johnson
Robert D. MacDougall
Charles Nichols
George C. Pangburn
David L. Siefken
J. Wassler
Rex G. Wescott
Derek Widmayer

Special Contributors

Willste CRESS Central Dictation Unit

Etta Nicolet, Supervisor
Carolyn Holly
Pauline Rock
Alice Werner, Proofreader
Irene Suissa
Marguerite Wason

Robert Fonner, Attorney, Office of the Executive Legal Director
Patricia A. Smith, Contracts Specialist, Office of Administration
Jacqueline Newbury, Secretary, LLW Licensing Branch
Charlette W. Henry, Secretary, LLW Licensing Branch

Dames and Moore Staff

Others contributing significantly to this environmental impact statement included personnel of the firm of Dames and Moore, Inc. (D&M) of White Plains, New York. The D&M contribution was directed by Dr. Oktay I. Oztunali, who assumed this responsibility upon the untimely death of Alexander E. Aikens in the early stages of the project.

Principal D&M Contributors

Oktay I. Oztunali
Ralph E. Wild
Gary C. Ré
James J. Clancy
Kathryn E. Kelly

Other D&M Contributors

M. Salah Abdelhamid
Patricia Buchinsky
Dara F. Gray
Perry M. Moskowitz
Peter C. Newsom
C. Joseph Pitt
Estaban D. Picazo

Chapter 1

INTRODUCTION

1.1 PURPOSE, SCOPE, AND STRUCTURE OF STATEMENT

This environmental impact statement (EIS) addresses development of a new regulation, Part 61, to the U.S. Nuclear Regulatory Commission (NRC) rules in Title 10, Code of Federal Regulations to provide specific requirements for licensing the land disposal of low-level radioactive waste (LLW).

There are three principal purposes to the regulation being developed:

- Establish general requirements for the land disposal of radioactive waste;
- Establish the technical requirements for disposal of radioactive waste by near-surface disposal including limits on the form and content of waste to classify or to define which wastes are acceptable for near-surface disposal; and
- Establish the administrative and procedural requirements which NRC will follow in licensing the land disposal of radioactive waste.

In this EIS, performance objectives are analyzed and presented for land disposal. Specific technical requirements are analyzed and presented for near-surface disposal methods--i.e., disposal that generally takes place within the top 15-20 meters of the earth's surface involving specific techniques such as shallow land burial, deeper burial and engineered designs and modifications. Finally, administrative, procedural, and financial requirements for licensing specific land disposal facilities are also developed and presented.

1.1.1 Purpose

NRC has a two-fold purpose in preparing this EIS. First, it is to fulfill NRC's responsibilities under the National Environmental Policy Act of 1969 (NEPA) (Ref. 1). Section 102(2)(c) of NEPA requires that an EIS be prepared by federal agencies for "major Federal actions significantly affecting the quality of the human environment..." NRC has determined that the promulgation of a new regulation governing the disposal of LLW constitutes such an action and that an EIS should therefore be prepared.

NRC has also prepared this EIS to demonstrate the decision process and bases applied in the establishment of technical requirements and licensing procedures to be included in the Part 61 regulation. It is the intent of NEPA to have federal agencies incorporate environmental values into the decisionmaking process at an early stage to assure a thorough consideration of such values. As will be shown in later chapters of this document, NRC has considered and analyzed alternative courses of action and requirements were selected with full

consideration of environmental, health, and safety effects to current and future generations.

1.1.2 Scope

This EIS analyzes requirements for the land disposal of radioactive waste. As will be discussed in greater detail in Chapter 2, there is a large range in alternative disposal methods which can be applied in the disposal of LLW including deep space, ocean disposal, and a range of land-based methods. It is not possible to develop one regulation dealing with such a large variation in disposal technologies. Thus, Part 61 will apply and this EIS will analyze requirements for the land disposal of waste. Requirements for ocean disposal are a responsibility of the EPA. Space disposal, although technically feasible is not developed to the point of routine technical and economic application.

This EIS is not a generic EIS in that it does not attempt to analyze all of the issues that are involved in the disposal of LLW. Rather, it is specific to providing a balanced decision analysis leading to the establishment of the technical requirements and procedures for licensing the disposal of LLW. Only issues that are germane to this decision process are analyzed and considered. Section 1.4 of this chapter summarizes these issues.

NRC had initially planned to develop and issue a regulation that would apply only to shallow land burial followed by amendments that would apply to othe specific alternative land-based disposal methods. Based on initial work in scoping and preparing this EIS, NRC has expanded the scope of this initial rulemaking action to include determination of overall performance objectives expected in land disposal; specific technical requirements for the disposal of waste "near surface" by such means as shallow burial, engineered designs and modifications and deeper burial; and general requirements for disposal of waste by other methods (e.g., deep-mined cavity or other very deep disposal). The development of specific technical requirements for deep mined cavities or for other very deep disposal methods will be considered at a later time through a separate rulemaking. The specific aspects of LLW disposal that are examined and analyzed to determine the requirements for near-surface disposal include the form and content of waste; institutional control and surveillance of a disposal facility after closure; natural site characteristics; disposal facility design and operations; and financial assurance. Administrative and procedural requirements for licensing the land disposal of LLW are also examined. Finally, this EIS also examines and establishes a classification or definition of which wastes are acceptable for disposal by near-surface disposal methods (and which wastes are not and must be disposed of by other methods).

1.1.3 Structure of the EIS

This EIS has been prepared in accordance with requirements of the National Environmental Policy Act (NEPA) and following Council on Environmental Quality (CEQ) regulations (Ref. 2) for preparation of environmental impact statements and NRC implementing regulations set out in Title 10, Code of Federal Regulations, Part 51, "Licensing and Regulatory Policy and Procedures for Environmental Protection." Both existing NRC requirements and those set out in a

Notice of Proposed Rulemaking to amend 10 CFR Part 51 to implement new CEQ regulations (Ref. 3) have been consulted in the preparation of this statement.

The EIS is divided into ten formal chapters which are listed and summarily described in the following paragraphs.

Chapter 1 - "Introduction" discusses the purpose, scope, and structure of the EIS, describes the proposed action and the need for it, reviews the scoping process used to focus the EIS, and sets out the specific issues involving radioactive waste disposal that will be addressed in this statement.

Chapter 2 - "Development of Regulations for LLW Disposal" presents the strategy NRC has followed in developing regulations for LLW disposal and presents and resolves three issues: the type of requirements to be developed, alternative disposal methods, and approach to classification of LLW.

Chapter 3 - "Description of the Affected Environment and Approach Followed in Preparing this EIS" describes the environment experiencing direct and indirect impacts and describes how, for purposes of analysis in this EIS, NRC developed a base of data about the environment and developed impact measures that can be applied in deciding the performance objectives and technical requirements that should be applied in the disposal of LLW.

Chapter 4 - "Presentation and Analysis of Alternatives-Intruder" presents an analysis of LLW disposal to determine pathways of human exposure thru inadvertent intrusion, analyzes the "no action alternative" presenting typical costs and impacts to an inadvertent intruder from LLW disposal as it has typically been carried out; analyzes a range of alternatives that can be applied in the design, operation, institutional control, and form of waste to reduce the impacts to an inadvertent intruder; presents and analyzes a range of numerical performance objectives and technical requirements to assure an adequate level of safety in LLW disposal; and selects a preferred performance objective and technical requirements.

Chapter 5 - "Presentation and Analysis of Alternatives-Long-Term Environmental Protection" analyzes long-term environmental pathways of release; analyzes the "no action alternative" presenting typical costs and impacts from environmental releases; analyzes a range of alternatives that can be applied to mitigate the impacts; presents and analyzes alternatives performance objectives and technical requirements for long-term environmental protection; and selects a preferred performance objective and technical requirements.

Chapter 6 - "Operational Safety" analyzes safety during the operation of a near-surface disposal facility including potential releases from accidents and waste processing at a central waste processing facility colocated with the disposal facility and sets out requirements directed at assuring safety during operations.

Chapter 7 - "Classification of Waste for Near-Surface Disposal" collectively ties all of the preferred technical requirements together to present a classification of waste for near-surface disposal, i.e., defines several categories

of waste based on the type, form, and concentration of various nuclides in waste and the requirements that should be applied in the disposal of each category. It also identifies wastes which would generally not be acceptable for near-surface disposal.

Chapter 8 - "Regulatory Program for LLW Disposal" reviews existing administrative and procedural requirements followed and applied by the NRC in licensing LLW disposal facilities and presents changes to these requirements.

Chapter 9 - "Financial Assurances for Closure, Postclosure, and Institutional Control" reviews the need for financial assurance requirements; presents and analyzes alternatives considered; and selects preferred requirements to assure adequate funds will be available for closure, postclosure, and institutional control.

Chapter 10 - "Environmenal Consequences of Part 61" presents the typical and unmitigated impacts of the new Part 61 rule including analysis of the disposal of waste on a regional basis following the preferred technical requirements identified in this EIS.

A series of Appendices which are being published as a separate volume contain the details of the assumptions, analysis methodology, computer programs, and detailed listing of results. Following is a listing of the Appendices.

Appendix A - "Reserved for Staff Analysis--Comments on Draft EIS and Propose Part 61 Rule"
Appendix B - "Reserved for Public Comments on Draft EIS and Proposed Part 61 Rule"
Appendix C - "Public Participation in the Development of the LLW Disposal Regulation"
Appendix D - "Low-Level Waste Sources and Processing Options"
Appendix E - "Description of a Reference Near-Surface Disposal Facility"
Appendix F - "Alternative Near-Surface Disposal Technologies"
Appendix G - "LLW Disposal Impacts Analysis Methodology"
Appendix H - "Alternatives Analysis Codes"
Appendix I - "NRC Branch Technical Position-Low-Level Waste Burial Ground Site Closure and Stabilization"
Appendix J - "Regional Case Studies"
Appendix K - "Financial Requirements for Closure, Postclosure and Active Institutional Control for a Disposal Facility"
Appendix L - "Reserved for Final EIS"
Appendix M - "Potential Long-Term Impact Other than Ground-Water Migration and Inadvertent Intrusion"
Appendix N - "Analysis of Existing Recommendations, Regulations, and Guides"
Appendix O - "Reserved for Final EIS"
Appendix P - "Reserved for Final EIS"
Appendix Q - "Calculation of Preoperational, Operational, Closure, and Active Institutional Control Costs"

1.2 NEED FOR AND DESCRIPTION OF THE PROPOSED ACTION

This section is designed to acquaint the reader with basic information on commercial waste disposal as it exists today and then, drawing upon this information, demonstrate the need for a comprehensive LLW regulation. The section also contains a brief description of the proposed action.

1.2.1 Background to Commercial LLW Disposal

The term "low-level waste" serves as a general term for a very wide range of radioactive waste. Any industry, hospital, medical, educational, or research institution, private or government laboratory, nuclear power plant, and other facilities forming part of the nuclear fuel cycle (e.g., a fuel fabrication plant) utilizing radioactive material as a part of their operational activities generates so-called low-level radioactive waste just as they generate other types of hazardous and nonhazardous waste. LLW consists of the radioactive materials themselves and materials which have been in contact with radioactive material and are contaminated or suspect of being contaminated.

Presently there are more than 20,000 companies, institutions, laboratories, and government facilities licensed by the NRC or Agreement States to use radioactive materials as a normal part of their day-to-day activities and most of these users generate some form of low-level radioactive waste which must be disposed of. Because of the wide range in the type of activities using these materials and the wide range in specific purposes of application, LLW is generated in a wide range of waste types, forms, and amounts. It ranges from suspect trash (e.g., laboratory wipes merely suspected of being contaminated) and hospital waste containing small quantities of short-lived radiopharmaceuticals to higher activity reactor filter sludges and sealed cobalt teletherapy sources. Currently about 85,000 m^3 (3 million ft^3) of commercial LLW is generated annually. Based on projections of LLW volume prepared by NRC for the 36 basic waste streams considered in this EIS, about 3.62 million m^3 (128 million ft^3) will be generated during the period 1980-2000. Of this, about 65% of the waste will be generated by fuel cycle sources and 35% by nonfuel cycle sources. Institutional generators will account for about 19% of the nonfuel cycle sources.

For most of the LLW that is generated in the U.S., the disposal process consists of three steps: processing and packaging; transport; and disposal. With regard to the first of these steps, most LLW, in its generated form, is placed in a U.S. Department of Transportation (DOT) shipping container and transported to a licensed commercial disposal facility for disposal. In other cases the waste may be further processed to reduce its volume or change its form (e.g., solidification of liquid wastes with cement) at which point it is placed inside a DOT-approved shipping container and shipped for disposal. (In some cases the type, form, and quantity of waste generated is such that the licensee can dispose of it directly under specific provisions of 10 CFR Part 20, e.g., discharge to the sanitary sewer system.)

In addition to those licensees who generate LLW, there are a number of licensed companies involved in the pickup, transport, and delivery of packaged LLW to

licensed disposal facilities for disposal. In some cases, these companies also provide additional services including supply of packaging, preparation of waste for shipment, and solidification of liquids. These companies generally pick up waste at customer facilities, consolidate individual waste packages into larger shipments, assume responsibility for the waste, and transport it to the disposal facility. A waste generator not using the services of such waste collectors will hire and consign the waste to a registered common or contract carrier for transport to the disposal facility. In this case the shipper retains responsibility for the waste.

Upon receipt of packaged LLW by a licensed commercial disposal site operator, it is disposed of by a method known as shallow land burial (SLB). This method of waste disposal consists of placing packaged waste into trenches that are about 150 m long by 30 m wide by 8 m deep. The trenches are backfilled with soil material excavated from the trench during construction, capped, and mounded to facilitate precipitation runoff.

1.2.2 Brief History of LLW Disposal

The disposal of commercial LLW by shallow land burial generally followed from the practices and procedures utilized by the Atomic Energy Commission (AEC) at national laboratories involved in atomic energy research and development and defense programs (Ref. 4). Activities in the programs involving use of radi active materials generated quantities of radioactive waste and means had to developed for their disposal.

Two principal methods of disposal were utilized: SLB and ocean disposal. The practice of SLB was quickly adopted as the preferred disposal practice. This technique could be utilized near the point where the waste was being generated, avoiding unnecessary transportation which might jeopardize the security of the project in the event of a transportation accident. In addition, SLB proved to be a fairly cost-effective technique as it employed practices commonly used in sanitary landfill operations and did not require unusual equipment or construction techniques.

With the growth of commercial applications, the AEC announced in 1960 that regional land burial sites for commercial LLW should be established on federal- or state-owned land and that the sites should be operated by private contractors subject to government licensing authority. With this announcement, the AEC indicated that its disposal sites would only be available for commercial use until adequate disposal capacity was established in the private sector. As an interim measure, pending designation of regional commercial waste sites, the AEC also announced that disposal sites at Idaho Falls, Idaho and Oak Ridge, Tennessee would continue to accept commercial wastes for disposal.

At the same time, the AEC also initiated a phase-out of sea disposal operations by placing a moratorium on the issuance of new sea disposal licenses. Existing licenses remained in effect and were phased out. The last disposal at sea took place in June 1970.

In February 1961, the AEC established a regulatory program for licensing the commercial operation of land burial sites on federal or state government-owned land. The regulations in existence at that time set out no specific technical criteria for site selection, design, operation, and closure although general considerations regarding site hydrology, geology, and other factors that should be addressed were identified. In September 1962, the AEC licensed the first commercial land burial site at Beatty, Nevada and, during the period 1962-1971, five additional commercial sites were licensed by the AEC or Agreement States resulting in a regional distribution of commercial disposal sites. These six sites were spread geographically throughout the United States and located near Richland, Washington (sited on the Hanford Reservation); Beatty, Nevada; Sheffield, Illinois; Maxey Flats, Kentucky; West Valley, New York; and Barnwell, South Carolina. In May 1962, the AEC withdrew its program of interim acceptance of commercial waste at Idaho Falls and Oak Ridge.

The DOE has operated 14 sites throughout the country for the disposal of wastes generated from defense programs and DOE research and development activities. A discussion of the characteristics and problems of the commercial and DOE sites has been extensively studied and is well-documented in the literature. Presently only three commercial sites remain open and two companies are involved in their operation: Chem-Nuclear Systems, Inc. (Barnwell, South Carolina) and U.S. Ecology, Inc. (Beatty, Nevada and Richland, Washington). Table 1.1 lists the six commercial sites, their respective operators, and current status.

Table 1.1 Commercial Waste Disposal Sites

Location	Operator	Originally Licensed By (year)	Currently Licensed By	Operational Status
Beatty, Nevada	U.S. Ecology, Inc.	AEC (1962)	State	Open
Maxey Flats, Kentucky	U.S. Ecology, Inc.	Kentucky (1962)	State	Closed
West Valley, New York	Nuclear Fuel Services, Inc.	New York (1963)	State	Closed
Richland, Washington	U.S. Ecology, Inc.	AEC (1965)	State and NRC*	Open
Sheffield, Illinois	U.S. Ecology, Inc.	AEC (1967)	NRC	Closed
Barnwell, S. Carolina	Chem-Nuclear Systems, Inc.	South Carolina (1971)	State and NRC*	Open

*NRC licenses only special nuclear material.

1.2.3 Federal and State Responsibilities in Commercial LLW Disposal

There are five key federal agencies that administer programs regarding the management and disposal of LLW. These include the Nuclear Regulatory Commission (NRC), the Environmental Protection Agency (EPA), the U.S. Geological Survey (USGS) in the Department of Interior, the Department of Energy (DOE), and the Department of Transportation (DOT).

The Nuclear Regulatory Commission (NRC) was established by the Energy Reorgan zation Act of 1974. This Act abolished the Atomic Energy Commission (AEC) an transferred all of its licensing and related regulatory functions assigned by the Atomic Energy Act of 1954 to NRC. Prior to 1974, the AEC had not only regulatory and licensing responsibilities, but also research and development functions with respect to atomic energy and related disciplines. The Energy Reorganization Act of 1974 split the AEC into two separate organizations: the NRC and the Energy Research and Development Administration (ERDA). The functions of ERDA have since been incorporated into the Department of Energy which carries out federal responsibilities for the research, development, and transfer of LLW disposal technology to commercial industry.

NRC has the responsibility in the United States of regulating and licensing the commercial and nondefense governmental use of source, byproduct, and special nuclear material. This responsibility extends to licensing commercial disposal of LLW in licensed facilities. NRC carries out its responsibilit in compliance with overall federal radiation protection guidance and envir mental standards established by the Environmental Protection Agency. EPA was charged with this responsibility in the Reorganization Plan Number Three of 1970. The U.S. Geological Survey is responsible for basic research in the geological sciences and development of basic data for application in the development of criteria and to provide technical advice in the assessment of specific disposal sites. The U.S. Department of Transportation has the primary responsibility for regulating waste containers, transport vehicles, and other aspects of the interstate transport of radioactive waste.

Existing NRC regulations for commercial LLW disposal in licensed disposal facilities are principally contained in a few paragraphs in 10 CFR Part 20 (§20.302). The requirements mainly describe in general terms the type of information to be included in an application for a disposal facility and require that LLW disposal facilities must be sited on land owned by the state or federal government. In addition to disposal of waste at commercially operated shallow land burial facilities, provisions of 10 CFR Part 20 provide other means that licensees may use to dispose of waste directly. These include discharge to the sanitary sewer system (§20.303), release to the air and water (§20.106), burial in the soil or other means of disposal upon specific license approval (§20.302), and treatment or disposal by incineration (§20.305). The NRC also recently adopted amendments to Part 20 (§20.306) that provide for routine disposal of carbon-14 and tritium in concentrations less than 0.05 μCi/gm (microcurie/gram) when contained in animal carcass and liquid scintillation cocktail waste.

Other NRC regulations, Part 30 ("Rules of General Applicability to Domestic Licensing of Byproduct Material"), Part 40 ("Domestic Licensing of Source Material"), and Part 70 ("Domestic Licensing of Special Nuclear Material")--apply to possession of licensed material by a disposal facility licensee. Part 2 ("Rules of Practice for Domestic Licensing Proceedings") contains general requirements for NRC licensing proceedings. Part 51 ("Licensing and Regulatory Policy and Procedures for Environmental Protection") contains requirements for compliance with the National Environmental Policy Act of 1969 (NEPA). Under the existing regulatory framework for LLW disposal licensing, regulatory requirements for a potential disposal facility licensee are not centralized, systematic, or readily identified.

In discharging its responsibilities, NRC is empowered by the Atomic Energy Act to relinquish part of its regulatory authority over source, byproduct, and special nuclear material to the states. Under Section 274 of the Act, before the NRC enters into such an agreement, the state must have a radiation control program that is compatible with NRC's, and the state's program must be judged adequate by NRC to protect the public health and safety. Currently, there are 26 such Agreement States. To the extent that a new regulation represents a change in NRC's radiation protection programs for source, byproduct, and special nuclear material, it is necessary that the Agreement States cooperate in the formulation of compatible regulations and revise their existing regulations as necessary. Current NRC regulations regarding NRC's relationship with the Agreement States are contained in 10 CFR Part 150.

Licensing of commercial LLW disposal facilities is part of the NRC's authority which may be assumed by an Agreement State. Of the six commercial disposal facilities which have operated in the United States, five of these facilities are located in Agreement States and are principally regulated by the Agreement States (See Table 1.1).

1.2.4 Need for Action

As mentioned earlier, the AEC established a regulatory program for licensing the commercial operation of land disposal sites in February 1961. No detailed technical requirements for site selection, design, operation, and closure were, however, established (Ref. 4). The following considerations were applied by the AEC and Agreement States in licensing the existing commercial disposal sites:

- A written commitment must be obtained from a government body or a responsible official that a state or federal agency would assume control over the burial site in the event of default or abandonment of the site by the commercial operator. The site must be located on land owned by the federal or state government.

- The geological or hydrological characteristics of the site must be such that waste material is contained in a manner that will not endanger public health or safety and that migration of radioactivity from the site is unlikely.

- The waste must be in solid form before burial. Liquid waste must be solidified or immobilized to minimize the potential for migration.

- The burial ground operator must establish and conduct an environmental monitoring program. To determine whether migration has occurred, operators must establish a baseline of radioactivity that exists in the environment before any waste was buried. The monitoring program must be continued to detect radioactivity increases beyond those original levels. Increases must be reported to the appropriate regulatory agency, which then analyzes the possible significance.

- The packages in which wastes are transported must comply with appropriate federal standards. Packaging is designed to provide protection during transportation and handling. Although packaging would provide a primary barrier, the packaging and form of the waste were not relied upon nor expected to provide any significant waste containment after burial. The geology of the site was solely to be relied upon for containment.

In the late 1960s and early 1970s difficulties were encountered at some of the commercial and AEC sites relating to management of precipitation collecting in completed disposal trenches and releases of small concentrations of radioactivity. At the commercial sites, the difficulties were principally evident at the Maxey Flats, Kentucky and West Valley, New York sites. The problems were predominately attributed to three factors: (1) the trench cap or covering over the trench was of a higher permeability than the surrounding soil which allowed precipitation to enter and collect in trenches; (2) disposal trenches were completed when they contained appreciable quantities of rainwater; and (3) the compressible, degradable, unstable nature of the waste being buried led to subsidence of the trench cap creating pathways for precipitation to readily enter the trenches. These factors led to the filling of trenches with water and to small releases of radioactivity through surface and ground-water pathways.

Studies and corrective actions were initiated at the sites. Trenches were pumped to remove the water, and trench leachates were treated through an evaporator at Maxey Flats and a liquid waste treatment system at West Valley. Measures were also taken to recap and stabilize trenches to reduce future water infiltration. Results of monitoring programs and studies at the sites showed that although releases of radioactivity had occurred, they were low and presented no hazard to the public health and safety (Refs. 5 and 6). The primary experience gained was that the compressible, degradable, unstable nature of the waste disposed of, coupled with site conditions, was leading to unstable site conditions requiring active maintenance for uncertain periods of time at high costs. Funds being collected for postoperational activities were also inadequate to cover the potential long-term costs involved (particularly the long-term maintenance costs involved) in caring for the sites over the long term. These sites are presently closed and may require continued active maintenance for many years to assure stability.

Similar problems were experienced at the Sheffield, Illinois site where compressible unstable wastes have created an unstable site condition where stabilization action and potential long-term maintenance is required. Funds collected by the state for this purpose have also proved insufficient to cover the estimated costs. This site is presently closed and is the subject of an ASLB hearing regarding conditions for final closure of the site.

Problems of a different nature have occurred at the Beatty, Nevada site. Over a period of several years, employees removed containers and certain waste materials (e.g., contaminated tools) for personal offsite use. These materials were removed from the site in violation of federal and state regulations and license conditions. Based on extensive surveys by both federal and state personnel, no public health and safety hazard was created by the illegal removal (Ref. 7). This incident pointed to the need for more attention to site security and controls in disposal facility operations.

More recent problems have involved a lack of attention to detail on the part of many waste generators relating to the form and content of waste shipped for disposal (Ref. 8). The shipment of leaking and damaged packages and improper waste forms resulted in the temporary shutdown of two of the three operating commercial sites. In addition, with the shutdown in three of the operating sites, an imbalance in the regional disposal facility capacity has resulted with most of the waste being generated in the east and most of the disposal capacity located in the west. Several actions have evolved in response to this. The South Carolina site is reducing the average monthly volume of waste it will accept to the average monthly volume received during 1977 (100,000 ft^3/month) (Ref. 9). A voter initiative was passed in the state of Washington to prohibit the receipt of out-of-state waste (except institutional waste) by July 1981 unless action is taken to form a regional state compact. This action was recently ruled unconstitutional and thus unenforceable by the U.S. District Court in Washington (Ref. 10). Congress also recently acted in this area by passing the "Low-Level Radioactive Waste Policy Act" (PL-96-573) which places the responsibility for assurance of adequate LLW disposal capacity on the states. The law stresses the regional solution to adequate LLW disposal capacity.

Also, in 1976, an NRC Task Force was created to review programs used by the NRC and state governments to regulate disposal of commercial low-level waste. A document entitled "NRC Task Force Report on Review of the Federal/State Program for Regulation of Commercial Low-Level Radioactive Waste Burial Grounds" (NUREG-0217) was published in March 1977 (Ref. 4). In the report the Task Force made a number of recommendations regarding federal and state regulation of LLW disposal and other related issues affecting commercial burial ground regulation and operation. These recommendations included development of a specific regulatory program for low-level waste disposal including development of more comprehensive regulations, standards, and criteria.

In addition, beginning in 1976, a series of reports were issued by the General Accounting Office, the Joint Committee on Atomic Energy, and the House Committee on Government Operations (Refs. 11, 12, 13, 14, and 15). The conclusions of these reports were wide ranging, but among the most basic was the conclusion that the existing sites had been selected and licensed on an inadequate geologic

and hydrologic data base and in the absence of well-documented criteria for identification of a suitable waste disposal site. As a result, a number of the existing sites were experiencing undesirable operational problems, i.e., cracking of trench covers, intrusion of precipitation and ground water, and subsequent releases of radioactivity to the environment. Moreover, in the absence of an improved data base on site characteristics and development of defensible standards and criteria for licensing, the reports noted that the selection of future waste disposal sites might well encounter the same types of problems.

In response to the Task Force and Congressional reports and identified need, the NRC staff subsequently developed a program plan for low-level waste management. Support for the development of such a program came not only from the Task Force and the aforementioned reports, but also from state and other federal agencies, industry, and public interest organizations. To formulate this program, the staff considered the Task Force recommendations; public comments on the Task Force Report; data gleaned from review of technical documents and participation in conferences and meetings, and discussions attended by industrial, state, and public organizations; and other correspondence and documents. A document describing the program entitled "NRC Low-Level Radioactive Waste Management Program" (NUREG-0240) was published in September 1977 (Ref. 16). This program is currently in progress and has resulted in technical studies to prepare a regulatory base; programs for development of regulations, regulatory guides, and licensing procedures; and this environmental impact statement.

1.2.5 Description of the Proposed Action

The proposed action being considered in this EIS is the issuance of a new regulation (Part 61) to the U.S. Nuclear Regulatory Commission (NRC) rules in Title 10, Code of Federal Regulations. Part 61 will provide licensing procedures, performance objectives, and technical requirements for the issuance of licenses for the land disposal of low-level radioactive waste. Specifically, the proposed action includes consideration of requirements on the standards of performance that should be met in LLW disposal; technical requirements for the siting, design, operation, closure and postoperational activities for a near-surface LLW disposal facility; technical requirements on waste form that waste generators would be required to meet for acceptance of waste at a disposal facility; classification of waste; administrative and procedural requirements for licensing a disposal facility; and provisions for adequate financial assurance.

1.3 SCOPING FOR THIS EIS

Scoping of an environmental impact statement is defined by the Council on Environmental Quality in 40 CFR Part 501.7 (Ref. 2) as "...an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action." Although the concept of scoping is a relatively recent development for EISs, NRC has been conducting scoping activities relative to the proposed Part 61 and this EIS since 1978. The activities constituting this process are discussed in the following paragraphs and include:

1. Public Notice of Development of a Radioactive Waste Disposal Classification System (Ref. 17)

2. Advance Notice of Proposed Rulemaking on the LLW Disposal Regulation (10 CFR Part 61) (Ref. 18)

3. Public Review and Comment on a Preliminary Draft of 10 CFR Part 61 (Ref. 19)

4. Regional Workshops on 10 CFR Part 61 (Refs. 20, 21, 22 and 23)

In 1974, the Atomic Energy Commission (AEC) proposed to prohibit the disposal of commercially generated transuranic (TRU) radionuclides by shallow land burial. Upon review of the proposed rule and the comments received from interested parties, the NRC staff initiated development of regulations which would govern the classification of all radioactive wastes--not just TRU-contaminated waste.

The staff initiated a study to develop an approach for classification of waste to help provide input into the regulations development effort and environmental impact statement. Several documents have been published regarding this study. On August 18, 1978, NRC published a Federal Register notice of "Development of a Radioactive Waste Disposal Classification System" (43 FR 36722). In this notice, the Commission requested comments on a study report entitled "A System for Classifying Radioactive Waste Disposal--What Waste Goes Where?" (NUREG-0456) to guide the further development of a waste classification methodology and the completion of the study. Comments were specifically requested in the following areas: the overall approach; the migration pathways and exposure mechanisms; the exposure guidelines; and applications of the methodology.

A summary of the comments received by the Commission is contained in Appendix C including an analysis of the comments as they relate to the development of Part 61.

On October 25, 1978, NRC published in the Federal Register an Advance Notice of Proposed Rulemaking (43 FR 49811) regarding the development of specific regulations for the disposal of LLW; a new Part 61 to Title 10, Code of Federal Regulations. The Commission requested advice, recommendations, and comments on the scope and content of the regulations and an environmental impact statement (EIS) that would be prepared to guide and support development of the regulations. As a part of this Notice, NRC announced its intention to:

- Develop technical requirements for the disposal of LLW by shallow land burial and alternative disposal methods;

- Prepare a supporting EIS for the regulation; and

- Coordinate development of technical requirements for shallow land burial and alternative disposal methods with requirements for the classification of waste.

Formal comments received in response to the Advance Notice were placed in the Public Document Room of the NRC as an official part of the record for this Part 61 rulemaking proceeding (Docket No. PR61). Details of the comments received are contained in Appendix C, including an analysis of comments received on each specific question of the Advance Notice.

In general, the respondents to the Advance Notice strongly supported NRC's development of specific requirements for the disposal of low-level waste. There was also support among the commenters that an overall EIS should be prepared to provide an essential part of the information and decisional base for the development of the requirements for the rulemaking action.

In addition to the comments received by NRC on the Advance Notice, NRC staff also considered input from the following other sources in scoping the content of this EIS.

- The results of program studies and other technical data on LLW management and disposal;
- Licensing experience and current LLW management techniques at existing disposal sites;
- Input from the State Planning Council, National Governors Association, National Council of State Legislatures and National Conference of State Radiation Control Program Directors;
- Programs of the Environmental Protection Agency (EPA) to develop criteria and standards for management of LLW and regulations for disposal of nonradioactive solid and chemically hazardous wastes;
- Recommendations of the Interagency Review Group on Nuclear Waste Management;
- A Natural Resources Defense Council (NRDC) Petition for Rulemaking;
- Discussions with industry and public interest groups, state and federal agencies, and others.

To help focus development of the EIS and possible contents of such a new regulation, NRC staff also prepared and widely distributed for public review and comment a preliminary draft Part 61 regulation dated November 5, 1979. The preliminary draft received wide distribution and copies were sent to the states, other federal agencies, public interest groups, the industry, and others. On February 28, 1980, NRC staff also published in the Federal Register a Notice of Availability of the Preliminary Draft Regulation (Ref. 24) announcing availability of the draft for public review and comment to help ensure wide distribution and early public review, comment, and input.

Comments received by the staff in response to the Notice of Availability have also been docketed and placed in the Commission's Public Document Room. Overall, the comments generally agreed with the need for, and approach and

general content of, the preliminary draft regulation. A summary of the comments received by the Commission is contained in Appendix C, including an analysis of comments received on each section of the preliminary draft of Part 61. A detailed listing of comments on specific sections of the preliminary draft of Part 61, prepared by the staff has also been placed in the Public Document Room, PR 61 Docket File.

During the summer and fall of 1980, NRC also contracted for and held 4 regional workshops to provide an opportunity for open dialogue between the states, public interest groups, industry, and others on the issues that needed to be addressed through the Part 61 rulemaking process. One workshop was sponsored by the Southern States Energy Board for the southeast region, a second by the Western Interstate Energy Board for the west, a third by the Midwestern Regional Office of the Council of State Governments for the central and midwest, and a fourth by the New England Regional Commission for the northeast. A copy of the full transcript for each meeting and a summary report documenting the collective views of the participants has been entered into the docket for this rulemaking and may also be examined at the Commission's Public Document Room. At these workshops, a range of institutional, organizational, and technical issues were discussed. Institutional issues such as land ownership, post-operational care, institutional controls, and financing were addressed. Consideration was also given to organizational issues such as state participation in NRC licensing action, Federal-Agreement relations, assistance to non-Agreement States, and regional siting. Technical issues that were examined included: performance objectives; de minimis levels; waste classification; nonradiological hazards; scope of regulatory guides and regulation; criteria for waste form; solidification of liquid wastes; volume reduction; and site characterization. In general, the workshops recommended that NRC adopt formal rules that establish broad performance objectives and administrative procedures, and set forth more specific program criteria and details in regulatory guides. A summary of the workshop findings and analysis of the findings on each specific issue considered is contained in Appendix C.

1.4 ISSUES ADDRESSED IN THIS EIS

Based on the results of NRC's scoping activities and the operating experience of the existing sites, the following issues were identified as those that were germane to this rulemaking action and of most importance in preparing this EIS:

1. The specific form and content of the requirements to be established and method to be applied in their development.

2. The alternative disposal methods which should be addressed in the rulemaking action.

3. The need to protect the public health and safety and environment during the short-term operational phase and over the long term relating to potential long-term releases to the environment.

4. The need to protect the inadvertent intruder.

5. The classification or definition of LLW based on hazard potential.

6. The need for adequate financial assurances in the disposal of LLW.

7. The need for long-term stability and predictability in disposal sites.

8. The need to eliminate long-term maintenance of disposal sites.

9. The NRC licensing process for waste disposal sites and the participation of the states, public and indian tribes in NRC's licensing process.

10. Long-term government land ownership and institutional control of disposal sites.

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Chapter 2

DEVELOPMENT OF REGULATIONS FOR LLW DISPOSAL

2.1 INTRODUCTION AND SUMMARY

This chapter reviews and resolves three key issues involved in developing a new Part 61 regulation. The resolution of these issues provides the basis upon which the technical and other requirements are developed. These issues are:

1. The type of requirements which should be developed and set out in Part 61 (i.e., performance objective or prescriptive requirements). The preferred alternative approach being followed by NRC in preparing these regulations is to develop both overall performance objectives that define acceptable safety standards that should be achieved in the disposal of LLW, as well as minimum technical requirements to control several key parameters important to assuring that the performance objectives will be met. Prescriptive requirements are established where possible;

2. The alternative methods of disposal which should be addressed in this rulemaking action. Based on an analysis of alternative disposal methods, NRC plans to address not only shallow land burial but also the full range of land disposal technology that can be applied near the earth's surface including shallow land burial, deeper burial and engineered designs; and

3. The methodology and approach that should be used to classify LLW and to direct particular types and forms of waste to disposal methods which ensure their safe disposal. Based on an analysis of alternative methods for classifying radioactive waste, NRC has further developed and applied the methodology previously described in two NRC documents (NUREG-0456 (Ref. 1) and NUREG/CR-1005 (Ref. 2)) to classify radioactive waste based on the requirements for its safe disposal.

2.2 PERFORMANCE OBJECTIVES VS PRESCRIPTIVE REQUIREMENTS

In developing specific regulations for LLW disposal, two basic types of requirements can be established: performance objectives and prescriptive requirements.

A performance objective regulation would establish the overall objectives that should be achieved in the disposal of LLW and leave flexibility in how the objectives would be achieved. The performance objectives would establish general technical requirements on the design and operation of an LLW disposal facility and would include a standard or standards to specify the level of radiological hazard which should not be exceeded at an LLW disposal facility.

A prescriptive regulation would set out specific detailed requirements for the design and operation of an LLW disposal facility. Prescriptive standards would

specify the particular practices, designs, or methods which are to be employed--for example, the thickness of the cover material over a shallow land burial disposal trench, or the maximum slope of the trench walls. NRC considered three alternatives regarding the type of requirements which should be considered in Part 61:

1. Development of performance objective requirements only;

2. Development of prescriptive requirements only; and

3. Development of both performance objective and prescriptive requirements.

2.2.1 Performance Objective

Performance objective requirements, by their nature in establishing overall objectives, would allow maximum flexibility in the application of new technology and innovative solutions to assuring safety in the disposal of LLW. They would allow for a systems' type approach in that the performance of the "disposal system" would be based on the combined interaction and effectiveness of the many factors or component parts of a disposal system. Positive and negative characteristics can be balanced such that the performance of all characteristics in combination can be considered rather than just the characteristics of one element. This would allow for consideration of site-specific conditions and variation in the design, operation and characteristics of waste on a site specific basis.

Performance objective requirements, however, require more effort and time in development as well as in licensing of specific facilities due to the large number of factors that must be considered to determine compliance. In addition, it may not be totally clear to an applicant or interested person how to design and operate a disposal facility to meet the general objectives.

2.2.2 Prescriptive Requirements

This approach would prescribe the specific methods, designs and practices which should be applied in disposal. It requires a thorough understanding of all the potential methods, designs and practices that can be applied in the disposal of LLW. It also assumes that the state of the art in disposal technology is developed to the point where there are clear choices to be made among all the potential alternatives that could be used. It would be easy for an applicant or licensee to demonstrate compliance with prescriptive requirements (and for NRC to license and inspect against them) since engineering limits are established which can be readily measured or calculated and the specific requirements for the design and operation of a LLW disposal facility would be clearly defined and readily apparent to an applicant or licensee.

Prescriptive requirements would, however, tend to discourage use of new or creative solutions to waste disposal problems even though they might result in lower environmental impacts and monetary costs. Prescriptive requirements are difficult to derive and would need to be frequently revised as the type and form of waste changed and as technology advanced. Prescriptive requirements

would also tend to concentrate on the individual components of a disposal system and would tend to treat all wastes uniformly regardless of hazard potential.

2.2.3 Performance Objective and Prescriptive Requirements

This approach would involve the establishment of overall objectives to define a level of safety for LLW disposal and subsequent development of specific technical requirements to assure that the overall performance objectives are met. This approach would allow for:

1. Increased flexibility in determining the disposal requirements of particular waste streams;
2. Increased flexibility in accounting for site-specific environmental conditions;
3. Increased ability to incorporate improvements in technology for LLW forms, packaging and disposal;
4. Specification of minimum technical and prescriptive requirements based on current understanding and known problems of the past; and
5. More rapid future development of technical requirements for alternative disposal methods.

Finally, this approach allows for consideration of the individual components of an LLW disposal system and their contribution toward achievement of the overall performance objectives as well as consideration of the combined effectiveness of these components as a system.

2.2.4 Comparative Analysis

NRC believes that development of a regulation using solely prescriptive requirements or solely performance objectives would not prove effective for the future regulation of LLW disposal. Given the wide variation in the form and characteristics of waste that has and will continue to be generated; given the wide range in potential site characteristics in various regions of the U.S.; and given the fact that technological innovation in waste disposal problems is now receiving greater emphasis in finding improved solutions to LLW disposal problems, requirements of both types are needed. Minimum performance objective standards are necessary to define the overall performance expected in LLW disposal, whereas specific minimum technical requirements are necessary to avoid recognized undesirable characteristics based on past experience and current understanding. The alternative of establishing purely prescriptive requirements could result in a collection of ad hoc requirements without a clear picture as to the overall effectiveness of such requirements. This could lead to a situation not greatly different from the current situation. Development of purely performance objective requirements, while workable, would not allow for establishment of more detailed prescriptive requirements in those areas where specific guidance is known to be needed.

In this rulemaking effort, NRC thus plans to establish overall performance objectives or standards of performance that should be achieved in the disposal of LLW, minimum technical performance requirements that should be considered in all cases in the disposal of LLW and where possible, detailed prescriptive requirements. Subsequent to this rulemaking, NRC plans to publish regulatory guides in the areas of waste form, site suitability and design and operations which will provide detailed prescriptive guidance.

2.3 ALTERNATIVE DISPOSAL METHODS

As a part of its LLW program leading to development of this EIS and LLW regulation, (Ref. 3) NRC conducted a study of alternative LLW disposal methods to help ensure that all viable disposal methods were considered and that the initial issuance of the regulation and subsequent amendments would be directed at and based on the methods of disposal that would most likely be used. The first part of this study consisted of an investigation and screening of possible alternative disposal methods and selection of those that appeared most viable and which should be evaluated further. To help assure completeness of the initial listing and adequacy of the selection of viable alternatives, a panel of technically competent individuals of recognized waste management expertise was consulted for review and guidance. The results of this effort were published as NUREG/CR-0308 "Screening of Alternative Disposal Methods for the Disposal of Low-Level Radioactive Waste" (Ref. 4). The second part of the study involved a further evaluation of those alternatives selected as being most viable. The analysis was generic in nature and considered technical, political and economic factors in the analysis. The results of the analysis were published as NUREG/CR-0680 "Evaluation of Alternative Methods for the Disposal of Low-Level Radioactive Wastes" (Ref. 5).

On the basis of this analysis, five disposal alternatives were identified as most promising. These included:

1. Shallow land burial;
2. Deeper "intermediate" depth burial;
3. Mined cavity disposal;
4. Engineered structures; and
5. Ocean disposal (ocean dumping and sea-bed disposal with projectiles).

The study also concluded, that although further specific detailed analysis of individual disposal methods was needed, the results did not indicate any compelling health, safety or environmental reason to abandon existing disposal methods (e.g., shallow land burial) in place of an entirely new method of disposal such as mined cavity disposal. The disposal of radioactive waste in outer space was considered to be not developed to the point of technical and economically feasible use.

In considering the development of regulations for LLW disposal, NRC was thus faced with two basic categories of alternatives: Ocean disposal (including ocean dumping and sea-bed projectiles) and land disposal (involving both near surface and deep disposal techniques).

Although ocean disposal had been used by the U.S. previously and is currently being used by the Europeans, the U.S. has not practiced ocean disposal since 1970. There is some current interest in resuming ocean disposal operations. Under the Marine Protection, Research and Sanctuaries Act of 1972, the Environmental Protection Agency has responsibility and a program underway leading to development of criteria and procedures for issuing permits for sea disposal of LLW. In addition, disposal requirements for ocean and land disposal may be sufficiently different that they should be developed separately. Public comments in response to the advance notice of proposed rulemaking also expressed concern regarding the ocean disposal of LLW. NRC has, therefore, concentrated its regulations development efforts on land disposal methods.

As noted earlier, land disposal methods logically divide into two subcategories: those that take place near the earth's surface and those that involve very deep disposal. Near surface disposal encompasses the full range in technology that can be applied in LLW disposal near the earth's surface: i.e., shallow land burial, deeper burial (depths of 15-20 meters) and the use of engineered designs, barriers and other concepts. This EIS and initial regulations development effort concentrates on land disposal requirements and specific requirements that should be applied to assure safety in the disposal of LLW by near-surface disposal technology. It is in wide use today and there is no compelling health and safety reason to abandon near-surface disposal technology in place of something different. Specific requirements for methods of very deep disposal such as deep mined cavities are not considered in this EIS, but will be addressed by NRC in a subsequent rulemaking effort. In addition, there are other specific types of disposal methods such as hydrofracture and deep well injection that have been successfully used. These methods are not being specifically addressed in this EIS since they will only work well for a very narrow range of waste types and require specific hydrogeological media characteristics. They will be dealt with at a later time.

2.4 RADIOACTIVE WASTE DISPOSAL CLASSIFICATION

In recognition of the wide range of potential hazards that may exist with different types and forms of LLW, NRC undertook a study to determine how various types and forms of LLW should be defined, classified or controlled for purposes of waste disposal. As early as 1974, the AEC had proposed to prohibit the burial of transuranic (TRU) contaminated commercial waste (Ref. 6). In the proposed rule, a measurement sensitivity limit of 10 nanocuries TRU waste per gram of material was proposed. Material exceeding the concentration limit, would have been consigned to retrievable storage facilities operated by the federal government pending the development of a facility for the ultimate disposition of the waste. Several problems, however, in implementation of the rule were identified by persons commenting on the proposed rule, and the rule was never adopted by the AEC for commercial waste.

At the same time, the staff recognized that there were other nuclides and waste types that should be controlled in disposal, as well as TRU contaminated waste, and initiated a waste classification study to define the concentrations of individual nuclides and disposal requirements that should be applied to

assure their safe disposal. The study has divided into three major parts. The first part involved examination of alternatives for classifying LLW and selection of a preferred approach. This part is described in the report "Determination of a Radioactive Waste Classification System," UCRL-52535 (Ref. 7). The second part involved development and application of a methodology to classify wastes following the preferred approach selected. This part is described in two reports, "A Classification System for Radioactive Waste Disposal--What Waste Goes Where?," NUREG-0456 (Ref. 1) and "A Radioactive Waste Disposal Classification System," NUREG/CR-1005 (Ref. 2). The third part of the study was carried out as a part of this EIS and involves development of a waste disposal classification regulation and, a decision basis for the final classification values.

2.4.1 Alternative Classification Systems Examined

There are two dominant aspects of LLW disposal that must be considered in the development and application of any waste classification system: the characteristics and properties of LLW and the performance capability presented by alternative disposal methods and variations within each method. The characteristics of LLW present wide ranges in degrees of radiological, chemical, biological and physical hazards as well as in degrees of persistence of the hazards. Individual disposal techniques also present varying degrees of containment and isolation capability. Near surface techniques, for example, place the waste in an area that is readily accessible to man, while others, such as deep mines, present greater difficulties in accessibility.

Other considerations that needed to be addressed in the classification of LLW included:

1. Any classification system developed must be applicable to all sources of waste and must provide a common basis for application by those generating the waste as well as those disposing of the waste.

2. It must provide a sound basis for determining the controls (or requirements) that must be placed on the disposal of the waste to assure protection of the public health and safety and environment and minimize the need for long-term social commitment.

3. The system should be practical and implementable without placing undue burdens on those directly affected by it.

NRC initially examined a number of existing classification systems for radioactive waste to see if any could be utilized and applied. As a part of this effort, assistance was also sought from representatives of industry, government, the public, and research and educational institutions through a technical advisory panel. The panel assisted in evaluating existing classification systems and in providing guidance to NRC in the selection of an approach which NRC could apply in classifying LLW. Some of the systems examined included existing classification systems such as:

- o The International Atomic Energy Agency Radioactive Waste Categories;
- o The American Institute of Chemical Engineers Radioactive Waste Categories;
- o The American National Standards Institute Radioactive Waste Categories; and
- o The Atomic Energy Commission Radioactive Waste Management Classifications.

Members of the Technical Advisory Panel also proposed five additional classification systems to provide further guidance and alternatives for consideration. These five systems and the existing systems considered are described in detail in the report "Determination of a Radioactive Waste Classification System," UCRL-52535 (Ref. 7).

2.4.2 Preferred System Selected

Based on this study, the existing classification systems generally fell into three categories: those based on the source or generator of the waste (e.g., reactor wastes, medical wastes, industrial wastes); those based on the characteristics of the waste (e.g., solid, liquid, gas) and those based on the method of disposal (e.g., shallow land burial, ocean dumping, deep geological repository).

Classification of waste based on the "source of waste" was not considered useful since it would reveal little about the characteristics of waste and the requirements needed for its safe disposal. Likewise the characteristics and properties of the waste needed to be considered in developing a classification system but not to the exclusion of the method to be used for disposal.

It was concluded, therefore, that the preferred approach should be to develop a classification system based on the method or requirements that should be applied for disposal. The requirements for disposal could then be defined by the waste characteristics, the containment and isolation capabilities of the method of disposal and the social commitment controls required to assure safe disposal of the waste.

A methodology to classify waste based on this preferred alternative was subsequently developed and is reported in detail in NUREGs-0456 and 1005 (Refs. 1 and 2). The methodology developed involved identifying a set of exposure events at model waste disposal facilities, describing potential radionuclide transport to man, and then calculating limiting concentrations or inventories of radionuclides in waste that may be placed in the model disposal sites to ensure that specified dose guidelines would not be exceeded. The set of potential exposure events that was considered in the analysis included events in which individuals may come in contact with the waste (e.g., inhalation of dust by an intruder digging in the waste at a future point in time) and events in which the waste radioactivity was transported offsite by water or air (e.g., groundwater migration to a water resource pathway). Preliminary activity

concentrations or inventories of material were calculated that would assure that the doses to any potentially exposed individual or total population would not exceed proposed acceptable dose guidelines assumed for purposes of the study. This is the approach that NRC has followed in developing a classification system for LLW. The details are presented in Chapter 7.

2.4.3 Other Issues Regarding Classification

Two final issues remain regarding classification. One involves classifying radioactive waste on the basis of total hazard. The second involves establishment of a de minimis classification of wastes. Each is discussed below.

2.4.3.1 Classification by Total Hazard

Given the wide range in potential hazards presented by LLW (e.g., chemical, biological, physical as well as radiological), NRC also initiated a study to examine chemical and other hazards associated with LLW and to examine if a quantitative method could be developed and applied for comparing radiological hazards with chemical hazards (Ref. 8). Also, recently the draft document "Managing Low-Level Radioactive Wastes: A Proposed Approach" (Ref. 9) suggests that a classification system should be developed based on total hazard-chemical, biological and physical as well as radiological. Based on the study results and current technical abilities to characterize potential effects of biologically and chemically hazardous wastes and to make direct comparisons with potential radiological hazards, it is not technically feasible at this time to break down all the different hazards and to assign a hazard factor that represents some weighted index of hazard.

Thus, NRC does not plan to address classification of waste by total hazard as part of its classification of LLW. Disposal requirements will be determined based principally on radiotoxicity. NRC plans, however, through specific requirements on waste form and content, to address associated potential chemical, biological and physical hazards. In general, the site and other requirements being developed for radioactive waste should be adequate to cover other hazards.

In some cases NRC is also taking specific action to eliminate or minimize potential chemical and biological hazards. A good example of this relates to the emphasis NRC has placed on the incineration of liquid scintillation fluids to destroy the organic solvents rather than continuing to utilize land disposal (Ref. 10).

Finally, as EPA develops its program of regulation for chemically hazardous waste, NRC will review EPA requirements for application at LLW disposal sites. The methodology and approach NRC is developing for classifying waste is sufficiently flexible that it should be able to accommodate any classification system EPA may develop for hazardous waste.

2.4.3.2 De Minimis

NRC recognizes the need for a "de minimis" classification of wastes that would be exempt from Part 61 and would be considered of no regulatory concern. NRC

believes, however, as has been recommended by the Federal Radiation Policy Council (Ref. 11), and supported by public comments in the scoping process that such exemptions should be determined on a specific waste stream basis. In this regard, a final rule was recently published that establishes such an exemption in a new §20.306 for tritium and carbon-14 not exceeding a concentration of 0.05 µCi/gm when contained in liquid scintillation cocktail and animal carcass waste (Ref. 12). Other waste streams may also readily lend themselves to treatment in this manner. Finally, as a part of each specific licensee's program, authorization can be obtained to store very short half-life radionuclides for decay (generally for 10 half-lives) and to dispose of such waste as nonradioactive waste according to the other properties of the waste. Thus, through this EIS, NRC does not plan to establish a generic "de minimis" category for waste.

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Chapter 3

DESCRIPTION OF THE AFFECTED ENVIRONMENT AND APPROACH FOLLOWED IN PREPARING THIS EIS

3.1 INTRODUCTION

The environment affected or potentially affected by the generation, transport and disposal of LLW encompasses the whole of society. It consists of all the industries, hospitals, private individuals, government agencies and laboratories that generate LLW through the use of radioactive materials as a normal part of their day-to-day activities and functions. It consists of those involved in providing services such as supplying packaging and waste processing services at waste generator facilities and transporting waste from waste generator to disposal facilities. It consists of those involved in the ownership, operation and long-term control of the disposal facilities and the various regulatory agencies such as NRC, DOT and the state radiation control programs that license, regulate and inspect all phases to assure an adequate level of safety. It consists of society; the individuals, small population groups (e.g., radiation workers) and the general population that can be potentially affected by the various activities involved in the generation and disposal of waste. Finally, it consists of the natural environment including the ground and surface water, the atmosphere and various plant and animal species that would be affected by site-specific activities.

The affected environment for a rulemaking is, by nature, quite differently divided into direct and indirect segments than the affected environment described for a specific facility that might be proposed to be licensed. In the case of a rulemaking proceeding, the environment experiencing direct impacts are those parts which may have to change their way of carrying out specific activities or whose activities would be influenced if a new regulation were developed. Included would be the generators of waste, those providing services, the regulatory agencies, those owning and operating disposal sites, and society as a whole. The parts of the environment experiencing indirect impacts would be the natural environment with respect to the impacts on ground water, air, and plant and animal species due to application of the rule at a specific site.

In this EIS, NRC has concentrated on those segments of the environment that would experience the greatest impacts; those generating and disposing of the waste, society and the natural environment that would be affected by the costs, exposures and commitment of social and natural resources required to properly dispose of LLW. In analyzing the impacts of disposal, NRC divided the disposal process into three principal phases: (1) generation involving the processing of waste prior to disposal either at the point of generation or at a central location, (2) transportation of the waste from the point of generation to the disposal location, and (3) disposal of the waste.

In the following sections, the process NRC has followed in this EIS to characterize and analyze the affected environment involving the generation, transport, and disposal of waste and the impacts on each segment due to

development of a new Part 61 rule is described. Section 3.2 reviews the approach NRC has followed in this EIS leading to development of performance objectives, technical and other requirements that are being codified through the Part 61 rulemaking action. Section 3.3 explains how NRC developed a base of data about LLW, methods of disposal and a calculational methodology to perform the required analyses. Section 3.4 deals with waste generation. It describes the waste generators and explains how NRC has organized a base of data about the sources and characteristics of waste to place it into a form and size that is manageable for purposes of this EIS. Section 3.5 deals with transportation. It describes the type of packaging and transport vehicles used, frequency of shipments, miles travelled, costs and other data. Section 3.6 deals with disposal. It describes the disposal of waste as it has been carried out through the characterization of a reference (base case) near-surface disposal facility. Analysis of the disposal of waste at the reference facility is performed in Chapters 4, 5, 6, and 7 and provides a base line level of the costs and impacts presented by the generation, transport, and disposal of waste. It represents the "no action" alternative. The incremental changes to these base line costs and impacts due to application of various alternatives which would be implemented because of new requirements in a new Part 61 regulation can then be evaluated leading to the selection of preferred requirements. Section 3.7 describes the various design and operations alternatives analyzed in the EIS. Section 3.8 describes the methodology developed to calculate various impact measures and the impact measures selected for use in this EIS to characterize the costs, benefits and radiological impacts of the generation, transport, and disposal of LLW. The impact measures which include dose to members of the public, occupational exposures, costs, energy, and land use, are applied to evaluate the costs and benefits of the various alternatives analyzed in Chapters 4, 5, 6, and 7. The analyses in Chapters 4, 5, 6, and 7 provide the basis for decisions on the specific performance objectives and technical requirements that should be included in Part 61. After selection of the preferred requirements, Chapter 10 analyzes the typical unmitigated costs and impacts of application of the rule to various sectors of society and the environment.

3.2 APPROACH TO PREPARATION OF THIS EIS

The performance objectives and technical requirements for low-level waste disposal are being developed based on the results of the analyses presented in this EIS. The analyses are tiered from the generic to the specific. First, overall performance objectives are evaluated and preferred objectives are selected to define a level of safety and social commitment that should be achieved in the disposal of LLW. Second, technical requirements for the near-surface disposal of waste are evaluated based on the performance objectives and preferred requirements are selected. The performance objectives and technical requirements collectively establish a classification of waste for near-surface disposal in that they define the controls which should be applied in the near-surface disposal of waste (and which wastes are generally not acceptable for near-surface disposal). Administrative and procedural requirements for licensing the land disposal of LLW are evaluated and preferred requirements selected. The need for and provisions for adequate

financial assurance for closure, postclosure care and institutional control are evaluated and preferred requirements selected. Finally, the unmitigated impacts of application of the preferred requirements are analyzed through evaluation of disposal of waste on a regional basis in accordance with the preferred requirements.

3.2.1 Need for Performance Objectives

NRC initially planned to develop only the technical requirements needed to assure safety and environmental protection in the disposal of LLW. These requirements would have been derived from a consideration of the currently established level of safety and environmental protection that should be achieved in LLW disposal. In evaluating the level of safety which should be achieved, NRC identified 3 components that needed to be considered:

1. Protection of occupationally exposed workers and the public during operation of the facility;

2. Long-term environmental protection; and

3. Protection of an inadvertent intruder.

A level of safety has been established for occupationally exposed workers and protection of the public during operation of the facility and is set out in the existing standards in 10 CFR Part 20 which applies to the activities of all NRC licensees. However, neither the federal government nor national and international organizations have defined such a level of safety specific to the disposal of LLW involving long-term environmental protection and protection of an inadvertent intruder. NRC thus had to also establish performance objectives to define the level of safety which should be achieved for each of these in disposal. With respect to standards on long-term releases to the environment, the Environmental Protection Agency is developing such standards through its overall program to develop generally applicable environmental standards; however, no standard for LLW disposal presently exists. Protection of an inadvertent intruder is a new concept, generally unique to disposal of waste. There are no existing standards for protection of an inadvertent intruder. In addition, there was a fourth component, generally unique to waste disposal that also needed to be addressed; long-term social commitment. Future generations should not be burdened with long-term expensive commitments to care for wastes generated today, and the development of requirements for the disposal of waste should take into account the long-term commitment of social and natural resources to care for waste over the long term. Thus, in addition to development of the technical requirements for how waste should be disposed of to meet an acceptable defined level of safety, NRC also had to develop and define such a level of safety for two areas--long-term environmental releases, and protection of an inadvertent intruder. (A level of safety for short-term operations has already been defined through 10 CFR Part 20.) NRC also had to consider the level or degree of social commitment that should be applied in the disposal of waste. These performance objectives would establish the level of safety and environmental protection that should not generally be exceeded in the disposal of LLW and the social commitment required in disposal.

3.2.2 Development of Performance Objectives, Technical and Other Requirements

The approach NRC has followed in the analyses of LLW disposal is to first analyze the generation and disposal of LLW as it has been carried out to see what the costs and impacts are. This analysis is termed the "base case" analysis and represents the "no action" alternative--i.e., no new requirements are developed and past practices continue. NRC next analyzes a range of modifications and improvements (alternatives to the base case) that could be applied with current technology and calculated the costs and impacts of such modifications and improvements. A range of alternative numerical performance objectives for intrusion and long-term environmental protection are also evaluated. These analyses are then utilized to select performance objectives for the intruder, environmental releases and social commitment. The preferred numerical objectives are selected based on a comparative evaluation of costs and benefits, are achievable today with existing technology and require some increased cost and effort. The objectives selected define an improved level of safety and environmental protection and reduced degree of long-term social commitment than that expected from past operations.

The analyses also identified three key aspects that are of most significance in ensuring long-term safety and environmental protection and in minimizing the degree of social commitment in the near-surface disposal of waste. These are: long-term stability of the disposal site; liquids in waste and the contact of water with waste both during operations and after closure; and institutional and other controls to reduce the likelihood of inadvertent intrusion. These three key aspects are then translated into technical requirements that must be applied in the near-surface disposal of waste. These requirements are applied to the four principal and readily identifiable components of a disposal system: site characteristics, site design and operations, waste form and packaging, and institutional control.

In analyzing past practices at the existing sites, only natural characteristics of the disposal site environment had been principally relied upon to provide confinement of the waste over the long term. The experiences at several of the existing sites have shown the need to consider several components collectively--a series of "multiple barriers"--rather than relying principally on just one component (i.e., the site).

This concept can be carried to an extreme such that each component of the system is designed so that it will guarantee success regardless of the performance of the other components. NRC has not followed this approach but has set levels of performance for each component, so that when considered individually, each will provide a degree of assurance and when considered collectively will provide a high level of assurance that the performance objectives will be met over the long term.

The following components collectively encompass the LLW disposal system and were specifically addressed in the development of technical criteria:

1. Site Characteristics - The geohydrological, geomorphological, climatological and other natural characteristics of the site on which the disposal facility is located.

2. Design and Operations - The methods by which the site is utilized, the disposal facility design, the methods of waste emplacement, and closure of the site.

3. Waste Form and Packaging - The characteristics of the waste and its packaging.

4. Institutional Controls - The actions, including assurance of adequate financial resources, which involve a government agency maintaining surveillance, monitoring, and control over access and utilization of the site after closure.

NRC next analyzed a range of specific alternatives that could be used in near-surface disposal to help ensure long-term stability, reduce water contact with waste, and reduce the potential for inadvertent intrusion. In some cases, based on the alternatives analysis and past known experience at the existing sites, a specific prescriptive requirement was selected and applied. For example, with respect to the use of active institutional controls to prevent inadvertent intrusion, NRC analyzed a range of alternative time periods for such controls (from 50-300 years) and selected 100 years as the preferred time upon which reliance should be placed on such controls. In a second case, placing certain higher activity wastes into a stable waste form, NRC evaluated a range of alternatives (including waste processing, use of containers and facility design) but selected no preferred alternative. In this case, each alternative presented an equivalent degree of long-term stability at a range of costs depending upon the particular type and volume of waste and the individual capabilities of the waste generator. No specific prescriptive requirement was selected to allow maximum flexibility in meeting the objective, to allow for individual preferences and capabilities and to allow for individual cost-benefit determinations. The performance objectives and technical requirements selected also collectively establish a definition or classification of waste for near-surface disposal in that they define the controls which should be applied in the disposal of waste at a near-surface disposal facility (and also define which wastes are generally not acceptable for near-surface disposal). NRC considered some alternatives for setting out the classification system and selected the alternative of establishing concentration limits for individual nuclides in wastes that generators and disposal site operators could readily apply in determining the classification of a particular waste and the particular controls that should be applied in the disposal of that waste.

As a part of the development of the minimum technical requirements, NRC also analyzed the need for financial assurance to cover the cost for closure and postclosure surveillance, monitoring and care. A range of alternatives was reviewed and requirements were developed from the preferred alternatives to ensure adequate financial assurance in the disposal of LLW. The results of the base case "no action" and alternatives analyses are set out in Chapters 4-6. The classification of waste for near-surface disposal is set out in Chapter 7. Financial assurance is addressed in Chapter 9.

Finally, as part of development of the technical requirements, NRC examined the existing administrative and procedural requirements that are applied by

NRC in the licensing of LLW disposal facilities including procedures for participation by states and others in the NRC licensing process. Alternatives for improvement were analyzed and preferred alternative changes to these procedural requirements were selected. The results of this analysis are set out in Chapter 8.

3.2.3 Codification of Requirements into a New Part 61 Rule

The performance objectives, technical and other requirements developed through the analyses presented in Chapters 4-9 collectively form the basis for the new requirements to be codified through the Part 61 rulemaking actions. The requirements developed seemed to fall into one of three categories: (1) requirements which were a codification of existing practice, (2) requirements which represented an improvement or deviation from existing practice, and (3) requirements which seemed to fall into both categories (1) (2)--e.g., a practice that may only currently be applied at one site. For those requirements which codified existing practice, no cost-benefit evaluation was carried out since they represent current state-of-the-art and are reflected in the base case analysis. For these, the cost of complying with the requirement was considered and included in the base case cost data and the impacts reflected in the impacts for the base case analysis. Requirements in Category 2 that represented improvements or modifications were subjected to cost-benefit evaluation in terms of the incremental cost increase over the base case and the resultant change (increase or decrease) in impacts resulting from application of the new requirement. For those in category (3), staff judgment was applied in placing the requirement into either category (1) or (2).

The results of the analyses presented in Chapters 4-9 indicate that with modest increases in cost relating to improving the form and properties of waste shipped for disposal and modest improvements in the design and operation of a near-surface disposal facility (many of which are being used at some of the existing sites today) the potential health, safety, and environmental impacts from disposal of LLW and the degree of long-term social commitment can be greatly reduced. The ability to predict the long-term performance and impacts of near-surface disposal facilities is also greatly improved and the uncertain and high costs required to care for disposal sites over the long term are reduced. Stated simply--we can put some modest increased effort and cost into the disposal of LLW today leading to reduction in potential impacts, reduction in long-term care costs and increased confidence in the performance capability of near-surface disposal facilities. Or, we can continue as we have in the past possibly leading to situations as has been evidenced at some existing sites where the potential impacts over the long term may be high, the costs for long-term care high, and confidence in the long-term performance low. The proper course of action is the former and the performance objectives, technical, and other procedural requirements selected are set out in a new Part 61 regulation and in amendments to existing parts of NRC's regulations.

3.2.4 Unmitigated Impacts of Implementing Part 61

Finally, as a part of this EIS, NRC has also conducted an analysis of the preferred requirements to be included in the new Part 61 rule to better judge

their applicability to the wide range in site and waste characteristics expected through regional disposal of LLW and to better judge the overall impacts of implementation of the rule. This analysis involves application of the requirements at several regionally located sites where the waste generated within each region is shipped for disposal. Each of the disposal facilities is sited, designed, and operated in compliance with the preferred requirements accounting for regional differences and variations that might be expected. The results of this analysis are set out in Chapter 10.

3.3 DEVELOPMENT OF DATA BASES FOR THE ANALYSES

To perform the base case and alternatives analyses, NRC developed a base of information and data about the affected environment and LLW disposal--who generates the waste; how is it processed, packaged, and shipped for disposal; how is it disposed of today; and what kinds of modifications and improvements can be made to existing practices and at what cost. In addition, NRC developed a methodology to calculate the costs and impacts of various combinations of site features, waste characteristics, designs, operating procedures, closure and long-term care conditions.

The data was divided into 5 major portions as follows:

- o Information on the sources, characteristics, treatment and packaging of LLW. (Set out in Appendix D)
- o Information on the siting, design, operation, closure and long-term care of a reference LLW disposal facility. (Set out in Appendix E)
- o Information on possible technological improvements and variations that could be applied to near-surface disposal technology. (Set out in Appendix F)
- o Information on assuring adequate financial resources and arrangements for site operations, closure and long-term care. (Set out in Appendix K)
- o Information on administrative and procedural considerations that should be applied in licensing a near-surface disposal facility. (Set out in Chapter 8)

A description of the methodology developed to calculate the costs and impacts for disposal is set out in Appendices G and H.

The application and use of these data bases in this EIS and their interrelationship is described below including the major assumptions made and method of analysis used. Each is described in greater specific detail in the referenced appendices.

As noted earlier, the data has been developed and analyzed according to three major phases: generation of the waste (described in Section 3.4), transport of the waste (described in Section 3.5), and final disposal (described in Section 3.6).

3.4 WASTE GENERATION

This section describes the affected environment made up of those generating LLW. It includes the industries, hospitals, colleges, and others who generate LLW; the physical, chemical, radiological, and other characteristics of the wastes as it is generated; the volume of the waste as it is generated; changes in waste characteristics due to treatment or processing of the waste; the packaging used for transport and disposal; and the occupational exposures, population exposures, costs and energy used for processing, packaging and handling of the waste at the point of generation.

3.4.1 Waste Generators

LLW is generated by more than 20,000 NRC and Agreement State licensees throughout the country and by a number of government operations, particularly Department of Energy (DOE) facilities. While some DOE wastes were previously disposed of at commercial disposal facilities, all DOE wastes are now disposed of at DOE owned and operated facilities which are not subject to NRC or Agreement State licensing authority. Such wastes are thus not addressed in this EIS. The waste addressed in this EIS is generated by a wide variety of licensed programs including fuel cycle facilities such as nuclear power reactors, reactor fuel fabrication plants and uranium hexafluoride conversion plants. Other wastes are generated by a number of nonfuel cycle facilities including hospitals, medical research institutions, colleges and universities, industrial research labs, government labs, facilities involved in the production of radiopharmaceuticals, and other industrial uses of radioactive materials.

3.4.2 Description of the Waste as Generated

In general, the waste is very diverse in terms of volume, activity, and characteristics. It essentially includes everything that is discarded as waste and ranges from trash that is only suspected of being contaminated to highly radioactive activated structural components from nuclear power reactors. Currently about 85,000 m^3 (3 million ft^3) of commercial LLW is generated annually that ranges in activity from hundreds to thousands of curies per cubic meter to less than a few microcuries per cubic meter. Most of the activity disposed of at the commercial sites is contained in a relatively small volume of waste and is generated by less than 100 licensees. The form of the waste generated can be solid, liquid, or gaseous. It can consist of a wide range of chemical forms and can be shipped in a number of different types of packages. Based on projections of LLW volume prepared by NRC for the basic waste streams considered in this EIS, about 3.62 million m^3 (128 million ft^3) will be generated during the period 1980-2000. Of this, about 65% of the waste will be generated by fuel cycle sources and 35% by nonfuel cycle sources. Institutional generators will account for about 19% of the nonfuel cycle sources.

3.4.2.1 Fuel Cycle Facilities

The LLW produced by commercial nuclear power plants can be divided into six basic categories: ion exchange resins, concentrated liquids, filter sludges,

compactible trash, noncompactible trash and nonfuel irradiated reactor components. Ion exchange resins are used in reactors to remove dissolved radioactivity from liquid streams. When spent, they are exchanged and the spent resins are placed into a shipping container (usually referred as a liner) where excess water is removed (dewatering) prior to transfer to a disposal site. In some cases the spent resins may be solidified with binders such as cement or urea-formaldehyde. Resin waste in shipping containers is usually transported in a cask or overpack that is shielded for radiation protection purposes. Concentrated liquid waste is produced by the evaporation of a wide variety of reactor liquid streams. These concentrated liquids are solidified in various materials such as cement, placed in a shipping container, and shipped to a disposal site. Filter sludge is waste produced by precoat filters and consists of powdered filter material. It is used to remove suspended and dissolved material from liquid streams. Filter sludge waste is generally dewatered and placed into a container for disposal. Compactible and noncompactible trash consists of everything from paper towels, plastic, and glassware to metallic components such as pipes and contaminated tools. Nonfuel irradiated components consist of fuel channels, control rods, and in-core instrumentation that has been exposed to in-core neutron flux.

Other nonfuel cycle waste streams include process waste and trash from uranium hexafluoride and fuel fabrication plants. This can include calcium fluoride generated in hydrogen fluoride gas scrubbers, filter sludges and paper, plastic, equipment and other trash. These are generally packaged in 55 gallon drums or larger containers and shipped for disposal.

3.4.2.2 Nonfuel Cycle Facilities

Institutional waste generators include colleges and universities, medical schools, medical research facilities, private physicians and hospitals. These institutions use radioactive materials in many diverse applications including analytical instruments, diagnosis and therapy, research and instruction. The type of waste generated generally falls into six groups: liquid scintillation vials, liquids, biological wastes, trash, accelerator targets and sealed sources. Liquid scintillation vials are generally made of glass and contain organic solvents and small amounts of radioactivity. They are ususally packaged in 55-gallon drums with absorbent material for disposal. Absorbed liquids consist of organic and aqueous liquids generated by various preparatory and analytical procedures involving radioactive material. They are absorbed on media such as diatomaceous earth and packaged in 55-gallon or smaller drums. Biological wastes consists of animal carcasses, tissues and culture media used in research programs. It is usually treated with lime and packaged in 55-gallon drums for disposal. Institutional trash consists mostly of paper, rubber, plastic, broken labware and disposable syringes. Sealed sources consist of radioactive material that has been encapsulated to contain and prevent leakage of the material. Sealed sources are packaged in a shielded container for transport and are sometimes disposed of in toner tubes or caissons backfilled with concrete.

Industrial waste generators include firms engaged in the production of radioisotopes for medical, research and industrial applications; industrial research

and development activities; manufacturing and distribution of products containing radioactive material; and uses in quality control and manufacturing processes. The uses of radioactive materials and resulting wastes produced are diverse and can consist of: sealed sources, compactible and noncompactible trash, radioisotope production wastes, and a range of biological, scintillation and absorbed liquids similiar to those generated by medical and educational institutions.

3.4.3 Characterization of LLW for Purposes of Analysis

Given the large number of individual waste generators and diverse nature of the waste generated, coupled with changes that can be made in the form of the waste due to processing and the number of different types of packaging that can be used, an infinite number of variations are possible. All such variations cannot be analyzed. To characterize such a wide diversity in possible waste streams and to bound the variations that might be expected, NRC analyzed currently available information about the sources, form, content and characteristics of waste. The data base developed, based on this analysis, consists of a projection of the volume and physical, chemical, and radiological characteristics of waste to be routinely generated during the period 1980 to the year 2000.

3.4.3.1 Waste Stream Characterization

Based on the analysis NRC was able to group the major types of wastes generated into 36 individual waste streams. The 36 streams are summarized in Table 3.1. The streams characterize the wastes that are presently being routinely generated or are expected to be routinely generated in the future. The major waste generators analyzed included nuclear fuel cycle facilities such as nuclear power, fuel fabrication and uranium hexafluoride conversion plants, and nonnuclear fuel cycle sources such as hospitals, colleges, research labs, medical isotope production facilities, and industrial facilities. Each waste stream represents a particular type of waste generated by a particular type of waste generator having particular physical, chemical, radiological, and other characteristics unique to that individual stream. (For example, one stream is ion exchange resins, generated by boiling water reactors which contains concentrations of several specific radionuclides. This waste is usually packaged in a dewatered form in a steel liner for disposal.) NRC reviewed existing information and characterized in detail each of the 36 waste streams. The most important radionuclides present in the waste streams were identified and the geometric mean of the range of activity concentrations for each radionuclide observed was determined from available data. The radionuclides considered are shown in Table 3.2. For those streams where limited data was available, estimates were made based on scaling factors from the known composition of similar or related waste streams. Each stream was identified by a particular alphameric symbol for ease in identification during computer analysis (e.g., boiling water ion exchange resins are denoted by B-IXRESIN). The following symbols have been used to denote the major waste generators:

Symbol	Generator
P	Pressurized Water Reactors
B	Boiling Water Reactors

Table 3-1 Waste Streams Considered in Analyses

Waste Stream	Symbol
Group I: LWR Process Wastes	
PWR Ion Exchange Resins	P-IXRESIN
PWR Concentrated Liquids	P-CONCLIQ
PWR Filter Sludges	P-FSLUDGE
PWR Filter Cartridges	P-FCARTRG
BWR Ion Exchange Resins	B-IXRESIN
BWR Concentrated Liquids	B-CONCLIQ
BWR Filter Sludges	B-FSLUDGE
Group II: Trash	
PWR Compactible Trash	P-COTRASH
PWR Noncompactible Trash	P-NCTRASH
BWR Compactible Trash	B-COTRASH
BWR Noncompactible Trash	B-NCTRASH
Fuel Fabrication Compactible Trash	F-COTRASH
Fuel Fabrication Noncompactible Trash	F-NCTRASH
Institutional Trash (large facilities)	I-COTRASH
Institutional Trash (small facilities)	I+COTRASH
Industrial SS* Trash (large facilities)	N-SSTRASH
Industrial SS Trash (small facilities)	N+SSTRASH
Industrial Low Trash (large facilities)	N-LOTRASH
Industrial Low Trash (small facilities)	N+LOTRASH
Group III: Low Specific Activity Wastes	
Fuel Fabrication Process Wastes	F-PROCESS
UF_6 Process Wastes	U-PROCESS
Institutional LSV** Waste (large facilities)	I-LIQSCVL
Institutional LSV** Waste (small facilities)	I+LIQSCVL
Institutional Liquid Waste (large facilities)	I-ABSLIQD
Institutional Liquid Waste (small facilities)	I+ABSLIQD
Institutional Biowaste (large facilities)	I-BIOWAST
Institutional Biowaste (small facilities)	I+BIOWAST
Industrial SS Waste	N-SSWASTE
Industrial Low Activity Waste	N-LOWASTE
Group IV: Special Wastes	
LWR Nonfuel Reactor Components	L-NFRCOMP
LWR Decontamination Resins	L-DECONRS
Waste from Isotope Production Facilities	N-ISOPROD
Tritium Production Waste	N-TRITIUM
Accelerator Targets	N-TARGETS
Sealed Sources	N-SOURCES
Industrial High Activity Waste	N-NIGHACT

*SS: Source and Special Nuclear Material
**LSV: Liquid Scintillation Vial

Table 3.2 Radionulides Considered in Analyses

Isotope	Half Life (years)	Radiation Emitted	Principal Means Of Production
H-3	12.3	β	Fission; Li-6 (n, α)
C-14	5730	β	N-14 (n, p)
Fe-55	2.60	γ	Fe-54 (n, γ)
Co-60	5.26	β, γ	Co-59 (n, γ)
Ni-59	80,000	γ	Ni-58 (n, γ)
Ni-63	92	β	Ni-62 (n, γ)
Sr-90	28.1	β	Fission
Nb-94	20,000	β, γ	Nb-93 (n, γ)
Tc-99	2.12×10^5	β	Fission; Mo-98 (n, γ), Mo-99 (β^-)
I-129	1.17×10^7	β, γ	Fission
Cs-135	3.0×10^6	β	Fission; daughter Xe-135
Cs-137	30.0	β, γ	Fission
U-235	7.1×10^8	α, γ	Natural
U-238	4.51×10^9	α, γ	Natural
Np-237	2.14×10^6	α, γ	U-238 (n, 2n), U-237 (β^-)
Pu-238	86.4	α, γ	Np-237 (n, γ), Np-238 (β^-); daughter Cm-242
Pu-239	24,400	α, γ	U-238 (n, γ), U-238 (β^-), Np-239 (β^-)
Pu-240	6,580	α, γ	Multiple n-capture
Pu-241	13.2	β, γ	Multiple n-capture
Pu-242	2.79×10^5	α	Multiple n-capture; daughter Am-242
Am-241	458	α, γ	Daughter Pu-241
Am-243	7950	α, γ	Multiple n-capture
Cm-243	32	α, γ	Multiple n-capture
Cm-244	17.6	α, γ	Multiple n-capture

Symbol	Generator
L	Light Water Reactors
F	Fuel Fabrication Facilities
U	UF_6 Conversion Plants
I	Institutional Facilities
N	Industrial Facilities

The streams were next divided into four general groups based upon common waste characteristics. The groups are: lightwater reactor process wastes, trash, low specific activity wastes, and wastes having unique special characteristics such as high activity. The grouping of waste streams was done to help increase the flexibility of the data base when considering the application of various waste processing techniques. Finally, six of the waste streams have been separated into two components and the additional six streams resulting from this separation have been denoted by a plus sign after the waste generator symbol (I or N) instead of the usual minus sign. This was done to identify the larger facilities (denoted by the minus sign) which could more easily implement their own waste treatment processes from smaller facilities (denoted by the plus sign) which cannot generally do the same. The as generated (untreated) isotopic concentrations for the various waste streams by group are shown in Table 3.3.

3.4.3.2 Volume of the Waste as Generated

NRC also analyzed currently available information about the current and projected rates of waste generation and calculated the volume of waste for each of the 36 waste streams projected to be generated on a regional basis. The regions used in the calculations correspond to the five NRC regions. The volume for each stream was projected from 1980 through the year 2000. Both high and low estimates of waste generation were considered. In developing the projections, nuclear fuel cycle waste volume was assumed to be proportional to the nuclear electrical generation capacity. Nonfuel cycle waste volumes were assumed to grow at a linear rate based upon least squares fit of existing data on individual waste streams. The "untreated" waste volumes assumed in this EIS are shown in Table 3.4.

3.4.3.3 Processing, Treatment and Packaging

NRC also analyzed the various types of processing and treatment options to which the waste, as generated, could be subjected that would change the as generated waste characteristics. Such processing and treatment could reduce the volume of the waste (e.g., compaction of trash, evaporation of liquids and incineration of combustible waste) or increase the volume of the waste (e.g., addition of absorbent materials to liquids and solidification of liquids with a media such as cement). Such processing would also change the chemical and physical properties of the waste as well as the activity concentration. Depending upon whether the processing or treatment option reduced or increased the volume of waste, volume decrease and increase factors were calculated for each stream processed based upon application of one of the above particular processing or treatment options.

Table 3.3 As Generated (Untreated) Isotopic Concentrations (Ci/m^3)

Group 1	P-IXRESIN	P-CONCLIQ	P-FSLUDGE	P-FCARTRG	B-IXRESIN	B-CONCLIQ	B-FSLUDGE
Total	3.36E-02	1.09E-01	1.06E+00	1.86E+00	4.63E00	2.77E-01	5.24E+00
H-3	2.66E-03	3.45E-03	2.59E-03	1.15E-03	1.92E-03	6.24E-04	1.26E-02
C-14	9.74E-05	1.27E-04	9.55E-05	4.25E-05	1.19E-03	3.89E-05	7.78E-04
FE-55	2.34E-03	2.27E-02	3.10E-01	5.55E-01	9.48E-01	7.60E-02	1.44E+00
NI-59	2.79E-06	2.71E-05	3.71E-04	6.60E-04	9.80E-04	7.85E-05	1.49E-03
CO-60	4.53E-03	4.40E-02	6.00E-01	1.07E+00	1.59E+00	1.27E-01	2.41E+00
NI-63	8.61E-04	8.36E-03	1.14E-01	2.04E-01	2.15E-02	1.72E-03	3.25E-02
NB-94	8.84E-08	8.58E-07	1.17E-05	2.09E-05	3.09E-05	2.48E-06	4.70E-05
SR-90	1.94E-04	2.52E-04	1.89E-04	8.40E-05	3.64E-03	1.18E-04	2.37E-03
TC-99	8.23E-07	1.07E-06	8.03E-07	3.58E-07	7.65E-05	2.50E-06	5.00E-05
I-129	2.44E-06	3.16E-06	2.37E-06	1.06E-06	2.04E-04	6.65E-06	1.33E-04
CS-135	8.23E-07	1.07E-06	8.03E-07	3.58E-07	7.65E-05	2.50E-06	5.00E-05
CS-137	2.19E-02	2.85E-02	2.14E-02	9.54E-03	2.04E+00	6.65E-02	1.33E+00
U-235	4.71E-08	6.15E-08	1.46E-07	3.64E-07	5.33E-08	3.44E-08	3.32E-07
U-238	3.71E-07	4.84E-07	1.15E-06	2.87E-06	4.20E-07	2.71E-07	2.61E-06
NP-237	9.06E-12	1.18E-11	2.81E-11	7.02E-11	1.02E-11	6.61E-12	6.38E-11
PU-238	2.60E-05	5.12E-05	4.76E-05	2.51E-04	8.34E-05	1.99E-04	4.66E-04
PU-239/240	1.82E-05	3.31E-05	1.55E-04	3.80E-04	5.34E-05	9.43E-05	2.36E-04
PU-241	7.94E-04	1.44E-03	6.75E-03	1.66E-02	2.60E-03	4.60E-03	1.15E-02
PU-242	3.99E-08	7.25E-08	3.39E-07	8.34E-07	1.17E-07	2.06E-07	5.18E-07
AM-241	1.87E-05	2.99E-05	2.64E-04	1.64E-04	2.32E-05	1.20E-04	1.56E-04
AM-243	1.26E-06	2.02E-06	1.78E-05	1.10E-05	1.57E-06	8.10E-06	1.05E-05
CM-243	9.92E-09	1.17E-08	3.10E-07	1.93E-07	2.70E-08	2.59E-07	2.97E-07
CM-244	1.38E-05	1.92E-05	1.77E-04	1.10E-04	1.82E-05	2.05E-04	2.24E-04

Table 3.3 (continued)

Group 2	P-COTRASH	P-NCTRASH	B-COTRASH	B-NCTRASH	F-COTRASH	F-NCTRASH	I-COTRASH	N-SSTRASH	N-LOTRASH
Total	2.28E-02	5.25E-01	2.35E-02	3.79E+00	5.58E-06	5.33E-06	1.13E-01	1.12E-05	3.53E-02
H-3	3.04E-04	6.99E-03	6.75E-05	1.09E-02	0	0	9.13E-02	0	2.85E-02
C-14	1.12E-05	2.57E-04	4.17E-06	6.73E-04	0	0	5.26E-03	0	1.64E-03
FE-55	5.97E-03	1.37E-01	6.01E-03	9.69E-01	0	0	0	0	0
NI-59	7.11E-06	1.64E-04	6.21E-06	1.00E-03	0	0	0	0	0
CO-60	1.15E-02	2.65E-01	1.01E-02	1.62E-00	0	0	1.04E-02	0	3.25E-03
NI-63	2.19E-03	5.05E-02	1.36E-04	2.19E-02	0	0	0	0	0
NB-94	2.25E-07	5.18E-06	1.96E-07	3.16E-05	0	0	0	0	0
SR-90	2.22E-05	5.11E-04	1.27E-05	2.05E-03	0	0	1.45E-03	0	4.53E-04
TC-99	9.42E-08	2.17E-06	2.68E-07	4.33E-05	0	0	3.39E-09	0	1.06E-09
I-129	2.78E-07	6.41E-06	7.14E-07	1.15E-04	0	0	0	0	0
CS-135	9.42E-08	2.17E-06	2.68E-07	4.33E-05	0	0	0	0	0
CS-137	2.51E-03	5.78E-02	7.14E-03	1.15E+00	0	0	4.56E-03	0	1.42E-03
U-235	7.89E-09	1.82E-07	1.22E-09	1.97E-07	1.18E-06	1.13E-06	0	2.36E-06	0
U-238	6.22E-08	1.43E-06	9.60E-09	1.55E-06	4.40E-06	4.20E-06	0	8.80E-06	0
NP-237	1.52E-12	3.49E-11	2.35E-13	3.78E-11	0	0	0	0	0
PU-238	5.97E-06	1.38E-04	2.30E-06	3.71E-04	0	0	0	0	0
PU-239/240	5.53E-06	1.27E-04	1.16E-06	1.86E-04	0	0	0	0	0
PU-241	2.41E-04	5.55E-03	5.63E-05	9.08E-03	0	0	0	0	0
PU-242	1.21E-08	2.79E-07	2.53E-09	4.08E-07	0	0	0	0	0
AM-241	3.96E-06	9.12E-05	9.67E-07	1.56E-04	0	0	0	0	0
AM-243	2.67E-07	6.15E-06	6.52E-08	1.05E-05	0	0	0	0	0
CM-243	2.74E-09	6.30E-08	1.93E-09	3.12E-07	0	0	0	0	0
CM-244	2.61E-06	6.00E-05	1.49E-06	2.41E-04	0	0	0	0	0

Table 3.3 (continued)

Group 3	F-PROCESS	U-PROCESS	I-LQSCNVL	I-ABSLIQD	I-BIOWAST	N-SSWASTE	N-LOWASTE
Total	1.08E-04	3.80E-04	9.60E-03	1.99E-01	2.06E-01	2.11E-02	
H-3	0	0	5.01E-03	1.42E-01	1.75E-01	0	1.63E-02
C-14	0	0	2.51E-04	8.16E-03	1.01E-02	0	9.36E-04
FE-55	0	0	0	0	0	0	0
NI-59	0	0	0	0	0	0	0
CO-60	0	0	0	3.12E-02	3.99E-03	0	1.47-03
NI-59	0	0	0	0	0	0	0
NB-63	0	0	0	0	0	0	0
SR-90	0	0	4.34E-03	4.34E-03	8.33E-03	0	1.31E-03
TC-99	0	0	0	1.02E-08	6.51E-09	0	7.76E-10
I-129	0	0	0	0	0	0	0
CS-135	0	0	0	0	0	0	0
CS-137	0	0	0	1.37E-02	8.76E-03	0	1.04E-03
U-235	2.30E-05	1.65E-05	0	0	0	4.60E-05	0
U-238	8.54E-05	3.64E-04	0	0	0	1.71E-04	0
NP-237	0	0	0	0	0	0	0
PU-238	0	0	0	0	0	0	0
PU-239/240	0	0	0	0	0	0	0
PU-241	0	0	0	0	0	0	0
PU-242	0	0	0	0	0	0	0
AM-241	0	0	0	0	0	0	0
AM-243	0	0	0	0	0	0	0
CM-243	0	0	0	0	0	0	0
CM-244	0	0	0	0	0	0	0

Table 3.3 (continued)

Group 4	L-NFRCOMP	L-DECONRS	N-ISOPROD	N-HIGHACT	N-TRITIUM	N-SOURCES	N-TARGETS
Total	4.04E+03	1.56E+02	1.50E+01	2.10E+02	2.33E+03	5.76E+03	8.04E+01
H-3	0	1.08E-02	4.20E-02	0	2.33E+03	8.63E+02	8.04E+01
C-14	2.59E-01	5.13E-04	4.51E-05	1.32E-02	0	5.76E+02	0
FE-55	2.23E+03	4.05E+01	0	1.15E+02	0	0	0
NI-59	1.40E+00	4.49E-02	0	6.56E-02	0	0	0
CO-60	1.60E+03	7.28E+01	0	8.48E+01	0	1.73E+03	0
NI-63	2.09E+02	3.69E+00	0	1.06E+01	0	2.30E+02	0
NB-94	8.19E-03	1.42E-03	0	4.47E-04	0	0	0
SR-90	0	4.28E-02	6.27E+00	0	0	1.15E+03	0
TC-99	0	1.20E-05	3.27E-04	0	0	0	0
I-129	0	3.34E-05	2.72E-06	0	0	0	0
CS-135	0	1.20E-05	3.27E-04	0	0	0	0
CS-137	0	3.18E-01	3.73E+00	0	0	1.15EE+03	0
U-235	0	6.84E-05	1.02E-05	0	0	0	0
U-238	0	5.40E-04	3.81E-05	0	0	0	0
NP-237	0	1.32E-08	5.33E-13	0	0	0	0
PU-238	0	1.34E+00	1.97E-04	0	0	0	0
PU-239/240	0	1.77E+00	5.55E-05	0	0	0	0
PU-241	0	3.55E+01	7.10E-03	0	0	0	0
PU-242	0	3.87E-03	9.57E-08	0	0	0	0
AM-241	0	5.29E-03	1.10E-05	0	0	5.76E+02	0
AM-243	0	3.59E-04	1.25E-06	0	0	0	0
CM-243	0	3.46E-04	1.65E-04	0	0	0	0
CM-244	0	3.27E-03	2.88E-07	0	0	0	0

Table 3.4 As Generated (Untreated) Waste Volumes Projected to be Generated-1980 to the Year 2000 (m^3)

	Region 1		Region 2		Region 3		Region 4*	
	Vol.	%	Vol.	%	Vol.	%	Vol.	%
P-IXRESIN	6.93E+03	0.79	1.30E+04	1.34	6.59E+03	1.00	8.14E+03	1.25
P-CONCLIQ	4.87E+04	5.54	9.12E+04	9.45	4.63E+04	7.06	5.72E+04	8.79
P-FSLUDGE	8.56E+02	0.10	1.60E+03	0.17	8.14E+02	0.12	1.01E+03	0.15
P-FCARTRG	4.35E+03	0.50	8.16E+03	0.84	4.14E+03	0.63	5.12E+03	0.79
B-IXRESIN	2.10E+04	2.39	2.51E+04	2.60	2.05E+04	3.12	9.67E+03	1.49
B-CONCLIQ	5.79E+04	6.59	6.93E+04	7.17	5.64E+04	8.60	2.67E+04	4.10
B-FSLUDOE	4.65E+04	5.30	5.57E+04	5.77	4.54E+04	6.92	2.14E+04	3.30
P-COTRASH	8.49E+04	9.66	1.59E+05	16.47	8.07E+04	12.31	9.97E+04	15.33
P-NCTRASH	4.36E+04	4.96	8.16E+04	8.45	4.14E+04	6.32	5.12E+04	7.87
B-COTRASH	5.74E+04	6.54	6.87E+04	7.12	5.60E+04	8.54	2.65E+04	4.07
B-NCTRASH	2.72E+04	3.10	3.26E+04	3.38	2.66E+04	4.05	1.26E+04	1.93
F-COTRASH	4.72E+04	5.37	1.18E+05	12.22	0	0	7.08E+04	10.88
F-NCTRASH	8.34E+03	0.95	2.09E+04	2.16	0	0	1.25E+04	1.
I-COTRASH	4.36E+04	4.97	3.10E+04	3.21	3.80E+04	5.79	2.81E+04	4.
I+COTRASH	4.36E+04	4.97	3.10E+04	3.21	3.80E+04	5.79	2.81E+04	4.33
N-SSTRASH	8.98E+04	10.22	1.80E+04	1.86	3.59E+04	5.48	3.59E+04	5.52
N+SSTRASH	8.98E+04	10.22	1.80E+04	1.86	3.59E+04	5.48	3.59E+04	5.52
N-LOTRASH	1.52E+04	1.73	1.01E+04	1.05	1.52E+04	2.32	1.01E+04	1.56
N+LOTRASH	1.52E+04	1.73	1.01E+04	1.05	1.52E+04	2.32	1.01E+04	1.56
F-PROCESS	1.56E+04	1.78	3.91E+04	4.05	0	0	2.34E+04	3.61
U-PROCESS	0	0	0	0	1.41E+04	2.14	1.41E+04	2.16
I-LQSCNVL	1.52E+04	1.73	1.08E+04	1.12	1.33E+04	2.02	9.83E+03	1.51
I+LQSCNVL	1.52E+04	1.73	1.08E+04	1.12	1.33E+04	2.02	9.83E+03	1.51
I-ABSLTQD	1.73E+03	0.20	1.23E+03	0.13	1.51E+03	0.23	1.12E+03	0.17
I+ABSLIQD	1.73E+03	0.20	1.23E+03	0.13	1.51E+03	0.23	1.12E+03	0.17
I-BIOWAST	4.87E+03	0.55	3.46E+03	0.36	4.24E+03	0.65	3.14E+03	0.48
I+BIOWAST	4.87E+03	0.55	3.46E+03	0.36	4.24E+03	0.65	3.14E+03	0.48
N-SSWASTE	3.17E+04	3.61	6.34E+03	0.66	1.27E+04	1.93	1.27E+04	1.95
N-LOWASTE	1.81E+04	2.06	1.21E+04	1.25	1.81E+04	2.76	1.21E+04	1.85
L-NFRCOMP	6.48E+02	0.07	1.04E+03	0.11	6.22E+02	0.09	5.77E+02	0.09
L-DECONRS	7.35E+03	0.84	1.22E+04	1.27	8.05E+03	1.23	7.35E+03	1.13
N-ISOPROD	5.20E+03	0.59	0	0	0	0	0	0
N-HIGHACT	8.09E+02	0.09	5.74E+02	0.06	7.04E+02	0.11	5.22E+02	0.08
N-TRITIUM	2.65E+03	0.30	2.09E+02	0.02	2.09E+02	0.03	4.18E+02	0.06
H-SOURCES	5.78E+01	0.01	4.10E+01	0.00	5.04E+01	0.01	3.73E+01	0.01
N-TARGETS	4.16E+02	0.05	2.95E+02	0.03	3.62E+02	0.06	2.68E+02	0.04
TOTAL	8.78E+05		9.66E+05		6.56E+05		6.50E+05	

*NRC Regions 4 and 5 are combined such that each region generates up to 10^6 m^3 of waste.

Three types of solidification processes or scenarios were assumed for this EIS as follows:

- Scenario A assumes continuation of existing practices resulting in waste performance characteristics which are comparatively less desirable than the following two types. Scenario A solidification is simulated by assuming that 50 percent of the waste stream is solidified using urea-formaldehyde systems and the other 50 percent using cement systems.

- Scenario B assumes improved waste performance characteristics over the previous case. Scenario B solidification is simulated by assuming that 50 percent of the waste stream is solified using cement systems and the other 50 percent using improved synthetic polymer systems.

- Scenario C assumes further improved waste performance characteristics achievable with currently available technology. Scenario C solidification is simulated by assuming that the waste stream is all solidified using improved synthetic polymer systems.

To characterize the change and variation in chemical and physical properties of the waste resulting from application of the processing or treatment options, NRC developed and applied 6 waste form indices: (1) Flammability--the ability of the waste form to catch fire and support combustion; (2) Dispersibility--the dispersibility of the waste form several decades after disposal; (3) Stability-the structural stability of the waste; (4) Leachability--the resistance of the waste form to leaching; (5) Chemical content--the content of chemicals such as chelating agents that could increase mobility; and (6) Accessibility--the accessibility of the radionuclides in the waste to transport by wind and water. NRC also analyzed the type of packaging that could be applied to the various waste streams. The various types of packaging assumed is reviewed in the next subsection. Finally data on the cost, occupational exposures, population exposures and energy use (i.e., gallons of fuel consumed) were calculated for each waste processing and treatment option. It is used in the alternatives analysis to account for the application of specific processing and treatment options to the various waste streams.

3.4.3.4 Waste Spectra

Although it is convenient to characterize wastes by stream for each waste generator, the waste disposed of at a disposal site never consists of just one stream. Rather, it consists of a cross section of all of the streams and there may be large differences between streams and within individual streams regarding the types of processing, treatment and packaging that is used. Thus, there is an infinite number of different types of wastes, in different types of forms, and in different types of packaging that could be shipped for disposal. To bound the range in waste that might be expected to be generated and disposed of, four "waste spectra" were derived. Each waste spectrum represents a cross section of all the waste streams that might be generated

and shipped for disposal under specific conditions of treatment and processing. Each spectrum is defined in terms of the total waste volume, waste performance and radionuclide concentrations that result from the application of a specific combination of waste treatment and processing options to specific waste streams. The spectra thus bound the range in waste that might be expected to be generated and disposed of. Four spectra were developed to characterize a range of alternative waste form properties and processing options from a continuation of existing and some past practices with little additional increase effort and cost to extreme volume reduction and improved waste form at very high effort and cost. Waste Spectrum No. 1 characterizes a continuation of existing and some past waste management practices and is used along with the base case site to calculate base case costs and impacts. Waste Spectrum No. 2 characterizes improvements in the form of the waste through processing and reduction in waste volume with modest expenditures of time and money. No. 3 characterizes further waste form improvements and volume reduction at further increased costs. No. 4 characterizes the maximum volume reduction and improved waste form that can currently be practically achieved. Waste being disposed of today falls between waste spectra Nos. 1 and 2, with the trend moving toward spectrum 2. Implementation of license conditions in effect at the existing sites regarding solidification of higher activity wastes would place the waste very close to waste spectrum No. 2. The four spectra are summarized in Table 3.5.

3.4.3.5 Impact Measures

Impact measures calculated by NRC for the generation and processing of waste include cost for processing and treatment; occupational exposures incurred during processing and treatment; population exposures resulting from processing and treatment and energy use (e.g., gallons of fuel consumed during processing and treatment). The costs for waste processing change from spectra 1 to 4 due to the greater application of processing options such as incineration. Processing options also have an impact on transportation costs, (discussed in the next subsection), since the volume of waste requiring packaging and transport can change depending upon the processing option used. The details of the description and characterization of waste, processing options, cost and impact data, and development of waste spectra is set out in Appendices D and G.

3.5 WASTE TRANSPORTATION AND PACKAGING

In addition to those generating the waste, there are a number of firms which supply intermediate services between the waste generator and disposal facility. These firms supply packaging for waste, assist in preparation of waste shipments, transport waste to disposal facilities and in some cases carry out waste processing and treatment operations at generator facilities.

Important to transportation is the size and type of packaging used for various types of waste; the type of transport vehicles and shielded overpacks used for transportation; miles travelled; and the degree of care involved in transportation and handling of waste during loading, unloading and emplacement at a

Table 3.5 Summary Description of Waste Spectra

Waste Spectrum 1

This spectrum assumes a continuation of existing and some past waste management practices. Some of the LWR wastes--namely P-CONCLIQ, B-CONCLIQ, and L-DECONRS waste streams--are solidified. However, no processing is done on organics, combustible wastes, or streams containing chelating agents. LWR resins and filter sludges are assumed to be shipped to disposal sites in a dewatered form. LWR concentrated liquids are assumed to be concentrated in accordance with current practices, and are solidified with various media designated as solidification scenario A. No special effort is made to compact trash. Institutional waste streams are shipped to disposal sites after they are packaged with currently utilized absorbent materials. Resins from LWR decontamination operations (L-DECONRS stream) are solidified in a media with highly improved characteristics (solidification scenario C).

Waste Spectrum 2

This spectrum assumes that LWR process wastes are solidified using improved solidification techniques (solidification scenario B). LWR concentrated liquids are additionally reduced in volume through an evaporator/crystallizer. All LWR concentrated liquids are evaporated in 50 weight percent solids, and all LWR process wastes are solidified using solidification scenario B procedures. In the case of cartridge filters, the solidification agent fills voids in the packaged waste but does not increase the volume. Liquid scintillation vials are crushed at large facilties and packed in absorbent material. All compactible trash streams are compacted; P-COTRASH, B-COTRASH, F-COTRASH, I-COTRASH, N-SSTRASH, and L-LOTRASH streams are compacted at the source of generation; and I+COTRASH, N+SSTRACH, and N+LOTRASH streams are compacted at the disposal facility. Liquids from medical isotope production are solidified using solidification scenario C procedures.

Waste Spectrum 3

In this spectrum, LWR process wastes are solidified assuming that further improved waste solidification agents are used (solidification scenario c). LWR concentrated liquids are first evaporated to 50 weight percent solids. All possible incineration of combustible material (except LWR process wastes) is performed; some incineration is done at the source of generation (fuel cycle trash, LWR decontamination resins, institutional wastes from large facilities and industrial trash from large facilties) and some at the disposal site (institutional and industrial trash from small facilities). All incineration ash is solidified using solidification scenario C procedures.

Waste Spectrum 4

This spectrum assumes extreme volume reduction. All wastes amenable to evaporation or incineration with fluidized bed technology are calcined and solidified using solidification scenario C procedures; LWR process wastes, except cartridge filters, are calcined in addition to the streams incinerated in Spectrum 3. All noncompactible wastes are reduced in volume at the disposal site or at a central processing facility using a large hydraulic press. This spectrum represents the maximum volume reduction that can currently be practically achieved.

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disposal facility. These latter aspects were considered together since the type of waste, its packaging size, radiation levels and other factors uniformly affect handling at the point of generation, during loading onto a transport vehicle, during transportation to the disposal site and during unloading and disposal operations at the disposal site.

3.5.1 Description of Services Provided

As discussed, several types of goods and services can be provided by various service organizations depending on individual generator needs, the composition of the waste, its volume and its frequency of generation. Transportation can be provided by common or contract carriers which pick up packaged waste at generator facilities and transport it to the point of disposal. In such cases, the carrier is providing only a transportation service and the shipper retains responsibility for the wastes until accepted at the disposal facility. Transportation can also be provided by the licensee generating the waste or by other private carriers which accept title to the waste upon receipt at a generator's facility. These firms are licensed by the NRC or an Agreement State for their possession of the waste and in some cases they provide other services such as supplying packaging, waste processing, and temporary storage.

For larger generators like nuclear power plants, these service activities generally consist of providing the necessary shipping containers, (e.g., shielded casks), transporting the waste to the disposal site, and in some cases, waste processing. Such large generators usually contract these services out to private firms specializing in the provision of such services. In these instances, the cask is usually leased on an as-needed basis and the truckloads of waste are transported directly from the generator to the disposal site. A return trip is normally required to return the empty shielded cask back to the generator to allow it to be refilled for the next shipment. Often, the rental of the cask and the actual transportation are performed by separate companies.

Smaller LLW generators such as educational institutions , hospitals, and many industries will use common, contract, or private carriers. In many cases, a firm collects the LLW from a number of small generators and transports it to a central, temporary storage facility. Here the wastes may be repackaged and consolidated until sufficient waste has been collected to make up a truckload. At this point, the wastes will be transported for disposal. Firms engaged in this collection and consolidation of waste are often referred to as "waste brokers" and can generate full truckloads with sufficient frequency so as to achieve much high equipment utilization rates and lower unit transport costs than smaller LLW generators can on their own.

The assumptions and organization of data regarding the type of packaging and services provided, transport vehicles used, frequency of shipments, and other data is described below. Further detail is set out in Appendices D and G.

3.5.2 Degree of Care Required in Handling the Waste and the Shielding Required During Transportation

Each waste stream contains different amounts of different radionuclides and thus emits different types of radiation at different levels. Also, depending on the package size and the amount of waste contained in a package, different waste packages have different surface radiation levels. The external radiation levels at the package surface affects the level of care that should be exercised during handling of the waste and the type of shielding that would be required during transportation to comply with existing DOT and NRC transportation regulations. To characterize the broad range in package surface radiation levels that would be presented by the various waste streams packaged in various packages, NRC established three categories to represent the level of care required to handle each waste stream based on the total activity and radiation emitted by each stream. These categories are denoted by:

- Those requiring regular care--i.e., those streams containing very little high energy gamma emitting radionuclides and thus very low external radiation levels;

- Those requiring extreme care--i.e., those streams containing large quantities of high energy gamma emitting radionuclides and thus very high external radiation levels; and

- Those streams in between the above and requiring special care--i.e., those streams containing some high-energy gamma emitting radionuclides and thus moderate external radiation levels.

Since the activity of individual waste streams can vary, NRC also estimated the fraction of each waste stream requiring a particular level of care based on the variation in activity. This would account for the normal variation expected in waste stream activity.

3.5.3 Type of Packaging Used

After determining the level of care, NRC also analyzed the different types of packaging that could be used for shipment and disposal of waste. Based on this analysis the packaging was generalized into 5 generic types of packaging as follows:

1. Large wooden boxes - 128 ft^3
2. Small wooden boxes - 16 ft^3
3. 55-gallon drums - 7.5 ft^3
4. Small liners - 50 ft^3
5. Large liners - 170 ft^3

NRC assumed, for purposes of this analysis, that "extreme care" wastes were only packaged in drums or liners which are remotely manipulated during loading and off-loading. "Regular" and "special" care wastes are assumed to be packaged in all 5 package types.

Finally, NRC determined the fractional use of each package type for each waste stream using available shipping and survey data.

3.5.4 Mode of Shipment

In the same way that there are a large number of package types that can be used for shipment and disposal of the waste, there are also a number of different shipment modes, vehicles and shielded overpaks that can be used to transport the waste to the disposal site. For purposes of this EIS, NRC conservatively assumed that all waste is transported to the disposal facility by truck (i.e., rail and barge transport are not used). NRC generalized the various types of transport vehicles and overpaks into 6 types:

1. Vans
2. Flatbed trailers
3. Shielded trailers
4. Large shielded casks
5. Small shielded casks
6. 1-drum shielded casks

Casks are assumed to be transported to the disposal facility on flatbed trailers.

Since the activity and packaging used for each waste stream varies, and also varies within each waste stream as noted above, NRC also determined the percentage use of different vehicles and overpaks for the transport of the various streams.

3.5.5 Impact Measures

Impact measures calculated by NRC for the packaging and transport of waste include cost, occupational exposures, population exposures and energy use. Cost was calculated including a mileage charge (and fuel surcharge), a cask rental charge, and an overweight shipment transportation charge. Energy use was calculated based on the total shipment miles, including empty cask return trips, and using an average fuel consumption rate of 6 miles/gallon. For the base case and alternatives analysis, transportation distance was not assumed to vary. Costs and impacts are calculated assuming an average distance of 400 miles from the point of waste generation to the waste disposal facility. Occupational and population exposures incurred during transportation were calculated based on total loaded miles and the number of loaded shipments (Return trips in which the vehicle was empty were excluded). Occupational exposures incurred during loading of the waste and during transportation are included together. The exposures were calculated based on the man-minutes required to load each package and the radiation field associated with each type of package handling environment. Occupational exposures were calculated for each waste care level, package type and shipment mode. Occupational exposures during unloading and disposal of the waste were also calculated based on the personnel time required to unload and dispose of the wastes and the assumed radiation fields associated with the handling environment that the workers are exposed to.

3.6 WASTE DISPOSAL

This section describes the affected environment made up of those owning and operating the disposal sites. It also describes the siting, licensing, design, operation, closure and postoperational activities of a reference base case LLW disposal facility.

The operators of LLW disposal sites offer the essential services of providing a licensed and controlled site where generators of LLW may dispose of their wastes. The sites are owned by the state or federal government. The facilities and procedures necessary to offer this service include the monitoring of transport vehicles and packages to verify compliance with established license conditions and regulations; off-loading, temporary storage and disposal of the wastes; and monitoring and surveillance of the disposed wastes throughout the operating lifetime of the site. Lease conditions between the operators and state landlords provide that states will assume reponsibility for the long-term control and surveillance of the sites after closure. The conditions also include provisions for the accrual of funds to pay for the state's long-term custodial responsibilities.

There are presently three operating, licensed commercial LLW disposal facilities. These are the Barnwell, South Carolina site operated by Chem-Nuclear Systems, Inc. and the Beatty, Nevada and Richland, Washington sites operated by U.S. Ecology, Inc. All three of the above sites are located in Agreement States and are sited on state-owned land, except the Richland site. In this case the site is located on federally-owned land that has been leased to the state of Washington. As noted earlier in Chapter 1, three other licensed, commercial LLW sites exist which are not currently operating. These are the Sheffield, Illinois; Maxey Flats, Kentucky; and West Valley, New York sites. The first two sites were operated by the Nuclear Engineering Company and the last was operated by Nuclear Fuel Services, Inc., a subsidiary of the Getty Oil Company.

Both LLW site licensees offer similar onsite services concerning the disposal of LLW. These include explicit criteria concerning the types of wastes acceptable for burial, as well as specifications for solidification agents permitted, packaging requirements and permissible activity levels. They survey incoming shipments for compliance with license requirements and DOT transportation and packaging criteria. Also, wastes may be segregated by type and activity level to increase safety and operational efficiency. Transportation services and shielded shipping casks for lease to LLW generators that produce wastes with higher activity levels may also be provided.

3.6.1 Characterization of a Reference Base Case LLW Disposal Facility for Purposes of EIS Analysis

To help provide conservative bounds to the potential costs and impacts of waste disposal, NRC characterized a reference LLW disposal facility that is assumed to be sited in a humid eastern environment. NRC staff anticipates that over the next 20 years, over three-quarters of the waste generated in the United States will be generated in humid environments, i.e., in the eastern and humid midwestern sections of the country. Regional disposal of waste

therefore implies that most of the waste generated in humid environments would also be disposed in humid environments. Potential ground-water impacts (and actions required to protect ground water) at a humid site are generally expected to be greater than those at an arid area. Some of the conditions at an eastern humid site which would indicate this include the relatively higher annual precipitation, shallower depths to ground water, and relatively shorter distances from the disposed waste to the point of ground-water discharge into surface streams.

The reference facility is sized to accept a relatively large quantity of waste--i.e., 50,000 m^3 of waste per year over a 20-year operating life, or a total volume of one million m^3. This corresponds to approximately one-quarter of the total volume of LLW projected in the United States to the year 2000. Disposal of one million m^3 of waste in the reference facility will require about 150 acres of land, which corresponds to an approximate upper bound of the land area of current commercial disposal facilities.

The site for the facility minimally meets all of the site suitability requirements set out in Chapter 5. The facility is also assumed to be operated in compliance with minimum radiation safety practices required by provisions of 10 CFR Part 20 (see Chapter 6). Although the facility is assumed to comply with the NRC Branch Technical Position on Site Closure and Stabilization (See Appendix I), no special effort is, however, assumed to be made during operations at the reference facility regarding the form of waste or design and operational practices to ensure long-term site stability. Several design and operational improvements directed at stability that have been instituted at some existing sites have not been assumed for the base case site, (e.g., vibratory compaction of backfill material). This has been done to establish a base case level of long-term costs and radiological impacts against which measures to improve site performance, achieve greater site stability, minimize radiological impacts, and to ensure adequate funding can be assessed. Figure 3.1 describes the life cycle of a typical disposal facility. Further information regarding design, operation, and closure of the facility is set out below. The details are described in Appendix E.

3.6.2 Facility Design

A conceptual layout of the reference disposal facility is illustrated in Figures 3.2 and 3.3. As shown in the figures, the disposal facility is divided into two basic areas: a "restricted area" and an "administration area."

The entire site is surrounded by a 2.4 m (8 ft) high chain-link fence topped with three strands of barbed wire. A 2.4 m high fence also separates the administration area from the restricted area. Access to the disposal site is via a state highway running close to the site from which two short gravel roads lead onto the disposal facility. Access to the restricted area is controlled by security check points near the gates in the fence separating the administration area and the restricted area.

Figure 3.1 Life Cycle of a Typical Near-Surface Disposal Facility

Number of Years	Activity	Description
1-2 Years	Site Selection and Characterization.	Site selection and characterization activities are carried out by the applicant in coordination with NRC, and state and local government. A preferred site is selected, and the site characterized in detail. A license application is prepared which includes a preliminary closure plan, environmental report, arrangements for government ownership of the land, lease arrangements for use of the site, and financial arrangements to cover the costs of closure and postclosure activities.
1-2 Years	Preoperational Licensing	The application is submitted to NRC (including a license fee) and docketed. A notice of receipt of the application is published in the Federal Register and an opportunity for requesting hearings is provided. State and local government officials are notified. An analysis of the application is carried out by the NRC licensing staff including preparation of an environmental impact statement. If no hearings are requested and upon a satisfactory licensing finding, NRC takes action to issue the license. A Notice of Issuance is published in the Federal Register and state and local government officials are notified. If hearings are requested, hearings are held including any Commission reviews and appeals. Upon resolution of all hearings and appeals and upon a satisfactory finding, NRC issues the license, publishes notices and notifies state and local governmental officials.

Figure 3.1 (Continued)

Number of Years	Activity	Description
20-40 Years	Construction and Active Disposal Operations	Upon issuance, the operator begins operations to construct the facility and to receive and disposal of waste. On a periodic basis--about every 5 years, or as stated in the license--NRC reviews the licensee's program including the preliminary site closure plan, financial arrangements for closure and post-closure activities, and continued assessment of environmental impacts.
1-2 Years	Site Closure and Stabilization	During the operating phase, the site is generally stabilized as it is filled (e.g., trench caps are put in place). At closure, final site stabilization activities are carried out. Facilities not needed for postclosure activities are decontaminated and dismantled. Costs for closure are provided by financial arrangements of the operator. Upon satisfactory closure, NRC terminates the license and control over the site reverts back to the government landowner.
100 Years	Institutional Control	The government landowner carries out custodial care of the site which includes continued government ownership and control of the site; carrying out activities such as posting, maintaining site security, monitoring of the environment, and carrying out any maintenance activities such as correction of subsidence depressions in trench covers due to consolidation of the waste. The terms and conditions of the lease and financial arrangements between operator and owner provide funds to cover the cost of these activities.

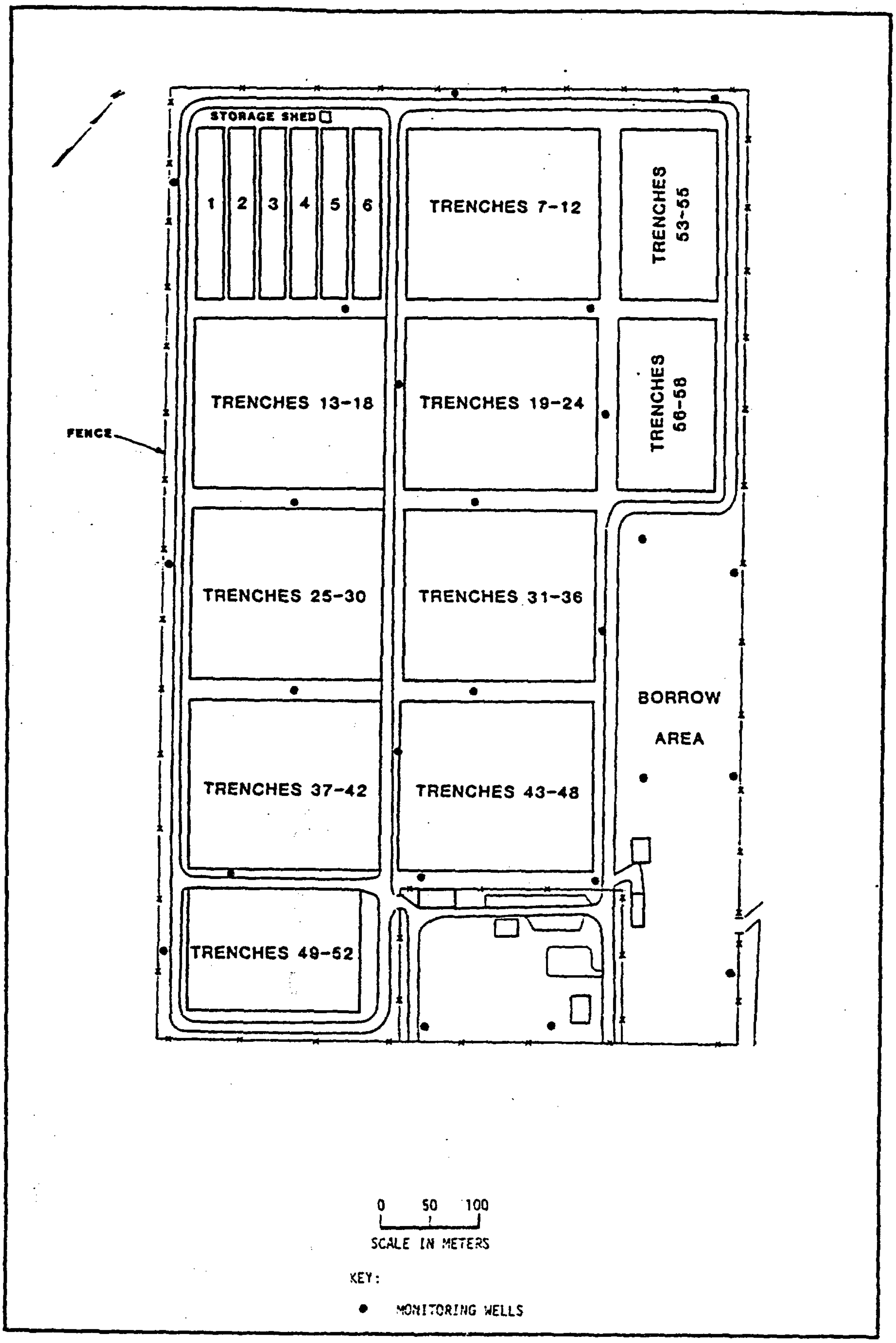

Figure 3.2 Conceptual Disposal Facility Layout

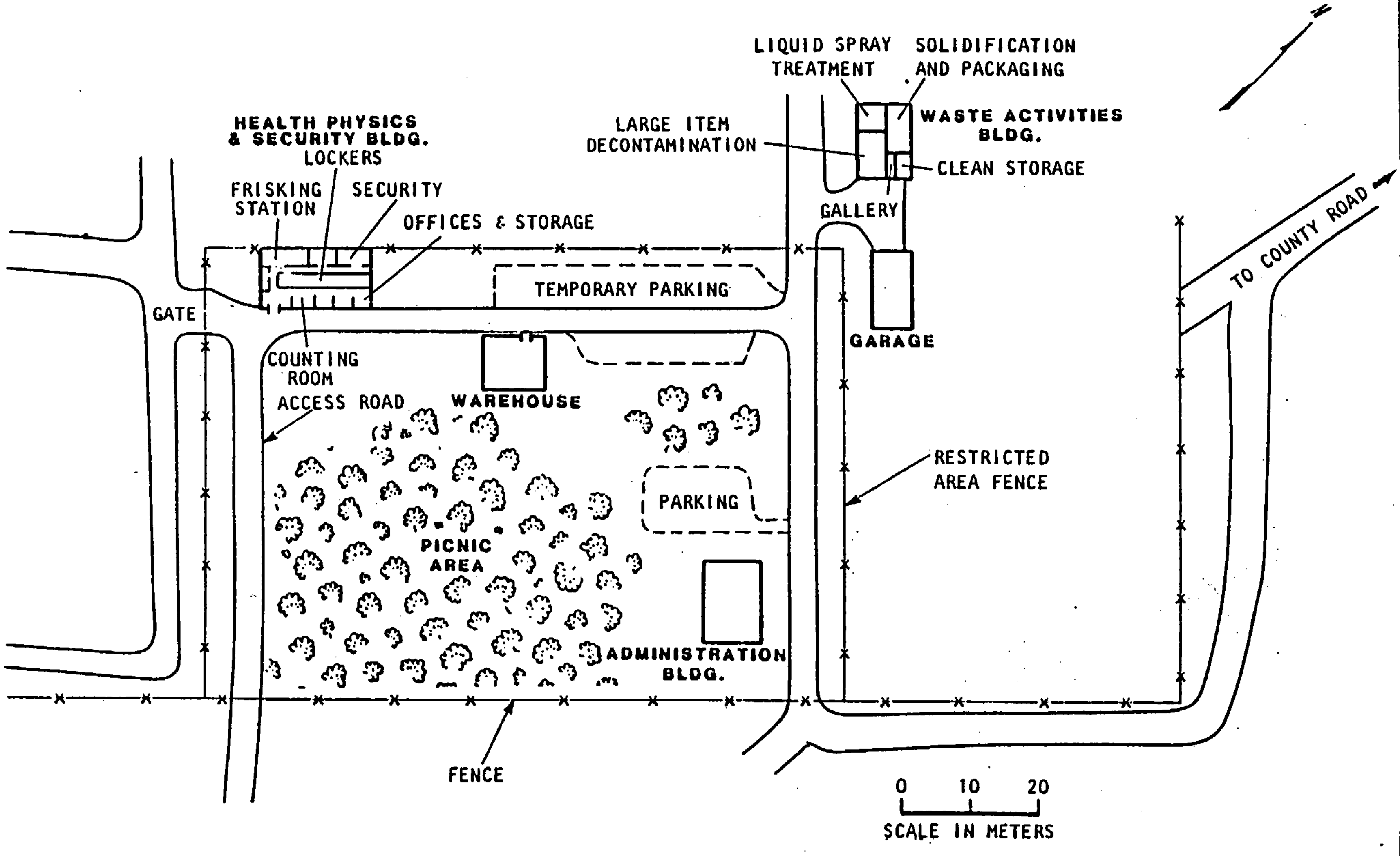

Figure 3.3 Conceptual Layout of Support Facilities

The disposal area at the reference facility includes 58 disposal trenches with average approximate dimensions of 180 m (591 ft) long, 30 m (100 ft) wide, and 8 m (26 ft) deep (see Figure 3.4). The rather large trench sizes assumed are representative of recent trends at existing disposal sites. A trench wall slope of 1 horizontal to 4 vertical (1:4) is assumed and the trenches are assumed to be separated by 3 m thick walls.

As a trench is constructed, the locations of the four corners of the trench are surveyed and referenced to a bench mark. An approximate one degree slope is provided in the bottom of a trench from end to end and from one side towards a 0.6 m x 0.6 m (2 ft x 2 ft) gravel filled French drain. The French drain runs the entire length on the lower elevation side to provide for collection of any liquid drainage that might occur. A gravel-filled sump is located at the low corner of the trench. Each trench is also equipped with a minimum of three 0.15 m (6 in) diameter polyvinyl chloride (PVC) standpipes located within the French drain and standing along the sidewalls of the trench.

Support facilities and structures include: (1) an administration building, (2) a health physics/security building, (3) a warehouse, (4) a garage, (5) a waste activities building, and (6) a storage shed. All structures at the site are one-story metallic structures on concrete pad foundations.

3.6.3 Facility Operations

The disposal facility is assumed to be operated for profit by a small corporation which is engaged in other nuclear-related business activities in addition to operating the disposal facility. Overall control of radiation health and safety at the corporate level is under the control of the senior radiation safety officer, who is responsible for conducting periodic reviews of site operations for compliance with health and safety regulations and license conditions, including periodic site inspections and audits. Operations at the disposal site are under the overall direction of a site manager and assistant site manager and have been divided into eight categories: the receipt, inspection, handling, storage, and disposal of waste; radiation and contamination control; site groundskeeping and maintenance; radiation safety and contamination control; environmental monitoring; security; recordkeeping and reporting; and quality assurance.

3.6.3.1 Waste Receipt and Inspection

Shipments of radioactive waste arrive by truck and are processed onto the site on a first-come, first-served basis. Accompanying the shipments are manifest documents--termed radioactive shipment records (RSRs)--which describe the content of the shipment. (An example of an RSR used at one disposal site is included in Appendix E.) Arriving shipments are inspected for compliance with applicable federal regulations and waste acceptance criteria established as conditions in the disposal site license.

Applicable federal regulations include those promulgated by NRC and DOT regarding waste packaging requirements, labelling requirements, vehicle placarding requirements, and allowable direct radiation and removable contamination levels at an accessible surface of transport vehicles.

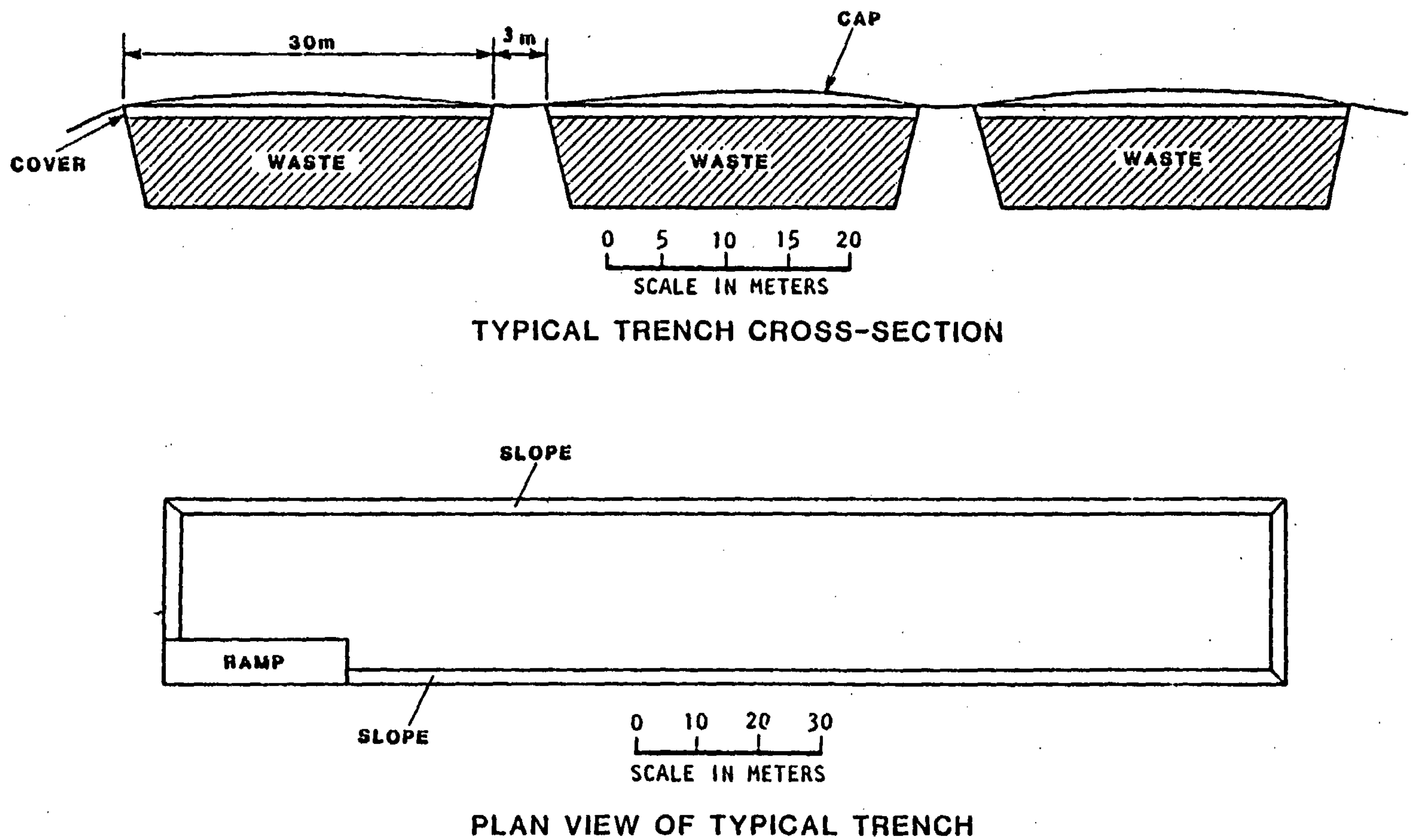

Figure 3.4 Details of Typical Disposal Trench

Shipments found to be in compliance with federal regulations and license conditions proceed into the disposal area for unloading. Depending upon license conditions, damaged or leaking waste containers may be overpacked or repackaged, and either accepted for disposal or returned to the sender. Activities such as overpacking and solidification are performed at the waste activities facility.

3.6.3.2 Waste Storage

Generally waste received at the site is disposed of within a few days. Waste that must be temporarily stored is generally left in transport vehicles or in temporary onsite storage areas.

3.6.3.3 Waste Disposal

Waste is randomly emplaced in the trench, sometimes using cranes and forklifts, and backfilled with dirt removed during trench excavation. Random waste emplacement results in a trench volume use efficiency of about 50 percent. Waste is not allowed to extend more than 100 feet beyond the backfilled portion of the trench. Backfill operations also commence if radiation readings greater than 100 mR/hr are recorded at the trench boundary, and continue until radiation levels are reduced below 100 mR/hr. Disposal commences at the high end of the trench and works down towards the lower end to prevent waste packages from being placed in water. Rainwater falling within the open trench drains away to the lower end of the trench where it can be removed.

Waste is emplaced to within one meter of the top of the trench, Earthen fill is then backfilled into the trench until the trench cover approximately corresponds to the original grade of the site surface. A one-meter thick cap composed of originally excavated soils is then placed upon the backfill and is mounded. No special compaction is performed on the fill and clay caps other than that provided by heavy earth moving equipment driven over the top of the cap. The cap is then covered with natural overburden material as necessary to provide good drainage characteristics and according to the final contours planned for the site surface. The overburden is reseeded to promote growth of a short-rooted grass cover.

Following trench capping, the disposal trenches are each marked with a monument which is inscribed with the following information:

- A trench identification number;
- Total trench activity of byproduct material in curies, and source and special nuclear material in grams;
- Date of completion of disposal into the trench; and
- Volume of waste in the trench.

In addition, each of the four top corners of the disposal trench are marked with a marker stone.

During waste handling and disposal, operations are monitored to ensure radiation safety. After the transport vehicle is unloaded it is again surveyed for contamination and decontaminated, as necessary, prior to leaving the restricted area. The results of the survey are recorded on the accompanying RSR.

3.6.3.4 Site Groundskeeping and Maintenance

Groundskeeping includes both the upkeep of grounds and the maintenance of external building surfaces. The purpose of groundskeeping is to promote site integrity by maintaining proper contour and soil conservation practices, by properly maintaining external structures and site systems, and by overseeing closed burial trenches in an efficient manner. Groundskeeping activities include countouring of the ground surface, emplacement of a soil cover material such as grass, fertilizing, mowing, and site drainage.

A site maintenance program entails routine inspection of site surfaces and fences for trench settlement, gullying, damage and debris. Repairs are made as necessary.

An important part of the reference site groundskeeping and maintenance program is surface water management. A surface water management program is site-specific (i.e., dependent on each site's topography, amount of rainfall, etc.), but its overall purpose is to divert surface water resulting from precipitation away from open trenches and to allow the surface water to flow offsite in a manner which will minimize erosion.

3.6.3.5 Site Safety, Radiation and Contamination Control

A program of site safety, radiation and contamination control is carried out at the site in compliance with existing standards in 10 CFR Part 20. It consists of 4 major activities:

- personnel radiation monitoring, including use of personnel monitoring devices, periodic internal monitoring, and administrative controls to ensure radiological safety;
- site radiation and contamination control, including routine radiological surveys to minimize the potential for spread of contamination or unnecessary exposure to radiation;
- abnormal or emergency procedures to quickly and safely handle abnormal occurrences or site emergencies; and
- personnel training and instruction in the hazards and controls of radioactive materials commensurate with the workers's duties and responsibilities for handling materials, and with the extent of anticipated worker exposure.

Monitoring devices are worn by all site personnel who may become occupationally exposed to ionizing radiation. A long-term record of cumulative personnel

exposures is maintained through the use of film or thermoluminescent dosimeter (TLD) badges. These are replaced, analyzed, and the resulting exposures reviewed and recorded on a periodic basis (usually on a monthly or quarterly schedule). Monitoring badges are replaced and analyzed whenever there is reason to believe that an employee may have received an unusually high radiation dose. Pocket dosimeters are also worn by site personnel and are used to provide an indication of radiation exposures over shorter time periods. These basic monitoring devices may, depending upon the circumstances, be supplemented by additional equipment such as electronic dose ratemeters, finger or wrist monitoring badges, or/and continuous air samplers.

3.6.3.6 Security

The site security program is needed both for radiation health and safety considerations as well as to protect the many thousands of dollars worth of equipment, buildings, and facilities located onsite. The security program at the base case facility is assumed to include the following:

- Full-time security personnel and a security training program;
- Controlled access and exit from site areas including fencing and lighting, material gate passes, badge control, personnel and vehicle search procedures, and lock and key control;
- Radio and telephone communication ability with emergency and law enforcement agencies;
- Identification badges and dosimetry for site employees and visitors; and
- Procedures for notifying site personnel and local authorities in the event of an emergency in compliance with federal and state regulations and conditions.

3.6.3.7 Recordkeeping and Reporting

A number of records are assumed to be maintained at the site to cover the areas required by NRC regulations, operational controls, and for future use. Records which are assumed to be maintained at the facility include:

- Personnel exposures;
- Waste receipt and disposal records;
- Personnel training records;
- Records from the QA program;
- Environmental monitoring data;
- Operating procedures; and
- Records of site surveillance and monitoring.

3.6.3.8 Quality Assurance

The quality assurance (QA) program at the site provides quality control and training support to the disposal site operations. The QA program includes the following areas:

- personnel monitoring;
- training;
- emergency drills and equipment;
- contamination control;
- working procedures;
- site maintenance;
- site groundskeeping;
- waste receipt, inspection, storage, and disposal;
- radiation instrument care and calibration;
- environmental monitoring;
- security;
- construction of disposal trenches;
- closure and stabilization; and
- recordkeeping

3.6.4 Facility Closure and Long-Term Site Control

Final closure is assumed to require approximately one to two years and involves dismantling and decontamination of site buildings, disposal of wastes produced during dismantlement and decontamination operations, and final site seeding and contouring. The final disposal trenches are filled, capped, graded, and seeded with a grass cover. The trench covers are left mounded. The licensee also makes a final survey of the disposal area to make sure direct radiation levels are at essentially background levels.

Following closure, the disposal license is terminated and control of the site is transferred to the site owner. For this EIS, the site owner is assumed to be a state agency which carries out an active institutional control program of surveillance, monitoring and maintenance for 100 years. Activities which take place during the institutional control period include site inspection, maintenance and site monitoring. Due to the compressible nature of much of the

wastes disposed of at the base case site and limited compaction during operations, a high degree of subsidence and slumping problems occur at the site. Base case site maintenance is, therefore, expected to be significant. The maintenance activities required during this time period mainly involve repair of slumping, subsidence and other disposal trench instability problems. During this phase, environmental surveillance and monitoring of the disposal facility continues.

3.6.5 Reference Disposal Facility Costs

Cost estimates for capital outlay, operational activities, and postoperational activities are provided in this section as a basis for comparison with the costs of alternatives. A summary of the three major components of the costs for reference facility capital outlay, operations, and postoperations are detailed in Table 3.6.

The capital outlay expended by the disposal company includes the costs of site selection, environmental impact studies, obtaining licenses and permits, the purchase price of the acquired land, road and building construction, engineering design fees, and peripheral systems such as fencing, lighting, and monitoring system components. The engineering design fees total 10 percent of the capital construction costs. The acquired 200 acres are assumed to be purchased at a price of \$1200/acre. The site buildings are constructed at costs ranging from \$10/ft^2 (storage shed) to \$50/ft^2 (waste activities building) with an average building cost of \$36/ft^2.

The operational costs include the cost of trench construction, equipment leasing, operation and maintenance costs for the equipment, payroll, and monitoring services. The elements of trench construction include excavation, sump and standpipe construction, French drain installation, backfilling, compacting, land clearing and grubbing, and revegetation (seeding and fertilizing). All equipment is assumed to be leased during the 20 years of operation. The annual payroll for this disposal company is \$1.13 million for the 70 employees. All radiochemical monitoring analyses are performed by a subcontractor and these costs are included in operations.

The cost of postoperational activities include closure, stabilization and long-term care. The closure and stabilization program for the reference site is similar to the "minimum plan" for the humid eastern site described in NUREG/CR-0570 (See Appendix Q). The minimum plan costs approximately \$1 million.

The institutional control or long-term care program for the reference site is carried out over a 100-year period and includes labor, material, and equipment costs. During the first (ten) years of the active insitutional control period, the annual costs of care are at their highest. As the site matures, the required costs diminish. The annual long-term costs for years zero through 10 (0-10), 11 through twenty-five (11-25), and twenty-six through one hundred (26-100) are \$440 thousand, \$302 thousand, and \$150 thousand, respectively. The types of activities which are carried out during the long-term care program

Table 3.6 Total Reference Site Costs

Direct Capital Costs (preconstruction and construction)	(1980$)
1. Site selection	500,000
2. Environmental impact studies	600,000
3. NRC licensing fees	325,000
4. Other licenses and permits	250,000
5. Land acquisition (200 acres @ $1200/acre)	240,000
6. Corporate administration	1,625,250
7. Construction administration	450,450
8. Legal fees	1,000,000
9. Road construction	200,000
10. Initial land preparation (40 acres @ $1145/acre)	45,800
11. Office and other miscellaneous equipment	400,000
12. Building construction	1,173,250
13. Utilities and supplies during construction	175,000
14. Peripheral systems (fencing, lighting, utilities installation, telephone, etc.	300,000
15. Engineering and design (10% of items 9, 12 and 14)	167,300
Total:	7,452,050

Indirect Capital Costs	Percentage of Direct Costs
Interest during construction	33%
Contingency	30%
Other Costs (insurance, sales tax)	10%
Total:	73%
Annual fixed capital charge rate for 20 years	25%
Assumed profit margin	20%

TOTAL CAPITAL COSTS

Direct costs x indirect costs x
annual fixed charge x profit

7,452,050 x 1.73 x 0.25 x 20 x 1.20 = 77,352,300

Table 3.6 (Continued)

Direct operational costs over 20 years	
1. Operations and maintenance	4,626,500
2. Disposal trench materials	124,200
3. Heavy equipment	12,228,000
4. Payroll:	
Base	22,560,000
Fringe	2,256,000
Overhead	12,408,000
5. Corporate administration (300k/yr)	6,000,000
6. Legal fees (150k/yr)	3,000,000
7. Environmental monitoring	534,000
8. Regulatory costs	1,138,000
9. Consumables (utilities, fuel, etc. - 200k/yr)	4,000,000
Total:	68,875,000
Indirect operational costs	30%
Assumed profit margin	20%
TOTAL OPERATIONAL COSTS	
Operational costs x indirect costs x profit 68,875,000 x 1.30 x 1.20 =	107,445,000
Postoperational Costs*	
1. Closure and stabilization (Cost over 20 years including inflation and surety)	3,640,000
3. Institutional Control - 100 Years	34,600,000
TOTAL POSTOPERATIONAL COSTS	38,240,000
TOTAL REFERENCE SITE COSTS	
Total Capital Costs plus Total Operational Costs plus Total Postoperational Costs	223,037,300
UNIT DISPOSAL COSTS	
Total reference site costs (223,037,300) = Total volume of waste over 20 year operation period (10^6 m^3)	223/m^3 (\$6.31/ft^3)

*Postoperational costs have been calculated based on a 9% inflation rate and 10% interest rate to reflect the actual costs to customers in 1980.

include erosion repair, vegetation management, subsidence repair, site access and drainage maintenance, surveillance and monitoring.

3.7 ALTERNATIVE WASTE DISPOSAL OPTIONS

NRC also analyzed a range in site characteristics and methods of design and operation that could be applied in the near-surface disposal of LLW. Some of the variations included differences in environmental and site parameters. Others included the specific methods used for the design and construction of the disposal facility including the method of disposal (e.g., trench with natural soil walls, trench with concrete walls), type of cover (e.g., soil, concrete) and whether special engineering designs were used for the disposal of particular wastes (e.g., slit trenches, caissons and tubes filled with concrete). Others included the procedures used for operation and placement of the waste including whether the waste was randomly dumped or neatly stacked, segregation of particular wastes due to unique characteristics, type of backfill, and stabilization and closure measures. Other aspects that also had to be considered were how much care a particular disposal facility might require after closure, and how long active institutional controls would be in effect at the facility.

3.7.1 Grouping of Alternatives

NRC generalized the various parameters which could be grouped to describe alternative site environments, methods of design, operation and closure, and postoperational institutional control activities into 13 categories as follows:

1. Region - The region specifies the geographic location of the disposal facility. (e.g., northeast, southeast) and as such determines all of the environmental properties that will be used in the analysis. Four regions were selected (Northeast, Southeast, Midwest, and West) Environmental properties common to each were selected for use in the analyses.

2. Design - Two principal design options are considered; use of a "regular" trench dug in the soil and use of a concrete walled trench.

3. Cover - Three principal cover designs are considered: thin, denoted by 1 meter of cover below grade and 1 meter of cover above grade; thick, denoted by 1 meter of cover below grade and 2 meters of compacted clay cover above grade, and intruder barrier, denoted by a 5-meter thick above grade highly engineered cover.

4. Emplacement Method - Three emplacement alternatives are considered:

   o Random, which simply involves dumping the waste directly into the disposal cell (a subset of this case is use of a highly permeable backfill);

   o Stacked, which involves stacking waste containers in neat piles (again, a subset of this case is use of a highly permeable backfill); and

- o Decontainerized which involves removing wastes from containers before disposal. In this case, structurally stable wastes in containers are randomly disposed and other low activity structurally unstable wastes are removed from their containers for disposal.

5. Layering - Layering involves the placement of selected higher activity waste streams on the bottom of disposal cells.

6. Segregation - Segregation involves the segregation and disposal in separate disposal cells of compressible wastes and those containing organic chemicals or radionuclide complexing chemicals.

7. Grouting - Grouting involves the use of concrete as a backfill material in place of natural soil.

8. Hot Waste Facility - A hot waste facility is a specialized disposal cell that would be used for higher activity wastes.

9. Stabilization - Stabilization denotes the extent to which disposal units are stabilized during operations, and during and after closure.

Three stabilization measures are considered:

- o A program in which no special compaction procedures are used except for the weight of heavy equipment;
- o A program in which improved compaction techniques such as sheepsfoot rollers and vibratory compaction are used; and
- o A program involving dynamic compaction or similar extreme measures.

10. Closure - Two types of actions implemented during the closure period are considered. One involves the application of standard practices such as dismantlement and decontamination of site buildings, disposal of any wastes generated, final contouring of the site, revegetation, final radiation surveys and other actions as set out in the NRC Branch Technical Position on Site Closure and Stabilization. The second involves the application of more extreme measures (in addition to the regular measure discussed above) including stripping of disposal unit covers, compaction using sheepsfoot rollers or similar measures, backfilling, recovering and revegetation of covers.

11. Care Level - Care level refers to the amount of active maintenance that will have to be carried out during the active institutional control period based on the design and operational procedures used at the facility. Three levels of care are considered:

- o Routine surveillance and minor maintenance;
- o Routine surveillance with some active maintenance such as periodic cover restabilization; and
- o Major stabilization and remedial actions such as active trench pumping and leachate treatment programs.

12. Postoperational Period - The postoperational period denotes the time between cessation of active disposal operation to assumption of control by the site owner. It includes the time required to close the site and any period of observation before assumption of control by the site owner.

13. Active Institutional Control Period - This period is the time between transfer of control of the site to the site owner and the time at which institutional controls are assumed to cease.

3.7.2 Impact Measures

Impact measures calculated by NRC for the disposal of waste include the costs for the design and operation of the disposal facility including a fixed return on investment; costs to close the facility and to care for it over the long term; energy use; land use and commitment; occupational exposures; and exposures to individuals and populations due to inadvertent contact with the disposed waste at a future time and due to long-term releases to the environment. These are discussed in further detail below.

3.8 IMPACT MEASURES USED AND METHOD OF CALCULATIONS

Impact measures can be grouped into two categories:

1. Benefits, consisting, for example, of the value of goods and services produced through the utilization of radioactive material that results in generation of the waste or the reduction in health and environmental hazards presented by the waste through application of a specific disposal technique; and

2. Costs, consisting for example, of the costs to dispose of the waste and the potential environmental and human health hazards created by the LLW.

Direct benefits to society from the generation of LLW are the value of the goods and services produced through the utilization of radioactive materials and include monetary and nonmonetary benefits. These goods and services encompass a wide range from consumer products (e.g., luminous wrist watches and smoke detectors) and energy (e.g., electricity from nuclear power plants) to less economically measureable goods (advances in scientific research activities) and services (health benefits from nuclear medicine procedures). Other benefits associated with the use of radioactive material would include the salaries of persons employed in the nuclear or radioisotope industry, and

local and regional socioeconomic benefits such as an increased tax base. Benefits to society and the natural environment derived from those involved in the disposal of waste and the regulation of these activities are the provision of goods and services for the safe disposal of radioactive waste and the reduction in potential environmental and human health hazards.

Direct costs to society would be the creation of the LLW and its attendant potential environmental and human health hazards and the short- and long-term financial, governmental, human and natural resources used to properly dispose of the waste. Persons will be exposed to the waste as it is being transported and after disposal through potential releases from the site. At any specific disposal site, the local ground water, biota and animal species will be affected by site operation. And, fuel will be consumed in transporting the waste to a disposal site and in powering equipment at the site involved in site operations. Finally, the cost for disposal of the waste will be reflected in the cost for goods and services provided by those generating the waste.

Thus, it is quite difficult to accurately assess the cost and benefit impacts on the many segments of the environment involved because many are nonmonetary (e.g., improved well-being due to improved diagnosis through nuclear medicine) and in many cases a small part of a much larger overall cost (e.g., that portion of electrical usage charges attributed to the disposal of LLW). It is equally difficult to quantify the impacts of application of the rule on the physical and local socioeconomic environment (e.g., ground water, ecology, local taxes) since the impacts can only be analyzed based upon a specific real site. Finally, given the rather large and diverse nature of the affected environment, a rather large number of potential factors can be identified which could be used to quantify environmental impacts. In this EIS, NRC has attempted to identify important segments of the environment (both direct and indirect) that lend themselves well to generic treatment, that can be easily quantified based upon existing information, and which provide a reasonable measure of the short- and long-term potential impacts that could be expected from implementation of a specific alternative course of action that might be set out as a requirement in the new regulation.

3.8.1 Impact Measures Used

NRC's overall goal is to assure protection of the public health and safety and environment. In considering radioactive waste disposal, this goal falls into two time frames: (1) protection of workers and the public during the short-term operational phase and, (2) protection of the public health and safety over the long term after operations cease. Each of the existing disposal sites was licensed on a case-by-case basis. As with other nuclear facilities, emphasis was placed on protection of the public health and safety focusing principally on operational safety and radioactivity releases and exposure of offsite individuals and populations. There was a tendency to focus on operational safety at the disposal sites with, perhaps, less attention given to the long-term performance of the disposal facility. Disposal facilities involve some quite different considerations than those applied to other nuclear facilities. At the end of their operating life, (e.g., 40 years) other nuclear facilities are decommissioned, decontaminated and released for unrestricted use. Disposal

facilities, however, although involving considerations of safety during its relatively short operating life (e.g., 20-40 years), are relied upon for significantly longer periods of time (e.g., several hundred years after waste emplacement) to perform their function of confining waste with reasonable assurance over the time the waste presents a significant potential hazard to the public health and safety.

Thus, safety must be assured during the short-term operational phase relating to onsite occupational exposures and exposure to individuals and populations offsite as well as over the long term relating to exposures to individuals and populations.

In addition, the long-term social commitment must be considered. For example, maintenance operations at some existing sites require an expenditure of manpower and money to maintain the site and to minimize impacts from potential offsite releases. Such "active" maintenance operations involve additional expenditures which were not foreseen nor planned at the time that the disposal facility was opened. They involve long-term social commitment in terms of manpower and money that was not planned for and which is difficult to assess in terms of how long such programs must be relied on to assure continued safety of the site. The function of an LLW disposal facility should be to assure that the public health and safety is protected without the need for long-term social commitment in the form of "active" maintenance programs at the sites.

Long-term social commitment is also important when considering future use of a disposal facility and intrusion. For example, governmental entities can continue to exercise active institutional control over a disposal facility after closure (i.e., continue to actively and physically control access to the site) for an indefinite time after closure. How long, however, should such controls last? If they last indefinitely, the long-term costs and social commitment of future generations would be very high. If they were not relied upon at all, the costs for disposal of low activity wastes would be very high. Thus, consideration of long-term social commitment is important such that institutional controls applied at a disposal facility are sufficiently long to allow most wastes to decay to acceptable levels yet not so long as to burden future generations.

Given the short- and long-term safety considerations, the potential exposure modes and need to consider social commitment, there are four basic performance objectives that should be achieved in the disposal of LLW:

1. Long-term protection of the intruder considering the need for long-term social commitment;

2. Long-term protection of the public from potential releases to the environment considering the need for long-term social commitment;

3. Short-term protection of workers and the public while the site is in operation; and

4. Long-term stability and elimination of the need for active maintenance.

The first two objectives point out the need for long-term stability and predictability in disposal facility performance as well as consideration of long-term social commitment. Potential long-term releases to the environment and potential exposure of an intruder should be accomplished in such a manner that major social commitment is not required and no undue burdens are placed on future generations. These, at the same time, need to be balanced with the costs for disposal to be borne by present generations based on a range of alternative approaches that can be followed to improve safety in disposal. Thus, the method of calculation developed and applied by NRC in this EIS calculates both short-term impacts that occur at the point of generation, during transport, and during disposal operations; and the long-term impacts that occur after the disposal facility closes. These can be divided into several impact evaluation factors as follows:

1. Short-term costs to a waste generator for processing, packaging, transport and disposal of the waste;

2. Short-term radiological impacts (occupational and public exposures) due to processing, packaging, transport, and disposal of waste;

3. Long-term costs to care for the site over the long term after operations cease;

4. Long-term radiological impacts (public exposures) due to disposal of the waste;

5. Energy consumed during processing, transport and disposal of the waste; and

6. Land committed for the disposal of waste.

Other potential impact measures such as man-hours expended and material requirements (e.g., clay, gravel, concrete, etc.) are implicitly included in the above measures. NRC also assumed that no land is permanently committed during waste processing and transportation activities. These impact measures can be grouped by the three principal phases of waste disposal discussed earlier, namely:

Waste Processing	Waste Transportation	Waste Disposal
Costs ($)	Costs ($)	Costs ($)
Occupational exposures (man-mrem)	Occupational exposures (man-mrem)	Occupational exposures (man-mrem)
Fuel use (gallons of fuel)	Fuel use (gallons of fuel)	Fuel use (gallons of fuel)
Population exposures (man-mrem)	Population exposures (man-mrem)	Exposure to individuals and populations (mrem and man-mrem)
		Land use (m^2)

Each of these are discussed in further detail below as a part of the description of the method of calculation used.

3.8.2 Method of Calculation

The various ways that a person can be exposed to radioactive waste may be divided into three principal categories:

1. Activities involving the processing and handling of the waste prior to disposal. This would include activities involved in the handling, processing, and packaging of the waste at its point of generation; transport of the waste from the point of generation to disposal; and activities at the disposal facility involving emplacement of the waste at the disposal facility (processing of waste at facilities other than the generating licensee's facility would also be included).

2. Man contacting the waste after disposal (i.e., intrusion into the disposal facility leading to exposure to disposed waste). This would include activities of man that would lead to his intruding into the disposal facility either purposefully (such as an archeologist in the future intentionally digging into the sites attempting to reclaim artifacts from the disposed waste) or inadvertently (such as an unknowing individual who might attempt to use the land for reasonable productive purposes in the future--e.g., farming or housing).

3. The waste entering one of several natural environmental pathways back to man (e.g., migration). This would include the potential leaching and transport of the waste through the ground water; intrusion and dispersion by plants and animals; long-term erosion of the site with eventual uncovering of the waste and surface water and air transport; and release of gaseous decomposition products from the waste containing radioactive species (e.g., tritiated methane gas).

The first mode involves primarily short-term considerations and the second and third, long-term considerations.

3.8.3 Waste Generation/Processing

Short-term impacts calculated at the point of waste generation include occupational exposures, population exposures, costs, and energy use. The impacts due to processing of the waste are described in this section. The occupational exposures involved with the handling of the waste during loading are described in the following section regarding transportation.

Waste processing options analyzed were divided into volume reduction processes such as compaction, evaporation and incineration; and volume increasing techniques such as solidification, addition of absorbent material and packaging.

NRC assumed that only incineration would result in the release of significant quantities of radioactivity to the environment and population exposures were calculated based upon fractional release rates for small (pathological) and

large (fluidized bed) incinerators; whether the processing was done at the point of generation or at a central facility; and the local environment. Institutional facilities were assumed to be located in an urban environment and all others in a rural environment. Occupational exposures were calculated based upon the person-hours required to process the waste and the radiation field associated with the general work environment.

The amount of energy required to process the waste was also determined and is expressed in units of gallons of fuel consumed. Labor hours and costs for processing were also determined based upon published data.

The unit rates for costs, energy use, and labor hours assumed for the processes considered in this EIS, compaction, evaporation, incineration and solidification are summarized in Table 3.7.

Table 3.7 Summary of Processing Unit Impact Rates

Process	Cost (1980 $)	Labor (hours)	Energy (g of fuel)	Units
Compaction				
Regular	335	15	4.6	Per m^3
Improved	503	15	4.6	of Input
Hydraulic Press	1,006	15	4.6	
Evaporation	690	4.42	56.3	Per m^3 of Input
Incineration				
Pathological	2,060	8	116	Per m^3
Fluidized Bed (small)	1,938	6.12	1.29	of Input
Fluidized Bed (large)	1,039	5.35	72	
Solidification				
Scenario A	1,200	17	47	Per m^3
Scenario B	1,700	14	39	of Output
Scenario C	1,900	12	33	

3.8.4 Waste Transportation

Impacts calculated during transportation of the waste include occupational exposures, population exposures, energy use and cost. Also included in this subsection because of similarities are the occupational exposures incurred during handling of the waste at the point of generation and at the disposal facility.

The occupational and population exposures incurred during transportation are calculated based on total loaded miles travelled and the number of loaded shipments (i.e., return trips when the vehicle is empty are excluded). The exposure rates used for occupational and population exposures incurred during transportation are summarized below:

	Population Doses (person-mrem)	Occupational Doses (person-mrem)
During transit per shipment mile	0.018	0.02
During stopover per shipment	2.0	2.0

The occupational exposure resulting from handling of the waste at the point of waste generation were calculated based on the man-minutes required to load each container and the radiation field associated with the level of care required to handle the container. Occupational exposures were also calculated for the handling of waste at the disposal facility during disposal based on the personnel time required for unloading and disposal and the radiation fields associated with the handling environment that the workers are exposed to.

Other impact measures calculated involved costs for transportation which include a mileage charge, fuel surcharge, cask use rental charge and the energy use calculated based on the total shipment miles traveled assuming an average fuel consumption rate of 6 miles per gallon.

3.8.5 Waste Disposal

Impacts calculated at the point of disposal include occupational exposures, population and individual exposures, costs for disposal, costs for long-term care, energy use and land use.

The calculation of land committed for waste disposal is based on the volume of waste disposal of, the method of waste emplacement and the particular design of the disposal facility.

Waste disposal costs may be divided into two types of costs--design and operation costs, and postoperational costs. Design and operation costs represent fees charged by the disposal facility operator to cover design and operation of the disposal facility, and to receive a fixed return on investment. These include capital costs (costs associated with siting, designing, licensing, and initial construction of the disposal facility) and operational costs (costs associated with receipt and disposal of waste, as well as construction of disposal cells).

Postoperational costs include costs for (1) facility closure, and (2) long-term care by the site owner. Included in the postoperational costs are costs associated with acquisition by the licensee of surety bonds, letters of credit, or other financial instruments which are used to provide assurance to the site owner that funding for closure and long-term care will be available.

Occupational exposures are calculated in two phases: the exposures to waste handlers who unload and dispose of the waste (discussed in the preceeding section) and occupational exposure of other site personnel performing routine operational and administrative functions not directly connected with waste handling. Occupational exposures, costs and energy consumption are related to the volume of waste disposed of, operational practices, and the design of the facility. Unit impact measures were calculated for the base case facility described in Appendix E and for the variations described in Appendix F. They are summarized in Table 3.8. The specific exposure pathways analyzed regarding disposal of the waste and the short- and long-term radiological impacts, and other costs of disposal are discussed in detail in Chapters 4, 5 and 6. Chapter 4 addresses exposure of an intruder, Chapter 5 addresses long-term environmental releases, and Chapter 6 addresses short-term releases during operations and processing of waste at a centralized regional processing facility.

The methodology calculates:

- o the occupational exposures and the exposures to the members of the public (individuals and population) resulting from the disposal of LLW;
- o the occupational and the population exposures resulting from the processing of the waste by the waste generators or by the operators of a centralized regional processing facility (assumed to be at the disposal site), and the transportation of the waste from the waste generators to the disposal site;
- o the costs and the energy use associated with processing, transportation, and disposal of LLW; and
- o the land area committed to disposal of LLW.

For waste processing purposes, population doses are limited to exposures due to airborne releases from waste incineration or calcination. For waste disposal, the calculational methodology determines the following exposures:

- o Ground-water migration
  - To an individual (an intruder) from a well located on the disposal facility following the end of the active institutional control period.
  - To an individual from a well located at the disposal facility site boundary.

Table 3.8 Unit Rates for Impact Measures

Activity	Cost (thousand 1980 $)	Occupational* Exposure (person-mrem)	Energy Use (thousand gallons)	Units**
Preoperational				
Reference Base Case	7,452	--	212	Lump Sum
Additive Alternatives†				
Walled Trench	594	--	--	Lump Sum
Stacking	226	--	--	Lump Sum
Segregation	1	--	--	Lump Sum
Layering	132	--	--	Lump Sum
Decontainerized Disposal	924	--	--	Lump Sum
Hot Waste Facility	260	--	--	Lump Sum
Grouting	55	--	--	Lump Sum
Intruder Barrier	281	--	--	Lump Sum
Extreme Stabilization	10	--	--	Lump Sum
Operational				
Reference Base Case				
Trench (-Cover)	2,341	300	200	Disposal Vol.
Regular Cover	1,420	2,400	100	Disposal Area
Other	63,696	1,000	200	Lump Sum
Additive Alternatives†				
Walled Trench	74,438	700	300	Disposal Vol.
Stacking	12,758	100	100	Total Waste Vol.
Segregation	3,888	100	30	Total Waste Vol.
Layering	15,400	-100	30	Vol. Disp. by Layer
Decontainerized Disposal	48,975	400	100	Vol. Disp. by Decon
Hot Waste Facility	176,979	-200	450	Vol. Disp. by HWF
Grouting	72,405	2,550	800	Grout Volume
Sand Backfill	3,270	--	185	Sand Volume
Cover Options				
Thick	15,524	2,400	150	Disposal Area
Intruder Barrier	103,854	2,400	300	Disposal Area
Moderate Stabilization	3,465	4,800	300	Disposal Area
Extreme Stabilization	33,345	4,800	600	Disposal Area

Table 3.8 (continued)

Activity	Cost (thousand 1980 $)	Occupational* Exposure (person-mrem)	Energy Use (thousand gallons)	Units**
Postoperational				
Closure Period				
Regular Closure	1,010	500††	15	Lump Sum
Extensive Closure	3,025	1,000	60	Lump Sum
Institutional Period#				
Low Care Level				
Years 1-10	150	--	2	Per Year
Years 11-25	63	--	2	Per Year
Years 26-100	51	--	2	Per Year
Medium Care Level				
Years 1-10	303	--	6	Per Year
Years 11-25	150	--	6	Per Year
Years 26-100	63	--	6	Per Year
High Care Level				
Years 1-10	440##	--	10	Per Year
Years 11-25	303	--	10	Per Year
Years 26-100	150	--	10	Per Year

*Occupational exposures associated with operations other than waste unloading and disposal.

**Lump sum items are assumed to be independent of the waste volume. Disposal volume dependency is for 1 million m^3 of disposal (not waste) volume; grout volume dependency is for 1 million m^3 of grout injected; sand volume dependency is for 1 million m^3 of sand backfill; disposal area dependency is for 1 million m^2 of trench cover area.

†Rates for alternatives are incremental rates in addition to the rates given for the reference system.

††Regular closure assumed to last 2 years, extensive closure is assumed to last four years. Both cases assume 5000 person-hours of field work per year in an average radiation field of 0.05 mR/hr.

#These costs are basic costs not considering inflation or interest. Details for complete calculation of the institutional period costs can be found in Appendix Q. The formulae given in Appendix Q are incorporated into the cost calculation procedure.

##To this cost, a contingency cost is added which depends on the soil conditions: $367,000 for medium-permeability soils; $168,000 for high-permeability soils; and, $1,007,000 for low-permeability soils.

- To a small population consuming water from a well located halfway between the facility and the hydrologic boundary (a steam).

- To a small population consuming water from the hydrologic boundary.

- o Exposures to an inadvertent intruder or small group of intruders who at some point in the future may potentially:

  - Construct a house on the site, or

  - Live in the house and consume food grown on the site in contaminated soil.

- o Exposures to a small population from:

  - Airborne transport of radionuclides due to uncovering of the disposed waste by either a potential intruder or through erosion; or

  - Waterborne transport of radionuclides due to uncovering of the disposed waste by either an intruder or through erosion.

- o Exposures to individuals located offsite through airborne release of radionuclides due to an operational accident such as a dropped container or a fire.

The details on development and application of the calculational methodology are set out in Appendices G, H and Q.

Chapter 4

PRESENTATION AND ANALYSIS OF ALTERNATIVES-INTRUDER

4.1 INTRODUCTION

This chapter reviews the potential hazard presented by inadvertent human intrusion into disposed waste and methods which may be used to mitigate the hazard. Two general concentration-limited inadvertent intrusion scenarios are considered:

1. Excavation into disposed waste or construction of a house or building at the disposal facility; and

2. Living on and consuming food grown at the disposal facility.

As implied above, the first general intrusion scenario may be broken into two sub-scenarios, depending upon the length of time that exposure occurs.

A third inadvertent intrusion scenario, which involves consumption of water from a well drilled at the site, is considered in Chapter 5 since it relates to ground-water migration.

Four methods are addressed by which potential human intrusion impacts may be mitigated:

1. Controlling the disposal of specific waste streams;

2. Waste form and packaging;

3. Institutional controls; and

4. Use of engineered and/or natural barriers to intrusion.

Section 2 presents background information about intrusion and selection of the specific scenarios analyzed in this EIS. Section 3 analyzes inadvertent human intrusion presenting the impacts of the base case "no action" alternative and incremental changes in those impacts due to application of a range of alternative controls involving disposal of specific waste streams, waste form and packaging, institutional controls, and use of natural and engineered barriers. Sections 4 and 5 analyze development of a performance objective for protection of an inadvertent intruder leading to selection of a preferred performance objective. Section 6 reviews technical requirements derived from the analyses, and those involving codification of existing practice, that should be applied in the near-surface disposal of waste to ensure protection of the inadvertent intruder. For those requirements involving a change to existing practice, a range of alternatives is considered and the costs and impacts presented. In some cases, based on a balancing of costs and benefits, a specific prescriptive requirement is selected. In other cases, flexibility in meeting the requirement is maintained to allow for individual cost-benefit considerations.

4.2 BACKGROUND INFORMATION ON HUMAN INTRUSION

In determining performance objectives and technical criteria for near-surface radioactive waste disposal, one of the considerations is the potential for human intrusion into the disposed waste. That is, at some time after the disposal facility is closed, an individual or group of individuals may perform such activities as excavating through the disposal cell covers and into the disposed waste.

It is recognized that the possibility of human intrusion into a closed near-surface disposal facility is only hypothetical. Existing regulations require that near-surface disposal facilities be sited on land owned and under the control of either the federal government or the government of the state in which the facility is located. As part of this "institutional control," the site owner would restrict the types of activities that would be carried out at the facility. For example, the closed facility may be fenced and maintained under periodic surveillance. As another example, an individual or a corporation may be licensed by the state or federal government to carry out productive surface activities on the facility, with the provision that the licensee does not excavate into the disposed waste.

The concern is that at some time after the facility is closed, institutional controls may break down and an intrusion event may occur. The one or few individuals intruding into the facility would then be exposed, through direct contact, to any waste disturbed through the intrusion event. Such intrusion may also act to increase the potential for ground-water migration by increasing the infiltration of precipitation into the waste and it may also bring wastes to the surface where they may potentially be dispersed by wind or water. These actions may result in radiation doses to the surrounding population. However, the largest radiation exposures by far would be to the individual intruders themselves.

Given the potential for human intrusion and the possibility of human exposures from intrusion, NRC believes it is reasonable to estimate the magnitude of exposures that could be received by an intruder. If such potential exposures appear to be significant, then it would be reasonable to explore ways in which such potential exposures can be reduced. First, however, some estimate should be made of the types of activities that could be potentially carried out by an intruder and of the potential pathways for exposure.

4.2.1 Human Intrusion Exposure Pathways

Intrusion into disposed waste may be either deliberate or inadvertent. A deliberate intrusion event implies that the intruder knows of the potential hazard of the disposed waste but for some reason deliberately chooses to ignore the hazard. For example, the intruder could be seeking something of potential value in the disposed waste. This would appear to be an unlikely scenario, however. The disposal facility would be under the surveillance and control of the government and deliberate intrusion into the waste to try and retrieve something of value would be a criminal act. Therefore, in order to

preclude discovery, the intruder would want to perform his activities as quickly as possible. In addition, if it is assumed that the intruder chooses to deliberately ignore a known potential radiation hazard, then it must also be assumed that the intruder would want to minimize his potential exposures by minimizing the time spent in contact with the waste. However, intrusion would involve digging through a few meters (e.g., 2 to 4) of soil prior to contacting the waste, which would take time. Power machinery would probably be needed to excavate soil and waste packages, which would make the assumed intrusion event rather conspicuous. In addition, the intruder would not have any knowledge regarding where a potentially valuable article might be. This means that the intruder would have to spend a considerable amount of time in a hazardous environment in order to find something of possible value during which the chance of discovery would be great (and would increase the longer the time spent) and the potential profit small. If would therefore appear that intentional intrusion after something of value would not be a profitable undertaking, and most people would not take the risk. In any case, it would appear to be difficult to establish regulations designed to protect a future individual who recognizes a hazard but then chooses to ignore the hazard.

On the other hand, inadvertent intrusion implies that an individual or group of individuals intrude into the waste either accidently or without realizing that there is a potential hazard. The former case appears to be the most likely. For example, a person who is licensed to maintain the facility might have some reason to excavate on the facility ground (e.g., to install a monitoring device) and could possibly misjudge the locations of the disposal cells and accidently dig into disposed waste. In this case, the hazard would be immediately recognized (certainly within a few minutes) and minimal exposures would result. (It must be assumed that individuals licensed to maintain the facility would have a knowledge of radiation safety and would at least be equipped with radiation detection equipment such as survey meters and would know how to use them.)

More significant exposures could occur if the intruder does not realize at first that there is a potential hazard. This could occur if there is a breakdown in institutional controls and the site owner mistakenly releases the facility for unrestricted use. (This, however, is unlikely as discussed in Section 4.3.6.) Assuming that such a thing occurs, then there are many possible scenarios for human exposure. A rather extreme scenario would be one in which the waste is contacted for extended periods of time.

The potential for inadvertent intrusion into a closed waste disposal facility assuming a breakdown in institutional controls has been examined in detail in studies by a number of investigators, including Lawrence Livermore Laboratory (Ref. 1), Ford, Bacon, and Davis, Utah (Refs. 2, 3), the Utility Waste Management Group (Ref. 4), and the Department of Energy (Ref. 5). A summary of the scenarios examined by these investigators are listed in Table 4.1. All of the studies were performed as part of efforts to classify radioactive wastes for disposal.

As can be seen, the studies investigated a number of scenarios in which a potential inadvertent intruder could be exposed, including construction of

Table 4.1 Comparison of Intruder Exposure Scenarios

Ford, Bacon and Davis (Ref. 2 3)	Department of Energy** (Ref. 5)	Utility Waste Management Group (Ref. 4)
(1) Inhalation of contaminated dust from construction activities*	(1) Sheet erosion of waste into a stream, followed by either:† o consumption of contaminated H_2O; o use of water for irrigation; or o consumption of fish obtained from the stream	(1) Leaching of waste into a water course
(2) Inhalation of contaminated dust by someone living on the disposal facility	(2) Ground-water migration of radionuclides to an aquifer, followed by either:† o consumption of contaminated H_2O;or o use of water for irrigation	(2) Spillage of waste on the ground, which is carried into a water course
(3) Consumption of contaminated water from an onsite well	(3) Retrieval of useful items by an artifact hunter	(3) Inhalation of spilled waste
(4) Consumption of food grown on contaminated soil*	(4) Exposure of waste, followed by persons living on the disposal facility being exposed through inhalation of contaminated dust and consumption of food grown on contaminated soil*	(4) Inhalation of dust during excavation by an intruder
(5) Direct gamma radiation exposure to a construction worker*		(5) Consumption of contaminated dirt by child
(6) Ground-water transport of radionuclides to a river		(6) Consumption of food grown in contaminated soil
(7) Sheet erosion of waste to a river		(7) Erosion of waste into water course
		(8) Inhalation of eroded waste
		(9) Direct gamma irradiation from 55-gallon drums
		(10) Direct gamma irradiation from the ground surface

*Determined by the authors to be generally controlling.

**The authors also reviewed, but did not treat in detail, other pathways including movement of waste to the surface by plant (nonfood) uptake, movement of waste to the surface by burrowing animals, and severe events, such as flooding, meteor impact, or glacial action.

†Whichever subpathway is most restrictive.

houses on top of a disposal facility, consumption of food grown in contaminated soil, and consumption of water from a well drilled into the disposal facility. Although a number of scenarios were investigated, all scenarios were composed of only three pathways of human exposure--i.e., inhalation of radionuclides, consumption of radionuclides through water or food, and direct gamma exposure. The pathways were used singly or in combination to determine impacts. One researcher examined the potential impacts of someone (a child) eating contaminated soil directly (Ref. 4). Another researcher examined the potential impacts from someone potentially retrieving an artifact contaminated with transuranic radionuclides from a disposal facility and using the artifact for his own purposes (Ref. 5). (Inhalation exposures are assumed to occur either while excavating or while the artifact hunter polishes the artifact.)

To calculate impacts (concentration limits for disposal) all investigators assumed that intrusion events take place some hundreds of years following waste disposal, after institutional controls cease. That is, for the first few hundred years following waste disposal, the disposal facility is assumed to be under the control of a government agency which precludes inappropriate use of the disposal facility. Following this time, the institutional controls are assumed to become ineffective and persons are assumed to be allowed to intrude into the disposed waste mass and carry out such typical activities as construction of houses or living on the facility. The most restrictive of the scenarios (the scenario leading to the highest exposures) is then used to determine limiting concentrations for disposal of waste by the disposal methods investigated.

In general, scenarios such as consumption of food, inhalation of dust, or direct gamma exposure were found in these studies to be more restrictive than scenarios involving contaminated ground water. The former types of scenarios may be termed "concentration-limited" scenarios. That is, to calculate impacts from such scenarios as inhalation of dust or consumption of food grown in contaminated soil, one is interested in the concentration of the radionuclides in which the activity takes place. The radionuclide concentrations or the total activity contained elsewhere in the disposal facility does not enter into the calculation. On the other hand, ground-water scenarios are "activity-limited" and the impacts depend upon the total activity contained in the facility and not especially on the concentration of radionuclides in any particular portion of the disposal facility. In addition, although the impacts from the concentration-limited scenarios are site-specific to a degree, they are much less site-specific than the activity-limited scenarios.

This implies that the concentration-limited scenarios may be a useful way to classify wastes in a relatively nonsite-specific manner. Intrusion is a hypothetical event, but the potential impacts represent a kind of "hazard index" with which to rank the potential "hazard" of different waste streams or to classify waste for disposal.

In addition, the previous investigators generally did not make allowances for waste form. It was generally assumed that the waste/soil mixture was indistinguishable from dirt. That is, the waste/soil mixture dispersed into the air in a similar manner as dust from bare soil. Root uptake into plants for human consumption was calculated assuming that the radionuclides essentially

existed in a dissolved state in soil. The radionuclides were readily available for uptake by plant roots. One investigator did, however, investigate possible limits for activated or surface-contaminated metals (Ref. 2). Another investigator intrinsically considered waste form as part of his consideration of impacts to a potential future archeologist or artifact hunter (Ref. 5).

4.2.2 Intrusion Pathways Considered in the EIS

Given the above discussion, there may be a number of scenarios by which a potential intruder could be exposed to radiation. These scenarios range from potentially trivial events to events which could cause relatively significant exposures, and each scenario may have a finite probability of occurrence associated with it. Given this potential for significant intruder exposures, additional analysis is indicated in this environmental impact statement of methods which may be used to mitigate these exposures. However, to perform this analysis some preliminary decisons must be made on how the analysis is to be performed. There are two basic alternatives:

1. Devise a number of scenarios from the likeliest to the unlikeliest, assign each a fixed probability, and perform a risk analysis of the impacts; and

2. Determine a limited number of the most restrictive (high consequence) scenarios, assume the event occurs, and perform a consequence analysis of the impacts.

Neither of these two alternatives is totally satisfactory. For the first alternative, there may be any number of potential scenarios which could be invented, including minor variations. It would be impossible to consider all of these scenarios. In addition, it would be extremely difficult if not impossible to determine and assign numerical probabilities. Inadvertent intrusion is a hypothetical event that may or may not occur in the future. Given this uncertainty, it appears that a better approach would be alternative 2. This is the general approach followed by the previous investigators on waste classification. However, this also has its drawbacks. If extremely conservative, yet clearly unlikely scenarios are used, then the calculated results (which may involve conservatisms multiplied by conservatisms) can quickly become unrealistic and overly restrictive. This is especially important considering the hypothetical nature of the intrusion event.

NRC has, therefore, adopted a somewhat combined approach for numerical analysis. A limited number of intrusion scenarios are conservatively assumed to occur based upon consideration of typical human activities. The potential consequences are then calculated. However, given the hypothetical nature of the scenarios, once the intrusion scenario occurs, reasonably conservative actions on the part of the intruders are assumed to occur. In addition, some judgment is made as to the likelihood and extent of the scenarios occurring depending upon specific waste forms and disposal practices.

The intrusion scenarios considered in this environmental impact statement were developed based upon consideration of the work performed on waste classification by the above investigators. Two concentration-limited scenarios are considered as well as one activity-limited scenario. The concentration limited scenarios analyzed in the following subsections include (1) excavation into disposed waste or construction of a house or building upon the disposal facility and (2) persons living on the disposal facility. The activity-limited scenario analyzed involves potential use of contaminated water from a well drilled onsite. This scenario is analyzed in Chapter 5 as part of the ground-water migration analysis. Potential population exposures from radioactive material dispersed by intruders is also analyzed. All three scenarios are assumed to occur after institutional controls are assumed to be temporarily lost.

All scenarios are believed to be conservative and are discussed in detail in Appendix G.

4.2.2.1 Intruder-Construction Scenario

This scenario involves the assumed construction of a house directly into the disposed waste, and is referred to as the intruder-construction scenario. During construction activities, some of the waste is assumed to be contacted by the workmen (this could happen, for example, through construction of a basement). During construction, some of the waste is assumed to be dispersed into the air and onto the immediate area around the house. Exposures would principally occur through such pathways as inhalation of contaminated dust and exposure to direct gamma radiation from standing on contaminated soil and being immersed in a contaminated dust cloud. (A subset of this scenario called the intruder-discovery scenario, and involving reduced relative impacts, is discussed in Section 4.3.4.3.)

4.2.2.2 Intruder-Agriculture Scenario

The second scenario involves a potential situation in which an individual or individuals live in the house thus constructed. In addition to the exposure pathways for the construction case, the potential intruder could be exposed through consumption of food grown in the contaminated soil. (Consumption of water by the intruder from a well drilled at the site is analyzed in Chapter 5.) The length of time that the individuals would spend in the contaminated area would be greater for this scenario than for the intruder-construction scenario. This scenario is referred to as the intruder-agriculture scenario.

4.2.2.3 Population Exposures from Intrusion Activities

In this scenario, the waste which is uncovered and brought to the surface through inadvertent intrusion is transported offsite by surface water and wind. Exposures are calculated to the surrounding population.

4.3 DESCRIPTION AND IMPACTS OF BASE CASE (NO ACTION) AND OTHER ALTERNATIVES

4.3.1 Description of Base Case (No Action) Alternative

Base case impacts to an inadvertent intruder are calculated considering two scenarios for potential inadvertent intrusion. One scenario is the assumed construction of a house directly into the disposed waste (intruder-construction scenario). The second scenario involves a potential situation in which an individual or individuals live in the house that is constructed and consumes food grown at the site (intruder-agriculture scenario). To calculate impacts from these intruder scenarios, waste spectrum 1 is assumed to be disposed of at the reference (base case) facility that is sited, designed, and operated as described in Chapter 3 and as set out in detail in Appendix E. The waste is disposed of in regular shallow land burial trenches with a standard thin cap. Waste spectrum 1 refers to the base case waste and much of the waste is assumed to be in an easily compressible, readily degradable waste form with relatively high leaching characteristics. The waste is assumed to be randomly disposed into the reference facility and no specific actions are taken to provide consideration of potential future inadvertent intrusion. For purposes of analysis, varying periods of institutional control from 50-2000 years are assumed to be in effect after closure during which inadvertent intrusion would not occur.

4.3.2 Costs and Impacts of Base Case (No Action) Alternative

The radiological hazard to a potential intruder for the base case (no action) alternative is listed in Table 4.2 for seven organs for several time periods following license termination. For this analysis, the termination of the disposal facility license was assumed to immediately follow a two-year closure period. The hazard listed (in mrem/yr to an individual) is summed over all 23 radionuclides considered in the analysis and volume-averaged over all 36 waste streams disposed into the disposal facility. As can be seen, the highest potential exposures are those to the bone. Over the first 500 years, potential exposures from the intruder-construction scenario drop by a factor of 6 from about 6 rems to about one rem. Over the next 1500 years, however, potential exposures are reasonably constant, and are still at about 800 mrem of 2000 years. A somewhat similar pattern is observed for potential exposures to the lung.

The potential exposures were conservatively calculated giving no credit (with the exception of activated metal) for the ability of waste form to reduce airborne dispersion of radionuclides or uptake by plant roots. That is, the waste is assumed to behave and disperse in a similar manner to ordinary dirt.

Other base case costs and impacts are summarized in Table 4.3 for waste spectrum 1. Also shown in Table 4.3 are the costs and impacts for disposal of waste spectra 2-4 at the base case reference disposal facility. The costs and impacts are calculated over 20 years of waste generation, processing, transport, and disposal. The format for Table 4.3 will be generally utilized throughout the remainder of the EIS to present the costs and impacts of the various alternatives analyzed. Included on the first page are population exposures from waste processing and transportation; occupational exposures for waste processing,

Table 4.2 Summary of Potential Inadvertent Intruder Hazard to Seven Organs for 36 Waste Streams (Waste Spectrum 1)

(mrem)

	Body	Bone	Liver	Thyroid	Kidney	Lung	G-I Tract
YR = 50.							
INT CONS	4.983E+03*	6.753E+03	6.290E+03	4.877E+03	5.482E+03	5.933E+03	4.878E+03
INT AGRI	6.461E+03	6.995E+03	6.867E+03	6.309E+03	6.546E+03	6.723E+03	6.319E+03
YR = 100.							
INT CONS	1.502E+03	3.095E+03	2.684E+03	1.407E+03	1.958E+03	2.341E+03	1.408E+03
INT AGRI	1.769E+03	2.482E+03	2.206E+03	1.703E+03	1.918E+03	2.068E+03	1.703E+03
YR = 150.							
INT CONS	5.454E+02	2.019E+03	1.638E+03	4.584E+02	9.670E+02	1.311E+03	4.587E+02
INT AGRI	5.891E+02	1.210E+03	1.013E+03	5.490E+02	7.475E+02	8.818E+02	5.465E+02
YR = 200.							
INT CONS	2.400E+02	1.623E+03	1.263E+03	1.588E+02	6.333E+02	9.556E+02	1.590E+02
INT AGRI	2.233E+02	7.881E+02	6.262E+02	1.923E+02	3.773E+02	5.032E+02	1.890E+02
YR = 300.							
INT CONS	1.058E+02	1.362E+03	1.026E+03	3.284E+01	4.542E+02	7.651E+02	3.300E+01
INT AGRI	6.818E+01	5.725E+02	4.328E+02	4.311E+01	2.068E+02	3.285E+02	3.941E+01
YR = 400.							
INT CONS	8.558E+01	1.255E+03	9.325E+02	1.859E+01	3.993E+02	7.191E+02	1.873E+01
INT AGRI	4.869E+01	5.168E+02	3.844E+02	2.623E+01	1.737E+02	2.990E+02	2.245E+01
YR = 500.							
INT CONS	7.808E+01	1.183E+03	8.687E+02	1.567E+01	3.637E+02	6.994E+02	1.579E+01
INT AGRI	4.336E+01	4.851E+02	3.568E+02	2.277E+01	1.572E+02	2.889E+02	1.894E+01
YR = 1000.							
INT CONS	5.869E+01	9.769E+02	6.822E+02	9.964E+00	2.570E+02	6.645E+02	1.004E+01
INT AGRI	3.112E+01	3.980E+02	2.782E+02	1.600E+01	1.101E+02	2.706E+02	1.208E+01
YR = 2000.							
INT CONS	4.491E+01	8.264E+02	5.482E+02	6.007E+00	1.817E+02	6.350E+02	6.048E+00
INT AGRI	2.251E+01	3.347E+02	2.219E+02	1.131E+01	7.691E+01	2.558E+02	7.317E+00

*The listed exposures are copied directly from the INTRUDE code output (See Appendix H).

Table 4.3 Costs and Other Impacts of Base Case (No Action) Alternative

	Waste Spectra			
Impacts	1	2	3	4
Short-term population exposures: (man-mrem)				
Processing by waste generator	0	0	7.86E+6	8.23E+6
Processing at regional processing center	0	0	3.74E+4	3.74E+4
Waste transportation	7.12E+5	7.03E+5	5.26E+5	2.16E+5
Short-term occupational exposures: (man-mrem)				
Processing by waste generator*	-	+1.68E+6	+1.18E+6	-3.50E+5
Processing at regional processing center	0	1.25E+5	2.45E+4	3.79E+4
Waste transportation	6.89E+6	6.49E+6	5.51E+6	2.19E+6
Waste disposal	3.05E+6	2.93E+6	2.49E+6	1.13E+6
Waste generation and transport costs: ($)				
Processing by waste generator*	-	+3.38E+8	+1.15E+9	+1.08E+9
Processing at regional processing center	0	3.63E+7	9.50E+7	1.05E+8
Waste transportation	2.49E+8	2.29E+8	1.88E+8	1.19E+8
Disposal costs: ($)				
Design and op.	1.85E+8	1.82E+8	1.81E+8	1.79E+8
Postoperational	3.82E+7	3.82E+7	3.82E+7	3.82E+7
Total	2.23E+8	2.20E+8	2.19E+8	2.17E+8
Unit ($/m^3)	223	315	445	916
Energy use: (gal)*	--	+7.89E+6	+5.84E+7	+6.61E+7
Land use: (m^2)	3.47E+5	2.42E+5	1.71E+5	8.24E+4
Waste volume disposed: (m^3)				
Regular:				
o Chemical-Stable	2.95E+4	6.22E+4	1.16E+4	8.49E+3
o Chemical-Unstable	1.17E+5	7.40E+4	6.57E+4	6.57E+4
o No Chemical-Stable	2.23E+5	3.30E+5	4.04E+4	1.61E+5
o No Chemical-Unstable	6.30E+5	2.32E+5	1.15E+4	1.92E+3
o Total	1.00E+6	6.98E+5	4.93E+5	2.37E+5

Table 4.3 (continued)

Impacts	Waste Spectra 1	2	3	4
Total volume not acceptable: (m^3)	0	0	0	0
Direct intruder impacts:				
Body (mrem)				
o 100 C	1.502E+3	1.899E+3	3.113E+3	6.469E+3
A	1.769E+3	2.235E+3	3.667E+3	7.619E+3
o 500 C	7.808E+1	1.115E+2	1.582E+2	3.287E+2
A	4.336E+1	6.175E+1	8.781E+1	1.825E+2
Bone (mrem)				
o 100 C	3.095E+3	4.179E+3	6.340E+3	1.317E+4
A	2.482E+3	3.255E+3	5.111E+3	1.062E+4
o 500 C	1.183E+3	1.693E+2	2.396E+3	4.978E+3
A	4.851E+2	6.942E+2	9.823E+2	2.041E+3
Offsite releases from intrusion (at 100 years):				
Airborne impacts (man-millirem)				
o Body	2.242E+3	2.193E+3	2.016E+3	4.181E+3
o Bone	4.060E+4	3.970E+4	3.650E+4	7.569E+4
Waterborne impacts (millirem)				
o Body	8.475E-2	1.213E-1	1.716E-1	3.566E-1
o Bone	5.097E-1	7.297E-1	1.032E+0	2.145E+0

*Occupational exposures and processing costs by the waste generator for waste spectra 2-4 are presented as additional exposures and costs to those associated with waste spectrum 1. Similarly, energy use for waste spectra 2-4 are presented as an additional increment to that associated with waste spectrum 1.

transportation, and disposal; costs for waste processing and transportation; cost for disposal divided into design and operation costs, postoperational costs (closure and long-term care costs), and total disposal costs; total incremental energy used for processing, transportation, and disposal; land used for disposal; and total waste volume disposed of. Included on the second page are the long-term individual and population exposures resulting from disposal of the waste.

No short-term population exposures are shown for processing of the waste either at the point of generation or at a central processing facility. For the base case, it was assumed that none of the waste streams were subjected to incineration and in waste spectrum 1, no waste streams are delivered to a regional processing center. As discussed in Chapter 3, NRC also assumed for purposes of this EIS analysis, that operational releases from other waste processing operations (e.g., compaction and solidification) would be very small and as such they were not included. In any case, such potential releases would already be analyzed as part of licensing individual facilities. For this EIS, NRC is interested in estimating releases due to additional, more extensive, waste processing techniques. These releases are expected to be significant only for incineration. The population exposures due to transportation of the waste to the disposal facility were calculated to 7.12E+5 man-mrem.

Occupational exposures due to waste processing (also waste processing costs and energy use) are presented in this EIS as exposures in addition to those associated with waste spectrum 1. The NRC staff believes that it would be difficult to attempt to estimate the existing occupational exposures for waste management for all NRC and Agreement State licensees. In addition, the principal purpose of this EIS in regard to waste processing occupational exposures is to estimate incremental exposures associated with additional waste processing activities. This is believed to be in keeping with the purpose of this EIS.

Occupational exposures were also calculated for transportation and for handling of the waste during disposal operations (6.89E+6 man-mrem and 3.05E+6 man-mrem respectively).

Costs for waste processing are also presented as costs in addition to those associated with waste spectrum 1. Costs from transportation and disposal, however, were calculated. Unit disposal costs average \$223 per m^3 or \$6.32 per ft^3. The reader is referred to Appendices E, G, and Q for information about the costs and the methods by which they were determined. Other impact measures such as energy and land use were also calculated and are shown.

Page 2 of Table 4.2 shows the exposures to the inadvertent intruder calculated for the two scenarios, intruder-construction and intruder-agriculture. The exposures are calculated for two periods of active institutional control--100, and 500 years--and for two organs: whole body and bone. For purposes of analysis, each scenario is assumed to occur immediately following the end of the active institutional control period.

Finally, Table 4.2 shows the population exposures calculated due to releases of material to the offsite environment due to the intrusion event. The exposures are calculated at a time period of 100 years following license termination. Airborne impacts are calculated for the surrounding population within a 50-mile radius of the disposal facility. Waterborne impacts, however, are calculated to an individual. In the calculations, rainwater is assumed to erode the soil/waste mixture exposed by the intruder, and carry the contamination offsite to a nearby stream. The contaminated stream water is then assumed to be used by an individual for consumption, irrigation of crops, etc. As shown, the impacts to the inadvertent intruder himself are orders of magnitude higher than those to the surrounding population.

Tables 4.2 and 4.3 establish a baseline of cost and impact data calculated for the base case site and waste against which varying ways to mitigate these impacts can be compared. The data shows that the exposures calculated are relatively high at 100 years at which point they begin to decrease, leveling off at around 400-500 years. Although the exposures to the inadvertent intruder are not so high as to cause great (immediate life threatening) concern for the one or few individuals who might be exposed, some additional controls could be exercised that could reduce such potential exposures to lower levels during the 100-500 year time frame. Furthermore, the major portion of the exposures may be contributed by a few waste streams that could be controlled to reduce potential exposures.

4.3.2.1 Waste Spectra Nos. 2-4

Table 4.3 also presents the costs and impacts of disposing of improved waste forms, represented by waste spectra 2-4, at the reference base case facility. These have been included in this table principally to provide reference data on the other spectra for comparison with waste spectra 1 and to demonstrate two points:

1. As the volume of the waste is decreased through waste processing techniques such as compaction and incineration, exposure to an inadvertent intruder increases; and

2. Offsite population exposures from inadvertent intrusion activities are low and do not change significantly from one spectrum to another.

Considerable additional discussion regarding the effects of the waste spectra on the impact measures is provided in Chapter 5.

4.3.3 <u>Description of Alternatives</u>

NRC next analyzed a range of alternatives that could be applied to reduce the impacts to an inadvertent intruder and the costs and impacts of the alternatives. The alternatives analyzed fell into four categories:

1. Controlling the disposal of specific waste streams;

2. Waste form and packaging;

3. Institutional controls; and

4. Engineered and natural "intruder barriers" created through disposal facility design and operations.

Each is presented and analyzed below.

With respect to siting, site characteristics were not specifically analyzed with respect to reduction of intruder impacts. Considerations such as future population growth and land use development in the vicinity of the site and the extent of and economic significance of natural resources at the site could effect the potential for inadvertent intrusion. Such considerations would be applied in the siting of a near-surface disposal facility today. In general, selection of a site that does not have much resource value and which is not desirable for human activities would reduce the potential for inadvertent intrusion.

4.3.3.1 Controlling the Disposal of Specific Waste Streams

For this alternative, it is useful to examine the potential hazard of some individual waste streams and groups of waste streams in terms of intruder exposures. Care needs to be taken in interpreting the potential hazard of individual waste streams, however, since the actual potential intruder hazard at any particular site would come from a mixture of waste streams, not just one individual waste stream. This is particularly important for waste streams which are small in volume. In this section, no credit is again assumed for the ability of improved waste forms to reduce airborne and plant root uptake.

As an example, a summary of potential intruder hazard to whole body and bone for BWR ion-exchange resins is shown in Table 4.4. As can be seen, the potential exposures to whole body and bone are principally dominated by direct gamma radiation in the intruder-construction and intruder-agriculture scenarios. The differences in potential exposures between the four spectra for the two cases are a function of the waste processing option considered. That is, for waste spectrum 1, ion-exchange resins are assumed to be dewatered while for waste spectrum 2, half of the resins are solidified in cement and half in a synthetic polymer. The increase in volume relative to the dewatered condition coupled with the self-shielding provided by the cement leads to a reduction in exposures of about 2. For spectrum 3, all resins are solidified in a synthetic polymer. Due to the negligible self-shielding and the different volume increase factor, the potential hazard is somewhat higher than spectrum 2 but lower than spectrum 1. For spectrum 4, all resins are calcined and then solidified in a synthetic polymer. The greatly increased volume reduction brought about by the calcining operation leads to radionuclide concentrations in the final waste form about a factor of 18 higher than for spectrum 3. Even with the higher concentrations, however, potential exposures drop quickly to about 100 mrem/yr after 500 years.

Table 4.4 Potential Intruder Exposures to Whole Body and Bone for BWR Ion-Exchange Resins

(mrem)

	Spectrum 1		Spectrum 2		Spectrum 3		Spectrum 4	
	Body	Bone	Body	Bone	Body	Bone	Body	Bone
YR = 50.								
INT CONS	6.197E+04	6.198E+04	3.005E+04	3.005E+04	3.098E+04	3.099E+04	5.577E+05	5.578E+05
INT AGRI	7.343E+04	7.356E+04	3.561E+04	3.569E+04	3.671E+04	3.678E+04	6.608E+05	6.620E+05
YR = 100.								
INT CONS	1.930E+04	1.931E+04	9.358E+03	9.365E+03	9.650E+03	9.656E+03	1.737E+05	1.738E+05
INT AGRI	2.287E+04	2.291E+04	1.109E+04	1.112E+04	1.143E+04	1.146E+04	2.058E+05	2.062E+05
YR = 150.								
INT CONS	6.087E+03	6.096E+03	2.915E+03	2.957E+03	3.043E+03	3.048E+03	5.478E+04	5.487E+04
INT AGRI	7.212E+03	7.229E+03	3.497E+03	3.507E+03	3.606E+03	3.614E+03	6.490E+04	6.506E+04
YR = 200.								
INT CONS	1.924E+03	1.932E+03	9.330E+02	9.380E+02	9.621E+02	9.662E+02	1.732E+04	1.739E+04
INT AGRI	2.280E+03	2.288E+03	1.105E+03	1.111E+03	1.140E+03	1.144E+03	2.052E+04	2.059E+04
YR = 300.								
INT CONS	1.993E+02	2.064E+02	9.671E+01	1.010E+02	9.967E+01	1.032E+02	1.794E+03	1.858E+03
INT AGRI	2.361E+02	2.404E+02	1.145E+02	1.171E+02	1.180E+02	1.202E+02	2.124E+03	2.162E+03
YR = 400.								
INT CONS	2.805E+01	3.431E+01	1.365E+01	1.745E+01	1.402E+01	1.716E+01	2.524E+02	3.088E+02
INT AGRI	3.317E+01	3.657E+01	1.613E+01	1.819E+01	1.658E+01	1.828E+01	2.981E+02	3.274E+02
YR = 500.								
INT CONS	1.097E+01	1.663E+01	5.363E+00	8.797E+00	5.484E+00	8.317E+00	9.872E+01	1.497E+02
INT AGRI	1.296E+01	1.593E+01	6.331E+00	8.134E+00	6.478E+00	7.966E+00	1.163E+02	1.417E+02
YR = 1000.								
INT CONS	8.769E+00	1.270E+01	4.281E+00	6.665E+00	4.385E+00	6.352E+00	7.892E+01	1.143E+02
INT AGRI	1.044E+01	1.255E+01	5.102E+00	6.379E+00	5.220E+00	6.273E+00	9.363E+01	1.113E+02
YR = 2000.								
INT CONS	8.361E+00	1.110E+01	4.072E+00	5.732E+00	4.181E+00	5.550E+00	7.525E+01	9.989E+01
INT AGRI	1.001E+01	1.157E+01	4.888E+00	5.833E+00	5.005E+00	5.785E+00	8.981E+01	1.027E+02

Also of interest is the potential thyroid hazard for BWR resins as shown in Table 4.5. BWR ion-exchange resins are estimated to contain a relatively high concentration of ^{129}I. Although several radionuclides contribute to the thyroid exposures, the high contribution from ^{129}I results in a somewhat different pattern of exposure than for whole body and bone. The calculations for both cases ignore the dilution of ^{129}I with stable iodine, which would act to reduce exposures.

A similar situation is shown in Table 4.6 for the BWR combustible trash stream. In waste spectrum 1, no special effort is made to reduce the volume of this waste stream while in waste spectrum 2, this stream is assumed to be compacted. In waste spectra 3 and 4, the stream is assumed to be incinerated and the ashes solidified in a synthetic polymer. Of interest are the effects of increased volume reduction. Even under extreme volume reduction--i.e., incineration--the potential hazard is under 500 mrem after 200 years and only a few millirems after 400 years.

This process may be potentially repeated for the other 34 waste streams. However, it is believed that presenting the results would be excessively voluminous. Table 4.6 was therefore prepared, which is a summary of potential intruder hazard to whole body and bone for 4 groups of waste streams under waste spectrum 2. (Waste spectrum 2 was selected since it represents readily achievable improvements in the form of waste shipped for disposal.) The 4 groups of waste streams are as follows:

- Group 1: LWR process waste streams (resins, filter media, solidified concentrated liquids and filter cartridges).
- Group 2: Trash waste streams for both fuel cycle and nonfuel cycle waste streams.
- Group 3: Other miscellaneous low-activity waste streams.
- Group 4: Miscellaneous "special" or high activity waste streams from both fuel-cycle and nonfuel-cycle waste streams.

As can be seen, exposures for group 1 (which is a volume-weighted average of 7 waste streams) are initially relatively high (e.g., about 5 rems at 100 years) but soon drop to relative low levels (e.g., about 500 mrem at 200 years and only a few mrem at 500 years). The hazard calculated for groups 2 and 3 are even less significant. However, the hazard from the group 4 waste streams (a mixture of 7 individual waste streams) appears to be significant. In addition, the potential hazard for group 4 waste streams does not decay as rapidly as the other group waste streams. For example, the hazard is approximately 10 times higher than group 1 at 100 years and a factor of 10^4 times higher than group 1 at 500 years.

The potential hazard in group 4 is principally contributed by only three waste streams, the total volume of which contributes only 20,200 m^3 out of the 698,000 m^3 disposed of in waste spectrum 2. These are:

Table 4.5 Potential Intruder Exposures to Thyroid for BWR Ion-Exchange Resins

	(mrem)			
	Spectrum 1	Spectrum 2	Spectrum 3	Spectrum 4
YR = 50.				
INT CONS	6.196E+04	3.004E+04	3.098E+04	5.576E+05
ING AGRI	7.345E+04	3.562E+04	3.672E+04	6.610E+05
YR = 100.				
INT CONS	1.930E+04	9.358E+03	9.650E+03	1.737E+05
INT AGRI	2.293E+04	1.113E+04	1.146E+04	2.063E+05
YR = 150.				
INT CONS	6.089E+03	2.953E+03	3.044E+03	5.480E+04
INT AGRI	7.281E+03	3.539E+03	3.641E+03	6.553E+04
YR = 200.				
INT CONS	1.927E+03	9.345E+02	9.633E+02	1.734E+04
INT AGRI	2.352E+03	1.150E+03	1.176E+03	2.117E+04
YR = 300.				
INT CONS	2.022E+02	9.843E+01	1.011E+02	1.820E+03
INT AGRI	3.102E+02	1.595E+02	1.551E+02	2.792E+03
YR = 400.				
INT CONS	3.097E+01	1.542E+01	1.548E+01	2.787E+02
INT AGRI	1.075E+02	6.117E+01	5.374E+01	9.669E+02
YR = 500.				
INT CONS	1.393E+01	7.158E+00	6.965E+00	1.254E+02
INT AGRI	8.730E+01	5.139E+01	4.365E+01	7.853E+02
YR = 1000.				
INT CONS	1.186E+01	6.154E+00	5.930E+00	1.067E+02
INT AGRI	8.483E+01	5.019E+01	4.242E+01	7.632E+02
YR = 2000.				
INT CONS	1.154E+01	5.999E+00	5.771E+00	1.039E+02
INT AGRI	8.444E+01	5.000E+01	4.222E+01	7.597E+02

Table 4.6 Summary of Potential Intruder Exposures to Whole Body and Bone for BWR Combustible Trash

(mrem)

	Spectrum 1		Spectrum 2		Spectrum 3		Spectrum 4	
	Body	Bone	Body	Bone	Body	Bone	Body	Bone
YR = 50.								
INT CONS	2.190E+02	2.193E+02	4.380E+02	4.386E+02	8.760E+03	8.772E+03	8.760E+03	8.772E+03
INT AGRI	2.595E+02	2.601E+02	5.190E+02	5.201E+02	1.038E+04	1.040E+04	1.038E+04	1.040E+04
YR = 100.								
INT CONS	6.760E+01	6.785E+01	1.352E+02	1.357E+02	2.704E+03	2.714E+03	2.704E+03	2.714E+03
INT AGRI	8.008E+01	8.033E+01	1.602E+02	1.607E+02	3.203E+03	3.212E+03	3.203E+03	3.213E+03
YR = 150.								
INT CONS	2.135E+01	2.157E+01	4.269E+01	4.314E+01	8.538E+02	8.628E+02	8.538E+02	8.628E+02
INT AGRI	2.528E+01	2.542E+01	5.056E+01	5.084E+01	1.011E+03	1.017E+03	1.011E+03	1.017E+03
YR = 200.								
INT CONS	6.775E+00	6.978E+00	1.355E+01	1.396E+01	2.710E+02	2.791E+02	2.710E+02	2.791E+02
INT AGRI	8.017E+00	8.120E+00	1.603E+01	1.624E+01	3.207E+02	3.248E+02	3.207E+02	3.248E+02
YR = 300.								
INT CONS	7.335E-01	9.105E-01	1.471E+00	1.821E+00	2.942E+01	3.642E+01	2.942E+01	3.642E+01
INT AGRI	8.632E-01	9.402E-01	1.726E+00	1.880E+00	3.452E+01	3.758E+01	3.452E+01	3.758E+01
YR = 400.								
INT CONS	1.343E-01	2.891E-01	2.685E-01	5.782E-01	5.371E+00	1.156E+01	5.371E+00	1.156E+01
INT AGRI	1.519E-01	2.178E-01	3.039E-01	4.357E-01	6.072E+00	8.687E+00	6.072E+00	8.687E+00
YR = 500.								
INT CONS	7.306E-02	2.125E-01	1.461E-01	4.249E-01	2.922E+00	8.498E+00	2.922E+00	8.498E+00
INT AGRI	8.025E-02	1.389E-01	1.605E-01	2.778E-01	3.205E+00	5.529E+00	3.205E+00	5.529E+00
YR = 1000.								
INT CONS	6.077E-02	1.548E-01	1.215E-01	3.096E-01	2.431E+00	6.192E+00	2.431E+00	6.192E+00
INT AGRI	6.830E-02	1.078E-01	1.366E-01	2.156E-01	2.727E+00	4.287E+00	2.727E+00	4.287E+00
YR = 2000.								
INT CONS	5.564E-02	1.183E-01	1.113E-01	2.366E-01	2.225E+00	4.731E+00	2.225E+00	4.731E+00
INT AGRI	6.401E-02	9.071E-02	1.280E-01	1.814E-01	2.556E+01	3.606E+00	2.556E+00	3.606E+00

Table 4.7 Summary of Potential Intruder Exposures to Whole Body and Bone for Four Groups of Waste Streams Under Waste Spectrum 2

(mrem)

	Group 1		Group 2		Group 3		Group 4	
	Body	Bone	Body	Bone	Body	Bone	Body	Bone
YR = 50.								
INT CONS	1.409E+04	1.412E+04	4.449E+02	4.467E+02	2.572E+01	2.651E+01	6.102E+04	1.312E+05
INT AGRI	1.670E+04	1.675E+04	5.375E+02	5.483E+02	4.938E+01	9.470E+01	9.417E+04	1.146E+05
YR = 100.								
INT CONS	4.347E+03	4.371E+03	1.364E+02	1.377E+02	7.989E+00	8.236E+00	1.746E+04	8.066E+04
INT AGRI	5.150E+03	5.174E+03	1.633E+02	1.688E+02	1.426E+02	2.856E+01	2.022E+04	4.826E+04
YR = 150.								
INT CONS	1.373E+03	1.395E+03	4.312E+01	4.431E+01	2.545E+00	2.635E+00	8.338E+03	6.680E+04
INT AGRI	1.626E+03	1.640E+03	5.162E+01	5.426E+01	4.440E+00	8.976E+00	7.598E+03	3.216E+04
YR = 200.								
INT CONS	4.362E+02	4.562E+02	1.375E+01	1.483E+01	8.330E-01	8.765E-01	5.305E+03	6.020E+04
INT AGRI	5.160E+02	5.264E+02	1.653E+01	1.821E+01	1.476E+00	3.126E+00	3.858E+03	2.622E+04
YR = 300.								
INT CONS	4.790E+01	6.511E+01	1.566E+00	2.507E+00	1.250E-01	1.513E-01	3.744E+03	5.359E+04
INT AGRI	5.595E+01	6.372E+01	2.004E+00	3.219E+00	2.890E+01	8.474E-01	2.165E+03	2.216E+04
YR = 400.								
INT CONS	9.193E+00	2.445E+01	3.476E-01	1.185E+00	5.494E-02	7.970E-02	3.317E+03	4.973E+04
INT AGRI	1.018E+01	1.677E+01	5.549E-01	1.660E+00	1.753E-01	6.365E-01	1.835E+03	2.040E+04
YR = 500.								
INT CONS	5.214E+00	1.897E+01	2.190E-01	9.747E-01	4.799E-02	7.261E-02	3.057E+03	4.691E+04
INT AGRI	5.549E+00	1.137E+01	4.037E-01	1.450E+00	1.633E-01	6.115E-01	1.668E+03	1.919E+04
YR = 1000.								
INT CONS	4.287E+00	1.361E+01	1.773E-01	6.881E-01	4.720E-02	7.168E-02	2.294E+03	3.876E+04
INT AGRI	4.705E+00	8.605E+00	3.576E-01	1.250E+00	1.559E-01	5.781E-01	1.189E+03	1.575E+04
YR = 2000.								
INT CONS	3.859E+00	1.010E+01	1.546E-01	4.945E-01	4.714E-02	7.139E-02	1.749E+03	3.280E+04
INT AGRI	4.373E+00	7.020E+00	3.212E-01	1.067E+00	1.444E-01	5.205E-01	8.495E+02	1.324E+04

- LWR decontamination resins (1.933E+4 m^3)
- Sources (51.51 m^3)
- LWR nonfuel reactor core components (797.5 m^3)

The potential hazard as a function of time for whole body and bone for LWR decontamination resins and sources is given in Tables 4.8 and 4.9, respectively. The potential hazard for seven organs for LWR nonfuel core components is shown in Table 4.10.

There is considerable uncertainty about the actual radionuclide concentrations in these waste streams. For example, the LWR decontamination resin stream is somewhat hypothetical and is based upon an assumption that all LWRs will undergo, in the future, a periodic full-scale decontamination process every 7 years. The purpose of such full-scale primary decontamination operations is to reduce plant personnel exposure by removing crud accumulated on surfaces in contact with the primary coolant. Although full-scale primary coolant decontamination operations have not been routinely performed in the past, NRC has fairly recently (October 1980) published an environmental impact statement regarding such an operation being performed at the Dresden Unit 1 nuclear power station (Ref. 6). Dresden 1 is a 200 MW(e) dual-cycle BWR which, over its 20-year operating life, has built up a thin layer of radioactive oxide deposits (principally Co-60) over the inner surfaces of pipes, valves, pumps, etc. In the decontamination process, a decontamination solution is circulated and flushed through the coolant system, which dissolves the crud deposits. The decontamination solution is then removed from the coolant system and processed through an evaporator. The evaporator bottoms are then solidified in vinyl ester styrene (a synthetic polymer), which are then shipped offsite for disposal. Since the solidified waste will contain a large quantity of chelating agents, the waste will be disposed only at a disposal facility located in an arid environment and segregated from other waste by at least 3 meters of soil (Ref. 6).

Although the Dresden 1 decontamination operation can be considered in some respects a prototype of future full-scale primary coolant decontamination operations at other power plants, it is still difficult to project future volumes and other characteristics of decontamination wastes. There may be a number of possible decontamination processes utilized--e.g., from dilute chemical processes on an annual basis to more concentrated processes at intervals of several years--and the waste streams generated may vary in kind (e.g., resins, solidified liquids) and in volume from operation to operation and plant to plant. Other plant-specific factors which would influence the volumes, radioactivity content, and other characteristics of the wastes generated would include the operating history of the plant (e.g., history of fuel failures), the design of the plant and liquid clean-up and processing systems, the chemistry of the primary coolant, and the length of time between decontamination operations. Institutional matters such as the policies of specific utilities could also be a consideration.

Notwithstanding this uncertainty, the NRC staff believes that wastes generated from routine full-scale decontamination of reactor primary coolant systems should be represented in the low-level waste source data base. For this EIS,

Table 4.8 Summary of Potential Intruder Hazard to Whole Body and Bone for Postulated Future LWR Decontamination Resin Stream

	(mrem)	
	Body	Bone
YR = 50.		
INT CONS	2.805E+04	1.187E+05
ING AGRI	2.927E+04	6.654E+04
YR = 100.		
INT CONS	7.522E+03	8.926E+04
INT AGRI	5.193E+03	3.829E+04
YR = 150.		
INT CONS	6.032E+03	8.170E+04
INT AGRI	3.664E+03	3.411E+04
YR = 200.		
INT CONS	5.356E+03	7.642E+04
INT AGRI	3.072E+03	3.158E+04
YR = 300.		
INT CONS	4.682E+03	6.923E+04
INT AGRI	2.598E+03	2.843E+04
YR = 400.		
INT CONS	4.265E+03	6.438E+04
INT AGRI	2.340E+03	2.637E+04
YR = 500.		
INT CONS	3.943E+03	6.076E+04
INT AGRI	2.142E+03	2.484E+04
YR = 1000.		
INT CONS	2.962E+03	5.026E+04
INT AGRI	1.527E+03	2.041E+04
YR = 2000.		
INT CONS	2.260E+03	4.257E+04
INT AGRI	1.090E+03	1.718E+04

Table 4.9 Summary of Potential Inadvertent Intruder Hazard for Whole Body and Bone for Postulated Sources Stream

	(mrem)	
	Body	Bone
YR = 50.		
INT CONS	1.064E+07	1.074E+07
INT AGRI	1.267E+07	1.276E+07
YR = 100.		
INT CONS	3.358E+06	3.450E+06
INT AGRI	3.983E+06	4.045E+06
YR = 150.		
INT CONS	1.064E+06	1.149E+06
ING AGRI	1.258E+06	1.300E+06
YR = 200.		
INT CONS	3.409E+05	4.195E+05
INT AGRI	3.998E+05	4.337E+05
YR = 300.		
INT CONS	4.036E+04	1.079E+05
INT AGRI	4.382E+04	7.107E+04
YR = 400.		
INT CONS	9.614E+03	6.771E+04
INT AGRI	7.920E+03	3.118E+04
YR = 500.		
INT CONS	5.777E+03	5.573E+04
INT AGRI	3.857E+03	2.384E+04
YR = 1000.		
INT CONS	2.562E+03	2.604E+04
INT AGRI	1.631E+03	1.102E+04
YR = 2000.		
INT CONS	5.661E+02	5.752E+03
INT AGRI	3.604E+02	2.434E+03

Table 4.10 Summary of Potential Inadvertent Intruder Exposures to Seven Organs for LWR Nonfuel Reactor Core Components

(mrem)

	Body	Bone	Liver	Thyroid	Kidney	Lung	GI Tract
YR = 50.							
INT CONS	7.363E+04	7.406E+04	7.365E+04	7.361E+04	7.361E+04	7.367E+04	7.362E+04
INT AGRI	8.733E+04	9.161E+04	8.749E+04	8.718E+04	8.718E+04	8.720E+04	8.725E+04
YR = 100.							
INT CONS	3.587E+02	6.559E+02	3.698E+02	3.485E+02	3.485E+02	3.572E+02	3.524E+02
INT AGRI	5.182E+02	3.460E+03	6.270E+02	4.162E+02	4.162E+02	4.196E+02	4.599E+02
YR = 150.							
INT CONS	2.555E+02	4.595E+02	2.631E+02	2.485E+02	2.485E+02	2.544E+02	2.511E+02
INT AGRI	3.678E+02	2.392E+03	4.427E+02	2.976E+02	2.976E+02	3.000E+02	3.278E+02
YR = 200.							
INT CONS	2.527E+02	3.925E+02	2.580E+02	2.479E+02	2.479E+02	2.520E+02	2.497E+02
INT AGRI	3.453E+02	1.739E+03	3.969E+02	2.970E+02	2.970E+02	2.986E+02	3.177E+02
YR = 300.							
INT CONS	2.494E+02	3.156E+02	2.159E+02	2.471E+02	2.471E+02	2.491E+02	2.480E+02
INT AGRI	3.191E+02	9.841E+02	3.436E+02	2.960E+02	2.960E+02	2.968E+02	3.059E+02
YR = 400.							
INT CONS	2.474E+02	2.788E+02	2.487E+02	2.463E+02	2.463E+02	2.473E+02	2.468E+02
INT AGRI	3.062E+02	6.278E+02	3.181E+02	2.950E+02	2.950E+02	2.954E+02	2.998E+02
YR = 500.							
INT CONS	2.461E+02	2.610E+02	2.467E+02	2.455E+02	2.455E+02	2.460E+02	2.458E+02
INT AGRI	2.996E+02	4.594E+02	3.055E+02	2.940E+02	2.940E+02	2.942E+02	2.964E+02
YR = 1000.							
INT CONS	2.417E+02	2.424E+02	2.418E+02	2.416E+02	2.416E+02	2.417E+02	2.417E+02
INT AGRI	2.899E+02	3.083E+02	2.906E+02	2.892E+02	2.892E+02	2.893E+02	2.895E+02
YR = 2000.							
INT CONS	2.341E+02	2.344E+02	2.341E+02	2.340E+02	2.340E+02	2.341E+02	2.340E+02
INT AGRI	2.804E+02	2.941E+02	2.810E+02	2.799E+02	2.799E+02	2.799E+02	2.801E+02

it is assumed that every operating LWR undergoes a full-scale primary coolant decontamination operation every 7 years using a dilute chemical decontamination process. Generated wastes are represented by spent ion exchange resins containing significant quantities of chelating agents and other decontamination chemicals.

To estimate concentrations, data was used based upon crud scrapings from the internals of a light water reactor. Use of this procedure to estimate radionuclide concentrations in this stream results in estimated transuranic concentrations in considerable excess of 10 nCi/gm. Thus, the waste stream as postulated would not be acceptable for disposal at existing LLW disposal facilities. Use of crud scrapings to estimate concentrations is believed to be conservative and perhaps overconservative, since data from the Dresden 1 decontamination operations indicates that the generated decontamination waste will have transuranic concentrations less than 10 nCi/gm (Ref. 6). Despite this, however, the NRC staff believes that the low Dresden 1 transuranic concentrations may not be indicative of all future large-scale decontamination operations. As discussed above, the characteristics of future decontamination wastes are uncertain and may be a function of a number of plant-specific conditions. Thus, it would appear to be appropriate to determine radionuclide concentrations in future full-scale decontamination waste streams on a plant-specific basis.

Another waste stream for which there is little information at this time is the sources waste stream. This waste stream is a composite of sealed sources, foils, and similar wastes, and in determining the radionuclide concentrations, the higher activity examples were given greatest consideration. As shown in Table 4.9, the calculated hazard is extremely high, which is unrealistic and is a function of the extremely small volume (51.5 m^3) of this waste stream. In reality, the actual potential impacts would be much lower due to the considerable dilution that would occur with the other lower activity waste streams. Given this, however, the table is still useful in that it illustrates the relative contribution of total hazard from different isotopes. Initially, most of the hazard is provided by gamma radiation emitted by Cs-137 (see Appendix D). As the cesium decays away (noted by the characteristic decay by a factor of 10 every 100 years), most of the longer-term hazard is provided by the assumed high concentrations of americium from large americium sources. Currently, disposal of large americium sources is not permitted in existing disposal facilities. NRC has, however, included such sources in the waste spectra to allow an estimate of the possible hazard of their disposal into a near-surface disposal facility.

The third stream--LWR nonfuel reactor core components--is composed of activated metal and the potential hazard is shown on Table 4.10. Since the waste stream is composed of activated metal, most of the hazard is from direct gamma radiation. As can be seen, the estimated hazard is somewhat higher than the group 1 process waste streams but considerably less than the other two streams discussed above.

Given the above analysis, it appears that by controlling the disposal of a few waste streams, potential intruder hazards could be considerably reduced. For example, Table 4.11 shows the potential hazard to whole body and bone from all waste streams assuming that the LWR decontamination stream (high TRU content) and the sources streams (large americium sources) are excluded from near-surface disposal. Comparing Table 4.11 with Tables 4.2 and 4.3, it can be seen that removal of these two streams results in only a slightly smaller hazard over the first few hundred years, which is the time period over which most of the hazard is dominated by direct gamma radiation from the disposed waste. However, the reduction in the potential long-term hazard is significant--i.e., only a few millirem rather than potentially several hundred millirem. Similarly, Table 4.7 is repeated as Table 4.12, except that the 2 waste streams in question are again removed from group 4. As can be seen, removal of these waste streams results in an overall reduction of hazard. The long-term hazard associated with group 4 is reduced by several orders of magnitude.

4.3.4 <u>Waste Form and Packaging</u>

Another way in which potential intruder exposures can be reduced is through improvements in waste form and packaging. These improvements can lead to reduced exposures in two principal ways:

1. The potential for the waste to be dispersed into a form which can be readily inhaled or taken up by plant roots is reduced if the waste is placed into a stable form or package; and

2. The likelihood that the intruder will stay in contact with the waste (e.g., construct in it, grow crops in it) is reduced if the waste is placed into a stable form or package.

4.3.4.1 Effectiveness of Waste Form

If the waste is contacted through inadvertent intrusion, then potential inhalation exposures should be reduced if the waste is in a stable, less dispersible waste form. Similarly, exposure pathways which occur through consumption of food grown in contaminated ground should also be reduced if the waste were in a low leaching form. In order for radionuclides to be taken up by plants, the radionuclides must first be dissolved and leached out of the waste.

Different conclusions regarding the effect of waste form have been reached by other investigators performing analyses regarding work on waste classification. For example, one group of investigators, in a study which followed their work on waste classification, questioned the option of placing the waste into a durable form, and concluded that it may be better to disperse the waste into soil rather than concentrate it into a waste package where it may be encountered by an intruder (Ref. 7). As stated by the authors:

> Packaging waste in durable containers has generally been considered beneficial to waste disposal. This is not always correct, because an effective container prevents the waste from being diluted with the

Table 4.11 Summary of Potential Intruder Exposures to Whole Body and Bone From 34 Waste Streams

(mrem)

	Spectrum 1		Spectrum 2		Spectrum 3		Spectrum 4	
	Body	Bone	Body	Bone	Body	Bone	Body	Bone
YR = 50.								
INT CONS	3.969E+03	3.981E+03	4.889E+03	4.906E+03	8.127E+03	8.151E+03	1.693E+04	1.698E+04
INT AGRI	5.344E+03	5.149E+03	6.720E+03	6.438E+03	1.090E+04	1.052E+04	2.271E+04	2.191E+04
YR = 100.								
INT CONS	1.207E+03	1.214E+03	1.484E+03	1.494E+03	2.473E+03	2.487E+03	5.152E+03	5.181E+03
INT AGRI	1.492E+03	1.563E+03	1.848E+03	1.950E+03	3.054E+03	3.195E+03	6.362E+03	6.655E+03
YR = 150.								
INT CONS	3.812E+02	3.865E+02	4.686E+02	4.764E+02	7.811E+02	7.917E+02	1.627E+03	1.649E+03
INT AGRI	4.623E+02	4.930E+02	5.707E+02	6.151E+02	9.466E+02	1.008E+03	1.972E+03	2.099E+03
YR = 200.								
INT CONS	1.211E+02	1.257E+02	1.490E+02	1.556E+02	2.482E+02	2.573E+02	5.170E+02	5.360E+02
INT AGRI	1.461E+02	1.578E+02	1.803E+02	1.971E+02	2.991E+02	3.221E+02	6.232E+02	6.708E+02
YR = 300.								
INT CONS	1.336E+01	1.716E+01	1.648E+01	2.196E+01	2.733E+01	3.488E+01	5.693E+01	7.267E+01
INT AGRI	1.597E+01	1.919E+01	1.973E+01	2.439E+01	3.258E+01	3.873E+01	6.786E+01	8.056E+01
YR = 400.								
INT CONS	2.624E+00	5.960E+00	3.280E+00	8.096E+00	5.327E+00	1.197E+01	1.110E+01	2.493E+01
INT AGRI	3.061E+00	5.122E+00	3.817E+00	6.793E+00	6.147E+00	9.975E+00	1.279E+01	2.071E+01
YR = 500.								
INT CONS	1.526E+00	4.522E+00	1.925E+00	6.251E+00	3.078E+00	9.041E+00	6.412E+00	1.883E+01
INT AGRI	1.756E+00	3.462E+00	2.205E+00	4.668E+00	3.475E+00	6.598E+00	7.224E+00	1.367E+01
YR = 1000.								
INT CONS	1.290E+00	3.312E+00	1.617E+00	4.536E+00	2.596E+00	6.619E+00	5.407E+00	1.379E+01
INT AGRI	1.521E+00	2.670E+00	1.906E+00	3.566E+00	2.997E+00	5.029E+00	6.230E+00	1.041E+01
YR = 2000.								
INT CONS	1.183E+00	2.537E+00	1.474E+00	3.429E+00	2.379E+00	5.073E+00	4.956E+00	1.057E+01
INT AGRI	1.424E+00	2.265E+00	1.779E+00	2.993E+00	2.807E+00	4.254E+00	5.834E+00	8.799E+00

Table 4.12 Summary of Potential Intruder Exposures to Whole Body and Bone for Four Waste Groups of 34 Waste Streams Under Waste Spectrum 2

(mrem)

	Group 1		Group 2		Group 3		Group 4	
	Body	Bone	Body	Bone	Body	Bone	Body	Bone
YR = 50.								
INT CONS	1.409E+04	1.412E+04	4.449E+02	4.467E+02	2.572E+01	2.651E+01	7.716E+04	7.808E+04
INT AGRI	1.670E+04	1.675E+04	5.375E+02	5.483E+02	4.938E+01	9.470E+01	2.001E+05	1.631E+05
YR = 100.								
INT CONS	4.347E+03	4.371E+03	1.364E+02	1.377E+02	7.989E+00	8.236E+00	2.096E+04	2.125E+04
INT AGRI	5.150E+03	5.174E+03	1.633E+02	1.688E+02	1.426E+01	2.856E+01	3.532E+04	4.592E+04
YR = 150.								
INT CONS	1.373E+03	1.395E+03	4.312E+01	4.431E+01	2.545E+00	2.635E+00	6.619E+03	6.724E+03
INT AGRI	1.626E+03	1.640E+03	5.162E+01	5.426E+01	4.440E+00	8.976E+00	9.630E+03	1.414E+04
YR = 200.								
INT CONS	4.362E+02	4.562E+02	1.375E+01	1.483E+01	8.330E-01	8.765E-01	2.109E+03	2.154E+03
INT AGRI	5.160E+02	5.264E+02	1.653E+01	1.821E+01	1.476E+00	3.126E+00	2.947E+03	4.450E+03
YR = 300.								
INT CONS	4.790E+01	6.511E+01	1.566E+00	2.507E+00	1.250E-01	1.513E-01	2.422E+02	2.564E+02
INT AGRI	5.595E01	6.372E+01	2.004E+00	3.219E+00	2.890E-01	8.474E-01	3.258E+02	5.323E+02
YR = 400.								
INT CONS	9.193E+00	2.445E+01	3.476E-01	1.185E+00	5.494E-02	7.970E-02	5.681E+01	6.404E+01
INT AGRI	1.018E+01	1.677E+01	5.549E-01	1.660E+00	1.753E-01	6.365E-01	7.200E+01	1.276E+02
YR = 500.								
INT CONS	5.214E+00	1.897E+01	2.190E-01	9.747E-01	4.799E-02	7.261E-02	3.823E+01	4.271E+01
INT AGRI	5.549E+00	1.137E+01	4.037E-01	1.450E+00	1.633E-01	6.115E-01	4.654E+01	6.069E+01
YR = 1000.								
INT CONS	4.287E+00	1.361E+01	1.773E-01	6.881E-01	4.720E-02	7.168E-02	3.547E+01	3.700E+01
INT AGRI	4.705E+00	8.605E+00	3.576E-01	1.250E+00	1.559E-01	5.781E-01	4.245E+01	4.562E+01
YR = 2000.								
INT CONS	3.859E+00	1.010E+01	1.546E-01	4.945E-01	4.714E-02	7.139E-02	3.428E+01	3.513E+01
INT AGRI	4.373E+00	7.020E+00	3.212E-01	1.067E+00	1.444E-01	5.205E-01	4.102E+01	4.327E+01

> surrounding soil. If the reclaimer scenarios are limiting, as for Class D and Class E waste [waste determined by the authors to be suitable for disposal by shallow land burial and by a sanitary landfill, respectively (see Ref. 3)] and the container keeps the waste from being diluted, the potential dose rate to the reclaimer can be higher.
>
> If the ground water or well water pathways are most restrictive, then the container or chemical form of the waste can greatly reduce the rate at which the isotopes enter the aquifer.

Other author questioned the practice of using plastic bags to cover pieces of transuranic-contaminated equipment to control the spread of contamination during waste handling and disposal. The author observed an example where waste which had been disposed of 14 years previously at the Savannah River Plant (a humid environment) was exhumed and examined. The waste material which had been disposed in plastic bags was still intact. In some cases the writing on paper within the plastic bags was still legible. The authors were concerned that at some indefinite time in the future, an individual could potentially dig into the disposed waste to retrieve an artifact either for its archeologic value or to make some use out of it. The authors concluded that it may be desirable to place potentially useful items in a degradable wrapping which would be adequate for handling and disposal but would quickly degrade in soil. The wrapped waste material would then tend to degrade, which would reduce its value as a potential artifact. As the authors state (Ref. 5):

> This indicated that the goal of providing improved packages to slow the migration of transuranics from the burial ground may be undesirable. The analyses that we have done indicate that the problem of movement from the area by leaching or erosion is much lower than the problem of artifacts remaining. This has led to the conclusion that degradable packages are of lower potential hazard than packages designed for long-time containment.

These conclusions, however, can be viewed differently. Assuming that a waste form and package is allowed to quickly degrade so that the waste radionuclides are "diluted," then the only way that dilution of the waste could occur is by high ground-water infiltration which would leach the radionuclides out of the waste, dispersing them in the soil. Such an action trades a hypothetical exposure to a few individuals intruding into the disposal facility for a fairly certain increased level of potential exposure to populations through increased potential for ground-water migration. The potential for exposures from one pathway would be increased while theoretically another pathway would be reduced. (As discussed in Chapter 5, this would also lead to increased long-term costs by the site owner for care and maintenance of the closed disposal facility.) Even under very extreme ground-water infiltration and leaching conditions, however, carried out for hundreds of years, almost all of the radionuclides would still be in the immediate disposal facility location. (This would be particularly true for the heavy metals.) Given the decomposition of the waste form and packages that would be allowed to occur, the radionuclides would actually be in a form which could be more readily dispersed into respirable particles or taken up by plant roots. Rather than decreasing potential intruder

exposures, degradable waste packages and forms could increase such exposures, both in the likelihood that intrusion scenarios such as housing construction would occur (see Section 4.3.4.3) and in the impacts that could result if the intrusion scenarios do occur. Furthermore, the potential for ground-water migration would be increased.

In the unlikely event that the facility is intruded into by an artifact hunter or for archeological purposes, improved waste forms and packages would also reduce potential impacts. The less degradation of waste forms that occur, the less exposures would be received by the artifact hunter while searching for the artifact. Assuming for the moment that a potentially valuable artifact was located and some time was subsequently spent polishing the artifact, then the less the artifact was degraded or corroded, the less the likelihood of respirable particles flying off. In addition, less time would be spent polishing the artifact. Even though ancient waste dumps are often inspected by current archeologists to acquire information about past civilizations, such investigation is done because the recordkeeping abilities of past civilizations was frequently poor and there is frequently little other way to acquire such information. The ability for civilization to maintain information has drastically improved and it is unlikely that future archeologists would need to exhume disposed waste to study our civilization. Archeology is a painstaking science and articles are not just dug up. Considerable research is generally performed to relate objects discovered with other records or information regarding the era. Assuming that a potentially valuable artifact is discovered, then some investigation would be required by the artifact hunter to confirm the value. This increases the chances that the potential hazard would be discovered.

The potential for waste form to reduce intruder impacts can also be illustrated numerically. To do so, NRC analyzed two cases: a "waste form credit case" and a "waste form no-credit case."

In the "waste form credit case," the degree to which radionuclides are dispersed from waste or are taken up by plant roots is assumed to be a function of waste form. For example, resins solidified in a synthetic polymer would be expected to be less leachable and less dispersible than dewatered resins. The relative degree to which wastes can be dispersed from waste is given by the following equation:

$$f_w = 10^{(I5-3)} \times 10^{(1-I9)}, \text{ where}$$

f_w is the waste form and package factor for dispersion;

I5 is the dispersibility index; and

I9 is the accessibility index.

The relative degree to which wastes may be taken up by plant roots is given by the following equation:

$f_w = M_o \times 10^{(1-I9)} \times \text{Mult}(I6,I7,I9)$ where,

f_w is the waste form and package factor for exposures through the food pathway;

M_o is the leach fraction of unsolidified wastes; and

Mult (I6,I7,I9) is the reduction due to solidification and the presence or absence of chelating chemicals which is characterized by the leachibility index (I6), chemical content index (I7), and whether waste streams containing chelating or chemical agents have been segregated from other wastes during disposal (the segregation index, IS).

The description of the derivation and use of these equations is given in Appendix G, and they indicate a reduction in dispersion and plant uptake depending upon waste form. It is believed that the above types of relationships assumed are reasonable; however, it is difficult to give precise values to the parameters or to say with certainty that the relationships will hold over long time periods. Nonetheless, they can be used to estimate a level of hazard from potential inadvertent intrusion given credit for a stable, nondispersible, low leaching waste form.

In the waste form no-credit case, which was the case assumed for all the previous analyses in this chapter, no credit is assumed to be taken for waste form in reducing plant uptake and airborne dispersion. Except for activated metals, the waste is assumed to disperse in a similar manner as soil. No credit is given for improvements in waste leaching characteristics to reduce plant uptake or airborne dispersion.

4.3.4.2 Analysis of Impacts

Tables 4.13 and 4.14 present a summary of potential inadvertent intruder exposures to whole body and bone as a function of time and waste spectrum, assuming that all 36 waste streams are uniformly mixed together and randomly disposed within the reference disposal facility trenches. Table 4.13 presents the "credit case" and Table 4.14 presents the "no-credit case." The time periods indicate the active institutional control period following the termination of the disposal facility license, which for this analysis is assumed to immediately follow a 2-year closure period.

The potential hazards (in mrem/yr) shown are summed over all 23 radionuclides considered in the analysis and volume averaged over all 36 waste streams, and are again shown for the two intruder scenarios--i.e., the "intruder-construction" scenario and the "intruder-agriculture" scenario. These potential hazard levels are calculated based upon a mixture of all waste streams having a range of activities. No cost or other impact data was calculated for this part of the analysis due to the narrow range of the question being addressed and the number of alternatives considered.

As shown in Table 4.13 for the credit case, the potential exposures for all four spectra drop off as a function of time due to decay of the radioisotopes

Table 4.13 Summary of Potential Intruder Exposure to Whole Body and Bone From 36 Waste Streams (Credit Case)

(mrem)

	Spectrum 1		Spectrum 2		Spectrum 3		Spectrum 4	
	Body	Bone	Body	Bone	Body	Bone	Body	Bone
YR = 50.*								
INT CONS**	4.875E+03	4.880E+03	6.160E+03	6.163E+03	1.010E+04	1.010E+04	2.099E+04	2.099E+04
INT AGRI	6.335E+03	5.914E+03	8.070E+03	7.375E+03	1.305E+04	1.205E+04	2.711E+04	2.504E+04
YR = 100.								
INT CONS	1.408E+03	1.412E+03	1.763E+03	1.765E+03	2.921E+03	2.924E+03	6.070E+03	6.077E+03
INT AGRI	1.708E+03	1.711E+03	2.139E+03	2.114E+03	3.529E+03	3.489E+03	7.333E+03	7.251E+03
YR = 150.								
INT CONS	4.585E+02	4.621E+02	5.766E+02	5.788E+02	9,505E+02	9.535E+02	6.070E+03	6.077E+03
INT AGRI	5.476E+02	5.581E+02	6.872E+02	6.931E+02	1.131E+03	1.137E+03	2.350E+03	2.363E+03
YR = 200.								
INT CONS	1.588E+02	1.621E+02	2.019E+02	2.039E+02	3.283E+02	3.311E+02	6.823E+02	6.881E+02
INT AGRI	1.889E+02	1.944E+02	2.398E+02	2.441E+02	3.895E+02	3.945E+02	8.095E+02	8.198E+02
YR = 300.								
INT CONS	3.282E+01	3.575E+01	4.411E+01	4.597E+01	6.699E+01	6.954E+01	1.392E+02	1.445E+02
INT AGRI	3.892E+01	4.136E+01	5.234E+01	5.455E+01	7.933E+01	8.181E+01	1.649E+02	1.700E+02
YR = 400.								
INT CONS	1.855E+01	2.120E+01	2.593E+01	2.766E+01	3.749E+01	3.986E+01	7.790E+01	8.284E+01
INT AGRI	2.196E+01	2.375E+01	3.077E+01	3.239E+01	4.435E+01	4.605E+01	9.216E+01	9.570E+01
YR = 500.								
INT CONS	1.562E+01	1.805E+01	2.196E+01	2.360E+01	3.150E+01	3.374E+01	6.545E+01	7.011E+01
INT AGRI	1.848E+01	1.999E+01	2.606E+01	2.742E+01	3.725E+01	3.860E+01	7.740E+01	8.021E+01
YR = 1000.								
INT CONS	9.865E+00	1.169E+01	1.381E+01	1.516E+01	1.990E+01	2.176E+01	4.135E+01	4.523E+01
INT AGRI	1.169E+01	1.278E+01	1.640E+01	1.741E+01	2.352E+01	2.444E+01	4.887E+01	5.078E+01
YR = 2000.								
INT CONS	5.77E+00	7.275E+00	8.139E+00	9.285E+00	1.186E+01	1.345E+01	2.465E+01	2.795E+01
INT AGRI	6.982E+00	7.840E+00	9.691E+00	1.054E+01	1.401E+01	1.477E+01	2.911E+01	3.068E+01

*"YR = " means number of years following termination of the disposal facility license.

**"INT-CONS" means intruder-construction scenario.
"INT-AGRI" means intruder-agriculture scenario.

Table 4.14 Summary of Potential Intruder Exposures to Whole Body and Bone From 36 Waste Streams (No-Credit Case)

(mrem)

	Spectrum 1		Spectrum 2		Spectrum 3		Spectrum 4	
	Body	Bone	Body	Bone	Body	Bone	Body	Bone
YR = 50.*								
INT CONS**	4.983E+03	6.753E+03	6.316E+03	8.849E+03	1.032E+04	1.390+04	2.144E+04	2.889E+04
INT AGRI	6.461E+03	6.995E+03	8.280E+03	9.044E+03	1.335E+04	1.443E+04	2.774E+04	3.000E+04
YR = 100								
INT CONS	1.502E+03	3.095E+03	1.899E+03	4.179E+03	3.113E+03	6.340E+03	6.469E+03	1.317E+04
INT AGRI	1.769E+03	4.482E+03	2.235E+03	3.255E+03	3.667E+03	5.111E+03	7.619E+03	1.062E+04
YR = 150.								
INT CONS	5.454E+02	2.019E+03	7.012E+02	2.811E+03	1.127E+03	4.111E+03	2.342E+03	8.544E+03
INT AGRI	5.891E+02	1.210E+03	7.492E+02	1.639E+03	1.219E+03	2.478E+03	2.534E+03	5.149E+03
YR = 200.								
INT CONS	2.400E+02	1.623E+02	3.183E+02	2.299E+03	4.931E+02	3.295E+03	1.025E+03	6.847E+03
INT AGRI	2.233E+02	7.881E+02	2.898E+02	1.098E+02	4.606E+02	1.604E+03	9.571E+02	3.334E+03
YR = 300.								
INT CONS	1.058E+02	1.362E+03	1.487E+02	1.947E+03	2.150E+02	2.759E+03	4.467E+02	5.733E+03
INT AGRI	6.818E+01	5.725E+02	9.437E+01	8.163E+02	1.389E+02	1.160E+03	2.886E+02	2.411E+03
YR = 400.								
INT CONS	8.558E+01	1.255E+03	1.220E+02	1.796E+03	1.735E+02	2.542E+03	3.604E+02	5.282E+03
INT AGRI	4.869E+01	5.168E+02	6.911E+01	7.392E+02	9.867E+01	1.046E+03	2.050E+02	2.175E+03
YR = 500.								
INT CONS	7.808E+01	1.183E+03	1.115E+02	1.693E+03	1.582E+02	2.396E+03	3.287E+02	4.978E+03
INT AGRI	4.336E+01	4.851E+02	6.175E+01	6.942E+02	8.781E+01	9.823E+02	1.825E+02	2.041E+03
YR = 1000.								
INT CONS	5.869E+01	9.769E+02	8.378E+01	1.398E+03	1.189E+02	1.979E+03	2.471E+02	4.112E+03
INT AGRI	3.112E+01	3.980E+02	4.427E+01	5.694E+02	6.301E+01	8.058E+02	1.309E+02	1.674E+03
YR = 2000.								
INT CONS	4.491E+01	8.264E+02	6.407E+01	1.183E+03	9.100E+01	1.674E+03	1.891E+02	3.478E+03
INT AGRI	2.251E+01	3.347E+02	3.195E+01	4.788E+02	4.556E+02	6.776E+02	9.466E+01	1.408E+03

*"YR =" means number of years following termination of the disposal facility license.

**"INT-CONS" means intruder-construction scenario.
"INT AGRI" means intruder-agriculture scenario.

within the waste. For example, intruder-agriculture bone doses range across the 4 spectra from about 1.7 to 7.3 rems at 100 years but fall to a range of only 20 to 80 millirems at 500 years. In only 400 years, potential exposure levels drop by 2 orders of magnitude. Thereafter, the rate that potential exposure levels drop is much less significant--e.g., about a factor of two from 500 years to 1000 years and another factor of about two from 1000 years to 2000 years.

In addition, it may be observed that potential exposures generally increase from waste spectrum 1 to waste spectrum 4. For each successive waste spectra, a number of the waste streams are subjected to more extensive volume reduction techniques and increasingly improved waste solidification techniques are employed. For example, in waste spectrum 1 no special effort is made to compact trash. However, combustible trash is compacted in waste spectrum 2 and incinerated in waste spectra 3 and 4. As another example, ion exchange resins are assumed to be dewatered in waste spectrum 1, solidified in waste spectra 2 and 3, and calcined and solidified in waste spectrum 4. The increased use of volume reduction techniques on the waste streams results in an overall increase in the concentration of radionuclides in the disposal facility, leading to higher potential exposures. However, since it is not practical to subject all streams to extensive volume reduction, the total potential exposures only rises by a factor of four from spectrum 1 to spectrum 4. (Even under extensive volume reduction assumptions there are still a number of low activity waste streams which "dilute" the higher activity waste streams.)

The improved waste forms assumed from one spectrum to the next tend to help mitigate the effects of the increased radionuclide concentrations. In the no-credit case, the approximate factor of four difference is still observed in potential inadvertent intruder exposures between spectrum 1 and spectrum 4. However, the level of exposures for all four spectra is higher for the no-credit case than for the credit case. The rate at which potential exposures drop is also much less for the no-credit case than for the credit case. For example, the potential intruder-construction exposures at 500 years are about two orders of magnitude higher in Table 4.14 than in Table 4.13. This is due to the fact that initially, most of the potential exposures are from direct gamma radiation from such isotopes as Cs-137 or Co-60. Except for some additional self-shielding achieved by solidification in cement and the somewhat decreased radionuclide concentrations resulting from solidification, improvements in waste form have little effect on reducing the direct gamma radiation component of the calculated hazard. However, most of these potential gamma exposures would be caused by relatively short-lived isotopes, and as shown in Table 4.13, these decay after a few hundred years to relatively low levels.

As the shorter-lived gamma-emitting isotopes decay away, the most significant exposures are caused by longer-lived isotopes which generally contribute to the exposures through inhalation and food pathways. (An exception is Nb-94, which is a long-lived gamma-emitting isotope.) For example, exposures from I-129 or Tc-99 would be generally contributed through food pathways while exposures from transuranics would be generally contributed through inhalation pathways. The potential exposures from Sr-90, which is relatively short-lived (28-year half-life), would also be mainly contributed by the food pathway.

As a further illustration, Tables 4.15 and 4.16 are included which provide waste form credit example impacts for BWR ion exchange resins. Table 4.15 illustrates exposures to whole body and bone while Table 4.16 illustrates exposures to thyroid. Tables 4.15 and 4.16 may be compared against the respective waste form no-credit cases in Tables 4.4 and 4.5. Comparing Table 4.4 with Table 4.15, it appears that although some reduction in exposures for the waste form credit case are evident, the reduction is not particularly high. This is because exposures to whole body and bone are mainly dominated by direct gamma radiation, and the reduction in dispersibility and plant uptake illustrated by the waste form credit case (Table 4.15) has no effect on the radiation levels. Taking credit for waste form has more effect on potential exposures to the thyroid, since much of the thyroid exposure is due to ingestion of I-129 and reduced leaching would result in reduced uptake by plants. For waste spectrum 3, for example, calculated thyroid exposures after 400 years are reduced from the no-credit case by a factor of about 6.

Thus, the credit given to the waste form in reducing dispersion, inhalation, and plant uptake would appear to result in less significant reduction in impacts during the first few 100 years, but lead to reduced impacts over the next several hundred years. During the first few hundred years, the exposures are predominantly due to direct gamma radiation exposure from shorter-lived gamma-emitting nuclides. During the next few 100 years, the shorter-lived nuclides decay, and exposures are principally due to inhalation and ingestion of the longer-lived radionuclides. The actual values of the results are recognized to be uncertain, but do indicate that improved waste forms and packaging would help to reduce potential intruder exposures.

Before analyzing the cost and benefits of improved stable waste forms in detail, the need for placing wastes into stable waste forms and the long-term effectiveness of stable waste forms should first be evaluated. The need for placing wastes into stable forms is reviewed in the next subsection which addresses the second aspect of improved waste forms--i.e., the reduction in the likelihood of inadvertent intrusion.

4.3.4.3 Reduction in the Likelihood of Inadvertent Intrusion

The two intruder scenarios analyzed both contain one very large assumption--that the soil/waste mixture in which construction or agriculture takes place is more or less indistinguishable from dirt. That is, the waste has decomposed to the point that the intruder does not know he is contacting waste. This assumption is necessary since without it, the scenarios could not happen. Wastes currently being sent to disposal facilities cover a wide variety of forms and contained activities. About 60 percent of the volume of the waste in waste spectrum 1 that is assumed to be disposed in the reference disposal facility consists of miscellaneous trash which is relatively unstable in that it decomposes, degrades, and compresses rapidly. It is conceivable that after several hundred years, such wastes streams would be decomposed to the point where construction or agricultrual activities could take place without a potential inadvertent intruder realizing that something was wrong (i.e., that he was digging into something other than soil). In addition, such waste streams are unstable and their decomposition can lead to slumping and subsidence of disposal cell covers

Table 4.15 Potential Intruder Exposures to Whole Body and Bone for BWR Ion-Exchange Resins (Credit Case)

(mrem)

	Spectrum 1		Spectrum 2		Spectrum 3		Spectrum 4	
	Body	Bone	Body	Bone	Body	Bone	Body	Bone
YR = 50.								
REC CONS	6.196E+04	6.196E+04	3.004E+04	3.004E+04	3.098E+04	3.098E+04	5.576E+05	5.576E+05
REC AGRI	7.341E+04	7.354E+04	3.558E+04	3.560E+04	3.669E+04	3.669E+04	6.603E+05	6.604E+05
YR = 100.								
REC CONS	1.930E+04	1.930E+04	9.356E+03	9.356E+03	9.648E+03	9.648E+03	1.737E+05	1.737E+05
REC AGRI	2.286E+04	2.290E+04	1.108E+04	1.109E+04	1.143E+04	1.143E+04	2.057E+05	2.057E+05
YR = 150.								
REC CONS	6.085E+03	6.086E+03	2.951E+03	2.951E+03	3.043E+03	3.043E+03	5.477E+04	5.477E+04
REC AGRI	7.210E+03	7.223E+03	3.495E+03	3.497E+03	3.603E+03	3.604E+03	6.486E+04	6.487E+04
YR = 200.								
REC CONS	1.923E+03	1.923E+03	9.325E+02	9.326E+02	9.617E+02	9.617E+02	1.731E+04	1.731E+04
REC AGRI	2.279E+03	2.284E+03	1.104E+03	1.105E+03	1.139E+03	1.139E+03	2.050E+04	2.050E+04
YR = 300.								
REC CONS	1.989E+02	1.989E+02	9.642E+01	9.646E+01	9.943E+01	9.943E+01	1.790E+03	1.790E+03
REC AGRI	2.358E+02	2.373E+02	1.142E+02	1.145E+02	1.178E+02	1.179E+02	2.120E+03	2.120E+03
YR = 400.								
REC CONS	2.764E+01	2.770E+01	1.340E+01	1.344E+01	1.382E+01	1.382E+01	2.487E+02	2.488E+02
REC AGRI	3.299E+01	3.389E+01	1.591E+01	1.606E+01	1.637E+01	1.640E+01	2.947E+02	2.951E+02
YR = 500.								
REC CONS	1.060E+01	1.066E+01	5.142E+00	5.176E+00	5.300E+00	5.303E+00	9.540E+01	9.545E+01
REC AGRI	1.280E+01	1.353E+01	6.125E+00	6.245E+00	6.284E+00	6.307E+00	1.131E+02	1.134E+02
YR = 1000.								
REC CONS	8.532E+00	8.571E+00	4.137E+00	4.161E+00	4.265E+00	4.267E+00	7.667E+01	7.680E+01
REC AGRI	1.034E+01	1.089E+01	4.934E+00	5.025E+00	5.058E+00	5.075E+00	9.102E+01	9.126E+01
YR = 2000.								
REC CONS	8.213E+00	8.240E+00	3.982E+00	3.999E+00	4.106E+00	4.107E+00	7.390E+01	7.393E+01
REC AGRI	9.845E+00	1.042E+01	4.748E+00	4.826E+00	4.869E+00	4.884E+00	8.762E+01	8.782E+01

Table 4.16 Potential Intruder Exposures to Thyroid for BWR Ion Exchange Resins (Credit Case)

	(mrem)			
	Spectrum 1	Spectrum 2	Spectrum 3	Spectrum 4
YR = 50.				
INT CONS	6.196E+04	3.004E+04	3.098E+04	5.576E+05
ING AGRI	7.344E+04	3.558E+04	3.669E+04	6.604E+05
YR = 100.				
INT CONS	1.930E+04	9.356E+03	9.648E+03	1.737E+05
INT AGRI	2.292E+04	1.109E+04	1.143E+04	2.057E+05
YR = 150.				
INT CONS	6.085E+03	2.951E+03	3.043E+03	5.477E+04
INT AGRI	7.276E+03	3.505E+03	3.605E+03	6.490E+04
YR = 200.				
INT CONS	1.923E+03	9.325E+02	9.617E+02	1.731E+04
INT AGRI	2.347E+03	1.115E+03	1.141E+03	2.054E+04
YR = 300.				
INT CONS	1.989E+02	9.643E+01	9.943E+01	1.790E+03
INT AGRI	3.050E+02	1.247E+02	1.199E+02	2.158E+03
YR = 400.				
INT CONS	2.767E+01	1.342E+01	1.382E+01	2.488E+02
INT AGRI	1.022E+02	2.642E+01	1.854E+01	3.336E+02
YR = 500.				
INT CONS	1.063E+01	5.160E+00	5.302E+00	9.543E+01
INT AGRI	8.203E+01	1.664E+01	8.449E+00	1.521E+02
YR = 1000.				
INT CONS	8.563E+00	4.156E+00	4.266E+00	7.680E+01
INT AGRI	7.957E+01	1.545E+01	7.222E+00	1.300E+02
YR = 2000.				
INT CONS	8.245E+00	4.001E+00	4.107E+00	7.393E+01
INT AGRI	7.918E+01	1.526E+01	7.033E+00	1.266E+02

at the disposal facility, increasing rainfall percolation into the disposal facility, and further accelerating waste decomposition.

Other wastes, however, are composed of more stable material such as liquids solidified into concrete. If such wastes are indiscriminately mixed with compressible wastes, then it is conceivably possible that construction and agriculture activities could take place without the inadvertent intruder realizing that something was wrong. Such stable waste streams may be sufficiently dispersed through the waste that the presence of an odd lump or two would be ignored. In addition, a higher level of decomposition of the stable waste would be expected due to disposal of the stable waste with the unstable waste.

If, on the other hand, the stable wastes were segregated from the easily degradable wastes, then the potential for degradation of the stable waste would be greatly decreased. Even after several hundred years, the waste mass should still be clearly recognizable as something other than ordinary dirt. It is not credible to suppose that an individual would attempt to construct a house on or grow crops in a location characterized by large stacked metal cylinders filled with concrete. For such cases, exposures would be confined to those received during discovery of the disposed waste. Upon discovery, it is reasonable to expect that the intruder would cease operations while the matter would be investigated. As discussed below under institutional controls (Section 4.3.8), all knowledge about a disposal facility should not be lost and information about the facility would be assessed in determining a proper course of action with respect to the inadvertent intruder. If the individual chose to ignore information about the facility, the event would no longer be considered inadvertent intrusion.

Potential inadvertent intruder hazards were calculated for the base case based upon an assumption that all waste streams are randomly mixed together during disposal. Due to the slumping, subsidence, and higher infiltration that would be associated with this disposal practice, rapid waste degradation could occur. As just discussed, however, if the wastes were placed into a stable form or package and were also segregated and disposed of in separate disposal cells so that waste degradation would be minimized, then the likelihood of inadvertent intrusion would be greatly reduced. It is not credible to suppose that such activities as housing construction or gardening could take place under these conditions since the inadvertent intruder would contact hunks of waste and realize that something is wrong. Potential exposures would be limited to those received during discovery of the waste. As an illustration, Table 4.17 may be compared with Table 4.18. Table 4.17 was prepared by removing the decontamination resin and sources waste streams (L-DECONRS and N-SOURCES) and dividing the remaining 34 streams into two groups: a "high activity" group and a "low activity" group. The high activity group is composed of LWR process wastes (group 1), PWR and BWR noncompactible trash, and the remaining 5 waste streams in group 4. Waste spectrum 2 is assumed, for which all of the waste streams in the high activity group have been placed into a stable form which will resist rapid decomposition. The low activity group is composed of the

Table 4.17 Potential Hazard to Whole Body and Bone for Two Groups Without Segregation for Waste Spectrum 2

	Waste Form Credit Case				Waste Form No-Credit Case			
	High Activity Group		Low Activity Group		High Activity Group		Low Activity Group	
	Body	Bone	Body	Bone	Body	Bone	Body	Bone
YR = 50.								
INT CONS	1.142E+04	1.142E+04	9.824E+01	9.862E+01	1.143E+04	1.147E+04	9.833E+01	9.930E+01
INT AGRI	1.537E+04	1.363E+04	1.322E+02	1.576E+02	1.571E+04	1.501E+04	1.326E+02	1.586E+02
YR = 100.								
INT CONS	3.464E+03	3.464E+03	2.989E+01	3.004E+01	3.467E+03	3.491E+03	2.994E+01	3.050E+01
INT AGRI	4.219E+03	4.138E+03	3.879E+01	4.815E+01	4.317E+03	4.546E+03	3.887E+01	4.858E+01
YR = 150.								
INT CONS	1.094E+03	1.094E+03	9.456E+00	9.530E+00	1.095E+03	1.113E+03	9.485E+00	9.912E+00
INT AGRI	1.304E+03	1.309E+03	1.224E+01	1.565E+01	1.333E+03	1.433E+03	1.227E+01	1.589E+01
YR = 200.								
INT CONS	3.470E+02	3.471E+02	3.020E+00	3.072E+00	3.481E+02	3.632E+02	3.043E+00	3.412E+00
INT AGRI	4.120E+02	4.172E+02	4.011E+00	5.596E+00	4.208E+02	4.582E+02	4.029E+00	5.774E+00
YR = 300.								
INT CONS	3.763E+01	3.775E+01	3.526E-01	3.935E-01	3.847E+01	5.100E+01	3.717E-01	6.849E-01
INT AGRI	4.470E+01	4.669E+01	6.289E-01	1.500E+00	4.578E+01	5.544E+01	6.410E-01	1.640E+00
YR = 400.								
INT CONS	6.894E+00	6.998E+00	8.690E-02	1.238E-01	7.614E+00	1.862E+01	1.037E-01	3.826E-01
INT AGRI	8.216E+00	9.161E+00	2.932E-01	1.086E+00	8.611E+00	1.441E+01	3.039E-01	1.210E+00
YR = 500.								
INT CONS	3.810E+00	3.904E+00	5.958E-02	9.376E-02	4.450E+00	1.434E+01	7.455E-02	3.268E-01
INT AGRI	4.546E+00	5.048E+00	2.570E-01	1.030E+00	4.850E+00	9.478E+00	2.669E-01	1.143E+00
YR = 1000.								
INT CONS	3.336E+00	3.400E+00	5.302E-02	7.902E-02	3.740E+00	1.041E+01	6.247E-02	2.333E-01
INT AGRI	3.973E+00	4.084E+00	2.384E-01	9.597E-01	4.172E+00	7.013E+00	2.458E-01	1.040E+01
YR = 2000.								
INT CON[illegible]	3.171E+00	3.213E+00	4.988E-02	7.011E[illegible]	3.411E+00	7.879E+00	5.543E-02	1.692E-0[illegible]
INT AG[illegible]	3.776E+00	3.861E+00	2.149E-01	8.531E[illegible]	3.907E+00	5.838E+00	2.204E-01	9.092E-01

remaining 20 waste streams, including the remaining trash streams and the streams composing group 3. The low activity stream is composed of compressible waste forms which easily degrade and can lead to trench subsidence. Table 4.18 shows the potential hazard of the same high activity waste assuming that it is disposed of in a segregated manner from the low activity group. In this case, the intruder-agriculture scenario does not occur and the hazard is calculated based upon a small number of hours during which the inadvertent intruder is exposed through the assumed discovery scenario. Comparing Table 4.17 with Table 4.18, the difference in potential impacts is striking.

Table 4.18 Potential Hazard to Whole Body and Bone for High Activity Group with Segregation (Waste Spectrum 2)

	Waste Form Credit		Waste Form No-Credit	
Year	Body	Bone	Body	Bone
50	1.37E+2	1.37E+2	1.37E+2	1.38E+2
100	4.16E+1	4.16E+1	4.16E+1	4.19E+1
150	1.31E+1	1.31E+1	1.31E+1	1.34E+1
200	4.16E+0	4.17E+0	4.18E+0	4.36E+0
300	4.52E-1	4.53E-1	4.62E-1	6.12E-1
400	8.27E-2	8.40E-2	9.14E-2	2.23E-1
500	4.57E-2	4.68E-2	5.34E-2	1.72E-1
1000	4.00E-2	4.08E-2	4.49E-2	1.25E-1
2000	3.81E-2	3.86E-2	4.09E-2	9.45E-2

The costs and impacts of placing the higher activity wastes into a stable form and disposing of them in separate segregated disposal cells is analyzed in detail in Chapter 5 as well as other alternatives evaluated by NRC to achieve long-term stability. Rather than repeating the analysis here, the reader is referred to Chapter 5.

4.3.4.4 Effectiveness of Stable Waste Form

One last issue remains--i.e., how long is it necessary to rely on the stable waste form?

If the disposal cell is stabilized so that minimum infiltration is introduced to the disposal cell, then the waste form should be effective against intrusion for several hundred years. It is not reasonable, however, to expect this to be the case indefinitely. From Table 4.18 one can see that after several hundred years (i.e., on the order of 500 years), most of the shorter-lived radionuclides will have decayed away, leaving the longer-lived radionuclides. The reduction in hazard after 500 years takes place at a much slower rate. It would appear, then, that for most wastes, a limit of 500 years would appear to be the maximum reasonable upper bound. Attempting to reduce intruder impacts through waste form beyond 500 years would for most wastes really not accomplish much in the way of additional protection. In addition, the period of time upon which institutional controls are relied upon will also effect the long-term stability of waste. After institutional control ceases a higher rate of infiltration into disposal cells could occur leading to an increased rate of waste decomposition.

4.3.5 Engineered and Natural "Intruder Barriers" Created Through Facility Design and Operations

Another method by which the hazard to a potential intruder may be reduced is to dispose of the waste in a manner that would make it more difficult for a potential intruder to contact the waste--that is, by placing one or more natural or engineered barriers between the waste and the intruder. The majority of the waste streams that could require disposal by methods that provide protection against inadvertent intrusion would probably also be characterized by high surface radiation levels. Some wastes having high surface radiation levels may be dominated by short-lived isotopes, and therefore may not be of significant concern to a potential future inadvertent intruder. However, the temporarily high radiation levels associated with such wastes would still require additional care during waste handling and disposal operations. It is useful, therefore, to consider a number of potential waste disposal concepts which may offer increased protection against the actions of a potential inadvertent intruder, while at the same time offer increased worker radiation protection during waste handling and disposal operations.

Typically, only a small fraction (about 10%) of the packages received at commercial radioactive waste disposal facilities would be characterized by elevated exposure rates (e.g., greater than 5 R/hr). These wastes pose some restrictions on operations at disposal facilities. At the present time, most high exposure rate ("hot") waste is dealt with on a case-by-case basis. For example, optimal locations for shielding in trenches are often reserved for high exposure rate waste packages. Optimal locations in trenches can include corner locations and positions between waste packages having low activity levels. Additionally, rapid partial backfilling of high exposure rate packages may be employed to reduce radiation levels to acceptable working levels.

Special "hot" waste disposal cells have been employed from time to time at some of the commercial disposal facilities, as well as at some of the U.S. Department of Energy radioactive waste disposal facilities. The types of disposal cells that have been employed for disposal of high exposure rate waste packages have included slit trenches, caissons, reinforced concrete

culvert pipes, concrete walled trenches, auger holes, and toner tubes (a specific type of caisson with a basket funnel for introducing waste packages). These disposal cells serve to provide shielding protection from the high radiation fields associated with hot waste packages.

NRC analyzed a number of such potential barriers to an intruder and these are described in detail in Appendix F. The barriers considered and additional costs are shown in Table 4.19. These costs are for facility design and operation and do not include costs for long-term care. In general, the barriers can be grouped into three major categories as follows:

Table 4.19 Summary of Incremental Barrier Costs For Facility Design and Operation

	Additional Disposal Costs		
Type of Barrier	$/m^3$	$/ft^3$	Note
No barrier	0	0	*
Thicker cap - 3m of soil	1.59	0.05	*
Thicker cap - 3m of compacted clay	10.89	0.31	*
Layered waste disposal	37.73	1.07	**
Slit trench (10% of waste)	91.49	2.59	**
Caisson disposal (10% of waste)	216.45	6.13	**
Walled trench (10% of waste)	256.09	7.25	**
Walled Trench (100% of waste)	160.99	4.56	*
Grouting--cement†	60.46	1.71	*
Grouting--low-strength cement†	46.86	1.33	*
Engineered intruder barrier	59.17	1.68	*
Intermediate depth burial	53-159	1.50-4.50	*
Mined cavity	327-654	9.26-18.52	*
Ocean disposal	710-2200	20.11-62.31	*
Space disposal	2E+6	56,600	*

*Unit costs based upon 1,000,000 m^3 of waste disposed.

**Unit costs based upon volume of waste disposed by the disposal method indicated. For this table, the costs are based upon a volume of about 100,000 m^3.

†Unit costs include additional costs for stacked waste emplacement.

1. Engineered barriers including caisson disposal, walled trenches, grouting, and a special "engineered intruder barrier"; and

2. Depth of disposal including thicker trench caps, layered waste disposal, and slit trenches;

3. Other methods of disposal including intermediate depth burial, mined cavities, ocean disposal, and space disposal.

An important consideration for these and other forms of intruder barriers is whether the barriers are needed. As discussed previously, most waste streams contain relatively low levels of activity while some contain relatively high levels of activity. It would not appear to be justified to require that all waste streams would require disposal using a barrier to an intruder. For most waste streams, the potential hazard falls off rapidly with time, e.g., to levels on the order of a few millirems or less after a few hundred years. Thus, the use of such barriers would only be required for the higher activity waste streams.

4.3.5.1 Engineered Barriers

The engineered barriers analyzed included the use of caissons, walled trenches, grouting, and the use of a specially engineered intruder barrier. Caissons and walled trenches are examples of the use of "engineered structures" for waste disposal. Other possible engineered structure designs have been examined elsewhere (Ref. 8).

Each engineered barrier is described below. In general, the engineered barriers can provide an effective deterrent to an inadvertent intruder, but at relatively high cost.

Caisson Disposal

To represent the estimated costs and anticipated benefits of use of caissons, tubes, and reinforced concrete pipes for disposal of high activity waste, an example case employing reinforced concrete pipes is evaluated. In the illustrative example presented in Appendix F, each such "hot" waste disposal cell is assumed to consist of a 30-in (0.6 m) inside diameter reinforced concrete culvert pipe which is 24 ft (7.3 m) in length. These culvert pipes are inserted vertically into a slit trench which is 15 m (50 ft) in length, 1.5 m (5 ft) in width, and 8 m (26 ft) in depth.

Each slit trench can accommodate 16 of the reinforced concrete culvert pipes, which can accommodate either 55- or 83-gallon drums. Larger diameter pipes would be used for larger waste packages. As a result of the lower potential for slope failure resulting from the lateral structural support provided by the culvert pipes and the shielding provided by the concrete, the inter-trench spacing can be reduced. Therefore, each slit trench is assumed to be separated from adjacent trenches by a minimum of 1 m (3.3 ft). This results in an overall land use efficiency which is about 60 to 65% of the efficiency attained for the reference trenches (180 m x 30 m x 8 m) described in Appendix E.

In the example, costs are estimated for disposal of 10% of the waste received at the disposal facility being disposed through caisson disposal. The estimated cost differential for this option is about $216/m^3$ ($6.13/ft^3$). These costs were calculated assuming that no shoring was used to construct the caisson trenches. If such shoring were required, unit differential costs would be higher. The reduction in occupational dose afforded by this option is probably similar to that estimated for the slit trench case described below (10 to 20%).

Concrete-Walled Trench Disposal

A second type of "hot waste" disposal cell which has been employed for selected wastes in foreign countries (e.g., Chalk River, Canada) is the concrete-walled trench. For illustrative purposes, a concrete-walled trench is assumed to be constructed of reinforced concrete and to have inside dimensions of 12 m length, 3 m width, and 7 m depth. The wall thickness of the walled trench is assumed to be 0.3 m (1 ft). The dimensions of these walled trenches can be increased to be able to handle larger-sized waste packages. The walled trenches described here are capable of handling 55- and 83-gallon drums, large wooden boxes, and steel liners. All void spaces between emplaced waste packages may be filled with earth or, for increased stability and intruder protection, by a controlled density fill such as concrete or grout. Filled trenches are covered by a 1 m thick concrete cap followed by a layer of overburden graded for drainage.

The spacing between walled trenches is assumed to be a minimum of 3 m as a result of the requirements for concrete forming work. Due to the larger spacing required for this type of disposal cell and the volume lost by the wall displacement, the land use efficiency disposal cell is calculated to be less than 25% of that for the reference trench.

Differential costs are estimated for (1) an example in which 10% of the waste volume delivered to the disposal facility is assumed to be disposed in concrete walled trenches, and (2) an example in which 100% of the waste is disposed in concrete walled trenches. These differential costs are calculated in Appendix F to be about $256/m^3$ for the former example, and about $161/m^3$ for the latter example. Effects of economics of scale are apparent. Additional land use for the two examples are, respectively, 4.1 acres and 39.5 acres. Costs (for 10%) of waste disposed are seen to be higher than the caisson trench example; however, less additional land is required.

Grouting

Grouting and the use of controlled density fill would generally significantly discourage most potential intruders, although the ability to excavate controlled density fill is higher than that for regular cement. The use of low-strength cement (at a cost of $47/m^3$) would offer intruder protection but not as much as higher-strength cement at a cost of $60/m^3$. (Unit costs include costs for stacked waste emplacement.) The waste would need to be placed in layers after which each layer would be grouted. Additional time would also be required to carry out grouting operations.

Engineered Intruder Barrier

The construction of an engineered barrier to the intruder would also significantly discourage most potential inadvertent intruders. For purposes of analysis, NRC assumed such a barrier would consist of multiple layers of different materials placed on top of the waste which would provide both depth in excess of that associated with most construction and agricultural activities as well as materials such as asphalt, concrete, and cobbles that would need to be removed at a relatively high cost to carry out such activities. The cost for such a barrier is high ($59/m^3) and it would be difficult to maintain if subsidence were a problem because of the multiple layers of various materials.

4.3.5.2 Depth of Disposal

The most obvious barrier is depth of disposal. Placing the waste at greater depths would be expected to remove it from most of man's near-surface activities. For example, raising the thickness of the cap to approximately 3 meters would result in a thickness of approximately 4 m between ground surface and the top of the disposed waste. The alternatives considered included thicker trench caps, layered waste disposal, and slit trenches.

Thicker Disposal Cell Covers

One alternative which may be used to minimize the potential for intrusion is simply to increase the thickness of the cover over the disposal cells.

At the reference disposal facility, the waste is assumed to be emplaced to a level approximately one meter below the top of the trench. This one meter space is filled with overburden, and a cap is then emplaced which is also assumed to be one meter thick. This results in approximately 2 meters (6.6 ft) of earth between the top of the waste and the surface of the ground. This thickness of cover would probably preclude contact of the waste through most potential agricultural activities, but may still allow partial contact through such activities as construction of a basement for a house.

An additional 3 meters of overburden would raise the distance between the waste and the ground surface to about 5 meters (16.4 ft). The thickness would place the top of the disposed waste about 2 meters below the level that typical basements would be constructed (about 3 m). An earthen thickness of 3 to 5 meters would also be expected to place the waste below typical burrowing depths of many burrowing insects and animals, as well as below the root depths of many plant species--particularly many food crops.

At existing disposal facilities, disposal trenches are excavated, filled with waste, covered over with previously excavated soils, and capped. There is usually considerable excess dirt from trench excavation and this dirt is generally applied as additional overburden over the trench cap. Existing disposal facilities often have as much as 2.4 to 3.7 m (8 to 12 feet) of earth separation between the top of the disposed waste and the surface of the earth.

Based upon the assumption that additional costs for fill royalties, hauling, spreading, and compaction efforts will be accrued, it is estimated that increasing the thickness of the trench cover by 3 meters will result in an increased operational cost of about $\$11/m^3$ of waste ($\$0.31/ft^3$). This figure is based upon the assumption that the additional fill is obtained from a clay borrow area located 10 miles offsite. The cost could be substantially reduced if the additional fill is obtained from excess excavated earth. In this latter case, additional design and operational costs would be reduced to about $\$2/m^3$. Of course, the clay cap provides greater protection against percolation into the disposed waste, resulting in reduced waste decomposition and lowered ground-water migration.

In a similar vein, an increased distance between the ground surface and the top of the disposed waste could be achieved by increasing the thickness of earthen material between the top of the waste and the top of the trench. For example, if only the bottom 4 m out of the 8 m excavation were used for waste disposal, the thickness of material between the waste and the top of the trench cap would be increased to 5 m (16.4 ft). The reduction in potential intruder impacts would be equivalent to the case described above regarding increased overburden thickness, but would be brought about by decreased land use efficiency. If at the reference disposal facility only the bottom 4 m (instead of the bottom 7 m) of all disposal trenches were used for waste disposal, then the land use efficiency would be dropped from 2.9 m^3/m^2 to approximately 1.6 m^3/m^2. The land area committed to waste disposal would be raised from 87 acres to about 105 acres, and the number of disposal trenches constructed raised from 58 to 105. Due to the additional amount of trench construction, filling, grading, seeding, and other groundskeeping activities that would be performed, costs would be proportionately raised (by about $\$5/m^3$).

<u>Layered Waste Disposal</u>

Protection against inadvertent intrusion may be accomplished by layering of the waste according to the relative hazard of the waste. The concept of trench layering involves placement of wastes having a higher potential hazard along the bottom of the trench with wastes having a lower potential hazard emplaced on top. Typically, higher potential hazard waste generally would include waste packages characterized by high surface radiation levels or wastes that could pose a significant airborne hazard if disturbed by excavation.

Layered waste disposal would use the same trenches described in the reference disposal facility (Appendix E). In the reference facility trench, only the bottom 7 m out of the 8 m excavated is used for disposal of waste. For layered waste disposal, the bottom 2 m (6.6 ft) of the excavation is assumed to be used for disposal of higher potential hazard waste material. The remaining 3-5 m of available space is used for disposal of lower potential hazard waste material. Thus, the inadvertent intruder would have to dig through 2 m of backfill and 3-5 m of lower hazard waste before encountering waste that could result in a significant potential exposure. Excavation work that uncovered boxes and drums of low activity waste would probably discourage further excavation long before the more hazardous material were reached. Layered

waste disposal would also help to reduce personnel exposures during disposal operations, by providing additional shielding for wastes having high gamma radiation levels.

The option of layered waste disposal would not appreciably alter design, operations or labor requirements. However, there would have to be an adequate mix of lower hazard to higher hazard waste on hand to allow for successful implementation of the option (i.e., a lower hazard waste to higher hazard waste volume ratio of about 2.5 to 1 or greater). Maintaining an input of waste at this ratio could on occassion require either careful scheduling of input from waste generators, and/or implementing greater storage capability at the site. It might also be necessary to have the capability of transporting the waste from a site waste storage area. Therefore, operational changes at the disposal facility might involve temporary storage of waste, additional coordination of waste receipt and emplacement, and transport of stored waste from the storage area to the disposal trench. The only significant operational cost differences would include possible construction of an inexpensive moderately sized waste storage facility (e.g., an open-sided roofed structure intended to provide some weather protection for the stored wastes, and perhaps a storage pad with tarpolins for large packages), and the aquisition of an onsite transport vehicle (e.g., a flatbed truck). Since these high activity wastes also present greater potential for migration and the need for greater stability over the long-term as discussed in Chapter 5, the lower activity wastes used for layering should also be in a stable, noncompressible form. The estimated cost differential for this option is about $38 per m^3 of waste requiring layered disposal. No additional land would be committed to waste disposal.

Slit Trench Disposal

A slit trench typically has a length dimension which is more than 5 times the width dimension (width dimension is generally less than 5 meters). The assumed dimensions of vertical-walled slit trenches in this EIS are 20 m in length, 3 m in width, and 8 m in depth. The minimum spacing employed between slit trenches is assumed to be 2 m. The assumed disposal efficiency is 50%, which means that only 50% of the total available void space is eventually occupied by waste packages.

It is assumed that 10% of the waste volume received at the facility will require disposal using slit trenches. The assumed slit trench dimensions and spacing imply that the land use efficiency of slit trench disposal is approximately half the efficiency of the reference trenches (180 m x 30 m x 8 m) described in Appendix E (or about 4.7 ft^2/ft^3). The anticipated cost differential between the base case unit disposal cost and the near-surface disposal facility employing slit trenches for "hot" waste is about $91 per m^3 of waste disposed into slit trenches. This cost is calculated assuming that no shoring is used during slit trench construction and waste emplacement. If shoring were used--either to allow construction work inside the slit trenches or to maintain side walls during waste emplacement--then unit costs for slit trench operations would be considerably higher.

The slit trench option results in an additional 2.8 ha (7 acres) committed to waste disposal. The overall land use efficiency for this option is estimated to be 8.75 ft^3/ft^2 (mixture of regular and slit trenches). The major anticipated benefit of employing this option is a reduction in the occupational exposures received by the waste emplacement labor force at the disposal facility. It is estimated that the use of slit trenches can possibly reduce occupational exposures by between 10 and 20%. Use of slit trenches for high activity wastes would be expected to reduce potential intruder exposures by a factor of about two. A drawback to the use of these slit trenches are the moderate slope failure hazards existing for vertical-walled trenches. In addition, the restricted width dimensions of slit trenches may preclude the burial of very large waste packages.

4.3.5.3 Other Methods of Disposal

Since this EIS is limited to near-surface disposal, NRC did not analyze in detail other methods of disposal. Other methods of disposal, however, such as intermediate depth burial, mined cavities, and ocean and space disposal can be very effective against intrusion. For example, use of a mined cavity would place the waste several hundred meters below the surface of the earth--far below most activities of man. Space disposal removes the waste entirely from the earth's surface. However, both options are very expensive--i.e., $500 to $840 per cubic meter for mined cavity disposal (not including postoperational costs) and $2 million/$m^3$ for space disposal. In the case of space disposal, the technology for routine implementation of this option is not available at the present time and the potential hazards are unknown. Therefore, if space disposal were required for all low-level waste, then large quantities of low-level waste would need to be stored until the technology was fully developed. This would be extremely expensive to licensees.

Waste can also be disposed of at much deeper depths. The opportunities for doing so may be limited at most eastern disposal sites, and an intermediate depth disposal facility at a western site (an unused open-pit mine) is illustrated in Appendix F as an example. This is expected to be effective against potential intrusion but could also be expensive. The reader is referred to Appendix F for further information. With respect to mined cavity disposal, there are currently no mined cavity disposal facilities licensed to operate in the country. If all low-level waste were required to be disposed of by this method, then all waste currently being generated would have to be stored until mined cavity facilities were licensed.

4.3.6 Institutional Controls

Another mechanism for reducing potential impacts to a potential inadvertent intruder is use of institutional controls.

4.3.6.1 Background

Institutional controls are controls which require performance of some action by a governmental agency to preclude human contact with the waste, or require a continuing social order. Examples include the following:

- Access to a disposal site can be controlled to restrict entry. For example, the site can be surrounded by a fence or other barrier to human or livestock intrusion. This barrier can be posted with warnings not to intrude upon the site. In addition, the site can be under routine surveillance by regulatory and/or law enforcement agencies to assure continued integrity of the fence and to inspect for possible disturbance.

- Controlled productive use of the site surface--for example, construction of a golf course--can be carried out under regulatory agency licensed control. In such instances, access to the site can be patrolled or otherwise restricted by those licensed to use the site. Controlled productive site use could also result in income which may partially off-set administrative costs incurred by the licensed custodial agency.

- Periodic inspection of the disposal site and monitoring for potential ground-water releases can be performed by a regulatory or other governmental agency. (The act of monitoring and inspection necessarily implies an understanding of the potential hazards contained within the site.)

This period of time can be termed a period of active observation. Gradually, however, such active means of institutional controls are anticipated to decrease. The interval between inspections lengthens. As regulators move on to other concerns, gradually less time and effort is placed upon surveillance and control of a particular site.

Ultimately, institutional controls must also rely upon relatively passive means involving some manner of social order. The types of controls which would be relied upon during this passive control period can include the following:

- The location of the disposal facility as well as the location of specific disposal areas on the facility can be referenced to USGS benchmarks. Long-lasting monuments can be emplaced which contain an inscription describing the nature of the hazard.

- The location and configuration of the disposal facility, together with a description of the hazard, can be inexpensively recorded and maintained in a number of different locations on a local, county, state, and national level. This redundancy in recordkeeping would help to ensure that knowledge of the disposal facility would be retained.

- Control of the disposal facility site can be maintained by a responsible government body--that is, the federal government or the government of the state in which the site is located. Government ownership of the land minimizes the potential for possible abandonment of the site. State or federal ownership is already a requirement in existing NRC regulations in 10 CFR Part 20.

- The title to the disposal site (the deed) can contain a convenant which specifically warns of the potential hazard and specifies a restriction on the use of the land.

Probably the most significant concepts for long-term passive institutional control measures are those of control of the land by a governmental organization, land-use restrictions in the form of titles or deeds, and multiplicity of records. As civilizations have evolved over the centuries, societies have characteristically erected superstructures (governments) to perform services--for example, protection of life, health, and property--which are less conveniently performed by individuals. Among the function performed by governments are control of titles to and uses of property. Placing the long-term control of a disposal site into the hands of a government organization helps to ensure that such motivies as profit and loss do not lead to possible abandonment of the property, or sale for inappropriate uses.

Certain governmental functions, such as tax collecting, land controls, and an interest in the health and welfare of the society, are independent of the type and form of government involved. Whether the government is capitalistic or socialistic, democratic or autocratic, use of land is controlled for what is perceived to be the maximum benefit of the society. From time to time societies have altered (or have had alterations performed by outside means) their type and form of government by peaceful or violent means. Yet, these societies have merely changed the form of the government, not eliminated government altogether. The government may change but the institution of government does not change. Germany, for example, has within the last 60 years undergone a number of upheavals resulting in radical changes in its government. During these upheavals, temporary breakdowns in several governmental functions have occurred. However, such functions were relatively quickly resumed by the newly established governments.

In the system familiar to Western culture, land may be owned by a government, an individual, or an organization. Title to the land is expressed through deeds--which often contain restrictions or specifications on the use of the land. Legal restrictions and administrative requirements (for example, records) are imposed upon the ownership and transfer of the land. On a number of occasions, title for a particular property has remained in the same hands--that is, by a family, an organization, or a government--for several centuries.

Similarly, the title to a piece of property may change hands, but the use of the land for a particular purpose (for example, cemeteries) will remain essentially the same for very long time periods. Even for land owned and used collectively, some organization controls the title to and prescribes the use of the land. The land is used for a specified purpose (for example, farming) by a particular group of people, and the land futhermore has boundaries.

The principle of government control of a near-surface disposal facility site does not preclude productive use of the land. The surface of a near-surface disposal facility, for example, can probably be used in perfect safety, as long as the users of the land are precluded from excavating deeply into the subsurface. Indeed, controlled use of the land may be potentially encouraged as a means to collect revenues to off-set the administrative costs of exercising control.

Markers on disposal cells which provide an approximate quantification of the hazard of disposed waste can also provide a passive warning to future generations that something out of the ordinary has occurred at the site. The use of such markers is current practice at all existing disposal facilities. Typically at current sites, a disposal trench will be marked with a monument inscribed with at least the following information:

- Total activity of radioactive material, in curies, excluding source and special nuclear materials; total amount of source material in kilograms; and total amount of special nuclear material, in grams, in the trench;
- Date of filling and capping the trench; and
- Volume of waste in the trench.

Typically, the information is inscribed upon a metal plate which is mounted onto a stone. In addition, marker stones are frequently used to denote the corners of a disposal trench. Costs for such markers have been included in the costs for the reference disposal facility.

4.3.6.2 Limitations to Institutional Controls

Institutional controls such as those outlined in the preceding section can be used to protect against the actions of an inadvertent intruder. However, such institutional controls are effective only insofar as they last. Markers and monuments established at a disposal site may be stolen or defaced and the nature of the hazard may be buried in forgotten governmental files. Land-use restrictions may be potentially ignored or a future government bureaucracy may simply mistakenly release a site for inappropriate use.

It is probably not realistic, however, to assume that institutional controls would be completely lost for extended time periods. It is certainly not credible to assume that all knowledge of a disposal facility would be lost. As previously discussed, records of the disposal facility, including the precise locations of waste disposal cells referenced to a bench mark, may be maintained in a number of separate locations. In addition, the general location of a disposal facility would likely be maintained in any number of other records. The locations of existing disposal facilities have been described in literally thousands of newspaper and magazine articles, professional journals, and private- and government-published documents.

Taking all possible passive control measures together, it seems reasonable to expect that institutional controls may be reasonably effective indefinitely. As stated earlier, there are a number of examples of property ownership or control by an institution or organization for centuries. However, during this time period, there is a possibility of one or more occurrences where institutional controls may break down, leading to inappropriate use of the site and potential human exposures. In the extreme, such occurrences may include such activities as construction of a housing development, as was the case at Love Canal. (At Love Canal, however, houses were not constructed directly into disposed waste. Human contact with the disposed waste was caused by leaching of contaminants out of the disposed waste by ground water and movement of the contaminants through the ground water and into areas inhabited by humans).

Compared to other types of potential environmental hazards, radiation is comparatively easy to detect. Furthermore, techniques to detect radiation are certain to become more sophisticated as time goes by. Future societies will undoubtedly continue to have organizations which are concerned with the health and well-being of the society's citizens. Any type of environmental, social, or warlike event that would completely eliminate all consideration of the public health and safety (and of instruments to detect potentially harmful radionuclides) would be so calamitous in nature that the potential impacts from the disposal facility would be entirely secondary.

In addition, it is likely that if someone sometime in the future did excavate into a near-surface disposal facility site, it would occur to the person that something was out of the ordinary and he would take steps to investigate the situation. A scenario that someone may excavate into disposed waste and grow vegetables on the exposed waste necessarily incorporates a somewhat farfetched presumption that all of the waste is sufficiently decomposed so that it is homogeneously mixed with soil. As discussed earlier, as long as the waste is in a stable waste form, then extensive construction or agricultural activities are not considered credible. Even under conditions of rapid decomposition of wastes which are disposed in an unstable form, extensive construction or agricultural activities must be considered unlikely.

Still, accidents happen, and it is reasonable to assume that, after a given period of time after disposal, some temporary breakdown in institutional controls may lead to an inadvertent use of a closed disposal facility which leads to potential exposures to a few individuals. As in the case of Love Canal, this could happen not because of a conscious decision to ignore public health and safety, but because someone simply made a mistake.

The maximum time period for which active institutional controls can be relied upon to preclude inadvertent intrusion has been investigated by a number of people (Refs. 1-5, 9). In EPA's "Proposed Criteria for Radioactive Wastes, Recommendations for Federal Radiation Guidance," (as published in the Federal Register in November 1978 (43 FR 53262) (Ref. 9)), EPA proposed that a limit of 100 years should be used as a limit for the length of institutional controls. This limit was proposed based upon consideration of public input received at a number of public forums on radioactive waste disposal held by EPA.

In various studies exploring ways in which to classify radioactive waste for disposal, different institutional control periods have been used (Ref. 1-5). The institutional control periods assumed in these studies were all less than a few hundreds of years and ranged in these studies from 100 to 200 years.

The maximum time period that should be assumed for active institutional controls was discussed extensively at a series of 4 regional workshops held on the preliminary draft of the Part 61 rule. These workshops were held in Atlanta, Georgia; Denver, Colorado; Chicago, Illinois; and Boston, Massachusetts. A more detailed summary of these workshops is contained in Appendix C. The general consensus of these workshops was that a 100-year limit for active institutional controls was appropriate. NRC also quantitatively analyzed varying periods of active institutional control ranging from 50 to 300 years. This analysis was performed concurrently with that leading to selection of the preferred performance objective and is described in Section 4.5.

4.4 CONCLUSIONS AND COMPARATIVE EVALUATION OF ALTERNATIVES

In summary, there are many potential methods which could be implemented to reduce potential exposures to an inadvertent intruder. All methods would involve increased costs for disposal--some significantly. In addition, many waste streams contain very small quantities of radioactivity and it would not appear to be reasonable to require the additional expense for all waste streams, particularly considering the hypothetical nature of the intrusion scenarios. Some criteria--preferentially based upon a dose level to a few individuals--is needed to distinguish between waste streams which should be disposed with additional protection against potential intrusion and those waste streams for which this would not be necessary. Such a dose level would also establish the level of safety to assure protection of an inadvertent intruder--i.e., a performance objective for intrusion.

It also appears that for most cases, simply layering the disposed wastes would provide sufficient protection to an intruder. For some streams perhaps even more additional protection would be needed--for example, use of a walled trench. Finally, some waste streams may not be suitable for near-surface disposal.

In determining which waste streams may not be acceptable for near-surface disposal, one of the key questions is how long barriers to a potential intruder may be expected to last. Such barriers, of course, would be expected to last several hundred years but not forever. Some barriers may last longer than others. For example, the effectiveness of a "hot waste facility" (walled trench) discussed above to deter the actions of a potential intruder could be expected to last longer than the intruder barrier provided by layering. As discussed above, the "hot waste facility" is assumed to consist in this EIS of a disposal trench which has a 0.3 m thick concrete base, 0.3 m thick concrete walls, and a one-meter thick concrete cap. This trench may be then covered over with fill.

From the analyses performed for this EIS, it can be seen that due to radioactive decay, exposures to a potential inadvertent intruder from almost all waste streams typically considered to be LLW fall to a few millirems after a few hundred years--e.g., 500 years. After 500 years, only a few waste streams are estimated to result in potential intruder exposures of a few hundred millirems. Very few (e.g., one or two) streams having small volumes are estimated to result in potential intruder exposures exceeding 500 mrem after 500 years. A time period of 1,000 years was assumed for a "hot waste facility" to provide an upper estimate of the degree to which near-surface disposal techniques can reduce potential intruder exposures.

On the other hand, waste streams that are generally considered to be "high-level waste" (e.g., spent reactor fuel, solidified first solvent extraction stages from a nuclear fuel reprocessing plant) contain much higher initial levels of radioactivity. Typically, the potential hazard from high-level waste disposal is dominated by fission products over approximately the first 600 years. After that approximate time period, most of the fission-product activity has decayed, except for iodine-129 and technetium-99; radioactivity is dominated thereafter by the actinides--e.g., U, Np, Pu, Am, Cm and their daughters.

This point was recognized by NRC during development of the regulation 10 CFR 60 for geologic disposal of high-level waste. In the Federal Register Advance Notice of Proposed Rulemaking on this rule (Ref. 10), there was included a draft requirement that high-level wastes should be placed into a canister that would last for 1,000 years to allow decay of the fission products. This requirement was later included as part of the Part 60 rule proposed in July 1981 (Ref. 11). It is apparent, then, that wastes which still contain appreciable activity after several hundred years (e.g., 500 years) would appear to more closely resemble high-level waste than what is usually considered to be low-level waste.

Finally, limitations on the effectiveness of barriers to a potential inadvertent intruder was discussed at the regional workshops on the Part 61 regulation. At these workshops, there appeared to be general agreement that a time period of 500 years seemed appropriate for most easy-to-implement intruder barriers.

Based upon the analyses and discussion of the previous subsections, the following conclusions can be reached:

1. The potential for inadvertent human intrusion into a closed disposal facility at some point after closure of the disposal facility is likely. Extensive intrusion activities such as major housing or apartment construction are unlikely. The potential exposures from inadvertent intrusion are relatively high for the first few hundred years (i.e., 3-6 rem/year) but, provided a few waste streams are removed, then drop to a low level (few mrem/year).

2. Some waste streams present relatively little hazard to an inadvertent intruder. Some present an initial high potential hazard. If inadvertent intruders can be protected against contacting these latter waste streams for a few hundred years, then such waste streams present much reduced potential hazards. Some waste streams may not be acceptable for near-surface disposal.

3. The extent and consequences of potential inadvertent intrusion are related to waste form, design, and operating practices. For example, improved waste form and packaging can reduce potential exposures through inhalation and food consumption pathways. Volume reduction may increase exposures from direct gamma radiation. If the waste is in a structually stable form and segregated from other wastes, then as long as the structural stability is retained, the possibility of extensive inadvertent intrusion activities is not considered credible.

4. Natural and engineered barriers can be used to reduce potential intruder exposures. However, there is a limit (e.g., 500 years) as to how long such barriers can be expected to last.

5. Institutional controls can be effective in reducing the potential for inadvertent intrusion and in reducing potential intruder exposures.

Two aspects must be analyzed in further detail and specific limits developed to determine the disposal requirements of different LLW streams based on protection

of an inadvertent intruder--that is, to determine which streams may be acceptable for near-surface disposal, which streams may require barriers to an intruder, and which streams may be altogether unacceptable for near-surface disposal. The aspects that must be developed include:

1. An exposure guideline to define an acceptable level of safety regarding protection of an inadvertent intruder which can be used to stipulate when controls against potential intrusion should be implemented;

2. A maximum time during which active institutional controls can be relied on to prevent inadvertent intrusion; and

These two aspects and others are addressed in the remaining two sections regarding development of an intruder performance objective and technical requirements.

4.5 DEVELOPMENT OF INTRUDER PERFORMANCE OBJECTIVE

4.5.1 Analysis of Intruder Dose Limitation Guidelines

Prior to determining a dose guideline for protection of a potential inadvertent intruder, it is useful to briefly review a number of radiation exposure guidelines which have been recommended by various bodies or adopted by regulatory agencies. The reader is referred to Appendix N, which presents a brief review of radiation exposure guidelines as have been developed by the following groups:

- ICRP
- NCRP
- EPA
- NRC

From the discussion in Appendix N, it appears that a wide range of exposure criteria have been recommended by national and international committees or adopted as regulations by NRC and EPA. These criteria range from a few millirem to a few dozen millirem to several rems. In general, the lower exposure limitation criteria (a few to a few dozen mrem) are used as standards assuming continuous exposure to radionuclides by populations. Higher dose limits (hundreds of mrem) are generally used as standards assuming exposures to a few individuals in unrestricted areas. Still higher exposure limits (a few rems) are considered appropriate for limits to radiation workers. Finally, a few dozen rems is an exposure guideline which has been recommended for once-in-a-lifetime exposures for an emergency situation.

Three alternative dose guidelines may be further examined, which serve to bound a low, moderate, and high dose guideline. In considering this range, one important concept that should be remembered is that the exposures potentially experienced by an intruder would not be routine. Such exposures would be accidental and would furthermore not be expected to last for long time periods--particularly if the waste so encountered has been placed into a stable form. The three guidelines so examined are in the following ranges:

1. 25 mrem to the whole body;
2. 500 mrem to the whole body; and
3. 5 rem to the whole body.

Twenty-five mrem/year is derived from 40 CFR Part 190 and is the EPA standard applied to the whole body and organ (except thyroid) exposures involving releases of material to the general environment through normal fuel cycle facility operations. This standard has been adopted by NRC as part of NRC regulations in 10 CFR Part 20. Since this is an accepted standard, it would appear to provide an adequate level of protection. It does not appear appropriate, however, to apply this standard to exposures to potential inadvertent intruders. This standard applies to routine releases to the general environment involving exposure of several individuals of larger population groups. The standard would not seem to apply to the type of localized "accidental" exposure to a few individuals who might intrude into the waste. Inadvertent intrusion is accidental and of a short-term temporary nature and is not expected to involve longer-term routine operational releases. A limit higher than 25 mrem/year would therefore appear to be appropriate, particularly since intrusion involves only a few individuals.

Five rem/year to the whole body is derived from the occupational external whole body radiation exposure guideline recommended by NCRP and set out by NRC in 10 CFR Part 20. Since this is also a generally accepted standard, it would also seem to provide an adequate level of protection. Such an exposure to an intruder would not be life threatening, and would involve exposures no higher than allowable today for some individuals. The standard, however, is applied to radiation workers who understand and accept the low risk of exposure involved in their job and livelihood. The inadvertent intruder is not a radiation worker and he may have no knowledge of the risk of exposure even after he digs into the waste.

Dose limitations in the range of 500 millirem/year to the whole body have been recommended by various groups for a number of years as adequate for protection of individuals. In making this recommendation, these groups maintain that protecting individuals to this level will almost certainly protect populations. For example, ICRP states that protection of an individual to a level of 500 mrem/year will almost certainly guarantee potential population exposures to less than one-tenth of the maximum individual dose. The current recommendations of the National Council on Radiation Protection and Measurements (NCRP) for radiation protection guidelines are 500 mrem/year (whole body) to the maximum exposed individual and 170 millirem/year as an average yearly population dose. These recommendations were adopted by the Federal Radiation Council (FRC) and recommended in 1960 as federal guidance. NRC limits in 10 CFR Part 20 for exposures to individuals in unrestricted areas are currently set at 500 mrem/year (whole body), based upon recommendations of the FRC and NCRP.

The International Commission on Radiation Protection (ICRP) has also recommended similar limits for a number of years. In more recent recommendations, however,

ICRP has retained the recommended whole body dose limits of 500 mrem/year but dropped the 170 mrem/year population dose recommendation as not necessary. In so doing, ICRP states that protection of an individual to a level of 500 mrem/year would almost certainly guarantee potential population exposures to less than one-tenth of the maximum individual dose. ICRP also now recommends use of a weighting system to account for the fact that certain bodily organs and extremities are more radiosensitive than others. In the system, the dose to any individual organ or groups of organs would be controlled so that the sum of the doses to each individual organ times a given organ-weighting factor would not exceed 500 millirem for all organs. This weighting system, however, has not been adopted by NRC, although it may be in the future.

A dose guideline of 500 mrem/year to the whole body would therefore appear to be acceptable for protection of an inadvertent intruder. Such potential intrusion may never occur and if it should occur, would only be expected to involve local exposure of a few individuals. The use of a 500 mrem/year dose guideline has also been extensively discussed at the four regional workshops held by NRC on LLW disposal. Comments on this guideline were also received on the preliminary draft regulation 10 CFR 61 which was made available for public comment. The workshops and public comments are discussed in Appendix C. Broad acceptance of this guideline was generally expressed in these workshops and comments.

4.5.2 Analysis of Alternatives

Alternative dose limitations and institutional control periods for use in establishing performance objectives for protection of a potential inadvertent intruder may also be examined numerically. That is, depending upon different assumptions regarding dose criteria and institutional control periods, different calculated volumes of waste would require disposal by various methods. These volumes (and the resulting intruder exposures calculated) may then be examined and an estimate made of the cost-effectiveness of different alternatives.

Two factors complicate this analysis. One is that in determining performance objectives for inadvertent intrusion, one cannot examine alternative dose limitations independently of the institutional control period. For example, in order to assess the effects of alternative dose limitations, one must first set an institutional control period. Similarly, one cannot assess the effects of alternative institutional control periods without first setting a dose limitation criteria. The second factor is the number of variables which could be considered in the analysis. Some of these variables include the dose limitation criteria, the waste spectrum, the institutional control period, the region of the country, and the facility design. Several thousand permutations are possible. Even if one limits oneself to 3 alternative dose limitation criteria, 4 alternative waste spectra, 4 alternative institutional control periods, 1 region (the reference facility), and 2 facility designs, the number of possible permutations comes to 96. If one also considers the effect on the results of "waste form credit" and "no waste form credit" assumptions regarding the effect of waste form on dispersibility and root uptake, the number of possible permutations becomes 192. Clearly, some simplifying assumptions must be made to enable meaningful results.

For the analysis, therefore, NRC staff has considered 24 cases as shown in Table 4.20. In Cases 1-8, the dose limitation criteria (500 mrem whole body) and the waste spectrum (spectrum 1) are fixed, and the effects of four different institutional control periods (50, 100, 150, and 300 years) are considered. In Cases 9 through 14, the dose limitation criteria is still fixed at 500 mrem (whole body) and the effects of different waste spectra are considered. Cases 15 through 19 consider the effects of a dose limitation in the range of 25 mrem (whole body), while Cases 20 through 24 consider the effects of a dose limitation criteria in the range of 5 rem (whole body).

In each of the 24 cases, the waste streams are assumed to be randomly disposed into the reference disposal facility. Three potential forms of disposal to reduce intruder impacts are considered--i.e., disposal near the surface, layering, and not acceptable for near-surface disposal. In the 24 cases, no credit is assumed for the ability of waste form to reduce dispersibility and plant root uptake. The details of the calculational procedure are set out in Appendices G and H. Briefly, however, each waste stream is first tested for intruder impacts from disposal near the earth's surface, assuming the intruder scenarios discussed earlier occur (i.e., the intruder-construction scenario and the intruder-agriculture scenario). The calculated impacts are compared against the assumed dose limitation criteria immediately after the assumed end of the institutional control period. If the calculated impacts exceed the dose limitation, the waste stream is then assumed to be layered (disposed at the bottom of the trench), which considerably reduces the potential exposures received. However, the effectiveness of layering as an intruder barrier is assumed only to be effective for 500 years, after which time the potential impacts from intrusion are again compared against the assumed dose limitation criteria. As before, the intruder-construction and intruder-agriculture scenarios are conservatively assumed to occur. If the calculated impacts exceed the dose limitation criteria, the waste stream is assumed to be not acceptable for near-surface disposal.

The volumes of waste assumed to be suitable for disposal by each classification--i.e., regular disposal, layered disposal, or not acceptable--are shown for each case on Table 4.20. Also shown is the volume averaged intruder impacts calculated for the intruder-construction scenario and the intruder-agriculture scenario to each of two organs: whole body and bone. The impacts are calculated at the end of the institutional control period and are volume-weighted averages of exposures received from all waste streams acceptable for disposal--i.e., from regular and layered disposal. The doses calculated are an indication of the range of the actual likely exposures received from application of the indicated dose limitation criteria after the end of the indicated institutional control period. Exposures are also shown for a time period 500 years after license termination, at which time no credit is assumed for layering to reduce intruder exposures.

Finally, two different disposal facility design practices are considered in the analysis--i.e., whether or not compressible wastes are segregated from other waste streams during disposal. As discussed earlier, this can have a significant effect on the potential intruder impacts. If waste segregation is implemented, then the extensive intruder-construction scenario and intruder-agriculture scenario is assumed to be only applicable to the compressible wastes. For wastes

Table 4.20 Comparison of Cases to Determine Intrusion Performance Objective

Case Description and Impact Measures	Case a	b	c	1	2	3	4	5	6	7	8	9	10
Case Description:													
Dose limitation criteria (mrem)	NA	NA (No TRU)	NA (No TRU)	500	500	500	500	500	500	500	500	500	500
Waste spectrum	1	1	1	1	1	1	1	1	1	1	1	2	2
Institutional control period (yrs)	100	100	100	50	50	100	100	150	150	300	300	100	100
Segregation (yes/no)	No	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Intruder Impacts:													
Body (mrem)													
o ICP C	1.50E+3	1.21E+3	1.16E+3	8.43E+1	8.69E+1	8.05E+1	3.09E+1	3.65E+1	2.12E+1	1.28E+1	1.22E+1	4.09E+1	3.26E+1
A	1.77E+3	1.49E+3	1.41E+3	9.51E+1	7.35E+1	8.47E+1	2.50E+1	3.83E+1	2.00E+1	1.44E+1	1.37E+1	4.59E+1	2.15E+1
o 500 C	7.81E+1	1.53E+0	1.53E+0	1.53E+0	1.53E+0	1.53E+0	1.53E+0	1.53E+0	1.53E+0	1.53E+0	1.53E+0	1.93E+0	1.93E+0
A	4.34E+1	1.76E+0	1.76E+0	1.76E+0	1.76E+0	1.76E+0	1.76E+0	1.76E+0	1.76E+0	1.76E+0	1.76E+0	2.21E+0	2.21E+0
Bone (mrem)													
o ICP C	3.10E+3	1.21E+3	1.17E+3	8.89E+1	9.53E+1	8.78E+1	3.62E+1	4.31E+1	2.62E+1	1.96E+1	1.77E+1	4.57E+1	3.36E+1
A	2.48E+3	1.56E+3	1.51E+3	1.10E+2	8.51E+1	9.08E+1	2.97E+1	4.12E+1	2.20E+1	1.64E+1	1.52E+1	5.50E+1	2.61E+1
o 500 C	1.18E+3	4.52E+0	4.52E+0	4.52E+0	4.52E+0	4.52E+0	4.52E+0	4.52E+0	4.52E+0	4.52E+0	4.52E+0	6.25E+0	6.25E+0
A	4.85E+2	3.46E+0	3.46E+0	3.46E+0	3.46E+0	3.46E+0	3.46E+0	3.46E+0	3.46E+0	3.46E+0	3.46E+0	4.67E+0	4.67E+0
Volumes: (m^3)													
Regular	1.0E+6	9.80E+5	9.80E+5	6.88E+5	8.64E+5	8.81E+5	8.82E+5	9.08E+5	9.09E+5	9.77E+5	9.77E+5	4.76E+5	6.76E+5
Layered	-	-	-	2.92E+5	1.15E+5	9.91E+4	9.77E+4	7.14E+4	7.04E+4	2.66E+3	2.66E+3	2.02E+5	2.87E+3
Not accept.	-	1.94E+4	1.94E+4	1.94E+4	1.94E+4	1.94E+4	1.94E+4	1.94E+4	1.94E+4	1.94E+4	1.94E+4	1.94E+4	1.94E+4
Disposal Costs: ($)													
Design and Op.	1.85E+8	1.85E+8	1.90E+8	1.93E+5	1.95E+8	1.88E+8	1.94E+8	1.88E+8	1.94E+8	1.86E+8	1.92E+8	1.88E+8	1.88E+8
Postoperational	3.82E+7	3.82E+7	3.82E+7	3.09E+7	3.09E+7	3.82E+7	3.82E+7	4.29E+7	4.29E+7	4.88E+7	4.88E+7	3.82E+7	3.82E+7
Total NSD:	2.23E+8	2.23E+8	2.28E+8	2.24E+8	2.26E+8	2.26E+8	2.32E+8	2.31E+8	2.37E+8	2.35E+8	2.41E+8	2.26E+8	2.26E+8
Mined Cavity ($)	-	9.93E+6	9.93E+6	9.93E+6	9.93E+6	9.93E+6	9.93E+6	9.93E+6	9.93E+6	9.93E+6	9.93E+6	9.93E+6	9.93E+6
Repository ($)	-	1.01E+8	1.01E+8	1.01E+8	1.01E+8	1.01E+8	1.01E+8	1.01E+8	1.01E+8	1.01E+8	1.01E+8	1.01E+8	1.01E+8

Table 4.20 (continued)

Case Description and Impact Measures	Case													
	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Case Description:														
Dose limitation criteria (mrem)	500	500	500	500	25	25	25	25	25	5000	5000	5000	5000	5000
Waste spectrum	2	2	3	4	1	1	2	3	4	1	1	2	3	4
Institutional control period (yrs)	300	300	100	100	100	100	100	100	100	100	100	100	100	100
Segregation (yes/no)	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Intruder Impacts:														
Body (mrem)														
o ICP C	1.50E+1	3.94E+1	2.83E+1	3.84E+1	1.37E+0	1.90E+0	2.47E+0	3.56E+0	2.12E+0	1.15E+2	6.71E+1	3.43E+1	3.08E+1	6.41E+1
A	1.71E+1	3.43E-1	2.11E+0	4.47E+1	2.74E+0	1.74E+0	5.02E-1	6.23E-1	1.30E+0	1.22E+2	6.34E+1	2.14E+1	2.10E+0	4.37E+0
o 500 C	1.93E+0	1.93E+0	3.08E+0	6.41E+0	2.50E-1	2.50E-1	1.58E+0	2.60E+0	6.90E-1	1.53E+0	1.53E+0	1.93E+0	3.08E+0	6.41E+0
A	2.21E+0	2.21E+0	3.48E+0	7.22E+0	3.08E-1	3.08E-1	1.81E+0	2.88E+0	8.06E-1	1.76E+0	1.76E+0	2.21E+0	3.48E+0	7.22E+0
Bone (mrem)														
o ICP C	2.26E+1	6.33E-1	2.90E+1	3.92E+1	1.85E+0	2.11E+0	2.65E+0	3.71E+0	2.29E+0	1.24E+2	7.41E+1	3.48E+1	3.10E+1	6.45E+1
A	2.00E+1	8.86E-1	4.53E+0	9.59E+0	6.71E+0	4.28E+0	1.99E+0	2.48E+0	5.18E+0	1.30E+2	7.07E+1	2.60E+1	4.50E+0	9.37E+0
o 500 C	6.25E+0	6.25E+0	9.04E+0	1.88E+1	1.66E+0	1.66E+0	5.59E+0	8.03E+0	3.19E+0	4.52E+0	4.52E+0	6.25E+0	9.04E+0	1.88E+1
A	4.67E+0	4.67E+0	6.60E+0	1.37E+1	1.23E+0	1.23E+0	3.96E+0	5.35E+0	2.30E+0	3.46E+0	3.46E+0	4.67E+0	6.60E+0	1.37E+1
Volumes: (m^3)														
Regular	6.75E+5	6.78E+5	4.89E+5	2.31E+5	3.32E+5	5.18E+5	3.97E+5	3.16E+5	1.52E+5	9.09E+5	9.10E+5	6.78E+5	4.92E+5	2.36E+5
Layered	3.67E+3	-	2.87E+3	5.21E+3	5.70E+5	3.84E+5	2.75E+5	1.65E+5	3.39E+4	7.06E+4	6.96E+4	-	-	-
Not accept.	1.94E+4	1.94E+4	1.13E+3	1.13E+3	9.70E+4	9.70E+4	2.62E+4	1.22E+4	5.19E+4	1.94E+4	1.94E+4	1.94E+4	1.13E+3	1.13E+3
Disposal Costs: ($)														
Design and Op.	1.84E+8	1.88E+8	1.85E+8	1.82E+8	1.99E+8	2.00E+8	1.94E+8	1.89E+8	1.82E+8	1.88E+8	1.94E+8	1.88E+8	1.85E+8	1.81E+8
Long-term Care	4.88E+7	4.88E+7	3.82E+7	3.82E+7	3.82E+7	3.82E+7	3.82E+7	3.83E+7	3.82E+7	3.82E+7	3.82E+7	3.82E+7	3.82E+7	3.82E+7
Total NSD:	2.33E+8	2.37E+8	2.23E+8	2.20E+8	2.37E+8	2.38E+8	2.32E+8	2.27E+8	2.20E+8	2.26E+8	2.32E+8	2.26E+8	2.23E+8	2.19E+8
Mined Cavity ($)	9.93E+6	9.93E+6	5.79E+5	5.79E+5	4.97E+7	4.97E+7	1.34E+7	6.25E+6	2.66E+7	9.93E+6	9.93E+6	9.93E+6	5.79E+5	5.79E+5
Repository ($)	1.01E+8	1.01E+8	5.88E+6	5.88E+6	5.04E+8	5.04E+8	1.36E+8	6.34E+7	2.70E+8	1.01E+8	1.01E+8	1.01E+8	5.88E+6	5.88E+6

which are segregated and stable, the intruder-agriculture scenario is assumed not to occur and the intruder-construction scenario is considerably reduced in its impact. (This is also termed the intruder-discovery scenario.) The full extensive intruder scenarios are conservatively applied for all waste streams at 500 years whether or not the waste stream is segregated or the waste is in a stable form. Impacts at the end of the institutional control period and at 500 years are again volume-averaged over all (stable and unstable) waste streams accepted for disposal.

4.5.3 Results of Analysis

The results of the 24 case studies are shown in Table 4.20. Also shown in this table is an additional case which illustrates costs and impacts of no action (case a), as well as two cases (cases b and c) for which the L-DECONRS and N-SOURCES waste streams are removed but no other action is taken to protect a potential inadvertent intruder (no layering is performed for any waste streams).

Across the top of the table are listed the descriptions of the cases. The variables considered include the dose limitation criteria, the waste spectrum, the institutional control period, and whether or not segregation is implemented at the disposal facility. Next, radiological impacts in mrem to whole body and bone are listed for the intruder-construction and intruder-agriculture scenario for two time periods after license termination: at the end of the assumed institutional control period and at 500 years. Next, the volumes (in m^3) are shown for waste disposed as regular waste, disposed as layered waste, and not acceptable for disposal.

Costs are listed toward the bottom of the table. Shown are design and operation costs, postoperational costs (closure and long-term care costs), and total (design and operation plus postoperational care) near-surface disposal costs. Design and operation costs are calculated as a total sum over 20 years of facility operation and are a function of facility design (whether or not segregation is implemented), the dose limitation criteria chosen, and the waste spectra. The less the volume of waste delivered to the disposal facility, the lower the total design and operation costs. For this analysis, postoperational costs were calculated by assuming a high level of long-term care effort for all cases. Differences in the long-term care costs for the cases are calculated solely as a function of the assumed length of the active institutional control period.

Costs for disposal of waste streams found to be not acceptable for near-surface disposal are also illustrated as two examples. In the first example, the waste streams unacceptable for near-surface disposal are assumed to be disposed into a mined cavity which is licensed to a commercial operator. Costs are calculated based upon an estimate of $512 per cubic meter of waste, which is the lower end of the range for mined cavity disposal given in Appendix F. This level of costs is based upon an assumption that an existing mine may be used and does not include any storage costs prior to shipment of the waste to the mine. In addition, the costs do not include cost for closure and long-term care of the mined cavity. In the second example, costs are estimated based upon an assumption that the Department of Energy accepts the waste for disposal into a federal

repository. Costs are calcualted based upon an estimate of $5200/m^3 of waste, which includes costs for retrievable storage, retrieval, processing, transportation, and disposal into a geologic repository.

These costs for the two examples are given in 1980 dollars and should be considered only illustrative approximations. There are currently no mined cavities licensed by either NRC or an Agreement State, and wastes would have to be stored until such time (if and when) such a facility is licensed. No analysis is performed in this EIS to determine if waste unacceptable for near-surface disposal would be acceptable in a commercially operated mined cavity. Many such wastes (particularly transuranic waste streams) unacceptable for near-surface disposal would probably end up as candidates for a federal repository. Additional costs would be involved for storage until either a disposal facility is available to accept the waste for disposal or DOE is in a position to accept the waste for retrievable storage.

Comparing Cases 1 through 8, several trends are observed:

1. The longer the assumed institutional control period, the greater the volume of waste that can be disposed by less expensive methods. For example, the ratio of the volume of waste that can be disposed by regular means vs. the volume of waste that must be disposed through layering is as follows: Case 2: 7.51; Case 4: 9.03; Case 6: 12.91; Case 8: 367.29. As long as only a relatively small volume of waste requires layering (e.g., as in Cases 4 through 8), then layering can be accomplished with little expense, with little or no disruption of existing practices, and with no decrease in disposal efficiency (no increase in land use). However, if large volumes of waste require layering (e.g., as in Case 1), then this could cause increased expense, some disruption of existing practices, and a decrease in disposal efficiency.

2. The longer the assumed institutional control period, the lower the potential exposures at the time that intrusion is assumed to occur (which is immediately after the end of the institutional control period). On the other hand, the longer the institutional control period, the greater the long-term care costs.

3. The practice of waste segregation generally slightly increases the quantity of wastes which may be disposed by less expensive means. For example, compare the volumes of waste in the "regular" class and the "layered" class for Cases 1 vs. 2; 3 vs. 4; and 5 vs. 6. This effect is of most significance for Cases 1 and 2.

4. The practice of waste segregation generally reduces potential intruder exposures.

5. The volume-weighted impacts calculated at the institutional control period are invariably significantly less than the assumed dose

limitation criteria. Of course, the longer the institutional control period, the lower the calculated impacts. Since varying the institutional control period does not vary the volume of waste calculated to be unacceptable for near-surface disposal (the N-SOURCES and L-DECONRS stream are calculated to be unacceptable in all 8 cases), the intruder impacts at 500 years do not vary from one case to the next. These impacts are in the range of about 1.5 to 4.5 mrem.

From the analysis in Cases 1 through 8, there does not appear to be any compelling analytical reason to choose one institutional control period over another. It appears that the assumption of whether or not waste segregation is carried out affects the volumes of waste disposed by either regular or layered means as much as the institutional control period chosen. In any case, provided waste segregation is implemented, there is no difference in total waste volumes disposed between an institutional control period of 50 years and 300 years.

Of the institutional control periods considered, 50 years would likely cause the most change to present practices, the most added design and operation expense, and the most likelihood of a potential decrease in disposal efficiency. In addition, it is very unlikely that the extensive intruder impacts considered in this EIS could occur at a time period only 50 years following license termination. Finally, implementation of a 50-year institutional control period may serve to inhibit volume reduction of wastes. In general, volume reduction is desirable as it can lower disposal costs to a waste generator, improve disposal efficiency (less land use), and increase the stability of the waste (lowering potential ground-water impacts and potential long-term care costs).

This leaves a choice in the range of 100 to 300 years. Since general support for 100 years was received at the regional workshops and the calculated difference in design and operations cost to a waste generator between 100 years and 300 years is low, the more conservative time period was selected.

Cases 9 through 14 illustrate the effects of other waste spectra, assuming a continuation of the previously assumed dose limitation criteria of 500 mrem to the whole body. Waste spectra 2 through 4 consider different degrees of volume reduction, and so the volumes classified are different from Cases 1 through 8. Of interest is a comparison of calculated intruder exposures for Cases 10, 13, and 14 with each other and with Case 4. In these four cases, the dose limit and the institutional control period are the same but different waste spectra are considered. The calculated exposures are similar at the end of the assumed institutional control period (100 years) for Cases 4, 10, and 13. Even for the extreme case of volume reduction assumed for waste spectrum 4 (Case 14), the calculated impacts are only a few mrem higher. After 500 years, intruder exposures are only slightly higher for all cases (except Case 14) than the exposures calculated for Cases 1-8. For Case 14, exposures are still less than 20 mrem for the intruder-construction scenario and less than 15 mrem for the intruder-agriculture scenario.

In addition, compared to Cases 1 through 8, no additional volumes of waste are classed as unacceptable for near-surface disposal. The same two streams as

before--the N-SOURCES and L-DECONRS streams--are involved. As a minor perturbation, for Cases 13 and 14, the L-DECONRS stream is assumed to be calcined, resulting in significant volume reduction (to 1.13 E+3 m^3). The N-SOURCES waste stream (51.5 m^3), for which no volume reduction is assumed for any of the 4 spectra, follows the familiar pattern of Cases 1 through 8.

What this analysis appears to indicate is that except for a few waste streams which are problematical in any case, use of an institutional control period of 100 years and dose limitation criteria of 500 mrem/yr (whole body) would not be expected to inhibit use of volume reduction as a waste processing technique.

Another interesting effect is observed by comparing Cases 7 and 8 with Cases 11 and 12. If waste segregation is not implemented, then the intruder impacts for waste spectrum 1 at 300 years is less than those for waste spectrum 2. However, if waste segregation is implemented, the opposite effect is seen.

The effects of using different dose limitation criteria are set out in Cases 15 through 24. In Cases 15 through 19, the dose limitation criteria is assumed to be in the range of 25 millirem whole body (75 millirem thyroid). In Cases 20 through 24, the dose limitation criteria is assumed to be 10 times that for Cases 1 through 14, or 5,000 mrem (5 rem) whole body. For all cases, the institutional control period is assumed to be 100 years.

As can be seen in Cases 15 through 19, use of an intruder dose limitation criteria in the range of 25 mrem (whole body) would tend to result in larger costs to waste generators. Due to reduced volumes of waste accepted for near-surface disposal, similar or somewhat reduced design and operation costs are calculated (e.g., compare Cases 15 and 16 with Cases 3 and 4; Case 17 with Case 10; or Case 18 with Case 13). However, mined cavity and repository costs are higher. For most of the waste spectra, approximately the same volume of waste must be layered as that which can be disposed unlayered. In addition, larger volumes of wastes would not be acceptable for near-surface disposal. For example, in Case 16, nearly 100,000 m^3 of waste would be classified as not acceptable. Compared to an intruder dose limitation criteria in the range of 500 mrem (whole body), use of the lower dose limitation criteria would result in higher costs, more changes to existing practices, and less efficient land use. There is no disposal facility yet constructed, such as a geologic repository, offering greater isolation than a near-surface disposal facility. This means that such wastes would have to be stored prior to disposal--perhaps for extended time periods.

In addition, although use of the 25 mrem dose limitation criteria results in reduced potential exposures at 100 years (by a factor of 10 for most cases), only a negligible difference in intruder exposures is seen at 500 years. This means that use of the 25 mrem (whole body) dose criteria will provide little additional reduction in long-term potential intruder exposures.

The effect of implementing the highest alternative dose limitation criteria (5 rem whole body) in Cases 20 through 24 is seen to be somewhat similar to the effects of a dose limitation criteria in the range of 500 mrem/yr. Similar to Cases 1 through 14, the L-DECONRS and N-SOURCES waste forms are always classed as being unacceptable.

Another interesting aspect is the volume-weighted intruder impacts. As before, the impacts calculated are invariably considerably less than the dose limitation criteria. In addition, the impacts calculated for the higher (5 rem) criteria are similar to those previously calculated for the 500 mrem criteria. This implies that one could possibly use two dose limitation criteria--a lower one (e.g., 500 mrem) for longer-lived higher hazard isotopes such as transuranics and a higher one (e.g., 5 rem) for shorter half-lived fission products such as Cs-137. Use of a higher dose limitation criteria for shorter-lived isotopes could cause an initial higher hazard. Use of such a criteria would have little effect on the long-term hazard, however. For example, if it is assumed that a raise in the Cs-137 limit by tenfold from 500 mrem to 5 rem causes a tenfold increase in potential intruder hazard (unlikely as the above analysis indicates) and the higher activity waste is stabilized and segregated (e.g., waste spectra 2, Cases 10 and 22), then the potential exposures would still be less than 500 mrem/yr. These higher potential exposures would only last for a short time period, and would fall by a factor of 10 in a space of only 100 years.

As shown, the impacts at 500 years are similar to those calculated for Cases 1-8.

It may also be useful to examine use of a "hot waste facility" for possible disposal of waste streams found in the 24 cases to be unacceptable for disposal.

For the purposes of this analysis, the hot waste facility is assumed to be a cement-walled trench into which wastes are stacked and then grouted in place. A one-meter thick concrete cap is then poured over the waste and a few meters of earth are then emplaced over the facility. Thus, the waste is enclosed in a large monolithic block of concrete. The facility is assumed to be effective for 1000 years, after which the potential intrusion impacts are calculated and compared against the assumed dose limitation criteria. The intruder-construction and intruder-agriculture scenarios are assumed to occur, but are assumed to be reduced by a factor of 10 due to the presence of the concrete fill. If the calculated exposures still exceed the assumed dose limitation criteria, the waste is assumed to be unacceptable for near-surface disposal.

It is recognized that there are uncertainties regarding use of the "hot waste facility," and its effectiveness. However, it is included to enable an estimate of the effectiveness of extensive near-surface disposal techniques to reduce potential intruder exposures. Use of a hot waste facility is estimated to be much more expensive than either regular or layered disposal. If a hot waste facility were not used at the disposal facility, then the waste streams assumed to be suitable for disposal into a hot waste facility would be considered unacceptable for near-surface disposal.

Potential use of the hot waste facility for disposal of probable material waste was tested for all 24 cases and in no case were the N-SOURCES and L-DECONRS streams found to be acceptable for hot waste facility disposal. This would be expected considering that these two streams are assumed to contain relatively large quantities of transuranic isotopes and no credit is being taken in the analysis for the long-term ability of improved waste forms to reduce dispersion

of the waste into respirable particles. However, in 4 cases, other waste streams previously found unacceptable for near-surface disposal were found to be suitable for hot waste facility disposal. These were Cases 15, 16, 18, and 19 and the costs and impacts of these 4 cases are presented in Table 4.21. All 4 cases involve use of the 25 mrem (whole body) dose limitation criteria.

As shown in Table 4.21, about half of the waste which was previously determined to be unacceptable for near-surface disposal in the 4 cases is found to be acceptable for hot waste facility disposal. However, design and operation costs are raised above the previous cases, and the total costs for mined cavity or repository disposal are still higher than equivalent cases using the other two alternative dose limitation criteria.

4.5.4 Selection of Preferred Alternative

Based upon the preceding analyses, a performance objective for potential inadvertent intrusion may be established. Establishing the performance objective requires establishing a dose limitation criteria for intrusion as well as a time limitation for active institutional controls.

The preferred dose limitation criteria objective selected by NRC is the same as the maximum unrestricted area exposures as set out in 10 CFR Part 20, or 500 mrem/yr to the whole body. A dose limit in the range of 25 mrem/year was judged to result in considerably more costs, more change in existing practices, and greater reduction in disposal efficiency than the other two alternatives. This is especially important considering the hypothetical nature of the intrusion event. The 5 rem alternative was seen to involve approximately the same costs and impacts as the 500 mrem alternative. The higher dose limit, however, could potentially allow disposal of larger quantities of long-lived isotopes, which could result in moderately higher intruder hazards which could extend for long time periods. Therefore, 500 mrem/yr was selected as a general dose limitation guideline. This limitation agrees with the concerns of the four regional workshops. In this regard, it was also observed in the above analysis that a higher limitation could actually be safely used for shorter-lived isotopes such as Cs-137. Use of such a limit would have no effect on the longer-term hazard to an intruder.

The second part of the inadvertent intrusion performance objective is how long should credit be given to active institutional controls to prevent such intrusion. A time period that is too short could result in very high disposal costs for much of the LLW. A period that is very long, on the other hand, may place an undue burden on future generations. NRC analyzed alternative institutional control periods of 50, 100, 150, and 300 years to see if there was any technical preference for selecting one time period over another. From the analysis, there did not appear to be any overly compelling numerical reason to adopt a particular institutional control period. NRC believes, however, that institutional controls will last at least 50 years. 300 years appeared to be too long of a time period and did not offer any compelling numerical advantage over 150 years. The preferred alternative was, therefore, in the range of 100 to 150 years. NRC selected 100 years as the preferred institutional control period. This period of time agrees with previous estimates on the effective

Table 4.21 Comparison of Cases Incorporating a Hot Waste Facility

Case Description and Impact Measures		Case 15	Case 16	Case 18	Case 19
Case Description:					
Dose limitation criteria (mrem)		25	25	25	25
Waste spectrum		1	1	3	4
Institutional control period (yrs)		100	100	100	100
Segregation (yes/no)		No	Yes	Yes	Yes
Intruder Impacts:					
Body (mrem)					
o 100	C	1.23E+0	1.75E+0	3.53E+0	2.11E+0
	A	2.38E+0	1.59E+0	6.18E-1	1.28E+0
o 500	C	2.50E-1	2.50E-1	2.60E+0	6.90E-1
	A	3.08E-1	3.08E-1	2.88E+0	8.06E-1
Bone (mrem)					
o 100	C	1.80E+0	2.03E+0	3.68E+0	2.31E+0
	A	5.84E+0	3.90E+0	2.46E+0	5.08E+0
o 500	C	1.66E+0	1.66E+0	8.03E+0	3.19E+0
	A	1.23E+0	1.23E+0	5.35E+0	2.30E+0
Volumes: (m^3)					
Regular		3.32E+5	5.18E+5	3.16E+5	1.52E+5
Layered		5.70E+5	3.84E+5	1.65E+5	3.39E+4
HWF		4.97E+4	4.97E+4	2.93E+3	2.93E+3
Not acceptable		4.73E+4	4.73E+4	9.26E+3	4.89E+4
Disposal Costs: ($)					
Design and op.		2.15E+8	2.16E+8	1.92E+8	1.85E+8
Postoperational		3.82E+7	3.82E+7	3.82E+7	3.82E+7
Total NSD:					
Mined Cavity: ($)		2.42E+7	2.42E+7	4.74E+6	2.50E+7
Repository: ($)		2.46E+8	2.46E+8	4.82E+7	2.54E+8

length of active institutional controls made by EPA and also is consistent with the consensus of the regional workshops. NRC identified no overriding social or political rationale for selection of one time period over another. Based on the comments received on the preliminary draft of Part 61 and the workshops held, the general consensus was that 100 years was about the right time period upon which reliance should be placed on active institutional controls.

4.6 DEVELOPMENT OF TECHNICAL CRITERIA

Based on the preceding analysis, NRC selected minimum requirements that should be considered and applied in all cases to help ensure that the performance objective will be met. The results indicate that with modest increases in cost (relating to improving the form and properties of waste shipped for disposal, improvements in the design and methods of disposal for certain high activity wastes, and application of institutional controls for a reasonable period of time), the potential impacts to an inadvertent intruder can be greatly reduced.

The following subsections present the technical requirements selected, based on the preceding analysis, to assure protection of the inadvertent intruder. The requirements deal with each of the four basic components of any disposal facility: institutional controls, site characteristics, design and operations, and waste form and packaging. The requirements are set out in general terms with the intention of setting out the overall intent of the requirements rather than providing the precise regulatory wording. Some of the requirements are new and are derived from the above analysis. Others only involve a codification of existing practices currently being applied at the existing disposal facilities.

4.6.1 Institutional Control Requirements

1. Requirement

   Disposal of radioactive waste received from other persons shall be permitted only on land owned by the federal government or by the state government in which the site is located.

Analysis

Present requirements in Section 20.302(b) of 10 CFR Part 20 require federal or state government ownership of land used for commercial disposal of radioactive waste. At 5 of the 6 existing commercial disposal sites, the land used for waste disposal was purchased by the disposal facility operator who then deeded the land to state ownership. The state then leased the land back to the disposal facility operator. At the commercial disposal facility located in the Hanford Reservation, however, the disposal site land is owned by the federal government. In this case, the land was leased by the federal government to the state of Washington, who then subleased the land to the disposal facility operator. NRC believes that the existing requirement for government land ownership should be continued since there is a higher degree of assurance that the state or federal

government will continue to exist for longer periods of time than a private organization. The need for control of near-surface disposal facilities will last for one hundred years. Adapting this provision in 10 CFR 61 for state or federal ownership of land used for disposal of waste received from other persons would involve no change from existing regulations and no increase in cost over what is already being done today. The costs for government land ownership have been included in the base case analyses of costs and impacts.

2. Requirement

The land owner shall carry out an active institutional control program to physically control access to the site following transfer of control from the site operator. Active institutional controls shall not be relied upon for more than 100 years.

Analysis

Active institutional control is an extension of the existing requirement for government land ownership and involves the physical controls and surveillance of a site carried out by the state or federal government land owner to preclude inadvertent intrusion and carry out other control and surveillance activities. As a part of these control and surveillance activities, the site owner would carry out an environmental monitoring program to check on the continued performance of the site, administer funds to cover the costs of these "active institutional control" activities, carry out minor maintenance activities that may be required (e.g., upkeep of a security fence), and carry out other necessary responsibilities. An active institutional control program is a codification of existing practice at the existing sites including the need to collect and administer funds to cover the costs of this control program.

Given such an active control program, a basic question remained, however, regarding how long reliance can or should be placed on such active institutional controls. NRC recognizes that such active controls could very well last for several hundreds of years based on the actions of those responsible for such a program in the future. For purposes of Part 61, however, NRC will assume such controls can only be relied upon for 100 years. The costs for 100 years of active institutional control have been included in the base case analysis of costs and impacts.

3. Requirement

Disposal cells shall be surveyed, mapped, and the location and hazard of the disposal facility recorded with a number of local, state, and federal agencies.

Analysis

By definition, an inadvertent intruder is one who unknowingly contacts the radioactive waste without knowing that it is there. Therefore, it is important to consider passive methods by which the presence of hazardous materials may be communicated to future generations, thus minimizing or potentially even eliminating the possibility of inadvertent intrusion. First, transferring

records of the disposal facility location to a diversity of locations throughout all levels of government will help to ensure that an awareness of the potentially hazardous condition at the site will be known to future generations. Diverse locations could include local libraries, local zoning boards, state land development offices, local and statewide executive offices, and federal archives. The cost for this is low. Depending on site-specific conditions, the government could put the land to controlled productive use during the active institutional control program where the disposed waste would not be disturbed. The potential hazard of the disposal facility could also be recorded upon the deed or title to the land.

It is also important to maintain an accurate record of the locations at a disposal facility which are actually used for waste disposal. The locations of disposal cells can be readily surveyed, mapped, and referenced to a benchmark such as a USGS benchmark. This practice has a number of advantages:

- Surveys help to perpetuate a record of the disposal facility.
- Surveys help to provide quality assurance checks that disposal cells used for waste disposal are constructed according to approved specifications.
- Care in recording the locations of disposed waste serve to help identify disposal cells in case remedial action is required in the future.

All of the disposal facilities presently operating now require that locations of disposal trenches be surveyed and referenced to a benchmark. The cost for such surveys has been included in the costs for the reference facility.

4.6.2 Site Characteristics

The following site suitability requirements reflect existing practice to consider future population growth, land use development, and potential natural resources at the site. Since they reflect existing practice the cost and impacts are considered through the base case analysis, and no cost benefit analysis has been performed.

Requirement

1. Within the region or state where the facility is to be located, a disposal site should be selected so that projected population growth and future developments are not likely to affect the ability of the disposal site to meet the intruder performance objective.
2. Areas must be avoided having economically significant natural resources, which, if exploited, would result in failure to meet the intruder performance objective.

Analysis

In siting of near-surface disposal facilities, areas of high population density should be avoided to help reduce the potential of inadvertent intrusion after

the end of institutional controls. Areas that are remote and less densely populated would generally be less likely to be immediately utilized, reducing the potential for inadvertent intrusion. In addition, the site should not have any extensive natural resources on the ground surface, in the hydrogeologic units used for disposal or at greater depth such as to encourage drilling or excavation within the site after institutional controls end. Sites having resources at much greater depths below the disposed waste would be acceptable provided the exploitation of such resources would not affect the performance of the facility (e.g., lead to increased ground-water contact with disposal waste or result in decreased ground water travel times).

4.6.3 <u>Design and Operations</u>

<u>Requirement</u>

1. Higher concentration waste presenting higher hazard potential to an inadvertent intruder must be disposed of at a minimum depth (to the top of the waste) of 5 meters below final grade (or the surface of the cover) or must be disposed of with natural or engineered barriers that are designed to protect against inadvertent intrusion for at least 500 years.

2. Compressible wastes shall be segregated from and disposed of separately from waste in a stable noncompressible form.

<u>Analysis</u>

Many alternatives may be applied to reduce the impacts of inadvertent intrusion. Many have either been applied in the past at existing disposal facilities or will require only minor modification to existing designs and operational practices. Those that NRC examined in the earlier analysis were:

- Use of thicker disposal cell covers
- Use of special waste disposal cells such as caissons, walled trenches, or other "engineered structures"
- Layered disposal
- Slit trench disposal
- Grouting
- Engineered intruder barrier

The results of the earlier analysis indicate that depth of burial (i.e., layering the waste) is the easiest to implement technically and costs the least. In this case, the more active waste would be preferentially placed toward the bottom of the trench. The potential intruder would tend to contact the lower-activity waste. Since many of high-activity waste streams which could be disposed in this manner would also be expected to contain high-surface gamma radiation levels, this technique would also help to reduce potential occupational exposures to disposal facility workers. The hot waste facility analyzed--a type of engineered structure--is probably the most difficult to implement technically and costs the most. Others fall in between except for significantly different methods of disposal (e.g., mined cavity disposal). To

maintain flexibility in assuring protection of the inadvertent intruder by placing greater controls on the higher activity wastes, NRC selected no specific prescriptive requirement. Such flexibility will allow for regional differences in site characteristics, different facility designs, and individual preferences of disposal facility operators.

In determining which waste streams may not be acceptable for near-surface disposal, one of the questions is how long barriers to a potential intruder may be expected to last. Such barriers, of course, would be expected to last several hundred years but not forever. Some barriers may last longer than others. For example, the effectiveness of the "hot waste facility" discussed above to deter the actions of a potential intruder would be expected to last longer than a disposal method such as layering. From the analyses performed earlier in the EIS, it can be seen that due to radioactive decay, exposures to a potential intruder from almost all waste streams typically considered to be LLW have fallen to a few millirems after a few hundred years--e.g., 500 years. After 500 years, only a few waste streams are estimated to result in potential intruder exposures of a few hundred millirems. Very few (e.g., one or two streams) having small volumes are estimated to result in potential intruder exposures exceeding 500 mrem after 500 years.

The segregation of compressible wastes is discussed in the concluding section on waste form.

4.6.4 Waste Form and Packaging

Requirement

Higher activity waste shall have structural stability. Structural stability can be provided by the waste form itself, processing the waste to a stable form, or placing the waste in a disposal container or structure that provides stability after disposal. Void spaces within the waste and between the waste and its package shall be reduced to the extent practicable. The waste must maintain its physical dimensions and consistency under conditions of the compressive load, radiation, and biodegradation to be encountered in disposal.

Analysis

In general, placing the higher activity waste into a stable form and disposing of them together in a separate disposal unit segregated from compressible wastes reduces the impacts to a potential inadvertent intruder. The waste is less available for inhalation and uptake, and someone intruding into the site would be more likely to identify that they were not digging in soil if they found the remains of solid waste, and would take action to find out what it was before proceeding too far. Other details regarding analysis of this requirement, alternatives considered, and the preferred alternative selected by NRC are set out in Chapter 5.

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Chapter 5

LONG-TERM ENVIRONMENTAL PROTECTION--PRESENTATION AND ANALYSIS OF ALTERNATIVES

5.1 INTRODUCTION

This chapter reviews a number of potential pathways for long-term release of radionuclides to the environment from disposed waste. These pathways include:

- Ground-water migration;
- Gaseous releases from decomposing waste;
- Plant and animal intrusion; and
- Wind and surface water erosion and transport.

Of these, NRC staff believes that the most significant pathway is ground-water migration. Gaseous releases do not have a large impact and can be reduced by assuring stable site conditions. Impacts from plant and animal intrusion are site-specific and can be reduced through engineering designs applied to reduce ground-water migration and potential intruder exposures. Erosion is a slow, long-term process which can be controlled through proper siting and good operational techniques.

Section 2 below analyzes ground-water migration presenting the impacts of the base case "no action" alternative and the incremental changes in those impacts due to application of a range of alternatives. In the analysis of alternatives, a number of cases are considered which represent a range of near-surface disposal technology options and waste forms. The results of these case study analyses illustrate a range of potential radiological impacts, disposal costs, and long-term maintenance requirements representative of application of current disposal technology. In these cases, the results from the preceding intruder analysis are incorporated into the case study analyses. This is done to account for any design and operational changes that may be required due to consideration of intruder protection.

Section 3 analyzes development of a performance objective for long-term releases to ground water leading to selection of a preferred performance objective. Section 4 reviews the other three potential environmental release pathways, presenting typical impacts based on existing published data in addition to ways to mitigate those impacts. Section 5 reviews technical requirements derived from the analyses, plus those involving codification of existing practice, that should be applied in the near-surface disposal of waste.

5.2 GROUND-WATER MIGRATION

To analyze potential ground-water migration impacts from near-surface radioactive waste disposal, NRC staff has adopted use of a model reference waste disposal facility located in a humid environment. To provide a reasonable yet conservative analysis, movement of radionuclides from the disposed waste and through ground water has been modeled based upon calculational procedures

derived from Darcy's Law. (Additional information is contained in References 1 and 2.) As depicted in Figure 5.1, a disposal cell (or group of disposal cells) is assumed to be located within an unsaturated zone of thickness (Zo). Both the unsaturated zone and the underlying saturated zone (aquifer) are assumed to be stationary, homogeneous, and isotropic, and the fluid moving through these zones is assumed to be incompressible and of constant viscosity. The disposal cell is filled with a heterogeneous mixture of waste streams ranging from streams having very low activity to streams having relatively high activity. Each waste stream contains a particular suite of radioisotopes and, if contacted by water, leaches at a particular rate. Precipitating water striking a covered disposal cell may percolate into and flow through the cell and leach out a portion of the radionuclides contained in the waste.

The source term of each radioisotope in the disposed waste leaving the bottom of the disposal cell is given by (Jo) in Curies/year. The radioactive source moves down through the unsaturated zone with hydraulic velocity (w), and mixes with the water in the saturated zone. The water in the saturated zone, carrying the radiocontaminants with it, is then assumed to flow horizontally with hydraulic velocity (v). As illustrated in Figure 5.1, the contaminated ground water can be visualized as crossing a discharge surface at some arbitrary distance (x) downstream of the disposal cell(s), having a radionuclide activity equal to J (in Ci/yr).

The source term (Jo), and the factors that go into its determination, are discussed more extensively in Appendix G and Reference 1. It is a somewhat complicated function of site environmental conditions, disposal facility design and operating practices, waste characteristics (including waste leaching characteristics, radionuclide concentrations, chemical content, and structural stability), and the potential for intrusion by humans, plants, or animals. To provide a reasonable yet conservative analyses, the reference facility is assumed to experience a relatively high precipitation rate (1.17 m/yr) and a high natural percolation rate (PERC = 180 mm/yr). The percolation of water into disposal cells at the reference facility is a variable depending upon facility design and operating practices and waste form. For example, unstable waste forms would result in higher percolation of rainwater into disposal cells (due to subsidence of disposal cell covers), while improved thicker disposal cell covers and compaction techniques would reduce percolation. If the unstable waste streams were disposed mixed with the stable waste streams, then all of the wastes would experience higher percolation rates. However, if the unstable waste streams were disposed segregated from the unstable waste streams, then only the unstable waste streams would experience the higher percolation.

Percolation rates into disposal cells may also be increased through intrusion by inadvertent humans, deep-rooted plants, and burrowing animals. During the active institutional control period following license termination, the site owner would be expected to survey and maintain the disposal facility, to prevent inadvertent intrusion by humans, and to control and limit potential intrusion by deep-rooted plants and burrowing animals. However, following the active institutional control period, breakdowns in such surveillance and control

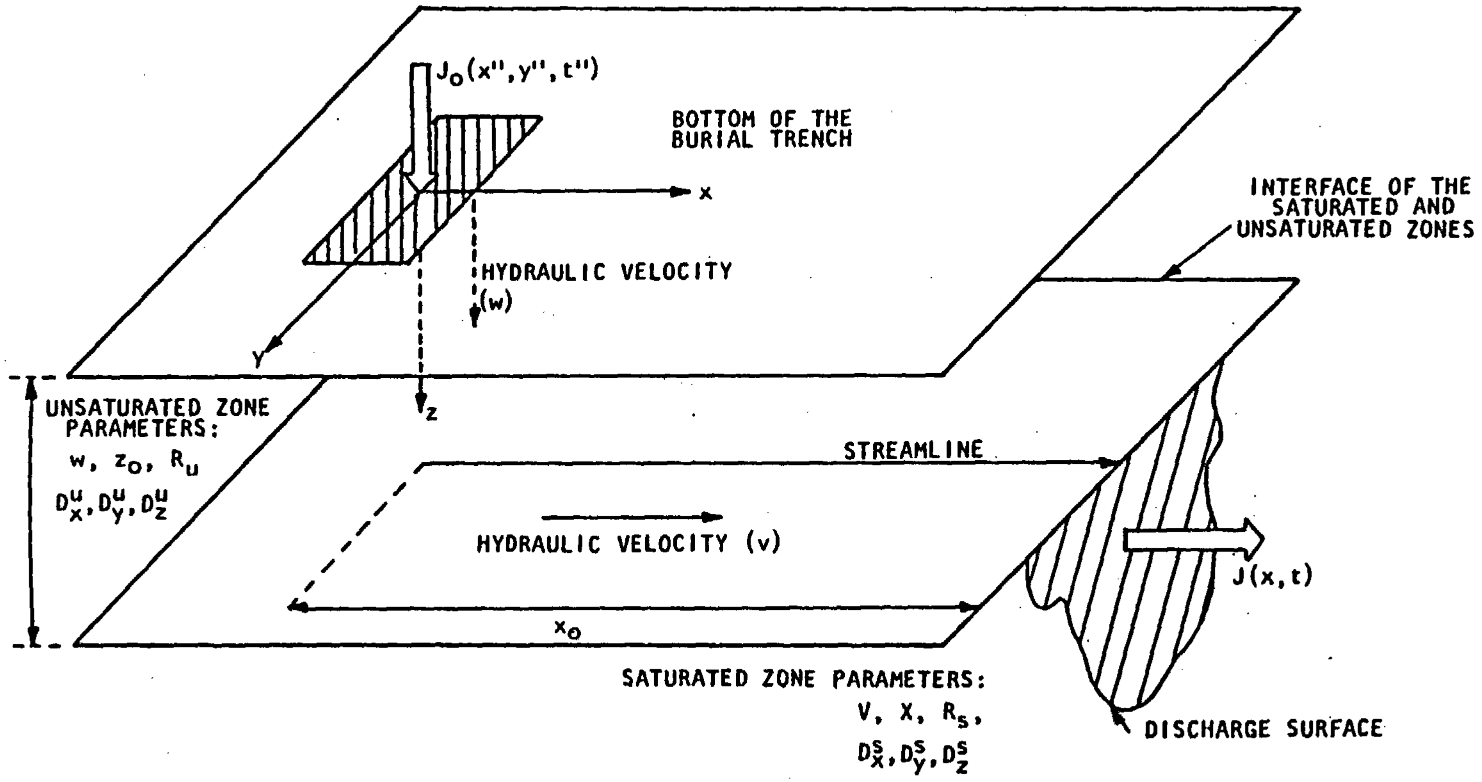

Figure 5.1 Geometry of Ground-Water Scenario

activities are postulated to occur. Therefore, for disposal facility designs which depend upon improved covers to reduce percolation (e.g., a walled trench, a compacted clay cap), a reduction in the effectiveness of these disposal covers is assumed at a time 100 years following license termination. The extent of this reduction in effectiveness is discussed in Appendix G. Briefly, however, 90% of the disposal area experiences percolation equal to twice the previously assumed value for that case. The remaining 10% experiences an even higher percolation, the specific value of which depends upon the case considered.

As another example, the leaching of radionuclides from the disposed waste depends upon the radionuclide content, whether the wastes are solidified, and the chemical content of the waste. Unsolidified waste streams are assumed to leach at a fraction corresponding to leach fractions measured under totally saturated conditions at the Maxey Flats, Kentucky and West Valley, New York disposal facilities. Solidified waste forms are assumed to leach at lower rates based upon an approximation derived from experimental data (Refs. 1, 3). However, increased leaching of solidified waste forms is assumed if chelating agents are present. If wastes containing chelating agents or organic chemicals are disposed in a segregated manner from other waste streams, then the higher leaching fractions are only applied to the segregated streams; otherwise, the higher leaching fraction is applied to all solidified streams.

After the radionuclides have left the disposal cell, the movement of radionuclides through ground water may be estimated by a number of calculation techniques-- many of which may be extremely complicated and require a great deal of site-specific information. Given the generic nature of this analysis, however, a simpler approximation in this EIS is used which allows rapid consideration and comparison of a number of alternatives. This approximation solves the Darcy's Law differential equations in terms of error functions as summarized in Appendix G. (Further information is contained in References 1 and 2.) Basically, however, the disposed waste is modeled as 10 distributed sources or sectors (which is more realistic than the assumption of a point source), as shown in Figure 5.2. Movement of radionuclides out of the sectors and to a biota access location is calculated principally as a function of the ground-water travel time from the sector to the access location, the Peclet number (basically the distance to the access location divided by the longitudinal dispersivity of the medium), and the retardation coefficients of the medium. The retardation coefficients assumed for the reference disposal facility are intended to correspond to soils having moderate permeability (See Table 5.2 in Section 5.2.1) and are radionuclide-specific. In this environmental impact statement, lower retardation coefficients are assumed for radionuclides contained in waste streams assumed to contain or be contacted by chelating agents or organic chemicals.

Radionuclide concentrations may be then determined as a function of time at four principal downstream biota access locations:

1. a well located on the disposal facility and potentially used by an inadvertent intruder following the end of the 100-year active institutional control period;

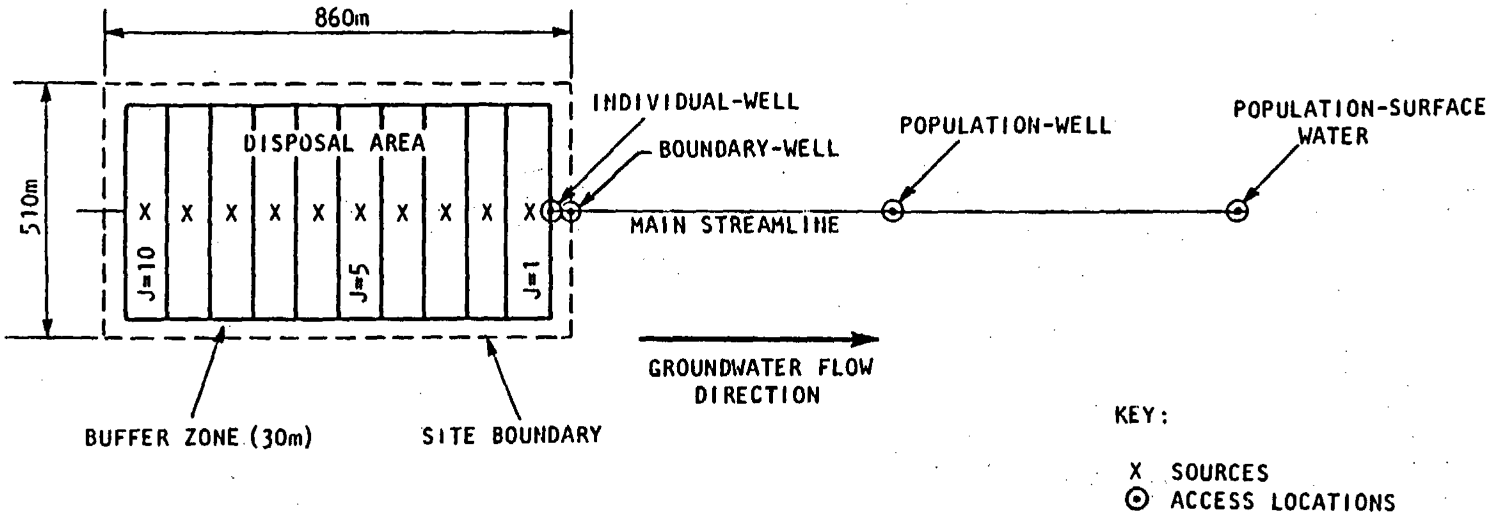

Figure 5.2 Geometric Relationships of Disposal Area and Ground-Water Access Locations

2. a well located at the site boundary which is assumed to be used by a few individuals;

3. a well assumed to be located approximately 500 meters down gradient from the disposal facility and used by a small population of about 100 persons; and

4. a small stream located about one kilometer down gradient from the disposal facility and assumed to be used by a small population of about 300 persons.

Once the concentrations at the biota access locations are determined, potential exposures from consumption and use of the water may be determined for seven bodily organs. These include whole body, bone, liver, thyroid, kidney, lung, and the gastro-intestinal (GI) tract.

As discussed earlier, the calculational procedure first estimates the source term Jo, in curies/year, leaving the disposal cell. However, the concentrations of radionuclides at the biota access locations are also determined by the volume of water with which the released and migrating radionuclides are diluted. All other considerations being equal, the larger the volume of water with which the radionuclides are diluted, the lower the concentration of the radionuclides in the water. The dilution volume is a site-specific variable, and is dependent upon the attributes of the aquifer (thickness, flow rate, dispersivity, etc.), the distance from the release point (the further away from the release point, the greater the mixing that would likely occur), and man-made perturbations such as pumping water from a well.

Given the generic nature of the analysis in this environmental impact statement, reasonable yet conservative assumptions are made regarding the dilution volumes. For the first two biota access locations (intruder well and boundary well), released radionuclides are assumed to be diluted by a volume of water equal to that provided by natural percolation of rainwater upon the disposal area (about 87 acres). (At the reference facility, this volume of water is equal to 63,400 m^3.) Of this volume, the individual using the contaminated water is assumed to withdraw 7700 m^3/year (3.84 gpm), which represents the basic annual needs of a single person living in a rural area (See Appendix G).

For the population well, the dilution volume is assumed to correspond to the annual volume of water withdrawn from a water well pumping at a rate of 100 gpm (200,000 m^3/yr). Small farming communities that utilize ground water for their needs usually have wells that range from 100 gpm to 1,000 gpm depending on the population. For the surface water access location, a stream is assumed having a flow rate of about 5 ft^3/sec (4.5 x 10^6 m^3/yr). A stream having a flow rate of much below this value is unlikely to be used for human consumption.

5.2.1 Description of Base Case No Action Alternative

Base case radiological impacts are calculated for the three base cases summariz in Table 5.1. Case 1 illustrates the potential ground-water impacts of disposi base case waste forms under conditions which promote disposal facility instability

Table 5.1. Base Cases Considered

Case 1 - Base Case-Moderately Permeable Soils

- Regular shallow land burial (SLB) trench (reference site and base case facility design as set out in Appendix E).
- Waste spectrum 1
- SLB with a thin cap
- No segregation of wastes containing chelates
- No segregation of compressible wastes
- Random disposal of waste
- Layering used as an intruder barrier
- Site soils are assumed to have moderate permeability

Case 2 - Base Case-Highly Permeable Soils

- Regular SLB trench
- Waste spectrum 1
- SLB with a thin cap
- No segregation of wastes containing chelates
- No segregation of compressible wastes
- Random disposal of waste
- Layering used as an intruder barrier
- Site soils are assumed to have relatively high permeability

Case 3 - Base Case-Low Permeable Soils

- Regular SLB trench
- Waste spectrum 1
- SLB with a thin cap
- No segregation of wastes containing chelates
- No segregation of compressible wastes
- Random disposal of waste
- Layering used as an intruder barrier
- Site soils are assumed to have relatively low permeability

at a site having moderately permeable soils. Case 2 illustrates the same impacts at a site having highly permeable soils and Case 3 a site having low permeable soils. The three base cases are analyzed to illustrate the relative difference in impacts that may occur due to differences in site-specific ground-water flow conditions. Relative to Case 1, the site for Case 2 is assumed to experience lower leaching due to shorter contact times between percolating water and the disposed wastes, shorter ground-water travel times between the disposed waste and the aquifer, and lower ion exchange. Relative to Case 1, the site for Case 3 is assumed to experience higher leaching (longer contact times), larger ground-water travel times between the disposed waste and the aquifer, and higher ion exchange.

A comparison of the retardation coefficients, contact times and ground-water travel times between the waste and the aquifer assumed for the three cases is included as Table 5.2.

The radiological impacts calculated for Cases 1-3 are conservative but do provide a baseline of data against which potential costs and radiological impacts of alternatives may be assessed. As referred to in Table 5.1, the facility for Cases 1-3 is sited, designed and operated as previously described in Chapter 3 and as set out in detail in Appendix E. The waste is disposed of in a regular shallow land burial trench with a "standard" thin cap.

The waste disposed of at the site is assumed to be that characterized as Waste Spectrum No. 1. "Waste Spectrum 1" refers to the base case waste form--much of which is assumed to be in an easily compressible, readily degradable waste form with relatively high leaching characteristics. Filter sludges and resins are dewatered and little to no compaction is performed for compressible wastes. The waste form for solidified liquids is assumed to be half urea-formaldehyde and half cement. Some liquids--e.g., those from institutional waste generators--are shipped to the disposal facility using absorbents rather than being solidified. Wastes containing organic chemicals, chelating agents, or compressible materials are assumed to be mixed with the higher activity wastes. The waste is also assumed to be randomly disposed into the reference facility, and due to the readily degradable nature of much of the waste, severe subsidence problems are assumed to occur. The facility is assumed to be characterized by potholes and subsidence depressions, leading to sources of rainwater infiltration. Percolation into the waste cells is assumed to be twice as high as the surrounding undisturbed soils. Finally, results from the preceeding intruder analysis are also included such that the higher activity wastes requiring increased intruder protection are disposed on the bottom of the trench. Some wastes, not acceptable for disposal based on the intruder analysis results, are excluded from the analysis.

5.2.2 Costs and Impacts of Base Case No Action Alternative

The base case costs and impacts are summarized on the following three tables which show the impacts and costs for the three cases analyzed. Table 5.3 summarizes the maximum exposures received over 10,000 years for each of the seven organs considered in the analysis from each of the four biota access locations: (1) a well located onsite which is assumed to be used by a potential inadvertent intruder following the end of the active institutional control period, (2) a well located at the site boundary which is assumed to be used by a few individuals, (3) a well assumed to be located approximately 500 meters down-gradient from the disposal facility and used by a small population of about 100 persons, and (4) a small stream located about one kilometer down gradient of the disposal facility, and assumed to be used by a small population of about 300 persons. Also shown is the approximate time, to 10,000 years, that these exposures occur. All exposures listed are to individuals. Table 5.4 illustrates the Case 1 calculated exposures to whole body and thyroid for each of the access locations for a number of time periods after facility closure. Table 5.5 contains a summary of other costs and impacts associated with waste disposal, including short-term population doses due to waste processing and transportation; short-term occupational doses due to waste processing, transport, and disposal; incremental energy

Table 5.2 Comparison of Assumed Environmental Characteristics for Cases 1, 2, and 3

Property	Case 1	Case 2	Case 3
Retardation set used (NRET)	3	2	4
Retardation coefficients			
H-3	1	1	1
C-14	10	10	10
Fe-55	2640	1290	5400
Ni-59	1750	860	3600
Ni-63	1750	860	3600
Co-60	1750	860	3600
Sr-90	36	18	73
Nb-94	4640	2150	10,000
Tc-99	4	3	5
I-129	4	3	5
Cs-135	350	173	720
Cs-137	350	173	7200
U-235	3520	1720	7200
U-238	3520	1720	7200
Np-237	1200	600	2500
Pu-238	3520	1720	7200
Pu-239/240	3520	1720	7200
Pu-241	3520	1720	7200
Pu-242	3520	1720	7200
Am-241	1200	600	2500
Am-243	1200	600	2500
Cm-243	1200	600	2500
Cm-244	1200	600	2500
Infiltrating percolation factor:*	1.16E-3 3.24E-5	1.16E-4 3.24E-6	1.16E-2 3.24E-4
Ground-water travel time from bottom of waste to aquifer (yrs)	10	<<1	60

*This factor is equal to $p \times t_c$. Substituting for t_c, this factor is equal to p^2/nv, where

p = amount of the precipitation (m/yr) that infiltrates into a disposal cell and comes into contact with the waste.

t_c = p/nv = percolation contact time with the waste.

n = waste cell effective porosity

v = speed of the percolating water

The first value for each case is for percolation through a disposal cell cover equivalent to natural percolation at the reference facility (180 mm/yr). The second value is for reduced percolation due to an improved disposal cell cover for which the integrity of the cover can be reasonably assumed. See Appendix G.

Table 5.3 Base Radiological Impacts for Cases 1-3

	(mrem/yr)						
Cases*	Body	Bone	Liver	Thyroid	Kidney	Lung	GI
(1)							
Intruder	3.044E+1	3.063E+0	3.044E+1	8.462E+2	3.044E+1	3.044E+1	3.044E+1
Well	(100)	(6,000)	(100)	(4,000)	(100)	(100)	(100)
Boundary	1.571E+2	3.061E+0	1.571E+2	8.462E+2	1.571E+2	1.571E+2	1.571E+2
Well	(70)	(6,000)	(70)	(4,000)	(70)	(70)	(70)
Population	4.434E-1	6,197E-1	2.121E-1	2.673E+2	3.887E-1	1.246E-1	2.839E-1
Well	(6,000)	(8,000)	(8,000)	(4,000)	(6,000)	(8,000)	(6,000)
Surface	1.781E-2	2.685E-2	7.190E-3	1.218E+1	1.526E-2	5.375E-3	1.040E-2
Water	(8,000)	(10,000)	(8,000)	(4,000)	(8,000)	(10,000)	(8,000)
(2)							
Intruder	9.505E+1	1.808E+0	9.498E+1	2.678E+2	9.504E+1	9.495E+1	9.501E+1
Well	(100)	(1,000)	(100)	(800)	(100)	(100)	(100)
Boundary	1.445E+2	1.620E+0	1.445E+2	2.678E+2	1.445E+2	1.445E+2	1.445E+2
Well	(70)	(2,000)	(70)	(2,000)	(70)	(70)	(70)
Population	5.538E-2	1.058E-1	3.210E-2	2.675E+1	4.991E-2	2.124E-2	3.943E-2
Well	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)
Surface	2.988E-3	7.152E-3	1.926E-3	1.219E+0	2.731E-3	1.432E-3	2.242E-3
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
(3)							
Intruder	9.344E+1	7.529E+0	9.344E+1	8.025E+2	9.344E+1	9.344E+1	9.344E+1
Well	(100)	(6,000)	(100)	(900)	(100)	(100)	(100)
Boundary	2.637E+1	7.266E+0	2.637E+1	8.246E+2	2.637E+1	2.637E+1	2.637E+1
Well	(120)	(6,000)	(120)	(2,000)	(120)	(120)	(120)
Population	1.025E+0	5.014E+0	1.010E+0	6.508E+2	1.022E+0	1.003E+0	1.014E+0
Well	(10,000)	(10,000)	(10,000)	(4,000)	(10,000)	(10,000)	(10,000)
Surface	4.314E-2	1.947E-1	4.029E-2	3.522E+1	4.243E-2	3.896E-2	4.108E-2
Water	10,000)	(10,000)	(10,000)	(4,000)	(10,000)	(10,000)	(10,000)

*The radiological impact estimates shown for each access location are the maximum over 10,000 years as calculated using the GRWATER code. The second number, in parentheses, is the year after facility closure that the calculated impacts occur. The impacts are listed as obtained from the code output and should not be interpreted as representing accuracy to three significant digits.

Table 5.4 Summary of Case 1 Calculated Exposures to Whole Body and Thyroid as a Function of Time

	(mrem/yr)							
	Whole Body				Thyroid			
Year Following Closure	Intruder Well	Boundary Well	Population Well	Surface Water	Intruder Well	Boundary Well	Population Well	Surface Water
40	9.775E+1	0	0	0	9.775E+1	0	0	0
50	5.012E+2	0	0	0	5.012E+2	0	0	0
60	2.854E+2	5.003E-1	0	0	2.854E+2	5.003E-1	0	0
70	1.625E+2	1.571E+2	0	0	1.625E+2	1.571E+2	0	0
80	9.257E+1	9.257E+2	0	0	9.257E+1	9.257E+1	0	0
90	5.272E+1	5.272E+1	0	0	5.272E+1	5.272E+1	0	0
100	3.044E+1	3.002E+1	0	0	3.044E+1	3.002E+1	0	0
120	1.958E+1	9.741E+0	0	0	1.957E+1	9.741E+1	0	0
200	4.414E-1	4.349E-1	0	0	8.491E+1	8.487E+1	0	0
300	2.315E-1	1.197E-1	0	0	1.644E+2	8.459E+1	0	0
400	2.489E-1	2.364E-1	2.209E-7	0	1.692E+2	1.692E+2	2.209E-7	0
500	4.656E-1	2.369E-1	3.147E-9	0	2.539E+2	1.695E+2	3.147E-9	0
600	4.644E-1	3.548E-1	2.190E-11	0	2.539E+2	2.538E+2	2.190E-11	0
700	5.811E-1	5.160E-1	1.014E-13	0	3.384E+2	2.944E+2	1.014E-13	0
800	6.079E-1	5.798E-1	5.074E-16	1.625E-18	3.586E+2	3.384E+2	5.074E-16	1.625E-18
900	6.967E-1	6.930E-1	2.108E-18	2.321E-20	4.230E+2	4.203E+2	2.108E-18	2.321E-20
1,000	8.006E-1	6.955E-1	8.965E-11	1.589E-22	4.973E+2	4.231E+2	6.416E-8	1.589E-22
2,000	1.460E+0	1.454E+0	2.235E-1	1.008E-19	8.461E+2	8.461E+2	1.600E+2	7.232E-17
4,000	1.618E+0	1.617E+0	3.851E-1	1.699E-2	8.462E+2	8.462E+2	2.673E+2	1.218E+1
6,000	1.695E+0	1.695E+0	4.434E-1	1.698E-2	8.462E+2	8.462E+2	2.673E+2	1.218E+1
8,000	7.549E-1	8.278E-1	3.998E-1	1.781E-2	2.200E+2	2.722E+2	2.155E+2	1.218E+1
10,000	3.880E-1	3.880E-1	1.226E-1	1.034E-2	2.623E+1	2.623E+1	8.290E+0	3.891E+0

Table 5.5 Other Impacts Associated With Cases 1-3

Impacts	Case 1	Case 2	Case 3
Short-term population exposures: (man-mrem)			
Processing at waste generator**	-	-	-
Processing at regional processing center	0	0	0
Waste tranportation	5.10E+5*	5.10E+5	5.10E+5
Short-term occupational exposures: (man-mrem)			
Processing at waste generator**	-	-	-
Processing at regional processing center	0	0	0
Waste transportation	5.82E+6	5.82E+6	5.82E+6
Waste disposal	2.46E+6	2.46E+6	2.46E+6
Waste generation and transport costs: ($)			
Processing at waste generator**	-	-	-
Processing at regional processing center	0	0	0
Waste transportation	2.05E+8	2.05E+8	2.05E+8
Disposal costs: ($)			
Design & Operational	1.88E+8	1.88E+8	1.88E+8
Postoperational	3.82E+7	3.46E+7	4.99E+7
Total	2.26E+8	2.23E+8	2.38E+8
Unit ($/m^3)	231	227	243
Energy use: (gal)**	-	-	-
Land use: (m^2)	3.40E+5	3.40E+5	3.40E+5
Waste volume disposed: (m^3)			
Regular:			
Chemical-stable	9.26E+3	9.26E+3	9.26E+3
Chemical-unstable	1.15E+5	1.15E+5	1.15E+5
No chemical-stable	2.22E+5	2.22E+5	2.22E+5
No chemical-unstable	5.34E+5	5.34E+5	5.34E+5
Total	8.81E+5	8.81E+5	8.81E+5
Layered:			
Chemical-stable	9.62E+2	9.62E+2	9.62E+2
Chemical-unstable	1.87E+3	1.87E+3	1.87E+3
No chemical-stable	3.70E+2	3.70E+2	3.70E+2
No chemical-unstable	9.59E+4	9.59E+4	9.59E+4
Total	9.91E+4	9.91E+4	9.91E+4
Hot Waste Facility:	0	0	0
Total Disposed:	9.80E+5	9.80E+5	9.80E+5
Total volume not acceptable: (m^3)	1.94E+4	1.94E+4	1.94E+4

*The notation 5.10 E+5 means 5.10×10^5

**In this chapter, population exposures due to waste processing by waste generators, occupational exposures due to waste processing by waste generators costs due to waste processing by waste generators, and energy use are presented as impacts and costs in addition to those associated with waste spectrum 1.

use in terms of total gallons of fuel; and committed land use. Total costs and impacts from processing, transport, and disposal of an entire spectrum of waste over 20 years are listed.

Ground-Water Impacts

As shown in Tables 5.3 and 5.4 the calculated doses are high for the base case. For Case 1, maximum doses to all organs, with the exception of the thyroid and bone are about 30 millirem at the intruder well, exceed 150 mrem at the boundary well, are on the order of 0.1 mrem at the population well, and are on the order of 10^{-2} to 10^{-3} mrem at the surface body water. Thyroid doses are in the range of 800 mrem at the intruder and population wells, 270 mrem at the population well, and 12 mrem at the surface water body. It is not likely that doses to actual individuals could ever be this high, notwithstanding the conservatism of the analysis. For one thing, potholes and depressions would be filled in by the site owner, thus reducing the percolation. In addition, ground-water movement of radionuclides would almost certainly be detected through monitoring wells long before appreciable exposures could be received by the public. A more important point is that a considerable amount of effort and cost to the site owner may be required to prevent such exposures from occurring. This is discussed in more detail later.

Table 5.4 provides an illustration of potential whole body and thyroid doses for Case 1 as a function of time. Exposures to whole body at the intruder and boundary wells are principally due to tritium, which constitutes (on a curie basis) the largest part of the radionuclide inventory at the reference disposal facility. Tritium has the largest leach fraction of the radionuclides considered and is also assumed to migrate with the speed of the ground water. Given the nature of the assumptions in the calculations, tritium leaves the disposed waste more or less as a slug flow. Due to dispersion, however, the edges of the pulse trail out. As the slug of contamination moves past the intruder well and then the boundary well, potential exposures at each well rise to a maximum and then fall to another low value. Tritium, however, has a relatively short half-life and due to radioactive decay has only a very minor impact at the population well and surface water body.

However, total impacts are from all radionuclides, each of which may have a different leach rate, retardation coefficient, and decay constant. The maximum concentration of each radionuclide in ground water therefore arrives at the access location of interest at different times--often at widely different times up to thousands of years. For example, typically following the tritium would be Tc-99 and I-129, followed by C-14. If graphed, the result would be typically a lumpy dose curve. As shown in Table 5.4 after an initial hump within a few hundreds of years, a low period is observed after which one or more humps are observed in the range of thousands of years. An exception is the thyroid, which illustrates a broad maximum which persists for long time periods. This dose is mainly a result of iodine-129.

As shown in Table 5.4, the calculated maximum exposures at the intruder well over 10,000 years occur at about 50 years following facility closure and are in the range of 500 millirem. However, prior to the assumed end of the 100-year

active institutional control period, the site owner would preclude inadvertent intrusion and possible construction and use of the intruder well. The maximum intruder well exposures for whole body are therefore determined to occur at about 100 years following disposal facility closure, or right at the assumed end of the active institutional control period. This results in larger whole body exposures at the boundary well than at the intruder well. Maximum thyroid exposures at the intruder well occur in the neighborhood of 4,000 years following facility closure.

Cases 2 and 3 illustrate the effect of some different assumptions regarding site-specific conditions. In Case 2, relatively low retardation coefficients are assumed, indicative of a sandy soil. The same sandy soil is used as a backfill around the waste packages, resulting in a reduced contact time with infiltrating rainwater. In Case 3, on the other hand, the soils in which the waste is disposed are assumed to be relatively impermeable, and have higher retardation coefficients than that of the reference facility. However, the same relatively tight soils are assumed to be backfilled into the disposal trenches. This results in relatively higher contact times with infiltrating precipitation. As can be seen in Table 5.3, Case 2 seems to generally exhibit somewhat lower exposures than Case 1 for the population well and surface water body. The opposite trend appears to occur at these two access locations for Case 3. For the intruder well and the boundary well, a clear-cut trend is not seen. Calculated exposures for Cases 2 and 3 are sometimes higher, and sometimes lower, than those for Case 1, depending upon the organ considered. For thyroid exposures at the boundary well, for example, calculated potential maximum exposures for Case 2 are about a factor of 3 lower than for Case 1. These calculated exposures occur over a very long time period, however--i.e., over a broad flat curve lasting greater than 9,000 years. Maximum thyroid exposures for Case 3 are in the same range as those calculated for Case 1 but the time period over which the maximum exposures occur is less pronounced.

This should not be interpreted to conclude that disposal sites having extremely permeable soils are the best for waste disposal or that sites having very impermeable soils should be avoided. The point is the importance of minimizing the quantity of radionuclides released from the waste. After the radionuclides have been released from the waste, the control one has over potential exposures is diminished. One has to depend upon ion-exchange properties in soil--properties which are difficult to predict with certainty.

The relative impacts of other options regarding near-surface waste disposal--that of reducing the quantity of water infiltrating into the trench and of reducing the radioactivity mobilized by the infiltrating water--is discussed extensively in subsequent cases. Prior to this, however, base case costs and short-term radiological impacts are examined for the three cases. This provides a basis against which other options may be compared.

5.2.2.1 Other Impacts

Base case costs and short-term radiological impacts are shown in Table 5.5 and consist of waste processing and transportation exposures, occupational exposures, costs, incremental energy use, and land use. Also shown are the waste volumes

disposed as well as individual and population intruder exposures to whole body and bone. Populational exposures from processing wastes at all generating facilities are not calculated for waste spectrum 1 as waste spectrum 1 is meant to represent conditions in which little or no waste processing is performed other than that required to meet safety requirements for transportation and disposal facility waste handling operations. In addition, such impacts are already considered as part of licensing such facilities. (This EIS is interested in the incremental exposures above the base case exposures.) Potential impacts from processing wastes at a regional processing center are also zero for the reference waste spectrum 1. (No regional waste processing is assumed to occur for waste spectrum 1.)

Total transportation population exposures are an estimated 510,000 man-millirem for 20 years delivery of waste to the disposal facility. This exposure was calculated assuming an average waste transport distance of 400 miles (one way) and an assumed population dose of 0.018 man-millirem per shipment per mile. In addition, each shipment is assumed to make one stop during the 400-mile trip, resulting in a population dose of 2.0 man-mrem per shipment stopover. The total population exposed is assumed to be 1.5×10^5 persons during transit and 500 persons per stopover.

Short-term occupational exposures are calculated as the total exposures over 20 years of (1) waste processing activities, (2) waste transportation, and (3) waste disposal. Occupational exposures from normal waste handling and packaging to meet DOT transportation requirements and to meet safety requirements at disposal facilities (e.g., specific packaging criteria for biological wastes, solidification of liquids) are not estimated for waste spectrum 1. These would be expected to vary widely among the many thousands of NRC and Agreement State licensees. However, additional potential exposures due to the additional waste treatment processes considered in waste spectra 2-4 are estimated as part of the impacts of these spectra. Occupational exposures due to waste transportation and waste disposal are estimated as about 5.82 and 2.46 man-millirem per m^3 of waste transported and disposed. Again, as no waste processing activities are assumed to take place at a regional processing center for waste spectrum 1, no occupational doses due to waste processing at the regional center are calculated for Cases 1-3.

Disposal facility occupational exposures are calculated as approximately 123,000 man-mrem/year. Assuming a total exposed working crew of about 45 persons, this calculates as an average estimated 2.73 rem per year per individual worker, which is within the general range of occupational exposures currently experienced at operating disposal facilities.

Costs are broken down into processing costs, transportation costs, and disposal costs. For waste spectrum 1, minimal waste processing is assumed to occur. The actual costs experienced by a waste generator are a function of many variables, including the characteristics of the waste processed, the volume of the waste processed, and the design of the waste processing equipment, if any. Processing costs are presented in this section as additional costs to those associated with waste spectrum 1.

Transportation costs may vary widely for different waste generators depending upon the distance from the waste generator to the disposal facility and the characteristics of the waste disposed. Information regarding the assumptions used to determine these costs are provided in Appendix G. For this EIS, a base case transportation cost of $205 million is estimated for transportation of about 50,000 m^3 of waste per year over 20 years ($209.2 per m^3 of waste).

Disposal costs are calculated in two parts: design and operational costs and postoperational costs. Design and operational costs are the fees charged by the disposal facility operator to pay for operating and overhead costs, and receive a return on investment. These costs are estimated at about $192/$m^3$ ($5.43/$ft^3$), which is about 18 cents/ft^3 higher than that presented in Table 4.3 for the reference facility. This is due to the assumption of the additional operational step of layering the higher activity waste to reduce potential intruder impacts.

Postoperational costs are fees assumed to be charged to the waste generator to ensure that sufficient funds will be available for facility closure and for long-term care, and are calculated as described in Appendix Q. As discussed in Appendix Q, funds for closure are assumed to be provided by the disposal facility licensee, but passed on to the disposal facility customers. The availability of sufficient funds for closure is assumed to be assured through a financial surety mechanism. Funds for 100 years of long-term care are assumed to be provided through a state-operated sinking fund. As shown, unit post-operational costs can, depending upon the case considered, range from $35/$m^3$ ($1.00/$ft^3$) to $51/$m^3$ ($1.44/$ft^3$).

The shear magnitude of the funds that would be needed to be collected over 20 years to ensure long-term care for the first three cases deserves special consideration--e.g., $50 million for Case 3. As discussed earlier, significant potential ground-water doses are estimated. These large calculated exposures result from the assumed practice of indiscriminately disposing of easily compressible, degradable waste streams (which frequently have only very low levels of contamination) with higher activity waste streams. These easily degradable waste streams (e.g., trash) frequently contain chemicals which may increase leaching and reduce sorption (ion exchange) of radionuclides during migration through ground water. As discussed earlier, these calculated levels of exposures are not likely to be actually realized. However, to prevent such potential exposures from occurring, a considerable amount of active site maintenance would be expected on the part of the site owner. It is difficult to predict how long this extensive site maintenance would be required or how much it would cost, although it is seen that many millions of dollars could be potentially involved.

It could be argued that it would be a simple matter to merely charge sufficient postoperational fees to provide for the required care. However, this concept has a number of drawbacks, including:

- There is no assurance that sufficient funds will be available for long-term care, or that funds collected will not be spent for other purposes. For example, the disposal facility may close prematurely and prior to collection of sufficient funds.

- There is no assurance that the extensive kinds of maintenance activities that would be required would actually be carried out in a timely manner. For example, at a site with very impermeable soils, subsidence could lead to disposal trenches filling up with water (the bathtub scenario), which could potentially be ignored until large expenditures were required to rectify the problem.

- Extensive site maintenance activities can lead to releases of quantities of radionuclides offsite. For example, if extensive water management activities such as removal and evaporation of large quantities of trench leachate are required (see Appendix Q), then offsite exposures will result. EPA has estimated that the potential impacts to a maximum exposed individual near a disposal facility evaporating about a million gallons of contaminated liquid per year to be in the neighborhood of 20 mrem (whole body) per year (Ref. 4).

Leaving a disposal facility in a condition so that extensive active maintenance activities are required to ensure public health and safety could result in a considerable financial burden to the site owner and to future generations.

Also shown in Table 5.5 is the estimated land use (3.4 E+5 m^2, or about 86 acres) to dispose of approximately one million m^3 of waste. In this chapter, energy use is presented in incremental gallons of equivalent fuel from that associated with Cases 1-3.

5.2.3 Need for Action

Based upon the results of the preceeding base case analysis and upon a review of existing experience and data regarding ground-water migration, a need for regulatory action is clearly indicated. That is, the no-action alternative is clearly unacceptable. For the further development of performance objectives and technical criteria to minimize potential ground-water impacts, four key factors can be set out:

1. Ground-water migration is very site-specific and depends on the meteorological, hydrological and geological conditions of the site;

2. Ground-water migration is enhanced by an unstable waste form which can lead to waste decomposition, trench collapse, and increased water infiltration. The long-term effects of an unstable waste form and resulting unstable site conditions are difficult to predict;

3. Unstable site conditions at some sites can lead to remedial action programs directed at minimizing potential long-term environmental releases. The programs can result in short-term environmental releases, considerable expenditures of funds which were not planned for at the time the facility was opened, and the possibility that such "active maintenance" programs will have to be carried out over an uncertain time period at uncertain high costs;

4. The potential for migration is increased by the extended contact of water with waste both during operations and after closure.

It is also apparent that potential long-term groundwater migration cannot be analyzed by only considering potential radiological impacts. The need for long-term social commitment to care for sites over the long term and to maintain potential radiological impacts to low levels must also be considered. Two related concepts which impact upon the potential for long-term radiological releases and upon the need for long-term social commitment are: (1) the stability of the waste form and disposal site, and (2) the predictability of the potential radiological impacts. Unless the waste and the disposal site are stable over time, it is difficult to predict the long-term radiological impacts of disposal, or the activities (maintenance, monitoring, etc.) and associated costs required to maintain potential impacts to low levels. If long-term radiological impacts and activities required by a site owner cannot be predicted, then it is difficult to assure the long-term protection of public health and safety, or to assure that future generations will not be burdened by large expenses to maintain a disposal site in a safe condition.

The unpredictable nature of waste/disposal site instability can lead to increased radiological and economic impacts at both humid and arid sites. At humid sites, stable disposal cell covers are needed to minimize water infiltration through the covers and thus maintain potential ground-water releases to levels as low as reasonably achievable. In cohesive, poorly drained soils the inherent longer contact time of infiltrating water leads to greater expected corrosion and decomposition rates than in well-drained permeable soils where the contact time would be less. One is basically trading greater leaching and higher ion-exchange rates in low permeable soils with smaller leaching (lower contact times) and lower ion-exchange rates in higher permeable soils. Waste instability in poorly drained soils can especially lead to a potential "bathtub" problem, which can further lead to costly trench pumping and site stabilization programs. In arid sites, trench instability can lead to subsidence and increased plant and animal intrusion plus increased potential for wind erosion and dispersion of trench contents. For example, at a government-operated disposal facility located on the arid Hanford Reservation, there was an occurrence in which boxes of disposed waste collapsed, resulting in a depression in the trench cover which exposed disposed waste. Portions of this exposed waste were subsequently dispersed by high winds.

Three factors contribute to waste form/disposal site instability, the contact of water with waste, and the resulting long-term radiological and economic consequences.

- site environment;
- site design and operations; and
- waste form.

To consider the maximum potential impacts from waste disposal, the base case site analyzed is a humid site, although as stated above, waste/site instability is also important at arid sites. Variations to site designs and operating practices can lead to greater site stability and minimize long-term migration.

Some of these variations include: (1) segregation of compressible wastes and wastes containing large quantities of organic chemicals or chelating agents, (2) thicker, less permeable disposal cell covers, (3) improved compaction of disposal cell covers, (4) stacked disposal of waste rather than random disposal, (5) grouting of disposed wastes, and (6) use of engineered structures such as concrete walled trenches.

The waste form is probably the most significant factor contributing to site stability--a factor containing the paradox that much if not most of the problems with site instability and high maintenance costs is caused by the wastes containing the least activity. Most of the waste sent to LLW disposal facilities consists of very low activity material such as trash which is frequently easily degradable. In the past, some of this waste has been packaged in easily degradable packages such as card board boxes. Most of the waste, however, is currently packaged in longer lasting, but still degradable, rigid containers such as wooden boxes and 55-gallon steel drums. Large void spaces can also exist within waste packages and the disposal cells after waste disposal. As the waste material degrades and compresses, a process which is accelerated by contact by water, additional voids are produced. This leads to settlement of the disposal cell contents, followed by subsidence or slumping of the disposal cell cover. This increases the percolation of water into disposal cells, accelerating the cycle. This slumping and subsidence is frequently quite sudden.

The use of the rigid containers would be expected to reduce the amount of short-term subsidence. Over the longer term, however, subsidence problems would still be observed, and factors contributing to this include: (1) the waste contained in the rigid containers is still frequently easily degradable, and (2) even if the waste is not readily degradable (e.g., activated alloy metal), it is frequently packaged into containers so that large voids are left within the containers. The rigid containers initially provide some structural support to the disposal cell covers, and act to "bridge" voids within the disposal cell and waste packages. (These voids may exist initially within the disposal cell and waste packages or may be produced as a result of waste decomposition.) Eventually, however, this structural support is lost as the rigid containers rust or rot out, leading to disposal cell settling at rates which are difficult to predict. The basic problem is the voids. If a waste container were completely filled with relatively nondegradable, noncompressible materials--e.g., activated metal with void spaces within the container filled with sand--then degradation of the waste package would not be expected to result in a subsidence problem.

In the following section, a number of cases are analyzed to investigate the cost-effectiveness of different ways in which to achieve improved disposal facility stability, reduce radionuclide migration, and minimize long-term social commitment in carrying out active maintenance programs. In these cases, the reference disposal facility (moderately permeable soils,) is assumed. The potential relative costs and impacts of variations in disposal facility design and operating practices are first investigated, followed by the potential relative costs and impacts of improvements in waste form.

5.2.4 Alternatives to the Base Case

The following description of alternatives considers a wide range of potential improvements that can be applied to design and operations to improve waste and site stability and to reduce the contact of waste by water. Eight major cases are examined, with variations on some cases also examined as appropriate. These cases include the following:

Case 1A - Use of sand backfill
Case 4 - Operationally improved case
Case 5 - Concrete walled trenches
Case 6 - Decontainerized disposal of compressible waste
Case 7 - Use of improved waste forms
Case 8 - Use of further improved waste forms
Case 9 - Walled trenches and further improved waste forms
Case 10 - High integrity containers

Case 1A is included to illustrate use of a sand backfill around waste packages to minimize contact time of percolating water with disposed waste. The disposal facility design and operating practices are assumed to be identical to Case 1. Waste spectrum 1 is also assumed.

Case 4 is included to illustrate a range of improvements to disposal facility design and operation without improvements in waste form. This case is composed of 5 subcases in which successive additional disposal facility design options are added, including (in order): waste segregation, improved compaction of the disposal cell cover, a thick clay cover, stacking of waste, and use of a hot waste facility.

Case 5 involves use of a highly engineered disposal technique to provide disposal facility stability. The waste is segregated, stacked within concrete walled trenches, and then grouted in place. A concrete trench floor and a one meter thick concrete cap is also provided in addition to a thick compacted clay cap. This case--a concrete walled trench--would be expected to involve costs similar to an above-ground engineered structure.

Case 6 is included to examine an alternative method of disposing of compressible wastes other than by extensive pretreatment operations. In this case, compressible wastes are delivered to the disposal facility in reusable containers. At special (segregated) trenches, the wastes are emptied out and compacted by heavy machinery. The wastes are periodically covered by a soil layer which is also compacted. To eliminate wind scatter, operations are conducted under an air support building.

This alternative is assumed to require a presorting operation to exclude sealed sources, activated metal, or other high radiation sources. Even so, worker exposures for such operations are expected to be high. The advantage of this operation is that since there are no rigid containers and trench voids are reduced, it may be possible to arrive at a stable site within a few years. However, higher maintenance activities would be initially expected until stability is achieved.

Case 7 is similar to Case 4 except that an improved waste form is used--i.e., waste spectrum 2. This spectrum represents a number of improved waste forms which can be implemented in a reasonably short time period. All liquids, filter sludges, and resins are solidified in improved waste forms (half cement and half synthetic polymer). Compressible wastes are compacted, which results in an improved waste form for these wastes. Higher activity wastes such as LWR noncompactible trash are packaged in a manner which resists compression over the long term.

This case consists of four subcases. Case 7A is similar to Case 1A in that the waste packages are assumed to be disposed without consideration of segregated disposal of compressible wastes and wastes containing organic chemicals or chelating agents. Cases 7B, 7C, and 7D are similar to Cases 4A, 4B, and 4C and include the following successive disposal facility design options: waste segregation, improved compaction of the disposal cell covers, and use of a thicker clay cover.

Case 8 is similar to Case 7D except that a further improved waste form is used--i.e., waste spectrum 3. This spectrum represents about the best overall waste form which can be reasonably implemented using existing technology. However, it is expensive and requires time to implement. In this spectrum, compressible wastes are incinerated and solidified. Liquids, resins, and filter sludges are also solidified. The solidification media is assumed to be a synthetic polymer. This spectrum generally provides a very stable waste form. This case represents minimal impacts and long-term maintenance costs at relatively high waste treatment costs.

Case 9 is similar to Case 5 and is included to illustrate use of extreme (expensive) measures to minimize migration and long-term maintenance requirements. Stability is achieved by both the waste form (waste spectrum 3) and the disposal operations (walled and grouted disposal trenches).

Case 10 is included to illustrate use of high-integrity containers (HICs) to package and dispose of certain waste streams. Case 10 consists of three subcases using similar disposal facility designs as Cases 4C and 7D.

5.2.4.1 Case 1A - Use of Sand Backfill

The following cases investigate use of a number of options for waste form, waste packaging, and disposal facility design and operation to increase disposal facility stability and to minimize radionuclide migration. To do this, the cases principally investigate methods to reduce percolation of water into disposal cells and/or reduce migration of radionuclides from disposed waste streams through improved waste forms (e.g., through solidification) or packaging.

Case 1A, on the other hand, follows from Case 2 and investigates use of a sand backfill around disposed waste packages. This reduces the contact time of percolating water and therefore reduces leaching of radionuclides from the waste packages. Since the sand fill would tend to readily flow into interstitial spaces between waste packages during backfill operations, some reduction in trench voids would also be expected to occur. The potential usefulness of this technique was previously alluded to during the discussion on Cases 1-3.

For Case 1A, the disposal facility design is assumed to be essentially the same as Case 1, and is summarized on Table 5.1. Waste packages are randomly disposed into disposal cells, with no segregation of compressible waste streams or waste streams containing organic chemicals or chelating agents. A thin earth cover is placed over the disposed wastes, and is subjected to indifferent compaction. Instead of backfilling the disposal cells with excavated soil, however, a clean sand fill is used for this purpose. In addition, a 0.3 m (1 ft) thick layer of sand is placed on the bottom of the disposal cell prior to waste emplacement. The waste is emplaced to within one meter of the top of the disposal cell, and then backfilled with sand to the level of the top of the cell. The cap is then emplaced. The sand fill is assumed to be obtained from a local borrow area and is stockpiled onsite until used.

Ground-Water Impacts

Ground-water impacts for Case 1A are shown in Table 5.6. In comparison with Case 1, use of the sand backfill reduces maximum ground-water impacts by about a factor of 10. In the analysis, the contact time is calculated as follows:

$t_c = \rho/nv$, where

p = the precipitation (m/yr) that infiltrates into a disposal cell and comes into contact with the disposed waste.

n = waste disposal cell effective porosity

v = speed of the percolating water (m/yr)

Table 5.6 Maximum Ground-Water Impacts Associated with Case 1A

	(mrem/yr)						
Case	Body	Bone	Liver	Thyroid	Kidney	Lung	GI
(1A)							
Intruder	3.044E+0	3.063E-1	3.044E+0	8.462E+1	3.044E+0	3.044E+0	3.044E+0
Well	(100)	(6,000)	(100)	(4,000)	(100)	(100)	(100)
Boundary	1.571E+1	3.061E-1	1.571E+1	8.462E+1	1.571E+1	1.571E+1	1.571E+1
Well	(70)	(6,000)	(70)	(4,000)	(70)	(70)	(70)
Population	4.845E-2	7.115E-2	2.516E-2	2.674E+1	4.290E-2	1.432E-2	3,229E-2
Well	(10,000)	(10,000)	(10,000)	(8,000)	(10,000)	(10,000)	(10,000)
Surface	2.190E-3	3.166E-3	1.128E-3	1.219E+0	1.934E-3	6.345E-4	1.445E-3
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)

For the reference disposal facility soils, a waste disposal cell effective porosity of about 25% is conservatively assumed. The speed of the percolating water is assumed to be about one foot per day, which corresponds to a permeability of about 10^{-4} cm/sec. For the sand backfill, the speed of the percolating water is assumed to be raised to about 10 ft/day.

Although lower impacts are calculated for this case, it should be recognized that the sand backfill can be a useful conjunction to a stable disposal facility but cannot be a replacement to a stable disposal facility. For one reason, the use of the backfill is effective for only so long as the percolating water can drain through the bottom of the disposal cells. If the rate at which the water drains through the bottom of the disposal cells is less than the percolation rate, water will tend to collect in the bottom of the disposal cells. If sufficient water collects to inundate the disposed waste packages, then of course the advantage of using the sand backfill is lost. As discussed previously, for Cases 1-3, this may especially be of concern for disposal facilities having highly impermeable soils. This "bath tub" scenario may potentially lead to over flow of leachate from disposal cells. At the least, it will lead to considerably higher long-term maintenance activities and costs.

Other Impacts

Other impacts associated with this case are listed in Table 5.7. Compared with Case 1, the principal change is in disposal costs. Design and operation costs are raised from \$188 million to \$195 million, total disposal costs raised from \$226 million to \$233 million, and unit costs raised from \$231/m³ to \$238/m³. Since the use of the sand backfill is not believed to materially increase the stability of the disposal facility, long-term care costs are still projected to be at a high level. Energy use is also raised somewhat.

5.2.4.2 Case 4 - Operationally Improved Case

Case 4 examines the costs and impacts associated with a range of moderate facility operational changes which are intended to improve site stability and reduce percolation. The waste form is assumed to be unchanged from Cases 1-3. The five subcases of Case 4 are summarized in Table 5.8. Relative to the reference facility in Case 1A, the following operational changes are made in each of the 5 subcases of Case 4:

Case 4A. In this case, easily compressible waste streams as well as waste streams containing significant quantities of chelating agents are assumed to be disposed in a segregated manner (e.g., separate disposal trenches) from other waste streams.

Case 4B. In addition to segregation of the compressible waste streams and waste streams containing chelating agents, the disposal trench covers containing unstable waste streams are assumed to be subjected to improved compaction techniques.

Case 4C. This case is similar to Case 4B except that improved disposal trench covers are assumed to be emplaced, which are also subjected to improved compaction techniques.

Table 5.7 Comparison of Other Impacts Associated with Case 1A

Short-term population exposures: (man-mrem)	
Processing at waste generator	-
Processing at regional processing center	0
Waste transportation	5.10E+5
Short-term occupational exposures: (man-mrem)	
Processing at waste generator	-
Processing at regional processing center	0
Waste transportation	5.82E+6
Waste disposal	2.46E+6
Waste generation and transport costs: ($)	
Processing at waste generator	-
Processing at regional processing center	0
Waste transportation	2.05E+8
Disposal costs: ($)	
Design and operation	1.95E+8
Postoperational	3.82E+7
Total	2.33E+8
Unit ($/m³)	238
Energy use: (gal)	+2.00E+5
Land use: (m²)	3.40E+5
Waste volume disposed: (m³)	
Regular:	
Chemical-stable	9.26E+3
Chemical-unstable	1.15E+5
No Chemical-stable	2.22E+5
No Chemical-unstable	5.34E+5
Total	8.81E+5
Layered:	
Chemical-stable	9.62E+2
Chemical-unstable	1.87E+3
No Chemical-stable	3.70E+2
No Chemical-unstable	9.59E+4
Total	9.91E+4
Hot Waste Facility:	0
Total Disposed	9.80E+5
Total not acceptable: (m³)	1.94E+4

Table 5.8 Five Subcases of Case 4

Case 4A - Operationally Improved Case: Segregation

- Regular SLB trench
- Waste spectrum 1
- SLB with a thin cap
- Segregation of wastes containing chelates
- Segregation of compressible wastes
- Random disposal of waste with a sand backfill
- Layering used as an intruder barrier

Case 4B - Operationally Improved Case: Segregation plus Compaction

- Regular SLB trench
- Waste spectrum 1
- SLB with a thin cap
- Compaction using improved methods
- Segregation of wastes containing chelates
- Segregation of compressible wastes
- Random disposal of waste with a sand backfill
- Layering used as an intruder barrier

Case 4C - Operationally Improved Case: Segregation, Compaction, and Improved Covers

- Regular SLB trench
- Waste spectrum 1
- SLB with a thicker clay cap
- Compaction using improved methods
- Segregation of wastes containing chelates
- Segregation of compressible wastes
- Random disposal of waste with a sand backfill
- Layering used as an intruder barrier

Case 4D - Operationally Improved Case: Segregation, Compaction, Improved Covers, Stacked Disposal

- Regular SLB trench
- Waste spectrum 1 SLB with a thicker clay cap
- Compaction using improved methods
- Segregation of wastes containing chelates
- Segregation of compressible wastes
- Stacked disposal of waste with a sand backfill
- Layering used as an intruder barrier

Case 4E - Operationally Improved Case: Hot Waste Facility

- Regular SLB trench
- Waste spectrum 1
- SLB with a thicker clay cap
- Compaction using improved methods
- Segregation of wastes containing chelates
- Segregation of compressible wastes
- Stacked disposal of waste with a sand backfill
- Hot waste facility for problematical wastes
- Layering used as an intruder barrier for other wastes.

Case 4D. This case is similar to Case 4C except that instead of random disposal, the waste is assumed to be stacked in the disposal cells.

Case 4E. This case is included to investigate the costs and impacts of addition of a "hot waste facility" to dispose of some high activity waste streams which would otherwise be excluded from near-surface disposal. In this case, the hot waste facility is assumed to be a cement walled trench. Except for the assumed addition of the hot waste facility, this case is identical to Case 4D.

Ground-Water Impacts

Estimated maximum ground-water impacts at each of the access locations considered for each of the 5 subcases of Case 4 are summarized in Table 5.9. As shown, for each improvement in disposal facility design and operation, generally reduced ground-water impacts are observed. Over Cases 4A through 4D, whole body exposures drop from 0.8 mrem/yr to 0.02 mrem/yr at the intruder well, from 4 mrem/yr to 0.07 mrem/yr at the boundary well, from 0.05 mrem/yr to 0.005 mrem/yr at the population well, and from 0.002 mrem/yr to 2. E-4 mrem/yr at the surface water access location. Similarly, thyroid exposures drop from 80.5 mrem/yr to 8.3 mrem/yr at the intruder and boundary wells, from 25.4 mrem/yr to 2.6 mrem/yr at the population well, and from 1.2 mrem/yr to 0.1 mrem/yr at the surface water access location.

Relative to Case 1A, lower exposures are calculated for Case 4A for the intruder and boundary wells, resulting from segregation of the stable waste streams from the unstable waste streams and waste streams containing organic chemicals or chelating agents. Lower exposures (than Case 1A) are also observed at the other two access locations: the population well and the surface stream.

In Cases 1-3 and 1A, since all waste streams are mixed together during disposal, all streams experience high (twice natural percolation) percolation rates. Leaching of all solidified waste forms is enhanced by the presence of organic chemicals and chelating agents and the retardation coefficients of the migrating radionuclides are reduced (e.g., from NRET = 3 to NRET = 2, see Appendix G). In Case 4A, however, the stable waste streams are segregated from unstable streams and wastes containing significant quantities of chelating agents and organic chemicals are also disposed in a segregated manner. In this case, since the disposal cells containing the stable waste streams would not experience significant subsidence problems, percolation into these disposal cells is reduced (to the natural percolation of the disposal facility site). The disposal cells containing the compressible waste streams, however, still experience the higher (twice natural percolation) percolation rates. Similarly, the increased leaching of solidified wastes and reduced ion-exchange capacity (reduced retardation) is applied only to the segregated waste streams in the disposal cells containing significant quantities of chelating agents and organic chemicals.

It should be noted that about 76% of the wastes in waste spectrum 1 are in an unstable waste form, including higher activity waste streams such as LWR ion exchange resins (P-IXRESINS and B-IXRESINS) and industrial radioisotope

Table 5.9 Estimated Maximum Radiological Ground-Water Impacts for Cases 4A Through 4E.

	(mrem/yr)						
Cases	Body	Bone	Liver	Thyroid	Kidney	Lung	GI
(4A)							
Intruder	7.719E-1	2.931E-1	7.719E-1	8.051E+1	7.719E-1	7.719E-1	7.719E-1
Well	(100)	(6,000)	(100)	(4,000)	(100)	(100)	(100)
Boundary	3.985E+0	2.929E-1	3.985E+0	8.051E+1	3.985E+0	3.985E+0	3.985E+0
Well	(70)	(6,000)	(70)	(4,000)	(70)	(70)	(70)
Population	4.617E-2	6.805E-2	2.401E-2	2.544E+1	4.091E-2	1.369E-2	3.084E-2
Well	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
Surface	2.087E-3	3.028E-3	1.077E-3	1.160E+0	1.844E-3	6.068E-4	1.380E-3
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
(4B)							
Intruder	7.654E-1	1.661E-1	7.654E-1	4.541E+1	7.654E-1	7.654E-1	7.654E-1
Well	(100)	(6,000)	(100)	(4,000)	(100)	(100)	(100)
Boundary	3.952E+0	1.660E-1	3.952E+0	4.541E+1	3.952E+0	3.952E+0	3.952E+0
Well	(70)	(6,000)	(70)	(4,000)	(70)	(70)	(70)
ulation	2.607E-2	3.855E-2	1.358E-2	1.435E+1	2.310E-2	7.756E-3	1.743E-2
ell	(10,000)	(10,000)	(10,000)	(6,000)	(10,000)	(10,000)	(10,000)
Surface	1.179E-3	1.715E-3	6,088E-4	6.540E-1	1.041E-3	3.437E-4	7.796E-4
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
(4C)							
Intruder	2.487E-2	4.517E-2	2.156E-2	1.238E+1	2.235E-2	2.156E-2	2.156E-2
Well	(6,000)	(6,000)	(100)	(4,000)	(6,000)	(100)	(100)
Boundary	1.113E-1	4.503E-2	1.113E-1	1.238E+1	1.113E-1	1.113E-1	1.113E-1
Well	(70)	(6,000)	(70)	(4,000)	(70)	(70)	(70)
Population	7.096E-3	1.045E-2	3.690E-3	3.911E+0	6.287E-3	2.103E-3	4.739E-3
Well	(10,000)	(10,000)	(10,000)	(6,000)	(10,000)	(10,000)	(10,000)
Surface	3.147E-4	4.347E-4	1.594E-4	1.783E-1	2.773E-4	8.713E-5	1.060E-4
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
(4D)							
Intruder	1.643E-2	2.933E-2	1.437E-2	8.252E+0	1.474E-2	1.437E-2	1.437E-2
Well	(6,000)	(6,000)	(100)	(4,000)	(6,000)	(100)	(100)
Boundary	7.420E-2	2.923E-2	7.420E-2	8.252E+0	7.420E-2	7.420E-2	7.420E-2
Well	(70)	(6,000)	(70)	(6,000)	(70)	(70)	(70)
Population	4.697E-3	6.799E-3	2.426E-3	2.607E+0	4.157E-3	1.368E-3	3.126E-3
Well	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
Surface	2.084E-4	2.829E-4	1.049E-4	1.188E-1	1.835E-4	5.671E-5	1.359E-4
Water	(10,000)	(10,000)	(10,000)	(6,000)	(10,000)	(10,000)	(10,000)

Table 5.9 (continued)

Cases	(mrem/yr) Body	Bone	Liver	Thyroid	Kidney	Lung	GI
(4E)							
Intruder	1.645E-2	2.947E-2	1.437E-2	8.252E+0	1.477E-2	1.437E-2	1.437E-2
Well	(6,000)	(6,000)	(100)	(4,000)	(6,000)	(100)	(100)
Boundary	7.420E-2	2.937E-2	7.420E-2	8.252E+0	7.420E-2	7.420E-2	7.420E-2
Well	(70)	(6,000)	(70)	(6,000)	(70)	(70)	(70)
Population	4.703E-3	6.829E-3	2.432E-3	2.607E+0	4.163E-3	1.374E-3	3.132E-3
Well	(10,000)	(10,000)	(10,000)	(6,000)	(10,000)	(10,000)	(10,000)
Surface	2.087E-4	2.841E-4	1.051E-4	1.188E-1	1.837E-4	5.695E-5	1.362E-4
Water	(10,000)	(10,000)	(10,000)	(6,000)	(10,000)	(10,000)	(10,000

production wastes (N-ISOPROD). Therefore, the effectiveness of segregated disposal of stable waste streams is not as significant as it would be if the higher activity waste streams were stabilized. This is especially observed in the thyroid exposures, which are principally the result of iodine-129. In the waste source data base used in this EIS, most of the iodine-129 is estimated to be contained in the 7 LWR process waste streams (P-IXRESIN, P-FSLUDGE, P-CONCLIQ, P-FCARTRG, B-IXRESIN, B-CONCLIQ, B-FSLUDGE). Of these, only the P-CONCLIQ and B-CONCLIQ waste streams are in a stable form in waste spectrum 1.

In Case 4B, the covers of the disposal cells containing the segregated compressible waste streams are subjected to improved compaction using heavy machinery such as a vibratory compactor. This is an inexpensive additional operational step and results in an estimated reduction of migration from the unstable cells by a factor of about 2. This results in a minor reduction in whole body exposures and a more significant reduction (by a factor of about 2) of thyroid exposures at the intruder and boundary wells. This is because most of the boundary well whole body dose is due to tritium, and most of the tritium delivered to the reference disposal facility is contained in two relatively small volume waste streams (N-TRITIUM and N-TARGETS). These streams are already assumed to be stable, and because stable waste streams are segregated and disposal cells containing stable waste streams are not subjected in Case 4B to the improved compaction, there is no reduction (relative to Case 4A) in percolation into the disposal cells. This effect is not seen at the other two access locations due to the extensive decay of the tritium before the contaminated ground water reaches the other two access locations (The ground-water travel times between the boundary well and the other two access locations are 334 years for the population well and 734 years for the surface water.)

However, since most of the iodine-129 is contained in unstable waste streams, compacting the disposal cells containing the unstable waste streams results in a more significant reduction in thyroid dose at the intruder and boundary wells.

Since iodine-129 has a very long half life, a similar relative reduction in thyroid dose relative to Case 4A is seen for the population well and the surface water.

In Case 4C, additional clay soil is assumed to be transported to the disposal facility from an offsite borrow area. This clay soil is emplaced and compacted in relatively thin (8 to 12 inch) layers over the disposal cells containing the unstable waste streams, raising the thickness of the disposal cell covers by two meters. The same thickness of compacted clay soil is placed over the disposal cells containing the stable waste streams. As a result, during the 100 year active institutional control period, percolation into the disposal cells containing the segregated stable waste streams is assumed to be reduced to 30 mm, while the percolation into the disposal cells containing the compressible waste streams is reduced to 60 mm. Compared to Case 4B, then, overall percolation into the disposal cells is reduced by a factor of about 6. However, at the end of the active institutional control period, a breakdown in institutional controls is assumed to occur. At this point, due to intrusion by humans, the percolation into 10% of the disposal cells is increased to 180 mm (the natural percolation of the site). The remainder of the disposal cells, due to intrusion by deep-rooted plants and burrowing animals, experience a general increase in percolation of twice the former value (i.e., 60 mm for the stable waste disposal cells and 120 mm for the unstable waste disposal cells).

The effects of this case are most seen in the boundary well exposures for the whole body and other organs (except thyroid). In the calculations, the percolation rate is squared (See Appendix G), and a reduction in the percolation by a factor of 6 into the disposal cells containing the stable waste streams results in an estimated reduction in tritium migration from the stable disposal cells by a factor of 36. Hence, whole body exposures due to tritium at the intruder and boundary wells are reduced by a factor of about 36. Considering that the full effectiveness of the additional compacted cover is only assumed for 100 years, this would appear to indicate that it only requires a relatively short hold-up of large quantities of tritium to considerably reduce potential boundary well exposures.

The reduction in impacts for whole body and other organs relative to Case 4B is less significant for the other two access locations. This is again due to decay of the tritium while being carried by ground water. Exposures at the population well and surface water access location are dominated by releases from the disposed unstable waste streams. As expected, since the waste streams containing most of the iodine-129 are still in an unstable form, thyroid exposures are reduced at each biota access location by about a factor of somewhat less than 4. In this case, thyroid exposures at the intruder and boundary wells and exposures to all organs at the other two access locations are dominated by the increased percolation rates experienced after the end of the active institutional control period.

Case 4D is similar to Case 4C with the exception that instead of random disposal, the waste containers are assumed to be neatly stacked into the disposal cells. Disposal efficiency is assumed to be increased by a factor of 1.5 from 0.5 to

0.75. In the calculations, the total volume of water percolating into the dispos cells is given by the percolation rate multiplied by the surface area of the disposal cells. Increasing the disposal efficiency by a factor of 1.5 reduces the surface area of the disposed waste by a factor of 1.5. This results in a calculated reduction in exposures at the 3 access locations by a factor of 1.5, as shown in Table 5.9.

As a result of the increased disposal efficiency, potential intruder impacts are also increased by a factor of 1.5. This results in one small volume (800 m^3 over 20 years) waste stream, L-NFRCOMP, being listed as unacceptable in Case 4D. Therefore, Case 4E investigates use of a "hot waste facility" for this waste stream. For this analysis, the hot waste facility is assumed to be a grouted cement walled trench. As can be seen in Table 5.9 only a minor increase in ground-water impacts are calculated from disposal of this waste stream within a hot waste facility.

Other Impacts

Other impacts for these cases are summarized in Table 5.10. Since waste spectrum one is used for the 5 subcases of Case 4, there is seen in Table 5.9 to be no change from the previously calculated values for several of the impact measures. These include population exposures for waste processing and transportation, occupational exposures due to waste processing, and costs due to waste processing and waste transportation. Other impacts and costs, however, are somewhat alte .

One example is occupational exposures. Waste transportation occupational exposures are the same in all subcases to those estimated for Cases 1-3 with the exception of Case 4D. In this case, the waste is assumed to be stacked in the disposal cells. This results in slightly higher intruder impacts, sufficient to make one stream, L-NFRCOMP, listed as unacceptable. This reduction in 800 m^3 of waste delivered to the site results in lower transportation occupational exposures for this case.

Disposal facility occupational exposures are calculated to be approximately 2.46 million man-millirem for Cases 4A through 4C, which is the same as that calculated for Cases 1 through 3, but rise to 5.21 million man-millirem for Cases 4D and 5.27 million man-millirem for Case 4E. The values calculated for Case 4A arise from the expectation that waste segregation is not expected to result in significant additional occupational exposures. Waste that would be contact-handled would still be contact-handled, while waste such as high activity resins that must be hoisted into place would still be handled in the same manner. The main difference is that the disposal facility would operate two or more disposal cells instead of one and there would have to be an additional determination at the time of waste receipt and inspection regarding the disposal status of the different waste forms. This determination, however, would not have to be performed in a radiation field. Additional exposures could result from the probable increased waste storage requirements, but most wastes thus stored would probably be of lower activity.

Table 5.10 Other Impacts Associated With Cases 4A Through 4E

Impacts	Case 4A	Case 4B	Case 4C	Case 4D	Case 4E
Short-term population exposures: (man-mrem)					
Processing at waste generator	-	-	-	-	-
Processing at regional processing center	0	0	0	0	0
Waste transportation	5.10E+5	5.10E+5	5.10E+5	4.94E+5	5.10E+5
Short-term occupational exposures: (man-mrem)					
Processing at waste generator	-	-	-	-	-
Processing at regional processing center	0	0	0	0	0
Waste transportation	5.82E+6	5.82E+6	5.82E+6	5.74E+6	5.82E+6
Waste disposal	2.46E+6	2.46E+6	2.46E+6	5.21E+6	5.27E+6
Waste generation and transport costs: ($)					
Processing at waste generator	-	-	-	-	-
Processing at regional processing center	0	0	0	0	0
Waste transportation	2.05E+8	2.05E+8	2.05E+8	2.01E+8	2.05E+8
Disposal costs: ($)					
Design and Operational	2.01E+8	2.01E+8	2.10E+8	2.22E+8	2.25E+8
Postoperational:	*	*	*	*	*
Total:	*	*	*	*	*
Unit ($/m^3)	223-244	223-244	233-253	245-266	248-268
Energy use: (gal)	+3.00E+5	+3.00E+5	-	4.00E+5	-2.00E+5
Land Use: (m^2)	3.40E+5	3.40E+5	3.40E+5	2.27E+5	2.27E+5
Waste volume disposed: (m^3)					
Regular:					
Chemical-stable	1.02E+4	1.02E+4	1.02E+4	1.02E+4	1.02E+4
Chemical-unstable	1.15E+5	1.15E+5	1.15E+5	1.15E+5	1.15E+5
No chemical-stable	2.23E+5	2.23E+5	2.23E+5	2.23E+5	2.23E+5
No chemical-unstable	5.34E+5	5.34E+5	5.34E+5	5.34E+5	5.34E+5
Total	8.82E+5	8.82E+5	8.82E+5	8.82E+5	8.82E+5

Table 5.10 (Continued)

Impacts	Case 4A	Case 4B	Case 4C	Case 4D	Case 4E
Layered:					
Chemical-stable	0	0	0	0	0
Chemical-unstable	1.87E+3	1.87E+3	1.87E+3	1.87E+3	1.87E+3
No chemical-stable	0	0	0	0	0
No chemical-unstable	9.59E+4	9.59E+4	9.59E+4	9.51E+4	9.51E+4
Total	9.77E+4	9.77E+4	9.77E+4	9.70E+4	9.70E+4
Hot waste facility:	0	0	0	0	0
Total disposed:	9.80E+5	9.80E+5	9.80E+5	9.79E+5	9.80E+5
Total volume not acceptable: (m^3)	1.94E+4	1.94E+4	1.94E+4	2.02E+4	1.94E+4

*Postoperational (closure and long-term care) costs are estimated to range from approximately $18.1 million to $38.2 million. In general, the higher end of the range would be associated with Case 4A and the lower end of range would be associated with Cases 4D and 4E. Total costs are therefore estimated to range as follows:

4A	4B	4C	4D	4E
2.19-2.39E+8	2.19-2.39E+8	2.28-2.48E+8	2.40-2.60E+8	2.43-2.63E+8

The additional operational steps for Cases 4B and 4C, which involve improved compaction for the former case and thicker disposal cell covers for the latter, are also not expected to result in significant additional exposures. For these cases, additional time would be spent on top of the disposal cells while installing the disposal cell covers. However, the disposal cell covers would provide considerable shielding (e.g., by a factor of about 1200 for every meter of soil) and any additional exposures would be small.

As shown for Cases 4D and 4E, however, a site operational procedure in which all waste containers are neatly stacked would be expected to increase occupational exposures by a factor of somewhat greater than 2. This may be an overestimate, however. At currently operating disposal facilities, a mixture of random and stacked disposal is generally used. High surface activity wastes and boxed low activity wastes are generally stacked (or otherwise emplaced in a neat manner using cranes or forklifts) while drummed low activity waste is generally disposed randomly. Additional stacking procedures would generally involve the lower activity waste streams. If waste segregation were not implemented, then the increased time spent in a high radiation environment would be expected to increase exposures. However, if the higher activity waste streams were disposed segregated from the low activity streams (most of the compressible wastes are trash and other low activity streams), then the radiation environment

while stacking the lower activity wastes would probably be lower. The resulting exposures would also be lower.

As expected, operation of the hot waste facility (to dispose of the L-NFRCOMP stream) results in a somewhat increased volume of waste delivered to the disposal facility and total operational exposures would be somewhat higher than for Case 4D. However, total occupational exposures would be lower than if the wastes were disposed with the remainder of the waste streams.

Disposal costs illustrate the fact that increased costs for improved facility design and operations would be expected to reduce long-term care costs. Compared with Case 1-3 ($188 million), Cases 4A through 4D illustrate increasing costs as additional work is performed onsite. Additional costs for segregation (Case 4A) are associated with the assumed construction of a waste storage area, aquisition of an additional onsite transport vehicle and hiring of additional personnel. For Case 4B, additional costs involve aquisition and use of a vibratory compactor. Addition of an improved cover (Case 4C) is estimated to be reasonably expensive (an additional $9 million over 20 years). This was calculated from the assumption that a high grade of clayey soil had to be transported to the disposal facility from several miles distance. Of course, if such soil were available nearer to the facility (e.g., an onsite borrow area), the costs would be considerably reduced. Similarly, additional costs are associated with waste stacking (Case 4D). As can be seen, operation of a hot waste facility would be expensive--i.e., an additional $3 million to dispose of only 800 m^3 of waste.

Long-term care costs are difficult to estimate and have not been broken out in as detailed a manner as the costs associated with operational variables. It is difficult to precisely judge or to exactly quantify how much a given facility design and operation alternative would be expected to reduce long-term care costs. For this EIS, long-term care costs have been broken out into three levels: high, moderate, and low. Cases 4A through 4E have been judged to involve a range of costs from moderate to high--i.e., from $18.1 million to $38.2 million.

Case 4A is estimated to involve long-term care costs toward the higher end of the range, but would nonetheless be expected to be less than those for Case 1. This is because 75% of the waste disposed at the facility (7.47E+5 m^3) is in an unstable form, and segregation of unstable waste streams from stable waste streams would reduce overall long-term maintenance requirements. Instead of all disposal trenches undergoing severe subsidence, only about 75% would experience such subsidence. Cases 4D and 4E are estimated to involve long-term costs toward the lower end of the range. (The addition of a hot waste facility for small volumes of waste would be expected to have little to no effect on long-term care costs.) Cases 4B and 4C would involve long-term care costs between the two ends of the range.

Total costs (design and operational costs plus long-term care costs) are also shown in Table 5.10, along with unit costs (total costs divided by the total volume of waste disposed). These are also presented as a range in costs.

The remaining impact measures are total land use and energy use, where the energy value listed is the incremental sum of the total gallons of fuel for waste

transport and disposal as well as for long-term care. For Cases 4A and 4B the total incremental energy use over 20 years is calculated to be 300,000 gallons. (Case 4B would actually be expected to involve slightly higher energy consumption than Case 4A, but the difference is too small to be illustrated.) For illustration purposes, incremental energy use for Cases 4A and 4B was calculated under an assumption of a high level of long-term care while incremental energy use for Cases 4C through 4E was calculated under an assumption of a moderate level of long-term care. As shown in Case 4C, although an additional operational step is involved (the thicker cap), the assumption of a moderate level of long-term care reduces the overall energy use to levels about the same as those for Case 1. In Case 4D and 4E, the waste containers are assumed to be stacked, which is an additional process step resulting in additional energy use. However, this is counteracted by the increase in disposal efficency, resulting in a decrease in land committed for waste disposal. Fewer disposal cells need to be constructed, backfilled, covered, compacted, and maintained. In addition, for Case 4D, less waste (by 800 m^3) is delivered to the disposal facility. Delivery of this waste to the facility and disposing of it in a hot waste facility (Case 4E) results in an increase in energy use over Case 4D.

The land use is 340,000 m^2 for Cases 4A-4C, and drops to 227,000 m^2 for Cases 4D and 4E. The reduction in land use is due to the assumption of waste stacking for the latter two cases. The disposal efficiency is assumed to be raised from 0.5 to 0.75. This may be difficult to achieve, however, in actual practice. Even if the waste is stacked, operational limitations may not reduce the interstitial void space between waste packages by very much.

5.2.4.3 Case 5 - Concrete Walled Trenches

This case is included to help assess the costs and radiological impacts of a potential disposal option in which site stability is achieved by engineering means. This case is summarized on Table 5.11. Appendix F investigates a number of methods by which subsidence and percolation of water into disposal cells may be reduced through engineering means. Other possible methods are investigated in Reference 5. These include such methods as grouting the disposed waste mass or placing the waste into engineered structures such as caissons or walled trenches. There may also be a number of other disposal designs which may be used.

Use of engineered methods at the disposal facility to achieve waste stability may, depending upon the particular disposal method utilized and the disposal site environment, involve a range of potential costs and radiological and other impacts. A rather "extreme" (expensive) method is illustrated in this example.

In this case, all wastes are assumed to be stacked into concrete walled trenches. In addition, unstable wastes and waste streams containing organic chemicals or complexing agents are disposed in segregated disposal cells. The spaces between the waste packages are grouted and a one-meter thick cap of concrete is poured over the waste, over which two meters of compacted clayey soil is emplaced and compacted. Grass is then planted.

Table 5.11 Summary of Cases 5 and 6

Case 5 - Cement Walled Trench

- Cement walled trench
- Waste spectrum 1
- Use of thicker, compacted clay cap
- Segregation of wastes containing chelates
- Segregation of compressible wastes
- Stacked disposal of waste
- Grouting emplaced between waste packages
- Cement walled trench used as an intruder barrier

Case 6 - Decontainerized Disposal of Compressible Wastes

- Regular SLB trench
- Waste spectrum 1
- Use of a thicker, compacted cap
- Segregation of wastes containing chelates
- Segregation of compressible wastes
- Random disposal except for low activity compressible wastes
- Decontainerized disposal of dry, low activity compressible wastes
- Use of a sand backfill
- Layering used as an intruder barrier

Ground-Water Impacts

Projected ground-water impacts are summarized in Table 5.12. As can be seen, all calculated exposures are lower than those estimated for the previous cases. The estimated organ doses, with the exception of thyroid and bone, are on the order of 10^{-3} mrem/yr at the site boundary well, are about 5 times higher at the intruder well, and drop by approximate orders of magnitude at both the population well and the surface water access location. The reason that boundary well whole body (and other organs) exposures are higher than those for the intruder well is that most of these exposures are still due to tritium, which is indicated by the observation that the maximum exposures occur at about 100 years following facility closure. (The actual maximum potential intruder well exposures are estimated to be about 1.3E-2 mrem, but occur prior (50 years) to the end of the active institutional control period.) For thyroid, there is less of a change. Exposures at the intruder and boundary wells are about 0.4 mrem/yr and those at the population well about 0.1 mrem/yr, while the surface water access is about an order of magnitude less. The reason that considerably less reduction in thyroid exposure is observed than for exposures to other organs is due to the assumption of a general deterioration in the disposal cells at the end of the active institutional control period. At a

Table 5.12 Estimated Radiological Ground-Water Impacts for Cases 5 and 6.

	(mrem/yr)						
Cases	Body	Bone	Liver	Thyroid	Kidney	Lung	GI
(5)							
Intruder	8.096E-4	1.434E-3	8.096E-4	3.873E-1	8.096E-4	8.096E-4	8.096E-4
Well	(100)	(6,000)	(100)	(4,000)	(100)	(100)	(100)
Boundary	4.179E-3	1.429E-3	4.179E-3	3.873E-1	4.179E-3	4.179E-3	4.179E-3
Well	(70)	(6,000)	(70)	(4,000)	(70)	(70)	(70)
Population	2.229E-4	3.314E-4	1.163E-4	1.224E-1	1.976E-4	6.667E-5	1.491E-4
Well	(10,000)	(10,000)	(10,000)	(6,000)	(10,000)	(10,000)	(10,000)
Surface	9.851E-6	1.363E-5	4.992E-6	5.577E-3	8.681E-6	2.732E-6	6.448E-6
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
(6)							
Intruder	2.487E-2	4.517E-2	2.156E-2	1.238E+1	2.235E-2	2.156E-2	2.156E-2
Well	(6,000)	(6,000)	(100)	(4,000)	(6,000)	(100)	(100)
Boundary	1.113E-1	4.503E-2	1.113E-1	1.238E+1	1.113E-1	1.113E-1	1.113E-1
Well	(70)	(6,000)	(70)	(4,000)	(70)	(70)	(70)
Population	7.096E-3	1.045E-2	3.690E-3	3.911E+0	6.287E-3	2.103E-3	4.739E-3
Well	(10,000)	(10,000)	(10,000)	(6,000)	(10,000)	(10,000)	(10,000)
Surface	3.147E-4	4.347E-4	1.594E-4	1.783E-1	2.773E-4	8.713E-5	2.060E-4
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)

time period equal to 100 years following license termination, approximately 10 percent of the disposal cells are assumed to be significantly disturbed by intrusion so that infiltration of rainwater into the disturbed disposal cells is increased from less than a millimeter per year to about 30 mm/year. The percolation over the remainder of the disposal area is raised to about 1.5 mm/yr. Since most of the boundary well exposures are due to migration of tritium, the hundred year time period of minimum infiltration allows considerable decay of the tritium inventory (by a factor of about 280) prior to initiation of the higher percolation rates. Since iodine-129 is so very long lived, the 100-year institutional control period has virtually no effect on the inventory in the disposal cells.

Other Impacts

Other impacts are listed in Table 5.13. It can be seen that the major differences from Cases 4A-4E are in occupational exposures at the disposal facility, costs, incremental energy use, and committed land.

Table 5.13 Other Impacts Associated with Cases 5 and 6

Impacts	Case 5	Case 6
Short-term population exposures: (man-mrem)		
Processing at waste generator	-	-
Processing at regional processing center	0	0
Waste transportation	5.10E+5	5.10E+5
Short-term occupational exposures: (man/mrem)		
Processing at waste generator	-	-
Processing at regional processing center	0	0
Waste transportation	5.82E+6	5.82E+6
Waste disposal	5.27E+6	1.05E+7
Waste generation and transport costs: ($)		
Processing at waste generator	-	-
Processing at regional processing center	0	0
Waste transportation	2.05E+8	2.05E+8
Disposal Costs: ($)		
Design and Operational	4.21E+8	2.56E+8
Postoperational	1.22E+7	1.81E+7
Total:	4.33E+8	2.74E+8
Unit ($/$m^3$)	442	280
Energy use: (gal)	+3.00E+5	-1.00E+5
Land use: (m^2)	5.33E+5	3.40E+5
Waste volume disposed: (m^3)		
Regular:		
Chemical-stable	1.02E+4	1.02E+4
Chemical-unstable	1.17E+5	1.15E+5
No chemical-stable	2.23E+5	2.23E+5
No chemical-unstable	6.30E+5	5.34E+5
Total	9.80E+5	8.82E+5
Layered:		
Chemical-stable	0	0
Chemical-unstable	0	1.87E+3
No chemical-stable	0	0
No chemical-unstable	0	9.59E+4
Total	0	9.77E+4
Hot Waste Facility	0	0
Total disposed:	9.80E+5	9.80E+5
Total volume not acceptable: (m^3)	1.94E+4	1.94E+4

Occupational exposures are seen to be in the range of 5.27 E+6 man-millirem, which is similar to the range of exposures calculated for Cases 4D and 4E, in which the waste is assumed to be stacked into the disposal cells. Waste is also assumed to be stacked for Case 5. These occupational exposures are more than twice those estimated for Case 1. Waste operations would all take place from the top of the disposal cells, and so the average distance between the workers and the disposed waste would be increased. On the other hand, waste disposal operations would take longer. In addition, use of walled trenches involves grouting of waste packages, which is an additional disposal step.

The most significant difference from earlier cases appears to be in the costs. Due to the expensive engineered disposal cells, facility design and operational costs for Case 4A are projected to climb to \$421 million (\$430/m^3, \$12.20/ft^3), which is an increase by a factor of 2.25 from Case 1 and by about 2 from Case 4C. This may actually be a low estimate. Since this disposal technique has not been implemented on a full-scale basis at any disposal facilities, there would undoubtably be a number of logistical and practical details to work out. These could raise costs well above those estimated here. One of the practical difficulties, for example, would involve emplacement of all wastes from above the disposal cells using slings and hoists. This would be a straightforward task for liners and boxes, but would be considerably more difficult for drummed wastes. This is especially significant when one considers that the great majority of the LLW delivered to disposal facilities are delivered in 55-gallon drums.

On the other hand, the site stability resulting from the extensive engineering practices represented by use of the walled trench results in a considerable reduction in estimated long-term care costs. Long-term care costs are estimated at the lowest level (\$12.2 million). Overall costs for Case 5 are estimated at \$433 million, or an average of about \$442 per m^3 of waste (\$12.50/ft^3). As discussed above, these costs may actually be higher.

Another concern is equitability. Much of the waste is very low hazard material and often only suspected of being contaminated with radioactivity. This waste is quite often generated by small businesses or other concerns such as clinics, colleges, research facilities, and small manufacturers. In addition, a particular licensee may generate only small quantities of waste material per year. These factors increase the difficulty of the analysis and arriving at an equitable solution. On one hand, it is difficult to justify requiring disposal methods involving significantly increased costs to dispose of waste which may otherwise be of very low hazard. Such significantly increased costs would probably principally impact licensees such as small businesses or other concerns which may also only generate relatively small volumes of waste per licensee. On the other hand, disposal facility instability has been shown to a significant factor in long-term costs to a site owner.

Energy use is estimated to increase relative to Case 1--in this case by 200,000 gallons of equivalent fuel. In this calculation, the reduced energy use associated with long-term care is somewhat offset by the increased energy consumption associated with construction of the walled trenches. Due to greatly decreased efficiency of the walled trenches, land use is estimated to be approximately 1.57 times that for Case 1 and 2.35 times that for Case 4D.

5.2.4.4 Case 6 - Decontainerized Disposal of Compressible Waste

Case 6 is included to assess a potential alternative method of disposing of low activity compressible wastes. In this case, lower activity compressible wastes are assumed to be emptied out of containers into segregated disposal trenches, where the waste is periodically covered by a soil layer. Trenches for which this practice occurred would be operated in a similar manner as a sanitary landfill. Operations would be carried out under weather shielding (such as an air support building) to reduce wind scatter. This case is summarized on Table 5.11.

The rationale for considering this case is that with no rigid containers, there would be an overall reduction in void spaces within the disposal trenches containing the compressible wastes. There would be some initial slumping as the waste degrades, but after a few years, it could be assumed that an equilibrium condition could occur. Long-term maintenance requirements, relative to Case 1, would be reduced. This technique, however, has never been extensively used at a radioactive waste disposal facility.

Ground-Water Impacts

Maximum estimated ground-water radiological impacts for this case are summarized in Table 5.12, while other impacts are summarized in Table 5.13. Relative to Case 4C, ground-water impacts are seen to be the same at the four biota access locations. Maximum organ doses, except for thyroid, at the boundary well are in the range of 0.1 mrem, with exposures at the population well and the surface water access location in the range of 10^{-3} mrem, and 10^{-4} mrem, respectively. Thyroid exposures are considerably higher than the other organ doses at all access locations. As discussed previously, the maximum exposures at the intruder and boundary wells are mostly due to tritium and iodine.

Other Impacts

Also of interest are the other impacts shown in Table 5.13. Of concern is the greatly increased occupational exposures received during waste handling and disposal operations at the disposal facility. These are estimated to be approximately 4 times those for Case 1 and twice those for Case 4D. These exposures are uncertain, since this disposal technique has never previously been extensively used at any disposal facility, and could be higher.

Disposal facility design and operational costs are lower than those for Case 5, but are significantly higher than Cases 1 through 4E. Long-term care costs are especially difficult to estimate. The idea behind this disposal technique is that the reduction in void space and the increased rate of decomposition would result in decreased long-term maintenance requirements. However, given the somewhat speculative nature of this disposal technique, a moderate (rather than low) level of long-term care costs has been assumed. This results in a total disposal cost of $274 million, or $280/m^3 ($7.93/ft^3). This is less than the unit costs for Case 5, but greater than unit costs for Cases 1 through 4E.

Due to the reduced long-term care requirements, incremental energy use is reduced relative to Case 1 by about 100,000 gallons of equivalent fuel. Land use is similar to Cases 1 through 4C.

5.2.4.5 Case 7 - Use of Improved Waste Forms

Case 7 presents a significant change relative to the previous cases in that waste spectrum 2 is assumed rather than waste spectrum 1. In waste spectrum 2 the following is assumed:

- All LWR concentrated liquids are evaporated to 50 weight percent solids.

- All LWR process wastes, including liquids, ion exchange resins, filter media, and cartridge filters are solidified using improved solidification techniques (solidification scenario B). In this case, half the waste is assumed to be solidified in cement and the other half is assumed to be solidified in an improved polymer solidification agent.

- Liquid waste streams from production of medical isotopes are assumed to be solidified in an improved polymer solidification agent (solidification scenario C).

- All combustible waste streams are assumed to be compacted. All fuel cycle trash streams and half of the institutional and industrial waste streams are assumed to be compacted by the waste generator. The other half of the institutional and industrial combustible waste streams (I+COTRASH, N+SSTRASH, N+LOTRASH) are assumed to be compacted at a regional processing facility which is assumed to be colocated with the disposal facility. This results in a total volume of 1.025 E+5 m^3 of compressible material which is processed at the regional processing center to an approximate volume of 2.98 E+4 m^3 prior to disposal.

- All higher activity waste streams are stabilized in a manner which is less likely to degrade and reduce in volume in a humid environment. These include the following waste streams: P-NCTRASH, B-NCTRASH, L-NFRCOMP, N-ISOPROD, AND N-HIGHACT. These waste streams are not in themselves unstable but are assumed to be packaged in waste spectrum 1 using compressible trash for shielding and/or containing large void spaces within the waste packages. There may be a number of ways in which these waste streams may be stabilized--e.g., for activated metals such as nonfuel reactor core components (L-NFRCOMP), void spaces within a waste package may be potentially filled with a nondegradable filter such as sand rather than compressible trash. The costs for such waste stabilization may vary depending upon the waste form and activity, but as an upper bound the costs of placing the waste streams into high integrity containers may be used. As discussed in Section 5.2.4.8, these costs are estimated as approximately $450 per m^3 of waste.

In a number of ways waste spectrum 2 represents the direction in waste form and packaging toward which waste generators are heading. For examples, although there are no regional processing facilities currently operating, many licensees (particularly large licensees) have installed or are installing waste compacting equipment. In addition, license conditions at operating waste disposal facilities will shortly require that LWR ion exchange resins and filter media be either solidified or packaged in a high integrity container.

Due to the additional waste processing carried out by the waste generators and at the regional processing center, the total volume of waste is reduced in waste spectrum 2 from one million m^3 to 6.978E+5 m^3. In addition, the volume of unstable waste streams is reduced from 76% to 45% of the total waste spectrum. The activity in this waste spectrum, however, is assumed to remain the same.

Case 7 consists of 4 subcases in which successive disposal facility design and operational improvements are made. These 4 subcases are summarized briefly below and in more detail in Table 5.14:

- Case 7A. Similarly to Case 1A, waste streams are randomly disposed into disposal cells with no segregation of compressible waste streams or waste streams containing organic chemicals or chelating agents. A thin soil cover ("standard cap") is placed over the disposed waste and little compaction of the trench cover takes place.

- Case 7B. This case is similar to Case 4A in that easily compressible waste streams as well as waste streams containing significant quantities of chelating agents are assumed to be disposed in a segregated manner.

- Case 7C. This case is similar to Case 4B. In addition to segregation of the compressible waste streams and waste streams containing chelating agents, the disposal cell covers containing compressible waste streams are subjected to improved compaction techniques.

- Case 7D. This case is similar to Case 4C. In addition to waste segregation, thicker disposal cell covers composed of a high-grade clay soil are assumed to be emplaced over all the disposal cells, which are also subjected to improved compaction techniques.

Ground-Water Impacts

Maximum ground-water impacts at each of the four biota access locations are listed in Table 5.15. In general, the impacts calculated in Case 7A for the intruder and boundary wells are, except for thyroid exposures, similar to those calculated for Case 1A. Similarly, boundary well impacts for Cases 7B through 7D are, except for thyroid exposures, similar to those respectively calculated for Cases 4A through 4C. However, a more significant difference is observed for thyroid exposures at the intruder and boundary wells, as well as exposures to all organs at the population well and the surface water access location.

Table 5.14 Summary of Cases 7A-7D

<u>Case 7A - Improved Waste Forms: No Segregation</u>

- o Regular SLB trench
- o Waste spectrum 2
- o SLB with a standard cap
- o No segregation of wastes containing chelates
- o No segregation of compressible wastes
- o Random disposal of waste with a sand backfill
- o Layering used as an intruder barrier

<u>Case 7B - Improved Waste Forms: Segregation</u>

- o Regular SLB trench
- o Waste spectrum 2
- o SLB with a standard cap
- o Segregation of wastes containing chelates
- o Segregation of compressible wastes
- o Random disposal of waste with a sand backfill
- o Layering used as an intruder barrier.

<u>Case 7C - Improved Waste Forms: Segregation Plus Compaction</u>

- o Regular SLB trench
- o Waste spectrum 2
- o SLB with a standard cap
- o Compaction using improved methods
- o Segregation of wastes containing chelates
- o Segregation of compressible wastes
- o Random disposal of waste with a sand backfill
- o Layering used as an intruder barrier

<u>Case 7D - Improved Waste Forms: Segregation, Compaction and Improved Covers</u>

- o Regular SLB trench
- o Waste spectrum 2
- o SLB with a thicker clay cap
- o Compaction using improved methods
- o Segregation of wastes containing chelates
- o Segregation of compressible wastes
- o Random disposal of waste with a sand backfill
- o Layering used as an intruder barrier

Table 5.15 Estimated Radiological Impacts from Ground-Water Migration for Cases 7A through 7D

	(mrem/yr)						
Cases	Body	Bone	Liver	Thyroid	Kidney	Lung	GI
(7A)							
Intruder	3.042E+0	2.466E-1	3.042E+0	2.353E+1	3.042E+0	3.042E+0	3.042E+0
Well	(100)	(6,000)	(100)	(6,000)	(100)	(100)	(100)
Boundary	1.570E+1	2.464E-1	1.570E+1	2.353E+1	1.570E+1	1.570E+1	1.570E+1
Well	(70)	(6,000)	(70)	(6,000)	(70)	(70)	(70)
Population	2.044E-2	5.468E-2	1.397E-2	7.430E+0	1.889E-2	1.096E-2	1.594E-2
Well	(10,000)	(10,000)	(10,000)	(8,000)	(10,000)	(10,000)	(10,000)
Surface	9.174E-4	2.425E-3	6.226E-4	3.387E-1	8.460E-4	4.855E-4	7.017E-4
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
(7B)							
Intruder	7.702E-1	2.158E-1	7.702E-1	2.500E+0	7.702E-1	7.702E-1	7.702E-1
Well	(100)	(6,000)	(100)	(6,000)	(100)	(100)	(100)
Boundary	3.976E+0	2.156E-1	3.976E+0	3.976E+0	3.976E+0	3.976E+0	3.976E+0
Well	(70)	(6,000)	(70)	(70)	(70)	(70)	(70)
Population	1.035E-2	4.680E-2	9.678E-3	7.858E+0	1.020E-2	9.362E-3	9.895E-3
Well	(10,000)	(10,000)	(10,000)	(8,000)	(10,000)	(10,000)	(10,000)
Surface	4.598E-4	2.072E-3	4.290E-4	3.5E81-2	4.525E-4	4.146E-4	4.386E-4
Water	(10,000)	(10,000)	(10,000)	(8,000)	(10,000	(10,000)	(10,000)
(7C)							
Intruder	7.645E-1	1.238E-1	7.645E-1	2.246E+0	7.645E-1	7.645E-1	7.645E-1
Well	(100)	(6,000)	(100)	(6,000)	(100)	(100)	(100)
Boundary	3.947E+0	1.237E-1	3.947E+0	2.246E+0	3.947E+0	3.947E+0	3.947E+0
Well	(70)	(6,000)	(70)	(6,000)	(70)	(70)	(70)
Population	6.279E-3	2.690E-2	5.668E-3	7.073E-1	6.139E-3	5.383E-3	5.868E-2
Well	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
Surface	2.792E-4	1.191E-3	2.514E-4	3.224E-2	2.727E-4	2.384E-4	2.602E-4
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
(7D)							
Intruder	2.151E-2	3.352E-2	2.151E-2	5.277E-1	2.151E-2	2.151E-2	2.151E-2
Well	(100)	(6,000)	(100)	(6,000)	(100)	(100)	(100)
Boundary	1.111E-1	3.339E-2	1.111E-1	5.277E-1	1.111E-1	1.111E-1	1.111E-1
Well	(70)	(6,000)	(70)	(6,000)	(70)	(70)	(70)
Population	1.661E-3	7.249E-3	1.517E-3	1.661E-1	1.627E-3	1.450E-3	1.564E-3
Well	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
Surface	6.848E-5	2.943E-4	6.194E-5	7.563E-3	6.695E-5	5.889E-5	6.402E-5
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)

This pattern is basically due to the fact that under waste spectrum 2, while no change in waste form is assumed for the two low volume waste streams delivered to the facility containing very high concentrations of tritium (N-TRITIUM and N-TARGETS), all LWR process waste streams are placed into a stable waste form through solidification. In addition, a number of higher activity waste streams are packaged to achieve greater waste form stability over the long term.

For Case 7A, even though there is an overall improvement in waste form in waste spectrum 2, the disposal practice of mixing compressible waste streams with stable waste streams still results in trench subsidence problems and increased percolation into all of the disposal cells. This increased percolation is conservatively assumed to be the same as that for Case 1, although the additional compaction applied to compressible waste streams would actually be expected to reduce the rate of subsidence and thus reduce percolation. This effect is difficult to quantify but would be expected to be most significant over the short term. At any rate, tritium releases from the N-TRITIUM and N-TARGETS waste streams are essentially identical to those experienced in Case 1A, and almost identical whole body exposures at the boundary well result. After this pulse of tritium passes, however, the next highest calculated whole body exposures at the boundary well are about 0.8 mrem for Case 7A, while the next highest whole body boundary well exposures for Case 1A are about twice as high. Both of these maximums occur at about 6,000 years following license termination.

The reduced secondary maximums in Case 7A (relative to Case 1A) is principally due to the assumed use of less leachable waste forms for LWR process streams. This effect may be observed, for example, by comparing population well and surface water exposures in Cases 7A through 7D with the respective Cases 1A and 4A through 4C. This effect is most easily observed, however, by comparing thyroid exposures at all of the access locations. Comparing Cases 7A through 7D with Cases 1A and 4A through 4C, thyroid exposures are reduced by a factor of about 4 at the population well and the surface water access location. This is expected given the assumed reduction in leaching achieved from solidification of the LWR process waste streams.

<u>Other Impacts</u>

Other impacts are set out in Table 5.16. In it can be seen that potential population exposures from waste processing are still taken to be at negligible levels. This is because essentially all of the waste processing is done through compaction techniques, and potential airborne effluents from compaction are taken to be negligible compared to those potential exposures from incineration. Population exposures from waste transportation are slightly reduced--i.e., from 5.10 E+5 man-millirem to about 5.01 E+5 man-millirem over 20 years--which is a result of the reduced volume of waste that is delivered to the reference facility under waste spectrum 2.

Occupational exposures are all expected to increase with respect to Case 1. For example, total exposures for waste processors are estimated to rise by

Table 5.16 Other Impacts for Cases 7A Through 7D

Impacts	Case 7A	Case 7B	Case 7C	Case 7D
Short-term population exposures: (man-mrem)				
Processing at waste generator	-	-	-	-
Processing at regional processing center	0	0	0	0
Waste transportation	5.01E+5	5.01E+5	5.01E+5	5.01E+5
Short-term occupational exposures: (man-mrem)				
Processing at waste generator	+1.68E+6	+1.68E+6	+1.68E+6	+1.68E+6
Processing at regional processing center	1.25E+5	1.25E+5	1.25E+5	1.25E+5
Waste transportation	5.43E+6	5.43E+6	5.43E+6	5.43E+6
Waste disposal	2.34E+6	2.34E+6	2.34E+6	2.34E+6
Waste generation and transport costs: ($)				
Processing at waste generator	+3.38E+8	+3.38E+8	+3.38E+8	+3.38E+8
Processing at regional processing center	3.63E+7	3.63E+7	3.63E+7	3.63E+7
Waste transportation	1.85E+8	1.85E+8	1.85E+8	1.85E+8
Disposal Costs: ($)				
Design and operational	1.93E+8	1.92E+8	1.93E+8	1.99E+8
Long-term care	3.82E+7	1.81-3.82E+7	1.81E+7	1.22E-1.81E+7
Total:	2.31E+8	2.10-2.30E+8	2.11E+8	2.11-2.17E+8
Unit ($/$m^3$) (a)	341	310-340	311	311-320
Energy Use: (gal)	+8.00E+6	+8.00+6	+7.80E+6	+7.80E+6
Land Use: (m^2)	2.36E+5	2.36E+5	2.36E+5	2.36E+5
Waste volume disposed: (m^3)				
Regular:				
Chemical-stable	3.90E+4	4.00E+4	4.00E+4	4.00E+4
Chemical-unstable	7.40E+4	7.40E+4	7.40E+4	7.40E+4
No chemical-stable	1.32E+5	3.30E+5	3.30E+5	3.30E+5
No chemical-unstable	2.32E+5	2.32E+5	2.32E+5	2.32E+5

Table 5.16 (Continued)

Impacts	Case 7A	Case 7B	Case 7C	Case 7D
Layered:				
Chemical-stable	3.83E+3	2.87 E+3	2.87 E+3	2.87 E+3
Chemical-unstable	0	0	0	0
No chemical-stable	1.98E+5	0	0	0
No chemical-unstable	0	0	0	0
Total	2.02E+5	2.87E+3	2.87E+3	2.87E+3
Hot waste facility:	0	0	0	0
Total disposed:	6.78E+5	6.78E+5	6.78E+5	6.78E+5
Total volume not acceptable: (m^3)	1.94E+4	1.94E+4	1.94E+4	1.94E+4

*The indicated unit costs are obtained from dividing the total disposal costs by the volume of waste delivered to the disposal facility, which is about 680,000 m^3 for Case 7. If unit disposal costs were calculated using the "unprocessed" (waste spectrum 1) volumes disposed for Cases 1 through 6, unit costs would be as follows:

7A	7B	7C	7D
236	214-235	215	215-221

2.23E+6 man-millirem. Waste processing exposures at the regional processing center are calculated at 1.25E+5 man-millirem, which translates to 8.4 man-rem per year. Assuming two shifts, each composed of a two-man crew, this translates into an annual exposure of about 1.6 rems per man.

Waste transportation occupational exposures and waste disposal facility occupational exposures are generally reduced from the exposures set out in the previous Cases 1 through 6. The volume reduction tends to increase the concentration of the radionuclides in the resulting waste streams. However, the concentration of radionuclides is already so low in the compacted streams that the increased concentration is more than off-set by the reduced number of waste packages that must be handled.

Similarly, total population exposures from waste transportation are reduced with respect to Cases 1 through 6. This is again because of the reduced number of waste shipments for transfer of the same activity of waste to the disposal facility.

Of interest in this case is the relationship between processing costs, transportation costs, and disposal costs. As discussed by Tekenkron, (Ref. 6) the actual costs are quite variable and are a complicated function of disposal charges at the facility, transportation distances, the potential need to use shielded transport vehicles, the volume of waste processed, the costs of installing and maintaining waste processing equipment, and so forth. Additional expenditures would be, of course, required by a waste generator to install, use, and maintain compaction equipment. However, less storage space would be required by the waste generator, fewer shipping containers would be needed, and overall transportation costs would be expected to be reduced. This is borne out by Table 5.16. For the same activity in the waste spectrum, overall transportation costs over 20 years are estimated to be reduced by a factor of 1.13 over waste spectrum 1--e.g., from \$205 million to \$185 million.

For waste spectrum 2, total processing costs over 20 years are raised relative to waste spectrum 1 by \$374.3 million. Of this additional \$374.3 million, \$36.3 million results from charges for processing by compaction of 1.025 E+5 m^3 of waste at the regional processing center. The compaction results in a total volume reduction of about 3.4 at an average cost of \$354 per meter of unprocessed waste (\$10.03/ft^3). Of the remaining additional \$338 million expended by waste generators, approximately \$40 million is due to processing 7 waste streams by compaction at the facilities at which the waste is generated. (These include the P-COTRASH, B-COTRASH, F-COTRASH, I-COTRASH, N-SSTRASH, N-LOTRASH, and I-LQSCNVL streams; which are reduced in total disposed volume relative to waste spectrum 1 from 3.8 E+5 m^3 to 2.2 E+5 m^3.) Of the remainder, approximately \$257 million is expended in solidifying previously unstable LWR process waste streams, while approximately \$41 million is conservatively assumed to be expended in stabilizing the higher activity waste streams.

Some care is required in interpreting these incremental waste processing costs. For example, costs for compaction of compressible wastes are already being borne by many licensees, generally as a means of reducing waste transport costs. The remaining expense is involved with stabilizing the higher activity waste streams. Much of the additional costs for waste stabilization involve costs for solidifying LWR ion exchange resins and filter media. Solidifying these waste streams is one way in which existing disposal license conditions may be met.

Some care is also required in interpreting the calculated disposal costs. As shown in Table 5.16, facility design and operation costs increase from \$193 million to \$199 million for Case 7A through 7D, reflecting the successive addition of facility design and operating options. Design and operating costs are reduced, however, for Cases 7A-7D compared with respective Cases 1A, 4A, 4B, and 4C. This is due to the reduced volume of waste delivered to the disposal facility.

Long-term care costs are difficult to estimate for Cases 7A through 7D, but would in general be considered to involve a reduced level of long-term care costs than those for the respective Cases 1A, 4A, 4B, and 4C. In Case 7A, for example, despite the additional processing costs and occupational exposures

borne by waste generators in waste spectrum 2, the stable waste streams are still randomly mixed with unstable waste streams in the disposal cells. The potential for subsidence problems involving all waste disposal cells requires an assumption of a high level of long-term care costs. This assumption, however, is more conservative than the similar assumption for Cases 1-3 and 1A. The improved waste form provided by the compaction would resist degradation better than noncompacted waste. Potential voids would be slower to form and potential slumping problems reduced. If subsidence does occur, it would occur at a lower rate. This would reduce the labor required to maintain the facility and also reduce the percolation of water into the disposal cells containing compressible material, thus reducing potential ground-water migration from these disposal cells.

Long-term care costs for Cases 7B through 7D are estimated to be further reduced depending upon facility design and operating practices. In Case 7D, for example, a low to moderate range of long-term care costs is estimated. This can be compared with Case 4C, in which something greater than a moderate level of long-term care costs are estimated. In Case 4A, 76 percent of the disposed waste volume is in an unstable form while for Case 7D, this has been reduced to 45%. In addition, for Case 7D, waste streams having high concentrations of radionuclides have been stabilized to resist extreme volume change due to waste or waste package degradation. The inventory of radionuclides in the disposal cells containing unstable wastes has been considerably reduced, therefore reducing the potential migration impacts from these waste streams. This should lessen the concern over maintenance of these segregated trenches and help to reduce long-term costs.

Total disposal costs range from about $210 million to about $231 million over the 4 subcases. It is interesting to observe that the difference in the total costs over the 4 cases ($21 million) is much greater than the difference in design and operating costs. This is because the increase in design and operating costs is compensated by the reduction in long-term care costs.

As shown and as compared with Cases 1A and 4A through 4C, total costs have decreased, since the total waste volume delivered to the disposal facility has decreased, while unit costs have increased. This makes estimation of unit costs difficult as well as use of unit costs to compare alternatives. On one hand, the disposal facility would not fill up with waste as fast and so would be able to accept additional waste for disposal. However, the disposal facility may be restricted to accepting waste only from a particular region or group of states, in which case the operating life of the disposal facility would be extended. In addition, the lower volume of waste being accepted means less revenues received by the disposal facility operator. Capital and other overhead costs are not linearly dependent upon the volume of waste received, since many of the same activities would have to be performed at a disposal facility accepting a large volume of waste as one accepting a small volume of waste. Disposal facility operators would therefore tend to raise their prices to cover expenses.

At any rate, Table 5.16 illustrates two unit cost figures. One is calculated by dividing the total disposal costs by the volume of waste actually delivered to the disposal facility, which is about 680,000 m^3 for Case 7. The other unit cost is calculated by dividing the total disposal costs by the "unprocessed" (waste spectrum 1) volumes delivered to the disposal facility for Cases 1 through 6. From this, it would appear that use of total (20 year) disposal costs is a better unit to compare alternatives than unit costs.

Committed land use for the 4 subcases of Case 7 is 236,000 m^2. This is a significant drop from Cases 1 through 6 (e.g., 340,000 m^2 for most of the earlier cases) and reflects the lower volume of waste delivered to the disposal facility under waste spectrum 2.

Incremental energy use varies over a fairly narrow range, and reflects the opposing mechanisms of increased energy consumption for additional facility design and operation options and decreased energy consumption due to lower long-term maintenance requirements. In addition, increased energy consumption is associated with waste processing, while decreased energy consumption is associated with waste transportation and waste disposal operations. In general, however, and due to the additional waste processing, incremental energy consumption for Cases 7A through 7D are higher than the respective Cases 1A and 4A through 4C.

5.2.4.6 Case 8 - Use of Further Improved Waste Forms

This case is similar to Case 7D except that waste spectrum 3 is used instead of waste spectrum 2. Under waste spectrum 3, LWR process wastes are assumed to be solidified using further improved solidification agents (solidification scenario C), which is represented by a synthetic polymer having low leaching characteristics. LWR concentrated liquids are first evaporated to 50 weight percent solids. Extensive incineration of combustible material (except LWR process wastes) is performed. In this scenario, fuel cycle trash, LWR decontamination resins (L-DECONRS stream), trash from large institutions, and trash from large industrial firms are assumed to be incinerated at the point of generation. Trash streams from small institutional and industrial facilities (which include the I+COTRASH, N+SSTRASH, AND N+COTRASH waste streams) are assumed to be delivered to a regional processing center for incineration. This regional processing center is assumed to be colocated with the disposal facility. After waste incineration, the ashes are assumed to be solidified prior to disposal using a synthetic polymer (solidification scenario C).

Processing the waste in this manner results in a significant reduction in the amount of waste delivered to the disposal facility that is in an unstable form. That is, only the I+LQSCNVL, I+BIOWAST, N-LOWASTE, AND F-NCTRASH streams still exist in an unstable form, which only totals 2.079 E+4 m out of the 4.92 E+5 m^3 eventually disposed at the disposal facility (representing only 4% of the disposed volume). The design of the disposal facility is assumed to be similar to that for Case 7D, and is summarized in Table 5.17.

Waste segregation is performed at the disposal facility, and following random emplacement of the waste packages in the disposal cells, a thick clay cover is emplaced which is compacted using improved compaction techniques.

Table 5.17 Summary of Cases 8 and 9

Case 8 - Further Improved Waste Forms
o Regular SLB trench
o Waste spectrum 3
o SLB with a thicker clay cap
o Compaction using improved methods
o Segregation of wastes containing chelates
o Segregation of compressible wastes
o Random disposal of waste using a sand backfill
o Layering used as an intruder barrier
Case 9 - Improved Waste Forms and Cement Walled Trench
o Cement walled trench
o Waste spectrum 3
o Use of thicker, compacted cap
o Segregation of wastes containing chelates
o Segregation of compressible wastes
o Stacked disposal of waste
o Grouting emplaced between waste packages
o Cement walled trench used as an intruder barrier

Ground-Water Impacts

Maximum ground-water impacts for this case for each of the four biota access locations are shown in Table 5.18. It is useful to compare these results with those for Case 7D. Compared with Case 7D, whole body intruder and boundary well exposures for Case 8 are only slightly reduced. This is because as in the case of waste spectra 1 and 2, no processing is performed on the N-TARGETS and N-TRITIUM waste streams. Releases of tritium from these waste streams are essentially at the same rates as in Case 7D. Comparing whole body exposures at the population well, however, reveals a reduction in exposures by a factor of between 5 and 6. Similarly, thyroid exposures for Case 8 have been reduced with respect to Case 7D. In Case 7D, maximum thyroid exposures at the intruder and boundary wells are about .5 millirem and occur at about 6,000 years following license termination. In Case 8, maximum intruder and boundary well thyroid exposures are about .22 millirem, a reduction by a factor of about 2.3.

Table 5.18 Summary of Ground-Water Impacts for Cases 8 and 9

	(mrem/yr)						
Cases	Body	Bone	Liver	Thyroid	Kidney	Lung	GI
(8)							
Intruder	2.119E-2	4.629E-3	2.119E-2	2.216E-2	2.119E-2	2.2119E-2	2.119E-2
Well	(100)	(6,000)	(100)	(6,000)	(100)	(100)	(100)
Boundary	1.094E-1	4.612E-3	1.094E-1	2.216E-1	1.094E-1	1.094E-1	1.094E-1
Well	(70)	(6,000)	(70)	(6,000)	(70)	(70)	(70)
Population	2.913E-4	1.010E-3	2.306E-4	6.994E-2	2.786E-4	2.022E-4	2.540E-4
Well	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
Surface	1.228E-5	4.109E-5	9.518E-6	3.187E-3	1.170E-5	8.223E-6	1.056E-5
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
(9)							
Intruder	8.060E-4	1.977E-4	8.060E-4	1.843E-2	8.060E-4	8.060E-4	8.060E-4
Well	(100)	(6,000)	(100)	(4,000)	(100)	(100)	(100)
Boundary	4.161E-3	1.968E-4	4.161E+3	1.843E-2	4.161E-3	4.161E-3	4.161E-3
Well	(70)	(6,000)	(70)	(4,000)	(70)	(70)	(70)
Population	1.617E-5	4.362E-5	1.111E-5	5.822E-3	1.512E-5	1.512E-6	8.742E-5
Well	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
urface	6.912E-7	1.762E-6	4.606E-7	2.653E-4	6.424E-7	3.527E-7	5.472E-7
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)

Other Impacts

Other impacts are listed on Table 5.19. Of interest are short-term population exposures, short-term occupational exposures, and costs. Due to the incineration of the waste, airborne releases are assumed to occur in the environs of the waste generators and the regional processing center. Total airborne population exposures over 20 years due to processing by waste generators are 7.86E+6 man-millirem, which reduce to about 3.93E+5 man-millirem per year or about 19 man-millirem per m^3 of waste processed. Waste processing activities at the regional processing center are estimated to result in a total population dose of 3.74E+4 man-millirem over 20 years, or about 1,870 man-millirem per year (0.09 man-millirem per m^3 of processed waste disposed at the disposal facility). Given the 480,000 persons assumed to reside within 50 miles of the regional processing center, this averages to approximately 3.9 E-3 millirem per year per person within 50 miles.

Table 5.19 Other Impacts Associated with Cases 8 and 9

Impacts	Case 8	Case 9
Short-term population exposures: (man-mrem)		
Processing at waste generator	+7.86E+6	+7.86E+6
Processing at regional processing center	3.74E+4	3.74E+4
Waste transportation	5.04E+5	5.04E+5
Short-term occupational exposures: (man-mrem)		
Processing at waste generator	+1.18E+6	+1.18E+6
Processing at regional processing center	2.45E+4	2.45E+4
Waste transportation	5.40E+6	5.40E+6
Waste disposal	2.43E+6	4.86E+6
Waste generation and transport costs: ($)		
Processing at waste generator	+1.15E+9	+1.15E+9
Processing at regional processing center	9.50E+7	9.50E+7
Waste transportation	1.83E+8	1.83E+8
Disposal costs: ($)		
Design and Operations	1.93E+8	3.14E+8
Postoperational	1.22E+7	1.22E+7
Total:	2.05E+8	3.26E+8
Unit ($/m^3)*	417	663
Energy use: (gal)	+6.08E+7	+6.10E+7
Land use: (m^2)	1.71E+5	2.68E+5
Waste volume disposed: (m^3)		
Regular:		
Chemical-stable	8.68E+3	1.16E+4
Chemical-unstable	6.57E+4	6.57E+4
No chemical-stable	4.03E+5	4.03E+5
No chemical-unstable	1.15E+4	1.15E+4
Total	4.89E+5	4.92E+5
Layered:		
Chemical-stable	2.87E+3	0
Chemical-unstable	0	0
No chemical-stable	0	0
No chemical-unstable	0	0
Total	2.87E+3	0
Hot waste facility:	0	0
Total disposed:	4.92E+5	4.92E+5
Total volume not acceptable: (m^3)	1.13E+3	1.13E+3

*The indicated unit costs are obtained from dividing the total disposal costs by the volume of waste delivered to the disposal facility, which is about $490,000 m^3 for Cases 8 and 9. If unit disposal costs were calculated using the "unprocessed" (waste spectrum 1) volumes disposed for Cases 1 through 6, unit costs would be as follows:

Case 8: $209/m^3

Case 9: $333/m^3

Population exposures from transportation are seen to be less than those for Cases 1 through 6 (waste spectrum 1) and are in the same range as those of Cases 7A through 7D (waste spectrum 2). In Case 8, a decreased volume of waste must be shipped, which would tend to reduce exposures. This is balanced by the increased number of higher activity waste shipments that must be transported to the disposal facility.

Short-term occupational exposures are, in several cases, reduced from Cases 7A through 7D. For example, total occupational exposures from processing waste streams at waste generator facilities and at the regional processing center are reduced from Cases 7A-7D. This is because the occupational exposures are estimated based upon the time required to be spent in a radiation environment processing the waste. It requires less time to process a given volume of waste by incineration; hence, the estimated occupational exposures are reduced. Waste transportation occupation exposures are somewhat reduced with respect to Cases 7A-7D while, disposal facility occupational exposures are somewhat higher. This is because although there is a decrease in the volume of waste delivered to the disposal facility, this is balanced by an increase in the number of higher activity waste containers. In the calculations, less time is taken in proximity to the higher activity waste streams during waste loading and transportation than during waste unloading and disposal. This results in slightly lower transportation occupational exposures and slightly higher waste disposal facility occupational exposures.

The estimated total costs for waste processing, transport, and disposal are seen to be significantly higher than for the other cases. The most significant additional costs are, of course, incurred during waste processing. As can be seen, total additional processing costs at the waste generators are approximately 2.4 times those calculated for Cases 7A-7D. Processing charges at the regional processing center run at about $927/m^3$ ($26.25/ft^3$), and are raised over Cases 7A-7D by a factor of about 2.6. Processing costs in this range again brings up the question of equitability. Incinerating the waste and solidifying the remaining ash does place the waste into a much more stable form. For some facilities which generate very large volumes of combustible waste, incineration may be an effective means of reducing transportation and disposal costs. It would be a difficult requirement to implement generally, however, as a means of stabilizing otherwise low hazard waste. Such extensive processing activities could not be implemented within a short time frame and would probably be a financial burden to most licensees--particularly small licensees such as hospitals and research laboratories.

Transport costs are about a factor of 1.14 less than those for Cases 1 through 6 and slightly lower than those for Cases 7A-7D. This is because on one hand, less shipments are required for transport of a given activity of waste to the disposal facility. On the other hand, more use must be made of expensive shielded transport vehicles and casks.

Total disposal costs relative to Cases 7A-7D are reduced. Unit costs, however, are raised. Because only about 4% of the waste is still in an unstable form and improved disposal cell covers and compaction techniques are implemented, the disposal facility is assumed to be placed in a stable condition.

Also predictably, land use is seen to drop to 1.65E+5 m^2, which is a reduction by a factor of 2 with respect to Case 1 and by a factor of 1.4 with respect to Case 7. Incremental fuel use is seen to be significantly greater than the preceding cases, which is basically caused by the increased use fuel to incinerate the waste.

5.2.4.7 Case 9 - Walled Trenches and Further Improved Waste Forms

This case investigates a rather extreme example of near-surface radioactive waste disposal. As in Case 8, waste spectrum 3 is assumed to be applied. However, in Case 9 as in Case 5, all wastes are assumed to be disposed into concrete walled trenches. The waste streams are segregated, stacked within the disposal cells, and grouted in place. A summary of this case is included as Table 5.17.

Ground-Water Impacts

Potential ground-water impacts are the lowest of the cases considered. Maximum exposures at the intruder and boundary wells are in the range of 10^{-4} to 10^{-3} mrem for most organs. Maximum thyroid exposures at the intruder and boundary wells are approximately .02 mrem at 4,000 years following license termination. The difference between the thyroid exposures and exposures to all other organs is more striking for the population well and surface water exposures. For the population well, for example, organ doses except thyroid are in the range of 10^{-7} to 10^{-5} millirem while thyroid exposures are in the range of 10^{-4} to 10^{-3} millirem.

Other Impacts

Other impacts are presented in Table 5.19. Since the same waste spectra is used, most of the short-term radiological impacts are the same as those for Case 8. However, occupational exposures are estimated to significantly rise due to the use of the concrete walled trench. Additional time must be spent in close proximity to the waste containers while emplacing the (stacked) waste and while grouting the waste mass.

Total disposal costs are estimated to be significantly ($123 million over 20 years) higher than for Case 8. Due to the use of the walled trench, design and operating costs are about $316 million, while again a low level of long term care and long term care costs are estimated ($12.2 million). Incremental energy use is some what higher than that for Case 8. Land use is also higher--e.g., by about a factor of about 1.6.

5.2.4.8 Case 10 - High Integrity Containers

The preceding case studies investigated a number of ways to improve the stability of the disposal facility. As discussed, improved facility stability can be achieved by segregating unstable low activity material from the higher activity waste material and by stabilizing the higher activity waste material. This stability can be achieved through disposal facility design and operating practices

(e.g., emplacing the waste into engineered disposal cells such as walled trenches or caissons) or through a stable waste form (e.g., solidifying dispersible high activity waste streams such as ion exchange resins or filter media, incinerating and solidifying compressible trash). These alternatives serve to maintain the integrity of the disposal cell covers and thus reduce the percolation of water through the disposal cell covers and subsequent contact with the waste. In the case of solidification, an additional improvement is gained in that the potential for radionuclides leaching from the solidified waste is assumed to be reduced.

Another viable alternative would be to place the high activity waste into a high integrity container (HIC). In this case, the container would be constructed in a much more robust manner than the containers generally used to transport wastes to disposal facilities. The HIC would be designed to resist crushing from static loads and corrosion from the contained wastes as well as the surrounding soils. The HIC could therefore provide the needed support to the disposal cell covers to minimize subsidence and to reduce infiltration. In addition, since the wastes would be contained inside the HIC, leaching of radionuclides from the HIC would be negligible as long as the HIC retained its integrity. (Note that corrosion through or damage of a portion of an HIC, which could compromise its ability to withstand leaching, would not be expected to generally reduce its ability to provide structural support for the disposal cell covers.) Another advantage to use of an HIC is that, compared with solidification, it may be easier to assure quality control over the final waste product.

To date, HICs have not been generally used to package wastes for disposal, although within the last few years there has been considerable interest in this concept--chiefly, as an alternative to solidification of ion exchange resins and filter media. Use of HICs is allowed by the South Carolina Department of Health and Environmental Control at the Barnwell, S.C. disposal facility. Performance criteria for HICs for the Barnwell facility have been drafted by South Carolina and these are listed in Table 5.20.

One HIC design which has been approved by the South Carolina Department of Health and Environmental Control is currently being marketed. The HIC is constructed principally of polyethylene and is currently available in designs ranging from 2.4 m^3 (84 ft^3) to 9 m^3 (316 ft^3). Special designs are advertised as being available upon request.

Other groups, including the Department of Energy, are also investigating HIC designs. Use of high integrity containers is planned for some waste streams generated from the decontamination of Three Mile Island Unit Two.

As a corollary to potential use of high integrity containers, there is also some interest is using polyethylene or other types of plastic 55-gallon drums for packaging lower activity wastes such as trash. Polyethylene drums are available, for example, which have been certified by DOT for use in transporting certain types of nonradioactive hazardous wastes such as oxidizers or corrosive solids. These are apparently available at approximately the same (or possibly reduced) price as standard steel 55-gallon drums. Compared to steel 55-gallon

Table 5.20 State of South Carolina Criteria for High Integrity Containers

The general criteria for high integrity containers to be used for high concentration waste forms is as follows:

1. The container must be capable of maintaining its contents until the radionuclides have decayed, approximately 300 years, since two of the major isotopes of concern in this respect are strontium-90 and cesium-137 with half-lives of 28 and 30 years, respectively.

2. The structural characteristics of the container with its contents must be adequate to withstand all the pressure and stresses it will encounter during all handling, lifting, loading, offloading, backfilling, and burial.

3. The container must not be susceptible to chemical, galvanic or other reactions from its contents or from the burial environment.

4. The container must not deteriorate when subjected to the elevated temperatures of the waste streams themselves, from processing materials inside the container, or during storage, transportation and burial.

5. The container must not be degraded or its characteristics diminished by radiation emitted from its contents, the burial trench or the sun during storage.

6. All lids, caps, fittings and closures must be of equivalent materials and construction to meet all of the above requirements and must be completely sealed to prevent any loss of the container contents.

Source: Chem-Nuclear Systems, Inc., "High Integrity Container Systems," November 17, 1980 (Ref. 7).

drums, which is the most common type of waste container used in the nuclear industry, a polyethylene or other type of plastic drum would be expected to degrade much slower after disposal, provided that the drum is designed to be compatible with the waste form and the disposal environment. The radionuclide containment capability would therefore be expected to be greater than a typical steel 55-gallon drum. More importantly, reduced container degradation would result in reduced compression of disposal cell contents, thus reducing subsidence and infiltration of water.

The following 3 cases examine use of high integrity containers from 2 viewpoints: (1) reduction of migration of tritium, and (2) as an alternative to solidification as a means of providing waste stability. For the former case, recall

that solidifying LWR process waste streams served to reduce exposures at the population well and surface water access location, but had less of an effect at the intruder well and the boundary well (e.g., see the results for Cases 7D and 8). These exposures were primarily due to migration of tritium. As discussed previously, two small volume industrial (nonfuel cycle) waste streams contain large quantities of tritium and yet were subjected to no improvements in waste form in waste spectra 2 and 3.

The 3 cases considered are the following:

- Case 10A. In this case, the design of the disposal facility is assumed to be the same as Cases 4C and 7D. Compressible wastes are segregated, the wastes are backfilled with sand, and a thick cover of clayey soil is emplaced which is compacted using improved compaction methods. Waste spectrum 2 is assumed. High integrity containers assumed to be effective for 100 years are applied to 2 industrial waste streams which contain large quantities of tritium: N-TRITIUM and N-TARGETS. The combined 20-year volume of these streams is only 1332 m^3, but the total tritium content is 2.27 million curies.

- Case 10B. This case is similar to Case 10A, except that waste spectrum 2 is assumed. Otherwise, the disposal facility is assumed to be the same design as Case 7D, and the 100-year HICs are applied to the same two low volume waste streams: N-TRITIUM and N-TARGETS.

- Case 10C. This case investigates the possible use of HICs for packaging of a number of waste streams. In this case, the same facility disposal design as the above two cases is assumed. Waste Spectrum 1 is also assumed. However, HICs assumed to be effective for 300 years are used for all LWR process waste streams except solidified liquids, as well as the 2 streams discussed above containing high quantities of tritium. In addition, other high activity waste streams which were packaged in a stable manner for waste spectrum 2 are also stabilized for this case. These include the following streams: P-NCTRASH, B-NCTRASH, L-NFRCOMP, N-ISOPROD, and N-HIGHACT.

Ground-Water Impacts

Estimated ground-water impacts from these two cases are presented in Table 5.21. These results may be compared with Cases 4C and 7D.

As can be seen by comparing Table 5.9 with Table 5.21, use of the HIC to package the two small volume tritium streams results for Case 10A in a reduction in boundary well impacts by a factor of about 4.5 to all organs except bone and thyroid. In the calculations, exposures to neither the bone nor the thyroid are limited by the migration of tritium. Hence, use of HICs has little effect on boundary well exposures to bone and essentially no effect on exposures to thyroid. Since tritium is a short half-lived isotope, use of the HICs on the two streams in question also has little effect on the exposures at the population well and the surface water.

Table 5.21 Estimated Radiological Impacts from Ground-Water Migration for High Integrity Container Cases 10A-10C

(mrem/yr)							
Cases	Body	Bone	Liver	Thyroid	Kidney	Lung	GI
(10A)							
Intruder	2.487E-2	4.517E-2	1.410E-2	1.238E+1	2.235E-2	9.074E-3	1.751E-2
Well	(6,000)	(6,000)	(6,000)	(4,000)	(6,000)	(6,000)	(6,000)
Boundary	2.485E-2	4.503E-2	1.407E-2	1.238E+1	2.232E-2	9.045E-3	1.749E-2
Well	(6,000)	(6,000)	(6,000)	(4,000)	(6,000)	(6,000)	(6,000)
Population	7.096E-3	1.045E-2	3.690E-3	3.911E+0	6.287E-3	2.103E-3	4.739E-3
Well	(10,000)	(10,000)	(10,000)	(6,000)	(10,000)	(10,000)	(10,000)
Surface	3.147E-4	4.347E-4	1.594E-4	1.783E-1	2.773E-4	8.713E-5	2.060E-4
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
(10B)							
Intruder	7.371E-3	3.352E-2	6.917E-3	5.277E-1	7.268E-3	6.706E-3	7.070E-3
Well	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)
Boundary	7.346E-3	3.339E-2	6.892E-3	5.277E-1	7.243E-3	6.680E-3	7.044E-3
Well	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)
Population	1.661E-3	7.249E-3	1.517E-3	1.661E-1	1.627E-3	1.450E-3	1.564E-
Well	(10,000)	(10,000)	(10,000)	(6,000)	(10,000)	(10,000)	(10,000)
Surface	6.848E-4	2.943E-4	6.194E-5	7.563E-3	6.695E-5	5.889E-5	6.402E-5
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
(10C)							
Intruder	1.352E-2	3.755E-2	9.431E-3	4.702E+0	1.256E-2	7.524E-3	1.072E-2
Well	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)
Boundary	1.347E-2	3.730E-2	9.382E-3	4.702E+0	1.251E-2	7.475E-3	1.068E-2
Well	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)	(6,000)
Population	3.568E-3	8.341E-3	2.275E-3	1.485E+0	3.260E-3	1.673E-3	2.672E-3
Well	(10,000)	(10,000)	(10,000)	(6,000)	(10,000)	(10,000)	(10,000)
Surface	1.548E-4	3.417E-4	9.585E-5	6.769E-2	1.406E-4	6.843E-5	1.135E-4
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)

Impacts for Case 10B may be compared with those for Case 7D in Table 5.15. Compared with Case 7D, boundary well exposures to organs other than bone and thyroid are also reduced by a factor of about 15. In Case 7D, several high activity waste streams are stabilized by solidification or improved packaging. Migration from these high activity streams (relative to Case 4C) is reduced, leaving the tritium. Use of 100-year HICs on the two high tritium content streams thus produces somewhat more dramatic results.

The reduction in impacts due to tritium migration calculated in Cases 10A and 10B is interesting, but should be viewed with caution. There has been little or no testing of tritium containment using high integrity containers. In addition, the usefullness of the HIC to contain tritium would be a strong function of the form of the tritium. A high integrity container would be ineffectual, for example, in containing tritium as a gas. Still, use of high integrity containers or other types of high integrity packaging is an interesting concept for further work.

Impacts shown for Case 10C fall between those calculated for Case 10A and 10B. Compared to Case 10A, impacts for most organs are reduced by about a factor of somewhat less than 2. However, compared to Case 10B, impacts for most organs except thyroid are raised by about a factor of 2. Thyroid exposures compared with Case 10B are raised by about a factor of about 9.

Other Impacts

Other impacts for the three cases are shown in Table 5.22. As shown, short-term population exposures and short-term occupational exposures are not expected to vary significantly from those respectively for Case 4C (Table 5.9) and Case 7D (Table 5.15). The same types of activities would be required to handle, process, transport, and dispose of the waste; one is merely substituting one container design for another. Similarly, as there would be no increase in waste volume from using HICs, transportation costs would not change from the previous cases.

Waste processing costs would increase somewhat. Since use of HICs is a relatively new concept and have only recently been commercially available, there is less data to compare costs with other waste stabilization techniques. However, using solidification of LWR ion-exchange resins and filter media as an example, an HIC would be more expensive than merely dewatering the resins and filter media but less expensive than solidification. No new equipment would need to be installed at the waste generator's facility.

Costs for use of an HIC would depend upon a number of variables such as the size of the container or the chemical content of the waste. In addition, use of an HIC may be sold as part of other services such as waste pick-up, transport, and disposal. One estimate is that an HIC would cost approximately 75% to 85% higher than a similarly sized carbon steel liner (Ref. 8). This figure has been used to estimate costs for use of an HIC as about $450 per cubic meter of packaged waste.

As shown, use of the HICs in the first two cases results in only a small increase in the total processing costs relative to the previous Cases 4C and 7D. Compared with Case 4C, higher costs are calculated for Case 10C since the volume of waste placed into HICs is significantly increased. However, total costs are significantly reduced from the processing costs calculated in Case 7D for waste solidification. Previously calculated additional solidification costs for LWR process wastes (waste spectrum 2) ran at about $257 million, while total costs for use of an HIC on 5 of the 7 process waste streams reduced costs to about $31 million. As in waste spectrum 2, stabilizing the other higher activity waste streams is conservatively estimated to cost an additional $41 million over 20 years of waste disposal.

Table 5.22 Other Impacts Associated with High Integrity Container Cases 10A-10C

Impacts	Case 10A	Case 10B	Case 10C
Short-term population exposures: (man-mrem)			
Processing at waste generator	0	0	0
Processing at regional processing center	0	0	0
Waste transportation	5.10E+5	5.01E+5	5.10E+5
Short-term occupational exposures: (man-mrem)			
Processing at waste generator	-	+1.68E+6	-
Processing at regional processing center	0	1.25 E+5	0
Waste transportation	5.82 E+6	5.43 E+6	5.82 E+6
Waste disposal	2.46 E+6	2.34 E+6	2.46 E+6
Waste generation and transport costs: ($)			
Processing at waste generator	+5.99E+5	+3.38E+8	+7.19E+7
Processing at regional processing center	0	3.63E+7	0
Waste transportation	2.05E+8	1.85E+8	2.05E+8
Disposal costs: ($)			
Design and operational:	2.10E+8	1.99E+8	2.08E+8
Postoperational:	1.81-3.82E+7	1.22-1.81E+7	1.22-1.81E+7
Total	2.28-2.48E+8	2.11-2.17E+8	2.20-2.26E+8
Unit ($/m^3)	233-253	311-320	224-231
Energy Use: (gal)	+4.00E+5	+7.80E+6	+1.00E+5
Land use: (m^2)	3.40E+5	2.36E+5	3.40E+5
Waste volume disposed: (m^3)			
Regular:			
Chemical-stable	1.02E+4	4.00E+4	1.02E+4
Chemical-unstable	1.15E+5	7.40E+4	1.15E+5
No chemical-stable	2.23E+5	3.30E+5	3.96E+5
No chemical-unstable	5.34E+5	2.32E+5	4.57E+5
Total	8.82E+5	6.76E+5	9.78E+5
Layered:			
Chemical-stable	0	2.87E+3	1.87E+3
Chemical-unstable	1.87E+3	0	0
No chemical-stable	0	0	0
No chemical-unstable	9.59E+4	2.87E+3	1.87E+3
Total	9.77E+4		
Hot waste facility:	0	0	0
Total disposed:	9.80E+5	6.78E+5	9.80E+5
Total volume not acceptable: (m^3)	1.94E+4	1.94E+4	1.94E+4

Little or no change to previously calculated disposal costs, total incremental energy use, or land use is estimated for Cases 10A and 10B.

In Case 10C, some minor changes to disposal costs compared with Case 4C are observed, due to the increased volume of stable waste streams delivered to the disposal facility.

5.2.5 Intruder Impacts Associated With the Case Study

This section addresses the following potential impacts from human intrusion into the disposal waste:

- o Potential exposures to inadvertent intruders associated with the design options in the case study.
- o Potential offsite exposures to individuals and populations from water and air transport to the environs of wastes exposed by the intruder.

These potential exposures are considered here for calculational convenience. In Chapter 4, the potential exposures associated with implementation of a performance objective for potential inadvertent intrusion were considered. In preceding sections of this chapter, costs and radiological impacts associated with minimizing long-term ground-water releases, while at the same time minimizing long-term social commitment were considered.

Table 5.23 presents potential intruder exposures, calculated at 100 years and 500 years following facility closure, for each of the design cases considered in the previous sections. Potential exposures to whole body and bone are shown, and the results are the volume-weighted average of the potential hazard of all waste streams delivered to the disposal facility. Table 5-23 also presents offsite exposures to bone and whole body from water and dispersion of waste streams exposed by a potential inadvertent intruder. Impacts are calculated at 100 years following termination of the facility license. Airborne releases are in man-millirem and are calculated for the total population within a 50-mile radius of the disposal facility. For this calculation, the expected population is assumed to be double that assumed for the reference facility while it is operating. Waterborne releases are calculated for an individual, and are estimated based upon the assumed erosion of the wastes into a nearby stream, where the water is used by the individual for consumption, watering crops, etc.

5.2.6 Summary of Observations and Conclusions Regarding the Case Study

The preceeding subsection of Section 5.2 presented 20 cases, including the base (no-action) cases, which were used to analyze costs and impacts associated with alternative methods to minimize contact of water with disposed waste and to reduce potential long-term maintenance costs. These methods included disposal facility design and operation alternatives, waste form and packaging alternatives, or combinations thereof.

Table 5.23 Waste Volume Averaged Individual and Population Intruder Impacts For the Ground-Water Migration Case Study

	Cases									
	1*	2	3	4A	4B	4C	4D	4E	5	6
Direct intruder impacts										
Body (mrem)										
o 100 C**	8.048E+1	8.048E+1	8.048E+1	3.085E+1	3.085E+1	3.085E+1	4.639E+1	4.636E+1	2.172E+0	3.085E+1
A	8.470E+1	8.470E+1	8.470E+1	2.499E+1	2.499E+1	2.499E+1	3.748E+1	3.745E+1	0	2.499E+1
o 500 C	1.526E+0	1.526E+0	1.526E+0	1.526E+0	1.526E+0	1.991E+0	1.991E+0	1.991E+0	2.290E-1	1.526E+0
A	1.756E+0	1.756E+0	1.756E+0	1.756E+0	1.756E+0	2.270E+0	2.270E+0	2.270E+0	2.634E-1	1.756E+0
Bone (mrem)										
o 100 C	8.780E+1	8.780E+1	8.780E+1	3.621E+1	3.621E+1	3.621E+1	5.412E+1	5.409E+1	2.185E+0	3.621E+1
A	9.080E+1	9.080E+1	9.080E+1	2.974E+1	2.974E+1	2.974E+1	4.461E+1	4.457E+1	0	2.974E+1
o 500 C	4.522E+0	4.522E+0	4.522E+0	4.522E+0	4.522E+0	4.522E+0	6.470E+0	6.470E+0	6.784E-1	4.522E+0
A	3.462E+0	3.462E+0	3.462E+0	3.462E+0	3.462E+0	3.462E+0	4.635E+0	4.635E+0	5.192E-1	3.462E+0
Offsite releases from intrusion:										
Airborne impacts (man-mrem)										
o Body	1.880E+3	1.880E+3	1.880E+3	1.387E+3	1.387E+3	1.387E+3	2.083E+3	2.081E+3	1.041+1	1.387E+3
o Bone	3.404E+4	3.404E+4	3.404E+4	2.152E+4	2.152E+4	2.152E+4	3.771E+4	3.768E+4	1.885E+2	2.152E+4
Waterborne impacts (mrem)										
o Body	4.121E-3	4.121E-3	4.121E-3	2.090E-3	2.090E-3	2.090E-3	3.131E-3	3.129E-3	3.599E-4	2.090E-3
o Bone	1.077E-2	1.077E-2	1.077E-2	7.300E-3	7.300E-3	7.300E-3	1.075E-2	1.074E-1	8.613E-4	7.300E-3

*Impacts for Case 1A are the same as those for Case 1.

**As shown, impacts are calculated at 100 and 500 years following license termination. The letter "C" signifies the intruder construction scenario, "A" the intruder-agriculture scenario.

Table 5.23 (continued)

	Cases								
	7A	7B	7C	7D	8	9	10A	10B	10C
<u>Direct intruder impacts</u>									
Body (mrem)									
o 100 C	4.093E+1	3.259E+1	3.259E+1	3.259E+1	2.825E+1	4.451E+0	3.085E+1	3.259E+1	2.517E+1
A	4.590E+1	2.151E+1	2.151E+1	2.151E+1	2.109E+0	0	2.499E+1	2.151E+1	1.507E+1
o 500 C	1.925E+0	1.925E+0	1.925E+0	1.925E+0	3.078E+0	4.617E-1	1.526E+0	1.925E+0	1.526E+0
A	2.205E+0	2.205E+0	2.205E+0	2.205E+0	3.475E+0	5.212E-1	1.756E+0	2.205E+0	1.756E+0
Bone (mrem)									
o 100 C	4.567E+1	3.360E+1	3.360E+1	3.360E+1	2.902E+1	4.477E+0	2.421E+1	3.360E+1	2.639E+1
A	5.500E+1	2.606E+1	2.606E+1	2.606E+1	4.526E+0	0	2.974E+1	2.606E+1	1.881E+1
o 500 C	6.251E+0	6.251E+0	6.251E+0	6.251E+0	9.041E+0	1.356E+0	4.522E+0	6.251E+0	4.522E+0
A	4.668E+0	4.668E+0	4.668E+0	4.668E+0	6.598E+0	9.898E-1	3.462E+0	4.668E+0	3.462E+0
<u>Offsite releases from intrusion</u>									
Airborne impacts (man-mrem)									
o Body	2.222E+3	1.194E+3	1.194E+3	1.194E+3	1.125E+3	6.564E+0	1.387E+3	1.194E+3	1.369E+3
o Bone	4.023E+4	2.161E+4	2.161E+4	2.161E+4	2.037E+4	1.188E+2	2.512E+4	2.161E+4	2.478E+4
Waterborne impacts (mrem)									
o Body	3.104E-3	1.848E-3	1.848E-3	1.848E-3	9.794E-4	7.165E-6	2.090E-3	1.848E-3	1.408E-3
o Body	1.088E-2	5.512E-3	5.512E-3	5.512E-3	2.867E-3	2.189E-5	7.300E-3	5.512E-3	4.338E-3

The costs and impacts of these 20 cases are summarized in Table 5.24. In this table, maximum ground-water impacts over 10,000 years following disposal facility closure are presented as potential exposures to whole body and thyroid from consumption and use of water obtained from wells assumed to be located down gradient of the disposed waste. One well, which is assumed to be located at the boundary of the disposal facility and 30 m downgradient of the edge of the disposed waste, is assumed to be used by individuals. The other well, which is assumed to be located 500 meters down gradient of the disposal facility boundary and halfway between the disposal facility and a hydrologic boundary (a stream), is assumed to supply the water needs for a small population.

Also shown in the table are total increment short-term population impacts in man-mrem, total incremental population impacts in man-mrem, and total incremental costs. Incremental impacts and costs are presented as additional costs and impacts to those associated with Case 1. Included in each incremental total impact measure are the following:

Total Short-Term Population Exposures	Total Short-Term Occupational Exposures	Total Costs
Processing at waste generator	Processing at waste generator	Processing at waste generator
Processing at regional center	Processing at regional center	Processing at regional center
Waste transport	Waste transport	Waste transport
	Waste disposal	Waste disposal: o design and op. o postoperational

Based upon the analyses in the preceding sections and as summarized in Table 5.24, a number of observations and conclusions can be reached:

1. Disposal facility stability is of great importance in reducing ground-water migration and minimizing costs for long-term care. Disposal facility stability is also believed to be an important prerequisite for other operational improvements such as improved disposal cell covers to minimize percolation of water and to reduce ground-water impacts to levels as low as reasonably achievable. In the EIS, the principal improved disposal cell cover examined was a thick compacted clay cap. There may be a number of other techniques such as polymer membranes or soil cement which may also be used. However, as long as the stability of the disposal cell cannot be reasonably assured, then the slumping and collapse associated with an unstable disposal cell will reduce (if not completely negate) the effectiveness of an improved cover.

Table 5.24 Summary of Costs and Impacts for Cases 1 through 10C

	Cases									
	1	2	3	1A	4A	4B	4C	4D	4E	5
Groundwater impacts: (mrem/yr)										
Boundary Well										
o Whole body	157	145	26.4	15.7	3.99	3.95	0.11	0.074	0.074	0.004
o Thyroid	846	268	825	84.6	80.5	45.4	12.4	8.3	8.3	0.39
Population Well										
o Whole body	0.44	0.055	1.03	0.048	0.046	0.026	0.007	0.005	0.005	0.0002
o Thyroid	267	26.8	651	26.7	25.4	14.4	3.91	2.61	2.61	0.12
Total incremental short-term population impacts: (man-mrem) ($\times 10^5$)	-	-	-	-	-	-	-	-0.16	-	-
Total incremental short-term occupational impacts: (man-mrem) ($\times 10^6$)	-	-	-	-	-	-	-	+2.72	+2.73	+2.81
Total incremental costs: (\$) ($\times 10^8$)	-	-0.03	+0.12	+.07	(-.07)-.13	(-.07)-.13	(-.02)-.22	.1-.3	.17-.37	2.07

Table 5.24 (Continued)

	Cases									
	6	7A	7B	7C	7D	8	9	10A	10B	10C
<u>Groundwater impacts:</u> (mrem/yr)										
Boundary Well										
o Whole body	.11	15.7	3.98	3.95	.11	.11	0.004	.025	.0073	.013
o Thyroid	12.4	23.5	3.98	2.25	.53	.22	0.018	12.4	.53	4.70
Population Well										
o Whole body	.0071	.02	.01	.0063	.0017	.0003	1.6E-5	.0071	.0017	.0036
o Thyroid	3.91	7.4	.79	.71	.17	.07	0.0006	3.91	.17	1.49
<u>Total incremental short-term population impacts:</u> (man-mrem) (x 10^5)	-	-0.09	-0.09	-0.09	-0.09	+7.89	+7.89	-	-0.09	-
<u>Total incremental short-term occupational impacts:</u> (man-mrem) (x 10^6)	+8.04	+1.30	+1.30	+1.30	+1.30	+.76	+3.18	-	+1.30	-
<u>Total incremental costs:</u> ($) (x 10^8)	.48	+3.59	3.38-3.58	+3.39	3.39-3.45	+12.02	+13.23	.026-.23	3.39-3.45	.66-.72

From the analysis, it appears that there are a number of ways in which greater disposal facility can be achieved, ranging from disposal facility design and operating practices, to waste form and packaging practices, to combinations thereof. The major ways investigated are summarized below.

2. One general way by which disposal facility stability can be achieved is to improve the form of the waste through waste processing and packaging techniques. For example, waste spectrum 1 is assumed for Cases 1 through 6 and in this waste spectrum, 75% of the waste is in an unstable, degradable form. Waste spectrum 2 is assumed for Cases 7A through 7D, for which 45% of the waste is in an unstable form. Finally, waste spectrum 3 is assumed for Cases 8 and 9, for which only 4% of the waste is in an unstable form. In each waste spectrum, additional stability is achieved at additional processing and additional expense--particularly for waste spectrum 3. The following is an illustrative summary of the additional (from waste spectrum 1) processing and transport costs and impacts associated with waste spectra 2 and 3. The numbers in the parentheses illustrate additional costs and impacts if no regional processing were performed.

	Spectra	
Impact measures	2	3
Population exposures	-0.09	78.9
($x10^5$ man-mrem)	(-0.09)	(78.5)
Occupation exposures	1.42	0.79
($x10^6$ man-mrem)	(1.29)	(0.76)
Costs	3.13	11.8
($x10^8$ \$)	(2.77)	(10.85)

Of interest is the comparison of population exposures and costs for waste spectra 2 and 3. In waste spectrum 2, the reduced population exposures compared with waste spectrum 1 are due to the reduced volume of waste transported. In waste spectrum 3, however, the greatly increased population exposures is due to the extensive incineration of combustible waste. Most of the (significant) cost differential between waste spectrum 2 and waste spectrum 3 is also due to waste incineration. Much of this additional cost would be borne by small scale enterprises such as hospitals and research laboratories.

Another important consideration is the timing for implementation of the waste spectra. For example, except for the assumed processing by compaction at a regional processing center, waste spectrum 2

represents in many respects the current trends of the waste generating industry. Many, if not most, of the larger waste generators have installed compactors and are compacting compressible waste streams as a means of reducing disposal costs. License conditions implemented by state action at all three operating disposal facilities will shortly require that resins, filter media, and other types of high activity wet wastes be either solidified or packaged in high integrity containers. Therefore, the degree of waste stability illustrated by waste spectrum 2 (all higher activity wastes are placed into a stable form) can be quickly achieved.

In contrast, the degree of stability achieved through waste spectrum 3 (96% of the waste volume is processed or packaged into a stable waste form) could not be implemented in a short time frame. Incinerators would have to be constructed and licensed, which would take several years. This option would also result in significantly larger short-term population exposures than waste spectrum 2. As shown, the great majority (99+%) of these additional exposures would result from processing the waste at the waste generator's facilities rather than at the regional processing center. The option is also expensive. For example, processing the waste at the regional processing center is estimated to cost about $927 per m^3 of waste delivered to the center ($26.25/$ft^3$). This represents a significant level of expense for the smaller waste generators such as hospitals, clinics, and research laboratories.

3. In waste spectra 2 and 3, stability for most waste streams was achieved through solidification of the waste. As a source term for the ground-water analyses, the leaching of unsolidified waste forms was first estimated through use of radionuclide concentrations of leachate samples acquired from the Maxey Flats disposal facility. It is believed that the use of this leachate is reasonable yet conservative. Then, fractional multipliers for solidified waste were estimated based upon limited leaching data obtained from studies by Brookhaven National Laboratory (BNL). It is recognized that the estimated fractional multipliers are only crude approximates, but were included in the analysis to assess the likely upper bound of what could be achieved through reducing the potential for leaching of radioactive waste forms.

Three cases examined for which the potential for improved overall leaching characteristics may be compared include Cases 4C (waste spectrum 1), 7D (waste spectrum 2), and 8 (waste spectrum 3). These three cases all assumed the same disposal facility design and operating practices but assumed different waste spectra. The calculated results for each of these three cases are as follows:

	Case 4C	Case 7D	Case 8
	Spectrum 1	Spectrum 2	Spectrum 3
Boundary Well			
o Whole body	.1	.1	.1
o Thyroid	12.4	0.5	0.2
Population Well			
o Whole body	.007	.002	.0003
o Thyroid	3.9	0.2	.07

The calculated impacts indicate that improved lower leaching waste forms do reduce ground-water migration. However, it is difficult to determine the actual degree of credit that should be given to improved leaching characteristics of waste forms in determining ground-water impacts. For example, most of the work on leaching of solidified waste has been performed on small samples under laboratory conditions. Little or no laboratory data is available for many of the radionuclides which appear to be of most concern from a ground-water migration standpoint (e.g., H-3, Tc-99, I-129). Given the current state of knowledge, it appears that the principal credit that can be assumed from waste solidification is that it tends to place the waste into a more stable form. (Solidified forms having lower relative leaching characteristics also appear to have better structural strengths.)

4. The analyses in Cases 10A-10C indicate that a high integrity container can be a useful alternative to solidification. It has potential for successful containment of waste and preclusion of migration until the shorter-lived radionuclides have decayed. Of both shorter- and longer-term interest, it appears to offer a less expensive (than waste solidification) means of waste stabilization.

5. One operational technique that the analysis indicates as being very useful in achieving greater disposal facility stability is by segregating unstable, compressible waste streams from stable waste streams. In the analysis, waste segregation was estimated to cost an approximate additional $6/m^3 ($0.17/ft^3) in disposal facility design and operating costs. However, the practice enables an overall reduction in long-term maintenance costs. If waste segregation is not implemented, then all of the disposal cells would contain significant quantities of compressible wastes and increased maintenance activities would be therefore expected for each disposal cell. If waste segregation is implemented, then the increased maintenance activities would only be required for the waste cells containing the compressible waste. This amounts to 75% of the waste for waste spectrum 1, 45% of the waste for waste spectrum 2, and only 4% of the waste for waste spectrum 3.

The effects of segregation on reducing ground-water impacts is illustrated to a certain extent by comparing ground-water impacts associated with Case 1A with those of Case 4A, and comparing those associated with Case 7A with those of Case 7B. That is:

	Case (mrem/yr)			
Organ	1A	4A	7A	7B
Boundary Well				
o Whole body	15.7	3.99	15.7	3.98
o Thyroid	84.6	80.5	23.5	3.98
Population Well				
o Whole body	.048	.046	.02	0.01
o Thyroid	26.7	25.4	7.43	.79

As shown by comparing the difference between Case 1A and Case 4A (waste spectrum 1) with Case 7A and 7B (waste spectrum 2), not segregating the waste streams reduces the effectiveness of the improved stability and leaching characteristics associated with spectrum 2. Segregation is also seen to be an important prerequisit for other operational improvements such as improved disposal cell covers and improved compaction. As long as the stability of a disposal cell cannot be assured, then the slumping and collapse associated with an unstable disposal cell will reduce (if not negate) the effectiveness of an improved cover.

6. Decontainerized disposal, which was analyzed as Case 6, does not appear to be a viable disposal technique for generalized applications. Decontainerized disposal would appear to be useful for occasional disposal of such wastes as low activity bulk solids, contaminated building rubble, or occasional large pieces of machinery, provided that the disposal operations were carried out in an operationally safe manner and that disposal cell voids were eliminated during disposal. As a general practice extended to all compressible wastes, however, the potential improvement in ground-water impacts does not appear to be particularly impressive. In addition, significantly higher occupational exposures are expected to occur. Finally, it is an option which would require significant changes in current disposal operations and would not appear to be achievable within a short time frame.

7. Stacked disposal of waste rather than random disposal of waste is estimated to reduce ground-water impacts by a factor of approximately 1.5. This is illustrated by comparing the results of Case 4C with Case 4D. At currently operating disposal facilities, wastes are

generally disposed by a mixture of techniques, depending upon the ease in which the particular waste container can be handled and the level of activity within the container. If all wastes were required to be stacked on disposal, then occupational impacts at the disposal facility would be expected to rise significantly. Based upon this, it does not appear that the potential reduction in ground-water migration due to stacking is sufficient by itself to require its use generally. However and as discussed below, waste stacking would appear to have a more favorable cost-benefit evaluation when it is carried out as part of other operational techniques such as grouting or placement of wastes into engineered structures.

8. Cases 5 and 9 investigate options in which more extensive operational measures are implemented at the disposal facility to achieve disposal facility stability. In Case 5, for example, waste spectrum 1 is assumed and the wastes are stacked and grouted into cement walled trenches. Case 9 is similar to Case 5 except that waste spectrum 3 is assumed.

   Both of these cases result in rather significant reductions in potential ground-water migration as well as postoperational costs at significantly additional disposal facility design and operation costs as well as additional occupational exposures. For example, compared with Case 1, Case 5 is estimated to result in an additional 2.73 E+6 man-mrem in occupational exposures (over 20 years) at the disposal facility. This is principally due to stacking the waste into the disposal cells. Total costs (due to disposal only) are estimated to run at an additional $207 million over 20 years. In comparison to Case 8, Case 9 is estimated to involve an additional 2.47E+6 in occupational exposures and an additional $121 million in total disposal costs.

9. Most of the alternative disposal facility design and operating practices examined ways in which the disposal facility can be stabilized so that influx of water into disposal cells is minimized. Case 1A investigated an example in which the disposal cells are backfilled with sand prior to installation of the cap. This is done to help fill voids between waste packages to increase the vertical speed of water percolating into the disposal cells, thus reducing the time of contact with the disposed waste. In Case 1A, this was estimated to reduce potential migration (compared with Case 1) by a factor of about 10. It is recognized that there is uncertainty regarding the precise effectiveness of techniques such as the sand backfill. Nonetheless, it appears to be a useful and inexpensive technique for reducing potential impacts.

10. In a recent amendment to 10 CFR Part 20, NRC exempted liquid scintillation vials and animal carcasses containing tritium or carbon-14 in quantities greater than .05 μCi/gm from disposal as radioactive waste (Ref. 9). That is, these waste streams do not have to be transferred

to a licensed disposal facility for disposal but may be disposed thro other means. Depending upon the nature of the nonradioactive materia of which the waste is composed, this may include disposal through ordinary refuse channels or disposal into a nonradioactive hazardous waste disposal facility.

It is currently difficult to gauge with accuracy the effect of this amendment to Part 20 on the volumes of wastes delivered to disposal facilities. The reduction in the volume of liquid scintillation waste and biowaste delivered to disposal facilities will undoubtably be significant. This amendment, however, will not completely eliminate the volumes of these wastes delivered to disposal facilities. For example:

- Wastes containing concentrations of tritium or carbon-14 exceeding 0.05 μCi/gm would still require disposal into a licensed radioactive waste disposal facility.
- Wastes containing radionuclides other than tritium or carbon-14 would still require disposal into a licensed radioactive waste disposal facility.
- There may be local pressure or requirements against a particular waste generator disposing of tritium and carbon-14 waste by other means than as radioactive waste.

Given this current uncertainty, the amendment has conservatively not been considered when calculating migrational impacts from waste disposal. That is, liquid scintillation and biowaste volumes have been assumed to be delivered to the reference disposal facility and disposed. The effect of this conservatism can be illustrated in the following two cases, in which ground-water calculations for Cases 1 and 7D are recalculated with the biowaste and liquid scintillation waste streams deleted from the disposed waste inventory.

Results are presented in Table 5.25, and may be compared with the results for Case 1 presented in Table 5.3 and with the results for Case 7D presented in Table 5.15. As shown, ground-water impacts in Table 5.25 are only slightly reduced over the respective impacts in Tables 5.3 and 5.15. For Case 1, for example, whole body exposures at the population well are reduced from 0.44 mrem to 0.43 mrem. Similarly, exposures to the GI tract at the population well are reduced for Case 7D from .0016 mrem to .0013 mrem. Apparently, inclusion of the liquid scintillation and biological waste streams in the calculations has had little effect upon the results.

11. In the analysis, the most significant short-term impacts appear to be due to tritium while the most significant long-term impacts appear to be due to iodine-129. Releases of both of these isotopes can be minimized by stable site conditions. Much of the tritium waste appears to be concentrated in a few low volume waste streams and for these streams it appears that further reductions in migration can possibly

Table 5.25 Summary Radiological Impacts for Cases 1 and 7D Without Liquid Scintillation Vial Waste and Biowaste

	(mrem/yr)						
Cases	Body	Bone	Liver	Thyroid	Kidney	Lung	GI
(1)							
Intruder	3.041E+1	2.710E+0	3.041E+1	8.461E+2	3.041E+1	3.041E+1	3.041E+1
Well	(100)	(6,000)	(100)	(4,000)	(100)	(100)	(100)
Boundary	1.570E+2	2.709E+0	1.570E+2	8.461E+2	1.570E+2	1.570E+2	1.570E+2
Well	(70)	(6,000)	(70)	(4,000)	(70)	(70)	(70)
Population	4.338E-1	5.519E-1	2.009E-1	2.673E+2	3.791E-1	1.111E-1	2.743E-1
Well	(6,000)	(8,000)	(6,000)	(4,000)	(6,000)	(8,000)	(8,000)
Surface	1.769E-2	2.348E-1	7.077E-3	1.218E+1	1.515E-2	4.700E-3	2.577E-1
Water	(8,000)	10,000)	(8,000)	(4,000)	(8,000)	(10,000)	(8,000)
(7D)							
Intruder	2.116E-2	2.812E-2	2.116E-2	5.266E-1	2.116E-2	2.116E-2	2.116E-2
Well	(100)	(6,000)	(100)	(6,000)	(100)	(100)	(100)
Boundary	1.107E-1	2.812E-2	1.107E-1	5.266E-1	1.107E-1	1.107E-1	1.107E-1
Well	(70)	(6,000)	(70)	(6,000)	(70)	(70)	(70)
Population	1.433E-3	6.110E-3	1.289E-3	1.659E-1	1.400E-3	1.223E-3	1.336E-3
Well	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)
Surface	5.924E-5	2.482E-4	5.270E-5	7.554E-3	5.771E-5	4.965E-5	5.478E-5
Water	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)	(10,000)

be achieved through use of improved containers (e.g., see high integrity container Cases 10A and 10B). For example, a container which provided 100 years of containment would reduce the contained activity through radioactive decay by a factor of 280.

Unlike tritium, however, iodine-129 has a very long half-life and the use of improved containers would provide only a negligible amount of additional decay. The principal gain is through improved disposal cell stability which allows reduced percolation of water through disposal cell covers. Another control mechanism would be to limit the disposal site inventory of iodine-129 and other long-lived mobile isotopes such as Tc-99 or C-14. Such an inventory limit could not be generic, however, but would have to be established on a site-specific basis.

Another important consideration which would tend to reduce the impact of migration of iodine-129 is dilution by natural iodine. Environmental concentrations of I-129 with respect to nautural iodine (I-127) has been the subject of several studies (Refs. 10, 11). One study indicates that around existing nuclear facilities, the atom-ratio of

I-129 to that of I-127 measured in biota ranges up to 3.9×10^{-5} in thyroid tissues of animals other than bovine (deer around the Hanford Reservation), and up to 1.7×10^{-6} in bovine thyroid tissues (around Northeastern Oregon) (Ref. 10). In another study, bovine thyroid tissues have been observed to have an I-129/I-127 atom ratio of 4.5×10^{-7} around the Savannah River plant (Ref. 11). It has also been estimated that the I-129/I-127 ratio may possibly be as high as 0.0035 in the waste/soil mixture in a disposal site (Ref. 12). This calculation assumes the disposal of waste from 25 reactors and an average I-127 concentration in soil of 1 ppm. The authors of Reference 12 further calculate that if this atom ratio is below 0.02 it would not be possible to exceed the existing dose guidelines for thyroid exposures.

It is also possible that the iodine-129 in waste may be diluted through natural iodine produced as a daughter of Te-127 (which is a fission product). Additional dilution could be potentially inexpensively achieved by merely adding stable iodine to waste streams containing iodine-129.

Experimental environmental data and calculations such as the above have led some investigators in the past to utilize the total body dose to humans as a better indicator of the exposure due to I-129 than the thyroid dose (Ref. 13). This selection results in a significant difference in exposures since the ingestion dose conversion factor for thyroid are about 800 times that of total body. A correction to the calculated I-129 thyroid exposures to account for dilution with natural iodine has not been made in this EIS, however. The concentration of natural iodine in soil varies from place to place and there has as yet been no confirmatory measurements of iodine-127 concentrations in the soils and underlying aquifers at any of the existing disposal facilities. Neither have any measurements or calculations been as yet performed regarding the I-129/I-127 ratio in waste streams such as BWR ion exchange resins.

5.3 DEVELOPMENT OF A PERFORMANCE OBJECTIVE FOR MIGRATION AND LONG-TERM STABILITY

Based upon the above case study and the observations and conclusions that can be derived from the case study, a performance objective for ground-water migration and disposal facility stability may be developed. It is necessary to consider these two concepts simultaneously, since disposal facility stability directly affects the potential for ground-water migration and the ease in which potential impacts may be predicted. Disposal facility stability also affects the viability of engineering measures which can be implemented to reduce percolation into disposal cells. (The specific measure examined numerically in this EIS was use of a thick compacted clay cap. However, this does not preclude use of other possible techniques such as polyester membranes or soil sealants). Unless disposal cell slumping and subsidence can be controlled to low levels, the effectiveness of such engineering measures can be seriously reduced.

Perhaps most importantly, disposal facility stability and the corresponding potential for ground-water migration directly affect the level of long-term care and maintenance by the site owner. Past experience with LLW disposal clearly indicates that one of the most important objectives of LLW disposal should be that the disposal facility is stabilized so that little or no maintenance is required by the site owner. NRC staff believes that the alternative of not considering this as a performance objective is clearly not acceptable.

Given this as an objective, then the question that arises is how it may be implemented, or how much should be spent now to reduce costs later. Much of the difficulty is caused by the form of the waste. Most of the waste sent to LLW disposal facilities consists of very low activity material such as trash which is frequently easily degradable and compressible, and packaged in containers such as large wooden boxes and 55-gallon mild steel drums. Large void spaces can also exist within waste packages and the disposal cell after waste disposal. As the waste material degrades and compresses, a process which is accelerated by contact by water, additional voids are produced. This leads to settlement of the disposal cell contents, followed by subsidence or slumping of the disposal cell cover. This increases the percolation of water into disposal cells, accelerating the cycle. This slumping and subsidence is frequently quite sudden.

A number of alternatives for increasing disposal cell stability were considered in the preceding case study. These alternatives included minor to moderate changes in disposal facility design and operating practices (e.g., waste segregation, improved compaction), more extensive changes to disposal facility design and operating practices (e.g., grouting, concrete walled trenches, decontainerized disposal), and improved waste forms and packaging. The analysis is complicated by the paradox that most of the waste streams that contribute the most to site instability are the same waste streams that contain the least activity. Much of this low activity waste is only suspected of being contaminated and/or is generated by small waste generators such as hospitals and research laboratories. These factors increase the difficulty of arriving at a cost-effective solution to the problem of disposal facility instability. That is, it is difficult to justify requiring large additional expenditures to dispose of otherwise low hazard material.

One alternative would be to incinerate and solidify all combustible waste streams. In general, although NRC staff believes that waste incineration may be a cost-effective solution for some waste generators, it would cause economic hardships if required generally, particularly to small waste generators such as hospitals and research laboratories. In addition, it is not a solution that could be generally instituted on a reasonable time basis. Other alternatives such as extensive engineered disposal techniques (e.g., grouted or concrete walled trenches, decontainerized disposal) also appeared to have a number of drawbacks for general application. These drawbacks included significant additional disposal costs and significantly increased occupational exposures at the disposal facility.

The most reasonable alternatives considered--those which could be implemented with reasonable costs and within a reasonable time frame--involved stabilization of higher activity waste streams coupled with segregated disposal of lower

activity unstable waste streams. Such stabilization of the higher activity streams could be accomplished by either stabilizing the waste form (e.g., through solidification), stabilizing the waste package (e.g, through use of high integrity containers), or by disposal facility design (e.g., by placing the waste into a structure which supports barriers to moisture). Once the disposal cells are stabilized, then improved barriers to moisture may be potentially emplaced, further reducing exposures to levels as low as reasonably achievable.

This means that there still may be some long-term maintenance required for the segregated lower activity waste disposal cells. However, this maintenance can be reduced through such measures as

- o improved fill
- o improved disposal cell covers, including improved compaction
- o compaction of compressible wastes
- o increased attention paid to minimizing voids in the waste containers
- o use of longer lasting waste containers (e.g., polye[illegible] ontainers)

Through such measures, it is possible that the level of main[illegible] uired for the low activity disposal cells can be reduced to very l[illegible] Increased consideration of disposal facility stability may be required [illegible] l facilities having very impermeable soils and located in a hu[illegible] ment.

Given this overall objective--the need for disposal facility [illegible] -numerical limits for migration are needed for purposes of evaluating t[illegible] afety of existing facilities and licensing new facilities.

An important factor that must be considered is that the development of limits for ground-water releases are part of EPA's establishment of generally applicable environmental standards for LLW disposal. At this time the EPA standards have not been developed and will not be developed prior to issuance of the Part 61 regulation. After review of the responsibilities, authorities, and relationship of NRC and EPA with respect to standards and regulations, it appears that there are two alternatives for further development of the Part 61 regulation:

- o Delay development of the numerical limits until EPA establishes generally applicable environmental standards for ground-water migration;
- o Establish interim performance objectives, and modify the interim objectives when the EPA standard is available.

The first alternative appears to be unacceptable as EPA does not intend to develop standards for LLW disposal within a short time frame. Development of

a ground-water migration performance objective--and the Part 61 regulation--would be delayed for an indefinite period until the EPA standard is developed and finalized. This delay could potentially last several years.

The second alternative is judged to be the preferred alternative and has been followed by NRC. Under this alternative, there is a potential for possible future changes to the performance objective when the EPA standard is implemented. These potential changes can be minimized, however, through NRC and EPA cooperation in the development of the Part 61 regulation and the EPA standard. In addition, draft EPA standards should be well under development and potentially issued by the time NRC is ready to issue final regulations. Setting out a range of alternatives and analyzing them as part of the LLW EIS would provide a basis for early discussion and focus of attention on what should be in the standard.

As for the case of the intruder analyses, a number of existing standards may be analyzed for consideration as a performance objective for ground-water migration. Except for the potential use of onsite water from a well excavated by an inadvertent intruder, potential exposures could be expected to be chronic and possibly be experienced by populations. Examples of existing standards which can be considered include the following:

- limits established in 10 CFR Part 20 for permissible levels of radiation in unrestricted areas (500 mrem/year to the whole body)
- 40 CFR 190
- 10 CFR 50, Appendix I
- 40 CFR 141

These standards, all which have been discussed in Chapter 4 as part of setting a performance objective for the potential inadvertent intrusion, represent a range of potential exposures of from 4 mrem/year to 500 mrem to the whole body. (Also see Appendix N for a more complete discussion of these existing standards.)

An important consideration is the point where the ground-water standard is to be applied, and the size of the population which could be potentially exposed. That is, in general, higher exposures could be allowed for a few individuals than to groups of people or populations.

It is believed that a general limit of 500 mrem/yr to the whole body (10 CFR 20.105 and 20.106) would not be generally applicable for the case of ground-water migration from disposal facility. In any case, EPA limits established in 40 CFR 190 have been adopted into 10 CFR 20 as a limit for releases from the nuclear fuel cycle. Most of the activity delivered to the disposal facility will probably be generated from nuclear fuel cycle activities, and such a limit would appear to be transferable to potential releases from a disposal facility. NRC currently uses a limit in this range for analyzing disposal facilities for long-term safety. As stated in the Low Level Waste Licensing Branch Technical Position on Burial Ground Closure and Stabilization (Appendix I), NRC staff currently use a criteria of small fractions of the limits in 10 CFR 20 at the site boundary and the

requirements in the National Primary Drinking Water Standards (40 CFR 141) at the nearest source of drinking water. The limits in 10 CFR 50, Appendix I are in the same general range.

As part of development of this standard, a number of discussions have been held with EPA staff regarding the NRC development of an interim standard and the ultimate development of the EPA general standard. During these discussions, EPA staff indicated that they expected that their general environmental release standard would probably end up in the same approximate range--i.e., from about one to 25 mrem/year at the site boundary.

At any case, Cases 1 through 10C can be used to analyze alternative limits for a ground-water migration performance objective. Table 4.24 summarizes these cases, and also provides a summary of whole body and thyroid exposures at the site boundary as well as at a well assumed to be approximately 500 meters downstream and used by a small population. In the case study, exposures to seven organs were calculated. Thyroid exposures were included in Table 5.24 since these exposures were generally the largest of the organs considered. Of the remaining 6 organs, whole body was selected for Table 5.24 as representative. In the case study, exposures to most of the other organs were comparable or somewhat lower. Exposures to bone, however, were generally somewhat higher (e.g., by a factor of about 2-3). Whole body was included, however, as it better illustrated the effects of tritium migration, which dominates the boundary well exposures but has little or no effect at the population well.

Exposures received at the nearest downstream drinking water supply to the disposal facility would appear to be more controlling than those at the boundary of the disposal facility. In the calculations, exposures at the intruder and boundary wells are principally characterized by a contribution from long-lived mobile isotopes such as Tc-99 and I-129 as well as a contribution by shorter-lived isotopes such as tritium or Sr-90. By the time the contamination reaches the population well, however, the shorter-lived isotopes have mostly decayed away and exposures are dominated by the longer-lived isotopes.

This is indicated by comparing the results of the case study in Table 5.24.

In Table 5.24, the largest (limiting) exposures are to the thyroid, which is principally due to iodine-129, a mobile long-lived (15.9 million years) isotope. According to the assumptions for this EIS, this isotope is only slightly retarded by ion exchange and therefore moves essentially at the speed of the ground water. Due to the long half-life, radioactive decay between the boundary well and the population well is negligible. Therefore, population well thyroid exposures generally differed by the amount of dilution provided by the well water withdrawn. This means that by establishing an interim exposure limit for the population well (in other words, the nearest downstream public water supply to the disposal facility), an effective limit for the disposal facility boundary is also effectively established for long-lived mobile radionuclides. As indicated by comparing whole body exposures at the boundary well and population well, the combination of radioactive decay for other shorter-lived isotopes such as H-3 or Cs-137 results in significantly reduced exposures at the population well compared with the boundary well.

The analysis boils down to a question of what can be achieved at what price. There is currently no EPA ground-water standard to assess compliance. EPA plans to develop such standards within the next few years and EPA staff has indicated to NRC staff that they expect that the standard will be in the range of 1 to 25 millirem. In the previous discussion, NRC staff indicated it they believed that an appropriate level for exposures at a potential water supply was in the area of 4 mrem. This is within the range indicated by EPA as a probable standard and corresponds to standards set by EPA in 40 CFR 141 for primary drinking water supplies. The results of the case study may be compared to see if a standard in this range is achievable and at what relative level of costs.

The case study appears to indicate that a limit in the range of 4 mrem/year can be achieved with some moderate costs and changes to existing practices. In comparing thyroid exposures at the population well, the exposures appear to fall into 3 or 4 groups of calculated exposures and costs. Exposures for Cases 1-3 and 1A range from 27 to 650 mrem at negligible incremental costs. Exposures for Cases 4A through 4E, in which a series of operational improvements are implemented, range from 2.6 to 25 mrem at generally somewhat higher incremental costs. For Cases 7B through 7D, in which Cases 4A-4C are repeated using a different waste spectrum (waste spectrum 2), calculated exposures range from 0.2 mrem to 0.8 mrem at incremental costs ranging from \$3.4 E+8 to \$3.6 E+8. Case 5, in which wastes in waste spectrum 1 are assumed to be placed in a highly engineered cement walled disposal cells, has calculated exposures in the same range as those for Cases 7B-7D with incremental costs in the range of \$2.1 E+8. Finally, Cases 8 and 9 illustrate even lower exposures (less than 0.1 mrem) at significantly higher costs than the other groups (\$12-13 E+8).

At first appearance, the costs for these 4 groups appear to be in three general ranges: those in the range of small incremental costs (waste spectrum 1), those in the range of moderate incremental costs (\$3.4-3.6 E+8 for waste spectrum 2), and those in the range of high incremental costs (\$12-13 E+8 for waste spectrum 3). However, this appearance should be viewed with some caution. In the last one or two years there has been considerable change in waste form and packaging practices by waste generators. This makes characterization of existing waste generator practices very difficult. Waste spectra 1 and 2 were therefore established to bound existing waste characteristics, with the realization that in many ways waste spectrum 2 represents conditions that waste generators are either at or are moving toward. Although there are currently no regional processing facilities, many if not most of the larger waste generators are compacting compressible waste streams prior to shipment to a disposal facility. License conditions at all existing disposal facilities will shortly require that some resins and filter media be either solidified or packaged in high integrity containers prior to disposal.

This means that the actual cost differential between Cases 1-4E and Cases 7A-7D is not quite as large as indicated. Of the \$374 million differential in waste processing costs between waste spectra 1 and 2, \$36 million is due to the assumed operation of a regional processing facility which compacts compressible waste streams generated by small waste generators. Of the remaining \$338 million, approximately \$40 million is due to the assumed installation of compactors by the larger waste generators and compaction of compressible waste streams prior

to delivery to the disposal facility. The remaining $298 million is mostly spent in stabilizing high activity waste streams through solidification and other means. Therefore, discounting the regional processing facilities costs, most of the additional costs associated with waste spectrum 2 either represent activities that many waste generators are already carrying out or represent costs associated with one general way in which existing disposal facility license conditions may be met. Another way in which existing disposal facility license conditions can be met is through use of high integrity containers. Case 10C examines a situation in which the higher activity waste streams are all stabilized through use of high integrity containers and in this case, thyroid exposures are 1.49 mrem at an incremental cost of about $7E+7.

Another consideration is equitability. The incremental costs calculated for Cases 5, 8 and 9 are spread out over a number of waste generators, including those which generate very low activity wastes. Most of the additional costs for Cases 7A-7D and 10C, however, are involved with stabilizing the higher activity waste streams. The latter cases would appear to be a more equitable distribution of increased costs based upon the relative hazard of the waste.

From this, it would appear that a performance objective that requires that existing EPA public drinking water regulations be met immediately downstream of a disposal facility can be achieved with some moderate changes in waste form and packaging techniques and disposal facility design and operating practices. These changes principally include methods by which the stability of the disposal facility may be enhanced:

- o stabilization of higher activity waste streams
- o segregated disposal of stabilized higher activity waste streams from unstable lower activity waste streams; and
- o increased attention paid to reducing contact of water with the waste.

Increased stability of the higher activity waste streams may be accomplished by placing the waste into a stable form (e.g., solidification), use of a stable waste package (e.g., high integrity containers), or through disposal cell design. For example, Class 4C, 7D, and 8 all assume the same disposal facility design but differ in the waste spectrum assumed. The calculated results for each of these cases are as follows:

	Case 4C	Case 7D	Case 8
	Spectrum 1	Spectrum 2	Spectrum 3
Boundary Well			
o Whole body	.1	.1	.1
o Thyroid	12.4	0.5	0.2
Population Well			
o Whole body	.007	.002	.0003
o Thyroid	3.9	0.2	.07

As stated above, the industry is moving toward waste spectrum 2 and therefore does not represent a significant change from existing practice. Spectrum 3, however, represents considerable existing costs.

In the waste spectra considered, the indicated reduction in impacts caused by waste spectra 2 and 3 is a result of two aspects: increased waste stability and improvements in leaching characteristics. The principal gain is believed to be the former (increased stability). Although the analysis does indicate that reduced groundwater impacts can be achieved through increased solidification and gives some indication of the level of impact reduction potentially achievable, it is currently difficult to rely on reduced leaching as a means of limiting impacts. There exists little or no information on the leaching characteristics of solidified waste forms for long lived mobile isotopes such as Tc-99, C-14, or I-129.

The effect of waste stabilization can also be assessed. In waste spectrum 2, all of the higher activity waste streams are stabilized by either solidification or waste packaging techniques. In Case 10C, waste spectrum 1 is assumed and the solidified waste streams are assumed to be stabilized through use of high integrity containers. As shown in Table 5.28, the total cost associated with the case is only $4.62 E+8. Impacts with this case may be compared with an example in which all high integrity containers are assumed to provide stability only. These are as follows:

	Case 10C	Case 10C (Stability Only)
Boundary Well		
o Whole Body	.01	0.1
o Thyroid	4.7	4.7
Population Well		
o Whole body	.004	.004
o Thyroid	1.49	1.49

That is, if the only credit given is to stability, then the performance objective is achievable.

Stability of the higher activity waste streams is also important in that it gives greater assurance that the performance objective can be met even under less than ideal conditions. For example, in Case 10C, the waste is assumed to be segregated and disposed in disposal cells having a thick compacted clay cap. It is useful to consider the impacts if this improved cap did not function as intended. For waste spectrum 1, this may be illustrated by the impacts associated with Case 4A. These impacts may be compared to a similar case in which the higher activity waste streams are stabilized. (The same waste form and packaging as Case 10C only the disposal facility design is the same as Case 4A). The impacts are as follows:

	Case 4A	Case 4A with stabilized higher activity streams
Boundary Well		
o Whole body	4.0	.07
o Thyroid	80.5	20.1
Population Well		
o Whole body	.05	.02
o Thyroid	25.4	6.6

As can be seen, the population well thyroid exposures are only a factor of 1.7 higher than the 4 mrem limit for the stabilized case while for Case 4A the calculated exposures are a factor of 6.4 higher.

Given the selection of a performance objective corresponding to EPA primary drinking water standards (40 CFR 141) at the nearest drinking water supply to the disposal facility, a performance objective may also be set out for potential exposures at the disposal facility boundary. While releases of longer-lived isotopes will be controlled by the performance objective for the nearest drinking water supply, there is a possibility for somewhat higher ground-water impacts at the boundary well due to the migration of short-lived isotopes. In addition, such exposures would impact a reduced number of individuals. For this reason, NRC staff believes a higher dose criteria could be implemented and have selected a close criteria corresponding to current EPA limits in 40 CFR 190 for releases from the nuclear fuel cycle (25 mrem to whole body, 75 mrem to thyroid, and 25 mrem to other organs). Twenty five mrem to whole body and to other organs at the facility boundary is at the upper end of the expected range of the future EPA limit for general ground-water releases.

5.4 OTHER POTENTIAL LONG-TERM ENVIRONMENTAL IMPACT PATHWAYS

This section addresses other potential long-term impacts associated with near-surface disposal of radioactive waste. These impacts may be divided into three areas:

1. Gaseous releases from decomposing wastes.
2. Plant and animal intrusion.
3. Erosion.

Potential ways to mitigate such impacts are also addressed. The details are set out in Appendix M.

5.4.1 Gaseous Releases From Decomposing Wastes

Much of the waste currently being disposed in shallow land burial facilities consists of organic material such as wood, paper, or animal carcasses. As such buried organic material decomposes over time, gaseous decomposition products

such as CO_2 or CH_4 (methane) are formed which can be transported upward, through the trench caps, and into the atmosphere. Such decomposition gases can contain tritium (H-3, or T), C-14, or other radioisotopes contained in the disposed waste.

The presence of tritium and carbon-14 tagged decomposition products at shallow land burial facilities was first observed by Matuszek, et al., (see Appendix M). Samples of gases collected from trench sumps at the Maxey Flats, Kentucky, and West Valley, New York disposal facilities have been shown to contain elevated quantities of tritiated gaseous compounds, primarily CH_3T and HTO, but also HT and other tritiated hydrocarbons. Such C-14-tagged hydrocarbons as $^{14}CO_2$ and $^{14}CH_3$ have also been identified as well as Kr-85 and Rn-222.

There are two concerns due to the observed generation of waste decomposition gases within disposal trenches: (1) offsite exposures due to release of radioactive gases, and (2) onsite nonradiological safety to operating crews.

In the former case, potential offsite releases and exposures to individuals do not appear to be significant. Although the existing data is limited, the emanation rates that have been measured at near-surface disposal facilities are small, and would indicate that potential offsite exposures would not be significant. That is, potential exposures would be expected to be orders of magnitude less than limits established in 10 CFR 20 and much less than limits established in 40 CFR 190 for effluents from operation of a nuclear fuel cycle facility. However, additional field investigation could be performed to verify this and to investigate the extent that differences in site design, operation, site climate, seasonal variation, measurement techniques, etc. have upon the emanation rates. For example, the observed differences in tritium emanation rates between the Beatty facility and the Maxey Flats facility may be influenced by the lesser permeability of the cover material at the Maxey Flats facility. The soil was generally saturated when the measurements were taken, which would impede upward gas flow. Other site specific conditions--such as the greatly increased evapotranspiration at the Beatty facility compared with the Maxey Flats facility--may also have an impact.

Decomposition of organic waste and generation of gases is a complex process which is accelerated by moist, saturated conditions and retarded by dry, unsaturated conditions. The former is illustrated by the conditions at the Maxey Flats and West Valley facilities, where waste decomposition has led to increased infiltration and saturated conditions, further accelerating decomposition. The latter situation is illustrated by the Beatty, Nevada facility, which has no water management problems and a greatly reduced rate of waste decomposition. Emanation of the generated gases through the trench cap is a variable depending upon such factors as trench cap thickness and composition. In general, emanation rates would be reduced by thicker covers composed of lower permeable materials.

Key variables, of course, are the composition of the waste material itself, as well as the disposal practices at a particular disposal facility. Compressible, easily degradable organic waste material can lead to water management problems at humid sites as well as increased generation of gaseous decomposition products.

Therefore, essentially the same improvements in waste form and disposal facility design and operation practices that would eliminate the need for active long-term maintenance activities following site closure would also act to greatly reduce the rate of decomposition of the waste material. Such a reduction in the decomposition rate of the disposed waste would not only reduce the instantaneous production rate of gaseous decomposition products, but would also allow time for decay of tritium (half life of about 12 years). Thus, total integrated releases over time would be smaller.

In summary, the emanation rates actually measured from LLW disposal sites are very small, and would be expected to result in very small offsite doses. Even under less than ideal conditions--that is, for example, at Maxey Flats where decomposing waste has produced a bathtub situation--decomposition gases have not resulted in significant releases. Furthermore, such generation rates would be expected to fall off over time. This is the experience seen by EPA for methane generation at nonradioactive solid waste disposal sites.

The second area of concern is of a relatively shorter-term nature--i.e., a potential nonradiological safety hazard at the disposal facility from generation of methane gas. Methane explosions have been observed at or nearby sanitary landfills. This potential concern, however, can be mitigated or eliminated at a low-level waste disposal facility by, for example, reducing the decomposition rate of the waste material. This has already been shown to be important for minimizing the need for active long-term maintenance. In addition, methane gas generation and migration may be readily monitored in sumps and observation wells through currently available techniques. If monitoring shows methane gas generation to be a potential problem, the technology for construction of engineered methane control systems has already been developed for sanitary landfills and chemical and hazardous waste disposal facilities, where methane generation would be expected to be a much greater problem due to the nature of the disposal technology utilized and the typically higher organic content of the disposed waste material. Application of a given methane gas control technology would be applied on a site-specific basis as part of licensing an individual facility.

5.4.2 Plant and Animal Intrusion

The intrusion of deep-rooted plants and burrowing animals into disposed waste could potentially affect disposal facilities in three ways:

- Radionuclides may be brought to the surface where they may be dispersed by wind and water;

- Contamination on or within plants and animals may be potentially eaten by humans; and

- Plant and animal intrusion can create pathways in a disposal trench cover for increased percolation of rainwater into the disposal trench, thus increasing ground-water migration.

Occasional cases of plant and animal intrusion have been documented at disposal facilities operated by the Department of Energy and are discussed in Section 2.2.4

of Appendix F. The uptake and dispersion of radioactivity by plants and animals has not been reported at commercial disposal facilities. The impacts from these documented cases have not been of major public health and safety concern. Actual uptake and dispersion impacts of plant and animal intrusion into disposed wastes would be site specific and difficult to predict due to differences in climate, plant and animal species and waste characteristics. The last effect of plant and animal intrusion--that of increasing percolation into disposal cells--was considered during the ground-water analysis in Section 5.2

In Appendix F, NRC looked at a number of ways in which the occurrence of plant and animal intrusion could be minimized or eliminated, including:

1. Increasing the thickness of earth fill between the top of the disposed waste and the disposal cell surfaces;

2. Placing higher activity material at greater depths;

3. Improvements in waste form; and

4. Using biological barriers such as rip-rap, cobbles, asphalt, root toxins and herbicides.

These are discussed in greater detail in Section 2.2.4 of Appendix F and in Section 2.0 of Appendix M. NRC concluded that the methods that would be applied to reduce impacts to man due to human intrusion and migration would also generally serve to reduce the potential impacts of plant and animal intrusion (e.g., thicker trench caps and placing high or activity waste deeper). With respect to specific engineered biological barriers, NRC concluded that such barriers may be useful as a means of helping to reduce potential ground-water migration to levels as low as reasonably achievable. However, additional work is believed to be needed regarding the application and use of biological barriers before specific requirements for their use could be established. For example, it is believed that the effectiveness of such biological barriers would be seriously reduced as long as instability of the disposal cells was a problem. The presence of the barriers may also make maintenance of unstable disposal cells more difficult and more expensive. NRC therefore concluded that at this time it is of more fundamental importance to concentrate on methods to achieve greater disposal cell stability. Thus, in designing disposal cell covers, plant and animal intrusion should be considered on a site-specific basis but requiring specific actions to include barriers to such intrusion is not believed to be generally appropriate at this time.

5.4.3 Erosion

Another source of potential environmental releases is through the effects of wind and water erosion. Through these mechanisms, the covers over disposal trenches may be removed over time, eventually exposing the disposed wastes which could then be potentially dispersed into the environment through airborne or water-borne pathways. In addition, a significant erosion problem would reduce the predictability of the disposal facility performance over time.

It is recognized that minimizing the effects of erosion is of significant importance when siting, designing and operating a disposal facility. Avoidance of areas which could result in erosion problems has been already addressed in the basic siting considerations set out in Appendix E. The effects of erosion and the types of erosion are site-specific and would be analyzed as part of individual licensing actions for a particular disposal facility. For some facilities--for example, those located in an arid region having high winds--wind erosion may be of most significance. For facilities located in humid environments, gully or sheet erosion due to the action of water may be of most significance. Gully erosion would effect less of the disposed waste, but could occur over a shorter time frame. Sheet erosion would eventually effect a larger area, and hence a larger amount of the disposed waste, but would take longer to occur.

It is believed that the effects of erosion at a disposal facility can be minimized through proper siting, design, and operation to the point that it need not be considered a problem. Practical measures which can be readily taken to minimize or eliminate this potential problem include the following examples:

- o Avoid areas characterized by rapid erosion, such as flood plains, areas of high topographic relief, and so forth.

- o Stabilize the site against erosion through application of a soil cover such as grass or a layer of rip-rap.

- o If drainage channels are used at the facility, minimize gully erosion through appropriate engineering such as lining with rip-rap.

Still, it is instructive to obtain an upper-bound estimate of the level of potential exposures that could occur if through some reason the waste did become exposed through erosion. To do this, an estimate must be made of the length of time that it takes for the cover over the waste to be removed through weathering activities. As stated above, gully erosion could be a fairly rapid process. However, its effects would tend to be localized and if it were to occur, then it would most likely be identified during the 100-year institutional control period. During this time period, the disposal site would be under the surveillance and control of a governmental agency and steps could be taken to correct the problem. Sheet erosion, however, would appear to be a less perceptible, longer-term potential problem.

A discussion of factors which influence wind and water erosion, as well as typical erosion rates in various parts of the country, is provided in Appendix M. For the purposes of this environmental impact statement, a time of 2,000 years is assumed to be required to uncover 2 meters of soil, or about 1,000 years per meter of cover over the disposed waste. This essentially assumes a soil loss of 6 tons per acre per year from the disposal trench. A continuous (over 2,000 years) soil loss rate of this magnitude from the disposal facility is extremely unlikely. It ignores ground cover and other surface engineering measures that would be incorporated into the disposal facility. The loss rate is at an upper range associated with typical farming activities. Such farming activities are unlikely to occur and if they do occur, it would be unlikely

that a continual soil loss rate of 6 tons per year would be tolerated by a farmer. Such rates would probably reduce the productivity of the soils to unacceptable levels long before the 2 meters of soil thickness is lost.

In any case, after a time period equal to 1,000 years per meter of cover thickness, the trench covers are hypothetically assumed to be eroded away and the scenario is initiated. As a further conservatism, no credit for waste form is assumed for the erosion scenario. The contaminated exposed soil/waste mixture is assumed to be carried by the water into a surface body water located one kilometer from the disposal facility. The natural mobilization rate calculated for the reference facility (about 0.75 tons/acre/year) is used. The reduction in the activity due to deposition along the route is neglected and the soil/waste mixture is assumed to all dissolve in the surface water, where the water is used by an individual for consumption, crop irrigation, and so forth. The total exposures received by all significant pathways may then be calculated.

Similarly, the effects of wind dispersal of the soil/waste mass exposed by the sheet erosion to the surrounding population are calculated. Details of the calculational procedures used to estimate surface water erosion impacts to individuals and airborne impacts to populations are provided in Appendix G. In these calculations, no credit is assumed for waste form.

The results of these calculations for the 20 cases considered in Section 5.2 in the ground-water migration case study are set out in Tables 5.26 and 5.27. As can be seen, the hypothetical waterborne exposures range from about .1 to 1 mrem to thyroid. All organ exposures are less than 4 mrem/year. Similarly, the hypothetical airborne exposures within 50 miles of the disposal facility range from about 3.5 to 7.3 man-mrem to whole body and from about 70 to 138 man-mrem to bone. The population is assumed to be three times the size of the population within the vicinity of the facility while the facility is operating. As can be seen, such exposures are very small and are an order of magnitude or so below those exposures calculated during the hypothetical operation of a regional waste incinerator (See Chapter 6).

5.4.4 Summary

The previous three sections investigated three additional pathways for potential long-term exposure of the public: gaseous releases from decomposing wastes, plant and animal intrusion, and erosion of the disposal facility. None of these three pathways would appear to result in potential exposures which would exceed the ground-water performance objective developed in Section 5.3.

For each of these potential pathways, there are a number of actions which may be taken to minimize such releases. By and large, such actions also serve to reduce potential exposures to humans through ground-water and intrusion pathways, as well as reduce the need for long-term maintenance of the site. For example, gaseous releases can be reduced by assuring stable site conditions. Erosion is a slow, long-term process which can be controlled through proper siting and good operational techniques. Impacts from plant and animal intrusion can be reduced through engineering designs applied to reduce ground-water migration and potential intruder exposures.

Table 5.26 Population Airborne Impacts from Potential Erosion of the Reference Facility

	Organ						
Case	Body	Bone	Liver	Thyroid	Kidney	Lung	GI
(man-millirem/yr)							
1	4.19	80.13	55.32	5.38	21.21	76.43	0.21
2	4.19	80.13	55.32	5.38	21.21	76.43	0.21
3	4.19	80.13	55.32	5.38	21.21	76.43	0.21
1A	4.19	80.13	55.32	5.38	21.21	76.43	0.21
4A	4.19	80.01	55.24	5.37	21.18	76.31	0.21
4B	4.19	80.01	55.24	5.37	21.18	76.31	0.21
4C	3.48	69.52	46.05	5.36	16.14	74.39	0.19
4D	3.48	69.46	46.01	5.35	16.13	74.33	0.19
4E	3.48	69.46	46.01	5.35	16.13	74.33	0.19
5	4.23	84.87	55.02	58.67	18.02	84.85	0.24
6	3.48	69.46	46.01	5.36	16.14	74.39	0.19
7A	3.11	59.29	40.19	3.17	15.21	70.66	0.23
7B	7.31	137.6	95.00	64.53	36.03	111.9	0.38
7C	7.31	137.6	95.00	64.53	36.03	111.9	0.38
7D	6.11	119.8	79.40	64.51	27.50	108.6	0.35
8	6.09	119.8	79.50	64.58	27.51	108.8	0.32
9	4.22	84.81	55.01	58.66	18.01	84.84	0.22
10A	3.48	69.52	46.05	5.36	16.14	74.39	0.19
10B	6.11	119.8	79.40	64.51	27.50	108.6	0.35
10C	6.10	119.5	79.22	64.36	27.43	108.4	0.35

Table 5.27 Individual Waterborne Impacts From Potential Erosion of the Reference Facility

	Organ						
Case	Body	Bone	Liver	Thyroid	Kidney	Lung	GI
(millirems/yr to an individual)							
1	5.37E-2	4.64E-1	7.61E-2	1.19E-1	9.17E-2	4.26E-2	7.27E-2
2	5.37E-2	4.64E-1	7.61E-2	1.19E-1	9.17E-2	4.26E-2	7.27E-2
3	5.37E-2	4.64E-1	7.61E-2	1.19E-1	9.17E-2	4.26E-2	7.27E-2
1A	5.37E-2	4.64E-1	7.61E-2	1.19E-1	9.17E-2	4.26E-2	7.27E-2
4A	5.36E-2	4.63E-1	7.59E-2	1.19E-1	9.15E-2	4.25E-2	7.26E-2
4B	5.36E-2	4.63E-1	7.59E-2	1.19E-1	9.15E-2	4.25E-2	7.26E-2
4C	4.74E-2	4.15E-1	6.35E-2	1.14E-1	7.63E-2	3.78E-2	6.53E-2
4D	4.74E-2	4.15E-1	6.34E-2	1.14E-1	7.62E-2	3.78E-2	6.53E-2
4E	4.74E-2	4.15E-1	6.34E-2	1.14E-1	7.62E-2	3.78E-2	6.53E-2
5	5.23E-2	4.56E-1	9.06E-2	8.79E-1	6.11E-2	2.37E-2	1.17E-1
6	4.74E-2	4.15E-1	6.35E-2	1.14E-1	7.63E-2	3.78E-2	6.53E-2
7A	6.42E-2	4.93E-1	7.81E-2	9.73E-2	9.73E-2	5.33E-2	8.13E-2
7B	9.76E-2	7.76E-1	1.61E-1	1.00E+0	1.32E-1	6.04E-2	1.95E-1
7C	9.76E-2	7.76E-1	1.61E-1	1.00E+0	1.32E-1	6.04E-2	1.95E-1
7D	8.87E-2	7.03E-1	1.41E-1	9.94E-1	1.08E-1	5.41E-2	1.81E-1
8	7.49E-2	6.35E-1	1.28E-1	9.82E-1	9.37E-2	4.02E-2	1.68E-1
9	4.69E-2	4.29E-1	8.52E-2	8.74E-1	5.57E-2	1.82E-2	1.11E-1
10A	4.74E-2	4.15E-1	6.35E-2	1.14E-1	7.63E-2	3.78E-2	6.53E-2
10B	8.87E-2	7.03E-1	1.41E-1	9.94E-1	1.08E-1	5.41E-2	1.81E-1
10C	8.85E-2	7.01E-1	1.41E-1	9.92E-1	1.07E-1	5.40E-2	1.81E-1

Further reductions in impacts from plant and animal intrusion--in particular, further reductions in long-term ground-water releases--may be potentially achieved through use of biological barriers to plant and animal intrusion. Some work has been performed to develop such biological barriers, but additional work is believed to be necessary (particularly in humid environments) prior to setting out criteria for their use. In any case, the effectiveness of biological barriers would appear to be dependent upon the degree of site stability achieved. Ways to achieve improved site stability over time would therefore be of more fundamental importance.

5.5 DEVELOPMENT OF TECHNICAL CRITERIA

Based on the results of the preceding alternatives analyses, NRC selects in this section minimum technical requirements that should be considered and applied in all cases to help ensure that the performance objectives will be met.

The results of the previous analyses indicate that with modest increases in cost relating to improving the form and properties of waste shipped for disposal and modest improvements in the design and operation of a near-surface disposal facility (many of which are being used at some of the existing sites today) the potential health, safety, and environmental impacts from disposal of LLW can be greatly reduced. In addition, the ability to predict the long-term performance and impacts of near-surface disposal facilities is improved and the uncertain and high costs required to care for disposal sites over the long term are reduced.

The minimum requirements developed in this section for near-surface disposal of radioactive waste are directed at four key aspects that are directly related to assuring the overall performance objectives for migration and long-term maintenance are met. These are:

1. Eliminate to the extent practicable, the contact of water with waste both during operations and after closure to reduce the potential for migration.

2. Assure long-term stability of the site and facility to eliminate the need for constant care and maintenance over the long term with attendant uncertain high costs and long-term commitment of social resources;

3. Assure a continuation of state-of-the-art procedures, understandings and techniques for the siting, design and operation of near-surface disposal facilities while maintaining flexibility to accommodate new advances in technology and understandings and to address special waste disposal problems.

4. Improve confidence in the predictability of the long-term performance capability of the facility.

Stability of the LLW disposal facility may be the single most important aspect and is related directly to the achievement of the performance objectives. Continued assurance of protection of the population from migration of radioactivity from a disposal site should not have to rely on the indefinite implementation of maintenance programs periodically or continually to ensure the continued integrity of the site. NRC believes that such instability will lead to situations where indefinite costs and resources will need to be applied for such maintenance programs in the future. In general, the costs for disposal should be paid by those generating the waste today and the need for active major maintenance should be eliminated through proper siting, design, operations, and closure. Thus, NRC's requirements should provide that proper preventive measures are taken today by those generating and disposing of the waste, to provide stability in an LLW disposal facility over the long term, eliminate the need for active maintenance, and reduce potential costs to future generations.

A second aspect, predictability, relates to the need to be able to adequately characterize and analyze the various components or barriers of a disposal system, and assess with a reasonable degree of assurance that they will operate effectively over the long term and will not be subject to any major unpredictable changes during the time that they must remain effective.

The predominant method used to date for disposal of LLW has been shallow land burial. The natural characteristics of the disposal site environment have been principally relied upon to provide confinement of the waste over the long term, although some very limited controls have been placed on waste form, facility design and operations, land ownership, and postoperational considerations. The experiences at several of the existing sites have shown the need to consider a series of "multiple barriers", rather than relying principally on one component (e.g., the site).

It is with these views in mind that NRC has selected minimum requirements addressing each of the four basic components of any disposal facility: institutional controls, site characteristics, design and operations, and waste form and packaging. The following sections present the development of the technical requirements for each of the four disposal system components considering the performance objectives. The requirements are set out in general terms with the intention of setting out the overall intent of the requirements rather then providing precise regulatory wording. They are divided into those involving codification of existing practice and those involving additional new requirements.

5.5.1 Codification of Existing Practice

5.5.1.1 Institutional Control Requirements

1. The land owner shall carry out an active institutional control program to physically control access to the site following transfer of control from the site operator.

2. Each applicant must demonstrate adequate financial resources to cover the estimated costs of conducting licensed activities over the planned operating life of the project.

3. Each applicant shall ensure that sufficient funds will be available to carry out final site closure and stabilization activities.

4. Each applicant shall ensure that sufficient funds will be available to cover the costs of postclosure surveillance, monitoring, and any required maintenance.

The need for active institutional controls at a site was discussed in detail in Chapter 4 regarding control of potential inadvertent intrusion. Such controls are also important from the standpoint of migration since the actions of an intruder could disturb the site surface, increasing the rate of infiltration of rainfall and thus the potential for migration. Such a program is also important with respect to carrying out an environmental monitoring program to help evaluate continued site performance and to carry out any minor maintenance activities that may be needed. Such maintenance could involve filling any subsidence depressions which would serve to reduce the potential for water infiltration. The need for adequate financial assurance is also discussed in detail in Chapter 9.0. Adequate financial assurance will help ensure that the

site is properly operated, closed, stabilized and cared for during the active institutional control period. Proper closure and stabilization will help reduce the need for active maintenance over the long term and reduce the potential for migration. An active institutional control program including provisions for adequate funding are a codification of existing practice and the costs have been included as part of those for the base case analysis.

5.5.1.2 Site Characteristics

To develop the minimum site suitability requirements, NRC has followed the practice of tiering, utilizing and relying on existing information and experience to provide a basis for the requirements. A great deal of experience has been gained over the years regarding the handling and disposal of radioactive waste. Based on that experience and experience regarding nonradioactive solid and hazardous (chemical) waste disposal facilities, a number of requirements and recommendations regarding the siting of disposal facilities have been developed by the USGS, EPA and others. NRC has utilized these requirements and recommendations to develop minimum site suitability requirements. These requirements were assumed in the development of the reference disposal facility described in Appendix E and the costs of application of these criteria are reflected in the costs of the reference facility. (It is difficult to individually quantify the impacts of the siting requirements since the performance of the facility is so closely linked to design and operations.) The primary emphasis given by the NRC in developing these requirements was selection of sites with natural characteristics which provide for isolation of wastes, reduced contact of water with wastes, long-term site stability, and predictability of long-term performance as opposed to short-term conveniences or benefits such as minimization of transportation or land acquisition costs.

A wide range of sites, ranging from the humid east to the arid west, are potentially available for use in siting a near-surface disposal facility. NRC has set out what are believed to be common sense site suitability requirements that can be consistently applied throughout the country. The requirements would eliminate from consideration limited areas in each region due to undesirable characteristics, leaving large areas in each region where acceptable sites may be found. The requirements are intended to eliminate, to the extent practicable given the variety of sites anticipated, certain characteristics that are known to lead to or have potential to lead to long-term problems. Each is briefly addressed below and further detail is provided in Section 2 of Appendix E.

1. Requirement: The site shall be capable of being characterized, modeled, analyzed and monitored.

Analysis: The hydrological and geological complexity of the site is important, and influences the ability of the applicant to demonstrate that the performance objectives will be met, to determine and characterize appropriate pathways, to construct a physical model of the site, and to predict the long-term performance capability of the site. Simple subsurface media are preferred for disposal sites so that representative values for input parameters can be determined, a

workable model for reliable transport predictions can be developed, and a representative monitoring network can be established to help evaluate the continued performance capability of the site over time.

2. Requirement: The site disposal areas shall be generally well drained and free of areas of flooding or frequent ponding. Waste disposal shall not take place in a 100-year flood plain, coastal high-hazard area, or wetland.

Analysis: Avoidance of significant surface water features such as wetlands, swamps, and bogs at site disposal areas will reduce the potential for significant quantities of water being available to enter disposal cells and to leach disposed waste. In addition, these areas frequently are ground-water discharge areas and environmentally sensitive areas which should be avoided. Executive Order 11988 requires avoidance of the 100-year flood plain (Ref. 14). Avoiding the flood plain and coastal high hazard areas will reduce the potential for flooding and erosion of the disposal site.

3. Requirement: Upstream drainage areas must be minimized to decrease the amount of runoff which could erode or inundate the disposal cells.

Analysis: The amount of runoff from upstream drainage areas must be controlled through site selection or diversion to prevent erosion or inundation of disposal cells. Such controls will lengthen the life of covers constructed over the disposal cells and will reduce the amount of water infiltrating into the wastes.

4. Requirement: The disposal site must provide sufficient depth to the water table so that ground-water intrusion, perennial or otherwise, into the waste will not occur.

Analysis: Disposal of the waste above the water table will significantly reduce the amount of water in contact with the wastes. Leachate will be released to the water table only when the soil moisture content exceeds field capacity--typically during the wet season in humid regions and infrequently in arid regions. Engineering design and construction techniques can reduce percolation of precipitation into disposal cells. Providing sufficient depth to the water table will eliminate the influx of significant quantities of water into disposal cells from below. Exceptions to this requirement can be considered when the site's hydrological and geological characteristics are such that diffusion is the predominant means of radionuclide movement.

5. Requirement: The hydrogeologic unit used for disposal must not discharge ground-water to the surface within the disposal site.

Analysis: A long ground-water travel distance between the disposal site and the nearest point of discharge to surface water is desirable to provide time for radioactive decay of radionuclides being transported by the ground water. In addition, the longer travel distance will typically increase dispersion and retardation of the radionuclides by the subsurface media. Providing long

travel distance to points of water discharge and use will reduce potential impacts since the amount of activity reaching such locations will be reduced. Thus, it is not desirable to locate a disposal facility within close proximity (e.g., a few hundred meters) of a municipal drinking water well field or to locate disposal cells within close proximity of a perennial steam.

6. Requirement: Areas must be avoided where tectonic process such as faulting, folding, seismic activity, or vulcanism may occur with such frequency and extent to significantly affect the ability of the disposal site to meet the performance objectives or may preclude defensible modeling and prediction of long-term impacts.

Analysis: The avoidance of these tectonic processes promotes the stability of the disposal facility and increases the simplicity of the site, enabling adequate characterization, modeling, analysis and monitoring. In addition, the avoidance of these processes reduces the likelihood of unidentified pathways of transport or failure mechanisms for disposal cell covers.

7. Requirement. Areas must be avoided where surface geologic processes such as mass wasting, erosion, slumping, landsliding, or weathering occur with such frequency and extent to significantly affect the ability of the site to meet the performance objectives or may preclude defensible modelling and prediction of long-term impacts.

Analysis: The rationale behind avoiding significant surface geologic processes relates to the desire to avoid active maintenance and exposure of the wastes to these processes. In addition these processes are typically associated with significant topographic relief, the avoidance of which increases the ability to manage surface water and prevent erosion. With respect to surface water management, a slight to moderate slope aids in the runoff of surface water and minimizes infiltration into the disposal unit. However, if the slope is too steep, then the higher velocities associated with runoff water may produce accelerated erosion or may necessitate surface runoff control systems that require active maintenance. Safe construction and maintenance of disposal cells can also be difficult on steep slopes.

8. Requirement: The disposal site must not be located where the operation of nearby municipal, government, commercial or other facilities could adversely impact the ability of the site to meet the performance objectives or significantly mask the environmental monitoring program.

Analysis: The rationale behind this requirement is to avoid the potential effect other facilities might have on a near-surface disposal facility through altering natural ground-water flow patterns, changing the natural moisture content of the soils, modifying the ion exchange properties of the soil and reducing the ability to monitor the performance of the site.

5.5.1.3 Design and Operations

The specific technical requirements on the design and operation of a near-surfac disposal facility are principally directed at assuring stability of the disposal

facility over the long term; reducing, to the extent practicable, the contact of water with the waste; improving the ability to predict the long-term performance capability of the disposal facility; and helping reduce or eliminate the need for active long-term maintenance operations.

1. Requirement: In general, the site design and operation features should emphasize long-term isolation of the waste, rather than ease of construction and operation, as well as avoiding the need for long-term active maintenance. Site design and operation of the facility should also be carried out in accordance with a plan for final site closure and stabilization and should be directed at complementing and improving the ability of the natural site characteristics to isolate the radioactive wastes. Site closure must be considered prior to disposal site licensing rather than as an afterthought. A site closure and stabilization plan which includes funding for closure and long-term care must be provided as a part of the application. This plan will be reviewed and updated periodically during the life of the site and a final plan must be reviewed and approved by NRC prior to final closure. In addition, after site closure, an observation period is needed between the time that a disposal facility is closed and the time the license is transferred to the site owner. This is to carry out any final active maintenance that may be required and to assure that the site is in a stable condition such that only passive care, surveillance and monitoring is required. Active waste disposal operations shall not have an adverse effect on completed closure and stabilization measures and appropriate closure and stabilization measures should be carried out as each disposal cell (e.g., each trench) is filled and covered. Finally, a buffer zone of land shall be maintained between any buried waste and the site boundary. The buffer zone shall extend at least 100 feet outward from the perimeter of the waste disposal area.

Analysis: One of the principal lessons learned from past experience with LLW disposal is that insufficient attention has been given to the long-term aspects of waste disposal. Short-term considerations such as ease of siting or operations were occasionally given higher consideration than long-term aspects such as the amount of long-term commitment and expense required to maintain the site in a safe condition. Since the principal function of a disposal site is to safely contain disposed waste over the long term in a manner that does not require extensive social commitment (e.g., periodic expensive major site rework), then it is axiomatic that this principal function be given major consideration all throughout the life of the site--that is, from the time the disposal site is licensed through the time that it is operated to the time that it is finally closed. As has been previously discussed, the final condition of the disposal facility should not require extensive maintenance--including extensive repairs of trench slumping or subsidence, or continued pumping and processing of the trench leachate--to maintain the site in a safe condition.

Therefore, any application for a near-surface disposal facility should contain a site closure plan which describes how the applicant will operate and prepare the site for closure and eventual transfer to the site owner (i.e., the state

or federal government). Such a plan would have to be approved before a disposal license would be granted. Arrangements to assure that sufficient funds are available for closure and long-term care would need to be provided as part of the plan.

During the operational life of a disposal site, additional data will be obtained regarding the expected long-term performance of the site. The site closure plan should therefore be reviewed on a periodic basis and modified as required to better assure that the overall performance objectives for near-surface waste disposal are met. Such periodic reviews should include a review of the funding arrangements and would most conveniently occur as part of renewals of the operating license. A final site closure plan should be reviewed and approved prior to final closure of the disposal site.

NRC staff believes that a site closure plan which is included with the application for a disposal site and periodically reviewed and updated during disposal site operation is essential for assurance of long-term public health and safety. NRC staff believes that the alternative of a specific site plan--that is, not requiring one and allowing site closure to be addressed when a particular site is filled to capacity--is clearly unacceptable. Such an alternative would ignore the lessons of past experience with LLW disposal.

Site closure of existing facilities has been addressed by NRC. On May 17, 1979, NRC issued a Low Level Waste Licensing Branch Technical Position entitled "Low-Level Waste Burial Ground Site Closure and Stabilization." The objectives of this Branch Technical Position have been incorporated into existing NRC and Agreement State disposal licenses. The specific requirements of this Branch Technical Position are set out in Appendix I.

In this Branch Technical Position, NRC staff also expressed its intent to require a site closure plan as part of any new disposal site licenses (which would currently be licensed under Parts 20, 30, 40, and 70 of the Commission's regulations) and to assess the plan against the 16 objectives in the Branch Technical Position.

The reference facility described in Appendix E assumes application of the Branch Technical Position and the costs and impacts of development and implementation of the plan have been included in the analyses. The costs for development and periodic updates of the plan have been estimated to be in the range of $600,000, or about $0.60 per m^3 of waste ($.02/ft^3). The costs for development of a site closure and stabilization plan for the various alternatives considered in this EIS does not change. The cost for implementation, however, can vary depending upon specific design and operational practices and long-term site stability. For example, Cases 1-3 in Section 5.2 assume, consistent with past practices at most sites, that no special efforts were made to ensure long-term site stability. Thus, the costs and impacts for implementation of the plan for the base case facility were high. This served to provide a base case of what could be expected if past practices were continued and against which improvements to ensure long-term stability can be analyzed and compared. The rest of the 20 cases considered in Section 5.2 considered alternative methods by which such improvements may be made.

The obvious alternative to requiring a site closure and stabilization plan is to not require one. Given the past experience at several of the existing sites and the fact that existing licensees are implementing the NRC Branch Technical Position, NRC did not consider this alternative viable. Other alternatives involve increasing the emphasis on site closure and stabilization and requiring additional actions to those already set out in the Branch Technical Position. Any such changes are reflected in the further specific requirements discussed below.

2. Requirement: Prior to any license application, the applicant shall conduct a preoperational environmental monitoring program to provide basic environmental data on site characteristics. The applicant shall obtain information about the ecology, meteorology, climate, hydrology, geology, and seismicity of the site. For those characteristics that are subject to seasonal variation, data shall cover at least one full year.

   During disposal facility construction and operation, the licensee shall maintain a monitoring program. Measurements and observations shall be made and recorded to provide data to evaluate the potential health and environmental impacts during construction and operation and enable the evaluation of long-term effects and the possible need for mitigative measures.

   After the site is closed, the licensee responsible for postoperational surveillance of the site shall maintain a monitoring system based on the operating history and the closure and stabilization of the site. The monitoring system shall be capable of detecting migration of radionuclides from the site.

Analysis

These requirements involve a codification of existing practice relating to environmental monitoring at a near-surface disposal facility. The environmental monitoring program should involve 3 principal phases: a preoperational monitoring program to be carried out prior to initiation of operations to provide baseline environmental data against which the changes in data due to operations of the facility can be compared; an operational phase during which the impacts of facility operation are monitored; and a postoperational phase where the long-term performance of the site is continually assessed. The costs and impacts of designing and carrying out a monitoring program are included as a part of the reference facility described in Appendix E and are representative of the types of environmental monitoring programs that would be expected at future sites.

NRC also very briefly examined some alternatives and costs of improving environmental monitoring programs. Two principal areas examined in which environmental monitoring can be improved compared to the reference facility are: (1) increasing the overall reliability of ground-water and surface runoff monitoring, and (2) airborne particulate monitoring. A monitoring system is intended to provide information on the potential movement of radionuclides away from active disposal trench areas, completed trenches, and other areas where radioactive materials

are handled. Over the long term, the monitoring system supplies information regarding performance of the site with respect to protection of ground water and protection of the health and safety of the public. The system should therefore be designed so that performance can be evaluated with confidence. Confidence in the monitoring system is afforded when it can be demonstrated analytically that no significant contamination can leave the site without being detected.

The improved ground-water monitoring system analyzed by NRC includes a total of 20 perimeter wells along the restricted area fence (as compared to 10 for the reference facility). Each of these perimeter wells extend several feet into the saturated zone (minimum depth of 19 m). The perimeter wells are sampled quarterly, as opposed to semiannually as in the reference facility. The number of monitoring wells within the trench areas is raised from 15 to 30, and these wells are also sampled on a quarterly basis. The locations of these wells are selected based on an analysis of site hydrogeological characteristics.

In the reference facility monitoring system, surface runoff is not routinely monitored. The improved monitoring system employs a flow activated automatic runoff monitoring system used in conjunction with a discharge channel located at one corner of the site. Flow composite samples are collected monthly and sent to an offsite laboratory for radiochemical analysis. This monitoring system is operated during the 20-year operational period.

The final component of the improved monitoring system is an expansion of airborne particulate monitoring. The three-location airborne particulate monitoring system is upgraded to include ten additional air sampling units, which are situated at various locations within the restricted area. The samplers provide positive additional data regarding the potential for airborne releases from an operating disposal facility. Particulate filter samples are collected on a daily level and analyzed for gross beta-gamma contamination. On a weekly basis, samples from each sample are assumed to be sent offsite to a laboratory for more detailed analysis such as a gamma spectrum analysis.

The benefit of the improved monitoring system would be a greater level of confidence in evaluating the performance of the site. The estimated differential cost for the improved monitoring system is about $1.90/m^3 ($0.05/ft^3).

5.5.1.4 Waste Form and Packaging

Several of the minimum waste form and package requirements set out in Section 6.5.2 of Chapter 6 relating to packaging and free liquid also help to minimize the potential for migration.

1. <u>Requirement</u>: Liquid wastes, or wastes containing liquid shall be converted into a form that contains as little free standing noncorrosive liquid as is reasonably achievable. In no case shall the liquid exceed 1% of the volume of the waste.

Analysis: Liquid radioactive waste and the presence of free standing liquid in radioactive waste shipments presents a number of possible health and safety problems, both over the short and long term. These problems are also aggravated by the corrosive nature of some of the liquids. Except for the disposal of liquid scintillation vials, license conditions at existing operating disposal facilities do not allow direct disposal of liquid waste.

The presence of free standing liquids in waste packages can cause a decrease in transportation safety by increasing the potential for the spread of contamination within waste transportation vehicles and by increasing potential exposures to the population along the route of the waste shipment as well as to disposal vehicle drivers. A corrosive free standing liquid serves to accelerate the potential for leakage, and may also present nonradioactive health hazards. (Present DOT regulations in 49 CFR 173.24 and NRC regulations in 10 CFR 71.31 both require that materials should be packaged so that there is no significant chemical or galvanic reaction between the contents and any component of the packaging).

Problems associated with free standing liquids increase once the waste packages arrive at a disposal facility. Operations at disposal facilities involve time spent near or in contact with waste packages. Leaking waste packages can cause increased contamination of and exposures to site personnel, as well as contamination of site grounds and equipment. Contaminated site grounds and equipment must be decontaminated to maintain safe working conditions causing potential additional exposure and contamination of site personnel. A corrosive leaking liquid creates an additional nonradiological hazard during waste handling and decontamination operations, and can possibly damage site equipment. Contamination of the site surface and equipment can also lead to increased offsite releases through the actions of wind and water. Besides increased population exposures, such operational releases effect environmental monitoring programs.

After disposal, free standing liquid in waste packages can potentially increase the migration of radionuclides in that liquid would be immediately available for migration. Corrosive free standing liquids can cause accelerated corrosion of adjacent waste containers and subsequent accelerated leaching of the package contents. Evidence also indicates that the ion exchange capabilities of a site for certain radionuclides may be impeded by very acidic and caustic conditions (Ref. 15).

In view of this, NRC does not consider the alternative of allowing the unrestricted disposal of liquid radionuclide waste, the "no action" alternative, to be acceptable. Rather, NRC has examined to the extent it can be, given current understanding and capability, the establishment of a specific requirement for free liquid.

One alternative for establishment of a free standing water requirement would be to set out allowable levels of free standing liquid as a function of potential radiation hazard, based upon transportation, storage, handling, and disposal considerations. This would, however, be a potentially overly-complicated requirement, and would be difficult to regulate.

A similar situation could occur if a free standing liquid requirement was established based upon disposal considerations. The potential additional impacts of migration of free standing liquids contained in disposed waste are not only radionuclide-specific but site-specific as well.

NRC staff believes that the most workable criteria would be one designed to eliminate to the extent practicable the presence of freestanding liquids, considering existing capabilities. This approach is consistent with current NRC licensing positions regarding radioactive waste solidification systems in reactors as well as with license conditions at existing disposal facilities.

At existing disposal facilities, disposal license conditions have used a basic percent volume limitation in addition to a total content limitation to account for larger waste containers. Some of these license conditions state that waste packages delivered to disposal facilities should contain no free standing liquid. No free standing liquid is then defined as being in trace quantities: not more than 0.5% or one gallon per container, whichever is less. Other site license conditions define no free standing liquid as constituting not more than 1% of the container volume. All the license conditions essentially state that the intent is to reduce or eliminate, to the extent practicable, the presence of free standing liquid, but allow for trace quantities in recognition of current ability to remove and detect free standing liquid and the possible presence of condensate liquid.

Comments filed on the preliminary draft of Part 61 pointed out that a 0.5% and 1 gallon requirement could result in large cost increases in the disposal of certain wastes and could potentially eliminate the use of certain options in meeting the waste stability requirement. NRC does not believe the overall difference between 0.5% and 1% is large. For 55-gallon drums, which constitute most waste packages, a 1.0% limit would correspond to a free standing liquid content of about two quarts. For large containers such as a 170 ft^3 liner, a 1.0% limit volume would correspond to a free standing liquid content of about 10 gallons.

After more experience is gained in development of procedures to detect and eliminate free standing liquid, a more restrictive definition of free standing liquid could be imposed. All of the sites also require that free liquids be noncorrosive. Noncorrosive means having a pH between 4 and 10.

No cost analysis has been prepared for this requirement since it reflects existing practice and is reflected in the costs and impacts of the base case.

5.5.2 Codification of New Requirements

5.5.2.1 Institutional Control Requirements

1. Requirement: For purposes of calculation, active institutional controls shall not be relied upon for more than 100 years.

Analysis: Although this is a new requirement, the analysis for this requirement was carried out in detail in Chapter 4 of this EIS regarding limiting potential

exposures to an inadvertent intruder. The reader is referred to Chapter 4 for further details. The 100-year time period was incorporated into the ground-water analyses in earlier sections. That is, after the end of the 100-year institutional control period, the percolation of water into waste disposal cells was conservatively assumed to increase due to potential intrusion by humans, deep-rooted plants or burrowing animals, or other factors.

2. Requirement: After site closure, an observation period of at least 5 years is needed between the time that a disposal facility is closed and the time the license is tranferred to the site owner to carry out any final maintenance required and to assure that the site is in a stable condition such that only passive care, surveillance and monitoring is required.

Analysis: To help ensure that site stability has indeed been achieved, NRC staff will require that a period of time (up to several years) ensue after closure and before a disposal facility operator's license is transferred to the custodial agency. During this period, the licensee would still be responsible for the care of the site and would be responsible for all site maintenance and environmental monitoring activities. This responsibility would be maintained by the licensee until the license is transferred.

Requiring such an observation period of several years between site closure and license transfer has a number of advantages. An observation period by the licensee would help reduce potential long-term migrational impacts and potential long-term costs to the site owner. Based on past experience at humid sites, subsidence problems would be expected to be observed (if they are going to occur) within a few to 7 to 10 years. If subsidence problems do occur, the licensee should take proper maintenance actions including payment of costs for such activities rather than the state or federal landowner. The need for and extent of such maintenance would be well documented at site closure since the licensee would have had 20-30 years of past operational data and experience regarding the behavior of the disposal cells. Potential long-term subsidence problems could then be anticipated, identified, and corrected during the observation period such that the site would be in a stable condition at license transfer and require only passive care, surveillance and monitoring.

During this observation and maintenance period, the licensee would no longer be receiving income from receipt of waste for disposal. The licensee would be expected to try to reduce maintenance costs during the observation period because of their uncertain nature and would try to ensure that the site has been stabilized as much as possible while the site is being operated. Thus, the requirement of an observation and maintenance period will also serve to place an incentive on the licensee to achieve as stable a site as possible during operations. As stated above, this reduces the risk of long-term monetary impacts borne by the site owner.

Requiring an observation period between the time the site is closed and the time the disposal license is transferred is similar to the intent of regulations promulgated in May 1980 by EPA for disposal of hazardous waste. As part of 40 CFR 265.117 ("Postclosure care and use of property; period of care"),

EPA requires that the operator of a hazardous waste disposal facility maintain a closed facility for 30 years prior to license termination (See Appendix N). In the EPA case, however, there is no provision for ownership by the state or federal government. In addition, a licensee may petition the EPA to reduce the postclosure time or the EPA may require that the observation period be extended. An interested person may also petition EPA to extend the observation period. In any case, the intent is the same--to require the licensee to ensure that the disposal facility is operated properly prior to closure, or run the risk of elevated maintenance costs after closure.

A disadvantage to the requirement of a postclosure observation period as compared to the alternative of not requiring one is that it would increase costs to the licensee and so increase the costs of disposal. This disadvantage, however, illustrated by considering the no action alternative--that is, not requiring a postclosure observation period--could actually result in equal or slightly increased costs due to the long-term and uncertain nature of such costs.

As stated earlier, most of the potential subsidence problems that have occurred at existing sites have occurred within 5 to 10 years of waste disposal. Therefore, if an observation period were not required, then the site owner could potentially be faced with expenses for carrying out such maintenance activities soon after site closure. The site owner, through the required financial assurances, could possibly allow for these potential expenses by increasing the amount of funds set aside for institutional control activities, thereby increasing the costs for disposal. Thus, disposal costs could increase whether or not an observation period is required. Finally, not requiring a postclosure observation period would tend to increase the risk of higher long-term institutional control costs to a site owner. In addition, a licensee might have less of an incentive to make sure that disposal was accomplished in a manner that assures a stable site over the long term.

A number of alternatives can be considered regarding the length of such an observation period:

1. Specify a fixed length of time followed by license transfer;

2. Specify no fixed length of time, but treat each specific facility on a case-by-case basis; and

3. Specify a minimum length of time, but treat the need to potentially extend the observation period on a case-by-case basis.

NRC staff has selected the third alternative as preferable. A fixed minimum period of time is needed; otherwise, one of the attributes of the observation period--that of providing an incentive to assuring site stability as part of site operations--is lost. A licensee could potentially cut corners on site design and operations directed at assuring long-term stability, and then petition NRC to terminate the license soon after site closure. In addition, NRC staff does not believe that it would be wise to terminate a license after a fixed period of time following site closure without consideration of site-specific

conditions. Additional time may be required at some sites to assure that stability has been achieved.

Based upon past experience, NRC staff believes that an observation period of at least 5 years would be appropriate. A disposal site is expected to be operated for 20 to 30 years, and coupled with a 5-year observation period, would provide 25 to 35 years of experience at the site to judge long-term site stability. If major subsidence problems had been experienced in earlier disposal cells during the operating life of the site and are expected to continue for more recent disposal cells, such problems will probably be identified within a 5- to 10-year period after disposal. A 5-year minimum observation period would thus allow the identification of any major subsidence problems, if they are to occur, associated with the last few years of waste disposal operations at the facility. If additional time is required for this maintenance, it can be provided.

The cost for implementing this requirement may be approximated by first estimating the annual costs to the disposal facility operator to maintain the site after it is closed, and then estimating the resulting costs to disposal facility customers, assuming that the observation period costs are passed onto the disposal facility customer during the facility's operating lifetime. Annual costs to the disposal facility operator are estimated (in 1980 dollars) at three levels, corresponding to three levels of site maintenance required. These three levels are:

high:	\$263,000/yr
moderate:	\$184,000/yr
low:	\$91,000/yr

The costs are derived based upon the estimated annual (in 1980 dollars) long-term care costs to the site owner presented in Appendix Q. However, no contingency is included in the high level of maintenance to account for possible occurrences such as extensive leachate pumping and treatment. The costs are then inflated to the start of the observation period assuming an inflation rate averaging about 9% per year. To assure the availability of funds for the observation period, the disposal facility operator is assumed to place a surcharge ($\$/m^3$) on the waste received at the site. Money thus collected is assumed to be placed into a fund or otherwise invested at an average interest rate of 10% per year.

The results of this calculation are presented in Table 5.28 for four alternative observation periods--no observation period, 5 years, 10 years, and 30 years--and three levels of site care during the observation and active institutional control periods. Also shown are the corresponding closure and long-term care (active institutional control) costs, as well as total postoperational costs. All costs are shown as total costs over a 20-year facility operating life to disposal facility customers. (Unit costs may be determined by dividing by 10^6.)

As shown in Table 5.28, the longer the observation period or the greater the level of care, the higher the observation period costs to the disposal facility customer. In addition, as the observation period increases, the long-term care costs decrease. This is due to the accrued interest in the state-operated long-term care fund during the observation period.

Table 5.28 Comparison of Costs for Alternative Observation Periods

Length of Observation Period (yrs)	($ x 10^6) Assumed Level of Care Required: High	Moderate	Low
0			
Closure	3.67	3.67	3.67
Observe	0	0	0
Long-term care	34.6	14.4	8.5
Total	38.2	18.1	12.2
5			
Closure	3.67	3.67	3.67
Observe	2.39	1.67	0.82
Long-term care	33.0	13.8	8.12
Total	39.1	19.1	12.6
10			
Closure	3.67	3.67	3.67
Observe	4.67	13.26	1.61
Long-term care	31.6	13.2	7.76
Total	39.9	20.1	13.0
30			
Closure	3.67	3.67	3.67
Observe	12.8	8.96	4.41
Long-term care	26.7	11.0	6.46
Total	42.8	23.6	14.5

Total postoperational costs are increased over the base case (no observation periods) costs for all three alternative observation periods. Assuming a 5-year observation period and a moderate to low range in the assumed care level, costs to the facility customer would range between $0.82/m^3 and $1.67/m^3 ($0.02/ft^3 to $0.05/ft^3). However, total postoperational costs, due to the reduced need to place funds into the state-operated long-term care fund, would be increased by only $0.40/m^3 to $1.00/m^3 ($0.01/ft^3 to $0.03/ft^3).

As shown, the requirement of a 5-year observation period would not appear to raise costs to the disposal facility customer operator. The requirement provides insurance to the site owner that he will not be faced with large immediate maintenance costs, as well as reduces the amount of long-term (institutional control) costs to the site owner.

5.5.2.2 Site Characteristics

No new site suitability requirements have been identified based on the analyses. The analyses support those leading to elimination of water and long-term maintenance and leading to a stable predictable site condition.

5.5.2.3 Design and Operations

Two new requirements for design and operations are identified. They are set out below.

5.5.2.3.1 Contact of Waste by Water

> Requirement. The disposal facility shall be designed to eliminate the contact of water with waste during storage, the contact of standing water with waste during disposal, and the contact of percolating or standing water with wastes after disposal. Covers of disposal cells shall be designed to prevent water infiltration, to direct percolating or surface water away from buried waste, and to resist degradation by surface geologic processes and biologic activity. Surface features shall direct surface water drainage away from disposal areas at velocities and gradients which will not result in erosion that will require ongoing active maintenance in the future.

Analysis: These requirements are directed at reducing the contact of waste with water, reducing the potential for percolation of water into disposal cells, providing long-term site stability, and reducing the need for long-term maintenance. They are relatively straightforward requirements and have generally been assumed for the reference facility. Several alternatives for accomplishing these objectives, however, were considered and analyzed by NRC including variations in the thickness, composition, and design of the disposal cell covers, measures to stabilize disposal cell covers, and measures to manage surface water drainage. Each is briefly discussed below. Other alternatives considered and the details for each are set out in Appendix F.

The use of certain of these alternatives will vary depending upon specific site characteristics (e.g., humid vs. arid site). Given this, none of these alternatives discussed are set out as preferred. To maintain flexibility in implementing the Part 61 rule, the specific measures that the licensee would utilize to comply with the above requirement would be analyzed on a site-specific case-by-case basis.

Improved Disposal Cell Covers and Designs

Installation and maintenance of an adequate cover (cap) over the disposed waste is one of the more important (if not one of the most important) considerations at a near-surface disposal facility. The trench cap provides radiation shielding and an infiltration barrier to moisture. A properly designed and constructed trench cover is also important in helping to minimize erosion and direct surface water away from disposed waste.

The role of the trench cap as an infiltration barrier is especially important. If significant quantities of water are allowed to infiltrate through the trench cap and contact the disposed waste, then some of the radioactivity contained in the waste may be leached from the waste and released into the environment. Optimal conditions at a disposal facility, then, would exclude the contact of significant quantities of water with the disposed waste. Minimizing water movement into disposed waste through use of disposal cell covers also reduces the moisture contact of the waste, which helps to reduce the rate of an aerobic bacterial degradation of waste.

In the reference facility discussed in Appendix E, the trench caps are assumed to consist of one meter of backfill to original grade, plus an additional one meter of soil added above the original grade. NRC analyzed alternatives for improving trench cap performance, including improved compaction techniques, thicker low permeable trench covers, and possible use of multiple moisture barriers. Further background information about different possible types of disposal cell covers is set out in Section 2.3.2.1 of Appendix F.

Use of More Densely Compacted, Thicker Trench Caps.

Improvements in cap performance can be obtained through increased attention to compaction of the waste, disposal cell backfill, and the disposal cell cover. Until fairly recently, little attention has been paid to compaction other than that compaction that can be achieved by application of several feet of trench cover, plus driving over trench covers with waste transport and other site vehicles. This is the case assumed at the reference disposal facility. Decreased infiltration and percolation through a trench cover (by reducing porosity and thus permeability) can be inexpensively achieved, however, through use of improved compaction techniques using commercially available compacting equipment such as vibratory compactors. Such compaction would also help to compress the compressible wastes and reduce voids, thus minimizing settlement and subsidence problems. Within the last few years, the operators of a site located in a humid environment have employed a mechanical vibratory compactor to provide additional compression of disposed waste and compaction of trench caps. The disposal site operators have reported that use of the vibratory compactor has greatly reduced subsequent maintenance of filled and capped trenches.

The cost for leasing and operating a vibratory compactor for use at the reference facility are estimated to total approximately $94,000 per year, or add approximately $\$.05/ft^3$ to the unit operating costs. The compactor would be originally used to compact the 1 m of earthen fill down to the approximate level of the original site grade. Then, a 1 m cap would be applied in reasonably uniform 20 to 31 cm (8-12 inch) thick layers and compacted to a minimum 95% of the maximum compactible density test.

Additional thicknesses of clayey cap material could also be applied. For example, an additional 2 meters of clay soil could be applied which would cost an additional $\$8.40/m^3$ ($\$0.24/ft^3$), assuming that the additional clayey soil would be imported at a cost of $\$3.50/yard^3$ from a borrow pit located approximately 10 miles from the disposal facility. (The details of the cost calculation are set out in

Appendix F.) The additional 2 m soil thicknesses would be applied in 8-12 inch layers and compacted using the mechanical compactors.

Use of Moisture Barriers

The second trench cap improvement could involve the installation of single or multiple moisture barriers within a thicker trench cap. As an example of possible use of moisture barriers, four moisture barrier cases were analyzed in Appendix F. The additional costs associated with these examples are shown in Table 5.29.

Table 5.29 Additional Facility Design and Operations Unit Costs For Improved Disposal Cell Covers

Case	Additional Cost
Base Case (Appendix E)	0
1m backfill to original grade	
1m cover above original grade	
Thicker Denser Cap	
2m additional cover above original grade	$ 8.41/m^3
3m additional cover above original grade	10.89/m^3
Moisture Barrier Case A	$11.45/$m^3$
One bentonite layer applied at 4 pounds/ ft^3 at 0.5m in 2m thicker denser cap	
Moisture Barrier Case B	$11.92/$m^3$
One 36mil reinforced hypalon polymer membrane place at 0.5m in 2m thicker denser cap	
Moisture Barrier Case C	$14.95/$m^3$
One polymer membrane at original grade and one bentonite clay layer at 0.5m in 2m thicker denser cap	
Moisture Barrier Case D	$15.42/$m^3$
two 36 mil reinforced hypalon polymer membranes	

Given these alternatives, there are a number of alternative disposal cell covers that can be applied at near-surface disposal facilities which cover a range of costs and lead to reduced impacts. The advantage of the use of the more exotic techniques of applying moisture barriers do not seem apparent but they have been included for purposes of comparison. A principal consideration in the

installation of such caps is the stability of the waste upon which the cap is placed since subsidence and compression of the waste would lead to collapse and cracking of the trench cap.

Stabilization and Final Covers

After a cover has been placed over a disposal cell, it is also important that the cap be stabilized by a final cover. A lack of such a final cover can lead to uncontrolled water and wind erosion of the unit caps. Two types of final covers are in general use today: natural vegetation (e.g., grass), and hard surface covers such as cobbles or rip-rap.

A natural vegetation cover at a disposal facility can serve several functions, such as physically stabilizing earth materials, reducing erosion and infiltration of precipitation into the disposed waste, and enhancing the appearance of a site. A thick grass cover, for example, breaks the impact of falling water droplets on the earth surface and reduces the run-off rate from the site, thereby reducing the potential for water erosion. By the same token, the plant roots help to hold the soil in place, thereby minimizing wind erosion.

Water absorbed into plant roots may also be transpired through the plant leaves. It is important, however, that the root systems of cover grasses be of shallow depth to preclude contact with and uptake of radionuclides from the disposed waste. Vegetation species native to the general area of the disposal site are preferable, as these species are more likely to be acclimated to the site climate. A layer of rip-rap or cobbles can also be effective as a final soil cover, particularly in arid climates where it is more difficult to establish a vegetative cover.

As a part of the description of the reference facility in Appendix E, NRC assumed that action was taken to stabilize the cover by establishing a final vegetative cover. The costs and impacts are, therefore, reflected in the base case analysis. Such actions should be continued and required of future sites.

Use of a Highly Permeable Backfill

One way in which the contact of disposed waste by infiltrating water may be reduced is to backfill the disposal trench with a highly permeable material such as sand. Use of the sand backfill would allow percolating water to quickly flow past disposed waste to the bottom of the trench, thus reducing the contact time and the potential for leaching. Use of a sand backfill would also be expected to readily sift down into the interstitial spaces between waste packages and therefore help reduce the presence of voids in a disposal cell.

As part of this, it would also be appropriate to place a layer of sand--perhaps six inches to a foot thick--at the bottom of the disposal cell prior to waste package emplacement. This would reduce the possibility of rainwater falling on an open disposal cell, or water percolating through a closed cap, from collecting and standing around the bottom waste packages. This is especially important when one considers that at existing disposal facilities higher activity waste packages are frequently emplaced on or near the bottom of the

disposal trenches to reduce radiation exposure to facility personnel. Water percolating to the bottom of the trench will percolate below the bottom waste packages into the sand layer, and flow into the French drain along one side of the trench. The French drain then directs the water to a sump at the low end of the trench before the percolating water has a chance to contact the lowest waste packages for extended periods of time. The sand layer also provides a smooth trafficable foundation for operation of vehicles such as fork lifts in the trench.

To implement this option, the disposal operations remain essentially the same as before, with the exception that the sand backfill is utilized instead of backfill composed of previously excavated site soils. The 1 m space between the top of the waste and the top of the trench is also filled with the sand backfill. The backfill is obtained from a local borrow pit.

Assuming one million m^3 of the randomly disposed waste at the facility, approximately 65,000 m^3 of sand would be required annually, or approximately 1.3 million m^3 over the 20 years operating life of the facility. This would result in an additional operational expense of approximately \$6.70/m^3 (\$0.19/ft^3) above that for the reference facility. Use of a sandy layer on trench floors in addition to use of a sandy backfill is presently part of standard operating practice at the Barnwell, SC disposal facility.

Surface Water Management and Drainage

The proper management of surface water drainage is important in quickly removing precipitation from the site surface and thereby eliminating the contact time and amount of water that will infiltrate the soil. Runoff and drainage, however, should not be so rapid so as to lead to erosion of disposal cell caps.

Surface water management in the reference facility consists of drainage control through grading of the site. Temporarily installed earth berms are used to direct flowing water away from open trenches which are being actively used for waste disposal. Surface drainage through the use of ditching and channelization can be useful in reducing the quantity of water which percolates into the soil. This is accomplished by transporting the runoff water from the site before significant volumes can infiltrate into the soil. The costs and impacts for proper management of surface water have been included in Appendix E. Appendix F, however, presents an example of one method which could be used to improve drainage from the site. The costs and effectiveness of similar types of drainage systems at a real disposal facility would be site-specific. However, the example in Appendix F illustrates the magnitude of the costs involved in such an improved drainage system--i.e., about \$7.50 per m^3 of waste (\$0.21/ft^3).

Trench Water

At the reference facility described in Appendix E, an approximate one degree slope is provided in the bottom of the trench from end to end and from one side toward a gravel-filled French drain. The French drain runs the entire length on the lower elevation side to provide for collection and drainage of precipitation entering a trench. A gravel-filled sump is located at the low corner of the trench which is used to remove precipitation from the trench during operations.

In Appendix F, the alternative of using a temporary structure such as a weather shield to minimize water contact with waste during operation is also considered and analyzed (Refer to Section 2.3.2.4). The weather shield would be employed to eliminate the amount of rainwater falling into an open trench during precipitation events. Such shields and air support building have been used at some DOE sites to provide weather shielding. Although the use of such weather support shields would eliminate the inflow of precipitation into trenches as they are constructed and filled, they would increase disposal facility costs by about $\$27/m^3$ and would increase occupational exposures as a result of increased in-trench handling of wastes without significant reduction in long-term impacts. NRC, thus, has concluded that the continuation of existing practices such as those described for the typical facility for removal of incipient precipitation from open trenches should continue to be required.

5.5.2.3.2 Stability of Disposal Cells

> Requirement - Compressible low activity wastes shall be segregated from and disposed of separately from higher activity stable noncompressive wastes. Waste stability may be achieved through the form of the waste, the waste packaging, or disposal facility design. Wastes which must be stablized shall be emplaced in an orderly manner that maintains package integrity during emplacement and disposal. Void spaces between waste packages shall be filled with earth or other material to reduce future subsidence within the disposal cell.

Analysis: A major problem that has been experienced at near-surface disposal facilities has been subsidence of disposal cell covers. Subsidence problems observed at disposal facilities have ranged from minor settling and trench cap cracking to extensive cap collapse and creation of large-scale sinkholes. Subsidence is caused by the existence of void spaces within disposal trenches created by degradation of compressible waste such as paper or other combustible trash and by void spaces within waste packages and between waste packages after disposal. Problems which have been observed in the past at disposal facilities have included:

- o Increased percolation of water into the disposed waste, resulting in potentially increased ground-water migration.
- o Creation of leachate accumulation problems at two disposal facilities located in humid environments.
- o Greatly increased site maintenance costs at some sites which were not expected when the waste was disposed.
- o At an arid western disposal facility, exposure of disposed waste which was then dispersed by wind.
- o A reduction in the ability to predict the long-term impacts of disposed wastes.

The control of subsidence and assurance of site stability is of major importance in the design and operation of a near-surface disposal facility. Any improvements in trench covers (previously addressed) would be directly related to the stability of the underlying waste. The following subsections review a number of alternative facility designs and operating practices which could be used to help control subsidence problems. These designs and practices generally involve ways in which voids can be reduced in disposal cells, and include waste emplacement and segregation techniques, improved trench compaction, use of grouting and controlled density fills, decontainerized disposal, and increased volume reduction. The use of engineered structures such as caissons and concrete walled trenches are also reviewed.

Waste Emplacement and Segregation

In general, waste emplacement at existing disposal facilities is accomplished by either random disposal (including dumping or rolling of containers into the disposal trenches, and placement of heavier items in a random fashion), or by stacked placement of items in some orderly or interlocking fashion. Stacked emplacement is used to either maximize trench space utilization or provide waste-shielded "pockets" in which higher activity containers may be placed. Variations of stacked emplacement have been used, including individual placement of stacked boxes, large right cylinders, and some individual smaller (200 liter) drums in specific spots. In cavities formed by these first-layer containers, higher-activity waste may be placed. Lower level waste may be then randomly stacked or rolled, depending on the mode of off-loading that is most efficient, on top of the first-layer containers. The stacking height is dependent on the types of containers received, the capabilities of the waste handling equipment, and the backfill required to maintain desirable radiation levels. Random waste emplacement with some stacking of large boxes and containers has been assumed for the reference facility described in Appendix E.

Variations in emplacement practices can directly affect the overall performance of the disposal facility. Container placement can affect future cap maintenance requirements as well as affect the potential ground-water migration of radionuclides from the disposal site.

Stacked Emplacement Disposal: One alternative that can be applied is to stack waste packages rather than randomly dump them. An expected advantage from the use of stacked rather than random placement of waste containers is that of enhanced stability of the disposed waste, resulting from a reduction in trench void space and an associated decrease in the potential for subsidence. The integrity of the trench cover would be enhanced and the infiltration of rainwater reduced, thus reducing the potential for ground-water migration. Stacked emplacement is also estimated to improve the trench volume use (disposal efficiency) from about 50% to about 75%, resulting in an effective 50% increase in trench capacity. Additional positive features of stacked emplacement include a reduction of stresses on the integrity of waste containers, more control over high activity containers, and use of other waste (instead of backfill) for shielding. Where trench space is at a premium and a sufficient fraction of the incoming waste packages have uniform configurations for stacking, it may be to the operator's advantage to use this method.

There are also disadvantages to stacking of waste containers. Stacking is a more labor-intensive effort compared with random placement. For containers requiring individual attachment to offloading devices, such as large (170 ft^3) liners or high activity drums, a reasonably conservative increase in manpower (or decrease in waste emplacement rate), of about 20% over random placement requirements is estimated to occur. For smaller containers such as drums, which are often rolled off of transport vehicles into the trenches, the labor requirements may be increased by as much as a factor of 4. This translates into an overall estimated increased labor requirement for waste handlers of about 1.5, when compared with random emplacement of all container types. This not only increases the labor cost per unit volume, but raises worker radiation exposure levels proportionately. Where segregation of high activity waste is not performed, trench radiation levels may at times also prohibit workers from assisting in desired positioning of containers.

Estimated changes in operational costs and impacts were assessed in Section 5.2. The details are summarized in Table 5.10. As shown, extensive use of stacked disposal for all waste packages is estimated to result in increasing operational costs by approximately $22/$m^3$ ($.63/$ft^3$). Overall radiation doses among waste handlers would also rise. These additional exposures could be possibly reduced if stacked disposal was carried out concurrently with a program to segregate wastes having higher surface radiation levels.

<u>Waste Segregation</u>: A second alternative that can be applied involves segregated disposal of high activity stable waste streams from low activity unstable waste streams. This alternative was determined to be preferred in the preceding analyses.

Given the mix of waste that is received for disposal, the trench subsidence problems created by disposal of compressible low activity trash waste with the more stable higher activity wastes, and the increased migration potential for the higher activity wastes with increased percolation through the trench cap, an initial conclusion would be to place all of the waste into a solid, noncompressible form such that long-term stability was assured. Such a requirement would help ensure stability, but would require the same level of treatment for all wastes regardless of hazard potential and the costs for disposal of low activity, short half-lived wastes would be high. A more cost-effective alternative to placing all the waste into a stable form would be to segregate and dispose of the low activity compressible wastes separately from the higher activity wastes. The higher activity wastes would be required to be stabilized to provide greater stability over the long term with decreased potential for migration. With segregation, the most innocuous wastes having limited activity and short half-lives could be disposed of under less stringent requirements since they would present minimal hazard potential from the standpoint of migration. More hazardous and longer half-lived wastes could concurrently be placed in a stable form and disposed in separate trenches. Although this concept is not a radical departure from current techniques, it will require that wastes requiring segregation from other wastes be identified on shipment manifest documents and be properly labelled.

The overall costs and impacts of waste segregation were analyzed in Section 5.2. These additional costs are expected to be relatively minor--i.e., an additional $6.10/m^3$ ($0.17/ft) in design and operational costs. This increase is due to the assumption that additional radiation workers will be needed to carry out segregated disposal operations as well as additional equipment leasing costs.

Decontainerized Disposal: Another alternative that could be applied to achieve greater stability is decontainerized disposal of low activity compressible waste streams. Decontainerized disposal refers to emplacement of wastes without any external shipping container. Presently, wastes such as bulk low activity material (e.g., calcium fluoride wastes) or large pieces of machinery are occasionally disposed of at disposal facilities without external shipping containers. This disposal technique could be extended to other low activity wastes, particularly compressible wastes such as dry trash, and biological wastes.

For decontainerized disposal, waste streams would be disposed of by methods similar to that employed at a sanitary landfill. Waste containers would be emptied onto the ground and periodically covered over with a soil layer using heavy equipment. The waste containers could then be decontaminated and reused. For decontainerized disposal, benefits would be realized both during and after disposal operations. The absence of containers would reduce waste volume, with additional savings occurring through container reconditioning and reuse. However, the major advantage would come from accelerated stabilization of disposal trenches.

A major disadvantage is the accompanying hazard of potential airborne contamination to the waste emplacement labor force and transport of contamination to the offsite environment. The costs and impacts were summarized in Tables 5.12 and 5.13.

Engineered Supports for Disposal Trench Covers

As discussed in the previous sections, waste stacking, waste segregation, and improved compaction all appear to offer improvements in the ability to reduce voids and to control (and possibly eliminate) subsidence. Decontainerized disposal would also reduce trench subsidence, and would be useful for such wastes as low activity bulk solids, contaminated building rubble, or occasional large pieces of machinery, provided that disposal of such wastes was carried out in an operationally safe manner and that disposal cell voids were eliminated during disposal. However, decontainerized disposal appears to be currently a nonviable option for general extension to all wastes.

Other types of alternatives could be used such as engineering supports for trench caps including caisson disposal, walled trench disposal, and grouting and controlled density fill. Caissons and walled trenches are examples of "engineered structures" disposal methods. These disposal concepts are reviewed briefly below.

Caisson Disposal: In addition to reducing exposures to site personnel during waste disposal operations as well as reducing potential impacts to a future inadvertent intruder, caisson disposal may be used as a means of providing support against subsidence and of reducing potential ground-water impacts.

In Appendix F, an example case was considered in which 10% of the waste delivered to the reference disposal facility was disposed using caissons. The additional costs for such disposal were estimated at about \$126 per m^3 of waste disposed in caissons, or about \$6.13/ft^3. Although caissons may be considered as a viable option for disposal of some high activity wastes, it would appear to be very expensive and wasteful of land for extension to all wastes. Much of the waste thus disposed would be of very low activity, and use of this elaborate disposal method for such wastes would not appear to be necessary to ensure protection of public health and safety. Difficulties would also be encountered in disposal of odd-shaped waste such as contaminated machinery or disposal of wastes shipped in large boxes.

Walled Trench Disposal: Concrete walled trenches may also be used as a means--albeit expensive--of providing stability and structural support for improved disposal cell covers. Waste is assumed to be stacked into the walled trenches, and then covered with a concrete cap. In Appendix F, two cases using walled trenches were considered: one case in which walled trenches were used to dispose of approximately 100,000 m^3 of waste and another case in which the concrete walled trenches were used to dispose of 1,000,000 m^3 of waste. The costs calculated for these cases were \$256 and \$161, respectively, per m^3 of disposed waste (\$7.25/ft^3 and \$4.56/ft^3). Occupational exposures from using the walled trenches were also estimated to be high, as well as the land use.

Grouting and Controlled Density Fill: Another method available to reduce subsidence is to fill the void spaces between waste packages with a material that will help support the trench cap. The types of agents available for void space filling include clay (bentonite) slurries, and grout, and a controlled density fill.

The use of grout which would be pumped into the void spaces between containers before backfilling appears most practical for trenches where stacked emplacement has been employed. The waste would need to be emplaced in layers and after each layer is completed, the trench would be grouted. The grout would be pumped through tremie pumps lowered to the base of the trench through void spaces between the waste packages at perhaps 6 to 8 separate locations until the grout level reached the top of the first waste layer. The pumping activities generally would be carried out in stages (grouting each layer in sections). After the first waste layer is grouted, additional waste emplacement could proceed. Each layer of waste would be similarly grouted.

Grouting would necessarily have an affect on the overall operations. The grouting operation for each layer would probably consume at least one to two weeks of time. In order that waste disposal operations not be halted during grouting, it would be necessary to operate with two or more trenches open concurrently. The labor force would also have to be augmented. Additional supplies and equipment required would include grouting equipment (pumps, hose, and tremie pipes), a batch cement mixing plant, and cement. A storage area would also be needed for warehousing the large quantities of cement required. The estimated differential cost for this disposal option is \$60.50/m^3 (\$1.71/ft^3). The resultant benefits include greater trench cap integrity, additional intruder protection, and increased resistance of the waste to leaching.

A second case would involve use of controlled density fill in place of the cement grout. In this example, the controlled density fill is assumed to be a commercially available lower strength concrete. The material is emplaced in layers using tremie pipes in a similar manner as the grout fill. The principal difference is cost because the low density concrete is considerably less expensive than high grade cement. The estimated differential cost for the controlled density fill is $47/m^3$ ($1.33/$ft^3$). Other than cost, the only appreciable difference in the final trench status is the overall strength of the fill. Controlled density fill will adequately support the trench cap but is more capable of being excavated than high grade cement. Therefore, the controlled density fill provides slightly less intruder protection. The benefits to trench cap integrity and leach resistance are assumed to be equivalent to that for grout cement.

An additional disadvantage is that grouting activities are expected to significantly increase occupational exposures at the disposal facility.

5.5.2.4 Waste Form and Packaging

1. Requirement: Certain high activity waste streams shall have structural stability. Structural stability can be provided by the waste form itself, processing the waste to a stable form, or placing the waste into a disposal container or structure that provides stability after disposal. Void spaces within the waste and between the waste and its package shall be reduced to the extent practicable. The waste must maintain its physical dimensions and consistency under the conditions of compressive load, radiation, and biodegradation expected to be encountered in disposal.

Analysis: The long-term stability of the disposal site has been previously discussed in detail and is quite important for several reasons:

1. A stable foundation is needed for the trench cover to preclude slumping, collapse, or other failing of the trench cap;

2. The need for active long-term maintenance is reduced; and

3. The ability to predict long-term performance improves.

NRC considered several alternatives that could be applied to help ensure long-term stability. These included use of walled trenches, caissons, grouting, waste processing (e.g., incineration of compressible wastes), and waste segregation. Based on the analyses presented in Section 5.2, NRC has selected segregation of waste as the preferred alternative since it provides the most cost-effective solution. The short-lived low activity wastes which present low hazard potential over time can continue to be disposed of in separate segregated disposal cells provided they meet the minimum waste form operational safety requirements (See Chapter 6). Other longer-lived and higher activity wastes would be subject to the stability requirements. Given selection of segregation as part of the preferred alternative to provide long-term stability of the higher activity wastes, questions remain as to the method or methods that could be applied to

place the waste into a stable form, the definition of stability, and the concentration of various radionuclides that would require stability over the long term.

With respect to stability, NRC examined a range of alternatives to achieve stability. Each varies with respect to cost and impacts, but each provides a means for assuring long-term stability. Consistent with maintaining maximum flexibility in implementation of the preferred requirements, NRC has not selected any option as a preferred alternative. Rather, NRC would prefer to allow licensees the flexibility of using a range of options to account for individual differences, site-specific disposal facility conditions, preferences and unique cost-benefit considerations for particular wastes which cannot be dealt with in this EIS. These options include:

- The form of the waste, as generated;
- Processing the waste into a stable form;
- Use of a high integrity container; and
- Disposal facility design.

Each is discussed in further detail below, including the incremental costs and impacts of implementation. Chapter 7 on waste classification presents the results of analyses from which radionuclide concentration guidelines for stable wastes are established. The discussion below reviews the definition of stability including the time over which the waste must be assumed to be stable. NRC has concluded that every attempt should be made to eliminate void spaces within waste and between waste and its packaging as a matter of routine operations at any licensed facility generating waste. The increased cost for this seems minimal since it principally involves only closer attention to the packaging of waste. The costs and impacts for compaction of waste is included under waste processing below.

Form of the Waste as Generated

In many cases the form of the waste itself will be adequate to provide long-term stability, provided that the waste is not packaged with other compressible, degradable material. This is expected to be the case with wastes such as sealed radioactive sources, activated structural steel from a nuclear reactor and contaminated concrete where there are essentially no voids within the waste (or waste package). Some increased costs would be required for these wastes to meet a structural stability requirement. The impacts from disposal of such wastes would be reduced, however, due to decreased water infiltration and leaching over the long term that would be characteristic of a stable disposal area. Long-term care requirements would also be reduced.

Processing the Waste into a Stable Form

Processing of the waste into a solid stable form could involve wastes which are in a wet form such as evaporater bottoms, resins, and filter sludges; and

loose compressible wastes such as paper trash. There are several alternatives for treatment of each which generally fall into one of the following two categories:

- o Solidification using a media such as concrete or synthetic polymer;
- o Incineration followed by solidification.

Solidification: There are a number of solidification processes that are currently in use or are being actively marketed. These include cement, urea formaldehyde, and other synthetic polymers such as vinyl ester styrene, epoxy, and bitumen.

Both cement and urea-formaldhyde solidification systems are currently used by light water reactors. Bitumen and vinyl ester styrene are being actively marketed. Other synthetic polymer systems are being evaluated in laboratory and pilot scale studies. Because of the number of potential individual solidification systems that may be marketed and thus the large number of possible variations that could be applied, NRC grouped the systems into three broad scenarios to provide a manageable number for evaluation while still covering the range in waste form characteristics that could be expected. Solidification scenario A assumes a continuation of existing practices and assumes that 50 percent of a particular waste stream is solidified using urea-formaldehyde systems and the other 50 percent using cement systems. Solidification scenario B assumes improved waste performance characteristics over the previous case. It assumes that 50 percent of the waste stream is solidified using cement systems and the other 50 percent using synthetic polymer systems. Solidification scenario C assumes further improved waste performance characteristics achievable with the currently available technology. In assumes that all the waste is solidified using synthetic polymer systems.

The costs and impacts of application of these three solidification types to light water reactor evaporator bottoms, resins and filter sludge waste were assessed in Section 5.2.

Incineration: The incineration of waste is not usually specifically directed at achieving a stable waste form. But, in addition to increasingly specific activity through reducing the volume of waste, incineration of certain wastes does lead to an improved and stable waste form. This is particularly evident in the incineration of biowastes, organic and other liquids, and trash. The resulting ash and solids remaining after incineration could then be solidified or placed in a high integrity container for disposal. Several waste streams were identified in Section 5.2 which could be treated by incineration.

Use of High Integrity Containers

NRC also considered the use of a high integrity container in lieu of solidification. Presently, there is less available information about the design characteristics of specific containers. Several containers are under evaluation and there do not appear to be any insurmountable technical problems involved in their use. At least one high integrity container is being marketed today. To

maintain maximum flexibility in meeting the structural stability requirement, NRC believes the high integrity container should be maintained as an option. In addition to providing stability, such a container can also provide equivalent or better performance with respect to containment of the waste after disposal. In some cases, such containers should be applied (e.g., in the disposal of large quantities of short-lived very mobile nuclides) to provide initial containment of waste for decay. Their use in this case should be evaluated on a case-by-case basis.

Disposal Facility Design

In this option, disposal facility design is utilized to provide stability in the same way as the high integrity container does. Several design options including use of caissons, walled trenches and grouted backfill were considered and evaluated. The reader is referred to Section 5.2 and Appendix F for information on these design modifications.

Definition of Stability

As concluded, long-term stability is important with respect to reducing potential impacts to an intruder, reducing potential for migration and reducing the need for long-term maintenance. A specific definition of stability is needed in measurable terms. NRC staff believes that disposal cell subsidence of about 1 to 1.5 feet can be tolerated without significant long-term effects. When considering individual disposal cells, a 1 to 1.5 foot substance would translate into about 5% of the assurred reference facility 8 m disposal depth. NRC staff also considered the weight that a package would receive if emplaced on the bottom of a trench covered by other emplaced waste packages and overburden. Assuming that the other packages were concrete with a density of 120 lbs/ft^3, and also considering additional overburden, a conservative value of 50 psi is derived.

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Chapter 6

OPERATIONAL SAFETY

6.1 INTRODUCTION

The function of a near-surface radioactive waste disposal facility is to contain disposed radionuclides over the long term, and potential long-term impacts are of major concern in licensing an LLW disposal facility and in determining disposal requirements for specific types and forms of waste. However, protection of public health and safety during the operational phase of the disposal facility is also of concern when licensing the facility and regulating its operation. For completeness in this environmental impact statement, therefore, potential exposures to the public due to offsite radiological releases during site operations are considered. Potential public exposures during site operations can be classed as either "normal" or "accidental," and are discussed below including consideration of potential occupational exposures. A performance objective for operational safety and technical requirements is developed. Also considered is the processing of waste at a regional processing center which for purposes of analysis in this EIS is assumed to be located at the disposal facility.

6.2 POTENTIAL PUBLIC IMPACTS DURING OPERATIONS AT THE DISPOSAL FACILITY

Normal operational releases at an LLW disposal facility can potentially occur through two principal routes: small spills and releases due to normal waste handling and disposal operations; and larger spills and releases due to operational accidents such as a dropped container or a fire. Releases have also occurred at some existing sites as a result of water management programs involving evaporation and treatment of trench leachate. Since the need for such active maintenance programs should be eliminated in the future, releases from such programs were not analyzed.

6.2.1 Potential Public Impacts From Small Spills During Normal Operations

Small leaks and spills from waste containers during normal operations can potentially be released to the air or contaminate the ground surface which can then be carried off of the site by the actions of wind or precipitation run-off. In addition to potential public exposures, surface runoff from contaminated ground surfaces can interfere with the facility environmental monitoring program. For example, at the disposal facility (now closed) located near Maxey Flats, Kentucky, small quantities of radioactivity have been found offsite. Much of this radioactivity is believed to be due to runoff from surface contamination. The presence of this runoff contamination has increased the difficulty of determining other potential modes of offsite release, such as ground-water migration.

It is believed that the contamination of the ground surfaces at the Maxey Flats facility was caused by earlier cases of inadequate waste handling and site maintenance procedures. It is known that waste packages delivered to the

facility frequently failed to properly contain the waste within the packages and/or ruptured during emplacement operations. In addition, bulk liquid shipments were often delivered to the facility for solidification prior to disposal. It is believed that insufficient care was taken in handling the bulk liquid delivered.

At currently operating facilities, however, considerably more attention is being paid to minimizing potential surface contamination. For example, disposal facilities currently in operation have procedures to survey facility areas on a routine basis, as well as when possible contamination is suspected. Allowable contamination limits have been established at operating facilities for buildings, grounds, and equipment. (The operational contamination limits for one facility are provided in Appendix E.) These contamination limits may then be inspected against for compliance. In addition, monitoring programs at all operating facilities have been improved and routinely sample for onsite surface contamination.

For example, Table 6.1 is a summary of analyses for soil samples collected in 1978 at the four corners of the commercial disposal facility operated by U.S. Ecology, Inc., and located in the center of the Hanford Reservation near Richland, Washington. The samples were collected and analyzed by the Washington State Department of Social and Health Services (Ref. 1). The state environmental monitoring sample collection is in addition to the licensee's environmental monitoring program.

The isotopes sampled include those from fallout as well as naturally occurring radionuclides. Also shown is a range of soil samples collected in various parts of the Hanford Reservation by DOE (Ref. 2). Within the last few years, both Washington State and U.S. Ecology have expanded their monitoring programs.

Also of interest are the environmental monitoring results for the Barnwell, South Carolina disposal facility operated by Chem-Nuclear Systems, Inc. (CNSI). This facility currently accepts approximately 50% of the low-level waste in the country and approximately a year ago accepted about 70%. Given the large volume of waste received at the facility, most of the operational impacts associated with low-level waste disposal would be expected to be associated with this facility.

For example, Table 6.2, obtained from Reference 3, is a typical set of analytical results of soil samples collected both onsite and offsite. As can be seen, the concentrations of Co-60 and Cs-137 measured onsite are within the range of measurements of samples collected offsite.

Thus, there appear to be no significant releases of radionuclides from the operating sites from surface contamination. This is principally due to increased attention by facility operators to minimizing facility contamination. The practice of delivering bulk liquids to disposal facilities for solidification has been discontinued. All disposal facilities have license conditions that

Table 6.1 Soil Samples Collected at Boundaries of U.S. Ecology Disposal Facility Located in Center of Hanford Reservation

(pCi/gm)

Isotopes	NE	NW	SE	SW	DOE* Min	DOE* Max
Ce-144	.27	<.14	<.15	.24	**	.62
Cs-137	.62	.08	.24	1.2	.06	1.9
K-40	16	14	11	15	12	18
Ra-226	.63	.45	.57	.64	.46	.91
Ru-103	.06	<.05	<.05	<.05	-	-
Ru-106	.33	<.28	<.28	.37	.40	.98
Th-232	.45	.60	.80	.69	-	-
Th-238	.63	.59	.60	.62	-	-
U-238	.86	.43	.87	<.67	.07†	.66†
Gross Beta	17	17	16	17	-	-

*From ERDA-1538 (Ref. 2).

**Less than the analytical limit, which is 0.1 pCi/gm.

†Total uranium.

Table 6.2 Soil Samples from Barnwell, South Carolina Disposal Facility

Date	Location	Analysis	Result pCi/gm Dry
092879	C-2	Gamma Scan	^{137}CS <6.2E-01 ^{60}CO <5.4E-01
092879	C-6	"	^{137}CS <1.5E+00 ^{60}CO <1.1E-01
092779	*CN-14	"	^{137}CS <2.0E+00 ^{60}CO <1.2E-01
092879	1-4	"	^{137}CS <1.6E+00 ^{60}CO <3.3E-01
092879	J-4	"	^{137}CS <2.3E+00 ^{60}CO <6.6E-01
092879	H-3	"	^{137}CS <1.2E+00 ^{60}CO <6.5E-01
092879	K-5	"	^{137}CS <1.9E+00 ^{60}CO <8.3E-01
092879	1-3	"	^{137}CS <1.0E+00 ^{60}CO <4.7E-01
092779	*CN-21	"	^{137}CS <1.6E+00 ^{60}CO <5.6E-01
092779	*CN-07	"	^{137}CS <1.0E+00 ^{60}CO <1.2E-01

*Onsite samples, all other samples are offsite.

restrict wastes delivered to the disposal facilities to dry solids, and include restrictions on the amount of free standing liquids allowed in the waste. Compliance with Department of Transportation Regulations is also required. Improvements in waste form and packaging required to protect the inadvertent intruder, improve stability and reduce potential for migration will also reduce the potential for surface contamination and subsequent release to offsite areas.

Other sources of normal operational releases may be from treatment of rain water that may collect in disposal facility trenches. As discussed in Appendix E, disposal trenches are typically sloped toward one side and one end so that precipitating water will flow toward a sump where it can be collected and treated by such methods as solar evaporation. Waste emplacement takes place at the high end of the trench, so that water will flow away from exposed waste packages. The potential for water to contact waste packages is reduced by restricting the amount of waste which may be emplaced before covering with soil. A further reduction in contact time can also be obtained by emplacement of a sandy base for the waste packages and by using a sandy backfill material.

Since releases during normal operations due to spills have not been significant and are not expected to be significant in the future, NRC conducted no detailed analysis of these potential pathways of release and potential public impacts. The impacts from a potential accident (e.g., dropped container or fire) at the site are larger. These two pathways are analyzed in the next section.

Finally, additional information regarding the potential for releases of radionuclides can be obtained through minor and relatively inexpensive improvements in disposal facility environmental monitoring programs. For example, as discussed in Appendix F, a network of 10 continuous air samplers installed at the perimeter of the reference disposal facility is estimated to cost approximately $9,000 (plus installation charges and other indirect costs) and $25,000 per year for sample analysis. This would be estimated to add an additional $\$0.05/ft^3$ to the operating costs for the reference disposal facility. These samplers can be very useful in locating and correcting minor sources of atmospheric releases--further reducing potential operational releases.

In summary, potential releases from airborne or waterborne carry-off from contaminated surfaces are expected to be small. They can be further reduced to negligible levels by:

1. Continuing to maintain strict housekeeping procedures to maintain potential contamination of equipment and surfaces to levels as low as reasonably achievable.

2. Improvements in waste form and packaging.

3. Enforcement of existing transportation regulations.

4. Minor improvements in environmental monitoring.

6.2.2 Potential Public Impacts From Operational Accidents

During the operation of an LLW disposal facility, potential releases of radioactive material to the environment can also occur through onsite accidents. Such potential accidents could include: (1) the sudden and complete rupturing of a waste container on the site and subsequent release of a portion of the contained radioactivity or (2) a fire igniting on the site and consuming a number of waste packages, with subsequent release of a portion of the contained radioactivity in the waste.

The scenario involving the rupture of an individual waste container is differentiated from the earlier discussion regarding the potential for minor leaks and spills on the site. In this case, it can be postulated that a waste container is very badly ruptured, such as from dropping the waste container from some height, and a more significant quantity (compared with the earlier case) of radionuclides are available for transport by the air. The offsite airborne impacts from this potential accident would be acute (that is, impacts would occur over a short time period). The accident would also contaminate a portion of the ground surface. However, as discussed in Section 6.2.1, all disposal facilities currently have and will continue to have requirements in the license and written procedures for rapidly cleaning up the contaminated surface. Thus, potential offsite transport from rainwater washing away the contaminated ground surface would be minimal.

A fire potentially arising on the LLW disposal facility site can also result in acute (short-term) airborne releases, as well as contamination of some of the ground surface. Again, the impact of this accident would be principally from the offsite airborne releases. The fire could potentially occur on a transport vehicle or in a group of waste packages stored onsite or placed in the trench but not yet covered by earth).

The types and magnitudes of accidents potentially occurring at an LLW disposal facility are generally similar to those potentially occurring during transportation of LLW to the disposal site. Impacts from such potential accidents have been addressed by an environmental statement on the transportation of radioactive material by air and other modes (Ref. 4). In addition, NRC has recently published (in July 1980) a contractor's report providing an analysis of potential radioactive material transportation impacts in urban environments (Ref. 5).

Consequences from potential accidents are site specific and would already fall under existing NRC regulations in 10 CFR Part 20. Such consequences would be addressed as part of normal licensing reviews. However, it is useful to consider the potential consequences of operational accidents in this environmental impact statement to determine if such impacts can be potentially reduced on a generic basis. The principal variable which may be considered would be potential improvements in waste forms. These potential improvements in waste form and reduction in potential offsite impacts are considered below.

6.2.2.1 Analysis of Accidental Fire

The methodology for estimating potential impacts from the operational fire accident is described in Appendix G and Reference 6. For this scenario, a fire is assumed to break out in a disposal trench and involve about 50 m^3 of waste. This volume is estimated from an assumed volume of 200 m^3 of waste received daily at the disposal facility, which corresponds to about one million m^3 of waste over 20 years. Two disposal cells are assumed to be simultaneously in operation, and half of the waste in one of the disposal cells is subjected to the accidental fire scenario. (The other half is assumed to be covered with back fill.) The fire is assumed to last for two hours, which is conservative considering that a potential fire can easily be extinguished through covering with soil, and entrained radionuclides are all assumed to travel in one direction and result in exposures to an individual located at the facility boundary in the centerline of the contaminated plume.

In this environmental impact statement, no credit is given for reduction in airborne releases due to waste packaging--that is, metal waste containers such as liners or 55-gallon drums would tend to retard the spread of fires from one waste container to another. However, the propensity of each waste stream to burn is considered and incorporated into the calculations. Each of the 36 waste streams for each waste spectrum are rated according to their inability to burn and assigned a value for the flammability index (I4) as follows: (See Appendices D and G)

Flammability Index (I4)	Description
0	nonflammable
1	low-flammability (mixture of material with indices of 0 and 2)
2	burns if heat is applied but does not otherwise support burning
3	flammable (supports burning)

In the analysis, the use of the indices is determined by the operating practices at the disposal facility. If waste segregation is not practiced at the disposal facility (i.e., all waste streams are disposed randomly and mixed together), then the fraction of radioactivity released from each waste stream is given by the relationship $0.1 \times 20.^{(I4-3)}$ By this, flammable waste streams (I4=3), are assumed to release the fraction 0.1 of the radioactivity within the waste

packages involved in the fire. Other waste streams having flammability indices equal to 0, 1, or 2 would not ordinarily burn by themselves. However, because these streams are assumed to be involved in the fire, a fractional release is assumed for each stream which is a function of the value of I4 for the stream. An exception is activated metals, which are always assumed to have a fractional release equal to zero.

If waste segregation is practiced (i.e., combustible material is separated and disposed in a segregated manner from other waste streams), then only the combustible material would be involved in the fire. In this case, the fractional release from the flammable waste streams would still be equal to 0.1 but the fractional releases from the other waste streams (I4 = 0, 1, or 2) would be equal to zero.

The impacts from a potential accidental fire are shown in Table 6.3. Table 6.3 summarizes the impacts calculated from each of the 36 waste streams, assuming 50 m^3 of each waste stream is involved in a fire. This is done to compare the relative impacts of each waste stream from one spectrum to the next. Also shown in Table 6.3 is a volume-weighted average of impacts from all waste streams. This is numerically equivalent to the assumption that of the 50 m^3 of waste assumed to be involved in the fire, the amount of each waste stream involved in the fire is proportional to the fractional volume of each waste stream delivered to the disposal facility. It is used as a "hazard index" for fires at the disposal facility.

As shown in Table 6.3, the practice of waste segregation would tend to reduce the overall potential hazard from an accidental fire. As can be seen, the volume weighted impacts for Case 1 are about 5.5 mrem to the whole body and 32 mrem to the lung. However, in Case 4A, in which waste segregation is practiced at the disposal facility, volume-weighted whole body and lung exposures are reduced to 3.9 and 18.7 mrem, respectively. In Case 1, as in all cases, the releases from activated metals (P-NCTRASH, B-NCTRASH, F-NCTRASH, LNFRCOMP, and N-HIGHACT) are taken to be essentially zero. In addition, since neither the N-SOURCES or the L-DECONRS streams are classified as being suitable for near-surface disposal, the impact from these two streams is also zero.

Waste spectrum 1 was assumed for both Cases 1 and 4A. However, waste spectrum 2 was assumed for Case 7A while waste spectrum 3 was assumed for Case 8. In waste spectrum 2, prior to delivery to the disposal facility, compressible waste streams such as P-COTRASH or I-COTRASH are assumed to be processed by compaction at the waste generator while the I+COTRASH, N+SSTRASH, and N+COTRASH are assumed to be processed by an improved compactor/shredder at a regional processing center. As shown in Case 7A, therefore, estimated impacts from the accidental fire are increased (due to increased radionuclide concentrations) for the waste streams subject to processing. As a result, overall volume-weighted impacts are increased relative to the preceeding two cases.

This may be a considerable overestimate, however. Although compaction increases the concentration of radionuclides in the packaged wastes, it also produces a waste form which is apt to burn at a slower rate. This would be expected to reduce the fraction of radionuclides released into air.

Table 6.3 Stream-by-Stream Impacts [illegible]

Stream	Case 1 (WS1)*		Case 4A (WS1)		Case 7A (WS2)		Case 8 (WS3)	
	Body	Lung	Body	Lung	Body	Lung	Body	Lung
P-IXRESIN	5.712E-01	3.058E+00	0.	0.	0.	0.	0.	0.
P-CONCLIQ	6.135E-02	5.102E-01	0.	0.	0.	0.	0.	0.
P-FSLUDGE	8.200E-01	7.780E+00	0.	0.	0.	0.	0.	0.
P-FCARTRG	2.829E+01	2.860E+02	0.	0.	0.	0.	0.	0.
B-IXRESIN	4.451E+01	3.968E+02	0.	0.	0.	0.	0.	0.
B-CONCLIQ	1.998E-01	1.617E+00	0.	0.	0.	0.	0.	0.
B-FSLUDGE	3.139E+00	3.085E+01	0.	0.	0.	0.	0.	0.
P-COTRASH	7.042E+00	6.561E+01	7.042E+00	6.561+01	1.408E+01	1.312E+02	0.	0.
P-NCTRASH	0.	0.	0.	0.	0.	0.	0.	0.
B-COTRASH	5.507E+00	5.228E+01	5.507E+00	5.228E+01	1.101E+01	1.046E+02	0.	0.
B-NCTRASH	0.	0.	0.	0.	0.	0.	0.	0.
F-COTRASH	1.810E-03	3.238E+00	1.810E-03	3.238E+00	2.715E-03	4.857E+00	0.	0.
F-NCTRASH	0.	0.	0.	0.	0.	0.	0.	0.
I-COTRASH	1.175E+01	5.086E+01	1.175E+01	5.086E+01	2.349E+01	1.017E+02	0.	0.
I+COTRASH	1.175E+01	5.086E+01	1.175E+01	5.086E+01	4.698E+01	2.034E+02	0.	0.
N-SSTRASH	1.810E-04	3.238E-01	0.	0.	0.	0.	0.	0.
N+SSTRASH	1.810E-04	3.238E-01	0.	0.	0.	0.	0.	0.
N-LOTRASH	3.670E+00	1.589E+01	3.670E+00	1.589E+01	7.340E+00	3.179E+01	0.	0.
N+LOTRASH	3.670E+00	1.589E+01	3.670E+00	1.589E+01	1.468E+01	6.357E+01	0.	0.
F-PROCESS	4.396E-06	7.863E-03	0.	0.	0.	0.	0.	0.
U-PROCESS	1.489E-05	2.725E-02	0.	0.	0.	0.	0.	0.
I-LQSCNVL	6.399E+00	5.285E-02	6.399E+00	5.285E-02	8.191E+00	6.765E-02	0.	0.
I+LQSCNVL	6.399E+00	5.285E-02	6.399E+00	5.285E-02	6.399E+00	5.285E-02	6.399E+00	5.285E-02
I-ABSLIQD	1.127E+01	5.047E+01	1.127E+01	5.047E+01	2.050E+01	9.177E+01	0.	0.
I+ABSLIQD	1.127E+01	5.047E+01	1.127E+01	5.047E+01	1.127E+01	5.047E+01	1.127E+01	5.047E+01
I-BIOWAST	1.024E+00	5.237E-01	0.	0.	0.	0.	0.	0.
I+BIOWAST	1.024E+00	5.237E-01	0.	0.	0.	0.	0.	0.
N-SSWASTE	8.800E-06	1.574E-02	0.	0.	0.	0.	0.	0.
N-LOWASTE	6.519E+00	7.200E+00	6.519E+00	7.200E+00	6.519E+00	7.200E+00	6.519E+00	7.200E+00
L-NFRCOMP	0.	0.	0.	0.	0.	0.	0.	0.
L-DECONRS	0.	0.	0.	0.	0.	0.	0.	0.
N-ISOPROD	5.480E+01	1.937E+00	0.	0.	0.	0.	0.	0.
N-HIGHACT	0.	0.	0.	0.	0.	0.	0.	0.
N-TRITIUM	5.338E+02	5.338E+02	5.338E+02	5.338E+02	5.338E+02	5.338E+02	5.338E+02	5.338E+02
N-SOURCES	0.	0.	0.	0.	0.	0.	0.	0.
N-TARGETS	2.303E-03	2.303E-03	0.	0.	0.	0.	0.	0.
Volume-Weighted Impacts	5.470E+0	3.208E+1	3.875E+0	1.868E+1	5.894E+0	2.841E+1	2.387E+0	2.219E+0

*Waste spectrum 1

In waste spectrum 3 (Case 8), most of the compressible waste streams are incinerated and the ashes solidified. As a result, these waste streams are convented into a nonflammable form. Volume-weighted impacts to body and bone are reduced to 2.4 mrem and 2.2 mrem, respectively.

6.2.2.2 Analysis of Dropped Container

The methodology for estimating potential impacts from the dropped-container operational accident scenario is described in Appendix G and Reference 6. For this scenario, a waste container is assumed to be dropped from a significant height so that the waste container breaks open and a portion of the radioactive contents of the package is released into the air where it is transported offsite and leads to subsequent human exposure. Potential releases are modeled as a "puff", and resulting human exposure would occur over a short time period. The potential exposures from this scenario are a strong function of the form of the waste delivered to the disposal facility--i.e., improved, less dispersible waste forms lead to lower potential releases and reduced potential human exposures.

In a similar manner to Section 6.2.2.1, impacts are first calculated for an equal volume of each of the 34 waste streams delivered to the disposal facility. (The N-SOURCES and L-DECONRS streams are excluded.) This allows comparison of the relative impacts of each waste stream from one spectrum to the next. Then, a volume-weighted average of impacts from all waste streams delivered to the disposal facility is calculated. This can be again envisioned as a "hazard index" for a dropped container accident at the diposal facility. Calculation of impacts is complicated by the fact that wastes are delivered to the disposal facility in a variety of container sizes--from 55-gallon drums to large wooden boxes to large carbon-steel liners. To calculate impacts, some simplifying assumptions must be made. This is acceptable with the understanding that the main purpose of this analysis is to compare the relative hazard of different waste forms.

The container size, therefore, is assumed to be 4.8 m^3 (170 ft^3), which is the size of a typical resin liner. This size is reasonable for many high activity waste streams (such as resins and filter media) but is a considerable overestimate for wastes packaged in 55-gallon drums (.21 m^3) but much less of an overestimate for wastes packaged in large wooden boxes (e.g., a 4' x 4' x 8' box has a volume of 128 ft^3, or 3.63 m^3).

Unsolidified waste streams such as trash are assumed to have a fractional release equal to 0.001. This value is believed to be very conservative and is the same as the dispersible fraction applied to dispersion of powdered PuO_2 from waste packages involved in transportation accidents (Ref. 6). However, this fractional release is multiplied by a factor which accounts for the relative dispersibility of improved waste forms. This factor is determined by the leachability index$^{(I6)}$ and is given as $10^{(1-I6)}$. Values calculated for this factor as a function of I6 are given as follows:

I6	Waste Form	$10^{(1-I6)}$
1	no solidification	1
2	solidification in half cement and half urea-formaldehyde	0.1
3	solidification in half cement and half synthetic polymer	0.01
4	solidification in 100% synthetic polymer	0.001

The property values for this comparative dispersibility are based upon consideration of comparative mechanical strengths (compressive, unnotched Izod impact, and fragmentation tests) measured for the waste forms (Ref. 7). Again, the dispersion from activated metals is assumed to be negligible.

Upon release from the waste packages, the entrained radioactive particles are conservatively assumed to travel in one direction and result in exposures to an individual located at the facility boundary in the centerline of the contaminated plume.

The calculated impacts are given in Table 6.4 for waste spectra 1 through 3. The improvement in relative impacts is significant from one spectrum to the next. Comparing Case 1 (waste spectrum 1) with Case 7A (waste spectrum 2), relative impacts associated with LWR process wastes (P-IXRESIN to B-FSLUDGE streams) are considerably reduced. A further reduction in relative impacts is seen for Case 8 (waste spectrum 3).

For some streams, such as P-COTRASH and N-LOTRASH, relative impacts are raised for waste spectrum 2 but drop to lower levels (than waste spectrum 1) for waste spectrum 3. This is because in waste spectrum 2, such waste streams are compacted and the resulting radionuclide concentrations are raised. However in waste spectrum 3, these waste streams are incinerated and solidified in a synthetic polymer. Although radionuclide concentrations are raised, the improved solidified waste form results in lowered releases and lowered relative impacts. (Compacting the waste (as in waste Spectrum 2) would also be expected to result in a form which is less readily dispersible. This consideration, however, was not included in the calculations.)

As can be seen, the total volume weighted impacts are 1.8 mrem whole body and 16.8 to the lung for Case 1. However, these drop for Case 7A by respective factors of 12 and 17 to .15 mrem whole body and 1 mrem to the lung. For Case 8, volume weighted impacts to whole body and lung are further reduced (by additional factors of 2.5 and 3) to .058 mrem and .033 mrem, respectively. Clearly, a large improvement in relative hazard is shown for waste spectrum 2 (where all sludges and filter media are solidified) over waste spectrum 1 (where sludges

Table 6.4 Stream-by-Stream Impacts to Whole Body and Lung from Dropped-Container Accident (mrem)

	Case 1 (WS1)*		Case 7A (WS2)		Case 8 (WS3)	
Stream	Body	Lung	Body	Lung	Body	Lung
P-IXRESIN	2.075E-01	1.110E+00	1.257E-03	6.730E-03	1.037E-04	5.552E-04
P-CONCLIQ	4.456E-02	3.706E-01	2.056E-02	1.710E-01	1.871E-03	1.556E-02
P-FSLUDGE	5.956E+00	5.651E+01	3.610E-02	3.425E-01	2.978E-03	2.826E-02
P-FCARTRG	1.027E+01	1.039E+02	1.027E-01	1.039E+00	1.027E-02	1.039E-01
B-IXRESIN	1.617E+01	1.441E+02	9.798E-02	8.734E-01	8.083E-03	7.206E-02
B-CONCLIQ	1.452E-01	1.175E+00	3.126E-02	2.530E-01	2.439E-03	1.974E-02
B-FSLUDGE	2.280E+01	2.241E+02	1.382E-01	1.358E+00	1.140E-02	1.120E-01
P-COTRASH	1.279E-01	1.191E+00	2.557E-01	2.383E+00	5.115E-03	4.766E-02
P-NCTRASH	0.	0.	0.	0.	0.	0.
B-COTRASH	1.000E-01	9.494E-01	2.000E-01	1.899E+00	4.000E-03	3.798E-02
B-NCTRASH	0.	0.	0.	0.	0.	0.
F-COTRASH	3.287E-05	5.879E-02	4.930E-05	8.819E-02	6.574E-07	1.176E-03
F-NCTRASH	0.	0.	0.	0.	0.	0.
I-COTRASH	2.133E-01	9.235E-01	4.266E-01	1.847E+00	2.129E-03	9.231E-03
I+COTRASH	2.133E-01	9.235E-01	8.531E-01	3.694E+00	8.517E-03	3.692E-02
N-SSTRASH	6.574E-05	1.176E-01	9.860E-05	1.764E-01	3.287E-07	5.879E-04
N+SSTRASH	6.574E-05	1.176E-01	1.972E-04	3.528E-01	1.315E-06	2.352E-03
N-LOTRASH	6.664E-02	2.886E-01	1.333E-01	5.772E-01	6.652E-04	2.885E-03
N+LOTRASH	6.664E-02	2.886E-01	2.666E-01	1.154E+00	2.661E-03	1.154E-02
F-PROCESS	6.386E-04	1.142E+00	6.386E-04	1.142E+00	6.386E-04	1.142E+00
U-PROCESS	2.163E-03	3.958E+00	2.163E-03	3.958E+00	2.163E-03	3.958E+00
I-LQSCNVL	1.162E-01	9.597E-04	1.487E-01	1.228E-03	7.878E-04	6.460E-06
I+LQSCNVL	1.162E-01	9.597E-04	1.162E-01	9.597E-04	1.162E-01	9.597E-04
I-ABSLIQD	2.047E-01	9.165E-01	3.722E-03	1.666E-02	3.071E-04	1.375E-03
I+ABSLIQD	2.047E-01	9.165E-01	2.047E-01	9.165E-01	2.047E-01	9.165E-01
I-BIOWAST	3.720E-01	1.902E-01	3.720E-01	1.902E-01	5.351E-03	2.733E-03
I+BIOWAST	3.720E-01	1.902E-01	3.720E-01	1.902E-01	3.720E-01	1.902E-01
N-SSWASTE	1.278E-03	2.286E+00	1.278E-03	2.286E+00	1.278E-03	2.286E+00
N-LOWASTE	1.184E-01	1.307E-01	1.184E-01	1.307E-01	1.184E-01	1.307E-01
L-NFRCOMP	0.	0.	0.	0.	0.	0.
L-DECONRS	0.	0.	0.	0.	0.	0.
N-ISOPROD	3.980E+00	1.407E-01	2.587E-01	9.146E-03	2.587E-01	9.146E-03
N-HIGHACT	0.	0.	0.	0.	0.	0
N-TRITIUM	9.694E+00	9.694E+00	9.694E+00	9.694E+00	9.694E+00	9.694E+00
N-SOURCES	0.	0.	0.	0.	0.	0.
N-TARGETS	3.345E-01	3.345E-01	3.345E-01	3.345E-01	3.345E-01	3.345E-01
Volume-Weighted Impacts	1.783E+0	1.676E+1	1.460E-1	9.680E-1	5.791E-2	3.288E-1

*Waste spectrum 1

and filter media are assumed to be dewatered). A much smaller improvement is seen for waste spectrum 3 (incorporating further improved waste forms) relative to waste spectrum 2.

High integrity containers (HICs) have not been specifically analyzed in this environmental impact statement for their behavior under accident conditions. However, to perform their function, HICs would be expected to be constructed in a more robust manner than ordinary waste containers such as carbon steel liners. Therefore, the potential hazard from operational accidents for wastes (such as dewatered resins) packaged in HICs would also be expected to be reduced.

6.2.2.3 Summary

The preceeding analysis examined the relative hazard from operational accidents at a disposal facility involving either (1) a potential fire in a disposal cell or (2) a potential dropped container which breaks open and disperses a portion of its contents into the air. In general, it was determined that actions that have previously been determined to reduce potential long-term impacts from ground water migration or inadvertent human intrusion also reduced short-term impacts from potential accidents. For example, segregation of compressible, easily degradable waste streams from stable waste streams reduces intruder impacts, ground-water impacts, and long-term care costs. Since most of these compressible waste forms are also flammable, waste segregation is also seen to reduce potential impacts from an accidental operational fire.

As another example, use of improved waste forms or high integrity containers were also shown to reduce intruder impacts, ground-water impacts, and long-term costs. Improved waste forms and high integrity containers would also act to reduce impacts from an accidentally dropped container.

6.3 OCCUPATIONAL EXPOSURES

Occupational exposures would occur through normal operations in the surveying of incoming packages and transport vehicles and in unloading and waste emplacement operations. Limits for occupational exposures have already been established in the existing regulation 10 CFR Part 20. Past history at the existing burial sites has shown that occupational exposures have been within the existing guidance for such exposures in 10 CFR Part 20. Licensee programs to minimize exposures are routinely analyzed as part of normal licensing actions at existing disposal facilities. The occupational exposures received based on analysis of the base case facility and alternatives considered have been previously summarized in Chapters 4 and 5.

6.4 PERFORMANCE OBJECTIVE

The NRC regulation, 10 CFR 20, already provides standards for control of and limitations for release of radioactive materials to the environment from operations of NRC-licensed facilities, as well as limitations on the allowable radiation doses to radiation workers and the public.

Limits in Part 20 for potential exposures to individuals in unrestricted areas are 0.5 rem (500 mrem) per year to the whole body of individuals in unrestricted areas. The regulation also provides in Appendix B, Table II, a table of maximum permissible concentrations (MPCs) of radionuclides in air or water from releases to unrestricted areas. These MPC values are based upon a maximum potential whole body dose commitment to an individual of 500 mrem/year. Limits for other organs include 500 mrem/year to blood forming organs, 3000 mrem/year to bone surfaces, and 1500 mrem/yr to other organs except thyroid. For thyroid, a limit of 3000 mrem/yr was used except for exposures from radioiodine, for which a limit of 1500 mrem/yr to a childs thyroid was used. Also contained in the regulation is a requirement that potential exposures to individuals and populations should be maintained to levels as low as reasonably achievable (ALARA). In practice releases to unrestricted areas and potential exposures from NRC and Agreement State licenses are maintained well below the 500 mrem/year limit.

For normal operations of a disposal facility, therefore, standards in 10 CFR Part 20 already exist and are already being applied. Facility compliance with this standard is already routinely assessed as part of normal licensing procedures.

6.5 DEVELOPMENT OF TECHNICAL CRITERIA

As discussed in Section 6.4, the proposed performance objective for potential offsite and occupational impacts during operation of the disposal facility is to continue to apply the radiological health and safety requirements in the existing regulation 10 CFR Part 20. In applying this performance objective to existing and future disposal facilities, one alternative approach would be to set out in 10 CFR Part 61 a number of prescriptive requirements for safe operation of disposal facilities. However, NRC staff believes that this alternative can lead to a number of practical difficulties. For example, measures which could be used to minimize potential operational releases will be influenced by site-specific conditions at the particular disposal facility site considered. More importantly, detailed prescriptive requirements would inhibit incorporation of potential improvements in site safety.

6.5.1 Licensing Review of Applicants Operational Health and Safety Program

Based upon past NRC licensing staff experience, a licensee's operational procedures and programs for compliance with the operational safety performance objective would be evaluated on a case-by-case basis. Each applicant for a license would be required to establish and implement such programs and would be required to describe such programs in detail in his license application. The acceptability of each licensee's operational procedures and programs would be evaluated as a part of the licensing process on a case-by-case basis considering the nature and scope of the operations to be conducted at the disposal facility. Following this evaluation and as a part of the licensing of a disposal facility, the licensee would be required to formally compile the final procedures into a site operations manual that would be utilized by the licensee for operation of the facility. Any subsequent and significant changes to the manual would be subject to NRC review.

The nature, details and costs of representative procedures and programs have been included in Appendix E as a part of the description of a typical disposal facility. The costs and impacts of these programs have been included in the analyses of the base case typical facility. Some of the procedures and programs which would be analyzed as part of a specific application would include the following:

- The applicant's radiation safety program for control and monitoring of radioactive effluents and occupational radiation exposure to demonstrate compliance with the Part 20 requirements and to control contamination of disposal facility personnel, vehicles, equipment, buildings, and the grounds. Both routine operations and accidents would be addressed, and the program description would include procedures, instrumentation, facilities, and equipment.

- The applicant's quality assurance program for siting, design, construction, and operation of the disposal facility, and the receipt, handling, and emplacement of waste. Audits and managerial controls would be included as part of this program.

- The applicant's procedures and plans for construction and operation of the disposal facility. These would include methods of construction; waste emplacement; procedures for and areas of waste segregation; types of intruder barriers; onsite traffic and drainage systems; methods and areas of waste storage; and methods to control surface water and ground-water access to the wastes.

- The applicant's environmental monitoring program to provide data to evaluate potential health and environmental impacts, as well as plans for taking corrective measures if migration of radionuclides is indicated.

- The applicant's administration procedures to control activities.

- The applicant's physical security measures.

- If the application includes the proposed receipt, possession, and disposal of special nuclear material, the procedures and provisions for criticality control.

6.5.2 Minimum Waste Form and Packaging Requirements

There are still a number of technical requirements that can be applied to waste form and packaging which will help to further improve operational safety. The analyses in Section 6.2 indicated that placing the higher activity waste streams such as ion exchange resins into a less dispersible waste form acts to improve operational safety. This can be accomplished by such techniques as waste solidification or use of high integrity containers. However, wastes delivered to disposal facilities are composed of a variety of forms and radionuclides contained in these wastes may vary over a wide range.

Over the years, a number of general waste form and packaging requirements have been developed and applied at disposal facilities to provide protection of the health and safety of site workers, to facilitate handling of waste, and to minimize the potential for releases to offsite areas. These requirements have been condensed from consideration of current practice at existing disposal facilities. These requirements have also been included as a part of the base case facility description and the costs and impacts are reflected in the costs and impacts of the base case. They are discussed in further detail below. These requirements are thus a codification of existing practice and include:

1. Requirement - The waste form and packaging must meet all applicable transportation requirements of the Commission as set forth in 10 CFR Part 71 and of the Department of Transportation (DOT) as set forth in 49 CFR Parts 171-179. Wastes, however, shall not be packaged for disposal in cardboard, fiberboard, or other paper packages. Wastes shall also not be in a liquid form or contain liquid exceeding 1% of the waste volume. Absorbants may be used for immobilization of liquid waste, provided that sufficient absorbant material is used to absorb twice the volume of liquid. Liquid scintillation fluids and other liquids and radioactive materials in individual units or vials used for clinical or laboratory testing may be packaged and disposed of provided the units or vials are packaged in sufficient absorbant material to absorb twice the total volume of liquid contained in the units or vials.

Analysis: The minimum requirements on waste form and packaging set out in DOT and NRC regulations for transportation are of primary importance with respect to the handling of the waste during storage, transportation and disposal. If package integrity is maintained during emplacement within disposal cells, the package can also provide an initial barrier to the release of package contents after disposal. Separate requirements on the packaging of waste could be established based on individual requirements for storage, transportation and disposal. For most wastes and for the normal and accident conditions encountered during storage, transportation and disposal, NRC believes the requirements imposed for safety in transportation are adequate and no additional requirements are needed. (In some cases, overpacks are also used to provide additional shielding during transportation.) NRC believes, however, that the use of cardboard or paper packages should be discontinued because they can easily rupture, contaminating waste transport vehicles and site surfaces, as well as increase occupational exposures. In the past, there have been several instances where cardboard or fibreboard containers have been improperly stacked during transportation and have been cracked by heavier wastes packages, thus contaminating the waste transport vehicle. In addition, cardboard or paper packages may readily compress after disposal. For some wastes, however (e.g., large quantities of very mobile nuclides such as tritium), the use of specially designed containers that would retard the release of package contents after disposal, allowing for decay, should be considered and used. NRC plans to review these on a case-by-case basis.

The disposal of bulk quantities of liquid waste should not be allowed because of the increased potential for more rapid migration and the demonstrated

increased potential for contamination of facility ground and equipment. Liquids, however, cannot be economically totally excluded from wastes, and NRC is applying a limit of 1% of the volume of the waste as a "free liquid requirement." NRC considered elimination of the use of absorbent material for liquid wastes but recognizes that certain types of liquids (e.g., organic solvents and oils) are quite difficult to solidify at this time. The use of absorbent materials should be allowed to continue for the low activity wastes until better processes for solidification or alternatives such as incineration are available.

No incremental cost/benefit evaluation for this requirement has been conducted since it reflects current practice. The costs and impacts have been included and analyzed as a part of the base case.

2. Requirement - Only radioactive waste shall be accepted for disposal at a near-surface disposal facility. Waste shall not be readily capable of detonation or of explosive decomposition or reaction at normal pressures and temperatures, or which reacts explosively with water. Waste shall not contain, or be capable of generating, appreciable quantities of toxic gases, vapors, or fumes. Pyrophoric materials contained in wastes shall be treated, prepared and packaged to be nonflammable.

   Wastes in a gaseous form shall be packaged at a pressure not to exceed one atmosphere at normal temperatures, and wastes containing biological, pathogenic, or infectious material shall be treated to reduce the potential hazard.

Analysis: These requirements are principally directed at health and safety considerations involved in the handling and placement of wastes in disposal trenches. Combustion, detonation, or excessive reaction of the waste at normal temperatures and pressures can lead to increased occupational exposures and releases of radioactive and toxic materials from the site. These materials, after disposal, can also accelerate migration of radionuclides through interaction with other wastes. The alternative of combined disposal of such wastes and other types of chemically hazardous waste with radioactive waste at a near-surface disposal facility was not considered a viable alternative.

No incremental cost/benefit analysis has been conducted for these requirements since they reflect current practice. They are currently being followed at the existing sites and the costs and impacts have been included in the base case analysis.

6.6 EFFLUENTS DUE TO WASTE PROCESSNG AT A REGIONAL PROCESSING CENTER (ASSUMED TO BE LOCATED AT THE DISPOSAL FACILITY)

As previously discussed, one of the viable options addressed in preceeding sections in this environmental impact statement was that of processing of waste on a regional basis at a central processing facility. Such a facility could be located at or separately from the disposal facility. Such central waste processing activities involves safety considerations separate from and beyond the purview of those involving the receipt, handling, and disposal of waste at

a disposal facility to be addressed in Part 61. In addition to occupational safety and other considerations at such a facility, such waste processing activities can lead to potential airborne releases of radionuclides and subsequent exposures to the public in the neighborhood of the regional processing facilities. NRC analyzed the potential population exposures due to the assumed operation of a central waste processing facility (an incinerator) which was colocated with the disposal facility. These exposures were estimated to be approximately 1.87 man-rem/year, arising from the assumed incineration of 100,000 m^3 of combustible trash per year. The total population assumed to be exposed was 480,000 within a 50-mile radius of the processing facility. (Also see Section 5.2.4.5 for further information.)

With respect to such potential exposures, a limiting criteria for such central waste processing operations should be considered. Such limiting criteria may perhaps best be developed by consideration of existing standards.

For example, effluents from nuclear power plants are limited to levels prescribed in 10 CFR Part 50, Appendix I. In addition, effluent limits for nuclear power operations have been established by EPA in 40 CFR 190. This regulation provides environmental radiation dose standards for operations which are part of the uranium fuel cycle. Specifically excluded from this regulation are uranium mining operations, operations at waste disposal sites, transportation of radioactive material in support of these operations, and the reuse of recovered non-uranium special nuclear and byproduct materials from the fuel cycle. The regulations provide limits for annual allowable doses to persons in the general environment (that is, 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ of any member of the public) as well as limitations for annual allowable releases of certain radionuclides (that is, Kr-85, I-129, and Pu-239).

A rule change to 10 CFR Part 20 formally incorporating the requirements in 40 CFR 190 into Part 20 was recently proposed by NRC (Ref. 8). The 40 CFR 190 limits, however, are being implemented by NRC staff in specific licensing actions.

Limits for airborne radionuclide releases in the range of 40 CFR 190 have also been extended to other licensing actions by NRC licensing staff. For example, NRC licensing staff have applied general limits in the range of 40 CFR 190--i.e., approximately 1/10 of 10 CFR Part 20 standards--for small institutional radioactive waste incinerators.

It would therefore appear that if waste processing activities were to take place at a central waste processing facility, an effluent limitation criteria incorporating the release limits of 40 CFR 190 would appear to be appropriate.

If extensive waste processing were carried out at a fuel cycle facility, the limits of 40 CFR 190 would be applied as part of existing standards. With respect to waste processing carried out at nonfuel cycle facilities, NRC licensing staff is already applying use of 1/10 of Part 20, Table II values as an objective. The processing of waste can either take place at the point of waste generation or at a central facility. If the processing does take place at a

central facility, it is logical to expect that the same limits that would apply at the point of generation should also be applied. In this case the lower limits established by 40 CFR 190 should be applied to population exposures from waste processing operations at an central processing facility. These annual limits are:

- o 25 mrem (whole body);
- o 75 mrem (thyroid);
- o 25 mrem (any other organ).

From the previous analysis, it is expected that these limits would be readily met at any such central waste processing facility.

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Chapter 7

WASTE CLASSIFICATION

7.1 INTRODUCTION

Radioactive waste classification is the culmination of the Part 61 rulemaking effort. First as part of the Part 61 rulemaking effort, overall performance objectives for near-surface disposal were developed. The analysis and rationale for arriving at these performance objectives are set out in Chapters 4, 5, and 6 of this environmental impact statement. Based on the overall performance objectives, a number of technical requirements were developed, including requirements for institutional controls, waste form and packaging, disposal facility siting, and disposal facility design and operation. Waste classification is the mechanism that helps assure that the overall performance objectives will be met over the long term through the collective reflection of the technical requirements and controls established for near-surface radioactive waste disposal. To a waste generator, it establishes requirements on the form and content of waste and establishes how he should treat and package particular wastes. To a waste disposal facility operator, it defines the requirements and controls he should use in the disposal of particular wastes.

Earlier work to develop a waste classification methodology and system has been described in Chapter 2 of this environmental impact statement. This work, which is reported in References 1, 2, and 3 developed the concept that radioactive wastes should be classified based upon their potential hazard following disposal. As part of this work, an omnibus classification system was proposed based upon not exceeding generic radiation exposure limits which defined safe disposal. For example, in NUREG-0456 (Ref. 2), safe disposal is first defined as a potential exposure limit of 500 mrem/yr to the critical organ. Then, classes of waste were determined based upon calculation of maximum concentrations of radionuclides so as not to exceed these overall exposure limits through various exposure pathways

In NUREG-0456, the classification system involves three types of actions in handling radioactive waste:

1. Discharge directly to the biosphere similar to handling routine trash.

2. Confine the waste for a period of time in a controlled manner with predictably low release rates.

3. Isolate the waste from the biosphere so that biologically significant releases or inadvertent reentry by mankind into the disposal area is highly unlikely.

In practice, this was modeled (and concentration limits were calculated based upon the assumed exposure limit) as:

1. Disposal into a sanitary landfill;

2. Disposal into a shallow land burial facility;

3. Disposal into a geologic repository.

In this work, the concept of disposal of waste at greater depths (deeper burial) was briefly discussed. This was expanded in a later work, NUREG/CR-1005, in which two more classes of waste were added based upon deeper burial (Ref. 3).

Based upon this work, NRC at one time considered developing a waste classification regulation as a separate rulemaking effort from the Part 61 regulation for low-level waste disposal. That is, an omnibus classification system would have been developed which would initially establish two classes of waste--one suitable for "de minimus" disposal and one for shallow land burial, with a third class of waste which would require disposal into a geologic repository. At the same time, the Part 61 regulation would develop requirements for shallow land burial. Subsequent rulemaking efforts would develop requirements and classification limits for disposal by other methods such as deeper burial or use of engineered structures.

NRC recognized, however, that such an omnibus classification system could have practical difficulties in that waste classification could not be developed independently of other requirements for waste disposal such as those for waste form and packaging. Therefore, the waste classification regulatory development effort was combined with that of the Part 61 regulatory effort. In addition, the Part 61 regulation was expanded to become an "umbrella" regulation under which a number of potential near-surface disposal techniques may be licensed.

Development of waste classification in terms of disposal requirements rather than an omnibus system is also of more practical use in determining types of wastes for which disposal should be of no regulatory concern. As observed by the Federal Radiation Policy Council (Ref. 4), an omnibus "de minimis" classification system would be likely to be so conservatively abstract as to be unworkable. In accordance with this policy, exemptions to Part 61 requirements are being handled on a specific waste stream basis. Analyzing specific waste stream exemptions on a case-by-case basis allows full consideration of the costs and benefits of such exemptions on a basis of need.

NRC has already followed this approach in establishing a new paragraph 20.306 to 10 CFR Part 20. This rule change exempts tritium and carbon-14 from disposal as radioactive waste when contained in liquid scintillation cocktail and animal carcass waste and not exceeding a concentration of .05 uCi/gm. Other waste streams may also readily lend themselves to treatment in this manner. An example would be very low activity residues from fuel fabrication operations or PWR secondary side resins.

7.1.1 Alternatives Considered

There are two principal alternatives that can be applied to classify waste for disposal:

1. Handle classification on a site-specific case-by-case basis; or

2. Develop a system that can be uniformly applied to all disposal facilities.

The actual impacts of near-surface disposal are site-specific and it could be possible to assure that the performance objectives and technical criteria are met at any site accepting all wastes by enforcing the Part 61 requirements at such a site on a case-by-case basis. The classification of waste would then be determined by site-specific conditions and considerations, and each site would have its own unique controls for particular wastes. However, it is difficult to regulate in this manner. Although the NRC staff believes that some flexibility to account for site-specific conditions needs to be included in the classification system, such flexibility could be very confusing to all parties concerned if carried to extremes. For example, waste generators could be faced with an extreme range in requirements and controls based on the particular site related requirements for disposal.

What is needed is a generic nonsite-specific classification system which can be uniformly applied by waste generators and disposal facility operators. The most convenient system to implement would be one in which actions are triggered by radionuclide quantity or concentration levels in waste streams. This would be more convenient to both regulators and licensees. Any waste generator, once the concentration or quantity of radionuclides in a particular waste stream is known, can then key the waste stream for a particular action at a disposal facility. Once the keyed waste stream arrives at the disposal site, the disposal facility operator can then carry out and exercise the appropriate controls for disposal.

7.1.2 Development of Waste Classes

Based upon the work in Chapters 4 and 5, there are two fundamental mechanisms to classify wastes for long-term hazard:

1. Consideration of potential hazard to an inadvertent intruder due to direct contact with the disposed waste; and

2. Consideration of potential hazard to an individual or a population from potential consumption or use of contaminated ground water.

From the analysis in Chapter 4, three general classes of waste have been determined and used in the analysis in Chapter 5:

A. Wastes for which there are no stability requirements but which should be disposed in a segregated manner from other wastes. The upper limit for these wastes is determined based upon a limit of 500 mrem/yr (whole body) to a potential intruder as calculated at the end of 100 years of institutional active control using the most restrictive limit from either the intruder-construction scenario or the intruder-agriculture scenario.

B. Wastes which need to be placed in a stable form and disposed in a segregated manner from unstable waste forms. Stability may be achieved through use of a solid waste form, packaging in a structurally stable container, or use of stabilization measures at a disposal facility. The upper limit for these wastes is determined based upon a limit of 500 mrem/yr (whole body) to a potential intruder as calculated at the end of 100 years of active institutional control using an intruder-discovery scenario.

C. Wastes which need to be placed into a stable form, disposed in a segregated manner from unstable waste forms and disposed of so that a barrier is provided against potential inadvertent intrusion. One type of acceptable barrier would be layering, covering the waste with a minimum of 5 meters of earth and lower activity wastes. An upper limit for these wastes is determined based upon a limit of 500 mrem/yr (whole body) to a potential intruder as calculated at 500 years from the beginning of the active institutional control period using the most restrictive limit from either the intruder-construction scenario or the intruder-agriculture scenario. (The barrier is assumed to be effective for only 500 years).

Wastes which exceed the upper limit as calculated by item C. above would normally be considered unacceptable for near-surface disposal. Wastes containing higher activities would be potentially allowed on a case-by-case basis depending upon specific waste forms and disposal methods. Such special consideration would be most applicable to wastes having radionuclides of moderate half lives (e.g., about 30-100 years).

In addition, two general classes of waste were developed in Chapter 5, according to ground-water considerations:

A. Waste streams which need not be placed into a stable form, but must be segregated from waste streams which have been placed into a stable waste form.

B. Waste streams which should be placed into a stable waste form and disposed in a segregated manner from unstable waste forms. As discussed, a stable waste form could be provided by the disposal facility design (e.g., grouting of the disposal cells), the waste form, waste processing, (e.g., solidification), or the waste package (e.g., use of a structurally stable container).

A third class of waste is also possible based upon ground-water migration considerations. This would include waste which would require additional disposal considerations (e.g., special packaging) or would be generally unacceptable for near-surface disposal.

These tentative waste classes for intrusion and ground-water migration can be combined into a matrix as shown in Figure 7.1 to yield 6 potential separate waste categories. There is no practical use, however, in setting out two

Figure 7.1 Tentative Waste Classification Matrix

Intruder	Migration: No Stability Requirements	Migration: Stable Waste
Segregated low activity	A	-
Stable, regular disposal	-	B
Stable, intruder protected	-	C

different unstable waste classes: one based on intruder considerations and one based on migration considerations. Similarly, there is no point in setting out classes of waste that must be stable by one consideration but are allowed to be unstable by another. And, if a waste stream is unacceptable by either intrusion or migration considerations, then it it is unacceptable. Therefore, the six potential classes become three and any waste exceeding the upper bound concentration calculated for Class C is generally not acceptable for near-surface disposal.

Such a classification system presents some difficulties in that of the two considerations--intrusion and migration--only the first appears to be directly applicable for waste classification purposes. The calculation of concentration limits for pathways involving exposures to an inadvertent intruder are relatively straightforward since potential exposure of an intruder is directly related to the concentration of the radionuclides available for uptake. It is considerably less straightforward to set out categories of waste based upon migration considerations. Potential ground-water migration impacts could occur to an intruder consuming water from a well located onsite, to individuals consuming water from a well located at the site boundary, or to populations consuming water from a public drinking water supply. Potential migrational impacts are much more a function of site-specific environmental and geohydrological conditions than concentration-limited intruder impacts. Potential migrational impacts are furthermore a function of the total inventory of radionuclides at a disposal site. This means that, unlike concentration-limited intruder impacts, potential migrational impacts are not as directly linked to concentration limit requirements.

The approach that has been taken, then, is to first determine waste classification requirements (based upon concentration limits) considering protection of a

potential inadvertent intruder. Then, the nuclides which were determined in Chapter 5 to be important from the standpoint of migration are identified such that inventory limits based upon ground-water migration considerations can be established on a site-specific basis.

7.2 WASTE CLASSIFICATION BASED UPON CONSIDERATION OF A POTENTIAL INADVERTENT INTRUDER

7.2.1 Classes of Waste

Table 7.1 sets out calculated concentration limits for each of the first three classes of waste discussed in Section 7.1. The concentrations are maximum average concentrations for each radionuclide in disposed waste. Column 1 establishes the interface concentration limit between those wastes which must be placed into a stable form and those in an unstable form requiring segregated disposal. Waste containing activity at or below the concentration limit for Column 1 is defined as "Class A" segregated waste. Above the concentration limit the waste is defined as "Class B" stable waste.

Column 2 establishes the minimum concentration for wastes that will require disposal with an additional barrier to inadvertent intrusion. Waste containing activity above the concentrations limit is defined as "Class C" intruder protected waste.

Column 3 establishes the upper bound concentration for waste that is considered to be generally unacceptable for near-surface disposal. Above this concentration limit, the waste is defined as generally unacceptable for near-surface disposal. Such waste will require special consideration and prior approval for disposal near surface. Column 4 has been prepared as an example of disposal of such "unacceptable waste" based upon one potential special disposal technique, the "hot waste" facility, as analyzed in Chapters 4 and 5. Column 4 defines the upper bound concentration of waste that would be acceptable for disposal in such a "hot waste" facility given the assumptions for design and operation set out in Chapter 5.

To establish the limits, the intruder performance objective (500 mrem/yr whole body) is used as established in Chapter 4, an active institutional control period of 100 years is assumed, and the most conservative assumption regarding the waste form is made. For organs other than whole body and bone, a dose limit of 1500 mrem was used. The waste is assumed to be as dispersible as ordinary dirt and no credit is taken for improved waste forms to reduce plant uptake. These concentration limits were calculated using the INVERSE computer code presented in Appendix H.

The table requires some interpretation. To calulate the limiting concentrations in the table, the extensive intruder scenarios used in Chapter 4 (intruder-construction and intruder-agriculture) were assumed for Columns 1, 3, and 4. The delay time prior to initiation of the event was 100 years for Column 1, 500 years for Column 3, and 1000 years for Column 4. In addition, due to the considerable quantity of concrete used in the "hot waste facility, Column 4 incorporates a factor of 10 additional shielding for gamma radiation. For

Table 7.1 Calculated Waste Classification Limits Assuming Worst-Case Waste Form

	(μCi/cc)			
	Column 1	Column 2	Column 3	Column 4
Isotope	Classes A & B*	Class C**	Generally Unacceptable†	††
H-3	36.2	1.1E+8	#	#
C-14	0.750	1.26E+4	0.787	0.836
Fe-55	#	#	#	#
Ni-59	2.15	233	2.16	11.4
Co-60	677	6.68 E+4	#	#
Ni-63	3.45	2.84E+3	70.2	3.03E+3
Nb-94	1.54E-3	0.152	1.57E-3	1.59E-2
Sr-90	3.76E-2	149	735	1.71E+8
Tc-99	0.262	5.55E+4	0.263	0.263
I-129	8.19E-3	14.8	8.19E-3	8.20E-3
Cs-135	84.3	9.85E+3	84.3	84.3
Cs-137	4.47E-2	4.41	460	4.76E+8
U-235	3.94E-2	3.29	3.94E-2	4.39E-2
U-238	4.76E-2	3.97	4.76E-2	4.78E-2
Np-237	4.08E-3	0.340	4.08E-3	4.13E-3
Pu-238	2.76E-2	2.30	0.681	37.6
Pu-239/40	1.04E-2	0.864	1.05E-2	1.06E-2
Pu-241	0.274	1.18E+4	0.501	1.099
Pu-242	1.11E-2	0.923	1.11E-2	1.11E-2
Am-241	7.89E-3	0.658	1.44E-2	3.16E-2
Am-243	6.62E-3	0.552	6.86E-3	7.64E-3
Cm-243	7.946	5.23	8.023	8.099
Cm-244	3.891	52.3	3.929	3.966

*Intruder-construction or intruder-agriculture limit at 100 years
**Intruder-discovery limit at 100 years
†Intruder-construction or intruder-agriculture limit at 500 years
††Intruder-construction or intruder-agriculture limit at 1000 years; Factor of 10 gamma shielding
#Natural specific activity of the isotope.

conf

Column 2, a delay time of 100 years (the end of active institutional control) was used. However, the waste is in a stable form and the potential intruder exposures are considerably less extensive--i.e., limited to those obtained during "discovery" of the waste, the intruder-discovery scenario.

The table reveals that as long as the waste is assumed to resemble dirt, use of intruder barriers and placing the waste into a stable, segregated form often does not result in a real reduction in overall hazard for long-lived isotopes. For long-lived isotopes such as Tc-99, concentrations in Columns 1, 2, and 4 are essentially the same. For other, shorter-lived radionuclides such as Cs-137, Sr-90, or Ni-63, the options of placing the waste into a stable form or disposing of it with a barrier has a large effect upon the concentrations calculated. Also, use of a "hot waste" facility for special high activity waste streams (Column 4) would really not provide any additional long-term protection for long-lived radionuclides but would be very useful for large quantities of shorter-lived radionuclides such as Cs-137 or Sr-90.

For short-lived radionuclides such as Fe-55 (2.5 year half life) or Co-60 (5 year half-life), extremely large quantities of these radionuclides could be disposed of with little or no regard to long-term intruder hazard. The radionuclides decay sufficiently quickly that at time periods much beyond 100 years, intruder hazard is negligible. As shown, there is no limit on the amount of Fe-55 that can be disposed in any class--i.e., the limits calculated for all four columns exceed the natural specific activity of Fe-55. A similar situation is observed for H-3 and Co-60 for Columns 3, and 4. In addition, the limit in Column 2 for H-3 is calculated to be 10^8 Ci/m^3. This is actually somewhat less than the natural specific activity for tritium (2.9 E+9 Ci/m^3) but is obviously sufficiently high that it will not be exceeded on a practical basis.

For Column 2 it is seen that the concentrations for several radionuclides are larger than those presented in Column 3. These are all long-lived isotopes for which disposing of the waste with an intruder barrier does not cause any significant reduction in the potential long-term hazard to an inadvertent intruder. For shorter-lived radionuclides such as C-137 use of a barrier does result in a reduction in potential impacts.

7.2.2 Corrections for Waste Form

As discussed in Chapter 4, the potential impacts from inadvertent intrusion were shown to be reduced through use of improved waste forms. Improved waste forms reduce the potential for waste decomposition, dispersion and uptake by plant roots. Based on the analysis, one alternative that could be applied to establishing concentration limits based on intruder considerations would be to establish separate limits for each waste form. In this way, consideration can be made of the tendency of each waste form to degrade into dispersible, respirable particles, to be taken up by plant roots, or to provide self shielding against direct gamma radiation from the contained radionuclides. In general, however, this would appear to be difficult to do. Some of the reasons are as follows:

- o There are in reality innumerable waste forms. It would be extremely difficult to attempt to characterize all possible waste forms and determine concentration limits for each.

- o Regulation would be very difficult. As discussed earlier regarding the alternative of establishing separate concentration limits for each disposal facility, providing separate concentration limits for each waste form would be generally confusing to both regulators and licensees. An occasional exception could be made, however.

- o It is difficult to predict the ability of particular waste forms to minimize dispersion and plant-uptake over the long term. For example, some assumptions have been made in this regard for wastes solidified in material such as cement or synthetic polymers. Although such assumptions may be reasonable, it is difficult to assure that they will be reasonable for thousands of years. For example, it would be difficult to have confidence in the long-term ability of waste forms such as cement to minimize dispersion of long-lived transuranic radionuclides such as Pu-239 over the long term. On the other hand, it is less difficult to have confidence in the long-term ability of waste forms such as activated metals to minimize dispersion of contained shorter-lived activation products.

In general, then, it would be more useful to set out limits applicable to all wastes, and then consider potential allowances for particular waste forms. Two such waste forms for which allowance for waste form should be made are activated or fixed-surface contaminated metals and uranium metal. To briefly summarize from Reference 5 and from Appendix G, many, if not most of the more highly activated metals' waste streams are composed of relatively noncorrosive materials such as stainless steel. Corrosion of such materials takes place at a slow, relatively predictable rate and produces finely-divided but highly insoluble oxides. Crud deposits on such waste streams as LWR nonfuel reactor core components can be very difficult to remove. In addition, the relative amounts of activated metals currently being generated and disposed at radioactive waste disposal facilities are small compared with other waste volumes. Another very small volume waste stream is uranium metals. Uranium metal is occasionally used for gamma shielding in waste transport casks. Other applications include counterweights in airplanes. NRC believes the concentrations of nuclides contained in metals, metal alloys or permanently fixed on metal as contamination can be increased by a factor of 10 to account for the inaccessibility of the nuclides. For natural or depleted uranium the concentrations can be increased to the natural specific activity.

7.2.3 Disposal Facility Design Considerations

This section considers possible variations in waste classes or concentrations in waste classes to account for a particular disposal facility design. That is, depending upon the disposal facility design, different classes or concentrations could be established.

As briefly discussed in Section 7.1 and similar to the argument regarding waste form in Section 7.2.2, if this concept were generally applied to waste classification, then a great multiplicity in waste categories could result. As an example, the effect of different cover thicknesses could be taken into account.

The previous calculations were based on an assumed average 2-meter thickness of earth over the waste, and minor variations on this assumed thickness--e.g., greater than 2 meters--could be incorporated into the calculations. However, this hardly seems worth the effort since as long as one is not speaking of large thicknesses such as 5 meters or intermediate depth disposal, the effect would be small. In any case, the depth of cover at most disposal facilities are often greater than 2 meters, which provides some conservatism into the calculations.

As another example, the calculations in Chapter 5 assumed a disposal efficiency of 0.5 for random disposal and 0.75 for stacked disposal. As discussed in Chapter 5, the higher disposal efficiency would result in higher intruder exposures. This effect could be potentially considered in the waste classification calculations and, depending upon the design of a particular facility, incorporated into classification limits calculated for that facility. However, it is believed to be difficult to actually achieve that high an efficiency level on a practical basis. The effect on intruder exposures would therefore be at most a factor of 1.5 and probably less.

A much more significant effect would be caused by use of grouting to provide additional stabilization of the disposal facility. In the EIS, use of grouting has been estimated to reduce potential intruder exposures by about a factor of 10. This factor is somewhat hypothetical; however, a significantly reduced hazard to a potential intruder would be expected over the short term, although potential long-term reductions in hazard are uncertain.

In general, the NRC staff believes that it would not be useful to incorporate the effect of minor site-specific design variations into the basic waste classification limits calculated. This could result in innumerable waste classes and would be overly confusing to waste generators, disposal facility operators, and regulators. However, it is also recognized that too rigid adherence to this conclusion leads to a loss of needed flexibility to account for disposal designs which would result in the same or improved performance. Therefore, while NRC believes that waste classification can be best implemented and regulated through use of a limited number of waste classes, flexibility should be incorporated into the waste classification requirements to account for variations or improvements in design. This would best be handled through a limited number of assessments carried out on a site-specific basis.

7.2.4 Effect of Environmental Conditions on Intruder Exposures

The previous section discussed the effect of variations in disposal facility design. This section considers the effect of site-specific environmental conditions on the intruder impact calculations themselves. The section is limited to concentration-limited impacts. The effect of site-specific environmental conditions on ground-water impacts is considered in Section 7.3.

On first glance it would appear that significantly higher intruder exposures would be expected at dry western disposal facilities and for the intruder-construction scenario. However, the higher site selection factors are balanced by a number of other compensating factors. One of the principal factors is

the significantly lower rate of decomposition of disposed waste that would occur at arid sites. This is borne out by the analysis in Appendix M, which compared measurements of decomposition gas (principally methane) generated as a result of waste decomposition at the humid Maxey Flats, Kentucky facility with the arid Beatty, Nevada facility. The measured methane concentration within disposal trench sumps was several orders of magnitude higher at the Maxey Flats facility. The lower rate of decomposition would result in considerably higher volumes of waste being in a form which is recognizable as something other than dirt. The potential for dispersion of the waste would be considerably reduced, as would the likelihood that the intrusion event occurs in the first place.

Another consideration is the depth of the water table. At many potential western sites, the water table is quite low. At the existing two western disposal facilities at Hanford, Washington and Beatty, Nevada, the water table is on the order of 100 m below the earth's surface. At the southwest regional site, the water table is on the order of 85 meters below the earth's surface. This means that disposal trenches can be (and currently are) excavated to much greater depths than at most humid eastern sites. This reduces the potential for intruder exposures, since layered higher activity waste streams would be placed at comparatively greater depths.

Another consideration is that the intruder-construction scenario occurs for less than a year while the intruder-agriculture event could potentially occur for several years. Higher exposures could potentially be allowed for the construction event, since it occurs over a shorter time period.

In conclusion, it does not appear to be generally useful to include variations in site-specific environmental conditions into the waste classification categories. The range of variation caused by site-specific conditions is expected to be small in the humid eastern sites, where over 75% of the LLW is generated. Assuming that regional disposal facilities are implemented, then this waste would also be disposed at humid eastern sites. Assuming that waste is dispersed by an intruder, then it is possible that higher intruder impacts could result from disposal of waste at arid sites. However, this is balanced by a number of other factors which reduce exposures, one of the principal factors being the greatly lower expected rate of waste decomposition.

7.2.5 Operational Limits--Maximum Average and Allowable Concentrations

The limits in Table 7.1 are maximum average concentrations of individual radionuclides in disposed waste. They were calculated based upon consideration of impacts to a potential inadvertent intruder such that exposure, due to contact with such average concentrations, would not exceed the 500 mrem/yr (whole body) intruder performance objective. If the calculated maximum average concentrations are then set out as the maximum allowable concentrations in waste used as operational limits, they would be applied by waste generators and disposal facility operators in determining the disposal requirements for particular wastes. If they were applied as operational limits, the actual average radionuclide concentrations in the disposed waste in any disposal facility would be less and in most cases significantly less than the calculated maximum average concentrations used in classifying each waste package for disposal. This is

due to the mixing (dilution) of all the various waste stream packages containing varying concentrations of radionuclides during disposal (e.g., some waste contains cesium--some at a high concentration and some at a low concentration--and some waste would not contain any cesium). The actual impacts to a potential inadvertent intruder are related to the average concentration of all the waste mixed together during disposal and thus would be less than the intruder performance objective dose limit used to calculate the maximum average concentrations for individual radionuclides.

This is borne out by the results of the analysis in Chapter 4. Using a dose limitation criteria of 500 millirem to the whole body, average volume weighted inadvertent intruder impacts were considerably less than 100 millirem at the end of an assumed 100-year active institutional control period and only a few millirem 400 years later. It was also observed that approximately the same volume-averaged intruder impacts would be achieved if the dose limitation criteria were a factor of 10 higher (e.g., 5 rems whole body). This led to the observation in Chapter 4 that one way to establish an intruder performance objective could be to set out one dose limitation criteria (e.g., 500 mrem) for longer-lived isotopes and a higher dose limitation criteria (e.g., 5 rems) for shorter-lived isotopes. The higher exposures would only last for a relatively short time period. (For example, the potential intruder hazard from Cs-137--half-life of about 30 years--drops by a factor of 10 every 100 years).

The relationship between maximum average concentrations and maximum allowable concentrations (or operational limits) has been addressed by others. For example, NUREG-0456 postulated a maximum-to-average ratio of 10 (Ref. 3). In NUREG/CR-1005, however, the maximum-to-average ratio was not applied (Ref. 3). This relationship was investigated more thoroughly by Healy and Rogers--particularly in regard to dilution by less contaminated waste (Ref. 6). As observed by Healy and Rogers in relationship with trash and other low activity scrap material generated by DOE activities:

> It is the practice in all DOE facilities to consider any material brought into a process or laboratory area as contaminated when it leaves as waste, whether it has contacted radioactive material or not. This is because of the difficulty and expense of measuring each piece of paper, cloth, rubber, etc. to a level that will assure that contamination levels are minimal and acceptable for uncontrolled release. This results in a dilution of the contaminated wastes with this clean material. Some additional dilution arises from the fact that most of the boxes will have lower concentrations than those at the maximum limit set for burial.

The authors then estimate the degree of dilution wrought by this practice. A survey of the five major DOE sites was referenced which indicated that greater than 97% of the waste disposed at these sites is only very lightly radioactive or is suspected of being radioactive because of the place that it is generated. (The 5 sites account for 86% of the total waste volume generated by DOE and 99.9+% of the activity.) As stated by the authors, if it is assumed that the 3% of the waste that is contaminated is at a maximum limit and the remaining 97% is either clean or only slightly radioactive, then dilution by a factor of

about 30 would occur. The authors also cite nine months of data regarding the transuranic content of room trash obtained from the Plutonium Research and Development Facility at Los Alamos Scientific Laboratory. From this data, the authors estimate that for a limit of 10 nCi/gm, a dilution factor of 20-60 could be expected for these wastes (Ref. 6).

Finally, Healy and Rogers differentiate between wastes such as trash, where considerable dilution with uncontaminated material would be expected to occur, and wastes such as sludges packaged in degradable containers or ash from incinerated combustibles, which would be expected to be more uniformly contaminated. In their work, the authors incorporated a dilution factor of 20 for material such as trash from water treatment and a dilution factor of 1 (no dilution) for more uniformly contaminated material (Ref. 6).

In the interest of maintaining exposures to levels as low as reasonably achievable, the NRC staff believe maximum allowable concentrations equivalent to the calculated maximum average concentrations should be conservatively set. This minimizes the potential long-term hazard from long-lived radionuclides. NRC staff also believes, however, that there should be flexibility and that exceptions should be considered when there is good reason to do so. Examples would include allowing a higher maximum concentration for short-lived isotopes and/or for concentrations in waste forms that are only present in small quantities.

A specific example in this matter is the isotope Cs-137. This isotope, which is a beta-gamma emitter having a half-life of 30 years, is present in significant quantities in some waste. For example, from 25 to 75 percent of the activity in spent LWR resins can be due to Cs-137. In the analyses performed in Chapters 4, 5, 6, concentrations of Cs-137 were used which were based upon geometric means of a number of data points. However, there was a considerable range in the concentrations in specific data points. It is therefore possible that the analysis in Chapter 4 could underestimate the volume (and costs) of LWR wastes which would have to be processed and disposed by more expensive means. If the Cs-137 concentrations were a factor of 10 higher, the overall intruder hazard at 100 years would not be greatly increased (the volume-weighted hazard would still be less than 500 millirem). Use of the higher concentrations would not effect the long-term potential hazard.

The Cs-137 concentrations may therefore be raised by a factor of 10 in Table 7.1 for Columns 2 and 3. A higher factor-i.e., 20--can be incorporated into Column 1 to account for the preponderance of trash in that class which would contain very low concentrations of cesium or none at all.

7.2.6 Transuranic Isotopes

For a number of years, a de facto limit of 10 nCi/gm has been applied to near-surface disposal of transuranic waste. At one time, transuranic waste was disposed at several near-surface disposal facilities operated by the AEC in addition to 5 of the 6 commercial disposal facilities. However, in 1970, the AEC initiated a policy whereby government-produced wastes containing most TRU isotopes in concentrations greater than 10 nanocuries per gram of waste

material were placed into retrievable storage pending transfer to a repository for ultimate disposal. The 10 nanocurie per gram limit was based upon rough comparison with the potential hazards of upper concentration levels of naturally occurring radium in the earth's crust. However, TRU waste generated as a result of AEC (and later DOE) contracts with private contractors and some DOE prime contractors) was still sent to commercial disposal facilities, in addition to TRU wastes from commercial mixed oxide fuel fabrication fabricators and source manufacturers.

Retrievable storage of commercially-generated TRU waste (pending development of an ultimate repository of the waste) by the federal government was the intent of a rule proposed by AEC in 1974. Under this proposed rule, commercial TRU waste would have been consigned to retrievable storage facilities operated by the federal government pending the development of a facility for the ultimate disposition of the waste. A sensitivity level of 10 nanocuries per gram was proposed for measurements to determine the presence or absence of TRU contamination. At the time of the proposed rule, it was expected that commercial recycle of plutonium fuel for use in breeder reactors and in light-water reactors as a mixed oxide would greatly increase in the near future. It was expected that significant additional volumes and quantities of TRU waste material would, therefore, soon be generated.

This rule, however, has never been finalized. The draft environmental impact statement published in support of the proposed rule was withdrawn by the Energy Research and Development Administration (ERDA) when the AEC was reorganized to form ERDA and NRC. The Department of Energy (DOE), ERDA's successor, is continuing the policy of retrievable storage of government-produced TRU waste.

In the meantime, individual state initiatives have resulted in a 10 nanocurie per gram disposal limit for TRU waste at all operating commercial low-level waste disposal facilities. Although at one time five of the six commercial LLW disposal sites accepted TRU waste for disposal (the Barnwell, South Carolina facility has never accepted TRU waste for disposal), this practice has been discontinued. The last commercial facility to accept TRU waste for disposal was the site located in the center of the Hanford Reservation near Richland, Washington and operated by U.S. Ecology, Inc. From 1976 to 1979, the Richland facility was the only commercial disposal facility accepting TRU waste for disposal. TRU waste acceptance at the Richland facility in concentrations exceeding 10 nCi/gm was prohibited by the state of Washington in November 1979.

Prior to the cutoff of TRU disposal at the Richland facility, there was (compared to TRU wastes generated by the federal government) relatively little TRU waste generated by the commercial sector. There is no operating commercial nuclear fuel reprocessing industry, and in 1976, President Carter announced a national policy of deferment of fuel reprocessing. This policy of deferring fuel reprocessing also halted most of the mixed oxide fuel research and development work in the commercial sector. At the time of the cutoff, most of the TRU waste generated from the commercial sector was generated through decontamination of the existing commercial mixed-oxide fuel fabrication test facilities.

Although it has been shown that the federal government and the nuclear industry can readily meet a 10 nCi/gm TRU limitation on near-surface waste disposal--whether as a matter of policy or license condition--there has been interest in deriving a limit by more formal analysis. If a higher limit than 10 nCi/gm could be justified, then there could be an economic gain realized. The earlier classification work (Refs. 2 and 3) suggested that the limit, based upon shallow land burial, could be potentially raised to about 100 nCi/cm^3 (about 60 nCi/gm). However, this limit was calculated based upon use of the older ICRP-2 lung model.

In the work conducted by Healy and Rodgers for DOE to determine limits for shallow land TRU disposal, the newer task group lung model was used, in addition to some different assumptions regarding actions of a potential intruder (Ref. 6). In this work, lower transuranic concentrations were calculated--e.g., in the range of 2 to 50 nCi/gm, depending upon the assumed distribution of contamination in the waste. The lower number was calculated for contamination which is uniform through the waste while the higher number was calculated for contamination which is distributed through the waste so that the average concentration is 5% of the maximum concentration.

Based upon the work performed for this environmental impact statement as well as work performed by others, NRC staff decided not to raise the existing working limit of 10 nCi/gm. This decision is based on several factors. In the work for this environmental impact statement, the newer task group lung model was also used, and as shown in Table 7.1, maximum average concentrations for near-surface disposal of many transuranic isotopes were calculated to be in the range of 10 nCi/cm^3 (the same value for a density equal to water). These calculations are conservative in that they do not allow for dilution by other wastes. In the spirit of the ALARA concept, the lower value of 10 nCi/gm has been demonstrated as an achievable concentration to control the disposal of transuranic nuclides. This value has been imposed by the Department of Energy for some eleven years and by most of the commercial disposal site operators for nearly that long. The last commercial site imposed the 10 nCi/gm restriction in 1979. Thus, there is no need to increase the limit from the standpoint of achievability. There is also a tendency toward a more conservative assessment of the hazard of certain transuranic nuclides (Ref. 13) and it does not seem prudent at this time to use higher calculated values. As more information is obtained regarding the physiological distribution and effects of radioactivity and as improved models describing this distribution are implemented generally more restrictive TRU impacts are calculated. The trend in radiation dose calculations methodology therefore does not appear to generally justify loosening the existing working limit.

In addition, it is believed that most of the potential for economic gain that would result from a higher limit (say in the range of 100 nCi/gm) would be negated by current limitations in routine measurement techniques. That is, it is difficult to routinely nondestructively analyze TRU content in a waste container--particularly in a gamma radiation field. Thus, most waste which currently falls under the heading of being transuranic-contaminated does so because it is suspected of being transuranic-contaminated. For example, it originates from a work area in which TRU isotopes are known to be present. Even if the current working limit were to be raised, it is not likely that the current practice of classifying waste as TRU due to suspicion would significantly change.

In adopting the existing limit of 10 nCi/gm, NRC staff recognizes that the principal concern regarding potential future health hazards of TRU disposal is due to long-lived alpha activity. However, many TRU isotopes are short-lived and/or are not alpha emitters. Some have half-lives less than seconds. Therefore, it is believed to be generally appropriate to restrict the 10 nCi/gm limit to alpha emitters with half lives greater than 5 years. One exception to this rule would be Pu-241, which is a beta emitter which decays with a 13.2 year half-life to Am-241, which is an alpha emitter having a half-life of 458 years. By the time the 100-year institutional control period ends, any Pu-241 disposed in a near surface disposal facility will be approximately one-two hundredths of its former activity. Impacts to a potential inadvertent intruder would mostly result from the daughter product, Am-241. The ratio of the specific activity of Pu-241 to Am-241 is about 35. Thus, to maintain an equivalent limit for alpha emitters of 10 nCi/gm, a limit of 350 nCi/gm could be allowed for Pu-241.

7.3 CONSIDERATION OF GROUND-WATER IMPACTS

The analyses in the previous sections established concentration limits for classes of waste based upon consideration of direct contact of the disposed waste by a potential inadvertent intruder. In this section, additional consideration is given to the impacts of ground-water migration.

Based on the work performed in Chapter 5 and as discussed in Section 7.1, it appears that at least two classes of waste may be established based upon consideration of ground-water migration and long-term costs to a site owner:

1. Wastes which need not be placed into a stable form. That is, the wastes contain sufficiently low quantities of radionuclides that, provided they are disposed in a segregated manner from higher activity waste streams, would not be expected to cause a severe ground-water migration problem.

2. Wastes which should be placed into a stable waste form and disposed in a segregated manner from unstable waste streams.

Clearly, these two waste classes are complementary to the first two classes based upon intruder considerations. In addition, there may also be another class of waste which may contain quantities of radionuclides for which additional requirements for ground-water protection may be needed, or which may not be suitable for near-surface disposal. For the analysis, one approach would be to establish average concentration limits for the above two groundwater classes and to compare the calculated limits with limits developed from intruder considerations. However, this would not appear to be particularly useful. Ground-water impacts are considerably more site-specific than concentration-limited intruder impacts. In addition, groundwater impacts are calculated from the total activity of disposed wastes, rather than the concentrations in any particular waste stream. In addition, ground-water impacts are related to the specific environmental conditions of the site and the design and operation of the disposal facility. Rather than establish concentration limits for

radionuclides, a better approach would be to establish inventory limits on a site and facility specific basis for those nuclides that are important with respect to ground-water migration.

In the previous analysis in Chapter 5, the NRC staff has identified three isotopes which are both long lived and mobile. That is, the isotopes move with the approximate speed of the ground water and ion exchange has relatively little effect to retard movement. These isotopes include C-14 (5,730 year half-life), Tc-99 (2.12×10^5 year half-life), and I-129 (1.7×10^7 year half-life). These isotopes have been identified as those contributing the principal long-term ground-water impacts. Tritium has also been identified as an isotope resulting in potentially significant ground-water impacts. Although it is relatively short lived (12.3 year half-life), it has the highest leach factor of the radionuclides considered in the analysis and has a retardation factor equal to 1 (moves with the speed of ground water). In addition, tritium composes the largest inventory of all the radionuclides disposed in the reference disposal facility. As shown in Chapter 5, impacts due to migration of tritium are almost totally observed close to the disposal facility, and it is the most significant contributor to exposures at the boundary well. Farther away from the disposal facility--e.g., at the population well and surface water access location--the ground-water migration time is such that tritium decays to the point that it is not a particular problem.

For these four isotopes, NRC staff believes that each disposal facility should be analyzed on a case-by-case basis and based on the analysis, inventory limits established for each facility that should not be exceeded.

In addition, the analyses in Chapter 5 also identified the fact that the presence of certain chemicals (e.g. chelating agents) in large concentrations in waste increased the potential for migration of radionuclides. Small quantities of these agents contained in waste do not significantly increase the potential for migration. Large single or multiple shipments, however, could affect the long-term ground-water impacts. To address these aspects, wastes containing chelating agents in relatively large amounts (defined by NRC to exceed 0.1% by weight) should be disposed of only upon prior approval of the Commission. This will enable site specific consideration of the increased potential for migration that disposal of these chemicals at the site might present.

7.4 FINAL CLASSIFICATION

This section presents the final classification of waste for near-surface disposal based upon consideration of the previous three sections of this chapter. This classification is presented as a list of radionuclides in Table 7.2. In the table, Column 1 lists the maximum concentrations ($\mu Ci/cm^3$) for "Class A segregated waste." Above these concentrations, the waste must be placed into a stable waste form and disposed in a segregated manner from unstable waste, and so becomes "Class B stable waste." Column 2 presents a list of concentrations above which the Class B stable waste becomes "Class C intruder waste." That is, these wastes must be in a stable waste form, segregated from unstable waste forms, and also disposed with a barrier to an intruder. This barrier

Table 7.2 Waste Classification Table

Isotope	Column 1 Maximum Concentration for Class A Segregated Waste. Above This, It Is Class B Stable Waste μCi/cm³	Column 2 Concentrations Above Which Some Wastes Become Class C Intruder Waste μCi/cm³	Column 3 Maximum Concentration For Any Waste Class μCi/cm³
Any with half-life less than 5 years	700	70,000	Theoretical maximum specific activity
H-3	40	10^8	Theoretical maximum* Specific Activity
C-14	0.8	0.8	0.8*
Ni-59	2.2	2.2	2.2
Co-60	700	70,000	Theoretical maximum specific activity
Ni-63	3.5	70	70
Nb-94	0.002	0.002	0.002
Sr-90	0.04	150	700
Tc-99	0.3	0.3	0.3*
I-129	0.008	0.008	0.008*
Cs-135	84	84	84
Cs-137	1.0	44	4600
Enriched Uranium	0.04	0.04	0.04
Natural or Depleted uranium	0.05	0.05	0.05
Alpha-emitting transuranic isotopes			10 nCi/g
Pu-241			350 nCi/g

*Near-surface disposal facilities will be limited to a specified quantity for the disposal site. This quantity will be determined at the time the license is issued and will be governed largely by the characteristics of the site.

For isotopes contained in metals, metal alloys, or permanently fixed on metal as contamination, the values above may be increased by a factor of ten, except natural or depleted uranium which can be the natural specific activity.

For isotopes not listed above, use the values for Sr-90 for beta-emitting isotopes with little or no gamma radiation; the values for Cs-137 for beta-emitting isotopes with significant gamma radiation; and the values for U-235 for alpha-emitting isotopes other than radium.

Wastes containing chelating agents in concentrations greater than 0.1% are not permitted except as specifically approved by the Commission.

For mixtures of the above isotopes, the sum of ratios of an isotope concentration in waste to the concentration in the above table shall not exceed one for any waste class.

Concentrations may be averaged over the volume of the package. For a 55-gallon drum, multiply the concentration limits by 200,000 to determine allowable total activity.

Until establishment and adoption of other values or criteria, the values in this table (or greater concentrations as may be approved by the Commission in particular cases) shall be used in categorizing waste for near-surface disposal.

could take many forms (e.g., concrete covers), but the minimum acceptable barrier would be disposal so that a minimum of 5 meters of earth or lower activity (Class B) waste, or a combination thereof, separates the waste from the potential inadvertent intruder. Other types of barriers would also be considered on a case-by-case basis.

Column 3 presents a list of radionuclide concentrations above which the waste would generally not be considered suitable for near-surface disposal. Wastes which exceed this concentration would need to be disposed of by disposal methods providing greater protection against potential intrusion. These methods could include much deeper disposal, mined cavity disposal, or special engineered disposal techniques. As noted in Chapter 2, NRC plans to address these other methods in subsequent rulemaking actions.

As discussed in Section 7.1, NRC also considered the use of a specially designed and engineered near-surface disposal facility (a "hot waste" facility) for disposal of wastes containing radionuclides in concentrations exceeding those listed in Column 3. NRC has not listed these concentrations because at this time staff believes that there are some uncertainties involved in use of such a facility and the volume of waste which could require disposal by this method would be small. NRC staff would prefer to address use of this potential disposal method on a case-by-case basis. From the analysis performed, however, the NRC staff believes that such an engineered disposal method would be suitable for wastes containing higher (than Column 3) concentrations of relatively short-lived isotopes such as Cs-137, Sr-90, or Ni-63. The additional long-term protection from longer-lived isotopes would be negligible.

Waste form requirements for the three classes of waste are presented in Table 7.3. These requirements were developed based upon the analyses in Chapters 4 through 6, and can be separated into minimum requirements and stability requirements. The minimum requirements are principally meant to help assure operational safety during handling and disposal, and should be met by all waste classes. The stability requirements are to be met by Classes B and C and are mainly intended to help provide long term structural stability and to minimize potential for inadvertent intrusion into and migration from Class B and Class C waste. In addition, each package of waste must be labeled to identify whether it is Class A, B or C waste and the total activity of H-3, C-14, I-129 and Tc-99 must be shown in the shipping manifest to enable the site operator to maintain an inventory of these isotopes disposed of at each site.

Alpha-emitting transuranic isotopes with a half life greater than 5 years are limited to 10 nCi/gm for near surface disposal. For Pu-241, which is a beta emitter and decays to Am-241, a limit of 350 nCi/gm is established.

As shown on the table, there is no upper limit on the allowable concentration of any isotope with a half-life under 5 years, H-3, or Co-60. The calculated limits exceed the natural specific activity of the isotopes. For isotopes with half-lives less than 5 years in Columns 1 and 2, NRC staff have used the concentration limits for Co-60. This is believed to be conservative, since Co-60 emits two energetic gamma rays. As discussed earlier, there is little cause for concern for potential intruder impacts for isotopes with half-lives less

Table 7.3 Waste Form and Packaging Requirements in Accordance with Waste Classification

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Minimum Requirements for all Waste Classes

1. The waste must be packaged and the waste form and packaging must meet all applicable transportation requirements of the Commission set forth in 10 CFR Part 71 and of the Department of Transportation set forth in 49 CFR Parts 171-179, as applicable.

2. Wastes must not be packaged for disposal in cardboard or fiberboard boxes.

3. Waste containing liquids must be packaged in sufficient absorbent material to absorb twice the volume of the liquid.

4. Waste must not be readily capable of detonation or of explosive decomposition or reaction at normal pressures and temperatures, or of explosive reaction with water.

5. Waste must not contain, or be capable of generating, quantities of toxic gases, vapors, or fumes harmful to persons transporting, handling, or disposing of the waste.

6. Wastes must not be pyrophoric. Pyrophoric materials contained in wastes shall be treated, prepared, and packaged to be nonflammable.

7. Wastes in a gaseous form must be packaged at a pressure that does not exceed one atmosphere at 20°C. Total activity must not exceed 100 curies per container.

8. Wastes containing biological, pathogenic, or infectious material must be treated to reduce to the maximum extent practicable the potential hazard.

Stability Requirements for Classes B and C

1. Waste must have structural stability. Structural stability can be provided by the waste form itself, processing the waste to a stable form, or placing the waste in a disposal container or structure that provides stability after disposal. A stable waste form will maintain its physical dimensions within 5% and its form, under the expected disposal conditions of compressive load of 50 psi, and factors such as the presence of moisture, and microbial activity, and internal factors such as radiation effects and chemical changes. Stability is intended to assure that the waste does not degrade and promote slumping, collapse, or other failure of the disposal unit and thereby lead to water infiltration. Stability is also a factor in limiting exposure to an inadvertent intruder, since it provides a recognizable and nondispersible waste.

2. Liquid wastes, or wastes containing liquid, must be converted into a form that contains as little free-standing noncorrosive liquid as is reasonably achievable, but in no case shall the liquid exceed 1% of the volume of the waste.

3. Void spaces within the waste and between the waste and its package must be reduced to the extent practicable.

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than 5 years. For example, and as shown in Section 7.2, the calculated limits for Fe-55, which has a 2.6 year half-life, exceeded the natural specific activity of the isotope in all columns. The principal reason for inclusion of classification limits is to help provide some additional operational safety during handling and disposal.

Other considerations are discussed below.

7.4.1 Limits for Ground-Water Migration

The concentration limits in the three columns were established based upon consideration of impacts to a potential inadvertent intruder. The NRC staff also believes that ground-water impacts are of critical importance but recognizes the extremely site-specific nature of ground-water migration and potential impacts. In addition, ground-water impacts are a function of the total inventory of particular radionuclides at the disposal facility, and it is difficult to convert this total inventory to concentration limits. Therefore, NRC has adopted a different approach for ground-water migration.

Based on the analyses in Chapter 5 and as discussed in Section 7.3, four isotopes were identified that are most important with respect to groundwater impacts. For these isotopes--H-3, C-14, Tc-99, and I-129--NRC staff believes that it would be most workable to analyze each disposal facility on a case-by-case basis. Depending upon the specific environmental conditions of the disposal facility, as well as the particular design of the disposal facility, a maximum site inventory of these radionuclides would be derived for the particular site. Then, a running inventory of these isotopes from waste delivered to the disposal facility would be maintained. This will also require special consideration by waste generators for the reporting of these isotopes.

7.4.2 Isotopes Not on List

The table lists 11 isotopes having half-lives over 5 years, natural, depleted and enriched uranium, plus transuranic radionuclides. These are believed to generally cover many, if not most, of the longer-lived radionuclides currently delivered to any disposal facility. Of the hundreds of radioactive isotopes that have been identified, most have half-lives in the range of days or less and only about 100 have half-lives exceeding 5 years. Many of these isotopes are so exceedingly long-lived--e.g., K-40 (1.26×10^9 year half-life), Pt-190 (6.9×10^{11} year half-life), Re-187 (4.3×10^{10} year-half life)--or occur in such small abundances that development of classification limitations is not believed to be of high priority.

However, it is recognized that there are several isotopes--particularly those of heavy metals such as thorium, lead, or radium--for which concentration limits should be developed. Others may also be identified. Development of concentration limits for such radionuclides are planned subsequently. In the meantime, some working concentration limits should be considered for isotopes not presently analyzed. For these, the NRC staff believes a reasonable, yet conservative, rule of thumb would be the following:

- Use of values for Sr-90 for beta-emitting isotopes with little or no gamma radiation;
- Use of values for Cs-137 for beta-emitting isotopes with significant gamma radiation; and.
- Use of values for enriched uranium (U-235) for alpha-emitting isotopes other than radium.

For radium, no limits are established as of yet. In addition, the limits established for natural uranium do not consider the ingrowth of daughter nuclides. NRC plans to analyze daughter ingrowth and determine whether the calculated values change based on consideration of daughter nuclides.

Mixtures of Radioisotopes

The list is given for concentrations of single isotopes. However, LLW packages delivered to disposal facilities seldom contain just one radioisotope; generally, the waste packages contain a mixture of radioisotopes. To account for this mixture, NRC staff propose to apply a similar sum-of-the-fractions rule to that described in Table II of the existing 10 CFR Part 20. That is, the sum of ratios of an isotope concentration in waste to the concentrations in the table shall not exceed unity for any waste class. That is,

$$\frac{C_a}{C'_a} + \frac{C_b}{C'_b} + \frac{C_c}{C'_c} \leq 1, \text{ where}$$

C_a, C_b, C_c = concentrations in waste of isotopes a, b, and c;

C'_a, C'_b, C'_c = limiting concentrations in a given waste class for isotopes a, b, and c.

In addition, concentrations may be averaged over the volume of any package. For example, for a 55 gallon drum, the concentration limits may be multiplied by a factor of 200,000 (the approximate volume of a 55 gallon drum in cm^3 to determine the allowable total activity that could be placed in a 55 gallon drum.

7.5 IMPLEMENTATION OF WASTE CLASSIFICATION REQUIREMENT

In order to implement a waste classification requirement, it will be necessary for waste generators to identify and quantify specific radionuclides in the final waste form as shipped for disposal. The concentrations (or total inventories) of the identified radionuclides in each waste package would be recorded on the shipment manifest documents accompanying the waste packages. Also indicated would be the classification of the shipped waste packages (i.e., either Class A, B, or C). The radionuclides listed explicitly in Table 7.2 are of particular importance for identification due to their mobility in the environment and/or their potential hazard to an inadvertent intruder.

This can lead to a number of operational difficulties, since (a) the identity and concentration of radionuclides in each waste package must be determined and entered on the shipment manifest prior to removal of the waste from the generator's facility and (b) the analytical procedures for a number of the radionuclides of interest are complex, expensive, and time-consuming. It is not believed practical in many cases to determine concentrations of all relevant specific radionuclides by direct measurements. In some cases measurements of gross radioactivity may be used; for example, (a) for waste having odd geometries or physical characteristics which make collection of samples and/or data prohibitively difficult; (b) when the total gross radioactivity concentrations are known to be a small fraction of the radioactivity of the mixtures of the radionuclides listed in the relevant column of Table 7.2; or (c) when gross radioactivity measurements are shown to be truly indicative of the actual concentration of the radionuclides contained in the waste. For most higher activity waste streams such as those generated by nuclear fuel cycle generators and occasionally by industrial and institutional generators, however, gross radioactivity measurements may not always be practical or acceptable.

A measurement procedure therefore would need to be implemented in many cases which would be a compromise between the need to identify and quantify specific radionuclides and the practical difficulties in routinely measuring all radionuclides. One solution could be to routinely measure only those radionuclides that can be reasonably and accurately measured without terribly expensive and sophisticated techniques. Concentrations of other radionuclides would be scaled to the measured radionuclides based upon existing or generator-specific data. Additional measurements would be performed to determine concentrations of other radionuclides if the measured radionuclide concentrations exceed given action levels. A more detailed set of measurements could be performed periodically (e.g., annually or semiannually) or after a significant process change to upgrade the scaling factors and the action levels.

For purposes of review and comment, NRC has prepared a specific example on the use of scaling factors and action levels for LWR waste streams. The example reflects the type of guidance which could be set out in a regulatory guide on classification of waste. Two radionuclides which are present in LWR waste streams and can be readily measured by Ge(Li) gamma spectroscopy are Co-60 and Cs-137. In the procedure, these two isotopes would be routinely measured and the concentration of other radionuclides estimated based upon scaling factors developed from either data specific to the facility or from a set of reference scaling factors developed from existing data. Samples may be taken for analysis either from (a) the final waste form, or (b) the waste after any and all volume reduction but prior to solidification. If the concentrations of Co-60 or Cs-137 exceed certain action levels, then other radionuclides would be measured. The action levels used may also be either based upon data specific to the facility or from a set of reference action levels based upon existing data. If the concentrations of Co-60 and Cs-137 do not exceed the action levels, then other radionuclides would not need to be analyzed.

An example set of scaling factors and action levels has been drafted and are included here (Ref. 7). To establish these factors and action levels, estimates of upper-range concentrations of particular radioisotopes were first established.

These upper-range estimates are presented in Table 7.4 and were made based upon maximum reported concentrations obtained from a number of studies performing measurements of transuranic and other radionuclide concentrations in LWR wastes (Refs. 8-11). For a number of radionuclides, however, there was insufficient experimental data. For these radionuclides, upper-range concentrations were estimated based upon use of the scaling procedures used to establish the waste stream concentrations in this environmental impact statement. Concentrations are presented for three BWR waste streams (ion exchange resins, concentrated liquids, and filter sludge) and four PWR waste streams (ion exchange resins, concentrated liquids, filter sludge, and filter cartridges). (Additional information may be obtained from Appendix D, and References 7 and 12.)

Once the upper-range concentrations were obtained, upper-range scaling factors for specific waste streams were calculated. These scaling factors for the above three BWR streams and four PWR streams are given in Table 7.5. Action levels are then calculated by dividing the concentration limits in Table 7.2 by the scaling factors in Table 7.5 to determine the Co-60 and Cs-137 concentrations at which the concentrations of radionuclides more difficult to measure would exceed these respective limits. These action levels for the BWR and PWR waste streams considered are presented in Tables 7.6 and 7.7.

As mentioned earlier, these scaling factors and action levels are believed to be generally conservative and would be used as an option. Generally, a waste generator could develop his own scaling factors and action levels based upon facility-specific data.

Table 7.4 Estimated Upper-Range Maximum Radionuclide Concentrations (μCi/cm³)

	BWRs			PWRs			
	IX Resins	Conc. Liq.	Filt. Sludge	IX Resins	Conc. Liq.	Filt. Sludge	Filt. Cartrg.
H-3	2.27E+02	1.07E+01	2.63E+02	1.44E+02	4.23E+00	1.68E-01	9.52E+00
C-14	6.68E+00	3.15E-01	7.74E+00	1.07E+03	3.12E+01	1.24E+00	7.02E+01
Fe-55	3.69E+02	1.01E+02	9.15E+02	9.75E+01	9.98E+01	6.30E+00	2.83E+01
Co-60	7.34E+01	2.00E+01	1.82E+02	2.54E+01	2.60E+01	1.64E+00	7.14E+01
Ni-59	4.53E+02	1.23E-02	1.12E-01	1.57E-02	1.60E-02	1.10E-03	4.41E+02
Ni-63	4.42E+00	1.20E+00	1.10E+01	1.71E+01	1.76E+01	1.11E+00	4.82E+01
Sr-90	2.17E+00	1.02E-01	2.51E+00	7.10E+01	2.08E+00	8.24E-02	4.68E+00
Nb-94	1.43E+03	3.90E-04	3.44E-03	4.95E-04	5.07E-04	3.20E-05	1.39E-03
Tc-99	2.00E-03	9.45E-05	2.32E-03	4.20E-03	1.23E-04	4.88E-06	2.77E-04
I-129	5.34E-02	2.52E-03	6.19E-02	5.94E-02	1.74E-03	6.89E-05	3.91E-03
Cs-135	2.00E-03	9.45E-05	2.32E-03	4.20E-03	1.23E-04	4.88E-06	2.77E-04
Cs-137	5.34E+01	2.52E+00	6.19E+01	1.12E+02	3.28E+00	1.30E-01	7.39E+00
U-235	1.85E-04	6.10E-11	8.74E-06	5.21E-06	2.39E-07	3.28E-07	7.62E-07
U-238	1.46E-06	4.80E-10	6.88E-05	4.10E-05	1.88E-06	2.58E-06	6.00E-06
Np-237	3.56E-11	1.17E-14	1.68E-09	1.00E-09	4.59E-11	6.30E-11	1.40E-10
Pu-238	7.36E-03	9.85E-02	3.35E-02	1.50E-02	1.03E-02	2.02E-04	2.64E-02
Pu-239/240	4.31E-03	1.44E-02	2.15E-02	2.26E-02	3.60E-02	5.07E-04	3.78E-02
Pu-241	6.29E+01	2.10E+02	3.14E+02	5.47E+02	8.71E+02	1.23E+01	9.15E+02
Pu-242	9.44E-06	3.15E-05	4.71E-05	4.95E-05	7.88E-05	1.11E-06	8.28E-05
Am-241	2.25E-03	1.51E-02	1.72E-03	1.01E-02	3.29E-03	2.64E-04	1.80E-02
Am-243	1.52E-04	1.02E-03	1.16E-04	6.83E-04	2.22E-04	1.78E-05	1.22E-03
Cm-243	2.50E-06	1.50E-05	7.79E-06	9.92E-05	4.43E-06	2.48E-06	2.65E-05
Cm-244	1.77E-02	1.25E-02	4.04E-03	1.76E-02	4.32E-03	1.28E-02	1.51E-02

Table 7.5 Calculated Scaling Factors for LWR Process Wastes

	BWRs			PWRs			
	Resins	Conc. Liq.	Filt. Sludge	IX Resins	Conc. Liq.	Filt. Sludge	Filt. Cartrg.
H-3 to Cs-137	4.25E+0	4.25E+0	4.25E+0	1.29E+0	1.29E+0	1.29E+0	1.29E+0
C-14 to Cs-137	1.25E-1	1.25E-1	1.25E-1	9.55E+0	9.51E+0	9.54E+0	9.51E+0
Fe-55 to Co-60	5.03E+0	5.05E+0	5.03E+0	3.84E+0	3.84E+0	3.84E+0	3.96E-1
Ni-59 to Co-60	6.17E-4	6.15E-4	6.15E-4	6.18E-4	6.15E-4	6.16E-4	6.18E-4
Ni-63 to Co-60	6.02E-2	6.00E-2	6.04E-2	6.73E-1	6.77E-1	6.77E-1	6.75E-1
Sr-90 to Cs-137	4.06E-2	4.05E-2	4.05E-2	6.34E-1	6.34E-1	6.34E-1	6.34E-1
Nb-94 to Co-60	1.95E-5	1.95E-5	1.95E-5	1.95E-5	1.95E-5	1.95E-5	1.95E-5
Tc-99 to Cs-137	3.75E-5	3.75E-5	3.75E-5	3.75E-5	3.75E-5	3.75E-5	3.75E-5
I-129 to Cs-137	1.00E-3	1.00E-3	1.00E-3	5.30E-4	5.30E-4	5.30E-4	5.30E-4
Cs-135 to Cs-137	3.75E-5	3.75E-5	3.75E-5	3.75E-5	3.75E-5	3.75E-5	3.75E-5
U-235 to Cs-137	3.46E-6	2.42E-11	1.41E-7	4.65E-8	7.29E-8	2.52E-6	1.03E-7
U-238 to Cs-137	2.73E-8	1.90E-10	1.11E-6	3.66E-7	5.73E-7	1.98E-5	8.13E-7
Pu-241 to Cs-137	1.18E+0	8.33E+1	5.07E+0	4.88E+0	2.66E+2	9.46E+1	1.24E+2
Tru to Cs-137	5.95E-4	5.62E-2	9.84E-4	6.34E-4	1.66E-2	1.06E-1	1.46E-2

TRU Isotopic Scaling Factors

	BWRs			PWRs			
	Resins	Conc. Liq.	Filt. Sludge	IX Resins	Conc. Liq.	Filt. Sludge	Filt. Cartrg.
Np-237 to Cs-137	6.67E-13	4.64E-15	2.71E-11	8.93E-12	1.40E-11	4.85E-10	1.98E-11
Pu-238 to Cs-137	1.38E-4	3.91E-2	5.41E-4	1.34E-4	3.14E-3	1.55E-3	3.58E-3
Pu-239/240 to Cs-137	8.07E-5	5.71E-3	3.47E-4	2.02E-4	1.10E-3	3.90E-3	5.12E-3
Pu-242 to Cs-137	1.77E-7	1.25E-5	7.61E-7	4.42E-7	2.40E-5	8.54E-6	1.12E-5
Am-241 to Cs-137	4.21E-5	5.99E-3	2.78E-5	9.02E-5	1.00E-3	2.03E-3	2.44E-3
Am-243 to Cs-137	2.85E-6	4.05E-4	1.87E-6	6.09E-6	6.77E-5	1.37E-4	1.65E-4
Cm-243 to Cs-137	4.68E-8	5.95E-6	1.26E-7	8.86E-7	1.35E-6	1.91E-5	3.59E-6
Cm-244 to Cs-137	3.31E-4	4.96E-3	6.53E-5	1.57E-4	1.32E-3	9.85E-2	3.33E-3

Table 7.6 Process Waste Action Limits for BWRs

1. Class A Segregated Wastes

Measured Co-60 Conc. (uCi/cm^3)	Waste Stream	Additional Direct Measurements
5.8E+1	Any*	Ni-63

Measured Cs-137 Conc. (uCi/cm^3)		
5.0E-3	CONCLIQ	Pu-242
5.9E-2	FSLUDGE	Pu-241
2.1E-1	CONCLIQ	TRU
2.4E-1	IXRESIN	Pu-241
9.9E-1	Any	Sr-90

2. Class B Stable Waste

Measured Co-60 Conc. (uCi/cm^3)		
1.0E+2	Any	Nb-94
1.2E+3	Any	Ni-63
3.6E+3	Any	Ni-59

Measured Cs-137 Conc. (uCi/cm^3)		
5.0E-3	CONCLIQ	Pu-241
5.9E-2	FSLUDGE	Pu-241
2.1E-1	CONCLIQ	TRU
2.4E-1	IXRESIN	Pu-241
6.4E+0	Any	C-14
8.7E+0	FSLUDGE	TRU
1.4E+1	IXRESIN	TRU

3. Class C Intruder Waste

Measured Co-60 Conc. (uCi/cm^3)		
1.0E+2	Any	Nb-94
1.2E+3	Any	Ni-63
3.6E+3	Any	Ni-59

Measured Cs-137 Conc. (uCi/cm^3)		
5.0E-3	CONCLIQ	Pu-241
5.9E-2	FSLUDGE	Pu-241
2.1E-1	CONCLIQ	TRU
2.4E-1	IXRESIN	pu-241
6.4E+0	Any	C-14
8.7E+0	FSLUDGE	TRU
1.4E+1	IXRESIN	TRU

*Any = IXRESIN, CONCLIQ, FSLUDGE.

Table 7.7 Process Waste Action Limits for PWRs

1. Class A Segregated Wastes

Measured Co-60 Conc. (uCi/cm³)	Waste Stream	Additional Direct Measurements
5.2E+0	Any[a]	Ni-63
Measured Cs-137 Con. (uCi/cm³)		
1.3E-3	CONCLIQ	Pu-241
1.7E-3	FCARTRG	Pu-241
3.2E	FSLUDGE	Pu-241
6.3E-2	Any	Sr-90
6.5E-2	IXRESIN	Pu-241
8.1E-2	FSLUDGE	TRU
8.4E-2	Any	C-14
4.1E-1	FCARTRG	TRU
6.0E-1	CONCLIQ	TRU

2. Class B Stable Waste

Measured Co-60 Conc. (uCi/cm³)		
1.0E+2	Any	Ni-63, Nb-94
3.6E+3	Any	Ni-59
Measured Cs-137 Conc. (uCi/cm³)		
1.3E-3	CONCLIQ	Pu-241
1.7E-3	FCARTRG	Pu-241
3.2E-3	FSLUDGE	Pu-241
6.5E-2	IXRESIN	Pu-241
8.1E-2	FSLUDGE	TRU
8.4E-2	Any	C-14
4.1E-1	FCARTRG	TRU
6.0E-1	CONCLIQ	TRU
1.43+1	IXRESIN	TRU
1.5E+1	Any	I-129

3. Class C Intruder Waste

Measured Co-60 Conc. (uCi/cm³)		
1.0E+2	Any	Ni-63, Nb-94
3.6E+3	Any	Ni-59
Measured Cs-137 Conc. (uCi/cm³)		
1.3E-3	CONCLIQ	Pu-241
1.7E-3	FCARTRG	Pu-241
3.2E-3	FSLUDGE	Pu-241
6.5E-2	IXRESIN	Pu-241
8.1E-2	FSLUDGE	TRU
8.4E-2	Any	C-14
4.1E-1	FCARTRG	TRU
6.0E-1	CONCLIQ	TRU
1.4E+1	IXRESIN	TRU
1.5E+1	Any	I-129
1.1E+3	Any	Sr-90
2.5E+3	FSLUDGE	U-238

*Any = IXRESIN, CONCLIQ, FSLUDGE, FCARTRG

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Chapter 8

REGULATORY PROGRAM--PRESENTATION AND ANALYSIS OF ALTERNATIVES

8.1 INTRODUCTION AND SUMMARY

The regulatory program is the combination of licensing procedures; requirements for recordkeeping, reports, and manifests; and participation by states and Indian tribes. The following discussion presents the existing licensing procedures, requirements for recordkeeping and reports, and state and tribal participation; alternatives and rationale considered; and changes proposed. The licensing procedures are discussed in two parts: (1) the licensing steps and (2) the information requirements and necessary Commission findings. The major changes in the licensing steps are to add a tendering step, to clarify renewals, and to define responsibilities and provide orderly steps after operations cease. The changes in required information and findings are directed at focusing on and complying with the performance objectives, technical criteria, financial requirements, and institutional controls. None of the changes in licensing procedures are judged to be a significant incremental burden. The major changes dealing with records, reports, and manifests are the initiation of a manifest system and specific reporting and recordkeeping requirements on the disposal facility operator. The manifest system requires the waste generator to provide more complete information in the shipping papers and to track shipments. The incremental burden is judged small. The facility operator must submit annual reports keep more complete records and participate in the manifest system. The new requirements reflect, to a large extent, existing practices imposed by host states and are not a significant new burden. The major changes concerning state and tribal participation are to propose a subpart establishing a formal mechanism for state and tribal participation in Commission license reviews, recognition of tribal rights, the initiation of interaction at the tendering step, and documentation concerning landownership and institutional care arrangements. The proposed changes are expected to improve state, tribal, and public participation and have little incremental impact on the applicant, the NRC, or the states, tribes, or public.

8.2 LICENSING PROCEDURES

Licensing procedures are the legal and procedural steps covering and defining the complete life cycle of a licensed activity. Requirements which the Commission must follow and which applicants must follow are included. Existing regulations for receipt of waste radioactive material from other persons for commercial disposal define procedural requirements which the Commission will follow in 10 CFR Part 2. General requirements that are to be followed by all byproduct, source, and special nuclear material applicants and licensees are specified in 10 CFR Parts 30, 40, and 70. Policies and procedures for complying with the requirements of the National Environmental Policy Act (NEPA) of 1969 are prescribed in 10 CFR Part 51. The decisions to be made are which of the existing requirements should be kept or modified, which dropped, and what new requirements should be added. Where the requirements should be located in the regulations must also be decided.

The placement of requirements for procedures for a land disposal facility is a matter of editorial preference and does not affect whether they apply or not and does not affect the impacts. The approach taken was to try and consolidate related requirements as much as possible and to relegate procedures which the Commission must follow in processing applications to 10 CFR Part 2, procedures for applicants and licensees to the new 10 CFR Part 61, and procedures for complying with NEPA to 10 CFR Part 51.

A basic objective in reviewing existing procedural requirements was to limit changes to those which would clearly improve the process. The following discussion will review the existing procedures and then discuss proposed changes including rationale and alternatives considered.

8.2.1 Existing Procedures

8.2.1.1 Licensing Steps

Existing procedures begin with receipt of an application. The application must be docketed upon receipt (10 CFR 2.101(a)). Local site and alternative site governmental officials must be notified by the applicant (10 CFR 2.101(b)), docketing noticed in the Federal Register by the Commission (10 CFR 2.101(d)), and the Governor and state officials notified by the Commission (10 CFR 2.101(d)). An environmental report (ER) must accompany the application (10 CFR 51.40(c)). Provisions such as §30.32(f) of Part 30 require that the ER be filed at least nine months before construction begins; however, 10 CFR 30.33(a)(5) provides that construction cannot begin until NEPA review by the Commission is finished. Under existing rules, hearings are held only if requested by the applicant or interested parties. Hearing procedures are described in 10 CFR Part 2.

After the Commission completes its review and prepares an environmental impact statement (10 CFR 51.5(b)), a decision to issue or deny the application is made. If no hearings have been requested and the decision is to issue a license, the notice of the proposed action must be published in the Federal Register (10 CFR 2.105(a)(2)). If no request for hearings are filed after the proposed action is noticed, the license is issued (10 CFR 2.105(e)) and state and local officials are notified and issuance noticed in the Federal Register (2.105(e) and 2.106(a)(1)). If hearings are requested, they are held in accordance with the rules in 10 CFR Part 2 beginning with hearings before an Atomic Safety and Licensing Board (ASLB). An Atomic Safety and Licensing Appeal Board and/or the Commission may review the findings of the ASLB or the ASLB findings may be appealed to the Appeal Board or the Commission and to the courts. Upon resolution of the hearings, reviews, and appeals a license is issued and noticed in the Federal Register.

After the license is issued it may be amended. Preparation of ERs and EISs is judgmental under Part 51 for amendments. If no hearings are requested and if the amendment involves a significant hazards consideration, it must be noticed in the Federal Register as a proposed action (2.105(a)(3)) and noticed after issuance (2.106(a)(1)). Renewals are handled in the same manner. Continued operation is provided if a timely application for renewal is filed (10 CFR 2.109). Termination of licenses is handled as an amendment and is not specifically mentioned in the regulations.

8.2.1.2 Contents of Applications

Parts 30, 40, and 70 provide general requirements for contents of applications and findings necessary for issuing licenses. The requirements for approving applications are in §§30.33, 40.32, and 70.23(a). A decision that the applicant's training and experience and equipment and facilities are adequate must be made. Procedures must be adequate and the proposed activities authorized by the Atomic Energy Act.

8.2.2 Changes and Alternatives to Existing Procedures

8.2.2.1 Scope of Procedures

A fundamental issue for the procedural aspects of the rulemaking is whether each of the procedures and requirements apply to all land disposal applicants and licensees or just to near-surface disposal applicants and licensees. The licensing steps to be prescribed in the proposed rulemaking should be equally valid for all methods of land disposal. The requirements for contents of applications, Commission findings, and other procedural requirements can also be general for all disposal methods.

8.2.2.2 Licensing Steps

8.2.2.2.1 Tendering

Alternatives to the process beginning with docketing were considered. One alternative was to require a notice of intent 3-6 months before filing an application. The notice of intent would be used to notify governors, legislatures, other state or municipal officials, or tribal governing bodies early in the process. Public concerns could be identified and factored into the applicant's proposal prior to submittal. This alternative was not adopted because: (1) it added an administrative burden on the applicant; (2) from a practical standpoint, it is probably not needed to assure early state input; and (3) its purpose can be accomplished by other means. For example, early state involvement is virtually assured by the "Low-Level Radioactive Waste Policy Act" (Ref. 1) which states that:

> "each State is responsible for providing for the availability of capacity either within or outside the State for the disposal of low-level radioactive wastes generated within its borders except for waste generated as a result of defense activities of the Secretary or Federal research and development activities."

States are reviewing needs, developing compacts, and taking other active measures concerning low-level wastes. Any applicant will have to develop a site in this context. Further, state ownership of the disposal site is likely and evidence of these negotiations are a required part of the application.

The second and preferred alternative was to provide a tendering step. Treating the application first as a tendered document allows the Commission to determine the extent to which the application and environmental report are complete and

acceptable for docketing. This should help avoid the delay associated with formally rejecting an application or environmental report that has been docketed and save the costs of reproducing and distributing copies that are incomplete or otherwise unacceptable for processing. Notification of state, local, and tribal officials at this point still allows early knowledge of the applicant's plans. Publication in the Federal Register at this early stage can be used to solicit public views and comments for consideration by the Commission and applicant. If the application and ER are acceptable for docketing as initially submitted, the time between tendering and docketing could be on the order of a month. Depending on the nature of the missing information, the time could be several months or more. Thus at no increased burden or delay for the applicant, a potential method for additional time for public input is provided. A new provision to explicitly state that Commission staff will be available was also added to help assure early interaction with state, county, and municipal officials and tribal governing bodies.

8.2.2.2.2 Docketing

The prescribed activities at the docketing stage for the applicant to distribute copies and the Commission to notice docketing in the Federal Register remain valid. With the tendering steps in place, no alternatives had merit.

8.2.2.2.3 NEPA

The requirements for the applicant to submit an ER and the Commission to prepare an EIS are consistent with NEPA and no alternatives were considered. The existing requirements, however, dealing with when construction may begin could be confusing to applicants. Since construction of a land disposal facility should not be complex or take more than a few months and since existing requirements provide that construction may not begin until the NEPA review is completed, no good reason to change this requirement seemed to exist. The language was, however, simplified. The major benefit of this requirement to not begin construction is to provide flexibility to consider alternative sites without the influence of commitments by the applicant at one site. Site exploration and associated activities are permitted and the commitment to investigate the site cannot be avoided.

8.2.2.2.4 Construction Authorization

The related issue of whether to issue a separate authorization for construction was also considered. Near-surface disposal facilities are current practice and are expected to dominate new applications. This expectation is discussed elsewhere and is the basis for developing specific technical requirements for this type facility first. The building of support facilities such as administrative offices, health physics labs, etc., and preparation of a near-surface facility for beginning operations would not ordinarily involve sufficient commitments to necessitate a separate authorization for construction. The one-step licensing as provided for under existing rules was maintained. If this one-step process should prove a burden for other land disposal methods, such a disposal in a mine, exemptions can be granted for construction work at the applicant's risk. Before authorizing receipt of waste, however, NRC will

inspect the facility to determine whether the facility is in conformance with the description, design, and construction described in the application.

8.2.2.2.5 Hearings

The only alternative to holding hearings if requested is to require hearings. This alternative was considered but not adopted for two principal reasons: (1) other means of input into the review of the application and environmental report are available and (2) the desire to minimize the burden on applicants consistent with health, safety, and environmental responsibilities. State, local and county officials, indian tribes, and the public can participate in the EIS scoping process and comment on the draft and final EIS documents. As discussed earlier, the state will probably be involved under the "Low-Level Radioactive Waste Policy Act" and is a potential landowner of the disposal site. Hearings require significant resources of all parties involved and at least a year to complete. If issues can be resolved by less formal methods, all benefit. The proposed revisions to 10 CFR Part 2 include offering a single opportunity for a hearing to the applicant and other affected persons in a Federal Register notice after docketing. The notice would be in accordance with existing requirements in §2.105. Noticing is not required for the applicant or interested parties to request hearings but it serves as a reminder. No changes were considered or proposed for the hearing process as currently defined in Part 2. Opportunity for hearings will also be specifically provided for renewals, site closure, license transfer, and license termination.

8.2.2.2.6 Issuing Licenses

Licenses are issued or denied under §2.103. Only a minor conforming change was considered and it was adopted. Section 2.103 requires, among other things, notification of state and local officials for initial issuance of a license for commercial disposal of wastes from other persons. This requirement was clarified and moved to the Notice of Issuance section (§2.106). The new subsection makes it clear that any action to issue a license for a land disposal facility or amendment of such a license involving a significant hazard consideration will be noticed in the Federal Register and officials notified regardless of whether hearings are held or not. No other changes to the amendment process were considered or proposed.

8.2.2.2.7 Renewals

Experience with existing sites has demonstrated a need to clarify the renewal process as it applies to disposal. Two alternatives were considered. One was to delete the provision for license expiration altogether. The license would remain in effect until terminated. The disadvantage of this alternative is primarily the lack of incentive to update the license to reflect the developing state-of-the-art technology and to fully factor operating experience and new site information and site performance into periodic reassessments of site operations and planning. The advantages are the reduced burden in fees and resources devoted to the renewal application by the licensee and in review by the Commission. The discipline of periodic renewals was chosen as the preferred

alternative. Other means of updating the license requirements such as submitting reports or reassessments under specific conditions of the license do not provide the same degree of assurance that the licensee and the Commission will act. Consistent with existing Commission practice for other licensees, no specific period for the renewal is specified in the regulations. For most licensees the usual period specified by specific license conditions is five years. Shorter or longer times are specified as judged appropriate. This same flexibility was retained.

The scope of the renewal process was also clarified based on experience with the existing sites. The renewal applies only to continued waste receipt and disposal operations not the licensee's continuing responsibility for disposed wastes. Existing specific license conditions for the Barnwell, South Carolina and Richland, Washington sites reflect this scope.

8.2.2.2.8 Closure

If the licensee no longer wishes to receive wastes, the licensee must file an application for site closure. Existing rules such as §30.34(f) require that licensees notify the Commission when they plan to discontinue licensed activities. Such procedures may be adequate when sealed sources, very small quantities, or very short half-lived materials are involved. They are not adequate for an orderly preparation of the disposal site for custodial care by the landowner. The closure activities are sufficiently important that specific provisions and guidance for this type of amendment was judged necessary and a less formal approval unacceptable. No alternatives were considered.

8.2.2.2.9 Postclosure

Once closure plans are approved by specific license amendment and implemented, several choices exist. The license can be terminated or transferred or the licensee can continue to control the site for a period of postclosure observation and maintenance. Although much of the work toward closure should be performed throughout the operational period, some final site contouring and preparation may be necessary. These measures need time to stabilize. Additional assurances that the site is performing as expected can be provided by a period of observation and monitoring. If the site closure measures need modification or correction, the facility operator would have the best experience to carry out the modification. Regulatory control and review of these activities provides additional assurances that the public health and safety are protected. The performance objectives to provide stability of the site after closure and to eliminate the need for ongoing active maintenance is aimed at the long-term care period. Continued responsibility of the facility operator for a period of at least five years of postclosure observation and maintenance was judged to provide reasonable assurances without undue burden (see the site closure and stabilization requirements in Chapter 5).

Following the period of licensed postclosure observation and maintenance, the the license may be terminated or transferred to the government agency which is to provide custodial care. The issue of whether the site owner should be licensed and, if so, how, is at the heart of this decision. By permitting use

of federal or state land or accepting title to the land, the government agency has accepted responsibility for long-term institutional control of the site. The nature and duration of the controls needed to assure that the performance objectives will be met is one of the findings the Commission must make in licensing the land disposal facility and in all subsequent licensing actions. For most land disposal facilities, reliance is placed on the institutional control and without it the public health and safety cannot be assured. The type of monitoring or surveillance performed might need to be changed during the custodial period based on site performance or other factors. In view of the reliance on institutional controls and the potential need for reassessing the control program, licensing the landowner was judged necessary for the Commission to fulfill its responsibilities.

The final question is how to license the custodial agency. The alternatives considered included: (1) issuing a general license to state and federal agencies for custodial care, (2) termination of the facility operator's license and issuing a new specific license to the custodial agency, (3) transferring an appropriately conditioned license to the custodial agency, (4) making the custodial agency a colicensee when the site is licensed, and (5) requiring that the custodial agency be the only licensee. The general license approach would provide regulatory authority over activities, provide a mechanism for requiring reports and allow inspections. The difficulty is in the site-specific nature of the control program, particularly the monitoring, and in the potential need to alter the program during the institutional control period. The general license does not provide sufficient flexibility and was not selected. Terminating one license and issuing another is procedurally more complex and requires development of specific requirements for contents and reviewing of such applications. Any action to terminate one license would have to be taken concurrently with the issuance of the new license to provide continuity of responsibility. Transfer of the license would accomplish continuity. Both would involve custodial agency consent to be a licensee. Consent by the agency has the advantage that the agency can assure that the site meets any applicable requirements not covered by the Commission's authority and that staff and resources are arranged to implement custodial care. It has the disadvantage that the agency may delay consent beyond the time the operator planned for in his financial arrangements.

Another way to assure continuity is to require that the state or federal agency be a colicensee when the site is initially licensed. The operators's responsibility would be terminated by amending the license to delete the operator and leave the agency as the only licensee. This arrangement does not eliminate the need for agreement between the parties but does provide the greatest assurances of responsibility. Colicensee arrangements involve complex agreements and arrangements between the two parties to clearly define roles and responsibility. Covering all situations can prove difficult. Because of the complexities and uncertainties a colicensee arrangement was not mandated. A final option considered was to require that the custodial agency be the only licensee. Any commericial firm involved would be a contractor only. The Commission has no basis to deny the commercial sector the right to be a licensee under existing authority. This option would require the government agency to be involved in the day-to-day operation at the site. The agency would be responsible for all activities and would, at the very least, have to audit and oversee the activities.

This option would eliminate the potential uncertainties and problems associated with termination, transfer, or even amendment to delete a colicensee.

The option selected is transfer of the license to the site owner. Administrative convenience and continuity are provided at little risk or burden to the licensee. The options for colicensees and site owner as required licensee are not precluded by the preferred option and may well be the option followed in some cases.

Active institutional care will be necessary to protect the public health and safety for a finite period. In analyses and findings throughout the earlier licensing phases, 100 years is the upper limit assumed for institutional control. Unless new information develops or future generations apply different criteria, the license should be terminated when the active institutional controls are no longer necessary and oversight and regulatory authority is no longer necessary. The only alternative is to leave the license open ended. A cutoff point and a specific provision for termination was judged preferable.

8.2.2.2.10 Summary

In summary, the licensing steps have been modified to add a tendering step, to clarify renewal, and to define responsibilities and provide orderly steps after operations cease. Specific license amendments are proposed for site closure, transfer to the site owner, and termination. The changes in licensing steps have been chosen to minimize the burdens on all parties. The incremental impacts caused should be positive in that more specific guidance is provided and roles are more clearly defined. No quantitative estimate of the impacts was attempted.

8.2.2.3 Contents of Applications and Findings

The license procedures also involve information exchange, analyses, and findings at each step. The existing very general requirements do not provide specific guidance to applicants or the Commission. The basic requirements such as complying with the Act, must still be met but questions such as how much detail should be in the regulations and how much deferred to other parts of the regulatory framework (e.g., regulatory guides, branch positions); how much flexibility can applicants and licensees be given and still accomplish the goal of minimizing resolution of issues on a case-by-case basis; and what is the resulting burden on applicants, licensees, or the Commission were considered in analyzing the contents of applications and other actions required. The results hopefully represent a reasonable balance of such considerations.

8.2.2.3.1 Contents of Applications

The principal purpose of the information in an application is to inform the Commission of the nature of the project and the safety evaluations that have been performed to evaluate whether the project can be carried out without undue risk to the health and safety of the public. The documentation of the information is the principal means (a) for an applicant to provide the information needed to understand the basis on which this conclusion has been

reached; (b) to be referenced in the license to describe the basis on which the license is issued; and (c) used by Commission inspectors to determine whether the project is being carried out within the licensed conditions.

A listing of the content of an application should be included to serve as a checklist and index to the requirements in the rule. It should be organized topically so that requirements are grouped together according to subject. The topics should include general information, specific technical information, technical analysis, institutional control, financial information, and a catchall: other information.

The general information required includes the identity of the applicant (the information requested should be similar to that requested in existing regulations, e.g., §70.22(a)(1), but should emphasize knowing exactly what corporate arrangements exist); the commitments for financial assurances and the long-term responsibilities of the site operator; a description of the technical qualifications of the applicant (existing regulations, e.g., §70.22(a)(6), already required this information); the organizational structure and maintenance of a trained complement of personnel; and a general description of the planned activity and types of waste to be accepted for disposal (e.g., see existing §§70.22(a)(2) and (4)).

The specific technical information to be included covers the data base needed to demonstrate compliance with the performance objectives and technical requirements. The data base must cover site characteristics, facility design, operating plans, site closure plans, detailed waste description, and procedures for quality assurance, radiation safety, and administrative control.

The technical analyses that should be conducted are those needed to demonstrate compliance with the performance objectives.

Information concerning arrangements for institutional control should be required for two reasons: (1) the importance of the control for assurance of protection of the public health and safety and (2) the desire not to expend Commission and applicant time and resources on projects that cannot be licensed. The state or federal agency that either owns the land where the disposal site will be located or will be expected to accept title to the land before a license is issued will be expected to assume responsibility for institutional control. Under the proposed licensing steps, the state or federal government will also be expected to accept transfer of the license following the postobservational and monitoring period and carry out the institutional control under license. By requiring information in the application that the intended landowner and institutional control agency are aware of and understand their responsibilities and are prepared to accept them, wasted efforts and misunderstandings should be minimized. Two specific provisions are proposed: (1) submission of a certification that the government agency is prepared to accept transfer of the license and (2) submission of evidence that the land is government-owned or that arrangements have been made for assumption of ownership before the Commission issues a license. More flexibility was provided on the ownership issue because ownership must be in place before the license is issued whereas the license

transfer occurs decades later. Also, specifying a certification to address all circumstances and to adequately protect the government agency's interests would prove difficult.

Provisions for financial information should require the applicant to demonstrate financial qualifications. Demonstrating financial qualifications is not new. Part 70 notes the option to require this information (§70.22(a)(8)).

A miscellaneous section or other information section was needed to pick up potentially applicable requirements for special nuclear materials (SNM) and provide the Commission the option to request additional information should the proposed activities warrant. Part 73 physical security measures can be referenced to alert the applicant to existing requirements. Any physical security measures would be in addition to provisions for industrial type security and measures to prevent unauthorized access to other materials that would be included in radiation safety and administrative procedures. Part 73 has threshold quantities of SNM expressed in terms of quantities; enrichment and other factors subject to change so referencing was chosen over repetition. Existing practice that such measures should apply only to materials at the facility before disposal was noted. Similar reasoning applies to criticality accident and alarm requirements. Part 73 applicability can be easily provided by amending the purpose and scope Section (§73.1). These changes were needed to maintain the status quo for SNM licensees. Past practices at sites have not warranted physical security or criticality alarms, but the potential for future storage of quantities of concern must be addressed. Requiring criticality control information for materials in storage and emplacement in the disposal unit reflects current practices and was retained.

With respect to the number of copies of the application and environmental report, referencing to eliminate repetition, and updating of application, existing practices should be maintained except that the applicant should file only three copies. The three-copy limit is a provision of the Paperwork Reduction Act of 1980 and even though the Act may not apply since fewer than 10 applicants are expected, compliance with the intent was chosen.

8.2.2.3.2 Findings

All actions taken by the Commission must be consistent with its responsibility to protect the public health and safety and assure that issuance of the license will not be inimical to the common defense and security of the public. In order to structure the considerations the Commission will follow in reaching a decision, specific findings should be listed in the Part 61 rule. Existing regulations (§§30.33 of Part 30, 40.32 of Part 40, and 70.23 of Part 70) also include lists of findings. For example, §70.23 lists findings concerning use consistent with the Atomic Energy Act; technical and financial qualification; adequate equipment, facilities and procedures; materials control; physical protection and security; emergency plans; and principal structures, systems, and components. The proposed findings should be of the same level of detail but structured to focus the

findings on the individual performance objectives and track the required content of an application. The findings should also acknowledge that the requirements of Part 51 must be met.

8.2.2.3.3 Conditions of Licenses

The conditions of licenses should reflect existing practices and provisions of Parts 30, 40, and 70. Prescribing specific license conditions in the regulations assures conformity on matters that are important and do not vary from licensee to licensee. Providing the authority to add specific conditions to individual licenses allows the Commission to address the site-specific considerations.

One provision should prohibit transfer of the license without Commission approval. Similar provisions are contained in 30.34(a) of Part 30; 40.41(b) of Part 40; and 70.32(a)(2) and 70.36 of Part 70. Another should provide the Commission the right to require necessary information in writing. Similar provisions are contained in 30.34(e)(4) of Part 30; 40.41(e)(4) of Part 40; and 70.32(b)(5) of Part 70.

A third should provide that the operator's license cannot be terminated until the site has been closed and stabilized and stabilization confirmed. Existing provisions in 30.34(f) of Part 30; 40.41(f) of Part 40; and 70.32(h) of Part 70 require that licensees notify the Commission when the licensee decides to discontinue activities under the license. The activities to be authorized pursuant to a new part for site operators include operation, closure and stabilization of the site, and postclosure observation and monitoring. The operator's responsibility does not cease when receipt of waste stops.

Other provisions should (1) subject the licensee to future rules, regulations, and orders and reflect existing language in 30.34(a) and (d) of Part 30; 40.41(a), (d), and (e) of Part 40; and 70.32(a)(8) and (b) of Part 70; (2) provide that licenses can be modified, revoked, or denied for false statements, compelling new information or failure to comply with the license and Commission rules, regulations, or orders as provided in existing regulations, e.g., 70.61(b) of Part 70 and (3) require that licensees confine activities to those in the license as in 30.34(c) of Part 30 and 40.41(c) of Part 40.

Authority to permit the Commission to add specific and detailed conditions to the licenses in accordance with existing practices as reflected in 30.34(e) of Part 30; 40.41(e) of Part 40; and 70.32(b) of Part 70 should also be provided.

One alternative provision considered was to provide flexibility to licensees to make minor changes to the facility or operating procedures without prior Commission approval. The best approach here was to create a hierarchy of license conditions. One category would be those which would require prior Commission approval and opportunity for hearing. A second category would be those requiring prior Commission approval but no opportunity for a hearing. A third category would be those which could be changed with Commission notification but without prior approval. In accordance with the provisions of Part 2, this would assure that those affecting health and safety would receive prior Commission approval and those involving significant health and safety considerations also the

opportunity for a hearing. At the same time, flexibility would be provided to the licensee to make minor changes without waiting for Commission approval.

8.2.2.3.4 License Amendments and Renewals

The provisions for amendments should follow existing practices in §§30.38 and 30.39 of Part 30; 40.44 and 40.45 of Part 40; and 70.34 and 70.35 of Part 70. Existing practices (e.g., §70.33) concerning renewals such as filing 30 days prior to expiration, timely extension, and specifically referencing previously submitted information should be retained. Specification that the Commission will apply the decision criteria and required findings for new applications to amendment and renewal applications should be included. This requirement is based on not compromising the basis for assurances that the performance objectives will be met and is a compact way of stating that the original criteria still apply.

8.2.2.3.5 Application for Closure

The contents of an application for closure should provide the final details of site closure based on all previous analyses and the collective experience during the operating phases. A final closure plan is required to pull all of the information together. Specific references to pertinent site data, test data, and environmental information should be provided as a reminder on the type of infor mation which may have been generated during operation that should be considered in developing the final plan. The Commission findings for issuing an amendment to implement closure are reasonable assurance that the performance objectives will be met.

8.2.2.3.6 Transfer of License

The information needed to determine whether the license may be transferred to the governmental site owner is confirmatory. Evidence that the site has been closed as approved, that the postclosure observation and maintenance has confirmed that the performance objectives should be met, and that the arrangements for transfer are in order must be provided so that the Commission can affirm the readiness for transfer and condition the license for custodial care.

Arrangements for transfer include that necessary transfers of funds and records has been accomplished. This requirement is to provide the custodial agency with the information base needed for future activities such as interpretation of monitoring results or planning of remedial work should it be necessary. Obviously, any funds for long-term care which have not already been turned over to the custodial agency should be transferred for use. The monitoring program should also be in place. For example, the custodian should not have to dig or case monitoring wells, and the custodial agency must be ready to assume the license. This finding is needed to assure that the transfer of responsibility to the site owner is orderly. All technical, institutional, and financial questions must be resolved in a manner acceptable to the site owner so that the custodial role may be assumed under the license.

8.2.2.3.7 Termination of License

The information needed and Commission findings are again confirmatory. The type and duration of custodial care found necessary when licensing the site and the types of wastes to be emplaced must be confirmed. The licensee must also demonstrate that any additional requirements imposed during the custodial period because of new information or requirements have been met.

In summary, as the proceeding discussion has shown, the steps leading to termination (1) acknowledge and address the unique nature of the activity being licensed, (2) focus needed attention on careful planning for closure and transfer for custodial care, (3) provide confirmatory observation, (4) remove existing uncertainties in the process, and (5) make maximum use of experience and operational history. The administrative and procedural aspects of the rule dealing with the licensing steps from tendering through termination do not impose new burdens or cause impacts in themselves. They codify, specify, and focus the process on the long-term performance objectives.

8.2.2.4 Miscellaneous Procedural Requirements

Standard practices concerning tests, inspections, and violations should be adopted.

8.2.2.4.1 Tests at Disposal Facilities

Provisions to require the licensee to permit the Commission to perform needed tests is standard existing practice (e.g., existing requirements in §30.53 of Part 30; §40.63 of Part 40; and §70.56 of Part 70).

8.2.2.4.2 Commission Inspection of Disposal Facilities

Provisions for Commission inspection are also standard existing practice. See, for example, §30.52 of Part 30.

8.2.2.4.3 Violations

Provisions for violations are standard existing practice. See, for example, §30.63 of Part 30.

8.3 RECORDKEEPING, REPORTS, MANIFESTS

8.3.1 Existing Requirements

Waste management involves the licensee who generates the waste, transporters or licensed waste collectors who handle packaged wastes, licensees who treat or repackage wastes, and the licensed disposal facility operator. Each of these licensees must meet a number of existing requirements in Parts 20, 30, 40, and 70 of the Commission regulations concerning transfer of licensed materials, recordkeeping, and reports. For example, §§ 30.41 of Part 30; 40.51 of Part 40; and 70.42 of Part 70 require that licensees verify that the intended recipient's license authorizes receipt of the type, form, and quality

of licensed material to be transferred. Further, § 20.401 of Part 20 requires that licensees keep records of disposals made under §§ 20.302 (any method not otherwise specifically authorized in the Commission's regulations which includes disposal facility operators), 20.303 (releases to sanitary sewerage systems) and deleted 20.304 (burial of small quantities in soil) until the Commission authorizes their disposition. Loss or theft of materials must be reported under § 20.402 of Part 20. Sections 30.51 and 40.61 of Parts 30 and 40 require that records of transfers of buried material be maintained for 5 years following transfers. Transfers and receipts of special nuclear material of greater than one gram must be reported on prescribed forms for safeguards accounting under § 70.54.

The collective result of the existing requirements in the Commission's rules is to generate a variety of records for retention by individual licensees. Minimum information requirements are not specified. The special needs for disposal activities including handling, emplacement, and data base generation are not addressed. No manifest or waste tracking system is currently provided.

8.3.2 Need for Manifest

The need for improved accountability for wastes and a better data base is reflected in activities of the EPA and the General Accounting Office (GAO). In rulemakings establishing 40 CFR 262-265 (Ref. 2), the EPA initiated a manifest tracking system for hazardous wastes. The new hazardous manifest system became effective November 19, 1980 and prescribes the requirements for and responsibilities of waste generators, waste transportors, and site operators. Contents of manifests, processing, and tracking shipments are specified. The GAO noted the need for improvements in these two areas for radioactive wastes in its report entitled, "The Problem of Disposing of Nuclear Low-Level Waste: Where Do We Go From Here?" published March 31, 1980 (Ref 3). The GAO recommended that NRC "Determine who the generators of low-level waste are in both the Agreement and non-Agreement States and how much waste each licensee is generating" and "Establish a method to track waste from the point of generation to the point of disposal."

The need for a tracking system for radioactive waste does not stem from a series of known lost or diverted shipments as was the case for hazardous wastes. However, the existing system does not preclude lost shipments. For example, wastes may be transferred by a waste generator to a common carrier for transport to a disposal facility. Under existing rules, the generator would only be aware that the shipment did not reach the disposal facility if he did not receive a bill from the disposal facility operator.

The need to have more specific information on who generated the wastes and waste content has been demonstrated in handling leaking or apparently leaking packages at the commerical burial grounds. Waste shipments are collected by brokers who prepare shipping papers for wastes from multiple generators. The packages and shipping papers did not indicate who actually filled the drums or other packages. If additional information on contents are needed to decide whether to open packages or evaluate the significance of leaking material, the broker could not provide the information.

States regulating the operation of the existing disposal facilities have initiated permitting systems to control who ships waste into the state for disposal. Nevada has a third-party inspection program for evaluating the waste programs of shippers. The states are reacting to the need for better control of shipments and shippers and better data bases.

8.3.3 Manifest

8.3.3.1 General Considerations

To address these needs, the Commission considered a number of alternatives. In developing alternatives, public input, EPA rulemaking, and state experiences were considered. One alternative was to defer to the individual states who host sites and let existing rules and the permitting systems of the state address the issues and not prepare any federal requirements. This alternative was rejected because the Commission recognized the need for positive controls, support of the states' efforts and more specific guidance for its licensees. A federally prescribed manifest system would provide uniformity for Commission licensees and a role for Agreement States to follow to minimize the effect of different schemes developed by different states.

Having decided to propose a manifest system to improve accountability for wastes and the data available, the Commission considered implementing alternatives. The central requirements for a manifest system are contents of manifests and how the manifests will be used. The Commission considered whether to put the manifest requirements in the parts of the regulation under which the waste is or will be generated (i.e., Parts 30, 40, 50, 60, 70, and 72) or in Part 20 which applies to all licensees. Part 20 was selected to centralize the requirement, eliminate repetition in the individual parts, and to avoid the problem of incorporation into new parts as they may be developed.

8.3.3.2 Contents and Format

For contents and format of a manifest, the Commission considered alternatives such as developing a specific form, prescribing minimum content, and how to most effectively use existing requirements for forms and papers. Since the Commission does not have a data processing program in place at this time that would require a specific form, minimum content was chosen. Shippers are already required to prepare shipping papers for radioactive shipments under DOT rules in 49 CFR 172. The DOT rules specifically allow (§172.201(a)(4)) other information to be included in the shipping papers. The least burden on licensees is to allow the use of a single form to meet DOT and NRC requirements. The minimum content identified by the Commission tracks DOT requirements and minimizes the incremental burden. The minimum contents proposed include: (1) the name, address, and telephone number of the persons generating and transporting the wastes; (2) as complete a description of the waste as practicable including type, volume, mass, radionuclide identity and concentration, total activity and chemical form; (3) solidification agents used; (4) 10 CFR Part 61 waste classification information; and (5) a certification of compliance.

The content requirements are somewhat more comprehensive than DOT requirements and reflect the minimal information needed for proper handling and emplacement of the waste at the disposal facility. Identifying the waste generator is new. The need to identify the generator surfaced during 1979 when problem shipments were being investigated. The generator can provide the most complete information concerning the shipment and answer questions concerning matters not covered in the manifest. Under DOT rules the shipper is identified for shipments by water only (49 CFR 172.202(a)(1)). The person transporting the waste would ordinarily provide the shipping papers and would be identified in the letterhead. The EPA hazardous manifest system requires specification of the generator, transportor intended, disposal site, and alternate disposal site. The proposed manifest requirements address generator and shipper in the paperwork and intended receiver through use of the manifest. Identity of the generator is preserved when brokers collect the waste by use of an indexing manifest with generator manifests attached. By attaching the generator's manifest, the broker does not have to copy the data.

The required description of the waste in the proposed mainifest is very similar to DOT requirements and provides for the practicable concept. DOT requires specification of the type or category, amount, names of radionuclides, total activity, and chemical or physical form if not special form. The proposed manifest adds only the requirement to specify the concentrations of individual nuclides as completely as practicable and the total quantity of critical long-lived nuclides which must be total site inventory controlled by the operator under the classification system in Part 61. Knowledge of radionuclide mix is also necessary under DOT rules to determine the type of labeling to use, so even this requirement is only marginally a new requirement. A specific requirement to identify the solidification agents used, if any, was added. Specifying the solidification agent is a subset of describing chemical/physical form that will be readily known by the generator. The current DOT requirements are not specific in this regard so that the agents are not routinely identified. Terms such as solid are used in DOT rules. This data will be of value in identify generic problems with certain agents and in assessing how to handle leaking or damaged packages.

Specifying the class of wastes based on waste classificaton specifications in Part 61 will be new but not a burden. The determination must be made in order to legally transfer the licensed material. Including the information in the manifest helps the disposal facility operator properly handle the waste by flagging it in the papers which are reviewed before off-loading begins.

The requirement for the waste generator to certify that the wastes are properly classified, described, packaged, labeled, ready for transport, and comply with DOT and NRC regulations is an existing practice. DOT rules (49 CFR 172.204(a) and disposal site host states already require this type of certification. The states also have additional certification and hold harmless provisions which should not be proposed in the revisions to Part 20 since they deal with clarifying state-shipper liabilities and relationships. The areas of certification are very similar to DOT. Only the requirement to classify according to 10 CFR Part 61 and abide by both DOT and NRC regulations is different. As noted above, preparation and classification of the waste according to 10 CFR

Part 61 will be necessary to comply with existing limits on transfers and verifying that the intended receiver is authorized to receive the waste. The Commission now has the regulatory requirement to comply with DOT (10 CFR 71.5 and 44 FR 63083) rules and it inspects and enforces compliance with DOT requirements. Certification is to remind licensees of the requirements and provide additional assurance of compliance.

8.3.3.3 Use

How the manifest is used determines its value in tracking the waste and generating a data base. Many options are possible in prescribing the number of copies, where they are sent, etc. In formulating the requirements for use, the complexity of the generator, broker, processor, and disposal facility operator system dictated that the use be specified by type of licensee. A single requirement would be unwieldy and confusing. The EPA hazardous rules are structured to provide standards, including manifest use, for the generator (40 CFR 262), transportor (40 CFR 263), and facility operator (40 CFR 264 and 265).

8.3.3.3.1 Generator

The Commission has approximately 9,000 licensees but probably only about 1/4 of these licensees ship waste for disposal. Exact numbers are not available since licensees are not required to submit reports on waste generation and transfer. Imposition of a reporting requirement on waste generators was considered but not imposed at this time. EPA hazardous rules require annual reports and provide a form for filing such reports. NRC is not prepared to process such reports, has the advantage of knowing the identity of its licensees, and felt that the manifest data could be processed to provide equivalent information. By the same token, a requirement to send a copy of the individual manifests to the Commission, a contractor, or another federal agency at the time of shipment was considered and dismissed for now. Mailing a copy to the Commission would take only a few minutes to tear off a carbon or xerox a copy. Transfers of SNM are already reportable as mentioned earlier. However, since a computer system to track shipments and to process the data is not in place the requirement was not included.

The manifest tracking system must clearly define responsibilities and be inspectable by the Commission. The system selected provides that the generator prepare the manifest, forward a copy to the intended recipient, include a copy with the shipment, retain a copy as long as needed to track shipments, and investigate late or missing shipments or parts of shipments. The generator is the only choice to complete the manifest. Forwarding a copy to the intended recipient is a new requirement to provide the basis for a crosscheck on shipments. The primary responsibility for assuring that the wastes reach its intended destination is the generator's. If the generator is transferring directly to the facility operator, the generator would forward a copy of the manifest to the operator. If the generator transfers to a broker who collects, stores, and delivers the waste, the broker would acknowledge receipt of transferred wastes and assume responsibility for tracking the waste to the disposal facility. Since the storage time permitted in broker licenses is

typically up to 6 months, timely acknowledgement of receipt of wastes by the disposal facility operator to the generator is not practical when a broker is involved. Thus the decision was made to transfer the responsibility. The generator forwarding a copy of the manifest or similar document with the shipmen is required to meet DOT shipping paper requirements so no alternatives were considered. No alternative to keeping a copy of the manifest until the wastes reach the disposal facility or are acknowledged by the broker were considered because communications or investigations concerning the waste would be hampered without the documents.

Investigating late or missing shipments or parts of shipments is part of the responsibility for tracking the waste. The alternative of NRC investigating the shipments was considered but dismissed because of the large number of licensees and limited Commission inspection resources and because the generator or broker would be more knowledgeable about the individual shipments and any contractors involved. The numbers of investigations should be small but no specific data are available. Preparing and filing reports on investigations will generate a data base to determine how much of a problem is involved. The licensee would need to document his investigation to show compliance with the regulatory requirement to investigate. A report is a reasonable means to document the efforts. Filing the report with the Commission will allow Commission review of the results to see if Commission followup action is required, and a measure of the number of such incidents. Thus the alternati of just maintaining the reports for inspection was not adopted. Other provisions in the Commission's rules require reports for similar investigations (e.g., 10 CFR 20.402 and 10 CFR 73.71).

8.3.3.3.2 Broker

The waste collector or broker is the licensee who collects packaged wastes from generators, consolidates wastes from many small generators for more economical shipment, and may provide other services to the generator. Brokers number in the tens of licensees. The broker's role has been discussed earlier in two respects: (1) the need to assume responsibility for tracking and conducting any investigations after taking possession and (2) the need for a mechanism to preserve information on the waste generator and how to minimize this burden. The broker is also important to preserving the acceptability of the waste for disposal. The generator must certify proper form, packaging, and classification at the point of transfer but cannot certify the actions of others. A certification by the broker that nothing has been done (such as opening containers and adding wastes) which would invalidate the generator's certification would highlight the broker's responsibility and provide additional assurances. The Commission decided that certification by the broker was preferable to no certification.

8.3.3.3.3 Processor

A licensed waste processor treats or repackages wastes. After receipt of the wastes, the processor becomes the new generator. The original generator cannot control what treatment or changes will occur. Therefore, the original generator's responsibility should end when acknowledgement of the receipt of

wastes is received under the proposed system. The information provided by the original generator is a key part of the basis for determining whether the waste classification and characteristics requirements in 10 CFR Part 61 are met and other provisions that must be certified. The processor would probably retain the manifests as records of receipts so a requirement that they be maintained until disposal is accomplished or investigations of late or mining shipments are investigated is not a burden and emphasizes their importance.

8.3.3.3.4 Disposal Facility Operator

The disposal facility operators (currently 2 companies for 3 disposal facilities) are the focal point of the manifest system and data collection. Since the facility is the ultimate destination of waste shipments, the facility operator must notify shippers that wastes were received so that generators or brokers will know whether to begin investigations to trace shipments. Several alternatives for imposing this requirement were considered. A very specific requirement specifying returning a copy of the manifest or some new form to the shipper was considered but not adopted. A general requirement to acknowledge the receipt was considered the least burdensome. Under the general requirement, methods such as telephone acknowledgement, billing, or an annotated copy of the manifest can meet the requirement. This flexibility will permit the operator to use the method best suited for the operator's administrative setup and flexibility from shipment to shipment in case of delays in disposal from the weather, etc.

A new requirement to document the conditions of received shipments and what is done to and with the wastes at the disposal facility would provide a record, focus attention on these activities, and consolidate data in one place. Requirements and practices already exist to perform survey evaluations and repackaging of shipments based on the need to assure safety during handling and emplacement of wastes. Facility operators routinely record the trench or trench location and date of disposal. They are also identifying problem shippers under the state permitting systems. Thus, the requirements to document all of this information on the manifest is not a burden. Certifying that handling and disposal of the wastes was conducted in accordance with the license and applicable Commission regulations provides further assurances that conscious attention was paid to the conditions and regulations.

Maintaining copies of the shipping papers is already practiced at the sites. A requirement to maintain the manifest that is used as shipping paper only codifies exisiting practices. The copies can be carbon, mechanically reproduced, or microfilm. The Commission considered having copies forwarded to the Commission, a contractor, or other agency, but did not require forwarding at this time. No data processing system is in place to handle the data. Maintaining records at the sites assures that the data exists. The Commission, other state or federal agencies, or the facility operators can access the data and conduct surveys or studies as needed. The current concern is that it exists. One site operator already has a computer data processing system in place to record information about the shipments. Imposing data processing on the site operator was considered but not adopted for two reasons: (1) to allow flexibility and (2) the federal agencies have been exploring a common data base and the feasibility of one national data processing capability.

Maintaining manifests is not a significant space burden. An estimate of the physical size of the records can be made from reviewing data provided for 1979 for the Barnwell site under contract to NRC. Copies of all shipping records were provided in 38 volumes. Each record is 8-1/2" x 14". The 38 volumes are collectively about 63" thick. The total volume of the records is therefore 7,500 cubic inches which is equivalent to 4.3 cubic feet. The records are from the disposal of 2.2 x 10^6 cubic feet of wastes. Nationally, 2.9 x 10^6 cubic feet of waste were disposed of so that nationwide the shipping records for 1979 would be about 5.7 cubic feet. No single facility will probably routinely handl volumes larger than Barnwell's 1979 volumes. Most will handle half or less.

8.3.3.3.5 Crosschecking

Under the proposed system the prime responsibility for tracking shipments is the shipper's. However, since no NRC or federal computer system is in place to crosscheck whether shipments reach their destination, other means of cross-checking was considered. Individual states do not have computer tracking system in place although such systems for tracking hazardous waste are being developed. As these systems are developed, joint use could be explored for crosschecking and enforcement. A national manifest is also being developed for hazardous waste that would standardize data for computer input. A major difference betwee tracking hazardous and radioactive wastes is that hazardous wastes typically do not cross state lines (or cross fewer lines) than radioactive wastes typicall do. A voluntary cooperative program with the states to track shipment might work but it would be difficult to coordinate and implement. If and when reg al compacts are in place as provided by the December 1980 "Low-Level Radioactive Waste Policy Act," such tracking may be included or equivalent accounting provide under the terms of the compact arrangement. The best interim measure would appear to be for the facility operators to provide a crosscheck. To accomplish the crosscheck, shippers would have to notify the facility operator that shipment are on the way. The simplest way to provide complete data to facility operators on shipments is to forward a copy of the manifest as the shipment is initiated. Mailing copies would only take the time to address an envelope. The facility operator would then periodically check to see that shipments for which advance manifests were received were actually received. Any descrepancies should be reported. Notifying the shipper would provide for resolution or an investigatior if necessary. Notifying the Commission would provide a check to see that reports have been filed and allow followup if needed. Because the number of radioactive disposal facilities is small (currently three are receiving wastes), the number of no show shipments due to shipment to alternative facilities should be small and would be a easy matter to resolve. Arrangements are usually made with facility operators before shipments are made to the existing sites. For the Barnwell site, the volume allocation system already results in the operator checking on late or missing shipments. Clerical or administrative time will be required to check for matching paperwork and to notify shippers and NRC.

8.3.3.3.6 Timing

Time limits on certain aspects of the manifest system can assure timeliness and remove uncertainties for the parties concerned. The most critical timir

is that relating to beginning investigations of late or missing shipments. The times involved are the transit time, the acknowledgment of the receipt of the waste, and beginning the investigation. The latter two are subject to Commission control. For acknowledging receipt, a range of one day to two weeks was considered. One week was selected to be both timely and to allow the disposal facility operator to have a regular schedule and possibly combine billing and notification. Since cross-country shipments may be involved and weather can be a factor, shipment to the disposal facility can take a week. Similiar consideration could apply to receipt by waste collectors and processors. Allowing 3-4 days for the acknowledgment to reach the shipper in the mail adds up to 17-18 days from the time of shipment to the receipt of acknowledgement. Thus, a time limit of 20 days appears both reasonable and timely for the initiation of an investigation. Longer times were considered but the longer the delay, the more chance for loss of control or not correcting a mishap.

Since the disposal facility operator check and audit of advanced versus received manifests is a backup system, the timing should not be as critical. Allowing about a month for the shipper to investigate and late shipments to arrive is arbitrary but reasonable. Therefore a 60-day limit was set for reporting. No specific time limit was set for investigating shipments because of the variety of situations which could occur. A few hours or days should be typical. Once the investigation is complete a timely report will enable timely Commission review of the report and Commission action if required. The licensee does need time to prepare the report and process it administratively. An upper limit of 2 weeks was selected.

8.3.4 Transfers

Changes to 10 CFR Part 20 should also include additional provisions governing transfers. The requirements should be placed in Part 20 for the same reasons the manifest system was. Two new requirements should be proposed for licensees generating wastes or treating and repackaging wastes. One should require that licensees prepare wastes so that the waste is classified according to Part 61 requirements and meets the waste characteristics requirements. No alternatives were considered other than where to put the requirement on waste preparation in the rules. Placing the requirement directly on the generating licensee provides a more direct and enforceable method of assuring waste form and content than relying on existing requirements for transfers. The second requirement is a requirement for a quality assurance program to assure that waste form and content comply with classification and characterization requirements. Good practice already dictates that licenses have quality assurance programs for activities under license. To illustrate, in Inspection and Enforcement Bulletin No. 79-19, issued August 10, 1979 (Ref. 4), concerning packaging of low-level radioactive waste for transport and burial, the importance of assuring compliance with regulations and disposal facility licenses and requirements was emphasized. Controls, audits, and training were noted as necessary to assure safe transfer, packaging, and transport. Complying with the new waste requirements in Part 61 is the generator's responsibility and the new provision would only codify it.

8.3.5 Part 61 Recordkeeping and Reporting Requirements

The recordkeeping and reporting requirements to be included in 10 CFR Part 61 apply to operators of land disposal facilities only. As indicated earlier, such operators subject to Commission authority are expected to number less than ten.

8.3.5.1 Recordkeeping

To adequately define recordkeeping requirements, the types of records to be maintained, the methods and periods of maintenance, and transfers of records should be addressed. The requirements to be included in Part 61 should general reflect standard practices for Commission licensees except that summary records are to be transferred to local and state officials. Transferring summary recor to the local, county, and state officials at license termination increases the institutional knowledge and enables better planning by these groups should questions or problems arise concerning the site after active institutional control ceases. Other recordkeeping matters for disposal facility operators were discussed under manifests. Case-by-case consideration of additional recordkeeping requirements can be made through license conditions.

8.3.5.2 Reports

The same case-by-case flexibility should be provided in the reporting requ ments. The proposed reporting requirements should generally reflect curren practice for other Commission licensees except for the submittal of annual financial reports. Monitoring the financial reliability of the licensee gives added assurances to financial surety arrangements. The burden of this new requirement was minimized by asking for copies of financial reports prepared in the ordinary course of business, if any. No separate reports would have to be prepared.

Certain reporting requirements are necessary because disposal facility licenses will be issued under Part 61, not Parts 30, 40, and 70 as in the past. For exam safeguards reporting requirements are contained in §§30.55, 40.64, 70.53, and 70.54 of these parts. When the quantities of materials would be subject to the requirements if licensed under Parts 30, 40, and 70, no good reason exists to exempt materials in storage at the facility. Existing practice not to requi inventory reports for materials after disposal should be codified for clarity. Rather than repeat the applicable section, they should be referenced. Referencing conserves space and eliminates the need to change Part 61 should the requirements change. The referencing approach was taken for reporting loss or theft of special nuclear material and criticality and controlling transfers of materials by facility operators. (Most licensed material received and possessed at the facility will be disposed of at the facility but occasional shipments to other disposal facilities or licensees may occur.)

An annual report concerning effluent releases, environmental monitoring, maintenance, disposed waste, and variations in site characteristics should also included. Existing requirements for reporting effluent releases in §40.65 Part 40 and 70.59 of Part 70 are similar for uranium mill tailings, processing

and fuel fabrication, scrap recovery and uranium conversion licensees. No reporting requirements for land disposal licensees could have been proposed or the reporting could have been limited to effluent releases but other areas of concern are of equal or greater concern in waste disposal. Little or no effluents are expected from land disposal facilities but this expectation should be confirmed. Existing facilities in New York and Kentucky experience releases from trench water treatment but such releases are the exception, not the rule. Maintenance activities help measure site performance and identify problems to consider in site-closure planning. Trends in environmental monitoring can be early indicators of problems even if action levels prescribed in the license are not exceeded. Summary reports of disposed waste are already provided to state officials so that reporting this information reflects current practice. Describing any instances in which observed site characteristics are different from those described in data forming the base for issuing a license is important for determining whether the initial findings are still valid. New information about the site will be available each time a trench is excavated which will confirm initial findings or differ. Since the reports are more comprehensive, annual reports are proposed instead of reports every 6 months to minimize the burden.

8.4. STATE, TRIBAL, AND PUBLIC PARTICIPATION

The purpose of this section is to review existing provisions for state, tribal, and public participation in the licensing process, discuss alternatives considered, and review proposed changes to the existing provisions.

8.4.1 Existing Provisions

State, tribal, and public participation was generally discussed in the preceeding general analysis of the licensing process. Steps in both the licensing process and the process for environmental impact assessment and review under the National Environmental Policy Act (NEPA) contain requirements of both the applicant and the Commission to ensure public and state participation.

8.4.1.1 Docketing

10 CFR Part 2 requires that the applicant provide a copy of the application and environmental report to the appropriate municipal or county officials of the proposed site and notify officials of alternative sites identified. Copies of the application and report are to be provided by the applicant to the alternate site officials upon request. The Commission is required to notice docketing in the Federal Register and notify the Governor or other appropriate state officals of docketing.

8.4.1.2 Hearings

Hearings are not required by existing rules. The rules do provide that the applicant or interested parties can file a written petition for a hearing and for leave to intervene. Affected states, tribes, and members of the public could qualify as interested parties. The Commission either accepts or rejects the request for hearings. If hearings will be held, the Commission must notify

the Governor of the host state or other appropriate official and the officials of the municipality as appropriate. The hearing process also provides for limited appearances by persons who are not the applicant or intervenor. Limited appearances involve presentation of oral or written statements on the issues at any session of the hearing or any prehearing conference. The regulations also provide that state, county, or municipal agencies may participate, introduce evidence, interrogate witnesses, and advise the Commission without taking a position on the issues. Findings, exceptions, and briefs may also be filed at the hearing board's discretion. Hearings may be requested for initial applications and subsequent license amendments including license renewals.

8.4.1.3 Docket Files

The Commission maintains docket files on all docketed cases. When hearings are involved, the docket files include all pertinent records such as transcripts orders, and notices. The docket files may be reviewed in the Commission's Public Document Room at H Street.

8.4.1.4 Landownership

Existing rules in 10 CFR Part 20 require that "the Commisson will not approve any applications for a license to receive licensed material from other persons for disposal on land not owned by the federal government or by a state government." States have traditionally accepted the role as landowner and entity responsible for long-term care of the disposal facilities. Assumption of th responsibility has afforded the states an opportunity to participate in site selection and to be involved in the applicant's developmental plans.

8.4.1.5 Low-Level Radioactive Waste Policy Act

This law, enacted in December 1980, establishes the individual state's responsibility for providing for disposal capacity for waste generated within its borders except for defense and federal research and development wastes. It provides for formation of regional state compacts to meet this responsibility. State planning and formation of compacts will afford a means for state involvement in development of new sites and in defining use of existing sites.

8.4.1.6 NEPA

Licensing commercial radioactive waste disposal by land burial is specifically listed in 10 CFR Part 51 as an action requiring preparation of an environmental impact statement (EIS). Whether to prepare an EIS for amendments and renewals is judgmental. If prepared, the same procedures followed for initial licensing would be followed for amendments and renewals. The Commission is required in Part 51 to notice its intent to prepare an EIS. Input from any source can be solicited by the Commission for the EIS scoping process. The applicant's environmental report is widely distributed for reaction and comment. Once drafted, the EIS must be distributed to federal, state, and local agencies and interested members of the public for comment. The availability of the draft must be noticed and press releases issued addressing the desire for comments and availability of the document. Comments and input from all these sources

are used to prepare the final EIS. If hearings are held, the final EIS is normally submitted as a major portion of the staff's testimony. The EIS process also gives due consideration to compliance with other environmental quality standards and requirements imposed by federal, state, and local agencies. The final EIS must be noticed and distributed in the same manner as the draft. To the extent practical, the final EIS must also be distributed to all parties who commented on the draft. All sustantive comments must be included and addressed in the final EIS. Responsible opposing views not adequately addressed in the draft must be discussed in the final EIS.

Copies of the environmental report, draft and final EISs, comments, and documented findings are placed in the docket files for public inspection.

8.4.2 Changes and Alternatives to Existing Procedures

8.4.2.1 General

In deciding whether to modify or supplement existing procedures for state, tribal, and public participation, the Commission considered factors such as the desire to foster early involvement so that issues are identified early in the process so that decisions may be made with less delay, the desire to reach all affected parties, and recognition that the applicant, Commission, and public should not be unduly burdened. Another important consideration is the policy set out in the Indian Self-Determination and Education Assistance Act (25 USC 450) (Ref. 5) to foster Indian participation in matters affecting them and self-determination by Indian people.

Although Indian tribal governments can participate as interested parties in hearings and comment on draft and final EISs under existing procedures, no special recognition is provided and the tribal governments are not listed in lists of appropriate officials. In proposed revisions to Part 2 and proposed provisions in the new Part 61, tribal governments should be explicitly included to provide additional assurances that they are informed and included in the licensing process and that early input is solicited. The specific recognition of tribal rights and concerns is important in and of itself also.

8.4.2.2 Docketing

The decision not to add a notice of intent to the front end of the licensing process was discussed earlier as was the addition of the tendering step prior to docketing. The proposed tendering step includes making Commission staff available for consultation and soliciting views and comments from states, tribes, and the public in the Federal Register and local newspapers. The existing requirements on the applicant and Commission upon docketing were retained. The Commission also considered more explicit requirements such as requirements for mandatory public meetings, noticing these public meetings in the newspapers, mandatory location for meetings, mandatory local public document rooms, and toll-free informational telephone numbers. While these ideas for methods of fostering and facilitating public, state, and tribal participation have merits, the Commission chose to consider such methods on a case-by-case basis rather than impose them in the regulations. Because the state will probably be

involved in the development of the site, many of the measures may not be warranted. Not requiring the measures does not preclude the implementation of one or all.

8.4.2.3 Hearings

The states, tribes, and public have ample opportunity to participate in the hearing process under existing requirements. As discussed earlier, mandatory hearings are not justified. No changes are proposed.

8.4.2.4 Docket Files

Changes to existing requirements considered were mandatory local public document rooms, mandatory public docket files in regional NRC offices, and more specificity about headquarters public document rooms. The Commission currently arranges local public document rooms or similar arrangements for active licenses for commercial disposal of wastes and expects to continue this practice. Case-by-case flexibility for local document rooms is preferable in case the state has made other arrangements or lack of interest or willingness for a local group to accept responsibility for maintaining the files. Similar considerations apply to regional files. Requiring rule changes for administrative handling of headquarters files is the major reason no additional specificity was proposed for these files.

8.4.2.5 Landownership

The need for institutional control dictates the continuation of the governmental ownership requirements. The Commission considered whether tribal ownership should be included. While the tribal governing bodies could, in many cases, provide the long-term institutional stability at the heart of this requirement, the responsibility and burden far outweigh any economic benefits to the tribe from the operation of the facilities. Furthermore, the state and federal government have responsibility for protecting and considering the interest of the state or nation as a whole. Tribal ownership was not proposed.

As discussed earlier, the applicant must demonstrate that arrangements for institutional control are in order. By requiring certification that the custodial agency understands and is prepared to accept the responsibility and license for institutional control, early negotiations with the agency are assured. Similar assurances stem from demonstrating landowner arrangements. Since the state will probably be the landowner, early state involvement is almost guaranteed. One alternative considered was to require state or federal ownership of the land at the time the application is filed. The Commision certainly wants to allow consideration of state and federal land in the site selection process. Requiring early transfer of land not state or federally owned could influence consideration of alternative sites. The applicant would have a significant financial commitment in acquiring the land compared to the commitment involved in an option. The government agency would also have to accept responsibility for the site before Commission review was completed and delays could result from determining that the proposed activities meet all requirements of the agency. Thus, this alternative was not adopted.

A general certification requirement would allow flexibility yet assure that applicant and Commission resources are not expended when the government agency knows it is unwilling to commit itself to a site. The Commission has no authority to force a state or federal agency to assume the responsibility for site ownership and institutional care. It can only refuse to issue a license if these responsibilities are not accepted. The commitment made by the government agency can be conditioned as desired with respect to issues and matters not preempted by the Atomic Energy Act. Even a provisional commitment should involve some process to involve the public. Several of the regional workshops on the draft rule suggested that a potential host state conduct a process like that for a finding of "public convenience and necessity" for proposed power plants. The Commission cannot require such a process but expects that whatever method will be used will involve opportunity for public comment and consultation with affected jurisdictions. According to state participants in the western regional workshop, intergovernmental consultation may be especially important when disposal is proposed on federal land and hopefully the federal land manager would include such consultation before making a commitment. The government agency commitment does not limit participation in the licensing proceedings under Part 2 or Part 51.

The Commission also considered requiring a certification from the intended landowner. Trying to word the certification to include all conditions and qualifications and cover all situations proved difficult. Another alternative considered and rejected was to require a commitment concerning all alternative sites identified in the application or environmental report. The proposed requirement should apply only to the proposed site. If an alternative site is found preferable, a commitment from the alternative site landowner can be obtained at that point in the proceeding. This arrangement is judged to be the least burdensome to all parties.

8.4.2.6 NEPA

The Commission has a separate rulemaking to update Part 51. No changes to NEPA activities were considered.

8.4.2.7 Participation by State or Tribal Governments

New requirements for participation by state or tribal governments should be established and patterned after the new Subpart C of 10 CFR Part 60 for high-level wastes. The subpart provides a formal mechanism for approving participation in the license review process. It does not grant any new rights or authorities but highlights an existing opportunity and outlines how the states can take advantage of the existing opportunity. Based on input from the states, such highlighting and structuring is needed.

The logical points to address in setting up a formal process are who should initiate the action; where, when, and how to submit an initiating proposal; what to include in a proposal; and how the proposal will be approved.

A request for formal participation should be prepared by the state or tribal governing body and submitted to the director no later than 120 days after

docketing of the application. The 120 days is the same time frame as provided in 10 CFR Part 60. It provides a reasonable time to consider filing and prepar a proposal but precipitates action while Commission review is still in its early stages.

The content of any proposals must adequately define what the state or tribe proposes to do. The proposed topics include identifying issues, impacts, products, and plans for local government and citizen participation. The suggested elements do not preclude submission of any other information the state or tribe desires.

The approval process should include meetings to discuss the proposal, decision criteria, and an appeal provision. No other changes to the basic approach set out in Part 60 were considered or adopted.

REFERENCES

1. Nuclear Waste Policy Act of 1980, P.L. 96-573.

2. U.S. Environmental Protection Agency, 40 CFR Parts 260-265 Hazardous Waste Management System Regulations, Federal Register 45 FR 33066-33588, May 19, 1980.

3. U.S. General Accounting Office, The Problem of Disposing of Nuclear Low-Level Waste: Where Do We Go From Here? EMD-80-68, March 31, 1980.

4. U.S. Nuclear Regulatory Commission, Office of Inspection and Enformcement Bulletin No. 79-19, Packaging of Low-Level Radioactive Waste For Transport and Burial, August 10, 1979.

5. Indian Self-Determination and Education Assistance Act, P.L. 93-638, January 4, 1975.

Chapter 9

FINANCIAL ASSURANCES FOR CLOSURE, POSTCLOSURE, AND INSTITUTIONAL CONTROL

9.1 INTRODUCTION

This chapter reviews the need to require financial assurances of licensees for closure, postclosure care, and active institutional control of a low-level waste disposal facility and presents the technical requirements developed by the staff to address this need. In Section 2, the staff presents their rationale of why it is necessary to require financial responsibility of low-level waste disposal licensees for closure, postclosure, and for active institutional control. Section 2 also summarizes operating experiences at low-level waste sites, and reviews federal and state regulatory precedents in this area. Section 3 presents the staff's development of technical requirements to assure adequate funds are available for final closure and postclosure care at the site. The section presents the staff's review of financial assurance mechanisms, and discusses the criteria for evaluating these alternatives. Section 4 presents the staff's development of technical requirements for financial assurances to cover costs during the long-term (institutional control) period.

Table 9.1 presents an overview of the financial assurances required at the various stages of the life cycle of a disposal facility following the proposed requirements in 10 CFR Part 61.

For a more detailed analysis of the financial assurance requirements for closure and for long-term care, as well as a history of the operating experiences at the low-level waste sites, and a review of federal and state precedents in the area of financial responsibility for hazardous waste sites, the reader is referred to Appendix K of this Environmental Impact Statement.

9.2 NEED FOR FINANCIAL PROTECTION REGULATIONS

Financial assurance requirements for low-level waste disposal facilities are needed to help ensure the long-term protection of the public health and safety and the environment. A review by the staff of the operating experiences at both hazardous waste and LLW disposal sites reveals that operators of both types of sites did not adequately plan for closure and long-term care activities. With respect to the LLW sites, the state and federal governments recognized the need to care for the sites over the long term. The sites had to be located on federal or state government-owned land and funds were collected for long-term care activities. In most cases, however, the funds collected for long-term care activities (e.g., the Maxey Flats, Kentucky site) were not adequate and there was essentially no financial planning for contingencies that might occur, (e.g., the need to pump trenches and treat trench leachate). In addition, until recently little planning or financial assurance was provided for funding the final closure and stabilization of the existing sites. This has led to a situation where financial responsibility for the continued assurance of protection of the public health and safety at several of the existing closed sites already has or could become a responsibility of the state or federal government. Early proper financial planning to assure the availability of

Table 9.1 Life Cycle Financial Assurances for a Disposal Facility Following Proposed 10 CFR Part 61

Time in Years	Activity	Form of Financial Assurance
1-2 yrs	Site Selection and Characterization	Licensee responsible for costs incurred
1-2 yrs	Licensing Activities	Licensee responsible for costs incurred including licensee fee
		Site closure plan including cost estimates for closure is submitted as part of licensee application
		Lease arrangement with long-term care arrangements for financial responsibility between licensee and state submitted for review to NRC for adequacy
		Licensee obtains adequate short-term suret to provide for closure
20-40 yrs	License Issued; Site is in Active Operation; Waste Received	Short-term sureties in place for closure: NRC periodically reviews and requires updating to account for changes in inflation, site conditions, etc.
		NRC periodically reviews revisions to lease arrangements to ensure that arrangements for financial responsibilities for long-term care are adequate
1-2 yrs	Site Closure and Stabilization	Costs covered from short-term sureties, if necessary; otherwise, licensee performs activities
		Lease arrangement between site owner and operator for long-term care is still in effect
5-15 yrs	Observation and Maintenance	Licensee still responsible for all further costs during this period, with short-term assurances still in place
100 yrs	License Transferred to Site Owner; "Active Institutional Control Period"	Terms and conditions of lease are met, and either state or licensee provides funds to pay for all required and necessary activities of this period

adequate financial resources for closure, contingencies, postclosure care, and institutional control could have prevented this from happening.

As discussed in the review of the operating histories of low-level waste disposal sites in Appendix K of the EIS, the necessary closure and long-term care activities have, in some cases, not been undertaken, or have had to be conducted by the state government, because of the lack of planning for and lack of financial assurances for such activities. Closure, postclosure, and active institutional care costs are generally incurred after the site operator is no longer receiving revenues from waste generators. Thus, proper planning during the operating phase when revenues can be accrued is essential.

Based on these considerations, there is a strong need for regulatory requirements to ensure that: (1) the licensee has sufficient financial resources to provide for final closure and postclosure care of the site, and (2) the licensee provides financial assurance for the active institutional control period after the site is closed and stabilized. The staff believes these closure and active institutional care costs should be identified early and should be provided for as part of the necessary costs of operating a site. Financial assurance mechanisms to provide for these costs should be established during the active operating period of the site, when revenues are still being received by the licensee, and he has access to financial resources. An applicant seeking a license for the disposal of low-level waste must estimate the costs of closure in order to provide for adequate financial assurances based on these estimates. Therefore, the amount of financial responsibility required of licensees will be consistent with the degree of risk associated with the closure and active institutional care of the site. (Estimates of the costs of various potential expenses of closure and postclosure care of a site are presented in Appendix Q of the EIS.)

Meeting such a technical requirement for closure and active institutional care will involve a cost to the licensee. However, proper closure should help to prevent other costs, such as remedial costs, administrative costs to the regulatory agency, and environmental costs. For example, failure to provide for adequate financial assurances for closure could result in a situation where it is necessary for the responsible regulatory agency or the site owner to provide for final closure and stabilization at taxpayer expense. Any corrective actions would also need to be taken by the agency as well as the longer term institutional control activities. Environmental costs that could be incurred if a licensee was unable to conduct final closure and stabilization could include increased potential for contamination of soil, air, and surface and ground waters. Adequate funds must be provided during operations to cover the costs for closure and for long-term care activities.

The need for stringent financial requirements to ensure that the licensee is financially responsible has been voiced by a number of sources, including the U.S. General Accounting Office, the National Conference of Radiation Control Program Director's Task Force on Bonding, numerous state officials, and also in public comments received on the preliminary draft regulation for low-level waste disposal. These comments, along with the federal and state regulatory precedents described in Appendix K have enabled the staff to examine a range of alternatives for financial assurances.

9.2.1 Federal and State Precedents for Closure, Postclosure, and Long-Term Care Requirements

In developing requirements for financial assurances for closure and postclosure and for long-term care, the NRC staff examined federal and state regulatory requirements. These other regulatory requirements not only provided precedents for the NRC regulations, but also enabled the staff to examine a range of financial assurance instruments. Furthermore, the experiences gained by the various agencies in administering these various mechanisms also enabled the staff to evaluate the administrative time required to implement them.

9.2.1.1 Federal Financial Assurance Mechanisms

9.2.1.1.1 Environmental Protection Agency (EPA)

The EPA is currently engaged in drafting financial protection regulations for operators engaged in the disposal of hazardous waste. Under the Resource Conservation and Recovery Act (RCRA), the EPA is required to establish financial responsibility standards applicable to owners and operators of hazardous waste management facilities. EPA concluded that financial responsibility performance standards are necessary to assure that funds will be available for the proper closure and postclosure care of the site. The interim final rules issued January 12, 1981 require the owner or operator of each hazardous waste treatment, storage, or disposal facility to establish financial assurances for closure and for postclosure care. Acceptable financial assurance mechanisms include trust funds, surety bonds, letters of credit, or a combination of these mechanisms.

9.2.1.1.2 U.S. Department of the Interior, Office of Surface Mining

The Interior Department issued regulations in 1979, pursuant to the 1977 Surface Mining Control and Reclamation Act, requiring operators of surface mining operations to obtain a performance bond to assure that the area will be managed in accordance with performance standards. Performance bonds include surety bonds, collateral bonds, escrow accounts, self-bonds, or a combination of these financial assurance mechanisms.

Collateral bonds may be supported by cash, certain negotiable bonds, certificates of deposits, irrevocable letters of credit, or a mortgage or security interest in property granted to the regulatory authority equal in value to the bond obligation. Companies may self-insure if they can show financial solvency and continuous operation for ten years.

9.2.1.1.3 Federal Maritime Commission (FMC)

The FMC has responsibility under several water pollution control acts for issuing and implementing regulations to require vessel operators to provide financial protection to ensure that they will be able to meet potential obligations arising from spills. The regulations allow the following methods: (1) insurance, (2) surety bonds, (3) self-insurance, based on the operator maintaining certain specified levels of net worth and working capital, (4) a guarantee where the guaranteer meets the self-insurance requirements, and (5) other evidence of financial responsibility.

9.2.1.2 State Financial Assurance Mechanisms

9.2.1.2.1 Illinois

U.S. Ecology, Inc. (formerly, The Nuclear Engineering Company, Inc.) operated a low-level waste disposal site at Sheffield, Illinois which is now closed. Financial arrangements for "perpetual care" are found in a lease arrangement signed between the site operator and the state. The original terms of the lease called for the operator to pay the state $0.05 for each cubic foot deposited at the site. However, at the time that the lease was executed, the state did not have an earmarked or state fund for the collection of these fees. Funds collected for care and maintenance prior to October 1976 were deposited into the general treasury of the state, and are not now available for closure and for postclosure care. In 1978, the lease was amended so that the operators had to pay into a state perpetual care and maintenance fund in the amount of $0.10 per cubic foot. The Illinois General Assembly also recognized that sites used for the disposal of radioactive waste would represent a continuing and perpetual responsibility in the interest of health, safety and general welfare. Fees collected after September 1976 were deposited in the state treasury and set apart in a special fund known as the Radioactive Waste Site Perpetual Care Fund. Monies from the invested funds were to be used by the Director of the Department of Public Health to monitor and maintain the site. However, as of December 1979, there was only approximately $50,000 in the fund, which state officials found to be insufficient for the purposes of any long-term care activities at the site.

9.2.1.2.2 Nevada

U.S. Ecology, Inc. operates a low-level waste disposal site at Beatty, Nevada and has collected funds for closure and for long-term care. A lease arrangement was set up originally, whereby the company agreed to collect a fee from waste generators who use the site. However, by 1976, state officials indicated to NRC staff that their earlier provisions for long-term care funds for the site were inadequate. Recently however, the state has taken measures to ensure that a larger amount of funds are available for closure and for postclosure activities. In 1977, the state enacted legislation which revised the radiation protection regulations as well as calling for the development of a long-term care fund for the radioactive disposal site. The legislation created a Radioactive Materials Disposal Fund in the state treasury. Fees collected from waste generators by the licensee are to be deposited into the fund and subsequently invested.

9.2.1.2.3 South Carolina

Chem-Nuclear Systems, Inc. operates a low-level waste disposal site at Barnwell, South Carolina. The company and the state of South Carolina are parties to a lease requiring the company to pay the state a cubic foot charge for long-term care of the site. The lease calls for increases in the amount of the surcharge every three years in accordance with changes in the Consumer Price Index. The escrow account into which the fees are deposited for long-term care continues to be maintained, and interest is earned on the monies accrued to the fund.

In May 1980, the company also submitted a draft trust fund arrangement to South Carolina to handle the collection of closure expenses as part of their preliminary site stabilization and closure plan for the site. The terms of the draft trust, which are currently being negotiated with the state, call for the company to transfer the collected surcharges to the trust fund, until a total of $1,000,000 is collected.

9.2.1.2.4 Kentucky

U.S. Ecology, Inc. operated a low-level waste disposal site at Maxey Flats, Kentucky which is now closed. In 1976, the Kentucky General Assembly passed an act that imposed an excise tax of $0.10 per pound on all radioactive materials delivered in the state for processing, packaging, storage, and disposal. A study prepared for the Kentucky legislature recommended that the monies from the surcharge should be placed in a special escrow account for long-term care and maintenance, rather than in the general fund, as had previously been the case. Additionally, NRC discussions with state officials indicated that there were insufficient funds available to pay for necessary closure and remedial activities. After the $0.10 surcharge became law on June 19, 1976, the quantity of nuclear waste disposed of at Maxey Flats declined by 95%. The site was closed in 1977, by order of the state, pending the completion of a water management program. Discussions with state officials indicate that insufficient funds were available from the Maxey Flats long-term care fund to provide for closure or long-term care activities.

9.2.1.2.5 Washington

U.S. Ecology also operates a low-level disposal site at Hanford, Washington. The state and NECO were both parties to a lease arrangement requiring the development of a long-term care fund, which consisted of fees collected from waste generators. Funds in the long-term care fund are invested by the State Finance Committee in the same manner as other state monies, and any interest accruing as a result of investment is returned to the fund. Since 1980, these funds have been collected on the basis of a $.25 per cubic foot surcharge levied on waste generators using the site.

9.2.1.2.6 New York

Nuclear Fuel Services (NFS) established a low-level waste burial ground at West Valley, New York in 1962. Under the terms and conditions of a lease negotiated between NFS and the state, NFS was required to maintain and provide storage and maintenance of the wastes before returning control to the state. NFS was also required to collect and turn over to the state or federal government at the point of closure a charge calculated to provide the estimated full costs for perpetual storage. In the 1970s, the low-level waste burial ground was closed. State government officials indicated that insufficient revenues were available to provide for maintenance at the site, and this issue has not been resolved.

9.2.1.2.7 Oregon

Oregon requires owners or operators to submit a closure and postclosure plan as part of a facility permit application. The state reviews each plan and

then estimates closure and postclosure care costs at the site. The state then requires each owner or operator to obtain a cash bond in the name of the state to cover closure and postclosure costs.

9.2.1.2.8 Wisconsin

Wisconsin requires hazardous waste facility operators and owners to submit a closure and postclosure plan. The state allows the owner or operator to provide proper closure and postclosure care. The owner or operator must set aside all necessary funds to close his facility before he may begin facility operations. However, payments may be made into the postclosure fund at regular intervals during the life of the site. The owner or operator is financially responsible for long-term care of his site for either 20 or 30 years after closure, when the state then assumes responsibility. The State Waste Management fund is also used to pay for costs of long-term care of a site occurring after the responsibility of the owner or operator has ended.

9.2.1.2.9 Kansas

The state of Kansas passed an act in 1979, that authorized the establishment of fees for monitoring hazardous waste storage sites, paying extraordinary costs, monitoring after site closure, payment of maintenance expenses, and repairs for environmental damage at a site. Kansas also requires hazardous waste facility owners or operators to submit a closure and postclosure care plan. Owners or operators are responsible for care of a site for 10 years after closure. Kansas requires a trust fund or performance bond to assure compliance with facility closure and monitoring requirements. In lieu of a trust or surety bond, the state will accept a deposit by the owner or operator of cash or U.S. Treasury notes to the State Treasury or to an escrow agent deemed satisfactory by the state.

9.2.1.2.10 Maryland

Maryland hazardous waste regulations require owners to demonstrate evidence of financial ability to provide closure and postclosure care of a hazardous waste management facility. The owner or operator must obtain a surety bond in an amount specified by the state, or transfer ownership or operation of the site prior to closure. The surety bond must cover any costs of monitoring, maintaining, and closing a facility, ensuring the security of a facility after its closure and guaranteeing fulfillment of all permit requirements.

9.3 FINANCIAL ASSURANCES FOR CLOSURE AND POSTCLOSURE CARE OF A LOW-LEVEL WASTE SITE

This section presents the staff's development of technical requirements for financial assurances for closure, stabilization, and postclosure observation and maintenance activities at a low-level waste disposal site.

9.3.1 Introduction

After a typical low-level waste disposal site has been filled to capacity, the site owner is no longer receiving commercial revenues from the receipt and

disposal of waste. However, even though he is no longer receiving revenues to operate the site, the licensee is still responsible for a variety of the site expenses, such as closure, stabilization, and postclosure observation and maintenance of the site. As discussed earlier, the experiences at LLW and other hazardous waste sites serves to indicate that there is a strong need for a regulatory mechanism to ensure that financial responsibility for closure be established at an early stage of site operations, so that sufficient resources are available for later closure activities. The staff believes low-level waste licenses should demonstrate financial assurances sufficient to provide for the full costs of all closure and postclosure care activities. (For a typical reference near-surface disposal facility, these closure costs are estimated by the staff to be in the range of $1.0 to $3.0 million, in constant 1980 dollars. See Appendix Q for a detailed breakout of estimated closure costs.)

9.3.2 Technical Requirements for Financial Assurances for Closure and Postclosure

Short-term financial assurance mechanisms refer to arrangements intended to ensure that the licensee is financially responsible for undertaking required decommissioning, closure, stabilization, and postclosure activities at a low-level waste site. In these arrangements, the concept of financial assurances does not include any requirements for third party liability coverage for damages to people or property resulting from operation of the facilities. Rather, the staff is establishing various financial assurance requirements which will ensure that the sites are properly closed, stabilized and monitored for up to 100 years. These activities would include closure and stabilization of the low-level waste site according to license requirements and regulations, and be particularly based on the site closure and stabilization plan. The need for ensuring financial responsibility for closure is based on the realization that a situation might occur where financial resources for closure are inadequate, causing the government to have to assume responsibility for closure costs. If no financial arrangements have been made, then the government would have to assume responsibility for the costs of closure in the event of licensee default.

Based on a review of previous experiences, the staff developed the following technical requirements for operators of a disposal facility:

- Each applicant must demonstrate adequate financial resources to cover the estimated costs of conducting all licensed activities over the planned life of the project including ensuring that sufficient funds will be available to carry out final site closure, postclosure care and stabilization activities.

- Prior to startup of operations, the licensee must obtain a short-term financial assurance mechanism found acceptable to the Commission that is sufficient at all times to cover all costs of closure, and postclosure care and must be based on a Commission approved plan for site closure and stabilization.

- The financial assurance mechanism must be full funded prior to the start of operation, to provide full assurance regardless of whether closure occurs as was originally planned, or occurs prematurely.

- o The short-term mechanism must be in effect throughout the operating period of the site.

- o The face value of the short-term financial assurances must be at least equal to the cost estimates submitted by the licensee in the approved plan for site closure and stabilization.

- o The licensee's cost estimates must take into consideration the total costs that would be incurred if an independent contractor were hired to perform the decommissioning and closure activities.

- o The license may use one or more financial assurance mechanisms to meet these requirements.

- o The financial assurance mechanism must be open-ended and cannot be cancellable.

- o Proof of forfeiture must not be necessary in order to collect the financial assurance mechanisms. If the licensee cannot provide an acceptable financial assurance substitute within the required period, then the original mechanism will be automatically collected prior to its expiration.

- o The Commission will allow the licensee to terminate the financial assurance mechanism after a finding that all license conditions have been met.

- o The adequacy of the amount of funds provided by the financial assurance mechanism to account for changes in inflation, site conditions, and technology will be reviewed annually.

The staff's development of these technical criteria for financial assurances for closure was based on recognition of the importance of balancing the need to require sufficiently stringent assurances with the economic consequences of the alternative. For example, in developing criteria that the financial assurance mechanism must be fully funded prior to start up of operations, the staff also considered the less stringent approach of allowing the funds to build up over the life of the site. The staff was aware that this second approach would have been a lesser financial burden to the operators, since it would not require them to set aside a large sum of capital. (In their development of RCRA regulations, the EPA also noted that the fully funded approach placed a tax burden on the operator, because current tax laws do not allow this fund to be considered a deductible expense; since no expense occurs in a tax sense until the funds are used for closure.) Nevertheless, the staff also realized that allowing a closure fund to build up over the life of the site could well result in having an inadequate fund available in the event of premature closure of the site, with the result being that the taxpayers would then be financially responsible. In weighing these two equity alternatives, the staff concluded that the fully funded approach to closure offered the most reasonable assurance that the licensee be fully responsible for the costs of closure.

9.3.3 Alternative Financial Assurance Mechanisms for Closure Considered by the Staff

There are a variety of short-term financial assurance mechanisms that could be used by a low-level waste operator to assure that sufficient funds are available for closure and postclosure care. Short-term financial assurance mechanisms considered by the staff include the following:

1. Surety bonds, obtained from a surety company;
2. Escrow arrangements between the bank, the government, and the licensee;
3. Trust funds, arranged between the government, a financial institution, and the licensee;
4. Certificates of deposit to a state or federal agency;
5. Cash deposits to a state or federal agency;
6. Deposits of securities to a state or federal agency;
7. Secured interests in the disposal operator's assets;
8. Letters of Credit from a financial institution;
9. Self-insurance by the low-level waste disposal operator;
10. Financial tests of the operator or his holding company;
11. Development of a sinking fund based on receipts from capacity surcharges.
12. Development of a closure assurance pool.

These types of financial assurances are standard commerical law arrangements being used by state and federal government agencies for the chemical waste, uranium milling, low-level waste, and surface coal mining industries. The staff considers these alternatives to be reasonable possibilities for consideration in this rule.

Each alternative was evaluated based upon a specific set of criteria. The primary factor considered by the staff in evaluating these alternative financial mechanisms was the degree of assurance provided by each method to ensure that funds were available for closure costs at the disposal site to provide for all necessary activities to protect the public's health and safety. Other criteria considered by the staff included the following:

- o Degree of security (or level of difficulty) in obtaining funds in case of default.

- o Amount of administrative time and expense of the regulatory agency required to implement and monitor the financial assurance mechanisms.

- o Cost of utilizing the financial assurance mechanism to the licensee.

The staff's review of the various financial alternatives is presented below, and discussed in greater detail in Appendix K.

9.3.3.1 Surety Bonds

A surety bond provides a cosigner on an obligation. The bond is essentially a contract among three parties, whereby the surety company promises to the obligee (the NRC) that the principal (the licensee) will perform specified closure activities. The surety company takes on a possible liability for a profit. The surety company will seek some sort of collateral from the principal, and the amount will vary depending on the financial conditions of the principal and other factors. The cost of a surety bond is dependent on the type of required activities covered by the bond, but fees or premiums generally range from between 1.0 and 1.5 percent of the face value of the bond. If a licensee with a surety bond were to become bankrupt, then the bonding company would provide the amount of the surety for all obligated closure costs.

The surety company also needs to have sufficient assets to provide for possible default. Surety companies have the option of filing with the U.S. Treasury, which sets limits on the face values of bonds. Since filing with the Treasury provides a form of certification, the Commission staff feels that surety bonds should only be accepted for the purposes of 10 CFR Part 61 if they are on the list of accepted companies listed in the Treasury Department's Circular #570, entitled "Surety Companies Acceptable on Federal Bonds", and only for an amount that is within the company's single policy limitation as identified.

Surety companies are generally regulated by state laws that are designed to ensure that the surety company is solvent and has assets of a certain minimum amount. Additionally, state regulation of sureties involves assessments of financial management practices, including examination of whether the sureties are diversified in their lines of credit. This review by state agencies, as well as the review conducted by the Treasury Department prior to issuance of Circular #570 give the regulatory agency concerned with closure of the site additional confidence that the surety company will be capable of paying in the event of default by the licensee.

The agency's administrative effort in monitoring a surety bond for the regulatory agency would not be significant. The regulatory agency would only have to periodically review the amount of the surety bond, to determine that there were sufficient resources to provide for changes in inflation, or site conditions.

A major problem with surety bonds is their availability. Staff discussions with surety company officials indicated that there may not be any companies willing to provide surety bonds because of their open-ended nature and the potentially long time period. However, staff decided to recommend the use of

a surety bond for a financial assurance mechanism because the bonds may be available in the future.

9.3.3.2 Cash Deposits into a Government Account

A cash deposit is another method of assuring financial responsibility for closure. An amount at least equal to the estimated cost of closure is deposite into a special account that could be held by a state or federal government agency. Use of the funds in this account would be restricted to covering the costs of closure and stabilization of the site. If the operator were to default, then the state or federal government could withdraw the funds from the special account and arrange for the necessary closure work to be completed at the site. The funds would have to be put into an earmarked fund and not deposited into the general treasury so that the funds are specifically retained to provide for the purpose they were intended for. The funds should also be invested in a prudent manner so that the face value increases to keep pace with changes in inflation.

The staff considers that use of a cash deposit by a licensee as a financial assurance mechanism for closure would be a secure method of ensuring that funds were available for closure. However, this method would result in a large loss of productive assets of the licensee, as he would have to put up the full face value of the costs of closure. This method would also entai some degree of administrative responsibility by the regulatory agency. The agency staff would have to periodically examine the amount in the special fund in order to ensure that the funds were invested properly, and that they were keeping pace with inflation.

9.3.3.3 Escrow Accounts

An escrow account can also be used to assure funds for closure and for decommissioning. Under such an agreement, cash or marketable securities in an amount equal to or greater than the estimated costs of closure are deposited into a special account held by a financial institution. An escrow account serves as a receptacle for the deposit of goods or property until such time as the licensee completes the required closure activities. The institution holding the assets is the depository and an escrow agreement is necessary to set out the terms and conditions by which the materials can pass to either party.

Depositors however, are not trustees. An escrow agreement involves a binding agreement with terms and conditions specifying that upon failure of the licensee to meet the prescribed closure activities, the fixed amount necessary for all closure activities held in escrow would pass to the appropriate state or federal government agency. Conversely, upon a finding that closure had been satisfactorily conducted, the escrow agreement would be terminated and the amount in the escrow returned to the licensee.

Generally, administrative fees are charged for the management of an escrow account and will vary depending on the degree of activities, not on the amount of funds. One of the big differences between a trust and an escrow account

occurs because a bank managing an escrow account generally will only perform those activities specified in the agreement. As with all other types of financial assurance arrangements, the types of investments made by the supervisory personal of the escrow would entail some administrative cost to the regulatory agency, in order for them to be assured that the funds were keeping pace with inflation. However, there would be little problem with asset valuation for the regulatory agency, since the financial institution would take that responsibility.

9.3.3.4 Trust Funds

A trust fund is a mechanism for holding property and applying it or income from it to a particular purpose. The concept of using a trust fund to provide for financial assurances for closing a waste disposal facility is not new. In 1980, a trust fund to provide for decommissioning and closure costs was proposed by Chem-Nuclear Systems, Inc., for their Barnwell, South Carolina LLW disposal site. The RCRA financial requirements being developed by the U.S. Environmental Protection Agency for hazardous waste sites have also recognized the trust mechanism as an acceptable type of financial assurance for closure.

A trust fund is a financial arrangement whereby one party holds and may even manage funds or property for the benefit of another. In this case, the beneficiary of the trust fund would be the state or federal government. The trustee of the closure trust would be a bank or financial institution. The terms of the trust would define the investment responsibilities of the trust. The trustee has possession of the property, or funds placed in trust by the party who created the trust (in this case, the state or federal government). The trustee is said to have the legal interest in the fund since he has control over it, can sue to protect it, and is responsible for its preservation. The beneficiary cannot use the trust funds, but is entitled to those benefits, (such as income) derived from the trust, and intended for him under the terms of the trust. The trustees are under a fiduciary duty to comply with the terms of the trust, and unless the trust provides otherwise, are liable for breaches of this duty.

A trust fund can contain more than just cash. Property such as securities or government notes can be placed in trusts. However, if cash substitutes are allowed within the framework of trusts, then the function and obligation of the trustee must be redefined, and they may possibly charge more for their services. If other types of assets are allowed, the trust would have to agree to pay the NRC or some other federal agency a stipulated cash amount. Additionally, if assets other than cash are deposited into the trust fund, it may be necessary for the trustee to buy and sell securities with the approval of the regulatory staff, or take other steps to manage the assets in order to maximize their value. However, unless specified in the terms of the trust, a trustee usually must invest under a reasonably prudent investor standard as defined by statute or case law of the jurisdiction where the trust is located. The trustee has a fiduciary obligation to honor the terms of the trust, and this standard of fiduciary duty is so strict that most trustees will only accept carefully defined responsibilities.

Trustee fees may be relatively constant, but are normally defined as a percentage of income; generally trustee funds may range from between 1% and 2% annually of the amount to be managed in the trust.

Trust funds provide a high degree of security that funds will be available for closure. They also do not place a significant administrative burden on the regulatory staff. This form of financial assurance mechanism also provides a productive use of assets, as the monies in the trust fund are managed by fiduciaries with expertise in investing.

9.3.3.5 Certificates of Deposit

Another financial assurance mechanism that the staff reviewed for assuring closure activities at a low-level waste disposal site is Certificates of Deposit (CDs). Generally, CDs may be issued by any bank. Cash or securities are deposited by the site owner with the bank, and a certificate is issued, made payable to a government agency. Only the government agency could cash the certificates. The CD would then be cashed by the regulatory agency if the operator was unable to complete decommissioning and closure activities. Again, as with all forms of financial assurance, the CD would be adjusted over time to reflect inflation. At the end of operations, if the operator satisfactorily closed the site, then the government agency would return the CD to the site operator.

A CD provides a high degree of security that sufficient funds will be available for closure activities. Certificates are a financial assurance mechanism that requires little effort by the regulatory agency staff except to periodically monitor the CD to ensure that the face amount is adjusted to reflect changes in inflation, technology, and site conditions.

9.3.3.6 Deposits of Securities

Using this financial assurance mechanism, the licensee would be responsible for depositing securities to the appropriate government agency with a face value equal to or greater than the highest cost of closure at the site. Theoretically, the securities could be of several different types, including long-term U.S. bonds, municipal bonds, or corporate securities. This mechanism could place a significant administrative burden on the regulatory staff because they would have to monitor and review the securities to ensure that inflation was not eroding the value of these securities. The staff plans to provide further guidance on the types of acceptable securities in a regulatory guide to be published later.

9.3.3.7 Pledges of Securities and Liens Against Property of the Operator (Secured Assets)

These financial assurance mechanisms are similar to self-insurance, except that the licensee pledges certain assets which could be used by the Commission to perform closure activities in the event of licensee default.

A secured interest is an interest in personal property or fixtures of the operator that gives to the holder of the interest, rights to possession of the property to ensure payment of an obligation. A secured interest payable to a government agency gives that government agency the right, in the event of default by an operator, to take possesion of the assets it has an interest in,

and sell them in satisfaction of the claim. In most cases where a secured interest has been properly created, the holder of the interests has first claim or priority over these assets in the event of licensee bankruptcy.

Secured interests have the particular advantage to the operator of involving few additional expenses. The only costs involved would be those legal costs associated with preparing the documents. However this financial assurance mechanism poses significant disadvantages for the regulatory agency. From a regulatory standpoint, the use of secured assets does not offer as stringent a degree of protection in the event of licensee default. Substantial problems will occur if the government must obtain assets in the event of default. Other creditors may place a lien on the company's assets, and the legal process may considerably delay recovery of the assets, thus necessitating legal proceedings. Another regulatory disadvantage of this financial assurance mechanism is the amount of time necessary for administration.

The regulatory staff would have to spend a significant amount of time evaluating the assets of the operator, and this review would have to be done on a periodic basis in order to account for changes in inflation, depreciation, etc. And finally, if the government did receive title to the assets of the operator in the event of licensee default, the government would have to undertake the task of disposing of the secured assets.

An Environmental Protection Agency review of this financial assurance mechanism has also found that liens suffer from an uncertain status in the event of financial failure of the operator.

9.3.3.8 Letters of Credit

Letters of credit are another short-term financial assurance mechanism investigated by the staff for the purposes of ensuring that sufficient funds are available for closure and postclosure care. The operator would apply to a bank for the issuance of a letter of credit that commits the bank to pay the beneficiary (the state or federal government) if the letter of credit comes due. A letter of credit consists of a bank's document written on behalf of the operator that would give the government agency the right to draw funds from the issuing bank upon the presentation of papers in accordance with the letters of credit. The guidelines for a letter of credit are found in the U.S. Treasury regulations. A national bank can issue letters of credit permissible under the Uniform Commercial Code on behalf of its customers.

An acceptable letter of credit for the purposes of this regulation would be to specify the NRC or some other governmental agency as the party who may draw upon the fund in the amount of the most recent closure care estimate required to be made by the regulations. The letter of credit should specify that the regulatory agency can draw upon the funds behind the letter of credit, following the finding of a violation of the closure requirements.

Fees for issuing a letter of credit are generally lower than those for trusts or bonds. The cost of a letter of credit is based on the face value of the amount. This financial assurance mechanism is advantageous to the regulatory

agency because it requires only a minimal amount of time to administer. There is also no problem of having to evaluate assets, since this activity is performed by the bank.

9.3.3.9 Self-Insurance by the Operator

As used in this analysis, self-insurance refers to an arrangement whereby the operator agrees to perform all closure and postclosure activities, and to finance the activities out of his own resources, such as cash working capital. In effect, it is an alternative involving no additional assurances other than the licensee's legal obligation to perform closure activities required by the regulation and as a condition of license. The legal obligation will exist regardless of any separate contract or lease.

The main problem for a regulatory agency contemplating self-insurance for a financial assurance mechanism is that there is no guarantee that the licensee will actually perform the closure activities. The licensee may not have sufficient funds to meet their license responsibilities and if this is the case, there is no special leverage that the regulatory agency can use to obtain the funds from the licensee. In case of default, the government agency would have to obtain a legal judgment based on its license contract with the licensee, and then would have to execute its judgment if the operator has assets out of which the judgment can be satisfied. This approach provides no assurances that sufficient funds will be available for closure.

9.3.3.10 Financial Tests

Financial tests are another variation on self-insurance, which have been used as a financial assurance mechanism by several other state and federal regulatory agencies. A financial test involves having the regulatory agency develop a set of criteria which shows that a licensee has sufficient unencumbered assets. The assets are not pledged or retained for closure. Rather financial tests would enable the Commission to monitor the financial health of the licensee's operations, and in the event of a deteriorating financial condition, the licensee would be required to establish another method of financial assurance.

There are a variety of financial tests which could be used by regulatory staff to ascertain that the licensee has sufficient financial health: net working capital, net worth, a review of the total liability to net worth ratio, current or quick ratio, and the age of the firm. The reader is referred to Appendix K of the EIS for a description of these financial tests.

While advantageous to the operator, the use of financial tests provides no degree of financial assurance that the licensee will have sufficient unencumbered assets to provide for closure. Additionally, the use of financial tests involves an inordinate amount of administrative time and effort by the regulatory staff, who must periodically review the financial information to verify that the operator has sufficient assets to provide for closure of the site.

9.3.3.11 No Financial Assurance Requirements for Closure and Postclosure

Another regulatory alternative for short-term care would be for the regulatory agency to not establish any funding requirement on waste licensees for financial responsibility for closure. With such a scenario, the custodial care regulatory agency or the site owner could be responsible for all costs incurred during closure and postclosure. Additionally, the staff did not consider this alternative for long-term care, since some form of financial assurance for closure and long-term care are already being implemented at existing LLW disposal sites. The Commission staff has also received comments on the need to establish financial responsibility for short-term closure and postclosure care activities of low-level waste sites.

Based on these findings, the staff has determined that a regulatory approach of not requiring short-term financial assurances for closure of a site is not acceptable.

9.3.3.12 Other Short-Term Sureties

9.3.3.12.1 Imposing a Surcharge on Waste Generators and Depositing Funds into a Sinking Fund

In the past, state regulatory authorities have frequently required operators of low-level waste disposal sites to impose a surcharge on a cubic foot or meter basis on the site's users, to recover some degree of closure and post-closure expenses. In a petition for rulemaking, the Natural Resources Defense Council also requested that a surcharge on a capacity basis be imposed on users of disposal sites. The staff recognizes the merit of such an approach from a regulatory standpoint. The use of a surcharge deposited into a sinking fund has been used as a collection method by several state regulatory agencies. The use of a surcharge also is an equitable system of providing for closure costs, because the responsibility for these costs is borne by the waste generators who use the waste disposal service. Nevertheless, there are several problems with the use of this financial assurance mechanism. First, a sinking fund builds up funds gradually over the life of the site, and therefore, the fund will not have sufficient assets during the early portion of its inception to account for the full costs of closure. Such a mechanism would not guarantee that the full costs of closure were available at all times to account for closure. (This problem could possibly be alleviated by simultaneously requiring another financial assurance mechanism on the balance of the closure funds.) A second reason why this financial assurance mechanism is not appropriate is because the NRC currently lacks the statutory authority to require a surcharge or a fee per unit volume of waste. Establishment of an earmarked fund would also require Congressional authorization. In 1978, the NRC staff responded to a petition for rulemaking by the Natural Resources Defense Council, that called for NRC establishment of a special fund based upon a cubic foot surcharge. In their response to the petition, the staff noted that a federally mandated fee per unit volume of waste that is not a product of the landlord/tenant contract (i.e., a lease) would be, in essence, a tax that requires legislative enactment. Based on landlord/tenant (state or federal government/site operator) contracts authorized by state law, the states containing commercial burial sites have

collected disposal fees from the site operator on a capacity basis. However, for the reasons stated above, a financial assurance requirement consisting of a surcharge as a means of collection cannot be imposed at the federal level.

9.3.3.12.2 Closure Pool

Another possible variation for assuring adequate financial funds for closure involves the development of a pool of closure assurance funds. Disposal facility operators (and possibly, operators of other fuel cycle facilities) would make payments to such a fund. An independent "Closure Assurance Agency" would be chartered to retain and invest the funds, and perhaps oversee activities and disperse payments to those conducting the activities. The pooling of funds into such a shared risk centralized agency could help to ensure closure even if a particular facility operator defaults. The agency would act in a fiduciary capacity for the public. Payments and interest received by the stewardship entity would possibly be exempt from federal income taxes, because the entity would be a creation of the U.S. or a state government and an exempt scientific entity.

The pool would be obligated to pay for closure of a site if the operator defaulted on performance of required closure activities. However, setting the appropriate premiums would be difficult, since the pool administrator would have to estimate the likelihood of nonperformance or partial performance, and then calculate the magnitude of the fund required to complete the closure. Such a pool would probably have to be established by the federal government and would require Congressional action.

9.3.4 Conclusions and Financial Assurance Mechanisms for Closure and Postclosure Found Acceptable by the Staff

Given the past history at some of the existing disposal sites, one of the key concerns is assurance of adequate financial qualification on the part of the applicant to construct and operate the disposal facility and to provide adequate financial provisions for disposal site closure and postoperational activities. The staff believes the applicant should be financially qualified to conduct all license activities during the construction and operational phases of the land disposal facility. Proof of the financial qualifications of applicants is not currently required by Parts 30 and 40. This new requirement will help assure that resources are not expended on projects without adequate backing. This requirement should minimize the potential for early default or the abandonment of the site by the operator.

Given the past history, the staff also concluded that the facility operator should provide financial assurances for closure and postclosure care. A requirement for financial assurance for closure can be viewed as a type of financial guarantee to ensure that in the event of operator default, there are funds available for closure. The NRC received evidence of a great deal of public interest concerning the issue of financial responsibility for closure of a disposal site. Numerous written comments were made on this portion of the draft regulation, and the issue was also raised at all four workshops held to review this regulation. Many commenters felt that the licensee should be

held responsible for the full costs of closure of a disposal site and that the license should not be terminated and the land returned to the custodial government authority until the licensee has completed satisfactory closure.

The amount of surety liability required should be based on cost estimates submitted by the licensee in an approved plan for disposal site closure and stabilization. The applicant must submit a cost estimate for disposal site closure that includes consideration of inflation, increases in the amount of disturbed land, and the closure and stabilization activities that have already occurred at the disposal site.

Based on the review of the alternative financial assurance mechanisms, the staff found a variety of financial assurance mechanisms acceptable. The decision to select specific alternatives was based on the degree to which the various mechanisms conformed to the technical requirements previously listed in this chapter. Additionally, consideration was given to the views and experiences of other regulatory agency staff with experience in administering these various financial assurance mechanisms.

The staff concluded that a number of financial assurance mechanisms exist that will provide adequate public protection to ensure that funds for closure and postclosure exist in the event that the site operator defaults or unforeseen site conditions require early closure of the site. The alternatives that the staff finds acceptable on a generic basis for a disposal facility licensee are:

- surety bonds
- trust funds
- escrow arrangements
- cash deposits
- certificates of deposit
- deposits of government securities
- irrevocable letters of credit
- combinations of the above

These alternatives were all found to be acceptable by the staff because they didn't impose a significant economic burden on the license, they didn't impose an administrative burden on the staff, and yet they each could be structured to ensure a high degree of confidence that funds would be available to ensure proper closure. The staff also has concluded that approving a range of satisfactory financial assurance alternatives allows the operator flexibility in selecting the mechanism that best suits his needs. While the other financial assurance mechanisms discussed earlier may be acceptable in certain isolated cases, they are not acceptable to the staff on a generic basis. Plans for alternative financial assurance mechanisms not discussed here would be evaluated and approved by the staff on a case-by-case basis. The costs for short-term financial assurances have been included as part of the costs for the reference facility described in Apppendix E.

9.4 LONG-TERM CARE (ACTIVE INSTITUTIONAL CONTROL PERIOD) FUNDING REQUIREMENTS

9.4.1 Introduction

Based on a review of the operating history at existing LLW disposal sites, the the staff finds that financial responsibility for long-term care (active institutional control) should be established throughout the operational life of the disposal facility. Financial assurances for active institutional control involve the financing of any required activities at a low-level waste site after completion of closure and postclosure care activities. These fundi assurances would cover surveillance, monitoring, and any necessary maintenance to assure that the stability and integrity of the site is maintained and that there are no disruptive human activities at the site for up to 100 years.

9.4.2 Need for Requiring Financial Assurances for the Active Institutional Control Period

A review of the history of commercial low-level waste sites in this country indicates that there has been continuing concern by the public and by regulator authorities over long-term financial responsibility for low-level waste disposa sites. In addition to questions over the equity issues of who pays for active institutional control over the site, the government and the public are concerned that funds be readily available for such postoperational activities in order to ensure that the public's health and safety are continually protected. Th controversy over postclosure control at the Sheffield, Illinois low-level waste disposal site is a contemporary illustration of the dilemma that exists in this area. Another event that has highlighted this controversy concerning the adequacy of long-term care funds occurred at the closing of the low-level waste disposal site at West Valley, New York. A report done by the U.S. General Accounting Office also found that the financial responsibility for this site raised larger policy issues "concerning whether or not, and to what extent, the federal government should provide financial assistance to the nuclear industry by taking over the cost of managing activities in the back end of the fuel cycle." Based on these considerations, the Commission staff concluded that requirements for financial guarantees for active institutional control should be included in the proposed low-level waste regulations in order to ensure that the public's health and safety are protected.

Existing state financial requirements for long-term care of a disposal site have frequently been referred to as "perpetual care arrangements." They are based on the same concept as scholarships, research endowment funds, or perpetual care funds for cemeteries. Funds are invested and a return is earned on this principal. When this amount of interest earned is adjusted by the annual inflation rate, the net rate of return is determined. If a sufficient return is earned, it is then used to pay for various activities, such as research, scholarships, maintenance at the cemetery, or conversely, surveillance, monitoring and maintenance at a low-level waste disposal site. If the net rate earned on the principal is larger than inflation, then the principal is left intact, and the principal can be invested again and again (in perpetuity) to fund these various activities through the return earned on the invested principal. However, if the interest rate earned on the principal is less than

the inflation rate, or large extraordinary expenses develop that were not originally planned for, then the principal must be used if the activities are to be paid for. In that case, the principal is eventually reduced to zero, the perpetual care fund has a short life, and other resources besides those of the operator must be utilized.

9.4.3 Technical Requirements for Financial Assurances for Active Institutional Control

Based on a review of existing experiences with long-term care funds at commercial low-level waste sites, the staff has concluded that it is necessary to require licensees to establish financial responsibility for active institutional control and long-term care of a site. The staff has concluded that the licensee must provide financial assurances for active institutional control that includes all necessary expenses, including surveillance, monitoring, any necessary maintenance, and inflation. These costs are of a finite nature, because a "perpetual" care financial arrangement for low-level waste disposal sites is not required. Rather, financial responsibility for postclosure care during the 100-year active institutional contol period is required. To the extent that the licensee and the licensing authority have correctly estimated the types of activities necessary during this period, along with their resultant costs (adjusted for inflation), then the long-term care funding mechanism should be adequate to properly handle the known and predictable expenses of this 100-year period. However, it is beyond the scope of this long-term requirement to consider provisions for contingency costs. Beyond the period of 100 years, no expenses have been calculated for inclusion into the determination of long-term care responsiblity.

9.4.4 Types of Active Institutional Control Costs

A variety of studies have been performed that have analyzed types and estimates of costs for active institutional control at low-level waste sites. Appendix Q provides a discussion of these studies and cost estimates that were developed. For the 100-year active institutional control period, total costs at a reference disposal facility are estimated to range from between $8.5 million to $34.6 million (inflated dollars) depending on various site conditions.

9.4.5 Types of Active Institutional Control Funding Arrangements

A review of the various financial assurance mechanisms commonly used in the commercial law area (see Section 9.3.3) reveals that few if any of these mechanisms are suitable for the long-term nature of a long-term financial assurance mechanism. The extended time period (100 years) means that few financial institutions are willing or able to handle that type of long-term financial assurance. There are, however, several other alternative long-term financial assurance mechanisms that can be used for active institutional control at a disposal site. Several technical criteria were applied in reviewing the adequacy of alternative financial assurance mechanisms for long-term care. The staff considered that the most important consideration for long-term financial assurances was the extent to which they were able to provide a guarantee that the necessary funds would be produced by the responsible parties. Another

necessary factor for consideration in evaluating the various financial assurance mechanisms at the federal government level was the extent to which enabling authority existed to allow the Commission staff to require such a mechanism. Several of the financial assurance mechanisms proposed by various parties would require enabling legislation that is currently lacking at the federal level. A brief description of these alternatives follows and each is described in greater detail in Appendix K.

9.4.6 Sinking Fund with Surcharge Recovered from Waste Generators

Several of the states currently require that their disposal licensees collect a specified surcharge from each waste generator who uses the site. The funds collected from these long-term care surcharges are then deposited into an earmarked state treasury account or sinking fund, where they are invested to keep pace with inflation. If such a sinking fund were used, in order for the regulatory agency to assure itself that there was protection to assure that funds for long-term care were available, a sinking fund would have to be combined with a performance bond on the unpaid balance. For example, suppose the regulatory agency determined that $10 million in 1980 dollars were necessary for active institutional control for 100 years. During the first year of operation the licensee might collect $.5 million from surcharges, which he would then deposit and then post a bond for $9.5 million. In the second year of operation, assuming that $1.0 million is deposited into the sinking fund, then the licensee would have to have a performance bond of $9.0 million, and so on. Such a fund could be set up in two ways. First, a fund could be established on a "perpetual" basis where the funds earned each year from the invested principal are used to pay for long-term activity costs. As long as the interest on the invested principal earned more than the inflation rate, and the net rate of return was positive, there would be sufficient funds for long-term care.

A second way that a long-term care fund could be set up is through the development of a finite period of control, such as a 100-year period. The funds would not be available in perpetuity, but rather for only a specified, finite period. The principal amount, which would be collected from surcharges on waste generators, would be drawn on over the 100-year period to pay for all necessary postclosure care, so that only a small amount of the principal and interest is left at the end of the 100-year period. Both of these two variants of long-term care funds are based on surcharges collected from waste generators. Although these two funding mechanisms have been used at the state level at commercial low-level waste disposal sites, the Nuclear Regulatory Commmission lacks the authority at the federal level to require that a surcharge (which is considered a tax) be imposed on waste generators. Therefore, the staff cannot recommend the use of this regulatory mechanism.

9.4.7 Low-Level Waste Disposal Site "Superfund"

Another type of financial assurance provision for active institutional control that has been proposed is the development of a federally administered long-term care program to which all disposal operators would be required to contribute. Using this scenario, the federal government would be responsible for

administering a radioactive "Superfund," that is similar in nature to the fund being developed by the federal government based on P.L. 96-510. Proponents of this funding mechanism argue that, since burial sites serve national and not state needs, the citizens of individual states should not be required to bear the cost of major contingency actions for long-term care activities at these sites. The 1977 NRC Task Force Report on the Review of the Federal/State Programs for Regulation of Commercial Low-level Radioactive Waste Burial Grounds came to a similar conclusion. The report stated that "it appears desirable and equitable for the federal government to assume responsibility for long-term care of the sites, since the states generally do not have the resources to assure adequate care under a variety of contingencies and also since the sites serve regional needs." However, this type of pooled risk long-term care mechanism would require enabling legislation from Congress, since the authority to establish such a pool does not currently exist. Therefore, for the purposes of this regulation the staff cannot recommend the use of such a financial assurance mechanism.

9.4.8 Lease or Binding Arrangement

Another type of financial assurance mechanism suitable for active institutional control is the use of a legally binding arrangement such as a lease, between the licensee and the site landowner, wherein the two parties agree to assume varying degrees of responsibility between themselves for all required and predictable costs of long-term care of the site. Such a regulatory approach has been used since 1962, with mixed success at the commercial LLW disposal sites. The leases have generally specified that the licensee collect a surcharge of some amount from the waste generators. In several cases, the amount of the surcharge has been inadequate to generate sufficient funds for long-term care. The terms and conditions of the leases have also been subject to legal challenges by the licensees and the site owner.

9.4.9 No Financial Assurance Requirements for Active Institutional Control

Another long-term care alternative would be to not establish any funding requirement on waste licensees for financial responsibility. In such a scenario, the custodial care agency or the site owner would be responsible for all costs incurred during the active institutional control period. However, under this alternative, the waste generator would not be paying the full costs of the sites, resulting in an inequitable situation. Additionally, the staff did not consider a no action alternative for long-term care, since all of the existing LLW disposal sites have had some form of funding arrangement since the first site was licensed in 1962. The Commission staff has received numerous oral and written comments on the need to establish funding assurances for long-term care of low-level waste sites. The staff has determined that such a regulatory approach of not requiring a long-term care fund is not acceptable.

9.4.10 Acceptable Financial Assurance Mechanisms for Active Institutional Control

The staff has determined that all low-level waste disposal site operators must establish evidence of financial responsibility for long-term care of the site

during the active institutional control period. Financial responsibility must be fixed well before closure for the costs of all required and necessary activities at the site, including surveillance, monitoring, inflation, and any required maintenance. Traditionally, states regulating existing commercial low-level waste disposal sites have required licensees to establish sinking funds based on surcharges collected from the waste generators, along with leases between themselves and the operator specifying financial responsibility for long-term care of the site. The staff is aware of the benefits of requiring disposal operators to require a surcharge on waste generators which is consequently deposited into a sinking fund and then invested. Such a cost recovery mechanism directly charges those parties benefiting (i.e., the waste generators) for the costs of long-term care. However, this approach cannot be used since the Commission lacks the authority to: (a) require that a long-term care fund be established, and (b) require that the operator impose a surcharge on waste generators. Appendix K of the EIS provides a description of the Commission's determination of these points.

Since the Commission lacks the authority to explicitly require that a surcharge be imposed and a sinking fund to be established, the staff considers that the next best regulatory alternative is to require that the operator be party to a binding arrangement such as a lease between himself and the site's landowner (current Commission regulations require the state or federal government to be the site land owner) which establishes evidence of financial responsibility for the 100-year institutional control period. The lease must also take into account changes in inflation over the 100-year period and the Commission wil periodically review the lease to ensure that the terms and conditions are kept current by the parties to reflect changes in inflation, technology, and specific site conditions. More guidance on the specifics of this binding arrangement will be presented in a forthcoming regulatory guide to be issued by the Commission. The staff is aware of the shortcomings of such an approach, but considers this the best regulatory alternative based on the current statutory authority of the Commission. (States licensing disposal sites pursuant to the State Agreement Program may have enabling authority to require that a sinking fund be established, and that a surcharge be required of waste generators, and they may wish to consider such a regulatory alternative.) However, for the purposes of this regulation, the staff recommends that a low-level waste disposal applicant provide the Commission with an assurance that adequate financial resources will be available to provide for all known and predictable expenses that occur during the active institutional control period at the site following closure. Such a regulatory requirement will help to ensure that the licensee or the site owner is responsible for performing all required long-term care activities that are necessary to protect the public health and safety and the environment.

The staff has included the costs for 100 years of active institutional control into the cost of the reference facility, and corresponding alternatives that have also been analyzed. The actual costs of long-term care, however, will vary depending upon the level of active maintenance required under varying disposal facility conditions. The staff assumed that these funds for active institutional control would be obtained through a surcharge based on waste received at the facility. Monies obtained from the surcharge would then be placed into an interest bearing account.

Chapter 10

ENVIRONMENTAL CONSEQUENCES

10.1 INTRODUCTION

The purpose of this chapter is to identify, evaluate, and quantify the effects of the proposed rulemaking action: NRC's promulgation of a comprehensive regulation governing the management of low-level radioactive waste disposal (10 CFR Part 61). The environmental consequences or impacts discussed are based on the proposed rule as developed in previous chapters and do not include consideration of impacts of alternative versions of the rule. The consequences discussed are incremental, in some cases, with respect to the current regulatory framework.

Both direct and indirect environmental impacts will occur as a result of the proposed Part 61 rule. Direct impacts are discussed first in this chapter (Section 10.2) and, although such impacts are readily identified and evaluated, they are significantly different than the impacts typically considered in an EIS for a physical project such as a nuclear power plant or a fuel fabrication facility. Because this EIS is being prepared for a rulemaking action, the direct effects of the action do not fall upon the physical and natural environments, but rather upon those segments of the human environment whose conduct of affairs will be affected by the change in regulatory requirements. Among the directly affected groups considered in Section 10.2 are:

- Waste generators and processors;
- Waste transporters;
- Waste disposal facility operators;
- Federal agencies and the states; and
- The public.

Section 10.3 discusses the indirect impacts of the proposed Part 61 rule. In this section the performance objectives and minimum technical requirements of the rule are applied to four reference disposal facility sites located on a regional basis. Through this analysis, the residual or unmitigated impacts are identified which will occur even with the application of Part 61 requirements. By applying these requirements to a reference facility design and analyzing the benefits and residual impacts, the reader is provided with an estimate of the "real world" effects of the rule in terms that are more reflective of a typical project-specific EIS.

10.2 ENVIRONMENTAL CONSEQUENCES OCCURRING DIRECTLY AS A RESULT OF THE PROPOSED PART 61 RULE

10.2.1 Impacts on Federal Agencies

In Chapter 1 a number of federal agencies were identified which have responsibilities relative to low-level waste management. These agencies are: NRC, the Environmental Protection Agency (EPA), the Department of Energy (DOE), the Department of Transportation (DOT) and the U.S. Geological Survey (USGS). The effects of the Part 61 rule on these agencies are discussed in the following subsections.

10.2.1.1 Impacts on NRC

In general terms, the chief impact of the adoption of 10 CFR Part 61 on NRC would be to more clearly define to the staff the established policies, licensing procedures, and performance objectives governing LLW disposal. It would also help ensure that LLW disposal facilities are treated uniformly in terms of complying with the above regulations and procedures.

Adoption of the Part 61 rule is not expected to significantly increase NRC's regulatory expenditures. Although the new requirements should result in some increased costs and effort, these probable increases in regulatory costs will be offset by gains in NRC's administrative efficiency. The application of a cr ·e·hensive set of regulations governing LLW will aid both potential licensees, states, the public, and NRC by more clearly defining respective responsibilities. requirements, analyses, and determinations. In particular, NRC would have a uniform set of administrative procedures and performance requirements to apply in each instance. NRC would also have a set of clearly enunciated technical performance requirements that would permit more effective control of the performance and operating procedures of commercial LLW disposal facilities.

10.2.1.2 Impacts on EPA

The Environmental Protection Agency (EPA) is charged with the responsibility of protection and enhancement of environmental quality and it carries out its mission through research, monitoring, regulatory, and enforcement functions. An important EPA role with regard to low-level radioactive waste management is in the establishment of generally applicable environmental standards for waste disposal. The Agency does not license radioactive waste disposal facilities.

At the present time, the overall environmental standards for waste disposal are in the development process. The fact that EPA's standards in this field are not currently established required NRC to make a choice with regard to development of the Part 61 rule: proceed with rulemaking based on interim standards developed by NRC and coordinated with EPA, or suspend rulemaking until the EPA standards are formulated. NRC chose the former course of action.

In proceeding, NRC consulted with EPA on the performance objectives, minimum technical criteria, and other aspects of the rule. As a result of this coor ated effort, the technical criteria established in this statement and the ru itself will not impact the ongoing program of that agency for establishing

overall environment standards for waste disposal. Rather, the NRC rulemaking effort may in fact advance EPA's efforts in this regard.

10.2.1.3 Impact on DOE

The Department of Energy (DOE) is responsible for managing disposal of low-level radioactive waste generated by government operations and for conducting research into various aspects of radioactive waste disposal. Disposal of LLW by DOE is exempted from NRC licensing authority and would remain so under the proposed Part 61 rule. Therefore, DOE's LLW disposal operations would be unaffected by the rule and could not come under its purview without an amendment to the Energy Reorganization Act of 1974.

One impact of the Part 61 rule on DOE would occur if DOE resumed using commercial disposal facilities for disposal of DOE LLW. Under this situation DOE would have to ensure that its waste conformed to applicable parts of the new rule. In addition, the Part 61 rule will help to provide additional specific guidance to DOE's programs of technology development and assistance to states in establishing new sites.

10.2.1.4 Impacts on DOT

Transportation of radioactive materials in the United States is jointly regulated by the Department of Transportation (DOT) and NRC. DOT regulates all radioactive materials in interstate commerce while NRC regulates the transportation of byproduct, source, and special nuclear material. The agencies continue to work closely in establishing standards and regulating packaging and other aspects of radioactive material transport. NRC's existing regulations for transport reflect the requirements of DOT and the situation will remain the same under the proposed Part 61 rule. The minimum requirements for waste form and packaging under the proposed rule are in compliance with existing DOT and NRC regulations and thus will not impact the regulatory program of DOT. The stability waste form requirements for higher activity wastes will help improve transportation safety as a byproduct, as will the minimum waste form requirements intended to improve operational safety at the disposal facility.

10.2.2 <u>Impacts on the States</u>

Promulgation by NRC of the proposed Part 61 regulation will have impacts on the states in addition to these realized by industry and federal agencies. These impacts will primarily affect those states which have entered into agreements with NRC for regulation of certain radioactive materials--i.e., the Agreement States.

Under provisions of the Atomic Energy Act, the states and NRC maintain compatible programs, which include specific rules and regulations. The promulgation of 10 CFR Part 61 would mean that the Agreement States would have to modify their regulations to include provisions compatible with the new NRC regulation. This process of modification would involve, at a minimum, the following steps:

- Preparation of draft regulations to reflect the requirements of the Part 61 rule;

- o Review and approval of proposed regulations by NRC; and
- o Public review and formal incorporation into state code.

In preparation of this EIS, NRC has not attempted to quantify the actual costs which would be incurred by the Agreement States in modification of their programs. In part, this is because the periodic updating and modification of Agreement State rules and regulations to maintain a program compatible with NRC regulations is part of the normal functioning of the Agreement State program. Moreover, the Agreement State programs vary from state to state and the costs to one state to assure compatibility may not necessarily reflect the costs to another state.

10.2.3 Impacts on the Public

Promulgation of the proposed Part 61 rule by NRC will impact the public most significantly. The purpose of the rule is to provide improved safeguards for protection of public health and safety and the environment, but despite these improvements, the technology of waste disposal is not risk-free. Whatever risks remain in the presence of the operative rule will be borne by the public, as will the ultimate costs of implementing the rule. In the following paragraphs, the beneficial as well as the adverse impacts of implementing the Part 61 rule are considered.

10.2.3.1 Beneficial Impacts

The requirements of the Part 61 regulation are expected to result in beneficial impacts to the public in threee major areas. First, the implementation and enforcement of performance objectives and uniform minimum technical requirements will improve the performance of future LLW disposal facilities and thereby reduce the hazards of LLW disposal to public health and safety and environmental quality. Although the benefits of the rule's requirements may not be immediately apparent, the staff believes that in the long term these requirements will improve the stability of both the waste form and the disposal facility and will lessen the potential for radionuclide migration into the environment and the need for active long-term maintenance of the facility.

Second, the requirements of the Part 61 rule should assure that near-surface disposal remains a safe viable option for the disposal of LLW. Therefore, the public can be assured of the continued availability of goods and services whose provision results in generation of LLW. Among these goods and services are electricity from nuclear power plants, medical diagnostic aids based on nuclear technology, and research into new applications of nuclear technology.

Finally, the Part 61 rule provides public benefits in the form of more explicit provisions for participation in the licensing process for future LLW disposal facilities. Licensing requirements and procedures have heretofore been fragmented and somewhat difficult for interested citizens to fathom. As set out in the rule, these procedures are consolidated, and expanded provisions for participation by state and tribal governments are set out under Subpart F of the rule.

10.2.3.2 Adverse Impacts

The proposed Part 61 rule will result in benefits to the public. However, the staff does not expect that implementation of the rule will be without adverse public impacts. Three primary impacts are expected to occur.

The first of these impacts will be residual environmental and human health hazards resulting from LLW disposal. Despite the provisions of the Part 61 rule, the variables and processes involved in LLW disposal are sufficiently complex that unmitigated impacts cannot be avoided. These may include occupational exposure, migration of radionuclides, and subsequent offsite exposures. (Section 10.3 discusses these unmitigated impacts in more detail.) It should be noted, however, that these impacts are not impacts caused by the rule, but rather impacts which are considered beyond the capability of the rule to eliminate entirely.

Achieving reductions in impacts from LLW disposal will not be without costs in an economic sense. Implementing the requirements of the Part 61 rule will involve costs to the disposal facility operators, waste transporters, and waste generators. These costs, of course, will be passed on to the public in the form of increased prices for goods and services whose provision involves the generation of LLW. It is not expected that the passing on of these costs will create an incremental change to the consumer, but rather will appear along with many other costs of doing business in aggregate price increases.

Finally, implementation and enforcement of the provisions of the Part 61 rule will require the allocation of federal and state resources during the operational and postoperational periods of a LLW disposal facility. To the extent that these public resources are allocated to regulation of LLW disposal, they are unavailable for other purposes. Conversely, to the extent that the public incurs this cost, it reduces (within limits) the costs of LLW disposal in terms of human health hazards and environmental impacts.

10.3 ENVIRONMENTAL CONSEQUENCES OCCURRING INDIRECTLY AS A RESULT OF THE PROPOSED PART 61 RULE

This section discusses the indirect impacts of the proposed Part 61 regulation. To estimate these impacts, the performance objectives and minimal technical criteria established in Chapters 4 through 9 are applied to four reference disposal facilities assumed to be constructed on four hypothetical regional sites. Through this analysis, the residual or unmitigated impacts that could occur even with the application of the Part 61 requirements are addressed.

This section is divided into four subsections as follows. Section 10.3.1 provides a brief summary of the assumed regional sites, while a description of the disposal facilities assumed to be constructed at each regional site is provided in Section 10.3.2. The waste forms assumed for the regional case study analysis are also summarized in Section 10.3.2. Section 10.3.3 presents the results of the analysis in terms of radiological impacts and costs. Section 10.3.4 presents a discussion of other impact measures such as air quality, land use, and incremental energy use.

10.3.1 Hypothetical Regional Sites

This section presents a description of the four hypothetical regional sites assumed in this EIS. For the purposes of this EIS, the conterminous U.S. has been divided into four regions having boundaries based upon the existing five NRC regions. These are referred to in this EIS as the northeast region (NRC Region I), the southeast region (NRC Region II), the midwest region (NRC Region III), and the western region (a combination of NRC Regions IV and V). Each region is projected to generate from 600,000 to 1,000,000 m^3 of LLW between the years 1980 and 2000. A disposal facility is assumed to be located at a hypothetical site within each region. The western regional site description is meant to be representative of the southwestern portion of the region, and is usually termed the southwest site in this EIS.

Each site description has been developed from a number of sources and is meant to be consistent with: (a) the basic disposal facility siting considerations discussed in Chapter 5 and Appendix E, and (b) the generic environmental characteristics within that region. The regional site descriptions are intended to describe reasonable realistic sites--i.e., sites that could be licensed under the Part 61 rule--but are not intended to represent the "best" sites that could be located within the regions. Although the regional sites are meant to be typical of the environmental characteristics within the regions, the sites are not meant to describe any existing or potentially planned disposal facil‘‘ or any specific location within a particular region. The site descriptions and ensuing case study analysis should also not be interpreted as NRC advocacy of any region or any specific location within a region. The principal purpose of the regional site descriptions is to provide a wide range of environmental conditions for consideration in the analysis.

The following provides a brief description of the regional disposal facility sites. More detailed descriptions are provided in Appendix E (southeast site) and Appendix J (the northeast, midwest, and southwest sites). A short summary of most of the principal site environmental properties used in the analyses is included as Table 10.1. Table 10.2 contains a summary of the (dimensionless) retardation coefficients assumed for the soils in the vicinity of the regional sites, while Table 10.3 contains a summary of the assumed population distributions

10.3.1.1 Northeast Site

The northeast site is assumed to be located within the Appalachian Upland portion of the Appalachian Plateau physiographic province. The area has been reworked by erosional and depositional forces associated with glacial and postglacial activities. The disposal facility site is on an upland area, having an average elevation of about 555 m (1,820 ft) above mean sea level (msl). Throughout most of the Appalachian upland, the bedrock is overlain by unconsolidated deposits of glacial origin. The thickness of these units is generally greater in the lowlands and valleys, gradually thinning out over the upland. The material properties of the deposits are highly variable.

Table 10.1 Summary of Regional Disposal Facility Site Environmental Properties

Environmental property	Regional Sites NE	SE	MW	SW
Mean average temperature °C (°F)	8°C (46°F)	17°C (63°F)	11°C (51°F)	14°C (57°F)
Average wind speed km/hr	16.6	13	17	25
Average annual precipitation mm (in)	1,034 (41)	1,168 (46)	777 (30.5)	485 (19)
Average annual natural percolation (PERC) into groundwater system mm (in)	74 (2.9)	180 (7.1)	50 (2.0)	1 (.04)
Precipitation-evaporation (PE) index of site vicinity	136	91	93	21
Average silt context of site soils (%)	65	50	85	65
Average cation exchange capacity (meg/100g)	15	10	12	5
Groundwater travel time (yrs)				
Waste to:				
o Water table	50	10	23	277
o Site boundary	200	32	130	280
o Population well	2,500	400	2,100	580
o Surface water body	5,000	800	3,800	880
Distance (m)				
Waste to:				
o Water table	4	5	4	84
o Site boundary	30	30	30	30
o Population well	500	500	1,250	3,000
o Surface water body	1,000	1,000	2,500	6,000
Average transportation distance to regional facility (miles)	300	400	600	1,000

Table 10.2 Retardation Coefficients Assumed for Regional Disposal Facility Sites

Isotope	Regional Site NE	SE	MW	SW
H-3	1	1	1	1
C-14	10	10	10	10
Fe-55	5,400	2,640	2,640	1,290
Ni-59	3,600	1,750	1,790	860
Ni-63	3,600	1,750	1,750	860
Co-60	3,600	1,750	1,750	860
Sr-90	73	36	36	18
Nb-94	10,000	4,640	4,640	2,150
Tc-99	5	4	4	3
I-129	5	4	4	3
Cs-135	720	350	350	173
Cs-137	7,200	350	350	173
U-235	7,200	3,520	3,520	1,720
U-238	7,200	3,520	3,520	1,720
Np-237	2,500	1,200	1,200	600
Pu-238	7,200	3,520	3,520	1,720
Pu-239/240	7,200	3,520	3,520	1,720
Pu-241	7,200	3,520	3,520	1,720
Pu-242	7,200	3,520	3,520	1,720
Am-241	2,500	1,200	1,200	600
Am-243	2,500	1,200	1,200	600
Cm-243	2,500	1,200	1,200	600
Cm-244	2,500	1,200	1,200	600

Table 10.3 Population Distributions for the Regional Disposal Facility Sites

Distance From Facility	Northeast	Southeast	Midwest	Southwest
0-5 miles	3,400	2,000	3,100	60
5-10 miles	20,500	8,100	5,000	180
10-20 miles	73,600	36,000	27,900	3,500
20-30 miles	121,600	125,000	104,200	9,100
30-40 miles	556,600	203,400	121,900	4,900
40-50 miles	1,012,800	104,900	359,100	27,200

The site is underlain by approximately 9 to 23 m (30 to 75 ft) of compacted glacial till frequently referred to as hardpan or fragipan. Thin and discontinuous layers of sand and gravel are observed locally in the area. Coarser-grained sediments are principally found in valleys and lowlands, and are associated with stream channels. Underlying the glacial mantle are flat-lying rocks consisting of marine, black, and gray shales and siltstones, with some thin sandstone layers. The predominant soil types belong to the Brickton, Warren, Chitta and Highland series. The parent material consists of acidic, dense glacial till having a low lime content. The site has slopes ranging from nearly level to moderately rolling, and the runoff potentials are correspondingly variable. The soils are deep and generally poorly drained. Permeabilities for the uppermost foot of soils are moderate. However, the dense silty fragipan subsoil is of considerable thickness and is highly impervious.

Ground and Surface Water

Ground water generally occurs where the bedrock and glacial till meet. The depth to ground water at the site averages about 12 meters. The amount of ground water available in the local upland area where the site is located is largely limited to that which reaches the zone of saturation from precipitation falling upgradient of the site. This recharge quantity is small because of the low permeability of the till and the heavily vegetated nature of the land surface which acts to hold water in the surficial organic matter resulting in greater loss via evapotranspiration. Ground water occurrence in the bedrock is limited to secondary openings along fracture zones and bedding planes. Generally, the fine-grained character associated with the shales and siltstones inhibits water movement.

Ground water usage in this rural setting is very low, although the quality of ground water in the unconsolidated deposits and upper shale units is generally good. Pumpage is limited to widely scattered wells serving as domestic supplies to local homes and farmsteads. Most of these rural supplies are obtained from bedrock wells, 30 to 61 m (100 to 200 ft) in depth, and having average yields ranging between 23 to 38 liters per minute (6 to 10 gpm).

The site vicinity is generally sloping, with total vegetative cover. The surface soils and vegetation allow for considerable retention of precipitation; only 20 to 30 percent of precipitation becomes surface runoff. A strong correlation exists between stream discharge and precipitation in the site basin. Mean annual discharge at the outlet of the basin is about 1 m^3/s (35 cfs), but a wide variation in flow occurs throughout the year.

Meteorology

The climate in the area of the northeast site is classified as humid continental, characterized by wide variations in seasonal precipitation and temperature. Moisture sources for precipitation are obtained from the southerly flow of Gulf air during the summer, cyclones that originate in the Great Lakes, and Atlantic coast systems. Precipitation is uniformly distributed over the year with the greatest average monthly amounts occurring during April through September in the form of thundershowers. The average annual precipitation is approximately 1034 mm (41 in).

The area is characterized by distinct seasonal temperature variations. Winters are predominantly cold with maximum temperatures ranging from 0 to 20°C (32 to 36°F), and nighttime minimums of from -9 to -7°C (15 to 20°F). The temperatures are generally mild during June through August and maximum average temperatures range from 24 to 26°C (75 - 78°F).

The prevailing wind direction is southerly from May through November and westerly during the winter and early spring. The average wind speeds during these periods are 15.6 and 17.8 km/hr (8.4 and 9.6 knots), respectively. The average annual windspeed near the site is 16.6 km/hr (10.3 mph), and occurs from the west-southwest direction. Thunderstorms occur on an average of about 30 days per year and are more vigorous during the warm season. Tornados are not common but may occur between late May and late August. Freezing rain storms generally occur on one or more occasions during the winter but are of short duration.

Ecology

The site is located within the Appalachian Highland division of the Hemlock White Pine-Northern Hardwoods region. The region is characterized by a pronounced alternating presence of decidious, coniferous, and mixed forest communities. Approximately half of the county is currently used for agriculture, with much of the remaining area covered by secondary forest growth.

The disposal facility site itself is partially forested. The dominant species are sugar maple, American beech, yellow birch, hemlock, and white pine. The immediate vicinity of the facility is also forested to a great extent, continuous with the woodlands found onsite.

No state or federally declared rare or endangered species are known to occur onsite. A variety of mammalian species are found onsite, the most abundant being small mammals such as the white-footed mouse, short-tailed shrew, woodland jumping mice, and meadow vole. Common medium-sized mammals include woodchuck, oppossum, and gray squirrel. White-tailed deer are also abundant in this area. A moderate number of reptiles have been also observed or are expected to occur within the deciduous woodlands. The affected aquatic environment of the site is limited to Point Creek (2 mi from the site to the east) and its tributary, Boyle Creek (1 mi from the site to the south). Both Point and Boyle Creeks are considered Class C waters, best suited for recreational fishing. The major primary producers of these waters consist of several genera of diatoms, green and blue-green algae. The most common phytoplankton are Tubellaria, Fragillaria, Asterionella, and Cyclotella.

Land Use

The general region in which the site is located is comprised mostly of forested land and active or inactive farmland. There are no farm dwellings or other residences located onsite. The site is not suited for any unique uses, but soils are considered to have potential for farming. There is no significant mineral resource development within 10 km (6 mi) of the facility. County plans for the site, which is not in a visually sensitive area, and surrounding land (2 to 7 km) include forestation and compatible uses.

There are no known mineral resources of economical consequence within the vicinity of the northeast site. Recovery operations in the area are limited to a small bedrock quarry located one mile to the north, and a sand and gravel quarry located one mile to the east. No oil and gas reserves of economically recoverable quantities are known to exist in the site area.

10.3.1.2 Southeast Site

The southeast site is assumed to be located within the Liptone Upland segment of the Atlantic Coastal Plain physiographic province. For the purposes of this EIS, the southeast site description is assumed to be consistent with the reference facility site described in Appendix E and Chapter 3.

10.3.1.3 Midwest Site

Falling within the central physiographic province, the midwest site rests at an average elevation of about 247 m (810 ft) above mean sea level. The general topography of the site is that of a well dissected plain which is virtually encircled by various branches of the West Fork of Finley Creek. The regional topographic surface undergoes only small changes in relief.

Geology and Soils

A considerable thickness (approximately 35 m or 115 ft) of unconsolidated deposits underlies the site. Most of this is composed of a rather impermeable glacial till consisting predominantly of pebbly and sandy clay and silt, and gumbotil. (Gumbotil is a clay-rich till produced as a result of thorough chemical decomposition.) Portions of the glacial drift may contain sand and gravel pockets of limited areal extent.

The bedrock consists of approximately 30 m (100 ft) of Mississippian age rocks belonging to the Dette and Adams series. The uppermost formation of the Dette series, which generally acts as an aquiclude to the underlying Karesh and Becker formations, is absent from the site area. The Karesh limestone is thin and discontinuous over the Becker. Both formations are chiefly dense, crystalline, lithographic, or tightly cemented fragmental limestones and dolomites with very low porosities. The basal 3 m (10 ft) of the Becker consists of cherty sandstone. Underlying the Dette series are the dense, cherty dolomites and limestones of the Adams series. These two series make up what is known as the Mississippian Aquifer. They are underlain by approximately 400 feet of siltstones and shales of Devonian age that serve as a good aquiclude to the underlying Devonian Aquifer.

Soils

The entire area in which the site is located is covered by about 3 to 3.5 m (10 to 12 ft) of Wisconsin loess which is the parent material of the site soils. The predominant soil types are silty clay loams belonging to the Wancho, Houlik, and Lyle series. These soils are generally moderately slow to moderately well-drained and have permeabilities ranging between 5 and 50 mm/hr (0.2 to 2.0 in/hr).

Ground and Surface Water

Ground water of appreciable amounts occur chiefly in sand and gravel deposits associated with glacial drift and buried channel systems. These "drift aquifers" are notably limited in areal extent, though they sometimes serve as a source for farmsteads and livestock drinking water.

The depth to the seasonally high ground-water table under the site is expected to be about 12 m (38 ft) from the ground surface. Local ground-water movement in the drift aquifer will be governed by the topography, draining toward and being discharged into the various branches of the West Fork of Finley Creek. Ground water from the surficial aquifer, and also from the shallow bedrock aquifer, can be expected to discharge to the buried alluvial deposits.

Ground-water usage in the area is limited to consumption as needed by local homes and farmsteads for domestic, irrigation, and livestock supplies. It is estimated that the majority of wells tap Mississipian aquifers and to a lesser degree, the drift aquifers. Yields of less than 76 lpm (20 gpm) are the rule for this area.

The site is located in an locale that is undergoing dissection as a result of recent climatic change. Approximately 90% of the streams in the drainage area are intermittent, flowing only 6 to 8 months of the year.

Meteorology

The area has a humid continental climate, with a total annual local precipitation of 777 mm (30.5 in). Approximately two-thirds of the annual precipitation occurs during the months of April through September. The source of this precipitation is the warm moist southerly air from the Gulf of Mexico. The normal mean snowfall for the site area is approximately 686 mm (27 in).

The average annual temperature in the site vicinity is approximately 11°C (51.0°F). July is the hottest month, having an average daily maximum of 31°C (87°F) and an average daily minimum of 18°C (64°F). During January, the coldest month, the daily temperature range is approximately -0.6°C (31°F) to -11°C (12°F).

The prevailing wind direction at the site is southerly at an average speed of 17 km/hr (9.0 knots). During the months November through March, a northwesterly wind component develops in response to the Canadian cold air outbreaks. Wind speeds during these months average 22 km/hr (12.1 knots). Severe weather events such as thunderstorms and tornados occasionally occur during midspring to late summer.

Ecology

The natural vegetation within the vicinity of the site is a mixture of oak-hickory forest and bluestem prairie. The forest community occurs primarily along

valley slopes and upland ridges. Big bluestem is the dominant grassland plant where the prairie remains. However, most of this area is cropland. The two major land uses in the county are pastureland (24 percent) and row crops (65 percent), with corn and soybeans representing the dominant crops. Almost 60 percent of the land area adjacent to the site is planted in corn.

No federally declared endangered or threatened species have been observed at or near the site. The most common mammals found onsite and within a five-mile radius are those for which corn is a predominant food source and can live in proximity to man. The most abundant species include the raccoon, striped skunk, eastern cottontail, opossum, and fox squirrel. Several burrowing mammals are also found in the area, primarily in fields not actively cultivated. Numerous resident bird species are also found onsite and in the surrounding cornfields. The most common species found, and which feed extensively on corn, include the redwing, cardinal, meadowlark, purple grackle, and common crow. Resident birds of prey include red-tailed hawk and great horned owl. Transient species include the coopers hawk, broad-winged hawk, and red-shouldered hawk. As a result of ongoing agricultural activities, the reptiles and amphibian population of the area is limited.

The West Fork of Finley Creek and its tributaries are Class B warm waters. Although the soils along the stream banks are moderately to highly erodable, the vegetated banks limit the amount of sediments that enter the streams. No federally declared endangered or threatened fish or snails are expected in these streams.

Land Use

The site is located on an area extensively used for cultivation of crops, mostly corn. Five houses are located within 5 km of the site. The site vicinity contains 4 towns--Mica, Grendle, Reed, and Lyme--but most of the land is not developed intensively. Hayer Industrial Park (10 acres) is located 4.8 km from the site. There are no other community facilities, historic places, or other visually sensitive land uses within an 8 km radius. Two state-owned lands, however, are located within 24 km of the site.

The chief source of economically important resources in the state lies in the substantial coal resources associated with Pennsylvanian age rocks. No such deposits occur under the site as the initial bedrock encountered is of Mississipian age. There is a potential for some natural gas deposits. However, the Ordivician source rocks are thin, making recovery unconsequential and uneconomical.

10.3.1.4 Southwest Site

The southwest site is assumed to be located within the Great Plains physiographic province. Regional topography shows sharply contrasting flat plains and rolling-to-rugged erosional breaks. The site has an estimated average elevation of 1219 m (4,000 ft) above mean sea level. As is characteristic of the area, the site is flat. Drainage is to the southeast and southwest to various intermittent branches of Hotsprings Creek.

Geology and Soils

Below a thin surface cover of loam and clay-loam soil are Pliocene age sedimentary deposits of the Bixler formation. These sediments were eroded from the ancient Rocky Mountains and transported by streams to this area. Because of their origin of deposition, their character varies both vertically and horizontally. As a general rule, however, the sand and gravels are in the basal portion of the formation.

The Bixler Formation is about 91 m (300 ft) thick in the site area. The upper 12 to 15 m (40 to 50 ft) is composed of caliche, a calcium-rich, carbonate-impermeable sandy clay similar to a hardpan. Underlying the caliche is approximately 15 m (50 ft) of dense, brown clay. Thin, discontinuous streaks of sand are also associated with the clays. The balance of the Bixler is composed principally of sand and gravel which extends down to the eroded surface of the Triassic rocks. The Triassic shales and sandstones belonging to the Maxwell group are estimated to be about 152 m (500 ft) thick in the site area. The first material encountered under the permeable Bixler strata is a red clay, indicative of the weathered shale surface.

The predominant soil types underlying the site are loams and clay loams belonging to the Starble, Nester, Wixman, and Jeeper series. These are moderately fine textured, calcareous, wind-blown sediments derived mostly from alluvial outwash from the Rocky Mountains. Because rainfall is low, there are long, dry periods, and soil development has been slow. The soils are seldom wet below the root zone, and, as a result, many of the soils have a horizon of powdery lime accumulation.

Ground and Surface Water

The Bixler formation is an unconfined aquifer with very limited consumptive use. The water occurs under water-table conditions, and differences in the thickness of the water-saturated material are closely related to the thickness of the Bixler formation. The saturated thickness underneath the site is only about 7.6 m (25 ft) as the water table lies some 84 m (275 ft) below ground surface.

The source of water (recharge) to the Bixler, and thence to the Triassic rocks, is precipitation on its more permeable surfaces. The amount of precipitation that enters the ground water is a very small percentage of the total precipitation falling at the surface. It has been estimated that less than 1 mm will reach the ground water annually. Due to the rather impervious nature of the onsite surficial materials, most of the precipitation will be lost by evaporation or drain to Hotsprings Creek as runoff. Part of this runoff will percolate downward through the coarser stream deposits and enter the ground water regime. This probably constitutes the major source of recharge within the area of the site. Some infiltration may work its way through the fractured portions of the caliche and slowly downward to the water table, but this is of limited quantity.

With the limited precipitation in the region, streams flow intermittently throughout the year. A wide variation in discharge occurs at the site. Since no base flow is known to occur in the area, precipitation accounts for all of the stream discharge. Short duration, high intensity thunderstorms account for the peak discharges from the site.

Meteorology

The climate of this site is considered semiarid, which is characterized by low humidity, wide temperature and precipitation variations, and frequent windstorms. The average annual precipitation for the site area is approximately 485 mm (19 inches). Departures from the norm can be great with extreme yearly totals ranging from 243 to 1010 mm (9.56 to 39.75 in). Nearly three-quarters of the total annual precipitation occurs during the months April through September, primarily in the form of thundershowers.

The average annual temperature for the site area is about 14°C (57°F). Maximum temperatures occur in the mid-summer months of June, July, and August. Rapid and wide variations are common, especially during the winter months when cold fronts from the Rocky Mountain and Plains States sweep across the plains. Temperature drops up to 16°C (60°F) occurring within a 12-hour period may be associated with these fronts. The highest recorded temperature in the region was 42°C (108°F) and the lowest was -27°C (-16°F).

The prevailing winds from March through October are southerly at 25 km/hr (13.6 knots), and southwesterly at 21 km (11.4 knots) during the winter months. The annual mean speed for all directional components is 24 km (13 knots) and southerly. These winds contribute to the evaporation rate associated with the region. The strongest winds generally occur in March and April and are associated with thunderstorm activity.

Ecology

The site area has been generally characterized as Grama Buffalo Grasslands. The most abundant native plant species are buffalograss, and blue grama. Total ground cover is relatively dense, and tends to increase under grazing. The preponderance of grass species results in large quantities of organic materials in the form of living and dead grass roots within the first ten to twelve centimeters of soil. Although various species of trees, including oaks, elms, and hackberries are often found along stream floodplains and steep-walled canyons, these are not found along Hotsprings Creek, an intermittent stream, or its intermittent feeder streams which surround the western, eastern, and southern portions of the site. Federally declared endangered species have not been observed within the site.

The mammalian fauna of this general area includes at least 50-60 species. During the hot daylight hours, a large number of mammals of this semiarid region live in burrows which they either dig themselves, or which they share or overtake from other species. The larger species which create their own underground burrows include the badger, plains pocket gopher, and swift fox.

Only the former two species were observed within 1 km of the site. Many other species also dig their own burrows, or use those of others, to escape the heat and predators, to search for food (insects, seeds, or other burrowing mammals) or to use as dens. However, these burrows are generally shallow.

Other nonburrowing mammals characteristic of this area and which have been noted onsite include the coyote, pronghorn antelope, bobcat, jackrabbit, great plains skunk, and eastern cottontail. The mixed grass prairie found onsite and in the general area also affords suitable habitat to numerous resident bird species. The most common small birds include Western meadowlark, dickcissel, bobolink, savanna sparrow, and prairie chicken. The most numerous resident birds of prey include the golden eagle, horned owl, and burrowing owl. Several species of lizards and snakes also inhabit the site. The more common ones include the northern earless lizard, prairie lizard, prairie rattlesnake, western diamondback rattlesnake, and bullsnake.

The aquatic environment of the site is limited to Hotsprings Creek and two feeder streams, all intermittent. After rainstorms when water does flow in the creeks and streams, aquatic biota is limited to algae, insects (which use the water to breed) and potential fish species such as minnows and sunfish. These fish survive the dry seasons by gathering in small pools of water that may remain throughout the year, and are then dispersed throughout the stream with the flowing waters.

Land Use

The site region is a plain containing numerous parcels of federally owned grassland. The site was privately owned before purchase by the state, and borders a federally owned parcel of the grasslands. There are no residences onsite or in the vicinity (1 mi) of the site. Portions of the immediately adjacent land (approximately 30%) extend onto the federally owned parcels, but most of it is privately owned.

The only known mineral resource occurring in the site area is caliche. This calcium carbonate cement is associated with sand and gravel deposits of the Bixler formation, and may be suitable for use as aggregate, however, these deposits are widespread throughout the entire region and do not represent unique resources.

Whereas numerous producing oil and gas wells have been drilled in the adjoining county, no historical production has occurred within the county in which the site is located. Prospect wells drilled within proximity to the site have not indicated the presence of oil or gas reserves of recoverable quantity.

10.3.2 Assumed Regional Disposal Facility Designs and Waste Source Term

This section provides a description of the disposal facilities assumed to be situated at the regional sites discussed in the preceding section, as well as the wastes which are assumed to be disposed in the facilities. The disposal facilities and waste forms described are intended to provide an example of

potential impacts associated with disposal of waste according to the minimum requirements of the Part 61 regulation. These should not be interpreted as representing the best or the only designs or waste forms which could be implemented in compliance with the rule. There may be a number of ways in which the Part 61 requirements may be met for a specific disposal facility, and compliance with the Part 61 rule, as well as measures which may be implemented to reduce potential impacts to levels as low as reasonably achievable, would be evaluated on a case-by-case basis. The examples, rather, are intended to illustrate an upper bound range of impacts from implementation of the rule, with the expectation that actual impacts from implementation of the rule at existing or future disposal facilities would be less.

Assumed Facility Designs

The design assumptions for the four regional disposal facilities are summarized in Table 10.4. As shown, the assumed design cases all involve disposal in "regular" shallow land burial disposal cells. All disposal cells for the four regional sites are assumed to be constructed to 8 meter depths below the earth's surface. This introduces an additional conservatism regarding intruder and erosional impacts calculated for the southwest site, since the great depth to the water table at this site would allow construction to much greater depth than at the other three sites. All cases assume segregated disposal of waste streams containing organic chemicals as well as low activity unstable waste streams containing compressible material. Layering is used as an intruder barrier.

The principal differences among the four cases lies in the methods to limit contact of water with disposed waste and to minimize long-term maintenance requirements. For the three humid sites (northeast, southeast, and midwest), a moisture barrier in the form of a thick clay cap is installed and compacted using standard construction techniques. In the southwest site, there is assumed to be considerably less concern regarding ground-water migration due to the extreme depth of the water table and the semiarid climate. In this case, the standard "thin" cap is assumed to be installed. Similar to the humid sites, however, the disposed waste, backfill, and cap are assumed to be compacted using improved methods (e.g., a vibratory compactor). This helps to reduce voids within the disposal cell and therefore reduces the potential for settling and further reduces potential long-term maintenance costs.

Due to the relatively impervious nature of the soils at the northeast site, there is a greater chance for a water accumulation problem than at the other two humid sites. For this case, therefore, and to provide one case for analysis of a more extreme engineering design, increased attention (and expense) is assumed to be paid to stabilizing the disposal facility. This is represented by the assumption that all waste packages are stacked into disposal cells and grouted in place. In the other humid disposal facility sites, an imported sand backfill is assumed to be used to reduce the contact time of percolating water. Since the soils at these sites are more permeable than those at the northeast site, there is a lesser possibility of a water accumulation problem in the disposal cells containing unstable waste streams. At the southwest site, the originally excavated material from the site is used as backfill.

Table 10.4 Design Assumptions for Regional Disposal Facilities

Northeast

- Regular SLB trench
- Use of a thick clay cap
- Compaction using improved methods
- Segregation of wastes containing organic chemicals
- Segregation of compressible wastes
- Stacked disposal of waste
- Grouting emplaced between waste packages
- Layering used as an intruder barrier
- Humid site having low permeable soils

Southeast

- Regular SLB trench
- Use of a thick clay cap
- Compaction using improved methods
- Segregation of wastes containing organic chemicals
- Segregation of compressible wastes
- Random disposal of waste
- Use of a sand backfill
- Layering used as an intruder barrier
- Humid site having moderately permeable soils

Midwest

- Regular SLB trench
- Use of a thick clay cap
- Compaction using improved methods
- Segregation of wastes containing organic chemicals
- Segregation of compressible wastes
- Random disposal of waste
- Use of a sand backfill
- Layering used as an intruder barrier
- Humid site having moderately permeable soils

Southwest

- Regular SLB trench
- Use of a "standard" cap
- Compaction using improved methods
- Segregation of wastes containing organic chemicals
- Segregation of compressible wastes
- Random disposal of waste
- Backfill with originally excavated soils
- Layering used as an intruder barrier
- Semiarid site having highly permeable soils

All regional facilities are assumed to be operated for 20 years, followed by a two-year closure period and a five-year observation period prior to license termination and transfer of site control to the site owner.

Assumed Waste Forms

In the analysis, the higher activity waste streams are assumed to be stabilized. A number of techniques may be potentially used to achieve waste stability, ranging from solidification to improved waste packaging. To provide a range of costs and impacts for the calculation, therefore, two waste spectra are considered: waste spectra 2 and waste spectra 1 modified by use of high-integrity containers. In waste spectrum 2, all of the LWR process waste streams are assumed to be solidified. Half are solidified in cement and half in a synthetic polymer binder. Waste streams for which most of the activity is principally contained in activated metal (P-NCTRASH, B-NCTRASH, L-NFRCOMP, N-HIGHACT) are stabilized using improved packages (e.g., filling void spaces within the package with a noncompressible material, use of high integrity containers, etc.), as is the N-ISOPROD stream.

In modified waste spectrum 1, LWR process waste streams except for solidified concentrated liquids (P-CONCLIQ and B-CONCLIQ) are packaged in high-integrity containers. Concentrated liquids are still assumed to be solidified. High-integrity containers are also used for packaging two waste streams containing large quantities of tritium (N-TRITIUM and N-TARGETS). The other higher activity waste streams (P-NCTRASH, B-NCTRASH, L-NFRCOMP, N-HIGHACT, and N-ISOPROD) are again assumed to be stabilized through improved packaging techniques or high-integrity containers.

The two waste spectra--spectrum 2 and modified spectrum 1--are assumed to be applied in the analysis to all four regional disposal facilities without consideration of possible additional waste form requirements that could be implemented at a particular site. An example requirement would be the prohibition of certain types of organic chemicals at a particular humid site. In addition, at the northeast site there could be a requirement for use of stronger, more long-lasting waste containers for the unstable waste streams. These and other potential additional requirements were conservatively (in terms of ground-water impacts) ignored in the analysis.

In the analysis, the volumes of waste projected to generated in each region over a 20-year period are processed according to the waste spectra considered and delivered to the disposal facility. This results in a range in projected waste volumes (in m^3) for each region as follows:

Waste Spectrum	Northeast	Southeast	Midwest	Southwest
Modified spectrum 1	9.92E+5	1.07E+6	7.56E+5	7.26E+5
Spectrum 2	6.85E+5	7.51E+5	5.29E+5	4.91E+5

As shown, the largest volumes are projected for the southeast region.

10.3.3 Results of the Regional Analysis

This section presents a discussion of the indirect unmitigated impacts of implementation of the Part 61 rule based on analysis of the above regional cases. The section is divided into subsections as follows: 10.3.1, long-term radiological impacts; 10.3.2, short-term radiological impacts; 10.3.3, costs; and 10.3.4, other impacts (including nonquantifiable impacts such as impacts to biota and cultural resources).

10.3.3.1 Long-Term Radiological Impacts

Long-term radiological impacts for the regional case study are summarized on Tables 10.5 and 10.6. Potential individual and population intruder impacts are summarized on Table 10.5, as are potential erosional impacts. Groundwater impacts are summarized on Table 10.6. A range of impacts are shown in Tables 10.5 and 10.6, corresponding to the assumed use of either modified waste spectrum 1 or waste spectrum 2 to achieve stability of the higher activity waste streams.

Potential intruder and erosional impacts for the regional case study are summarized on Table 10.5. Individual intruder impacts are summarized for three organs (whole body, bone, and lung) for both the intruder-construction scenario and the intruder-agriculture scenario at time periods equal to 100 and 500 years following disposal facility closure. Population intruder impacts are also summarized as estimated at 100 years following facility closure. Airborne impacts are presented for whole body, bone, and lung as total populational exposures (in man-mrem) to persons living within 50 miles of the disposal facility. Waterborne impacts are presented for whole body, bone, lung, and thyroid to an individual who is assumed to use water from a surface stream contaminated from overland flow of material released from the facility by the intruder. Potential erosional impacts are also shown as impacts to populations for airborne releases and as impacts to an individual for waterborne releases. These are calculated at a time period equal to 2000 years following facility closure for the 3 humid sites and at 1000 years following facility closure for the southwest site.

As shown, the limiting individual inadvertent intruder impacts appear to be to the bone. In the analysis, the assumed use of grouting to stabilize the northeast site results in reduced exposures relative to the southeast and midwest sites. For these latter two sites, inadvertent intruder exposures averaged over the total waste volume disposed at the sites range from about 15 to 35 mrem at 100 years but drop to a few (4 to 9) mrem at 500 years. If the long-term reduction in intruder exposures brought about by the grouting is discounted for the northeast site, then potential exposures at 500 years would be expected to be similar to those for the southeast and midwest sites.

In the analysis, the increased volume reduction associated with waste spectrum 2 results in higher overall radionuclide concentrations then for modified spectrum with resulting slightly higher estimated impacts. In the analysis, no credit has

Table 10.5 Summary of Potential Intruder and Erosional Impacts for Regional Case Study

		Modified Waste Spectrum 1				Waste Spectrum 2			
Impact Measures		Northeast	Southeast	Midwest	Southwest	Northeast	Southeast	Midwest	Southwest
Individual Intruder Impacts: (mrem)									
Body-100	C*	3.78E+0	2.29E+1	2.69E+1	1.71E+2	5.21E+0	2.93E+1	3.45E+1	2.32E+1
	A	1.97E+0	1.28E+1	1.59E+1	1.21E+1	2.80E+0	1.80E+1	2.24E+1	1.77E+1
500	C	2.02E-1	1.67E+0	1.85E+0	4.38E+0	2.53E-1	2.08E+0	2.30E+0	6.31E+0
	A	2.51E-1	1.89E+0	2.07E+0	3.43E+0	3.18E-1	2.34E+0	2.55E+0	4.87E+0
Bone-100	C	3.80E+0	2.32E+1	2.73E+1	2.09E+1	5.23E+0	2.97E+1	3.50E+1	2.86E+1
	A	2.51E+0	1.52E+1	2.02E+1	1.56E+1	3.47E+0	2.10E+1	2.75E+1	2.21E+1
500	C	3.92E-1	5.00E+0	6.19E+0	3.15E+1	5.29E-1	6.84E+0	8.50E+0	4.63E+1
	A	4.83E-1	3.66E+0	4.10E+0	7.20E+0	6.54E-1	4.87E+0	5.45E+0	1.04E+1
Lung-100	C	3.78E+0	2.30E+1	2.70E+1	1.83E+1	5.21E+0	2.94E+1	3.46E+1	2.51E+1
	A	1.81E+0	1.21E+1	1.46E+1	1.12E+1	2.61E+0	1.72E+1	2.09E+1	1.66E+1
500	C	2.84E-1	2.90E+0	3.64E+0	1.89E+1	3.73E-1	3.83E+0	4.86E+0	2.78E+1
	A	3.15E-1	2.36E+0	2.64E+0	4.49E+0	4.10E-1	3.01E+0	3.37E+0	6.43E+0
Population Intruder Impacts:									
Airborne (man-mrem)									
Body		6.45E+3	1.07E+3	1.77E+3	1.03E+1	5.61E+3	9.13E+3	1.55E+3	9.22E+0
Bone		1.70E+5	1.93E+4	3.22E+4	1.87E+2	1.02E+5	1.66E+4	2.80E+4	1.67E+2
Lung		5.30E+4	8.76E+3	1.46E+4	8.46E+1	4.61E+4	7.50E+3	1.27E+4	7.57E+1
Waterborne (mrem)									
Body		2.56E-3	1.07E-3	1.56E-3	1.16E-3	3.44E-3	1.41E-3	2.03E-3	1.55E-3
Bone		8.29E-3	3.17E-3	4.82E-3	4.36E-3	1.09E-2	4.04E-3	6.05E-3	5.78E-3
Lung		2.53E-4	1.38E-4	1.88E-4	1.33E-4	3.65E-4	1.97E-4	2.67E-4	1.96E-4
Thyroid		1.20E-4	5.92E-5	9.24E-5	6.85E-5	1.72E-4	8.41E-5	1.31E-4	1.01E-4

*See footnote, last page of table.

Table 10.5 (continued)

Impact Measures	Modified Waste Spectrum 1				Waste Spectrum 2			
	Northeast	Southeast	Midwest	Southwest	Northeast	Southeast	Midwest	Southwest
Erosion Impacts:								
Airborne (man-mrem)								
Body	1.59E+1	7.56E+0	5.84E+0	3.77E-1	1.59E+1	7.56E+0	5.84E+0	3.77E-1
Bone	3.11E+2	1.49E+2	1.42E+2	6.11E+0	3.11E+2	1.49E+2	1.42E+2	6.11E+0
Lung	2.91E+2	1.22E+2	1.03E+2	5.65E+0	2.91E+2	1.22E+2	1.03E+2	5.65E+0
Waterborne (mrem)								
Body	8.55E-2	9.43E-2	7.82E-2	2.92E-1	8.55E-2	9.43E-2	7.82E-2	2.92E-1
Bone	6.66E-1	7.67E-1	6.13E-1	1.68E+0	6.66E-1	7.67E-1	6.13E-1	1.68E+0
Lung	5.46E-1	5.32E-2	4.96E-2	1.44E-1	5.46E-2	5.32E-2	4.96E-2	1.44E-1
Thyroid	9.77E-1	1.18E+0	9.47E-1	5.90E-1	9.77E-1	1.18E+0	9.47E-1	5.90E-1

*Impacts are calculated at 100 and 500 years following disposal facility license termination. In the table, "C" stands for the intruder-construction scenario; "A" stands for the intruder-agriculture scenario.

Table 10.6 Summary of Potential Ground-Water Impacts for Regional Case Study

Impact Measures	(mrem/yr) Modified Waste Spectrum 1 Northeast	Modified Waste Spectrum 1 Southeast	Modified Waste Spectrum 1 Midwest	Modified Waste Spectrum 1 Southwest	Waste Spectrum 2 Northeast	Waste Spectrum 2 Southeast	Waste Spectrum 2 Midwest	Waste Spectrum 2 Southwest
Intruder Well								
Body	7.66E-1 (120)	1.35E-2 (6,000)	6.29E-2 (100)	1.41E-2 (100)	6.59E-1 (120)	7.74E-3 (100)	5.37E-2 (120)	1.39E-2 (100)
Bone	1.04E+0 (100)	3.17E-2 (6,000)	1.77E-1 (100)	4.46E-3 (100)	3.55E-1 (100)	2.70E-2 (6,000)	1.37E-1 (100)	3.60E-3 (100)
Thyroid	6.43E+0 (10,000)	5.62E+0 (6,000)	6.84E+0 (6,000)	2.53E-2 (100)	7.25E-1 (120)	6.36E-1 (6,000)	6.73E-1 (6,000)	1.45E-2 (100)
Boundary Well								
Body	1.16E-2 (10,000)	4.01E-2 (70)	1.15E-2 (10,000)	1.10E-4 (4,000)	3.97E-3 (8,000)	3.99E-2 (70)	2.66E-3 (10,000)	7.72E-5 (4,000)
Bone	1.98E-2 (8,000)	3.15E-2 (6,000)	6.84E+0 (10,000)	2.45E-2 (4,000)	1.65E-2 (8,000)	2.68E-2 (6,000)	9.01E-3 (10,000)	3.68E-4 (4,000)
Thyroid	6.02E+0 (10,000)	5.62E+0 (6,000)	6.84E+0 (6,000)	2.45E-2 (4,000)	6.52E-1 (8,000)	6.36E-1 (6,000)	6.73E-1 (8,000)	2.91E-3 (4,000)
Population Well								
Body	$<10^{-9}$ (10,000)	3.70E-3 (10,000)	4.55E-4 (10,000)	3.11E-6 (10,000)	$<10^{-9}$ (10,000)	1.42E-3 (10,000)	4.47E-5 (10,000)	1.89E-6 (8,000)
Bone	$<10^{-9}$ (10,000)	7.15E-3 (10,000)	1.90E-4 (10,000)	9.54E-6 (10,000)	$<10^{-9}$ (10,000)	5.84E-3 (10,000)	1.87E-5 (10,000)	8.75E-6 (8,000)
Thyroid	$<10^{-9}$ (10,000)	1.78E+0 (6,000)	3.26E-1 (10,000)	9.40E-4 (10,000)	$<10^{-9}$ (10,000)	2.01E-1 (10,000)	3.20E-2 (10,000)	1.11E-4 (8,000)
Surface Water								
Body	$<10^{-9}$ (10,000)	1.62E-4 (10,000)	$<10^{-9}$ (10,000)	*	$<10^{-9}$ (10,000)	5.89E-5 (10,000)	$<10^{-9}$ (10,000)	*
Bone	$<10^{-9}$ (10,000)	2.93E-4 (10,000)	$<10^{-9}$ (10,000)	*	$<10^{-9}$ (10,000)	2.36E-4 (10,000)	$<10^{-9}$ (10,000)	*
Thyroid	$<10^{-9}$ (10,000)	8.09E-2 (10,000)	$<10^{-9}$ (10,000)	*	$<10^{-9}$ (10,000)	9.14E-3 (10,000)	$<10^{-9}$ (10,000)	*

*Impacts at the surface water body are not calculated for the southwest site due to the intermittent nature of the nearest stream to the site and the extreme depth to ground water at the site.

been taken for improved waste forms to reduce dispersion and plant root uptake. This improved waste form would tend to reduce intruder exposures for waste spectrum 2.

As shown, the highest individual intruder exposures are estimated to occur at the southwest site. These exposures run at about 46 mrem to bone but are still a factor of 10 less than the 500 mrem limit. The increased exposure is due to the increased silt content of the site soils as well as the increased wind speeds relative to the other three sites. These impacts are believed to be very conservative, since the great depth to the water table allows disposal at much greater depths than at the other three sites--further reducing the potential for inadvertent intrusion into the more highly active waste streams.

With respect to the southwest site, the opposite trend is seen for the intruder airborne population impacts. These run at a few orders of magnitude less than for the other two sites and are principally due to the low population density in the environs of the site. On the other hand, the waterborne impacts all appear to be comparable for the four facilities and are all very low--i.e., on the order of 10^{-3} mrem or less.

The intruder population airborne and waterborne impacts may be compared to those for the assumed erosion event. (It may be repeated that disposal facilities under the Part 61 regulation would be sited to avoid problems with erosion, and the estimates are, therefore, a rather improbable upper bound of potential impacts.) The airborne impacts are again reasonably comparable for the three humid sites and (due to the lower expected population density) a few orders of magnitude less for the southwest site. Waterborne impacts are also more or less comparable, with the highest impacts at 1.7 mrem (to bone) and occurring at the southwest site. This is still less than the ground-water migration limit of 4 mrem at the nearest drinking water supply.

As shown in Table 10.6, the highest exposures due to ground-water migration are to the thyroid, although in all cases the performance objectives as set out in Chapters 4 and 5 for inadvertent intrusion and ground-water migration are met. The estimated impacts reflect the differing volumes of waste streams and corresponding radionuclide inventories within each regional facility, as well as the differing environmental characteristics of each regional site. Of the three humid regional disposal facilities considered (northeast, southeast, and midwest), reasonably comparable impacts are estimated at the intruder well and the boundary well. For the intruder well, the highest exposures to whole body and bone (.8 mrem and 1 mrem, respectively) occur at the northeast site. Intruder well exposures to thyroid are very similar among the three humid sites, with the highest exposures (7 mrem) occurring at the midwest site, followed by the northeast site. For the boundary well, the highest exposures to whole body and bone (.04 mrem and .03 mrem, respectively) are estimated for the southeast site, while the highest thyroid exposures (7 mrem) are again estimated for the midwest site.

Of the three humid regional sites, the southeast is assumed to experience the largest percolation component (PERC) as well as the quickest ground-water travel times to biota access locations. In addition, the midwest and southeast site soils are assumed to have moderate retardation capabilities (NRET=3) while the retardation capability of the northeast site soil is higher (NRET=4). The influence of these factors is clearly seen in calculated exposures for the

population well and the surface water body. The highest estimated population well and surface water body exposures occur at the southeast site. Population well thyroid exposures for the midwest site are about 5 times less than those for the southeast site. Surface water exposures for the midwest site are all less than 10^{-9} mrem at 10,000 years following disposal facility closure.

The southwest site is somewhat of a different case. The site is assumed to be located in a semiarid area and a water balance calculation for the site indicated that due to the low rainfall and high evapotranspiration, essentially no precipitation falling upon the site reaches the underlying aquifer. For completeness in this analysis, however, a percolation coefficient of 1 mm was conservatively assumed for the site. The resulting estimated exposures are a few orders of magnitude less than those for the other three sites at the intruder, boundary, and population wells. The surface water body exposures are not presented for the southwest site, however. The closest water body down-gradient of the site is an intermittent stream, and in any case, the water table is located on the order of 80 meters below ground surface.

10.3.3.2 Short-Term Radiological Impacts

Short-term radiological impacts for modified waste spectrum 1 and waste spectrum 2 are summarized in Table 10.7. Included in this table are (1) potential impacts to populations (in man-mrem) from transporting waste to the regional facilities, (2) potential occupational impacts (in man-mrem) associated with processing, transporting, and disposing of waste within the region, and (3) potential impacts from an operational accident at the disposal facility averaged across all wastes transported to the facility.

As shown, transportation impacts over 20 years range from about 420 to 1,100 man-rems, or about 21 to 55 man-rems per year. Of interest is the narrow range of impacts for the three humid sites compared to the higher (about double) impacts calculated for the southwest. The higher estimated impacts are due to the greater transportation distance for the western region as compared to the other three regions (1,000 miles vs. 300 to 600 miles).

Occupational impacts are listed as total impacts over 20 years for waste processing, transportation to the disposal facility, and waste disposal. Waste processing occupational exposures are presented as additional exposures to those associated with waste spectrum 1.

Also included are the occupational exposures that are estimated to be associated with operation of a regional processing center. For waste spectrum 2, waste processing is assumed to consist of compaction of compressible waste streams by large compactor/shredders. This is likely not be a cost effective operation but has been included for completeness. It may also be of interest for the sake of completeness to list occupational exposures and other impact measures estimated to be associated with incineration of the same waste streams at the regional processing centers. These impact measures--population exposures due to airborne releases from the incinerators, occupational exposures from operation of the regional processing center, and costs--are listed in Table 10.8. All impacts are over 20 years of facility operation.

Table 10.7 Summary of Short-Term Radiological Impacts for the Regional Case Study

Impact Measures	Modified Waste Spectrum 1				Waste Spectrum 2			
	Northeast	Southeast	Midwest	Southwest	Northeast	Southeast	Midwest	Southwest
Transportation Population Impacts: (man-mrem)	4.16E+5	6.02E+5	6.54E+5	1.10E+6	4.02E+5	5.97E+5	6.52E+5	1.08E+6
Occupational Impacts: (man-mrem)								
Waste Process								
By Generators	-	-	-	-	+1.70E+6	+1.98E+6	+1.50E+6	+9.00E+5
Regional Center	0	0	0	0	1.81E+5	7.15E+4	1.08E+5	9.02E+4
Transportation	5.54E+6	6.92E+6	5.04E+6	4.89E+6	5.21E+6	6.43E+6	4.79E+6	4.54E+6
Waste Disposal	5.10E+6	2.96E+6	2.03E+6	2.80E+6	4.78E+6	2.81E+6	1.96E+6	1.68E+6
Accident at Disposal Facility: (mrem)								
Dropped container								
Body	1.36E+0	1.98E+0	1.66E+0	5.93E-1	1.33E-1	1.27E-1	1.17E-1	7.10E-2
Bone	3.00E+0	4.44E+0	3.65E+0	1.32E+0	3.47E-1	4.45E-1	3.91E-1	2.44E-1
Lung	1.25E+1	1.88E+1	1.57E+1	5.59E+0	7.12E-1	9.51E-1	8.03E-1	5.36E-1
Fire in disposal cell								
Body	4.70E+0	3.19E+0	3.97E+0	3.63E+0	7.09E+0	4.87E+0	5.92E+0	5.72E+0
Bone	1.15E+1	1.20E+1	1.38E+1	1.27E+1	1.73E+1	1.83E+1	2.07E+1	2.00E+1
Lung	1.73E+1	1.97E+1	1.93E+1	1.86E+1	2.60E+1	3.00E+1	2.89E+1	2.93E+1

Table 10.8 Summary of Population Exposures, Occupational Exposures, and Costs for Regional Incineration

Impact Measures	Northeast	Southeast	Midwest	Southwest
Population exposures: (man-mrem)	4.19E+4	2.95E+4	3.70E+4	2.71E+4
Occupational exposures: (man-mrem)	3.67E+4	1.34E+4	2.08E+4	1.77E+4
Costs: ($)	1.39E+8	5.41E+7	8.22E+7	6.88E+7

As expected, the largest occupational exposures for waste disposal are those estimated for the northeast site. This is due to the assumed additional operational practices carried out at the northeast site.

Operational accidents are listed for the two potential scenarios considered in this EIS--a waste container accidentally dropped from a height and an accidental fire in a disposal cell. Impacts are calculated in an extremely conservative manner and are to an individual potentially standing approximately 100 m immediately downwind of the accident. In addition, impacts are averaged over all waste streams delivered to the disposal facility.

10.3.3.3 Costs

Costs, including waste processing, transport, and disposal costs are listed in Table 10.9. Similarly to occupational exposures, costs due to processing the waste by the waste generator are presented as additional costs to those associated with waste spectrum 1. For the modified spectrum 1 case, these additional costs involve stabilizing high activity waste streams at an estimated cost of \$450 per m^3 of waste so stabilized, which is the approximate cost of placing the waste streams into high-integrity containers. It is expected that some of the waste streams may be stabilized by less expensive means; however, using the high integrity container costs provides an upper bound. For waste spectrum 2, stability of many of the waste streams--particularly LWR process waste streams--is provided through solidification. Costs for stabilization of other waste streams is again represented by estimated costs for high integrity containers. Finally, in waste spectrum 2, additional costs are incurred through compaction of compressible waste streams, both by waste generators and at a regional center.

Of these costs, the only additional waste processing costs that would be incurred through implementation of the Part 61 regulation would be through stabilization of the higher activity streams. For waste spectrum 2, these are conservatively estimated as follows:

Table 10.9 Summary of Costs for Regional Case Study

	(mrem/yr)							
	Modified Waste Spectrum 1				Waste Spectrum 2			
Impact Measures	Northeast	Southeast	Midwest	Southwest	Northeast	Southeast	Midwest	Southwest
Waste Processing Costs: ($)								
Waste Generator	+7.28E+7	+9.89E+7	+6.63E+7	+5.22E+7	+3.47E+8	+3.95E+8	+2.92E+8	+1.91E+8
Regional Center	0	0	0	0	+5.29E+7	+2.07E+7	+3.14E+7	+2.63E+7
Waste Transportation Costs: ($)	1.45E+8	2.43E+8	2.40E+8	3.41E+8	1.32E+8	2.18E+8	2.22E+8	3.08E+8
Waste Disposal Costs: ($)								
Design & Op.	2.75E+8	2.10E+8	2.01E+8	1.89E+8	2.53E+8	2.01E+8	1.94E+8	1.86E+8
Post operational	1.26E+7	1.91E+7	1.91E+7	1.26E+7	1.26E+7	1.26E+7	1.26E+7	1.26E+7
Total	2.88E+8	2.29E+8	2.20E+8	2.02E+8	2.66E+8	2.14E+8	2.07E+8	1.99E+8
Unit ($/m^3)	290	214	291	278	388	285	391	405

Waste Spectrum 2	Northeast	Southeast	Midwest	Southwest
$(x10^8)	2.82	3.58	2.70	1.64
$/m^3	1363	1310	1390	1158

Thus, the requirement that higher activity wastes be stabilized would appear to involve additional processing costs in the following range.

	Northeast	Southeast	Midwest	Southwest
Low ($x10^7)	7.3	9.9	6.6	5.2
High ($x10^7)	28.2	35.8	27.0	16.4

This range is believed to be conservatively high, however. In addition, much of the above costs would be expended in any case to comply with license conditions already implemented by the states at existing disposal facilities.

Waste transportation costs range from about $130 to $240 million, depending upon the waste spectra and the region considered. The largest costs are for the southwest region, for which the reduced volume of waste relative to the other three regions is counterbalanced by the longer transportation distances. The effects of the Part 61 regulation on transportation costs is expected to be low. Use of high-integrity containers to stabilize higher activity waste streams would result in little or no increased waste volume and would therefore not increase transportation costs. On the other hand, use of solidification to stabilize higher activity waste streams such as ion exchange resins would tend to increase waste volumes and thus increase transportation cost. However, if solidification is coupled with volume reduction of compressible waste streams through compaction (which improves disposal facility stability), then, as shown for waste spectrum 2, overall transportation costs could be reduced.

Waste disposal costs are set out into design and operational costs and post-operational costs, where postoperational costs include costs to waste customers (over 20 years of operation) for providing for: (1) facility closure, (2) a 5-year observation and maintenance period, and (3) 100 years of institutional control. Also shown are total disposal costs as well as unit ($/m^3) costs.

As shown, the most significant design and operational costs are for the northeast ite, due to the assumed use of grouting to assure stabilization of wastes. ıe design and operational costs for the other three sites are clustered within a relatively small range. In addition it may be observed that reducing

the waste volumes delivered to the site also lowers the design and operational costs, although not proportionately. Due to the use of the grouting at the northeast site, a low level of postoperational costs are projected for this site. The southwest site is also projected to experience a low level of postoperational costs, due to the semiarid nature of the site. A low to moderate range in postoperational costs, however, is projected for the southeast and midwest sites. A low level of postoperational costs is projected for waste spectrum 2 due to the assumed extensive compaction of compressible waste streams. Since this extensive compaction is not carried out for modified waste spectrum 1, a somewhat higher potential for maintenance is assumed and a moderate level of postoperational costs is conservatively projected.

Unit costs are seen to vary widely depending upon the assumed design and operating practices carried out at the particular disposal facility as well as the volumes of waste delivered to the facility. For example, the design and operation of the southeast site is essentially the same as the midwest facility. However, the volume of waste delivered to the midwest facility is much less than the southeast facility, while the design and operational costs are only slightly less. This is because capital costs to construct the disposal facility are much less dependent upon the volumes of waste delivered to the facility than the operating costs. Many of the same expenses to design, build, and operate the facility would be incurred whether a high or a low volume of waste was received.

10.3.3.4 Other Impacts

This section discusses indirect impacts associated with the proposed Part 61 regulation other than radiological impacts or costs. The impacts are broken down into the following subsections: Air quality (nonradiological), biota (ecology), land use, energy use, and social impacts.

Air Quality

Nonradiological impacts to air quality due to LLW management and disposal would principally arise from two sources: combustion of fossil fuels during processing, transporting, and disposing of waste and (2) particulate matter (dust) released into the air due to earth moving activities at the disposal facility. Typical combustion products would include suspended particulates, sulphur dioxide, CO_2, CO, various hydrocarbons, and various nitrogen oxides.

It is believed that implementation of the Part 61 regulation would have a relatively slight effect upon overall air quality. For example, increased waste processing such as compaction and solidification would probably result in increased combustion of fossil fuels, with correspondingly increased release of combustion products into the air. However, many waste generators are already performing such waste processing activities to reduce transportation costs or to comply with existing license conditions at disposal facilities. Moreover, waste processing activities that reduce waste volumes would tend to reduce releases of fossil fuel combustion products during transportation.

At the disposal facility, local impacts to air quality result from combustion of fossil fuels by vehicles delivering waste to the facility, by vehicles owned by facility personnel, and by heavy equipment operated at the facility. Dust could be raised by excavating, backfilling, and grading activities. However, combustion of fossil fuels and earth-moving activities are not unique to the fact that it is a disposal facility. Similar types of impacts can and would be raised by many other types of small industrial concerns.

Since the Part 61 regulation emphasizes increased disposal facility stability, somewhat additional air quality impacts could result during the operating life of the disposal facility. That is, additional personnel may be needed as well as additional equipment to segregate waste, carry out improved compaction techniques, install improved disposal cell covers, and so forth. However, such additional impacts would be felt only during the time the facility was operating. In addition, if the facility was left in an unstable condition after operation, increased longer-term air quality impacts could result due to operating machinery to repair holes in disposal cell covers, potential operation of a leachate evaporator, and so forth. Placing the facility in a more stable condition during site operations reduces the maintenance that would be required after closure and during the institutional control period. Since less maintenance would be required, lower longer term nonradiological air quality impacts would result.

Biota

The operation of a disposal facility would involve acquiring and fencing in up to a few hundred acres of land. Existing vegetation would be mostly cleared, and after waste disposal, the disposal cells would be regraded, recontoured, and probably reseeded with short-rooted local vegetation. During this process, impacts to biota could result from destruction of habitat. Such impacts would again not be caused by the fact that the facility is used for waste disposal, but arise from the decision to change the land from one use to another. Similar types of impacts would result from other uses of the land which involve heavy construction. These could include, for example, clearing the land for a small industrial concern, a school, a farm, and so forth.

Implementation of the Part 61 rule is expected to have little effect on the potential for impacts to biota. There are already existing federal and state laws and regulations governing protection of endangered or unique flora and fauna. These regulations and laws would be considered during licensing of a disposal facility whether or not the Part 61 regulation is implemented. To the extent that the Part 61 regulation makes the requirement of considering endangered or unique flora and fauna more explicit during licensing, however, overall impacts to biota could potentially be reduced.

Land Use

In most cases, the operation of a licensed nuclear facility by a licensee does not result in the land being permanently committed to that activity. That is, at the end of operation of the facility it may be decontaminated, if necessary, and used for another purpose. At an LLW disposal facility, however, possible

future use of the facility after it has closed is greatly influenced and somewhat circumscribed by the presence of the disposed waste. This does not mean that land used for LLW disposal is permanently excluded from productive use. Rather, as long as care was taken to restrict activities to those which would not involve excavating into the disposed waste or bringing contamination to the surface, there may be a number of useful purposes the facility surface may be put to. These could possibly include use of the facility for grazing, golf courses, recreational areas, or light industry.

Notwithstanding this, however, it is useful to consider the amount of land that would be committed to LLW disposal over the next 20 years. It is difficult to assess the influence of the Part 61 regulation on this land use. Depending upon the design and operation of the disposal facility and the manner in which higher activity wastes are stabilized, land use could be lower or potentially higher than without the regulation. A range in land use may be estimated, however, using the regional analysis as a guide. Land use for each of the regions is shown below for the 2 waste spectra considered in the analysis.

	$m^2 \times 10^5$ (acres)			
	Northeast	Southeast	Midwest	Southwest
Modified Waste Spectrum 1	2.30 (56.8)	3.72 (91.9)	2.62 (64.7)	2.52 (62.3)
Waste Spectrum 2	1.59 (39.3)	2.61 (64.5)	1.84 (45.5)	1.71 (42.3)

As shown, land use ranges from about 160,000 m^2 to 370,000 m^2 at the regional sites, depending upon the volume of waste disposed and the disposal technology implemented. For modified spectrum 1, the total amount of land committed to LLW disposal over 20 years is estimated to be 1.1 million m^2, or about 276 acres For waste spectrum 2, for which increased use is made of volume reduction, this land use is reduced to 775,000 m^2 or 192 acres. This includes an assumed 3-meter spacing between disposal cells but does not include other land such as administrative areas, buffer zones, onsite roads, and so forth.

Energy Use

One way in which the effects of a proposed action can be quantified is to estimate the total energy requirements associated with that action. In terms of LLW management and disposal, this would be a difficult project given the large number of waste generators, the many different types and forms of LLW, and the many possible processing techniques that could be used. As a simplification, then, an effort has been made to estimate the increase in energy use due to the promulgation of the Part 61 rule. This is still realized as a

difficult task given the recent increase in the level of waste processing activities carried out by waste generators. In addition, there may be a number of ways in which the Part 61 requirements may be met and there are considerable uncertainties regarding the energy use associated with various technologies, etc.

In any case, bounding estimates can be made using the regional analysis as a guide. The estimated increase in energy use due to the Part 61 regulation is listed below in gallons of equivalent fuel for each region for both waste spectra considered:

	(gal x 10^5)			
	Northeast	Southeast	Midwest	Southwest
Modified Waste Spectrum 1	+0.6	-2.7	-2.6	-1.86
Waste Spectrum 2	+83.1	+89.7	+64.7	+21.3

As shown, incremental energy use ranges from -270,000 gal to +8,970,000 gal. It should be realized that there are large uncertainties in these calculations. Much of the projected increase in energy use is due to activities such as increased disposal stability or increased waste processing which by and large are already being carried out. In general, the overall tendency of the Part 61 regulation would be to increase short-term energy use but reduce long-term energy use.

Social Impacts

In general, social impacts due to promulgation of the Part 61 regulation are difficult to address. These impacts are very site-specific and would include such aspects as the effect of bringing a labor force into an area on local utilities, schools, and other services. These types of impacts are typically of most concern during the siting, construction, and operation of large facilities such as a large nuclear power plant. A low-level waste disposal facility is by comparison a very small operation, and the proposed Part 61 regulation is not expected to result in any significant incremental changes in social impacts associated with operation of LLW disposal facilities.

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The four volume draft environmental impact statement (DEIS) is prepared to guide and support publication of a proposed new regulation, 10 CFR Part 61, for the land disposal of low-level radioactive waste. The analysis in the DEIS include a systematic analysis of a broad range of alternatives relating to the form and content of waste, the engineering design of disposal facilities, the method of operation of the facilities, institutional controls, financial assurances, and administrative and procedural requirements. From the analysis, four main performance objectives are established in the proposed regulation relating to (1) minimizing long-term social commitment and costs, (2) minimizing long-term environmental releases, (3) minimizing long-term impacts to humans potentially inadvertently intruding into disposed waste, and (4) assuring short-term operational safety. Based upon the analysis and overall performance objectives, a number of technical, financial, procedural, and administrative requirements are also developed.

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