DOE/EIS-0200-D-Vol.3

DRAFT
WASTE MANAGEMENT
PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT
for
Managing Treatment, Storage, and Disposal of
Radioactive and Hazardous Waste

Volume III of IV

Appendix A Public Response to Revised NOI
Appendix B Environmental Restoration
Appendix C Environmental Impact Analysis Methods
Appendix D Risk

August 1995

MASTER

U.S. Department of Energy
Office of Environmental Management
1000 Independence Ave.
Washington, DC 20585

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Appendix A

Public Comments to DOE's Proposed Revisions to the Scope of the WM PEIS

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

U.S. Department of Energy
Waste Management Programmatic Environmental Impact Statement

August 1995

Contents

A.1	Public Comments and DOE Response	A–1
Attachment 1	Federal Register Notice, October 22, 1990 (55 FR 42633)	A1–1
Attachment 2	Federal Register Notice, January 24, 1995 (60 FR 4607)	A2–1
Attachment 3	Federal Register Notice, March 16, 1995 (60 FR 14275)	A3–1
Attachment 4	Natural Resources Defense Council's Comments on the Department of Energy's Proposed Modification in Scope of the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement	A4–1

APPENDIX A
Public Comments to DOE's Proposed Revisions to the Scope of the WM PEIS

On June 27, 1989, twenty-two citizens' groups, led by the Natural Resources Defense Council, filed suit to compel the Department of Energy to prepare a programmatic environmental impact statement on proposals for the cleanup and modernization of the nuclear weapons production complex. Consequently, on January 12, 1990, the Secretary of Energy decided to prepare two programmatic environmental impact statements, one on the modernization of the nuclear weapons complex and the other on the Five-year Environmental Restoration and Waste Management Plan. Accordingly, on October 22, 1990, the Department of Energy issued a Notice of Intent (55 FR 42633) to prepare the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement (see Attachment 1). In the Notice of Intent, the Department identified the proposed action as follows: "to formulate and implement an integrated environmental restoration and waste management program in a safe and environmentally sound manner and in compliance with applicable laws, regulations and standards." The Notice of Intent identified two separate sets of alternatives to be evaluated, one for environmental restoration and one for waste management.

The public scoping period on the Programmatic Environmental Impact Statement extended from October 22, 1990 to February 19, 1991. Beginning on December 3, 1990, the Department held 23 scoping meetings at various locations across the country to ensure adequate opportunity for participation by the public and other government agencies. During the public comment period, over 1,200 people provided approximately 7,000 comments, either by participating in the meetings or by submitting materials and letters. Most concerns were related to the public perception of the Department and to environmental, health, and safety issues.

To record the results of the public scoping meetings and to serve as a plan for preparing the Programmatic Environmental Impact Statement, a Draft Implementation Plan was prepared and made publicly available on February 4, 1992 (57 FR 4193). The Draft Implementation Plan summarized the comments received during the public scoping meetings and identified those issues, as suggested by the comments, that would be considered in preparing the Programmatic Environmental Impact Statement. A public comment period

on the Draft Implementation Plan extended from February 4, 1992 until April 24, 1992. During this time, six regional public workshops were held.

The Final Implementation Plan was completed in January 1994 and made available to the public (59 FR 7990, February 17, 1994). It addressed comments received during the public scoping meetings and those received on the Draft Implementation Plan as well.

Subsequently, the Department attempted to meaningfully analyze the environmental restoration alternatives that it originally defined in the Final Implementation Plan but concluded, after considerable effort, that it would not be appropriate to make programmatic decisions regarding cleanup strategies that would be applicable to all of the Department's sites.

Accordingly, the Department announced on January 24, 1995 (60 FR 4607), an opportunity for public comment on its proposal to shift the focus and change the title of the Programmatic Environmental Impact Statement (see Attachment 2). The proposed modification would eliminate the environmental restoration alternatives and modify the proposed action. On March 16, 1995 (60 FR 14275) in response to a request from the public, the Department announced an extension of the public comment period on the proposed scope to April 10, 1995 (see Attachment 3). In both announcements, the Department stated that the draft PEIS would contain an appendix summarizing comments received during the resulting public comment period.

On April 10, 1995, the Natural Resources Defense Council filed a public comment in response to the notices of opportunity on the proposed modification to the scope and title of the Programmatic Environmental Impact Statement. The Council's comments were the only comments received.

The Council's letter (see Attachment 4) referred to the prior litigation between the Natural Resources Defense Council and the Department of Energy and stated that the Department indicated that its cleanup and waste management activities constituted actions that fall within the meaning of the National Environmental Policy Act and are thus subject to review. The letter also stated that the Department, during the course of litigation, committed to preparing a programmatic environmental impact statement that included environmental restoration.

The Council cited several program-level issues that it believes warrants full analysis and public participation, including those pertaining to uniform versus site-specific standards; the scope and pace of the cleanup program; land use restrictions in setting cleanup levels; inter- and intra-facility priorities in light of budget constraints; and public participation in the decision process for cleanup. Further, the Council noted that as a matter of policy, the Department does not perform reviews under the National Environmental Policy Act for actions taken pursuant to the Comprehensive Environmental Response, Compensation and Liability Act.

The Department agrees that there are issues with regard to the cleanup program for which a national perspective and public discussion are appropriate. These issues concern implementation of the national environmental restoration program, which will involve some broad strategic initiatives and the need for consistency in site-specific decisions to ensure an adequate level of protection and adequate financial controls. DOE is considering some enhanced public participation to obtain input on such national environmental restoration isssues. However, the Department believes that there are suitable analytical tools and venues available other than the programmatic environmental impact statement, to address the issues raised in the Council's letter. These are discussed below.

As the Department notes in the Federal Register Notices of Opportunity to comment on the proposed change in scope, the fundamental reasoning behind its decision to carefully refocus the scope of the draft Environmental Impact Statement was that cleanup decisions should reflect site-specific cleanup conditions commensurate with the regulatory framework under the Comprehensive Environmental Response, Compensation and Liability Act and the Resource Conservation and Recovery Act. The site-specific nature of cleanup decisions is inconsistent with the idea of making decisions under a programmatic environmental impact statement that will be implemented nationwide. In other words, for environmental restoration, there is not a proposed action leading to a programmatic decision in this document. Consequently, a programmatic environmental impact statement is not an appropriate vehicle for analysis.

Arriving at cleanup decisions on a site-specific basis does not preclude public involvement in such decisions, nor does it alter the Department's commitments and requirements to complete appropriate reviews under the National Environmental Policy Act. On the contrary, this permits the necessary specific reviews, considerations, and deliberations for cleanup actions, including considerations of land use issues, to be reached properly with the approval of state and federal regulators and with the direct involvement of the local community.

Additionally, with regard to using land use restrictions in setting cleanup levels, the Department has embarked on an extensive land use initiative to gain an understanding of the long-term future site uses, which is essential to effective planning and decision making for a myriad of Departmental activities. Specifically, this initiative is to provide a basis for cleanup decision making and for site development and comprehensive planning. Each of the Department's major sites is developing future land use preferences with significant involvement of interested and affected stakeholders.

The Department has conducted an ongoing national dialogue with regard to the budget and priorities. The Department actively sought the involvement of regulators and other stakeholders in establishing priorities and developing the FY 1997 budget. The Department designed a process to give regulators and stakeholders a meaningful voice in developing site priorities, which were then used to develop a budget. The goal of this collaborative effort was to plan what could and could not be done with available resources to try to achieve an optimum balance among priorities within a site, and to some extent, between sites. This process resulted in a reprioritizing of activities and modification of schedules to ensure that the program would be as effective and cost-efficient as possible. As part of this open deliberative decision making process, a national meeting was also held with regulators and stakeholders to discuss national priorities and cross-cutting issues as well as any changes to the field budget submission. The pace as well as the scope of the program, therefore, were taken into consideration and are reflected in the priorities and the budget.

With respect to the role of site-specific advisory boards and other means of public participation in the decision making process for cleanup, while not considered an appropriate topic for review in an impact statement, is of critical concern to the Department. The Department has established several advisory boards at its major sites. The boards, which are one means for involving the public, have negotiated their roles and responsibilities. Moreover, agendas are left to the boards, in conjunction with the regulators and the Department, to determine. The boards are informed of ongoing cleanup activities and issues including land use planning, budget planning and development, and priority setting, and are invited into the decision making process.

In the Fiscal Year 1994 National Defense Authorization Acts, Congress directed the Department to provide a life-cycle cost estimate for the program, delineated by specific projects and activities. The Baseline Environmental Management Report systematically analyzed potential life-cycle costs of meeting legal commitments as well as addressing other issues related to the management of hazardous and radioactive materials and waste within the system. The report provided cost estimates associated with various program-

wide alternatives given differing land use assumptions, residual contamination standards funding and schedule changes, waste treatment, storage and disposal options, and potential technology improvements. This report is a valuable analytical tool for exploring cost consequences of potential options.

In addition, the Risk Report, when considered with the Baseline Environmental Management Report as well as other analyses, helps to provide a foundation of technical, environmental, financial, and social analysis needed to inform the national debate on a number of issues, including those raised in the Council's letter. The purpose of the analysis, prepared in response to direction from the Energy and Water Subcommittee of the Committee on Appropriations, was to help the Department develop a mechanism for establishing priorities among competing cleanup requirements.

After careful consideration of the Council's comments, and given these various opportunities for discussion and the analytical tools available to informed debate on national issues, the Department determined that these activities, processes and analyses are useful, but not necessarily sufficient mechanisms to analyze and involve the public in broad environmental strategy issues. Consequently, the Department is considering the addition of some enhanced public participation methods to involve people in the future course of the environmental restoration program to the extent that national decisions and initiatives will occur. Nonetheless, the Department decided that the title and scope of the Programmatic Environmental Impact Statement should be modified as proposed to consider the management of the Department's radiological and hazardous wastes and sites at which the wastes could be managed in the future. This approach is consistent with the alternatives outlined for waste management in the Final Implementation Plan.

As previously set forth in the Final Implementation Plan, the Waste Management Programmatic Environmental Impact Statement will evaluate decentralized, regional, and centralized approaches for storage of high-level waste; treatment and storage of transuranic waste; treatment and disposal of low-level and low-level mixed waste; and treatment of hazardous waste. Waste generated by restoration activities in the future that must be managed as part of the Department's program to manage all of its wastes will be considered in the Waste Management Programmatic Environmental Impact Statement.

Attachment 1
(to WM PEIS Appendix A)

Federal Register Notice
(Volume 55, Number 204, Monday October 22, 1990)
[55 FR 42633]

Department of Energy
"Intent to Prepare a Programmatic Environmental Impact Statement on the Department of Energy's Proposed Integrated Environmental Restoration and Waste Management Program, and to Conduct Public Scoping Meetings"

Federal Register / Vol. 55, No. 204 / Monday, October 22, 1990 / Notices 42683

DEPARTMENT OF ENERGY

Intent To Prepare a Programmatic Environmental Impact Statement on the Department of Energy's Proposed Integrated Environmental Restoration and Waste Management Program, and To Conduct Public Scoping Meetings

AGENCY: U.S. Department of Energy (DOE).

ACTION: Notice of intent (NOI) to prepare a programmatic environmental impact statement (PEIS).

SUMMARY: The Department of Energy announces its intent to prepare a PEIS pursuant to the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321, *et seq.*), as amended, and to conduct a series of public scoping meetings nationwide. The PEIS will assess the potential environmental consequences of alternatives for implementing an integrated environmental restoration and waste management program.

The purpose of DOE's proposed integrated environmental restoration and waste management program is to provide a broad, systematic approach to addressing cleanup activities and waste management practices. The Department is committed to ensuring that potential risks to human health and the environment from the cleanup of contamination resulting from past operations and from future waste management activities are at safe levels. DOE is further committed to full compliance with environmental regulations and to a goal of completing environmental restoration by 2019.

INVITATION TO COMMENT: To ensure that the full range of issues related to this proposal are addressed, comments on the proposed scope of the PEIS are invited from all interested parties. Written comments to assist DOE in identifying significant environmental issues and defining the appropriate scope of the PEIS should be directed to Mr. Wisenbaker at the address indicated below. Agencies, organizations, and the general public also are invited to present oral comments pertinent to the preparation of the PEIS at the public scoping meetings to be held nationwide, as described below. Written and oral comments will be given equal weight.

Following the completion of the public scoping process, a PEIS Implementation Plan will be issued for public comment. The Implementation Plan will record the results of the scoping process and define the alternatives and issues to be evaluated in the PEIS. DOE intends to

complete the draft PEIS in early 1992. Its availability will be announced in the Federal Register, and public comments again will be solicited. Comments on the draft PEIS will be considered in preparing the final PEIS, scheduled for 1993.

DATES: The public scoping period will continue until February 19, 1991. Written comments should be postmarked by February 19, 1991 to assure consideration. Comments received after that date will be considered to the extent practicable. The public scoping meetings will begin in December 1990. The dates and locations of the meetings will be announced in a subsequent Federal Register notice and in local public notices in advance of the planned meetings.

ADDRESSES AND FURTHER INFORMATION: Written comments on the scope of the PEIS, questions concerning the program, and requests for copies of the draft PEIS should be directed to: Mr. W. E. Wisenbaker, Acting Director, Division of Program Support, Office of Environmental Restoration (EM-43), U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585, (202) 353-2950.

For further information on the DOE NEPA process please contact: Ms. Carol M. Borgstrom, Director, Office of NEPA Oversight (EH-25), U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585, (202) 586-4600.

PUBLIC SCOPING MEETINGS: Public scoping meetings will be held in the following cities beginning in December 1990. The dates and locations of these meetings will be published in a subsequent Federal Register notice. This information will also be announced in local public notices before the planned meetings.

Oakland, California
Denver, Colorado
Washington, DC
Tampa, Florida
Atlanta, Georgia
Boise, Idaho
Idaho Falls, Idaho
Chicago, Illinois
Paducah, Kentucky
St. Louis, Missouri
Las Vegas, Nevada
Princeton, New Jersey
Albuquerque, New Mexico
Newburgh, New York
Cincinnati, Ohio
Columbus, Ohio
Portland, Oregon
Columbia, South Carolina
Oak Ridge, Tennessee
Amarillo, Texas
Richland, Washington
Seattle, Washington
Spokane, Washington

SUPPLEMENTARY INFORMATION:

Background. In November 1989, the Secretary of Energy established the DOE Office of Environmental Restoration and Waste Management (EM) for the purpose of consolidating the Department's environmental restoration and waste management activities. In January 1990, the Secretary determined that DOE will prepare an Environmental Impact Statement on a newly proposed integrated environmental restoration and waste management program.

Some of the waste management practices that DOE and its predecessor agencies once considered safe and prudent under then existing requirements and guidelines have resulted in the need for remediation under applicable current Federal and state requirements and guidelines. DOE's environmental restoration activities include the assessment and physical cleanup of contamination at DOE installations and other properties. Environmental restoration activities also include the decontamination and decommissioning (D&D) of DOE's surplus facilities. These facilities and properties may have contamination from radioactive, hazardous, or mixed (radioactive and hazardous) waste. As decisions are made for the handling of contamination at various sites and facilities, new wastes will be generated that will require management.

DOE's waste management operations include the treatment, storage, transportation, and disposal of wastes generated by ongoing nuclear energy, energy research, and defense activities; by environmental restoration activities; and by other sources. These wastes include: high-level radioactive waste (HLW); low-level radioactive waste (LLW); transuranic waste (TRU); mixed waste (MW); greater-than-Class C waste (GTCC) waste; and hazardous waste.

The Affected Installations. DOE's environmental restoration and waste management activities occur throughout the U.S. The largest number of facilities that require environmental restoration or that generate or store the largest volumes of radioactive, hazardous, and mixed waste are located at these installations: Hanford Reservation (Washington); Savannah River Site (South Carolina); Oak Ridge Reservation (Tennessee); Rocky Flats Plant (Colorado); Feed Materials Production Center, Mound Plant and Portsmouth Gaseous Diffusion Plant (Ohio); Idaho National Engineering Laboratory (Idaho); Lawrence Livermore National Laboratory (California); Argonne National Laboratory (Illinois); Paducah Gaseous Diffusion Plant (Kentucky); Nevada Test Site (Nevada); Los Alamos National Laboratory and Sandia National Laboratory (New Mexico); and Pantex Plant (Texas). The Appendix contains a listing of DOE locations where current environmental restoration and waste management activities occur that DOE believes are within the scope of this PEIS. Additional sites may be added in the course of the development of the PEIS.

The Regulatory Framework. Federal laws of major importance to DOE's environmental restoration and waste management activities include, among others, the Atomic Energy Act of 1954 (42 U.S.C. 2011, *et seq.*), as amended; the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) (42 U.S.C. 9601, *et seq.*), as amended; and the Resource Conservation and Recovery Act (RCRA) (42 U.S.C. 6901, *et seq.*), as amended. The Atomic Energy Act requires the management, processing, and utilization of radioactive materials in a manner that protects the public health and the environment. CERCLA requires responses to releases or threatened releases of hazardous substances into the environment and establishes a process to clean up abandoned or uncontrolled hazardous waste sites which may endanger public health or the environment. RCRA requires management of waste currently being generated, including the treatment, storage, transportation, and disposal of hazardous waste, and cleanup of hazardous waste releases from past and present operations that pose a threat to human health and the environment. It is DOE's policy to apply NEPA to its waste management and cleanup activities. To minimize delay and duplication of effort in meeting these responsibilities, DOE is supplementing, where necessary, and integrating the procedural documentation and public participation requirements for CERCLA and RCRA to facilitate compliance with NEPA requirements (DOE Order 5400.4, Comprehensive Environmental Response, Compensation, and Liability Act Requirements).

DOE environmental restoration and waste management activities are subject to other applicable Federal and state requirements and to enforceable agreements. Additionally, certain Federal statutes require DOE to undertake specific environmental restoration and waste management activities. For example, under Title I of the Uranium Mill Tailings Radiation Control Act, DOE must remediate inactive uranium milling sites in accordance with Environmental

Protection Agency standards (40 CFR part 192) established for that purpose.

Wastes are categorized in accordance with Federal statutes and regulations and DOE Orders. High-level waste is defined in the Nuclear Waste Policy Act of 1982 (42 U.S.C. 10101(12)). Low-level, transuranic, and radioactive mixed wastes are defined in DOE Order 5820.2A (Radioactive Waste Management). Hazardous wastes are those wastes that are defined as hazardous by U.S. Environmental Protection Agency regulations implementing RCRA (40 CFR Part 261) and by applicable state regulations.

Current Practices for Waste Management. To date, DOE's waste management operations have focused on site-by-site treatment, storage, transportation, and disposal of waste. Transuranic, low-level, hazardous, and radioactive mixed waste are generated at many DOE installations; only a few installations generate high-level waste.

DOE generates or stores high-level waste at four installations: the Savannah River Site, the Hanford Reservation, the Idaho National Engineering Laboratory, and the West Valley Demonstration Project. To date, high-level waste has undergone only limited treatment. DOE intends to immobilize the waste in a stable, solid form acceptable for disposal in a geologic repository. Under current law, only one potential repository site (at Yucca Mountain, Nevada) for this waste is currently being characterized.

Most TRU waste has been generated at DOE's Rocky Flats Plant in Golden, Colorado. Transuranic waste is currently stored at several facilities including the Rocky Flats Plant, the Idaho National Engineering Laboratory, the Hanford Reservation, the Oak Ridge Reservation, the Nevada Test Site, Los Alamos National Laboratory, and the Savannah River Site. The Idaho National Engineering Laboratory has the largest management program for this waste. The Department is currently evaluating the Waste Isolation Pilot Plant in Carlsbad, New Mexico, as a potential disposal site for TRU waste.

Low-level waste requires relatively minimal treatment. Although in some instances other methods may be used, DOE currently disposes of the majority of its LLW in near-surface facilities, including installations at the Savannah River Site, the Oak Ridge Reservation, the Nevada Test Site, the Hanford Reservation, Los Alamos National Laboratory, and the Idaho National Engineering Laboratory.

DOE Order 5820.2A (Radioactive Waste Management) requires that the DOE waste equivalent to commercially generated Greater-than-Class C (GTCC) waste be handled as a special case by each site. The Department is also responsible for disposal of commercially generated GTCC waste. DOE has developed a three-part strategy for managing this waste. The first phase would provide a storage facility for those generators that cannot continue to store the waste. The second phase would provide a central storage facility for all commercially generated GTCC waste.

The final phase would transfer the stored waste to a high-level waste repository or provide for the development of a separate GTCC disposal facility.

For hazardous waste, DOE's near-term objective is to treat the waste as it is generated, thereby minimizing the need for storage capacity. DOE disposes of treated hazardous waste in permitted DOE or commercial facilities.

Mixed wastes are generated at many DOE installations. Mixed waste may include high-level waste, transuranic waste, and low-level waste. DOE stores these wastes until they can be treated and disposed of in permitted facilities. The Department currently treats a small amount of MW by thermal destruction to eliminate some hazardous components. In addition, DOE treats some low-level MW by solidification.

The PEIS will address these practices and any reasonable alternatives that are amenable to environmental analysis. (See Scope of PEIS, below)

Current Practices for Environmental Restoration. DOE will continue to seek, to the extent possible, to negotiate a comprehensive Federal Facilities Agreement with the Environmental Protection Agency (EPA) and the involved state to cover its remediation activities at an installation. Such agreements establish technical requirements and schedules for characterization, feasibility assessment and cleanup at each of the affected sites, and delineate the roles and responsibilities of each party to the agreement, to comply with the requirements of Section 120 of CERCLA. DOE is in the early stages of site assessment and characterization at many facilities. These initial activities are being reviewed in compliance with NEPA. DOE has determined that these early remediation activities are normally categorically excluded under its NEPA guidelines (55 FR 37174, September 7, 1990).

Decontamination and decommissioning activities have several objectives: (1) To maintain facilities awaiting additional D&D activities in a manner that protects workers, the public, and the environment; (2) to decontaminate facilities intended for reuse; and (3) decommission other facilities in accordance with requirements set forth in an approved environmental compliance plan. Currently, D&D activities are planned and executed on a site-by-site basis.

The PEIS will address these practices and any reasonable alternatives amenable to environmental analysis.

Need for an Integrated Environmental Restoration and Waste Management Program. The fundamental goal of DOE's Office of Environmental Restoration and Waste Management is to ensure that potential risks to human health and to the environment posed by wastes under its jurisdiction are at safe levels. To help achieve this goal, DOE proposes to conduct an integrated environmental restoration and waste management program.

Historically, DOE environmental restoration and waste management operations have been conducted on a site-by-site basis. This practice has led to differing approaches to cleanup and waste management among DOE sites. DOE's recent consolidation of waste program responsibilities (environmental restoration and waste management) provides the opportunity to establish a systematic approach to programmatic requirements and practices.

Remediation and D & D activities result in large amounts of waste that will require management, in addition to the wastes generated from production, research, and other activities. Because environmental restoration activities will be a significant source of waste, cleanup and waste management activities are closely related. The resolution of certain key issues, such as future land-usability objectives, will determine the amount, type, and timing of environmental restoration waste being introduced into the waste management part of the system. Land-usability policy relates to cleanup standards and the degree of reliance on institutional controls for long-term health and environmental protection.

PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT: On January 12, 1990, the Secretary of Energy determined that a PEIS should be prepared for DOE's newly proposed integrated environmental restoration and waste management program. The Secretary stated that preparation of this PEIS will ensure that a comprehensive and cumulative environmental analysis of waste management proposals and alternatives will be available to DOE decisionmakers and the public.

The PEIS will assess broad programmatic issues and integrated approaches to DOE's environmental restoration and waste management activities. DOE aims, to the extent this is feasible, for the PEIS to provide the primary environmental basis for selecting waste management methods and technologies and the locations at which they would be implemented. However, DOE does not intend the PEIS to assess impacts related to alternative choices of locations within a site. Such detailed decisions would be based on site-specific NEPA documents tiered to this PEIS.

PRELIMINARY DESCRIPTION OF ALTERNATIVES: *Scope of PEIS.* DOE solicits public input on all aspects of the proposed program described in this notice. DOE plans to structure this PEIS in two sections to facilitate public review and comments. One section of the PEIS will focus on key environmental restoration issues. The second section will analyze reasonably foreseeable potential impacts associated with various waste management alternatives within the integrated program.

As discussed previously, current environmental restoration and waste management practices for which reasonable alternatives that are amenable to environmental analysis can be identified are within the scope of the PEIS. Under the Nuclear Waste Policy Act of 1982 (42 U.S.C. 10101, *et seq.*), as amended, DOE currently plans to dispose of high-level waste resulting from Departmental activities in a repository to be developed for spent fuel from commercial nuclear utilities. In addition, under section 213(a) of the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980 (42 U.S.C. 7272, *et seq.*), as amended, the Department plans to demonstrate the disposal of defense transuranic waste at the Waste Isolation Pilot Plant in Carlsbad, New Mexico. These decisions will not be revisited in the programmatic EIS. In addition, there is a national program, under Congressional direction, to address the management of commercial nuclear reactor spent fuel. The activities associated with that program will be considered in separate NEPA documentation and not in this PEIS. Commercial LLW is not the Department's responsibility and therefore is outside the scope of the PEIS. Uranium Mill Tailings Remedial Action Program (UMTRAP) tailings cleanup and disposal activities are within DOE's purview, but are expected to be close to completion prior to the issuance of the Record of Decision and will not be considered in the PEIS. The groundwater remediation activities associated with UMTRAP are just beginning, however, and therefore are within the scope of this PEIS.

Proposed action. The proposed action is to formulate and implement an integrated Environmental Restoration and Waste Management Program in a safe and environmentally sound manner, and in compliance with applicable laws, regulations and standards. Alternative approaches are discussed below.

Environmental Restoration Analysis:. NEPA requires DOE to analyze reasonable alternatives to its proposed actions. DOE realizes that in the current environmental restoration decisionmaking framework for remediation activities there are statutory and regulatory requirements that must be fulfilled. DOE will continue to follow established processes in conducting ongoing environmental restoration activities.

For example, the framework Congress established under CERCLA for remedial actions imposes a strong preference for permanent remedies that comply with all applicable and appropriate requirements established under environmental laws. Consequently, DOE's overall environmental restoration efforts have focused on cleaning up sites adequately for unrestricted future use. The framework also requires that cleanup requirements and remedies be selected site-specifically. This produces final decisions made both discretely and diversely.

DOE believes, however, that there are important national issues that it should analyze in carrying out its responsibilities. These issues include, but are not limited to, (1) the degree to which DOE should rely on proven technologies in contrast to making strong resource commitments to developing innovative technologies; (2) the manner in which DOE should manage wastes until adequate treatment and disposal capacity is available; (3) whether DOE's installations should invariably be cleaned up for unrestricted use; and (4) the environmental basis for deciding cleanup priorities.

DOE seeks to develop and analyze programmatic alternatives that bear on these issues. DOE believes that important information on the costs and benefits of alternative program management strategies could thereby be obtained. DOE is especially interested in receiving public comments on these issues.

Decontamination and decommissioning activities are not subject to the decisionmaking framework that governs remediation activities. DOE proposes, therefore, to approach all D&D activities in an integrated, systematic fashion.

Waste Management Analysis: Waste treatment, storage, transportation, and disposal alternatives primarily depend on the waste category (such as radioactive, hazardous, or radioactive mixed waste). Alternatives will reflect centralized, regional, or installation-specific strategies. The analysis would provide environmental information for deciding which waste management capabilities should be established centrally, regionally, or at each site. Transportation of waste and the potential associated impacts will also be evaluated.

No Action. This alternative would continue present practices. DOE would not adopt and integrated environmental restoration and waste management program. DOE would continue to operate its environmental restoration activities and its waste operations as discrete site-specific actions. If site requirements dictate the need for offsite or new facilities, management decisions would be made on a project specific basis.

DOE would maintain existing facilities for waste management operations. New waste management activities, projects, and technological development would be considered case-by-case.

IDENTIFICATION OF ENVIRONMENTAL ISSUES: The following environmental issues have been identified for analysis in the PEIS. This list is presented to facilitate discussion on the scope of the PEIS and is not intended to be all-inclusive or to predetermine the scope. Therefore, DOE invites comments on these and additional issues relevant to this PEIS.

(1) The potential impacts (both beneficial and adverse) to worker health, public health, and the environment under various alternatives for environmental restoration and waste management.

(2) The potential impacts to workers, public health, and the environment under various alternatives from routine transportation of wastes and potential transportation accidents.

(3) The development of needed technologies and methods for environmental restoration and waste management and the potential impacts (both beneficial and adverse) from their implementation.

(4) Any obstacles to achieving full compliance with all applicable federal, state, and local environmental statutes, regulations, and requirements.

(5) The socioeconomic impacts of alternatives for dispersed, regional, and centralized waste management.

(6) The potential impacts of applying various land-usability strategies to the cleanup of DOE installations and sites.

RELATIONSHIP TO OTHER ACTIONS: *Five-Year Plan.* DOE issued a Five-Year Plan for Environmental Restoration and Waste Management (DOE/S-0070) in August 1989 that was subsequently revised, updated, and reissued (DOE/S-0078P) in June 1990. The Plan summarizes current DOE practices and identifies short- and long-term goals. The activities described are for the near-term (e.g., remediation of seepage basins at the Savannah River Site, and radioactive storage upgrades at the Kansas City Plant). Only general objectives, criteria, and guidance, in addition to those set in applicable environmental regulations and statutes, are specified for implementing environmental restoration and waste management activities on a long-term basis. For example, the Plan states that the majority of solid low-level waste generally will continue to be disposed of using shallow land burial, but recognizes that this may not be suitable for all locations. The Plan also states DOE's general intent that facilities and sites be returned to a condition suitable for unrestricted use, but recognizes that in-place remedies may sometimes be preferred.

The Five-Year Plan is not a proposal within the context of NEPA. Rather, it is preliminary to the Environmental Restoration and Waste Management PEIS in which DOE will evaluate integrating its long-term environmental restoration and waste management activities. The PEIS will specifically address the long-term goals and issues generally summarized in the Five-Year Plan.

As the Plan states, completion of the PEIS process may result in changes in specific programs, which would be reflected in future editions of the Plan.

Environmental Restoration and Waste Management Configuration Study. The Environmental Restoration and Waste Management Configuration Study is a strategic planning study for the long-term (the next 25 years). The study will support the definition of waste system configuration alternatives in this PEIS. DOE intends to issue the draft configuration study concurrently with the draft PEIS for public information and use in reviewing the draft PEIS.

Many factors influence the configuration and updating of DOE's waste management operations, including: (1) Increasingly strict environmental, safety, and health standards and requirements; (2) facilities dating from the late 1940s to the middle 1960s becoming obsolete; (3) increasing costs to maintain and upgrade these facilities; (4) difficulties in managing widely dispersed waste storage facilities in different environmental settings; (5) potential changes in the locations, volumes, and types of waste to be managed, after consideration of a PEIS on reconfiguring (modernizing) the nuclear weapons complex; (6) availability of improved technologies; (7) population growth near once-remote facilities such as areas near Rocky Flats, Colorado, Fernald, Ohio, Oak Ridge, Tennessee, and Livermore, California, which has led to local demands for restricting DOE operations; and (8) transition from waste accumulation and storage to waste treatment and disposal.

PEIS for the Nuclear Weapons Complex (NWC). In concert with the decision to prepare this PEIS, the Secretary decided that a separate PEIS on DOE's proposal to modernize (reconfigure) the nuclear weapons complex will also be prepared. The reconfiguration of the nuclear weapons complex would affect DOE's program for environmental restoration and waste management because it would change the locations, volumes, and types of waste to be managed. The environmental restoration and waste management PEIS, therefore, will take into account, to the extent practical, the materials generated in the preparation of the NWC PEIS. Separate statements are being prepared, however, because the programs are driven by distinct missions, requirements, and schedules. If the PEIS on the NWC is not issued first, DOE will prepare a supplement to the Environmental Restoration and waste management PEIS, if appropriate.

PUBLIC SCOPING MEETINGS AND INVITATION TO COMMENT: DOE is committed to providing opportunities for the involvement of interested individuals and groups in this and other DOE planning activities.

DOE will conduct a series of public scoping meetings nationwide and invites all interested people to attend and to present oral comments concerning: (1) the scope of the PEIS, (2) the issues that should be addressed, and (3) the alternative integrated approaches to be analyzed in the PEIS. DOE also invites written comments.

Oral and written comments will be given equal consideration. Instructions for submitting written comments are given above. People desiring to speak at the public scoping meetings should submit their requests to do so to the contact persons to be designated in a subsequent Federal Register notice. Oral presentation requests for each meeting should be received by DOE at least two days before the meeting.

The meetings will be chaired by a presiding officer. They will not be conducted as evidentiary hearings. Speakers will not be cross-examined, although the DOE representatives present may ask them clarifying questions.

To ensure everyone an adequate opportunity to speak, five minutes will be allotted for each speaker. Depending on the number of persons requesting to speak, the presiding officer may allow more time for speakers representing multiple parties or organizations. Persons wishing to speak on behalf of organizations should identify the organization in their request. Persons who have not submitted a timely request to speak may register at the meetings, and will be called on to speak if time permits. Written comments also will be accepted at the meetings, and speakers are encouraged to provide written versions of their oral comments for the record.

The public scoping meetings will begin in December 1990. Detailed information on the meetings will be provided in a subsequent Federal Register notice. This information will also be announced in local public notices before the planned meetings.

DOE will make a transcript of each meeting. Copies will be made available for inspection at the DOE Freedom of Information Reading Room (Room 1E-190), Forrestal Building, 1000 Independence Avenue SW., Washington, DC 20585, during business hours, Monday through Friday and in local DOE reading rooms. Locations of local reading rooms will be provided in the subsequent Federal Register notice regarding the scoping meetings.

RELATED NEPA DOCUMENTATION: DOE expects to prepare additional NEPA documents for implementing programmatic and facility-specific decisions based upon this PEIS. These generally site-specific documents will analyze future technology and siting alternatives for implementing DOE's environmental restoration and waste management activities. Their analyses will address such local concerns as floodplains and wetlands, historic and archaeological sites, land use, and threatened and endangered species. The PEIS will examine these issues only to the degree necessary for selection of an integrated program.

Interim Actions. DOE may need to conduct many diverse and discrete site-

specific environmental restoration and waste management activities while the PEIS is being prepared. Many of these activities are required by Federal and state regulatory agencies under environmental compliance agreements and some are required by court decrees. DOE will have to determine case-by-case whether site-specific actions may proceed before the PEIS is completed. This will be done in accordance with all applicable requirements, including the test for interim actions found in Council on Environmental Quality's NEPA Regulations (40 CFR 1506.1(c)).

Other. DOE has prepared, or is currently preparing, NEPA documents for many of DOE's site-specific actions. Examples of some major relevant waste management NEPA documents are listed below:

1. Final Environmental Impact Statement, Disposal of Hanford Defense High-level, Transuranic and Tank Wastes, Hanford Site, Richland, Washington. DOE/EIS-0113, December 1987, U.S. Department of Energy, Washington, DC.

2. Final Environmental Impact Statement, Waste Management Activities for Groundwater Protection, Savannah River Plant, Aiken, South Carolina. DOE/EIS-0120, December 1987, U.S. Department of Energy, Washington, DC.

3. Final Supplemental Environmental Impact Statement, Waste Isolation Pilot Plant, DOE/EIS-0026-FS, January 1990, U.S. Department of Energy, Washington, DC.

4. Draft Environmental Impact Statement, Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington, DOE/EIS-0119d, March 1988, U.S. Department of Energy, Washington, DC.

These documents, the Five-Year Plan (DOE/S-0078P), transcripts from the public scoping meetings (when they become available), and other related documents will be available for inspection at DOE Freedom of Information Reading Rooms.

Issued in Washington, DC, this 15th day of October 1990.

Peter N. Brush,

Acting Assistant Secretary, Environment, Safety and Health.

Appendix: Locations of Activities Embraced by the PEIS

Name	Location
Amchitka Island	Amchitka Island, AK.
Lawrence Berkeley Laboratory	Berkeley, CA.
University of California	Berkeley, CA.
Atomics International	Canoga Park, CA.
Laboratory for Energy-Related Health Research	Davis, CA.
Sandia National Laboratory-Livermore	Livermore, CA.
Lawrence Livermore Laboratory	Livermore, CA.
Bare Canyon	Los Alamos, CA.
Stanford Linear Accelerator Center	Palo Alto, CA.
General Atomics	San Diego, CA.
Energy Technology Engineering Center	Santa Susana, CA.
General Electric Vallecitos Nuclear Center	Vallecitos, CA.
Rocky Flats Plant	Golden, CO.
Grand Junction Project Office	Grand Junction, CO.
Project Rulison Site	Grand Valley, CO.
Project Rioblanco Site	Rifle, CO.
Seymour Specialty Wire	Seymour, CT.
Pinellas Plant	St. Petersburg, FL.
Kauai Test Facility	Kauai, HI.
Ames Laboratory	Ames, IA.
Idaho National Engineering Laboratory	Idaho Falls, ID.
Argonne National Laboratory—West	Idaho Falls, ID.
Argonne National Laboratory—East	Chicago, IL.
National Guard Armory	Chicago, IL.
Palos Forest	Chicago, IL.
Fermi National Accelerator Laboratory	Batavia, IL.
University of Chicago	Chicago, IL.
Johnston Atoll	Johnston Atoll.
Paducah Gaseous Diffusion Plant	Paducah, KY
Ventron, Beverly	Beverly, MA.
Shpack Landfill	Norton, MA.
W.R. Grace & Co.	Curtis Bay, MD.
General Motors	Adrian, MI.
Hazelwood (Latty Avenue)	Hazelwood, MO.
Kansas City Plant	Kansas City, MO.
St. Louis Airport Storage Site	St. Louis, MO.
Mallinckrodt, Inc.	St. Louis, MO.
St. Louis Airport Storage Site Vicinity Properties	St. Louis, MO.
Weldon Spring Site Remedial Action Project	St. Charles, MO.
Tatum Dome	Tatum Dome, MS.
Component Development & Integration Facility	Butte, MT
Hallam Nuclear Power Facility	Lincoln, NE.
Du Pont & Company	Deepwater, NJ.
Kellex/Pierpont	Jersey City, NJ.
Maywood	Maywood, NJ.
Middlesex Landfill	Middlesex, NJ.
Middlesex Sampling Plant	Middlesex, NJ.
New Brunswick Laboratory	New Brunswick, NJ.
Princeton Plasma Physics Laboratory	Princeton, NJ.
Wayne/Pequannock	Wayne/Pequannock, NJ.
Inhalation Toxicology Research Institute	Albuquerque, NM.
Sandia National Laboratory—Albuquerque	Albuquerque, NM.
Ross Aviation	Albuquerque, NM.
Project GNOME Site	Carlsbad, NM.
Waste Isolation Pilot Plant	Carlsbad, NM.
Project GASBUGGY Site	Farmington, NM.
Los Alamos National Laboratory	Los Alamos, NM.
Acid/Pueblo Canyon	Los Alamos, NM.
Chupadera Mesa	White Sands Missile Range, NM.
Central Nevada Test Area	Central Nevada Test Area, NV.
Project Shoal Site	Fallon, NV.
Nevada Test Site	Las Vegas, NV
Tonopah Test Range	Nellis Air Force Base, NV.
Colonie	Colonie, NY.
Niagara Falls Storage Site Vicinity Properties	Lewiston, NY
Niagara Falls Storage Site	Niagara Falls, NY
Ashland Oil Co. #2	Tonawanda, NY
Linde Air Products	Tonawanda, NY.
Seaway Industrial Park	Tonawanda, NY.
Ashland Oil Co. #1	Tonawanda, NY.
Brookhaven National Laboratory	Upton, Long Island, NY.
West Valley Demonstration Project	West Valley, NY.
Reactive Metals Inc.	Ashtabula, OH.
Battelle Columbus Laboratories	Columbus, OH.
Feed Materials Production Center	Fernald, OH.
Mound Laboratory	Miamisburg, OH.
Piqua Nuclear Power Facility	Piqua, OH.
Portsmouth Gaseous Diffusion Plant	Portsmouth, OH.
Albany Metallurgical Research Center	Albany, OR.
Universal Cyclops	Aliquippa, PA.
Center for Energy and Environmental Research	Mayaguez, PR.
Savannah River Site	Aiken, SC.
Oak Ridge National Laboratory	Oak Ridge, TN.
Oak Ridge Gaseous Diffusion Plant	Oak Ridge, TN.
Y-12 Plant	Oak Ridge, TN.
Pantex Plant	Amarillo, TX.
Hanford Reservation	Richland, WA.
24 Site Covered under Title I of the Uranium Mill Tailings Radiation Control Act	Various Locations.

Attachment 2
(to WM PEIS Appendix A)

Federal Register Notice
(Volume 60, Number 15, Tuesday January 24, 1995)
[60 FR 4607]

Department of Energy
"Environmental Restoration and Waste Management; Programmatic Environmental Impact Statement"

Federal Register / Vol. 60, No. 15 / Tuesday, January 24, 1995 / Notices 4607

DEPARTMENT OF ENERGY

Environmental Restoration and Waste Management; Programmatic Environmental Impact Statement

AGENCY: U.S. Department of Energy.

ACTION: Notice of opportunity for public comment.

SUMMARY: The Department of Energy is giving the public the opportunity to comment on proposed modifications to the title and scope of the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement. The Department proposes to modify the scope and name of the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement (PEIS). The proposed action would focus primarily on the evaluation and analysis of waste management issues confronting the Department and would be renamed the Waste Management Programmatic Environmental Impact Statement.

DATES: To ensure that the public's concerns and views are fully considered, DOE is providing a 45-day written comment period that will extend until March 10, 1995, to comment on the proposed modification to the Programmatic Environmental Impact Statement.

ADDRESSES AND FURTHER INFORMATION: Written comments and requests for further information on the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement should be directed to: James A. Turi, Office of Waste Management (EM-33), U.S.

Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585–0002, (301) 903–7147. For information on the Department's National Environmental Policy Act process, contact: Carol M. Borgstrom, Director, Office of NEPA Oversight (EH–25), U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585, (202) 586–4600 or leave a message at 1–800–472–2756.

SUPPLEMENTARY INFORMATION: On October 22, 1990, the Department of Energy issued a Notice of Intent to prepare the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement (PEIS) (55 FR 42633). In the Notice of Intent and in an Implementation Plan issued in January 1994, the Department identified the proposed action as follows: "to formulate and implement an integrated environmental restoration and waste management program in a safe and environmentally sound manner and in compliance with applicable laws, regulations and standards." The Notice of Intent and the Implementation Plan identified two separate sets of alternatives to be evaluated, for environmental restoration and for waste management.

The Department attempted to meaningfully analyze the environmental restoration alternatives that it originally defined as part of the "proposed action." After considerable effort, the Department has concluded that it would not be appropriate to make programmatic decisions regarding cleanup strategies that would be applicable to all of the Department's sites. The fundamental reasoning behind the Department's conclusion is that cleanup decisions should reflect site-specific conditions, and, in any event, can only be reached with the approval of state and federal regulators and the involvement of the public. It would be inconsistent with the site-specific nature of cleanup decisions, therefore, to make these decisions under this PEIS that would be implemented nationwide.

Accordingly, the Department proposes to eliminate the analysis of environmental restoration alternatives and to modify the proposed action. As modified, the PEIS would consider how to manage the subject wastes and analyze alternative sites at which the wastes could be managed in the future. The PEIS would focus its programmatic evaluations on waste management facilities, and would henceforth be known as the "Waste Management Programmatic Environmental Impact Statement." As previously set forth in the Implementation Plan, the PEIS would evaluate decentralized regional, and centralized approaches for storage of high-level waste; treatment and storage of transuranic waste; treatment and disposal of low-level and low level mixed waste; and treatment of hazardous waste. Waste generated by restoration activities in the future that must be managed as part of the Department's program to manage all of its wastes would be considered in the PEIS's projected waste inventories. The draft PEIS is currently scheduled for publication in late spring of 1995.

In the October 22, 1990, Notice of Intent in the **Federal Register**, the Department of Energy discussed the preparation of a Programmatic Environmental Impact Statement based on formulating and implementing an integrated environmental restoration and waste management program in a safe and environmentally sound manner and in compliance with applicable requirements. The Notice of Intent stated that the purpose of the integrated environmental restoration and waste management program was to provide a broad, systematic approach to addressing site cleanup and waste management. Although the proposed action was defined in terms of integrating environmental restoration and waste management, the description of the alternatives in the Implementation Plan set forth separate sets of alternatives for environmental restoration and waste management.

When the Department published the Notice of Intent in 1990, there were important national issues regarding the direction of its environmental restoration program that could be meaningfully evaluated in the PEIS. These issues focused primarily on the level and extent of cleanup of the Department's facilities. The Department continues to believe that cleanup of its sites involves important issues such as land use, public health, worker risks, and cleanup standards. The Department has concluded, however, that programmatic decisions regarding environmental restoration cannot be made because these decisions should reflect the particular conditions at each site, and require the approval of state regulators and the involvement of stakeholders. The Department believes that the proposed action originally considered in the PEIS should be modified by eliminating the analysis of environmental restoration alternatives. In view of this modification the PEIS would be renamed the "Waste Management Programmatic Environmental Impact Statement."

The modified proposed action would focus on the evaluation and analysis of waste management issues confronting the Department and would incorporate potential impacts of environmental restoration on the management of wastes. The Department believes the proposed action as modified will identify and analyze waste management issues and activities for which the Department is responsible. A summary of the comments received in response to this notice will be contained in an appendix to the draft Waste Management Programmatic Environmental Impact Statement. Comments previously received during the public comment process on the scope of the PEIS that are still relevant in light of the proposed modification to the PEIS, and the issues raised by such comments, would be evaluated as discussed in the Implementation Plan. Comments on the scope of the PEIS that are relevant to other analyses being conducted in connection with site-specific environmental restoration at DOE's sites will be considered in the preparation of those analyses.

Issued in Washington, D.C., on January 18, 1995.

Thomas P. Grumbly,

Assistant Secretary for Environmental Management.

[FR Doc. 95–1754 Filed 1–23–95; 8:45 am]

BILLING CODE 6450–01–P

Attachment 3
(to WM PEIS Appendix A)

Federal Register Notice
(Volume 60, Thursday March 16, 1995)
[60 FR 14275]

Department of Energy
"Extension of Public Comment Period for The Environmental Management Programmatic Environmental Impact Statement"

[6450-01-P]

DEPARTMENT OF ENERGY

Extension of Public Comment Period for the Environmental Management Programmatic Environmental Impact Statement

AGENCY: U.S. Department of Energy

ACTION: Extension of public comment period.

SUMMARY: On October 22, 1990, the Department of Energy issued a Notice of Intent to prepare the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement (PEIS). (55 FR 42633). In the Notice of Intent and in an Implementation Plan issued in January 1994, the Department identified the proposed action as follows: "to formulate and implement an integrated environmental restoration and waste management program in a safe and environmentally sound manner and in compliance with applicable laws, regulations and standards." A notice was issued on January 24, 1995, inviting the public to provide written comments on a proposed modification to the scope and name of the PEIS. (60 FR 4607). In the notice, the Department proposed to modify the proposed action to eliminate the analysis of environmental restoration alternatives. As modified, the PEIS would consider how to manage certain types of radioactive and hazardous waste, and analyze alternative sites at which the wastes could be managed in the future. The PEIS would focus its programmatic evaluations on waste management facilities, and would henceforth be known as the "Waste Management Programmatic Environmental Impact Statement."

INVITATION TO COMMENT: In response to a request from the public, the Department is extending for 30 days, until April 10, 1995, the written comment period for the proposed modification to the Programmatic Environmental Impact Statement. A summary of the comments received in response to this notice will be contained in an appendix to the draft Waste Management Programmatic Environmental Impact Statement.

ADDRESSES AND FURTHER INFORMATION: Written comments and requests for further information on the Programmatic Environmental Impact Statement should be directed to: James A. Turi, Office of Waste Management (EM-33), U.S. Department of Energy, 1000 Independence Avenue, S.W., Washington, DC 20585-0002, (301) 903-7147. For information on the Department's National Environmental Policy Act process, contact: Carol M. Borgstrom, Director, Office of NEPA Policy and Assistance (EH-42), U.S. Department of Energy, 1000 Independence Avenue, S.W., Washington, DC 20585, (202) 586-4600 or leave a message at 1-800-472-2756.

Issued in Washington, D.C., this 10th day of March 1995.

Thomas P. Grumbly
Assistant Secretary for Environmental Management

Attachment 4
(to WM PEIS Appendix A)

Natural Resources Defense Council's (NRDC's) Comments on the Department of Energy's (DOE's) Proposed Modification in Scope of the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement (Letter: Andrew P. Caputo [NRDC] to James A. Turi [DOE], April 10, 1995)

Natural Resources Defense Council

1350 New York Ave., N.W.
Washington, DC 20005
202 783-7800
Fax 202 783-5917

April 10, 1995

James A. Turi
Office of Waste Management (EM-33)
U.S. Department of Energy
1000 Independence Avenue SW
Washington, D.C. 20585-0002

Dear Mr. Turi:

The Natural Resources Defense Council ("NRDC"), lead plaintiff in NRDC v. Watkins, Civ. No. 89-1835-SS (D.D.C.) (stipulation filed Oct. 22, 1990), files the following comments on the Department of Energy's proposed modification in scope of the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement. Notice of the proposed modification was published in the Federal Register at 60 Fed. Reg. 4,607 (Jan. 24, 1995), and the comment period was extended to today pursuant to a notice published at 60 Fed. Reg. 14,275 (March 16, 1995).

NRDC opposes the proposed modification for both legal and policy reasons. As a legal matter, the National Environmental Policy Act ("NEPA") requires the Energy Department to prepare a programmatic environmental impact statement ("EIS") on its program of environmental restoration activities, for all of the reasons explained in the submissions by NRDC leading up to and during the above-cited litigation. Moreover, during this litigation the Department specifically conceded that its program of environmental restoration and waste management constitutes "'a group of concerted actions' within the meaning of NEPA,"[1] which triggers a duty to prepare a programmatic EIS pursuant to 40 C.F.R. § 1508.18(b)(3). Finally, the Department committed to prepare such a document in the course of the NRDC v. Watkins litigation.

The case for a programmatic EIS on the environmental restoration program is just as strong from a policy perspective as it is from a legal perspective. While it is certainly true that "cleanup decisions should reflect site-specific conditions," 60 Fed. Reg. at 4,608, it is

1. Memorandum from James D. Watkins, Secretary, DOE, to Leo P. Duffy, Director, Office of Environmental Restoration and Waste Management, DOE, Jan. 12, 1990.

A4-

100% Recycled Paper

40 West 20th Street
New York, New York 10011
212 727-2700
Fax 212 727-1773

71 Stevenson Street
San Francisco, CA 94105
415 777-0220
Fax 415 495-5996

6310 San Vicente Blvd., Suite 250
Los Angeles, CA 90048
213 934-6900
Fax 213 934-1210

equally true that there are a number of important program-level issues relating to the environmental restoration program that demand a full, prospective, program-level analysis with full public participation. These issues include the scope and pace of the environmental restoration program in light of budgetary and other constraints; the choice between using uniform cleanup standards or site-specific cleanup standards as part of the program; the programmatic implications of using land-use restrictions in setting cleanup levels; issues of inter- and intra-facility priority setting, particularly in a situation of budget scarcity; and the programmatic role of site-specific advisory boards and other avenues for public participation in making cleanup decisions. A programmatic analysis of these and other important issues in the environmental restoration program has become even more important in recent months and years, in light of such developments as departmental discussions concerning land-use considerations in the cleanup process, the findings of the Baseline Environmental Management Report, and budget developments.

The need for a program-level analysis of the environmental restoration program is enhanced by the fact that the Department, as a matter of policy, does not perform NEPA compliance on site-specific environmental restoration actions taken pursuant to the Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA"). Thus, a program-level EIS seems the only NEPA analysis available to citizens on many of the important issues facing the environmental restoration program. Moreover, no alternative to the NEPA process currently exists for analyzing these issues in a programmatic, prospective manner with full public participation.

Sincerely,

Andrew Caputo

Andrew P. Caputo
Attorney

cc: Assistant Secretary Thomas P. Grumbly

Appendix B

Environmental Restoration Sensitivity Analysis

U.S. Department of Energy
Waste Management Programmatic Environmental Impact Statement

August 1995

Contents

Appendix B Environmental Restoration Sensitivity Analysis B-1
B.1 Introduction B-1
B.2 DOE Environmental Restoration Program B-1
B.3 Remedial Waste Estimation Methodology B-3
B.3.1 Source of Environmental Restoration Data B-3
B.3.2 The Effect on Waste Volumes of Varying Cleanup Goals B-4
B.3.3 Estimating the Volume of Waste B-5
B.4 Assumptions B-5
B.5 Environmental Restoration-Generated Waste Loads B-6
Appendix B References B-9

Tables

Table B.3–1. PEIS Environmental Restoration Sensitivity Analysis Methodology B-4
Table B.3–2. Summary of Estimated Environmental Restoration-Generated Waste Volumes (Cubic Meters) B-4
Table B.4–1. Assumptions Affecting Environmental Restoration-Generated Waste Loads B-6
Table B.4–2. Waste Stream Assumptions for the Environmental Restoration Sensitivity Analysis . . B-7
Table B.5–1. Current Program Environmental Restoration-Generated Waste Volumes to Waste Management B-8

APPENDIX B
Environmental Restoration Sensitivity Analysis

B.1 Introduction

This appendix provides the Department of Energy (DOE) estimate of waste to be generated by environmental restoration activities throughout the DOE which will require treatment and disposal within the waste management complex. In addition, the appendix presents the methodology used to determine if the addition of the estimated environmental restoration-generated waste loads would effect DOE waste management decisions.

The purpose of the environmental restoration sensitivity study is to identify those alternatives (if any) that are particularly sensitive to the addition of environmental restoration activities and wastes, and to specifically address two questions:

- Will feasible alternatives for waste management become less desirable when environmental restoration-generated wastes are added?

- Does the addition of environmental restoration-generated waste to the planned waste management waste volume increase any impact to an unacceptable level?

B.2 DOE Environmental Restoration Program

A legacy of the Nuclear Weapons Program is environmental contamination at the sites where research, development, test, and production of nuclear weapons took place. The volumes of contaminated media at some locations are quite large. The Environmental Restoration Program was established to address this problem. It encompasses a wide range of activities such as stabilizing contaminated soil, treating groundwater, decommissioning process buildings, including nuclear reactors and chemical separations plants, and exhuming buried drums of waste. The extent to which a site is "cleaned up" will depend largely on assumptions regarding future land use. For most sites, the process of determining future site use has just begun.

The general process to reach decisions concerning cleanup actions is laid out by statutes, including the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC 9601 *et seq*). The process is generally implemented at specific sites through agreements among DOE, the Environmental Protection Agency (EPA), and frequently the host state. The process can be described as follows:

First, a site or portion of a site is "characterized" to identify contaminants, determine the extent of contamination, and assess potential threats to public health and the environment. If significant contamination is indicated, and limited action will result in mitigation of risk, an expedited response action or interim action may be conducted as a means to quickly address the problem. Upon completion of characterization, a detailed analysis is performed to quantify risk and evaluate remedial alternatives. The analysis is followed by a formal decision process including public hearings and formal comment period.

If the results of the analysis indicate that a potential release site is not a threat to health and the environment or that an interim action adequately remediated the contamination, a recommendation of no further action is made to the regulators. If, however, a threat is deemed to be present, the appropriate remediation is identified, and a recommendation is submitted for formal approval. In either case, DOE makes a recommendation on what action is to be taken. The decision on what action will be taken is made by the regulator, not DOE.

During each stage of the environmental restoration process from characterization to final remedial decisions, the potential exists for contaminated media to be generated. The projected volumes of contaminated media to be managed from environmental restoration activities were analyzed by each DOE site during development of the Baseline Environmental Management Report (BEMR) (DOE, 1995). These analyses included consideration of DOE treatment, storage, and disposal capabilities, existing or planned, project-specific restoration requirements, and negotiations with state and federal regulatory authorities in order to estimate what portion of the contaminated media would need treatment, storage, and disposal as a waste within the DOE waste management program. The resulting estimates of these portions of waste are contained in the BEMR as described in Section B.3.

DOE has identified over 11,000 contaminated sites across the complex (PNL, 1995). Contamination at these sites ranges from small areas contaminated from leaking underground storage tanks to large burial pits. A

complete discussion of the environmental restoration program is in the DOE Pamphlet entitled "Committed to Results: DOE's Environmental Management Program" (DOE, 1994).

B.3 Remedial Waste Estimation Methodology

DOE has commissioned several major studies to prepare projections of environmental restoration-generated wastes and their potential impacts. For the WM PEIS analysis the DOE used waste generation data from the BEMR. The process used to develop environmental restoration waste projections had three major steps: Step 1—estimate the volume of remedial derived waste from each installation, Step 2—define each remedial derived waste stream according to what treatment and disposal would be necessary by the waste management system, and Step 3—adjust the potential volumes according to available DOE installation, field office, and local plans for future land use. The environmental restoration-generated waste volumes that are expected to be provided to waste management do not appear explicitly in the published volumes of the BEMR but were provided from internal BEMR working documents in February 1995.

Table B.3-1 provides the steps used in the WM PEIS analysis for the environmental restoration sensitivity analysis and waste type analysis. In general, the process involves preparing reasonable estimates of the volumes ("loads") of environmental restoration-generated waste that may be handled by waste management, comparing the projected environmental restoration-generated waste volumes with the estimated waste management volumes for each waste type, and then drawing qualitative inferences as to the effect the additional impact might have on a selected waste management alternative. Each waste type chapter presents tables showing the relative percentage increases. Based on this information, conclusions can be drawn for the probable impact of the added environmental restoration-generated waste. This is a study of the *sensitivity* of waste management decisions to the imposition of environmental restoration-generated wastes and not intended to be an absolute statement of the potential impacts from managing these environmental restoration-generated wastes.

B.3.1 Source of Environmental Restoration Data

The amount, schedule, and degree of remedial action will be determined by local decisions within the context of applicable laws and regulations which will define the specific sources, types, and schedules for

Table B.3-1. PEIS Environmental Restoration Sensitivity Analysis Methodology

In Each Waste Type Chapter in the WM PEIS	
Step 1	Select waste management alternatives to represent two bounding cases and one mid-range case for each waste type.
Step 2	Compare the projected environmental restoration-generated wastes as a percentage of the waste management legacy and production wastes for each selected waste management alternative, for each DOE site.
Step 3	Draw conclusions assessing potential of waste management impacts that result from the change in volume due to environmental restoration-generated waste volumes.

environmental restoration waste generation. However, these decisions will occur over an extended time frame as these are made on a site-by-site basis. Secondary environmental restoration-generated wastes were estimated based on a rigorous "bottom up" examination of about 3,500 individual release sites, the DOE site projections based on the current program, and on existing land use agreements.

Table B.3-2 shows the total volume of contaminated wastes expected to be generated by environmental restoration activities. These wastes often require no further treatment before disposal. Some of the remedial actions require treatment and replacement of the contaminated medium (soil, water, debris) within the cleanup unit. In these instances, the contaminated material and its impacts are included as part of the CERCLA action. Because of this approach, these types of remedial actions will produce no wastes requiring treatment and disposal.

Table B.3-2. Summary of Estimated Environmental Restoration-Generated Waste Volumes (Cubic Meters)

	LLMW	LLW	TRUW	HW
Treatment & Disposal	70,266	267,551	1,420	183,188
Disposal Only	120,891	531,599	21,336	64,728
Total	191,157	799,150	22,756	247,916

B.3.2 The Effect on Waste Volumes of Varying Cleanup Goals

The amount of waste, consequent costs, and risks, from individual remedial actions is a direct function of the cleanup goal set for that site. Restoring a site to its original pristine condition will probably generate

the greatest volume of waste. Retaining complete restriction and control over the release site by containing any further spread of contamination will generate the smallest amounts of secondary wastes. An intermediate cleanup goal allowing partial use of the property (e.g., an industrial area) will likely generate environmental restoration waste volumes that fall between the two extremes.

In preparing the WM PEIS, the DOE recognized that cleanup activities are influenced by a combination of the various national and local laws and the desires of local stakeholders on the preferred use of the DOE sites after remediation. Therefore, for each release site, the land use was projected that resulted from probable cleanup goals. The final accumulation and tabulation of waste loads reflects the likelihood that for any given DOE installation, the land uses may be a mixture of the various cleanup levels.

B.3.3 Estimating the Volume of Waste

DOE developed a computer model, the Automated Remedial Action Methodology (ARAM) to examine thousands of release sites. Based on actual release site source term data and on analysis at the sub-release site level, the model estimates waste loads and impacts. To develop environmental restoration-generated waste volume projections for the BEMR, the DOE combined individual DOE site projections based upon the current program with ARAM outputs for releases sites and D&D facilities not yet within the environmental restoration program.

B.4 Assumptions

The scope of this estimate does not include remediation of contamination problems where application of existing technologies would be prohibitively expensive or where their use would cause intolerable ecological damage. Some of the problems facing the Department do not yet have technological solutions. Areas of the Nevada Test Site, where the Department conducted above and below-ground nuclear weapons tests, would be prohibitively expensive to remediate using existing technologies. Remediation of major river systems, such as the mercury contaminated sediments in Tennessee's Clinch River, would cause significant ecological damage because of the necessity to divert river flow to accomplish remediation. Waste loads for these types of environmental problems were not determined for this estimate.

Table B.4–1 summarizes the principal assumptions that form the basis for these projections. This is not an exhaustive list but does provide a general understanding of the underlying assumptions which were used to estimate the environmental restoration-generated waste loads.

Table B.4–1. Assumptions Affecting Environmental Restoration-Generated Waste Loads

- No allowance is made for massive sites, for which no feasible remedial technology is available. (Examples, nuclear test sites, major contaminated aquifers.)
- Some Pre-1970 buried TRUW is excluded if no feasible technology exists for retrieval, (Primarily at SRS). Other pre-1970 TRUW is included (INEL is a major contributor).
- The level, the schedule, and the degree of remedial action are by local decision in the context of regulations and local laws.
- Volume of waste generated is dependent upon the expected land use.
- DOE sites may be geographically divided into separate areas with specific land uses assigned to each.
- Existing land use planning assumptions at a site will be used for the baseline land use.
- Hazardous waste is treated and disposed at commercial facilities to the maximum extent possible.
- Waste from transition of facilities from production to remediation is included in these waste loads.

Table B.4–2 summarizes key assumptions associated with the environmental restoration-generated waste stream characteristics and those that were necessary to conduct efficiently the sensitivity analysis.

B.5 Environmental Restoration-Generated Waste Loads

Table B.5–1 provides a summary of the environmental restoration-generated wastes by waste type that are projected to be generated by environmental restoration activities which would require treatment and/or disposal within the waste management system. Some of the wastes generated by environmental restoration remedial activities are actually stabilized and ready for onsite disposal or for transportation and disposal offsite. These wastes are shown as "dispose" in the waste load tables.

Table B.4–2. Waste Stream Assumptions for the Environmental Restoration Sensitivity Analysis

- LLMW from environmental restoration are all non-alpha.
- Remedial derived TRUW from environmental restoration are all contact handled.
- Treatment for environmental restoration wastes results in disposal volumes at ratio of 1 m^3 yields 1 m^3.
- The relative constituents and treatability categories are assumed to not vary as the amount of environmental restoration-generated waste increases at any location.
- Environmental restoration wastes are assumed to fall into the same treatability groups as the waste management waste of each type and, therefore, can be processed in waste management treatment plants.
- Environmental restoration wastes are assumed to be transported to the same sites as waste management waste for treatment and/or disposal.
- Except where noted, environmental restoration-generated wastes follow the same treatment or disposal configuration as waste management.
- Excess waste management plant capacity can be used for environmental restoration wastes; after planned 10 year production period, 20 years of operational capacity are available to treat environmental restoration wastes without significant additional construction impacts.
- Disposal of environmental restoration wastes requires an equivalent area for disposal as waste management waste.
- Generation of environmental restoration wastes will occur primarily over the thirty-year period from 2003 to 2033.

Table B.5–1. Current Program Environmental Restoration-Generated Waste Volumes to Waste Management

Installation	LLMW		LLW		TRUW		HW	
	Environmental Restoration Waste Load (m^3)		Environmental Restoration Waste Load (m^3)		Environmental Restoration Waste Load (m^3)		Environmental Restoration Waste Load (m^3)	
	Treatment	Disposal	Treatment	Disposal	Treatment	Disposal	Treatment	Disposal
ANL-E		138		2,918				
ANL-W (1)								
BCL		25				71		
BNL		29,250		35,730				
ETEC								
FEMP				86,579				
GA		550		1,740				
GE						20		
GJPO				1				
Hanford								
INEL (1)	15	6,819	1,621	18,333		21,082	229	654
K-25 (1)								
LANL								
LBL		40		42,490				49,752
LEHR		35		892				
LLNL (1)								
Mound				285,236				
NTS				6,030				1
ORNL (1)								
ORR (1)	24,704	24,704	185,518	185,518	1,364	1,364	164,742	164,742
Paducah								
Pantex								
Ports								
RFETS	33,241	115,722	76,210	113,579	56	56		12,878
RMI		5		4,648				
SNL-NM (1)			4,171	15,426				
SRS	12,305	13,869	30	30		163	18,216	19,888
WIPP								
WVDP								
Y-12 (1)								
Total	**70,266**	**191,157**	**267,551**	**799,150**	**1,420**	**22,756**	**183,188**	**247,916**

Note: Amounts for disposal include amounts for treatment.

References

42 USC 9601 *et seq*. Comprehensive Environmental Response, Compensation, and Liability Act of 1980, As Amended by the Superfund and Reauthorization Act of 1986.

DOE. *See* U.S. Department of Energy.

Pacific Northwest Laboratories. 1995. *Description of Source Term Data on Contaminated Sites and Buildings Compiled for the Waste Management Programmatic Environmental Impact Statement (Waste Management PEIS)* by S.M. Short, D.E. Smith, J.G. Hill, and M.E. Lerchen. PNL-10450, AD-940. September Draft. Richland, Washington.

PNL. *See* Pacific Northwest Laboratories.

U.S. Department of Energy. April 1994. *Committed to Results: DOE's Environmental Management Program.* DOE/EM-0152P. April. Washington, DC: Office of Environmental Restoration and Waste Management.

U.S. Department of Energy. 1995. *Estimating the Cold War Mortgage: The 1995 Baseline Environmental Management Report, Volume I and Volume II.* DOE/EM-0232. March. Washington, DC: Office of Environmental Management.

Appendix C

Environmental Impacts Analysis Methods

U.S. Department of Energy
Waste Management Programmatic Environmental Impact Statement

August 1995

Contents

C.1	PEIS Environmental Impacts Analysis Approach	C-1
C.2	Phase I: Engineering Analysis using a Generic Design	C-3
C.2.1	Waste Loads	C-3
C.2.2	WM Technologies	C-5
C.2.3	WM Facilities	C-6
C.2.4	Alternatives	C-7
C.2.5	Transportation	C-8
C.3	Phase II: Engineering Analysis Outputs	C-10
C.3.1	Resource Use	C-11
C.3.1.1	Modular Estimating Approach	C-11
C.3.1.1.1	Construction Resource Use	C-11
C.3.1.2.2	Operations Socioeconomic Resource Use	C-15
C.3.1.3	Resources Associated With Portable Modules	C-20
C.3.1.4	Resource Data Estimate Methodologies for the PEIS Alternatives	C-21
C.3.2	Cost Estimating	C-21
C.3.2.1	Cost-Estimating Process Details	C-21
C.3.2.1.1	Waste Management Facility Cost Information Reports	C-22
C.3.2.1.2	Modular Estimating Approach	C-23
C.3.2.1.3	Cost-Estimating Basis	C-25
C.3.2.1.4	Cost Components	C-25
C.3.2.1.5	Cost Estimates Development	C-26
C.3.2.2	PEIS Cost-Estimating Methodology	C-27
C.3.2.2.1	Description of Alternatives	C-27
C.3.2.2.2	Waste Loads Development	C-27
C.3.2.2.3	Existing Facilities Assessment	C-28
C.3.2.2.4	Bounding Parameters and Assumptions	C-28
C.3.2.2.5	Application of the Waste Management Facility Cost Information Methodology	C-30
C.3.2.2.6	Transportation Cost Estimates	C-33
C.3.2.2.7	Quality Assurance	C-34
C.3.2.2.8	Cost-Estimating Procedures for High-Level Waste Canister Storage and Transportation	C-34
C.3.2.2.9	Transportation of Vitrified HLW Canisters	C-37
C.4	Phase III: Environmental Impacts Evaluation	C-38
C.4.1	Human Health Impacts	C-41
C.4.2	Air Quality Impacts	C-41
C.4.2.1	Air Quality Impacts Analysis Methods	C-41
C.4.2.1.1	Air Pollutants Considered	C-42

C.4.2.1.2 Air Quality Impacts Analysis Procedures C-43
C.4.2.1.3 Air Quality Impacts Evaluation C-51
C.4.3 Water Resources Impacts Analysis Methods C-56
C.4.3.1 Introduction C-56
C.4.3.2 Regulatory Considerations C-57
C.4.3.3 Assumptions C-59
C.4.3.4 Impacts Considered But Not Evaluated in Detail C-61
C.4.3.5 Impact Assessment Methods for Water Resources C-65
C.4.4 Ecological Impacts Analysis Methods C-72
C.4.4.1 Routine WM Activity Impacts C-73
C.4.4.1.1 Direct Nonsensitive Habitat Impacts C-73
C.4.4.1.2 Indirect Sensitive Habitat Impacts C-74
C.4.4.1.3 Potential Toxicity to Terrestrial Wildlife C-76
C.4.4.1.4 Potential Impacts to Sensitive Species C-78
C.4.4.2 Impacts of Accidental Releases C-78
C.4.5 Economic Impacts Analysis Methods C-81
C.4.5.1 Focus of the Economic Impact Assessment C-81
C.4.5.2 Quantitative Effects C-82
C.4.5.3 Impacts Analysis Procedures C-95
C.4.5.3.1 Development of Regional Multipliers C-95
C.4.5.3.2 Analysis Assumptions C-98
C.4.5.3.3 Multiplier Analysis C-98
C.4.5.3.4 Limitations of the Multiplier Analysis C-103
C.4.5.3.5 Analysis Data C-103
C.4.5.3.6 Evaluation Techniques C-104
C.4.5.3.7 Presentation of Results C-104
C.4.6 Population Impacts C-104
C.4.6.1 Regions of Influence C-105
C.4.6.1.1 Potential Impacts of WM Project Labor Requirements C-105
C.4.6.1.2 Method of Population Analysis C-107
C.4.7 Environmental Justice Impacts C-110
C.4.7.1 Environmental Justice Overview C-110
C.4.7.1.1 Studies Supporting Environmental Justice Concerns C-110
C.4.7.1.2 Issuance of the Executive Order on Environmental Justice C-111
C.4.7.1.3 Status of DOE Guidance on Environmental Justice C-113
C.4.7.2 Approach to PEIS Consideration of Environmental Justice Impacts C-114
C.4.7.2.1 Identification and Mapping of Minority and Low-Income Populations C-114
C.4.7.2.2 Review of High and Adverse Health Risks and Environmental Impacts C-116
C.4.8 Land Use Impacts C-116
C.4.9 Infrastructure Impacts Methodology C-117

C.4.9.1 Site Infrastructure Impacts C-118
C.4.9.2 Community Infrastructure Impacts C-119
C.4.9.3 Site and Community Infrastructure Baseline C-119
C.4.10 Cultural Resources Impacts C-120
C.4.10.1 Cultural Resources Considered C-121
C.4.10.1.1 Prehistoric and Historic Properties C-121
C.4.10.1.2 Native American Resources C-121
C.4.10.1.3 Paleontological Resources C-122
C.4.10.2 Cultural Resources Protection Procedures C-122
C.4.10.3 Consideration of Cultural Resources Impacts in the PEIS C-123
References C-125

Tables

Table C.2–1 Number of Alternatives Analyzed in the PEIS C-9
Table C.3–1 Facility Cost Modules Included in WMFCI Reports C-24
Table C.3–2 Assumed Relationship for the Four Transportation Cost Components C-38
Table C.4–1 WM Actions Analyzed for Environmental Impacts C-39
Table C.4–2 Impacts Evaluated for Air Quality C-44
Table C.4–3 Site Criteria Pollutant Attainment Designation C-52
Table C.4–4 Nonattainment Status Definitions C-53
Table C.4–5 PSD Increments for Criteria Pollutant Emissions in Attainment Areas C-53
Table C.4–6 General Conformity Rule de minimis Levels for Nonattainment Areas C-54
Table C.4–7 Impacts Evaluated in Detail for Water Resources C-67
Table C.4–8 Affected Environment Data for Water Resources[a] C-68
Table C.4–9 Water Quality Comparison Criteria[a] C-70
Table C.4–10 Ecological Resources Impacts Analyzed for the WM Alternatives C-74
Table C.4–11 Economic Impacts Analyzed for the WM Alternatives C-81
Table C.4–12 Baseline Employment Data C-85
Table C.4–13 Baseline Personal Income C-90
Table C.4–14 Duration in Years of WM Activity Phases Assumed for Waste Type Economic Analysis C-100
Table C.4–15 Wage Deductions Used in the Income Multiplier Analysis C-100
Table C.4–16 Grand Mean Multipliers C-101
Table C.4–17 Multipliers' Coefficient of Variance C-102
Table C.4–18 Percentage of Construction Workers Expected to in-Migrate to Each of the 17 Major DOE Sites C-109
Table C.4–19 Baseline Infrastructure Data for the 17 Major DOE Sites C-120

Figures

Figure C.1–1 PEIS Analytical Relationships. C-2

APPENDIX C
Environmental Impact Analysis Methods

The Waste Management Programmatic Environmental Impact Statement (WM PEIS) environmental impacts analysis was accomplished using an engineering analysis of generic designs for treatment, storage, and disposal facilities as required to manage each waste type at the sites and estimates of transportation requirements. Outputs from the engineering analysis were estimates of resource requirements, environmental discharges, and costs. These outputs were used as inputs to evaluate human health risks, air quality, water quality, ecological, economic, population, land use, and infrastructure impacts at the sites and in transportation corridors, and were the basis for discussions of environmental justice and cultural resources concerns.

C.1 PEIS Environmental Impacts Analysis Approach

The environmental impacts for the five waste types were evaluated using an analytical process consisting of three phases for the waste management alternatives. This three-phased approach was applied as applicable for each of the waste types at the 17 major DOE sites in the analysis of treatment, transportation, storage, and disposal activities. The three phases, as shown in Figure C.1-1, were: 1) a Generic Design Engineering Analysis Phase; 2) an Engineering Analysis Output Phase; and 3) an Environmental Impacts Analysis Phase.

The environmental resources for which detailed impacts analysis methods are presented in this appendix include:

- **Cost**
- **Air Quality**
- **Water Resources**
- **Ecological Resources**
- **Economic Resources**
- **Population Impacts**
- **Environmental Justice**
- **Land Use**
- **Infrastructure**
- **Cultural Resources**

Engineering Analysis using a Generic Design: In the first phase, DOE made assumptions regarding waste loads for the five waste types. These assumptions related to the volume of waste currently in inventory and anticipated from future operations of DOE facilities and to its physical (gaseous, liquid, solid), chemical, and radiological characteristics. DOE distributed these estimated waste loads among specified DOE sites according to the definitions of the waste management alternatives to determine how much waste would be handled at each site under each alternative. DOE also developed a generic design of the waste management processes and facilities and selected one technology option for purposes of analysis. The facilities considered and the technology chosen for each waste type, and the rationale for that selection, are described more fully in the waste-type chapters.

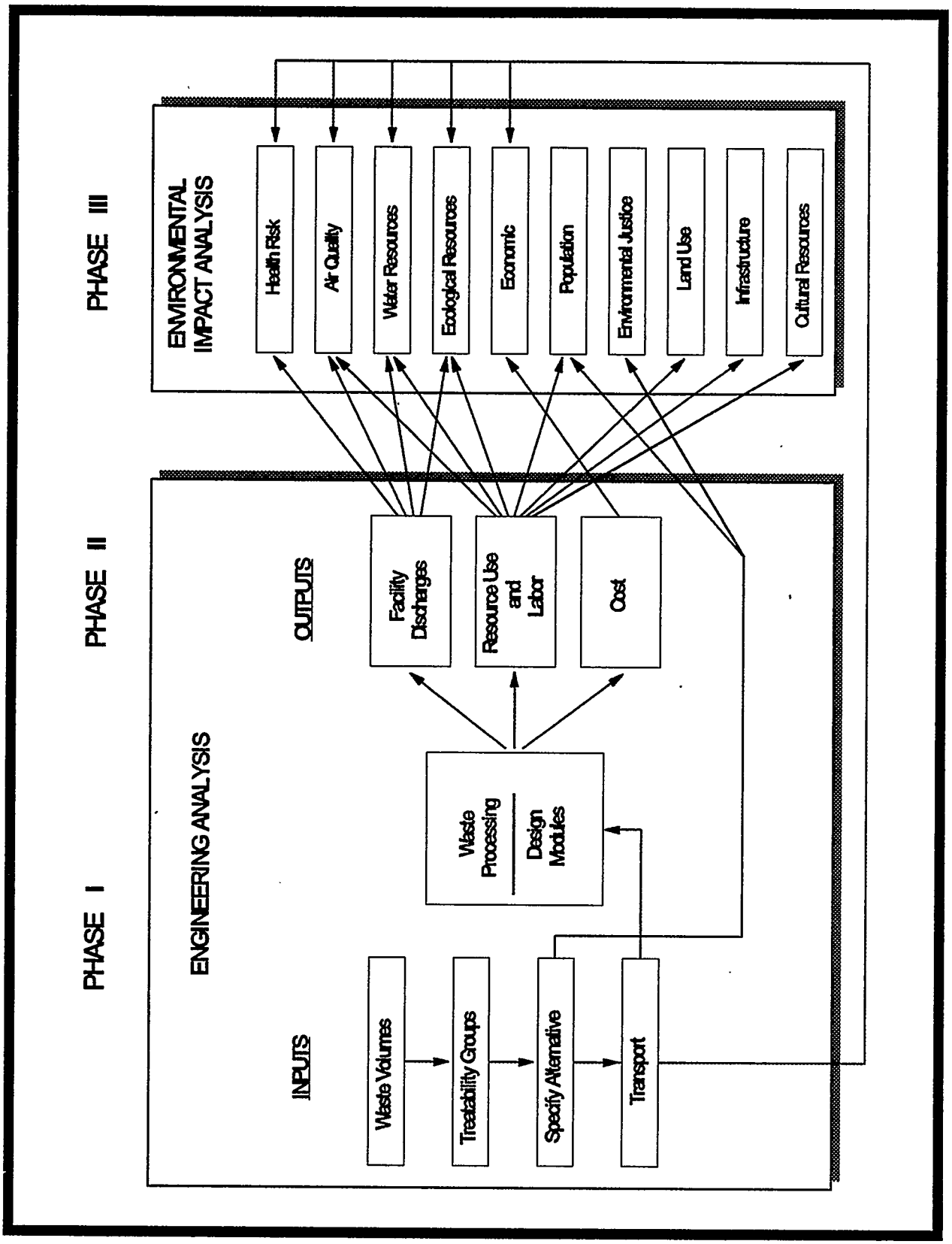


Figure C.1-1. PEIS Analytical Relationships

Engineering Analysis Outputs: In the second phase, the wasteloads allocated to each site under each alternative were generically "processed" through a mathematical model of the generic WM facility design, and estimates of outputs were obtained for the amounts and rates of radiological and chemical effluents released to the environment, volume and rates of resources required or consumed, numbers of full-time equivalent (FTE) workers required, and costs to build, operate, maintain, decontaminate and decommission the WM facilities.

Environmental Impact Evaluation: In the third phase, the effluents, resources, and costs became the input for evaluation of environmental and socioeconomic impacts, and human health risks.

C.2 Phase I: Engineering Analysis using a Generic Design

C.2.1 Waste Loads

Waste Volumes: The PEIS impact and cost analyses used DOE and Environmental Protection Agency (EPA) databases for waste inventories and generation rates. However, these databases are constantly upgraded and a cutoff date was established for the data to allow the analyses to proceed. Sources of data for each of the waste types are listed below:

- **Low-level mixed waste (LLMW)**—The Mixed Waste Inventory Report (DOE, 1994a) was used for all LLMW inventories and generation rates.

- **Low-level waste (LLW), non-mixed transuranic waste (TRUW), and high-level waste (HLW)**—The Integrated Data Base (DOE, 1992a) was used for generation rates and inventories of stored waste. The Waste Management Information System (DOE, 1992b) was consulted for data not available in the Integrated Data Base.

- **Mixed TRUW waste**—The Interim Mixed Waste Inventory Report (DOE, 1993a) was used for mixed TRUW inventories and generation rates.

- **Hazardous waste (HW)**—The EPA Information System biennial reports and DOE Site Inventory Reports were used for generation rates.

The waste loads analyzed in this PEIS do not include wastes that may be generated as a result of environmental restoration (ER) activities. The anticipated ER waste loads are described in the waste- type chapters (Chapters 6 to 10) on a site-by-site basis, and compared to the anticipated WM waste loads at those sites. It is not anticipated that HLW will be generated through ER activities. These chapters also contain a qualitative discussion of the extent to which ER waste loads could affect the conclusions regarding environmental impacts.

Treatability Groups: While this PEIS covers five waste types, those wastes are not homogenous and are derived from thousands of different waste streams. Thus, the wastes were combined into treatability groups for purposes of developing treatment system designs. Each treatability group is identified with one of the five waste types considered in the PEIS and a treatment method, where appropriate, that EPA recognizes as meeting the requirements of the Resource Conservation and Recovery Act (RCRA) (42 USC 6901 *et seq.*). For the PEIS analyses, the physical structure of the waste was used for the initial sort for treatability. At the most basic level of analysis, all waste can be grouped into six physical categories using common engineering criteria design parameters, which also served as the initial set of treatability categories:

- **Aqueous liquids**—Primarily water with organic content less than 1% (such as wastewater)

- **Organic liquids**—Liquids and slurries with organic content greater than 1% (such as solvents)

- **Organic and inorganic sludge and particulates**—Solid and semi-solid material other than debris (such as sludge from treatment plants, resins, and solids less than 2.5-inch diameter particle size)

- **Soils**—Contaminated soils (such as contaminated earth requiring remediation)

- **Debris**—Solid material exceeding 2.5-inch diameter particle size that is either (1) manufactured, or (2) plant or animal matter, or (3) discarded natural or geological material (such as cobblestones)

- **Other**—Special waste streams (such as batteries, laboratory packs, reactive metals, and toxic metals, which include mercury, lead, and beryllium)

Four waste types use this basic framework analysis: LLMW, LLW, TRUW, and HW. For purposes of the PEIS analysis, HLW, also in the above treatability categories, is assumed to have been treated (vitrified). The PEIS only addresses the environmental consequences of storing and transporting vitrified HLW.

Radiological and Chemical Composition: DOE used standard radiological profiles for each site and made assumptions about the concentration of contaminants in each treatability group based on available data. Hazardous constituents were apportioned to the treatability groups on the basis of the most prevalent hazardous chemicals using an average composition for all DOE sites. The assumptions for both radioactive and hazardous constituents are waste-type specific and are addressed in more detail in the waste-type chapters.

C.2.2 WM TECHNOLOGIES

Various technologies are used to sort and handle waste, reduce waste volume, destroy organic chemicals in waste, remove toxic metals from waste, treat hazardous characteristics to render them non-hazardous, recover and recycle materials, and stabilize and package waste for disposal. The facilities that use these technologies must be designed to accommodate the various physical and chemical forms and the radioactive and chemical characteristics discussed in previous sections. Existing, generic technologies necessary to meet the treatment, storage, and disposal requirements for each waste type were identified and sized to meet anticipated waste volume needs. For analytical purposes, and to facilitate utilization in any system at any site, the waste management technologies were grouped into **common functions** (front-end support such as administrative and laboratory services; receiving, inspecting, dumping, and sorting the waste; maintenance of facilities; and certification and shipping of the waste), **pre-treatment** (shredding and compaction), **primary treatment** (incineration, special processing, neutralization, deactivation, aqueous waste treatment, lead recovery, and mercury separation and recovery), **secondary treatment and stabilization** (polymer stabilization, grout stabilization, packaging, and vitrification of secondary processing residues), **storage** (administration, receiving and inspection, contact-handled

storage, and remote-handled silo storage), and **disposal** (administration, receiving and inspection, shallow land disposal, engineered vault disposal, silo disposal, and borehole disposal).

C.2.3 WM FACILITIES

Treatment, transportation, storage, and disposal "modules" were developed to represent every component required for waste management. Each module was assumed to contain several types of equipment, each able to perform a step needed in the waste management process.

Individual modules were linked together for each treatability group and were adjusted for the chemical and physical type of waste. This method was used so that impacts could be compared among sites, with each site assumed to be using the identical array of linked modules. Any variation in impacts would then result from site-specific environmental differences. This approach also allowed an examination of the changes in impacts resulting from changes in the linked modules.

Typically the type of facility considered was a building structure; i.e., a "fixed" facility at a given site. The analysis also considered the possible use of mobile treatment facilities that could be moved from site to site for treatment of the very small amounts of waste that exist at a number of the sites considered.

The generic design of the WM facility, consisting of these treatment, storage, transportation, and disposal modules, enabled the calculation of land utilization, worker-years, resource consumption (i.e., water and electricity), pollutant discharges, and costs for the treatment, storage, transportation, and disposal of each waste type. The engineering features of the generic facility and the waste loads "processed" through the generic facility formed the basis for the risk and environmental impacts analysis.

For purposes of analysis, the following assumptions were made regarding the construction and operation of the waste management facilities:

- The facilities were assumed to be built over a 10-year period and operated over a 10-year period to process accumulated inventories in a 20-year period.

- The facilities were assumed to operate 240 days per year with three 8-hour shifts.

- Except for HLW, a 20-year period of analysis is generally used for each waste type; the specific assumptions made for HLW are discussed in Chapter 9.

C.2.4 ALTERNATIVES

In the PEIS, an alternative identifies the configuration of sites for treating, storing, or disposing of a specific waste type. Depending on the waste type, certain of these activities may not be analyzed in this PEIS. The categories of alternatives analyzed in this PEIS for each waste type are a no action alternative, decentralized alternative, regionalized alternative, and centralized alternative. These alternatives are described below:

- **No Action Alternative:** These alternatives would involve using only currently existing or approved WM facilities at DOE sites or commercial venders.

- **Decentralized Alternative:** These alternatives would result in leaving waste at the site where it is currently stored or where it will be generated, treated, or disposed in the future. Unlike the no action alternatives, the decentralized alternatives may require the siting, construction, and operation of new facilities or the modification of existing facilities. Under the decentralized alternatives, the WM facilities would be located at a larger number of sites than under the regionalized or centralized alternatives.

- **Regionalized Alternatives:** These alternatives would result in transporting waste to various numbers of sites (fewer than the number of sites considered for the decentralized alternative, but greater than the number of sites considered for the centralized alternatives). Generally, those sites that now have the largest volumes of a given waste type were considered as regional sites for treatment, storage, or disposal.

- **Centralized Alternative:** These alternatives would result in transporting wastes to one or two sites for treatment, storage, or disposal. As was the case with the regionalized alternatives, the sites that have the largest volumes of a given waste type were considered as sites for centralized treatment, storage, or disposal.

These four categories of alternatives encompass the range of reasonable alternatives available to DOE for siting of facilities for the management of the five waste types that are the subject of this PEIS. However, under each category of alternative, there are many possible combinations for the number and location of DOE sites for treatment, storage, and disposal facilities. To narrow these combinations to a number under which a programmatic analysis was feasible, DOE selected particular alternatives for analysis under each category.

The alternatives were developed and defined based on waste type origin and character, volumes and locations within the DOE complex, existing facilities and capabilities, and specialized treatment and disposal requirements. DOE determined where the largest waste volumes are located and where transportation requirements would be minimized. Treatment, storage, or disposal facilities were analyzed at those sites. For example, if seven sites were to be considered under a regionalized alternative, then the seven sites with the largest volume of that type of waste became candidate sites for the analysis. Another regionalized alternative for the waste type being analyzed may evaluate management at three sites; in that situation, the three sites with the largest volume of that type of waste were considered as candidate sites. As shown in Table C.2–1, a combined total of 36 alternatives were evaluated for the five waste types. The waste type chapters (6-10) contain more information on the alternatives analyzed in the PEIS.

C.2.5 TRANSPORTATION

Transportation is an integral component of the alternatives being considered for the management of each type of waste in the PEIS. The magnitude of the transportation related activities varies with each alternative, ranging from minimal transportation under the decentralized alternatives to significant transportation under some of the centralized alternatives.

Table C.2-1. Number of Alternatives Analyzed in the PEIS

Alternatives	LLMW	LLW	TRUW	HLW *	HW	Total
No Action	1	1	1	1	1	5
Decentralized	1	1	1	1	1	5
Regionalized	4	7	3	2	2	18
Centralized	1	5	1	1	0	8
Total	7	14	6	5	4	36

* HLW alternatives are analyzed in terms of both final disposal beginning in 2015 and final disposal beginning at some later date.

The transportation assessment included the onsite and offsite transportation of radioactive waste. Offsite transportation refers to transporting waste between distinct sites, including parts of the routes that may be within the boundaries of the origin and destination sites. Onsite transportation was evaluated for one sample site; Hanford.

The transportation linkages among generator, treatment, and disposal sites depend on the type of waste and are defined explicitly for each alternative under consideration. For the PEIS, representative offsite truck and rail routes were determined for all possible pairs of origin and destination sites. The routes were selected to be consistent with existing routing practices and all applicable routing regulations and guidelines.

The representative truck routes were determined by using the routing model HIGHWAY 3.1 (ORNL, 1993a). INTERLINE 5.0 (ORNL, 1993b) was used to determine the rail routes. For truck and rail transportation, the route characteristics most important to the assessment included the total shipping distance between each origin and destination pair and the fraction of travel in rural, suburban, and urban areas. Because the routes were determined for the purposes of impact assessment, they are not simply representative of the actual routes that would be used to transport waste in the future.

For the offsite transportation assessment, each specific alternative is defined as a set of pairs (origin and destination) representing shipping linkages among generator, treatment, and disposal sites. The number of origin-destination pairs varies among alternatives, ranging from a small number for the decentralized alternatives, to many pairs for the centralized alternatives. The sites that would not have the capability

to dispose of wastes would ship their wastes to a sites that does. Appendix E contains more detailed information on the transportation analysis.

C.3 Phase II: Engineering Analysis Outputs

The engineering features of the generic facility and the waste loads "processed" through the facility formed the basis for the estimates of resources required, effluents released, and cost. The resources required and effluents emitted, were used to estimate environmental impacts from construction and operation of the WM facilities.

Resource Use

The Waste Management Facility Cost Information (WMFCI) methodology model was used to estimate the resources required for construction and operations of each WM facility. The resources included labor (number of FTEs), land, water, electrical energy, fuel (natural gas, diesel oil, and coal), chemicals, concrete, carbon steel, and stainless steel. A description of the engineering analysis used to estimate the resources used is provided in this section. Details are provided in the WM Engineering Analysis Technical Reports.

Facility Environmental Discharges

Once the generic designs and the volumes and characteristics of the waste and the model throughput requirements were specified, the WASTE_MGMT model was used to estimate discharges from the treatment, storage, and disposal modules. DOE estimated the radiological and chemical components in air and water effluents from processing the waste, and the chemical components in air effluents from the burning of fuel during the operations period. A description of the modeling of effluent releases is given in the Human Health Risk Assessment Technical Report. Section C.4.2 of this Appendix identifies the airborne emissions used in the analysis of air quality impacts. Section C.4.3 provides the estimates of releases from LLMW and LLW disposal units into groundwater that were used in evaluating water quality impacts.

Facility and Transportation Costs

The WMFCI methodology was also used to estimate life-cycle facility costs. Total cost of each alternative include the sum of the treatment, storage, disposal, and transportation costs, and in some instances, special costs. Examples of special costs include the Oak Ridge Reservation "B&C Pond sludge" treatment and disposal actions. Section C.3.2 describes the details of the engineering cost estimation procedures.

C.3.1 RESOURCE USE

The resource use data-estimating process for LLMW, LLW, TRUW, and HW (part of the WMFCI methodology), used the mass/volume throughput to quantify resource consumption for each WM module. Supplemental methodologies provided resource estimates for modular throughputs which were bounded by WMFCI estimates. Samples of tabular presentations of resource use data accompany the discussions. Tabular details are provided (INEL, 1995f). The resource use data estimating process for HLW used regression formulas developed by Argonne National Laboratory (ANL) (ANL, 1995b).

C.3.1.1 Modular Estimating Approach

The resource consumption estimated for each module was dictated by a series of allocation rules. These rules were applied to each module to obtain resource quantities for the module size selected. The resource categories were selected before the actual analysis of any alternatives. During the impacts analysis process, it was determined that several resource categories were not directly needed in the analysis. However, the allocation rules for resources for all facilities are discussed.

C.3.1.1.1 *Construction Resource Use*

The following assumptions were common to developing the resource use parameters for construction activities.

A construction year was defined as 252 workdays, thus allowing time for holidays and weekends. Each workweek is assumed to be 40 hours and composed of five 8-hour days. An FTE employee represents one person working full-time for one construction year, one shift per day.

Most modules were assigned a 2-year construction period, representing the total time assumed from the startup to end of construction activity. A 3-year period was assigned to modules requiring installation of more complex equipment or special construction. The time needed to construct each module was included in tables in the resource use computer code. It was assumed that multiple modules will be placed within a single building. The time required to finish the entire plant is controlled by the interface requirements and staggered delivery schedules normally experienced during construction of a multipurpose facility. On any given site, construction of all required modules was assumed to take three to four years.

Many of the resource use parameters for construction were based on an estimate derived for construction of a generic treatment plant. A 120,000-square-foot generic plant and 3-year construction period were assumed (INEL, 1994).

The module area was a key parameter used in calculating the construction material quantities required. In the construction data tables of the resource use computer program, each construction material quantity is specified in terms of units per square foot. The area was used as a multiplier to calculate the total construction material quantities. The module area was determined from the plant area calculation presented later in this section. All buildings were assumed to be rectangular with a length-to-width ratio of 4:1.

Additional allocation rules for construction socioeconomic resource data included the following for electrical energy, electrical load, fuel, water, laydown area, plant area, parking area, peak employment, and annual costs. Allocation rules for concrete, carbon steel, stainless steel, chemicals, and type of skills which were not used in evaluating environmental impacts are presented in the Environmental Impacts Technical Report.

- **Electrical Energy** (in megawatt-hours): This value represents the total amount of electrical energy consumed during construction.

  Estimate Basis: Electrical energy was calculated by multiplying the connected electrical load, by the hours of use. The hours of use were based on a standard construction year (252 days). The average capacity was assumed to be 65%, which was determined by estimating the electrical energy consumed for construction of the generic treatment facility described above.

The typical allocation of electrical energy during construction was assumed to be 0.017 kilowatts per square foot for all types of facility modules.

- **Electrical Load** (in kilowatts): This is an estimate of the connected electrical sources required during construction.

  Estimate Basis: The electrical load factors for treatment and administration modules were based on the estimates developed for the generic treatment facility described above. The electrical load factor for each module was calculated in kilowatts per square foot of plant area. Total electrical load was obtained by multiplying the module area by 0.017 kilowatts per square foot for all types of facility modules.

  Disposal modules with significantly less construction activity, such as the above-ground disposal module (AGDSP), silo disposal module (SIDSP), and silo storage module (STOSI), had an electrical load factor assumed to be approximately 20% of that of treatment modules. Modules such as shallow land disposal module (SLDSP), which do not include a plant with concrete and metal works, were assumed to have an electrical load factor of only 8%. Borehole disposal (BHDSP) was assumed to be constructed without electricity.

- **Fuel** (in gallons): Fuel oil, gasoline, and propane are included in this parameter. In addition, an allowance of 840 gallons per FTE was assumed to account for fuel used by each employee on the job site and fuel required for travel to and from work.

  Estimate Basis: The fuel factor for construction equipment was based on the fuel consumption estimate for the generic treatment facility described above. A consumption rate in gallons per square foot of plant area per year of construction was derived. A significantly lower value was estimated for the disposal modules. The fuel consumed by construction equipment for each module was obtained by multiplying by the module's area. Fuel consumption during construction for all modules was computed as the module area times 2.35 gallons per square foot of area.

  Fuel consumption by construction employees was estimated by assuming that the workers will travel a 50-mile round trip to the construction site each day of a construction year. A fuel consumption rate of 15 miles per gallon was assumed. This gives 840 gallons per workyear (FTE) for all modules.

- **Water** (in gallons): Estimates for water use include the water consumed during construction activities, potable water consumed by employees, and process water.

  Estimate Basis: The estimate for the amount of water consumed during construction was based on the generic treatment facility estimate described above. The average use of water for dust control, equipment washdown, concrete water, and general cleaning of work areas was determined on a per square foot of plant area basis. A value equal to half of this estimate was used for all disposal and storage modules, based on the fact that fewer construction activities are included with these modules. Total water used for these activities was obtained by multiplying the quantity needed per square foot by the module's area.

  The generic treatment facility estimate was also used to derive the amount of water used by a construction worker per year. The resulting yearly water usage factor was 3,400 gallons per FTE. General construction requirements were 27.5 gallons per square foot of area per year for all modules.

- **Laydown Area** (in acres): The construction laydown area includes the area for each plant module plus that used for equipment and material storage.

  Estimate Basis: The laydown area was estimated by adding a 25-foot-wide buffer to all four sides of the area required for each module. The laydown area for the site was obtained by adding the laydown areas for all modules composing the facility. A length-to-width ratio of 4:1 was assumed for all modules and the buildings containing the modules. The plant area was taken from the calculation below.

- **Plant Area** (in acres): The plant area was obtained by summing the area requirements of the individual modules that constitute the facility. Each module's area was obtained by utilizing a relationship that relates the space required to the module's throughput capacity.

  Estimate Basis: Three different module sizes were used to baseline the cost rollup and resource use data for most modules. Only two were used in a limited number of cases. The area required by any module was obtained by calculating a regression curve relating the three baseline sizes to their throughput capacity. The area needed for any other module was then obtained from this curve, based

on the throughput capacity of the module in question. A scaling factor was applied in instances where the throughput capacity of the module in question was outside the range of the baseline facilities.

- **Parking Area** (in acres): The parking area was obtained by allocating 400 square feet of space to 85% of the number of workers constituting peak employment.

  Estimate Basis: A total individual parking area of 400 square feet was assumed, which includes space for both parking and maneuvering. The number of parking spaces required was based on the peak number of FTEs needed for construction. Parking space was assigned to 85% of this number, assuming that 15% will carpool. Unload/offload was assumed to take place in the laydown area.

- **Peak Employment** (in FTEs): Peak employment is defined as the maximum number of construction employees that will be on the site on any workday during the entire construction period.

  Estimate Basis: The total number of construction FTEs was obtained from the cost rollup data. The total number of FTEs divided by the construction period (in years) provided the average yearly FTEs. Peak employment was estimated as 1.41 (i.e., the square root of 2) times the average number of FTEs per year.

- **Annual Costs** (in $\$\times 1{,}000$): Each of the various average annual construction cost items is divided among labor, material, or equipment categories.

  Estimate Basis: The percentage of labor, materials, and equipment involved in the cost item breakdown was based on previously designed and constructed structures involving similar facilities. This cost information was taken from the cost rollup data.

C.3.1.2.2 *Operations Socioeconomic Resource Use*

The following assumptions were common to developing resource use parameters for facility operations.

An FTE employee represented one person working one shift per day for 252 days per year. Yearly plant operation was taken to be 4,032 hours assuming three 8-hour shifts daily, 240 days per year, with the plant available 70% of the time. The difference between an FTE-year and an operational year allows for the time when an employee may be working but the facility is not operating.

All socioeconomic parameters given for facility operations were annualized.

The module area were also an important factor in calculating operational resource use data. The calculation for module area used in this section is the same as that employed in the construction section.

Additional allocation rules for operations socioeconomic resource data include the following for electrical energy; electrical load; fuel, natural gas or liquid propane gas; fuel, liquid; water; total disturbed area; plant area; total number of worker years; hours per week for labor; O&M labor; operations costs; and maintenance costs.

- **Electrical Energy** (in megawatt-hours): This value represents the total electrical energy consumed during plant operations for one year.

  Estimate Basis: Electrical energy was calculated by multiplying the connected electrical load by the hours of use. It was assumed that the equipment will operate half the time the plant is available. The "hotel load" (i.e., the electricity required for people), in watts per square foot, was multiplied by the module area (from below). Both were multiplied by the hours of use per year. The plant is assumed to operate 4,032 hours per year. This assumes three shifts per day, 240 days per year, with the module available 70% of the time.

- **Electrical Load** (in kilowatts): This value represents the connected electrical load expressed in kilowatts. It was based on the electrical requirements of the equipment in the module plus the hotel load (i.e., the electrical load needed to support human occupancy). The hotel load includes lights, wall plugs, and where appropriate, air conditioning.

  Estimate Basis: The resource use computer code contains estimates for the horsepower requirements of the equipment in the middle (or small) baseline facility. This was converted into watts and multiplied by the ratio of the module's throughput capacity to that of the baseline facility. A scaling

factor was applied in instances where the throughput capacity of the module in question was outside the range of the baseline facilities.

The code also contains estimates of the hotel load in watts per square foot for each module. The hotel load was multiplied by the module's area and converted to kilowatts. Estimates of the hotel loads for the processing, storage, and administrative modules were based on supporting technical documentation (INEL, 1995f).

- **Fuel, Natural Gas or Liquid Propane Gas** (in pounds): This value represents the fuel needed to heat the building for one year, assumed to be natural gas.

  Estimate Basis: This estimate was based on supporting technical documentation (INEL, 1995f). The calculation assumed that to heat the module for the entire winter, the furnace runs an equivalent of 2 months, 24 hours per day. It was further assumed that 3 British thermal units (BTUs) are needed to heat 1 cubic foot of volume for one hour. Multiplying the module volume by 3 BTUs/hour by 1440 hours yielded the total heat required. One cubic foot of natural gas equals 1,030 BTUs.

- **Fuel, liquid** (in gallons): This quantity represents the fuel required to operate specific pieces of process equipment for one year. Where required, it accounted for operating the equipment at full power as well as maintaining equipment in a hot standby condition. The fuel assumed for these calculations was standard diesel oil.

  Estimate Basis: Some of the modules that process waste require fuel to operate. For those modules, the quantity of fuel required was calculated from the throughput capacity. Tables in the resource use computer program give the quantity needed for each 100 pounds of waste processed. The amount of fuel calculated from the throughput capacity per hour was then multiplied by the hours of operation per year.

  In addition to the fuel needed to process waste, fuel is needed to keep the equipment in a hot standby condition. It was estimated that 75% of the amount needed for operation is required during the hours per year the plant is available. The plant was assumed to operate 4,032 hours per year; three shifts per day, 240 days per year, with the module available 70% of the time.

- **Water** (in gallons): When required, water needed for operating process equipment was calculated specifically for the module in question. In addition, the quantities of water used and consumed by O&M employees were estimated. These were summed to derive the total water used per year.

  Estimate Basis: Some of the modules that process waste utilize water. For those modules, the quantity of water required was calculated from the throughput capacity. Tables in the resource use computer program give the quantity needed for each 100 pounds of waste processed. The amount of water calculated from the throughput capacity per hour was then multiplied by the hours of operation. The plant was assumed to operate 4,032 hours per year, three shifts per day, 240 days per year, with the module available 70% of the time.

  Aqueous waste treatment was assumed to generate 86.7 pounds of water per hour for every 100 pounds of waste mass processed per hour. Incineration was assumed to use 109 pounds of water per hour, grouting 26.1 pounds of water per hour, and mercury recovery 10 pounds of water per hour.

  Each FTE was assumed to use 20 gallons of water per day. The operating year for water use was taken as 252 days. The total water used was the sum of that used by the processing equipment and that used by the O&M personnel.

- **Total Disturbed Area** (in acres): The disturbed area required for an individual module was assumed to encompass a space with sides 10 feet from the area needed for processing or other activities. The module was assumed to be rectangular with sides in a ratio of 4:1. The disturbed areas for each module were summed and the area of the parking lot added to yield the total disturbed area for the plant.

- **Plant Area** (in acres): For each module, this value represents only the area needed for conducting the stated operation. The total facility area is a simple sum of the individual module areas that make up the facility.

  Estimate Basis: Three different module sizes were used to baseline the cost rollup and resource use data for most modules. Only two sizes were used in a limited number of cases. The area required by any module can be obtained by calculating a regression curve relating the three baseline sizes to their throughput capacity. The area needed for any other module was then obtained from this curve,

based on the throughput capacity of the module in question. A scaling factor was applied in instances where the throughput capacity of the module in question was outside the range of the baseline facilities.

- **Parking Area** (in acres): Parking space was assigned to each FTE. Visitor parking was accounted for by assuming 15% of the FTEs will carpool. Unload/offload parking was assumed to be included within the plant area.

  Estimate Basis: The number of FTEs was obtained from the cost rollup data by dividing the total number of O&M FTEs by the number of operating years. A total of 400 square feet was assigned to each FTE. This total included both parking area and maneuvering room.

- **Total Number of Worker Years** (in FTEs): This value, in FTEs, was taken from the cost rollup data. An FTE represented one person working an 8-hour shift for 1 year composed of 252 days.

- **Hours per Week for Labor** (in hours): A total of 40 hours was assumed.

- **Types of Skills as a Percentage of Total Skills** (in percent):

  Operating Labor: The total labor pool (i.e., the total number of O&M FTEs) less the number required for maintenance.

  Estimate Basis: The average annual number of FTEs needed for both operations and maintenance was obtained from the cost rollup data. This number is equal to the total number of O&M FTEs divided by the number of operating years assumed for each module. The percentage of FTEs used for operating labor was obtained as follows: First, maintenance labor cost was calculated based on the equipment cost (see below). Next, the number of annual FTE maintenance employees was obtained by assuming each worker has an expense of $140,000 per year. The annual number of FTE operating personnel was obtained by subtracting the number needed for maintenance from the total average annual number of O&M FTEs. The ratio of annual operating FTEs to the total annual average O&M FTEs yielded a percentage.

Maintenance Labor: Annual maintenance labor was assumed to be equal to a percentage of the equipment cost plus a contingency factor. Equipment costs were obtained from the cost rollup data.

Estimate Basis: The annual number of maintenance FTEs was calculated as follows. First, the maintenance costs for labor were estimated by assuming that the labor costs are equal to 250% of the maintenance material costs for each module. The maintenance material costs were taken as a percentage of the equipment cost (between 3% and 7% depending on the module). By assuming each FTE cost was $140,000 per year, the total number of maintenance FTEs was calculated. The ratio of annual maintenance FTEs to the total annual average O&M FTEs yielded a percentage.

- **Maintenance** ($\times$1,000): Annual maintenance costs were composed of two factors, material and labor. These values were estimated as a percentage of the cost of the equipment.

  Estimate Basis: Maintenance cost was based on the equipment cost. It is assumed that 3% to 7% of the equipment cost was spent annually for maintenance materials, and the cost of maintenance labor is 2.5 times the material costs. To derive the total maintenance cost, a 25% contingency factor was added to this sum.

- **Operations** ($\times$1,000): Operating costs constitute all costs needed except those required for maintenance.

  Estimate Basis: The total annual cost of O&M was obtained from the cost rollup analysis. The annual cost was obtained by dividing the total cost by the number of operating years assumed for each module. The number of operating years was also obtained from the cost rollup data. The annual cost of operations was obtained by subtracting the maintenance costs (from above) from the annual O&M cost.

C.3.1.3 Resources Associated With Portable Modules

Small generator sites typically generate very small quantities of certain wastes. Where portable modules were used (TRUW and LLMW), resource consumption was identified for each portable module and its contribution was rolled up into the site resource totals.

C.3.1.4 Resource Data Estimate Methodologies for the PEIS Alternatives

To analyze resources, the PEIS waste volume data were first divided into four waste types: LLW, LLMW, TRUW, and HW. These waste types were then subdivided into cases to analyze the alternatives. The cases were subdivided according to handling characteristics, sites, and construction or operations activities. Generic technology modules were identified and sized to meet the treatment, storage, and disposal requirements for each case. Resource data results were compiled for each alternative by summing the various resource data components for each module, then summing the module results for each site (DOE, 1995a).

For some alternatives, supplementary extrapolation methodologies were applied. The data for these alternatives were obtained from similar data computed as described in Sections 3.1.1-3.1.3, then scaled based on either cost or waste processing rates. The supplemental resource methodologies used for LLW, LLMW, TRUW, and HW can be found in Waste Management Environmental and Socioeconomic Impacts Methods and Results (DOE, 1995a).

C.3.2 Cost Estimating

Costs were estimated using an approach that tied the cost of facilities and transportation to waste quantities. In addition, DOE used costs associated with existing technologies and historical industrial cost experience for estimating purposes.

C.3.2.1 Cost-Estimating Process Details

Each alternative includes a definition of the assumed technologies for the complete treatment process. For each site and each alternative, wastes were hypothetically routed through the waste management process, and the modules were individually sized to handled the processing requirements. Since many sites have existing treatment, storage, and disposal capabilities (INEL, 1994), the analyses accounts for existing facilities to minimize additional construction requirements. However, only O&M costs were estimated for existing facilities.

C.3.2.1.1 *Waste Management Facility Cost Information Reports*

The PEIS used a set of reports, collectively referred to as the "WMFCI reports," to develop cost and manpower estimates for the various alternatives and cases being considered. These reports were prepared for DOE by EG&G Idaho to provide a generic facility costing and resource use estimating methodology for programmatic analysis of treatment, storage, disposal, and inter-site transportation of radioactive and hazardous waste. The WMFCI reports consist of the following:

- Data extracts of the detailed facility equipment and construction estimates and other costing factors applied to base estimates for waste types

- Management analysis reports summarizing the findings of the data extract reports according to waste type

- Procedural reports that describe how to compute costs and manpower for the modules used for the treatment, storage, and disposal of waste types

- Data reports computed by PEIS alternative/case by waste type for cost and FTEs, and for resource consumption data supporting the environmental impacts analysis

The WMFCI reports provide a consistent and defensible basis for generating life-cycle cost information for treatment, storage, and disposal facilities using specific data for each major waste type. The WMFCI reports present cost and manpower information reports for LLMW, LLW, TRUW, and HW. (INEL, 1995a; INEL, 1995b; INEL, 1995c; INEL, 1995d). Within the waste-type categories listed above, cost information was developed for alpha-contaminated wastes (both LLW and LLMW) and RH waste (LLW, and TRUW). For some treatment processes, costs for portable systems were developed for non-alpha contaminated waste (LLW and LLMW); these were deemed more realistic and lower cost approach for treating extremely small waste loads. A separate report (INEL, 1995e) was developed to provide a cost computation methodology applicable to the shipment and routing information provided in Appendix E for the transportation of radioactive and hazardous wastes. A full listing of WMFCI reports is provided in the references cited section of this appendix.

The WMFCI reports were developed specifically for DOE-owned facilities. The cost-estimating used in the reports included provisions necessary to comply with all applicable regulatory requirements for a particular waste type and to meet the requirements of all applicable DOE orders. Indirect costs and overhead burden rates used in the WMFCI reports were based on those historically encountered at DOE's Idaho National Engineering Laboratory (INEL), which fall approximately in the middle of the range of cost factors found at several other DOE sites and which are, therefore, considered to be representative for complex-wide estimating purposes.

C.3.2.1.2 *Modular Estimating Approach*

To facilitate the development of comprehensive cost estimates covering cradle-to-grave management of wastes, the WMFCI reports categorized all necessary WM activities into a series of modules, each representing a discrete facility that carries out a single WM function. A unique set of cost information was developed for each WMFCI module (see Table C.3-1). Within a given module, a series of unit operations necessary to accomplish the specified function was defined in sufficient detail to enable development of the planning level cost information. For example, the incineration module included each of the following unit operations: feed preparation, incineration, secondary combustion, and off-gas treatment. The array of unit operations is sufficiently broad to accomplish the incineration tasks required by the identified waste inventories.

Once a particular WM alternative-based scenario was defined, a series of modules was selected that best represented all activities required to accomplish the necessary WM functions. Some scenarios may have required only 1 or 2 modules to fully define the WM functions, while others may have required 10 or more modules to capture all necessary functions. This modular approach to establishing the cost-estimating basis provided maximum flexibility; thus, the WMFCI was designed to be the full used to support a broad range of WM options.

Design of the WMFCI was based on standard, proven technologies and WM approaches. The modules represent a variety of treatment, storage, disposal, material handling, and support facilities, that were developed for all major DOE waste streams. The cost modules, are listed by waste type in tables found in (INEL, 1995f).

Table C.3-1. Facility Cost Modules Included in WMFCI Reports

Module	LLW	LLMW	TRUW	HW
Treatment Front-end Support	x	x	x	x
Small Generator Front-End/Back-End Support	x	x		
Waste Characterization			x	
Packaging	x	x	x	
Stored Waste Retrieval			x	
Receiving and Inspection	x	x	x	x
Open, Dump, and Sort	x	x	x	
Assay, Sort, and Package				x
Maintenance	x	x	x	
Incineration	x	x	x	x
Aqueous Waste Treatment		x	x	x
Neutralization	x		x	
Shredding/Compaction	x	x	x	
Supercompaction	x			
Metal Melting	x	x		
Wet-Air Oxidation		x		
Thermal Desorption		x		
Debris Washing		x		
Soil Washing		x		
Lead Recovery		x	x	
Mercury Separation		x	x	x
Organic Removal				x
Deactivation		x	x	x
Special Waste Processing	x	x	x	
Recycling				x
Organic Stabilization			x	
Grout Stabilization	x	x	x	x
Polymer Stabilization	x	x		
Vitrification	x	x	x	
Certification and Shipping	x	x	x	x
Storage Front-End and Back-End Support	x	x	x	
Storage Receiving and Shipping			x	
Storage	x	x	x	
Silo Storage	x		x	
Disposal Front-End Support	x	x		
Engineered Disposal	x	x		
Shallow Land Disposal	x	x		x
Silo Disposal	x	x		
Borehole Disposal	x	x		

Note: HLW facilities are covered in a separate report (ANL, 1995b) but included only storage facilities.

C.3.2.1.3 *Cost-Estimating Basis*

A "bottom-up" estimating approach was used to develop the WMFCI unit costs. Initially, a capacity range for each facility cost module was established by studying the currently stored and future projections of DOE waste volumes. Process functional diagrams and facility layout drawings were developed at the individual unit operation level. After all unit operations required for a module were defined, major equipment lists, building configurations, and square footage requirements were established, and cost estimates for each facility were developed.

Data from the study defined baseline capacities for five facility sizes: portable, minimum-fixed, small, medium, and large. Using the five facility sizes, a generic design package for each cost module was developed and used as the basis for the Program Life Cycle Cost (PLCC) estimates. Each design package included a summary functional and operational requirements description, a process functional diagram with mass flow rates, a facility layout, manpower requirements for the processes, and cost and manpower (FTE) capacity-to-requirement curves. The design packages used as much available data from existing or planned DOE facilities as possible. This approach, referred to as "anchoring," provides the reference point used to estimate the various cost components. New designs were generated only if no existing data were available.

C.3.2.1.4 *Cost Components (Work Breakdown Structure)*

The costs for each WM facility included the following four components (each estimated separately): (1) pre-operational activities, including the costs of studies, demonstrations, generic designs, permitting, and startup; (2) facility construction, including definitive design, equipment and building, and construction labor costs; (3) O&M costs; and (4) decontamination and decommissioning (D&D) costs. Usages were determined separately for resources used during the construction period (which includes pre-operations and construction) and resources used during the period of operations (which includes O&M, and D&D).

Resource usage was estimated for all treatment, storage, and disposal facilities configured at each site for each waste type under each alternative. Building unit costs for various functions were developed by generating detailed material quantities, labor hours, and related costs for construction, using rates applicable to INEL. These building functional unit costs were multiplied by the functional floor space

required within each module. The functional cost sub-totals were summed to give a total building cost for each module.

Equipment costs were estimated either by soliciting budgetary costs from suppliers, by using existing data, or by making engineering judgments. Costs for the other three components of the estimate (operating budget-funded activities [pre-operation], O&M, D&D) were obtained from actual costs of existing facilities and from engineering estimates. These cost components do not include various site costs for the supporting infrastructure and basic site services known as "chargebacks." The allocation rules for chargebacks are site-specific and provide a similar site effect for all alternatives. They do not affect the relative cost ranking of the alternatives, and are not included in the PEIS.

To provide a comprehensive analysis of the WM facility requirements for support, the facilities required to manage the waste (for example, administration and maintenance) were also provided as separate facility cost modules. This approach facilitated analysis of scenarios that involve existing facilities where none, some, or all of the administrative functions may have already been in place.

C.3.2.1.5 *Cost Estimates Development*

To assist in application of the WMFCI, the baseline cost/capacity relationships defined for each cost module were translated into parametric cost relationships. These relationships were defined by linear and log-linear equations that uniquely define the costs over a broad range of capacity requirements. Each facility module had specific cost equations that defined the pre-operations costs, facility construction costs, O&M costs, and D&D costs. The cost relationships allowed the WMFCI to be consistently applied over a wide range of estimating scenarios.

Both DOE and the commercial nuclear industry have facilities similar to some of the cost modules examined by the WMFCI. Several facilities (for example, incinerators, metal-melters, supercompactors, SNF storage, and engineered disposal) were surveyed to obtain functional and operational requirements, capacity limitations, capital and operating costs, and other information needed to provide a basis for the WMFCI data.

To the extent possible, major equipment costs in each cost module were taken from similar facilities that had been constructed or that were in the advanced design stage. Before using costs from existing facilities, the data were adjusted to account for capacity differences and escalation. These cost validation steps established a cost confidence level for the PLCC estimates of plus or minus 30%.

Facility construction costs were based on the current cost-per-square-foot rates for five typical building functional envelopes defined by use—low hazard, moderate hazard, alpha-treatment, storage, and disposal functions—planned and under construction at INEL.

C.3.2.2 PEIS Cost-Estimating Methodology

C.3.2.2.1 *Description of Alternatives*

Cost estimates for each PEIS alternative were developed at the module level for each site within the DOE complex. For a given WM alternative, every site with waste of that type played a role in management of that waste and consequently incurred some cost. The roles of the various sites could have ranged from simply packaging and shipping their own wastes to treating and disposing their own wastes and wastes from other sites. The contribution each site made toward the cradle-to-grave management of a given waste type was defined in each alternative through designation of treatment, storage, and disposal locations for each site's waste. The alternatives generally covered the range of possible configurations from a centralized waste management strategy to a decentralized scenario. Other parameters that were also varied within the alternatives analyzed for a particular waste type included the level of treatment performed and the final waste form produced. Therefore, for each alternative, a unique set of responsibilities was defined for each site; this established the activities that had to be performed at each site and provided the basis upon which the cost estimates were developed.

C.3.2.2.2 *Waste Loads Development*

Once the WM activities to be performed at each site were defined for a particular alternative, the quantity of waste to be processed or handled through each module was calculated. This step was accomplished

using a set of "raw" data that accounted for all waste stored and generated at each site. The waste information included quantities of waste currently in storage and projections for future waste generation. Each classification of waste (LLW, LLMW, TRUW, and HW) was broken down into "treatability groups." The treatability groups, based on the characteristics of the waste, helped to define which treatment processes were necessary to meet regulatory requirements for that waste type. (The generic configurations of processing modules necessary to treat, store, and dispose each waste treatability group were discussed earlier.) The raw data were transposed into the waste loads for each facility by applying the constraints and assumptions integral to the configuration designated for each alternative. Once a time factor was incorporated (for example, a 10-year operating period), the waste load for each module became a waste processing rate. The processing rates (throughput capacities) for each module was used to determine facility size and was the key factors used in developing the cost estimates.

C.3.2.2.3 *Existing Facilities Assessment*

A survey of existing and planned-or-approved WM facilities at each site, and their capacities, was performed to provide the baseline for cost-estimating purposes. Where existing capacities were identified, the total required operating capacity was reduced by that amount so that only the minimum necessary new facility construction was costed. Since existing facilities and their capacities were taken into account, the cost estimates developed for each alternative could be considered to be representative of actual future capital investments necessary to provide the additional capabilities required for the WM operations outlined in each alternative.

In some alternatives, where a homogeneous waste stream was currently being treated in a dedicated facility and actual operating costs were known, these actual costs were used in the PEIS cost estimates (rather than using bottom-up cost estimates for generic facilities designed to treat the same waste).

C.3.2.2.4 *Bounding Parameters and Assumptions*

The PEIS alternatives generally assumed that a 10-year implementation period was necessary to construct and start up the new WM facilities required for each alternative, and that a 10-year operating period would be used to work off the projected waste inventories.

Costs under the no action alternative for each waste type were estimated using a unique set of assumptions. The no action alternatives (with some exceptions for storage and disposal) used existing facilities for 20 years. Where projected waste loads exceeded existing treatment facility capacities, waste was assumed to be stored.

The HW alternatives were assumed to use commercial treatment and disposal contractors for 20 years; possible regional on-site treatment and disposal costs were also evaluated.

Costs associated with treating quantities totaling less than 0.1 pounds per hour or disposing quantities totaling less than 0.1 cubic feet per hour were considered to be insignificant and costs were not developed. These volume totals equate to treating a drum or less of waste per year and disposing 60 drums (one semi-trailer load) or less of LLW or LLMW per year. In such instances, bench-top-type treatment, or shipment to another facility, would be likely to occur.

The receiving and inspection module was used only for wastes received from another site for regionalized or centralized treatment. It was assumed that wastes generated on site would be characterized to the extent that inspection would not be required and that the waste could be transported directly to the treatment facility. Representative sampling of on-site waste characterization was assumed to be performed as necessary through a variety of modules: certification and shipping (found at all sites), administration—with laboratory—(found at all treating, storing, and disposing sites), and waste characterization (found at all TRUW sites).

The "open, dump, and sort" module was used only for waste volumes currently in storage. It was assumed that these containerized wastes are heterogeneous and would need to be sorted before treatment. It was further assumed that wastes presently being generated or to be generated in the future would be segregated by treatment need and would not require sorting.

Except for TRUW, it was assumed that treated wastes would be accumulated in small batches (railcar or truckload quantities) and would be shipped directly for disposal, eliminating the need for storage. For TRUW, it was assumed that shipment could not be made directly to WIPP; therefore, costs were estimated for one year of storage before transportation to WIPP.

C.3.2.2.5 *Application of the Waste Management Facility Cost Information Methodology*

Curves for cost-versus-capacity and FTEs-versus-capacity were developed for each module through a bottom-up estimating method. These curves were developed over a finite range of capacities (referred to as the "standard capacity range") that, at the time the range was selected, would fit the anticipated cost-estimating needs. The standard capacity range selected was specific to each module. Cost versus capacity curves were developed for equipment (including installation), building requirements, operating labor, and operating materials. From these curves all other costs were determined through application of various cost factors. Combining all derived costs produced the life-cycle costs for each module. Costs for all modules were based on a 48-week year, three shifts per day, 5 days per week, and 70% availability, for a total operating period of 4,032 hours per year. The 4,032 hour year is a "rating" of achievable production capacity possible in a full 52-week workyear.

Curves for cost versus capacity were developed for numerous modules handling CH LLMW, CH alpha-LLMW, RH LLMW, CH LLW, CH alpha-LLW, CH TRUW, RH TRUW, and HW. FTEs-versus-capacity curves were determined by applying a factor to the costs for an appropriate category.

With the release of updated waste data, the need for costs at capacities outside the standard capacity range of developed data became necessary. The following methodology was used to estimate the costs when the capacities fell outside the standard range for any particular module.

C.3.2.2.5.1 Costs Determination for Treatment Outside Standard Capacity Range

To estimate the costs for a treatment module at a throughput capacity falling below the standard range, the following extrapolation method was used. An "economy of scale" function was assumed to exist beyond the upper and lower bounds of the capacity-to-cost curve (developed as discussed above). The upper and lower bounds were the waste processing throughput capacities of the largest and smallest standard commercially available processing equipment for the particular module being adjusted. The basic formula is shown below:

[Cost for higher/lower capacity] =[Cost for high/low bounding point] × [(waste throughput capacity of higher/lower requirement)/(waste throughput capacity of high/low bounding point)]$^{0.7}$

The ratio of required throughput capacity to the throughput capacity of the high or low bounding point of the capacity-to-cost curve was raised to the 0.7 power. The use of the 0.7 power scaling factor was based on estimating methods presented by Peters and Timmerhaus, and Remer and Chai, Chemical Engineering, April 1990. The resulting value was used to adjust the cost of the equipment, building requirements, operating labor, and operating materials. These adjusted costs were then used to estimate the costs associated for the lower-than-standard capacity (to eliminate unrealistically small modules). A module was never scaled down to below 10% of the smallest capacity in the standard range. Similar judgment would have been used when scaling to modules several times larger than the upper bounding capacity; however, waste loads never became that large, so this approach was not tested.

For the incinerator module and the small generator front-end support module, costs were developed for a module of "minimum" size designation. This represented the smallest module size that could be constructed with off-the-shelf equipment. A slightly different approach was used to estimate costs. For capacities falling between the minimum capacity and the lowest capacity in the standard capacity range, the costs were determined by the method described above. For capacities falling at or below the minimum, the "minimum module" capital cost was used and operating costs were scaled down from the minimum capacity using the 0.7 power factor method. To eliminate an unrealistically small module for very small capacity requirements, the number of shifts was limited to 0.1 shift per workday.

For seven other non-alpha modules (aqueous waste treatment, wet-air oxidation, thermal desorption, deactivation, lead recovery, mercury separation, and polymer stabilization), the minimum module was the same as the lowest capacity in the standard range. Costs for these seven modules were treated in a parallel manner as stated for incineration (above). For capacity below the range associated with these seven modules, capital costs from the minimum module were used and the operating costs were scaled down from the minimum capacity using the 0.7 power factor method.

To determine the costs of an engineered disposal module (AGDSP) or a shallow land disposal module (SLDSP) at a capacity falling below the standard range (18 to 126 cubic feet per hour), the following extrapolation method was used. For disposal capacities within the standard capacity range (1.44 to 5.9

cubic feet per hour) for the silo disposal module (SIDSP), costs for silo disposal were used. For disposal capacities falling between the standard ranges of the SIDSP and the AGDSP or SLDSP (5.9 to 18 cubic feet per hour), the ratio of the actual capacity to the lowest capacity of the AGDSP or SLDSP standard capacity range was raised to the 0.7 power. The resulting factor was used to adjust the cost of the equipment, building requirements, operating labor, and operating materials. These adjusted costs were then used to estimate the associated costs. For disposal capacities falling below the standard capacity range of the SIDSP, costs were determined by scaling down with a factor developed by taking the ratio of the actual capacity and the smallest capacity in the standard range for the SIDSP raised to the 0.7 power.

C.3.2.2.5.2 Portable Module Costs

Small generator sites typically generate very small quantities of certain wastes. To treat these small quantities, installation of permanent treatment facilities would not always be cost effective. To handle these small quantities, portable treatment modules were identified as an economical alternative. Portable modules were used for certification and shipping, decontamination, polymerization (which is capable of performing grout stabilization for very small volumes), thermal desorption, and wet oxidation (which could substitute for incineration for very small volumes).

Costs for portable treatment modules were developed based on processing 2.5 cubic meters of waste per treatment campaign. Waste to be processed was assumed to have an incoming density of 40 pounds per cubic foot for all modules, except aqueous waste, which has a density of 62.4 pounds per cubic foot. Each treatment campaign was assumed to require 2 weeks, including setup, processing, and shutdown. Counting travel time and equipment maintenance time, the number of campaigns was limited to 12 per year. (If waste quantities were sufficiently high to exceed 12 campaigns per year, permanently installed modules were estimated.) The portable equipment was assumed to have a useful life of 5 years, or 60 campaigns. A host facility (warehouse, garage, or similar structure) with suitable utility support was assumed to be required.

Costs associated with portable modules were developed on a campaign basis. Each portable module has its unique campaign cost, computed to include all programmatic life-cycle cost components.

C.3.2.2.5.3 Supplemental Cost-Estimating Methods

For most WM alternatives, costs, manpower, and resource use data were computed using the above-described methodology. The computations were made by selecting the same data results from cases estimated using the WMFCI methods in LLW Cases 5, 7, 12, and 14 for cost/manpower and in Cases 1, 2, 4, 5, 7, 12, 14, and 14a for resource data; in HW Case 1 for cost/manpower and Cases 1 and 2 for resource data; in TRUW Cases 1, 10, and 11 for resource data; and in LLMW Cases 1, 7, 10, and 17 for resource data. For certain data points, exact matches did not exist; in such instances, data were scaled linearly, using waste processing throughput proportions, from the nearest data point computed using the WMFCI method. These computations are summarized in Sherick and Shropshire, 1995. Resource use data estimates were discussed in part C.3.1.

Where modifications to the originally computed data were required because of changes in costing assumptions, a similar "exact selection, or scaling from closest data point" method was used. These computations have been summarized (INEL, 1995f).

In the case of HLW, cost and manpower estimates for canister storage and transportation were abstracted from the many cost studies performed for vitrification of HLW at the West Valley Demonstration Project (WVDP), Savannah River Site (SRS), Hanford, and INEL. A summary of these findings is found at Section C.3.2.2.8.

C.3.2.2.6 *Transportation Cost Estimates*

Transportation costs were calculated for each alternative using mileage between sites (either by highway or rail) and mass quantities requiring shipment. Transportation costs were included for waste shipments between generator sites and treatment sites, between generator sites and disposal sites, and between treatment sites and disposal sites. Costs were compiled for each alternative for both truck and rail transportation. Transportation costs for most waste types were computed using linear regression formulas, where a fixed cost per trip (depending upon waste type) was multiplied by the number of shipments and added to a variable cost-per-loaded-mile multiplied by the total shipping mileage. The fixed and variable costs per waste type and the background of the transportation cost-estimate development are provided (INEL, 1995e). The cost-estimating process for the transportation of HLW is found at Section C.3.2.2.8.

C.3.2.2.7 *Quality Assurance*

The PEIS cost estimates were compiled for each alternative, and the detailed estimating backup information is documented in data packages retained in the PEIS engineering files. Each cost data package was thoroughly reviewed before publication of any cost results. The quality reviews verified that the estimating methodology was correctly and consistently applied, that the assumptions and alternative descriptions were followed, and that the results provided reasonable PLCC that can be used to compare the relative costs of the various alternatives.

C.3.2.2.8 *Cost-Estimating Procedures for High-Level Waste Canister Storage and Transportation*

The generic cost methodology used was modified to reflect the specific assumptions for HLW. These modifications are discussed below.

C.3.2.2.8.1 Methodology and Assumptions

The life-cycle costs are the "cradle to grave" costs, incurred from the time the waste is generated to the end of its institutional control. The total life-cycle costs include all costs associated with waste handling following its generation, current storage and treatment, transportation, future disposal and monitoring. The WM PEIS does not provide cost analysis of the current storage of HLW, pretreatment and treatment of HLW (resulting in canisters of vitrified waste), or environmental impacts of HLW disposal. The WM PEIS does provide cost analysis of the storage of canisters and the transportation to storage sites and a candidate geologic repository. Because of the possibility of a prolonged delay of HLW disposal, two sets of timing assumptions for acceptance of HLW at the candidate repository were analyzed.

Projecting the cost of the HLW alternatives involved developing estimates of the individual cost components. The cost was divided into two components—capital investment and annual operating charges. The capital cost of a facility was assumed to include process equipment, construction materials (for example, steel and concrete), and labor, as well as indirect costs such as those for design, contingencies, and environmental compliance. The annual O&M costs were expenses estimated for O&M staff, fixed and variable supplies, annual operating fees, administration, and general expenses. These two cost

components were estimated by reviewing and abstracting available data on the costs of storage and transportation of HLW (ANL, 1995b).

C.3.2.2.8.2 Canister Storage

Vitrified HLW from Hanford, SRS, WVDP and INEL would be placed in on-site storage facilities awaiting transport to the candidate geologic repository. The WM PEIS alternatives for HLW management include: (1) No Action—Continued storage (assumed for 30 years), (2) Decentralized—All sites provide storage for canisters until the candidate geologic repository begins accepting DOE HLW in 2015, with shipments beginning in 2016; (3) Regionalized 1—WVDP ships its canisters to SRS for storage until transportation to the candidate repository starting in 2016; (4) Regionalized 2—WVDP ships its canisters to Hanford for storage until transportation to the candidate repository begins in 2016; and (5) Centralized—WVDP, SRS, and INEL ship their canisters to Hanford for storage until transportation to the candidate repository begins in 2016. For the alternatives, the assumption was made that the approval of the candidate repository will occur in a timely manner so that the amount of storage facilities to be constructed could be kept to the minimum required.

The second set of timing assumptions is configured identically to the No Action, Decentralized, Regionalized 1, Regionalized 2, and Centralized Alternatives, except that acceptance of DOE HLW at the candidate repository is deferred past 2015, requiring the construction of storage facilities at each site capable of holding the full amount of canisters to be stored at that site. These alternatives are costed assuming that the approval of the candidate repository is made in time to begin transportation in 2016 but after each site has completed construction of storage facilities for all canisters produced at that site. Further deferrals of the decision will increase the total cost of storage. Depending upon the alternative, the costs for storage operations will increase by an additional $8 million for every year past 2015 that acceptance of HLW canisters at the candidate geologic repository is delayed.

The storage technology selected for costing is the modular dry vault storage (MVDS) concept. It is assumed that the interim canister storage facility at Hanford and at SRS for the vitrified HLW would hold canisters in vertically sealed cavities within a concrete structure forming the storage vault. Each canister storage vault (CISV) will be an air-cooled dry storage vault for vitrified HLW. A thermosyphon ventilation system would be used to remove heat generated by the stored vitrified HLW. Activities at a

given CISV include receipt and unloading of transportation cask containing canister(s) of vitrified waste, inspection of the canister, and storage of the waste until transfer to a permanent geologic repository. The CISV consists of rows of tubes or vaults laced below grade into which the canisters are lowered. Concrete plugs provide a cover for the tubes. The canisters are to be stored in sealed sleeves so that the cooling air would not directly come into contact with the potentially contaminated surfaces of the HLW canisters. Although the design for storage of canisters at INEL has not been decided, the PEIS assumed the storage technology to be the same as that for Hanford and SRS. Because the storage facility has been constructed at WVDP, these costs are not included in the PEIS analysis.

The rationale for costing the construction and operations of these facilities is provided (ANL, 1995b). The cost experience for monitored retrievable storage facilities was modified to the above concept. The below formula was developed to estimate capital costs:

Formula C-1

$$[\text{Capital Cost (\$ million)}]_{MVDS} = 0.71\ [\text{Capacity (HLW Canister)}]^{0.53}$$

Annual O&M costs include the routine handling, storage, and retrieval, with the predominance of costs pertaining to the operation of facilities. The operating lifetime of the various storage facilities varies depending upon the transportation instruction for each Alternative. The correlation of the annual operating costs for the storage period as a function of capacity is:

Formula C-2

$$[\text{Annual O\&M Cost (\$1,000/yr)}]_{Storage} = 38.6 + 0.27 \times [\text{Capacity (HLW canisters being stored)}]$$

Loading/unloading operations were evaluated in the reference; the following formula was developed:

Formula C-3

$$[\text{Annual O\&M Cost (\$1,000/yr)}]_{Loading} = 770 \times [\text{Throughput (HLW Canisters shipped/yr)}]^{0.52}$$

With respect to the shipping rate to be assumed for the various alternatives, the loading rate into storage is taken to equal the maximum annual vitrification rate (190 canisters per year for SRS, 790 canisters per year for Hanford (No Action is 320 canisters per year), 300 canisters per year for WVDP, and 327

canisters per year for INEL). The total time for unloading the HLW canisters before shipment to the candidate repository is assumed to be performed at a rate of 800 canisters per year. The loading/unloading duration is dependent upon the shipping rate.

The quantities and timings shown in Chapter 9 were applied to the formulas C-1, C-2, and C-3, and totaled for each alternative under both sets of timing assumptions. The computation summaries are provided (INEL, 1995f).

C.3.2.2.9 *Transportation of Vitrified HLW Canisters*

The rationale for costing transportation of HLW canisters between sites is provided in Folga, et al., 1995. Based on numerous reports, there is general agreement that transportation costs for HLW would be similar in cost for spent nuclear fuel. The life-cycle cost for HLW transportation can, in general, be calculated by summing the following cost categories: shipping cost; security cost; cask, capital and decommissioning cost; cask maintenance cost; inspection cost; demurrage cost; handling cost (loading and unloading); and transportation support system costs.

The following assumptions were made for the HLW transportation cost analysis:

- The costs associated with the inspection cost category are included in the annual operating charges for the various HLW storage facilities.

- Demurrage (the charge for the detention of a freight car or truck by the shipper or receiver beyond the time allowed for loading, unloading, or shipping) is assumed to be negligible in comparison with other cost components.

- The handling cost for loading and unloading at the HLW storage facility has already been considered in the storage cost; the handling cost at the candidate repository is assumed to be out-of-scope for this PEIS.

- Transportation support system cost include the costs to maintain the railcars and trailers which are assumed to be negligible (average annual O&M cost for a truck trailer is approximately $14,000; for a rail car, $5,000).

Table C.3-2 presents the formulas used to compute truck and rail transportation costs.

C.4 Phase III: Environmental Impacts Evaluation

This section describes the scientific approach and analytical methods used to evaluate the impacts of the WM alternatives on air quality, water resources, ecological resources, the local and National economies and social environments, environmental justice issues, land use, infrastructure, and cultural resources.

Table C.3-2. Assumed Relationship for the Four Transportation Cost Components

Cost Variable	Relationship Assumed in This Study	
	Rail-Based	Truck-Based
SPEED (mph)	DIS/(0.04204 x DIS + 4)[a]	35 (i.e., a constant value)[b]
Annual Cask Requirement, ACR	Σ {[(2 x DIS)/$SPEED_{rail}$]/24 + 2 x (5 days)}[c]	Σ {[(2 x DIS/$SPEED_{truck}$]/24 + 2 x (3 days)}[c]
Shipping Cost, less than 1,000 miles ($1985)	Σ ([2.32 + 0.0067 x DIS] x 2,000) + ([2.15 + 0.0063 x DIS] x 1,800) x [No. of Canisters]/5[c,d]	Σ ([1.493 + 0.0033 x DIS] x 500) + ([0.428 + 0.0034 x DIS] x 475) x [No. of Canisters][c]
Shipping Cost, greater than 1,000 miles ($1985)	Σ ([5.07 + 0.004 x DIS] x 2,000) + ([4.72 + 0.0037 x DIS] x 1,800) x [No. of Canisters]/5[c,d]	Σ ([-0.16 + 0.0049 x DIS] x 500) + ([-0.19 + 0.004 x DIS] x 475) x [No. of Canisters][c]
Security Cost ($1985)	Σ {291.65 x [$DIS^{-0.5987}$] x DIS} x [No. Of Canisters]/5	Σ {7.93 x [$DIS^{-0.1855}$] x DIS} x [No. of Canisters]
Cask Capital Cost ($1985)[e]	Σ (ACR/300) x [No. of Canisters] x (2.5×10^5)	Σ (ACR/300) x [No. of Canisters] x (1.5×10^5)
Cask Maintenance Cost ($1985)[f]	Σ (ACR/300) x [No. of Canisters] x (2.5×10^4)	Σ (ACR/300) x [No. of Canisters] x (1.5×10^4)

[a] DIS = distance traveled (one-way miles); is a function of WM PEIS alternative.
[b] Conservative value, based on [DOE, 1986]; a value of 40 mph is cited in [DOE, 1991].
[c] The summations are to be performed over all shipping routes.
[d] Assumes five HLW canisters per rail shipping cask, one HLW canister per truck shipping cask [DOE, 1986].
[e] Assumes a capital cost of $2.5 million for rail cask, $1.5 million for truck cask (both in $1985 dollars) [DOE, 1986].
[f] Assumes an annual maintenance cost of $125,000 for rail cask, $75,000 for truck cask (both in $1985 dollars) [DOE, 1986].

The general impacts methods were applied as appropriate to analyze the effects of management alternatives for each of the five waste types. Construction and operation of treatment, storage and disposal facilities and intersite transportation of wastes were the principal activities analyzed for impacts, as applicable (Table C.4–1) under each of the waste-type alternatives.

The engineering analysis Phase II output data served as the input data for the environmental impacts assessments. These engineering outputs included estimates of the costs, labor, and resources required to build and operate the WM facilities and estimated facility discharges of pollutants to air and water.

Table C.4–1. WM Actions Analyzed for Environmental Impacts

WM Action	Waste Type				
	LLMW	LLW	TRUW	HLW	HW
Treatment Facility Construction and Operation	✓	✓	✓		✓
Storage Facility Construction and Operation	✓*		✓	✓	
Disposal Facility Construction and Operation/(& Postclosure Effects)	✓	✓			
Transportation of Wastes Between Sites	✓	✓	✓	✓	✓
Waste Transport to Repository or Commercial Treatment/Disposal			✓	✓	✓

* For No Action Alternative only.

Air quality impacts were analyzed by comparing estimated pollutant increases to applicable standards for the Air Quality Control Region at each site. The analysis addressed criteria pollutants, airborne radionuclides and other hazardous and toxic air pollutants from construction and operation of WM facilities at each DOE site. Criteria pollutant increases from mobile (transportation) and stationary sources were evaluated, as applicable.

Water resources impacts were analyzed by evaluating the effects on natural water sources of the use or discharge of large volumes of water during construction or operation of WM facilities at each site. Water quality impacts were evaluated for hypothetical releases of waste, that could leach into groundwater the releases were assumed to come from deteriorating packages or containers in disposal facilities.

Ecological impacts were evaluated in terms of the potential for loss of habitat from site clearing for WM facility construction, indirect facility construction and operation effects on sensitive habitats, exposure of terrestrial species to airborne contaminants released from treatment facilities, and a scenario-based assessment of the consequences of releases of wastes to aquatic habitats in transportation accidents.

Economic impacts were analyzed by estimating job and income increases in the regional economies supporting the DOE sites that might be caused by the infusion of funds to build and operate WM facilities. Impacts on the National economy were also assessed using the sum of all expenditures at all sites and for waste transportation under each waste-type alternative.

Population impacts were evaluated in terms of changes caused by the influx of labor for construction and operation of facilities.

An analysis of environmental justice considerations —disproportionate effects on minorities or low-income populations—discusses and displays the minority and poverty status of the populations at each WM site to highlight sites where those populations might be disproportionately affected by WM activities.

Land use impacts were evaluated by estimating the likelihood that building WM facilities at the sites under a WM alternative would require a commitment of land that might substantively alter the use of land at the site or that might require DOE to acquire additional land to implement the alternative. Conflicts with site development plans and current adjacent land uses were also considered.

Infrastructure impacts were evaluated by estimating the effects of building and operating WM facilities on site water supply, waste water treatment facilities, electrical power supply, and transportation infrastructure. Community infrastructure impacts were evaluated in terms of the estimated level of increased demand on community infrastructure caused by the influx of new labor and their families to support the WM projects.

The potential for cultural resources effects was considered comparatively in terms of the extent of construction site disturbance at each site under each alternative as an indicator of the requirement for cultural resources surveys that would be conducted at the site or project level. Impacts on cultural resources were not evaluated directly because the WM facility locations on each site are not yet proposed.

Environmental impacts considered in the PEIS, but not evaluated in detail, included effects on geology and soils, the noise environment, and visual resources. Those impacts are discussed in Chapter 5 of the PEIS.

All chemical and radiological discharges and direct radiation effects were estimated using computer models that simulate the fate and transport of contaminants in the environment. The computer models are described in the sections on air quality, water resources, and ecological resources. The models are further described in the facility risk appendixes (D and F) and the transportation risk appendix (E).

C.4.1 Human Health Impacts

Human health effects were evaluated for all aspects of the construction and operation of treatment, storage, and disposal facilities, for transportation of wastes, for accidents involving facilities at the sites, and for transportation accidents. Details of the human health risk assessment that estimated risks at the facilities during routine construction and operations activities and during facility accidents are given in Appendix D. Details of the routine transportation and transportation accident risk assessments are given in Appendix E. Further details of the facility accident risks are given in Appendix F.

C.4.2 Air Quality Impacts

Air quality impacts were determined for pollutant-emitting activities associated with managing each of the five waste types: LLMW, LLW, TRUW, HLW, and HW. Air quality impacts were assessed for the construction of new treatment, storage, and disposal facilities; for the O&M of the facilities; and for shipment of wastes between sites. The following sections describe in detail the methods used to estimate the air quality impacts for each WM alternative.

C.4.2.1 Air Quality Impacts Analysis Methods

Air quality impact assessments predict the consequences in terms of deterioration in air quality at off-site locations resulting from the release of contaminants from various categories of pollutant sources. This PEIS evaluated the potential for any of the alternative WM actions to lead to deterioration of local or

regional air quality at any of the sites. The analysis also evaluated the potential for the actions across sites, in combination with pollutants emitted in the waste transportation corridors, to lead to deterioration of National air quality.

C.4.2.1.1 *Air Pollutants Considered*

> ***Major Types of Air Pollutants***
>
> ***Criteria Air Pollutants:*** *carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_x), lead (Pb), ozone (O_3), and particulate matter less than 10 microns in diameter (PM_{10})*
>
> ***Hazardous Air Pollutants:*** *189 hazardous substances (including radionuclides) whose emissions are regulated by the Clean Air Act*
>
> ***Toxic Air Pollutants:*** *Other toxic compounds regulated by EPA and state or local governments*
>
> ***Ozone Depleting Substances:*** *Certain man-made halocarbons (including chlorofluorocarbons [CFCs], halons, carbon tetrachloride, and 1,1,1-trichloroethane) whose manufacture and use is regulated by EPA under the Clean Air Act.*

The air quality impacts analysis estimated the air emissions for WM facility construction and O&M activities. O&M activities include waste treatment, storage, disposal, and transportation of waste. Estimates were made for each action for four classes of air pollutants: (1) the criteria air pollutants regulated under the National and State Ambient Air Quality Standards (NAAQS and AAQS), (2) radionuclides and other Hazardous Air Pollutants (HAPs) regulated under the National Emissions Standards for Hazardous Air Pollutants (NESHAP), and (3) other types of toxic air pollutants (TAPs), which are regulated by some states, and (4) ozone depleting substances (ODS), such as chlorofluorocarbons (CFCs) and halons. The analysis evaluated air quality impacts qualitatively from stationary-sources and transportation sources for the first three classes of pollutants. ODS impacts are discussed qualitatively but their emissions were not quantified.

Criteria pollutants consist of the six substances regulated by EPA (40 CFR 50) for which NAAQS have been established under the Clean Air Act (CAA): CO, SO_2, NO_2, Pb, O_3, and PM_{10}. They are regulated both in terms of annual production in tons per year and in terms of ambient concentrations emanating from point and mobile sources. Unlike the other five criteria pollutants ozone is not a direct emission, but is formed in the atmosphere through a complex reaction of ozone precursor pollutants, sunlight, and temperature. ***Ozone precursor*** pollutants include nitrogen oxides (NO_x) and non-methane hydrocarbons (NMHCs). The analysis of ozone impacts was done by evaluating NO_x and VOCs emissions as criteria pollutants.

Hazardous air pollutants include 189 substances listed in Section 112 of the Clean Air Act of 1990 (42 USC 7401 *et seq.*), as amended through May 1992, whose emissions standards are regulated by the NESHAP in 40 CFR 61. In particular, HAPs include cancer-causing agents such as arsenic, benzene, carbon tetrachloride, and formaldehyde, as well as materials with non-cancer health hazards, such as fluoride, ammonia, and hydrochloric and sulfuric acids. EPA regulates radionuclides as a total annual dose limit (10 mrem/yr) from the air pathway under the NESHAP (40 CFR 61). ***Radionuclides*** are also regulated by the DOE (DOE, 1990; DOE, 1993b) as a total annual dose limit (100 mrem/yr).

Toxic air pollutants include cancer causing agents and compounds with non-cancer health hazards. These substances are regulated by the EPA and on a state or local basis, through allowable ambient standards or guidelines.

Ozone depleting substances are certain man-made halocarbons, including chlorofluorocarbons (CFCs), halons, carbon tetrachloride and 1,1,1-trichloroethane that react in the upper atmosphere to deplete the stratospheric ozone layer. These compounds are regulated through the CAA and by the Montreal Protocol on Substances that Deplete the Ozone Layer.

C.4.2.1.2 *Air Quality Impacts Analysis Procedures*

The air quality impacts analysis varied according to the pollutant classes and emissions sources expected to be important in each WM activity. Different analytical assumptions and techniques were used to best estimate the amounts of pollutants that could be emitted by each source. A summary of the air quality impacts that were evaluated in the PEIS is shown in Table C.4–2.

Table C.4-2. Impacts Evaluated for Air Quality

Impacts Assessed	Relevant Waste Types	Period of Analysis	Activities for Which Impacts are Assessed	Impacts Measure	Presentation of Results
Criteria Air Pollutant Emissions	All five waste types	Construction	Use of construction equipment and worker vehicles	Percent of tons/year standard	Tabular or text discussion
		Operations	Operation of incinerators, fuel use by all other WM facilities, worker vehicles, and waste shipment vehicles, where applicable	Percent of tons/year or concentration standard	Tabular or text discussion
Radionuclide Emissions	LLMW, LLW and TRUW[a]	Operations[c]	Operation of WM treatment, storage and disposal facilities, where applicable	Percent of dose standard	Tabular or text discussion
Hazardous and Toxic Air Pollutant Emissions	LLMW, TRU and HW[b]	Operations[c]	Operation of WM treatment, storage and disposal facilities, where applicable	Percent of concentration standard	Tabular or text discussion

[a] Emissions of radionuclides from HW and vitrified HLW are assumed to be negligible.
[b] Emissions of hazardous and toxic air pollutants from LLW and vitrified HLW are assumed to be negligible.
[c] Emissions assumed to be negligible during construction.

C.4.2.1.2.1 Analytical Approach for Different Pollutant Classes

For the air quality impacts analysis, stationary-source and area-source emissions were modeled and simple vehicular emissions factors were used to estimate mobile-source emissions for worker vehicle trips and waste transportation activities under each alternative.

C.4.2.1.2.1.1 Comparisons with Emission-based and Concentration-based Standards

The analysis of criteria pollutants varied according to the attainment status of a site's Air Quality Control Region for each pollutant. Annual emissions of the criteria pollutants from sites located in attainment

areas were estimated for comparison with the allowable increment levels established in the Prevention of Significant Deterioration (PSD) regulations (40 CFR 52.21). The PSD allowable increments, in tons per year, regulate stationary-source emissions and do not include mobile-source emissions such as those from automobiles. Criteria pollutant emissions from sites located in nonattainment areas were estimated for comparison with the General Conformity Guidelines de-minimis levels, in tons per year (40 CFR 93). The Conformity Guidelines regulate both stationary-source and mobile-source emissions.

Ambient concentrations of the criteria pollutants were estimated for comparison with the NAAQS and State AAQS. Concentrations of the HAPs (including radionuclides) and TAPs were estimated to compare with the EPA or State ambient allowable limits (AALs).

C.4.2.1.2.1.2 Stationary-Source Estimates from Human Health Risk Modeling

In the analysis of air quality impacts from stationary-source emissions, it was assumed that ambient concentrations of criteria, hazardous, and radioactive pollutants would increase according to estimated emissions from treatment, storage, and disposal facilities and that the most conservative estimates of those increases would be the estimates of concentrations that the maximally exposed individual (MEI) would be subject to in the human health risk assessment done for this PEIS (ORNL, 1995a). Therefore, the air quality impacts analysis of stationary-source emissions used data on emissions, airborne transport and fate, and MEI doses assembled for the human health risk assessment to evaluate air quality effects. This is a conservative approach that will result in overestimating air quality impacts because the MEI doses from the health risk assessment include ingestion of farm products in addition to direct inhalation. The air quality impacts analysis used modeled estimates of local stationary-source ambient concentrations for hazardous and toxic air pollutants by waste type. Radionuclide data were taken directly from the off-site MEI doses estimated in the human health risk assessment.

C.4.2.1.2.1.3 Transportation Source Assumptions

In the air quality analysis, it was assumed that transportation sources (mobile-sources) may be an important source of criteria pollutant emissions in addition to those emanating from the facilities. Transportation sources were not expected to contribute significantly to hazardous (including radioactive)

and toxic airborne contaminants in routine operations. Therefore, for criteria pollutants only, the analysis estimated local transportation-source annual tonnage of criteria pollutants, intersite transportation annual tonnage of criteria pollutants, and a national annual tonnage of criteria pollutants from all activities proposed under each alternative.

C.4.2.1.2.2 Emissions Estimation Techniques

Details of the estimation methods for construction-phase and operations-phase air emissions are presented in this section.

C.4.2.1.2.2.1 Construction-Phase Air Emissions Estimates

Emissions due to construction activities were calculated using estimates the amount of fuel used by construction equipment, and by construction workers traveling to and from the work site.

Construction Equipment Fuel Use. Fuel use in gallons of liquid fuel for the construction of WM facilities (as described in Section C.3) were used to calculate annual emissions for the WM alternatives, in tons per year, for the criteria pollutants CO, NO_2, SO_2, PM_{10}, and ozone (as NO_x and VOC).

The fuel use values were divided by the WM alternative construction period (in years) to obtain an annual fuel usage in gallons. For the assessment of air emissions it was assumed that diesel fuel was used to operate construction equipment at the site. Emission rate factors, in pounds per gallon of fuel consumed, were obtained from *Compilation of Air Pollutant Emission Factors, Volume II, Mobile Sources*, also known as AP-42 (EPA, 1985a). The gallons of fuel used were multiplied by the pounds of pollutant per gallon consumed to obtain the annual emissions in pounds per year. This amount was divided by 2,000 pounds per ton to obtain the annual tons emitted for each of the criteria pollutants.

Worker Vehicle Fuel Use. The total number of FTEs for the construction period (as described in Section C.3) was divided by the construction period in years to obtain the total number of annual workers for each site and alternative combination. In order to provide an upper bound on air quality impacts, it was

assumed that each construction worker travels to and from the construction site in a single vehicle, and that no employees carpool.

Vehicle emissions rates for the worker vehicle trips were obtained by running the EPA-approved vehicle emissions models Mobile5a (EPA, 1994a) and PART5 (EPA, 1994b). Emissions from the Mobile5a model were calculated in grams of pollutant emitted per vehicle mile traveled (VMT) for the pollutants CO, NO_2, and VOC. The PART5 model calculated PM_{10} emissions from vehicle exhaust in grams of pollutant emitted per VMT. For local impacts, it was assumed that the worker vehicles traveled 20 miles to and from work or 40 miles round trip each day. The total number of worker trips per day was multiplied by 40 miles per day and then by 240 working days per year to obtain the VMT per year. The annual VMT was then multiplied by the Mobile5a and PART5 emission rate factors in grams of pollutant per VMT to obtain the total number of grams emitted per year for the criteria pollutants CO, NO_2, VOC, and PM_{10}. The annual emissions in grams were then multiplied by 0.0022 pounds per gram and divided by 2,000 pounds per ton to obtain the annual emissions for worker vehicles in tons per year.

C.4.2.1.2.2.2 Operations-Phase Air Emissions Estimates

The impacts to air quality from the operation and maintenance of WM treatment, storage, and disposal facilities were determined by calculating the emissions from facility fuel use, incineration of waste, transportation of waste, and worker vehicle trips to and from the sites.

Waste Management Fuel Use. Facility fuel use values during the operation period of WM facilities were supplied in pounds of natural gas and gallons of liquid fuel. These fuel use values were used to calculate annual emissions for the WM Alternative, in tons per year, for the six criteria pollutants at each site under each alternative.

The fuel use values were divided by the WM alternative period (in years) to obtain an annual usage for both natural gas, in pounds, and liquid fuel, in gallons. It was assumed that both classes of fuel were burned in an industrial boiler to produce heat and steam for the WM facilities. Emission characteristics for the burning of No. 4 fuel oil, with an assumed sulfur content of 1%, were used to represent the liquid fuel.

Emission rate factors in pounds per million cubic feet for natural gas and pounds per 1,000 gallons of liquid fuel for No. 4 fuel oil were obtained from the *Compilation of Air Pollutant Emission Factors, Volume I Stationary Sources* (AP-42) (EPA, 1985b). The estimates of natural gas use, in pounds, were divided by a natural gas density of 0.0448 pounds per cubic foot to obtain a total number of cubic feet. The total number of cubic feet was then divided by 1 million to obtain the number of million cubic feet used. The number of million cubic feet used was multiplied by the pollutant emission factor, in pounds per million cubic feet, to obtain the amount of pollutant emitted in pounds per year. The total annual pounds emitted was divided by 2,000 pounds per ton to obtain the annual tons emitted for each of the six criteria pollutants.

Direct Emissions from Incinerators: Criteria Pollutants. Criteria pollutant emissions from incineration of waste were calculated for annual emissions, in tons per year, and in parts per million or micrograms per cubic meter. The annual emissions were calculated using waste volumes for treatment and pollutant emission rate data. The emission rate data were supplied for each of the six criteria pollutants in grams of pollutant emitted per kilogram of waste incinerated. The kilograms of waste incinerated per year were multiplied by the grams of pollutant per kilogram of waste treated to obtain the total amount of pollutants emitted in grams per year. The total grams emitted per year were multiplied by 0.0022 pounds per gram and then divided by 2,000 pounds per ton to obtain the total amount of pollutant emissions in tons per year.

Ambient concentrations of the criteria pollutant emissions were calculated by obtaining the annual emissions in grams per year, as described above, and dividing by the period of incineration operation, in seconds per year, to obtain a pollutant emission rate in grams per second. The annual emission rate in grams per second was multiplied by the highest off-site receptor concentration obtained from dispersion modeling. The dispersion model used was the EPA-approved Industrial Source Complex Long Term Revision 2 (ISC2) dispersion model (EPA, 1987). The model was run using an emission rate of one gram per second to produce annual receptor concentration values in micrograms per cubic meter per one gram per second ($\mu g/m^3/g/sec$). To obtain a new concentration value for a different emission rate, the normalized concentration was multiplied by the new emission rate; the new concentration value was in micrograms per cubic meter ($\mu g/m^3$). The new annual concentration was divided by averaging period persistence factors, obtained from the EPA document *Air/Superfund National Technical Guidance Study Series, Screening Procedures for Estimating the Air Impacts of Incineration at Superfund Sites* (EPA,

1992a) to produce short-term concentrations for different averaging periods. These concentration values were compared to the NAAQS or State AAQS pollutant specific averaging periods as appropriate.

Direct Emissions from Incinerators: Hazardous and Toxic Air Pollutants. Annual exposure concentrations of HAPs and TAPs, in $\mu g/m^3$, to the off-site MEI were obtained from the human health risk assessment (Appendix D). For comparison of the HAPs and TAPs concentrations to State or EPA AALs, the concentrations were multiplied by the appropriate AAL averaging period persistence factor. The HAPs concentrations were divided by the AALs to obtain the percentage of the HAPs to the AALs.

The following four AAL guidelines were used; State, EPA Region III, EPA Region IX, and EPA long-term action level. The order in which the different guidelines were applied was as follows: the state guideline was applied in all cases where the state had established guidelines; for those states with no adopted guidelines and located in either EPA Region III or IX, the EPA Region guidelines were applied; for those states with no guidelines which were not located in either EPA Region III or IX, the EPA long-term action levels were applied.

Worker Vehicle Fuel Use. The total number of FTE employees for the waste treatment period was divided by the treatment period in years to obtain the total annual number of workers for each site and WM alternative. It was assumed (with the exception of Hanford) that each worker travels to and from the site in a single vehicle each day. For Hanford, the worker trips were adjusted to account for the percentage of employees who participate in ride-sharing programs. A worker trip reduction value of approximately 19% was obtained from the *FY 1993 Annual Report on In-house Energy Management* (Kaiser Engineers Hanford and Westinghouse Hanford Company, 1994), and applied to all Hanford worker trip numbers.

Vehicle emissions rates for the worker vehicle trips were obtained by running the EPA-approved vehicle emissions models Mobile5a and PART5. Emissions from the Mobile5a model are calculated in grams of pollutant exhaust per VMT for the pollutants CO, NO_2, and VOC. The PART5 model calculated PM_{10} emissions from vehicle exhaust in grams of pollutant emitted per VMT.

For local impacts, it was assumed that the worker vehicle traveled 20 miles to and from work, or a round trip distance of 40 miles per day. The total number of worker trips per day was multiplied by 40 miles per day and then by 240 working days per year to obtain the total VMT per year. The annual VMT was

multiplied by the Mobile5a and PART5 emission factors in grams of pollutant per VMT to obtain the total number of grams emitted per year for the criteria pollutants CO, NO_2, VOC, and PM_{10}. The annual emissions in grams were multiplied by 0.0022 pounds per gram and then divided by 2,000 pounds per ton to obtain the annual emissions for worker vehicle trips in tons per year.

Indirect Emissions from Waste Shipments. Air emissions from shipment of waste from site to site (intersite), and to commercial waste handlers for HW, were calculated for local and national impacts. Local impacts were calculated for the site region of influence (ROI) (defined as a 50-mile radius), while intersite impacts were calculated based on the mileage traveled between sites, excluding the emissions calculated locally in the 50-mile radius. The intersite shipment emissions represent the contributions to regional or national levels of the criteria air pollutants, which are not accounted for in the site analysis.

The total number of waste shipments entering and leaving each WM site for the treatment period was obtained from ANL. The number of shipments per treatment period was then divided by the length of the treatment period in years to obtain the total number of shipments to and from the site on an annual basis.

Vehicle emissions rates for the truck shipments were obtained by running the EPA approved vehicle emissions models Mobile5a and PART5 as described above.

For local impacts the shipment miles were calculated using a travel distance of 50 miles to and from the site, or a round trip of 100 miles. The annual shipment numbers were multiplied by 100 miles to obtain the total annual VMT. The annual VMT was then multiplied by the Mobile5a and PART5 emission rate factors, in grams of pollutant per VMT, to obtain the total annual number of grams emitted for the criteria pollutants CO, NO_2, VOC, and PM_{10}. The annual emissions in grams were then multiplied by 0.0022 pounds per gram and then divided by 2,000 pounds per ton to obtain the annual emissions for shipment by truck in tons per year.

Radiation Dose Estimates. Total radiation dose values, in rem, were obtained from the human health risk assessment for the MEI at an off-site location. The total dose values in rem were multiplied by 1,000 to obtain the dose in millirem (mrem). The dose was then divided by the period of operation (10 or 20 years) and compared to the NESHAP dose standard of 10 mrem per year.

C.4.2.1.3 *Air Quality Impacts Evaluation*

In general, air quality impacts were evaluated by comparing estimated emissions and concentrations to 10% and 100% of Federal or State standards.

C.4.2.1.3.1 Impacts Evaluation for Criteria Pollutants

Criteria pollutant effects were assessed based on the air quality *attainment status* of each site's air quality control region (AQCR), for each of the six criteria pollutants. In general, the site's applicable AQCR is in attainment for a particular criteria pollutant if monitored ambient levels are below the NAAQS for that pollutant. The site's applicable AQCR is a nonattainment area for a particular criteria pollutant if ambient levels equal or exceed the NAAQS for that pollutant. The attainment status of the DOE sites for the NAAQS criteria pollutants are listed in Table C.4–3. Table C.4–4 explains the nonattainment status designations.

C.4.2.1.3.1.1 Impacts for Installations in Attainment Regions

Any predicted increases to ambient concentration levels in areas designated as attainment by the EPA were compared to the NAAQS. If the estimated ambient concentrations exceeded the NAAQS then that WM alternative and the affected area were noted in the PEIS.

The annual criteria emissions, in tons per year, were compared to the allowable increase levels specified in 40 CFR 52.21, Regulations for the Prevention of Significant Deterioration (PSD) of Ambient Air Quality. PSD regulations are applicable in those areas which are listed as in attainment of the NAAQS for each of the criteria pollutants. These allowable increases are referred to in the PSD regulations as PSD increments. If the estimated annual emissions exceeded the allowable PSD increments then that WM alternative and the affected area were noted in the PEIS. PSD increments account for all stationary-source emissions that can be reasonably attributed to the action but do not account for emission from mobile sources. PSD increments for attainment areas are listed in Table C.4–5.

Table C.4-3. Site Criteria Pollutant Attainment Designation

Site	State	NAAQS Attainment Status					
		CO	NO_2	O_3	Pb	PM_{10}	SO_2
ANL-E	IL	A	A	S-17	A	MOD	A
BNL	NY	A	A	S-17	A	A	A
FEMP	OH	A	A	MOD	A	A	A
Hanford	WA	A	A	A	A	A	A
INEL	ID	A	A	A	A	A	A
LANL	NM	A	A	A	A	A	A
LLNL	CA	MOD-1	A	MOD	A	A	A
NTS	NV	MOD-2	A	A	A	MOD	A
ORR	TN	A	A	A	A	A	A
PGDP	KY	A	A	MAR	A	A	A
PORTS	OH	A	A	A	A	A	A
Pantex	TX	A	A	A	A	A	A
RFETS	CO	MOD-2	A	TRANS	A	MOD	A
SNL-NM	NM	MOD-1	A	A	A	A	A
SRS	SC	A	A	A	A	A	A
WIPP	NM	A	A	A	A	A	A
WVDP	NY	A	A	A	A	A	A

CO = carbon monoxide; NO_2 = nitrogen dioxide; O_3 = ozone; Pb = lead; PM_{10} = particulate matter <10 microns; SO_2 = sulfur dioxide. A = Attainment, Nonattainment codes: S-17 = Severe-17; MOD-2 = Moderate-2; MOD-1 = Moderate-1; MOD = Moderate; MAR = Marginal; TRANS = Transitional.

Source: 40 CFR 81, Subpart C: Section 107 *Attainment Status Designations*.

Table C.4-4. Nonattainment Status Definitions

Criteria Pollutant	Nonattainment Designation	NAAQS Exceedance Range
Carbon monoxide (CO)	Moderate-1	9.1 to 12.7 ppm
	Moderate-2	12.8 to 16.4 ppm
Ozone (O_3)	Marginal	0.121 to 0.138 ppm
	Moderate	0.138 to 0.160 ppm
	Severe-17	0.190 to 0.280 ppm
Particulate matter (PM_{10})	Moderate	Greater than NAAQS

[a] Only the nonattainment status designations used in Table C.4-3 are shown.

Table C.4-5. PSD Increments for Criteria Pollutant Emissions in Attainment Areas

Pollutant	Tons/Year
Carbon Monoxide (CO)	100
Nitrogen Dioxide (NO_2)	40
Ozone (O_3)	40
Lead (Pb)	0.6
Particulate (TSP)	25
Particulate (PM_{10})	15
Sulfur Dioxide (SO_2)	40

Source: 40 CFR 52.21.

C.4.2.1.3.1.2 Impacts for Installations in Nonattainment Regions

New stationary sources or major modifications of existing sources located in *nonattainment* areas for criteria pollutants must conform to New Source Performance Standards for new, or modified, existing pollutant sources. In addition, Federal actions which are located in nonattainment areas are required to follow the guidelines of the Clean Air Act General Conformity Rule (GCR) (40 CFR 93) in determining the conformity of the action to Section 176(c) of the Clean Air Act and to approved state or federal implementation plans. The GCR establishes specified *de minimis* levels for criteria pollutant emissions,

in tons per year, based on the AQCR's nonattainment designation. Actions producing emissions which are below the *de minimis* levels are considered to conform, while those equal to or above the limits are required to perform a conformity determination as outlined in the GCR. The GCR accounts for all stationary-sources and mobile sources of emissions that can be reasonably attributed to the action. GCR limits for criteria pollutants in nonattainment areas are listed in Table C.4-6.

Table C.4-6. General Conformity Rule de minimis Levels for Nonattainment Areas

Pollutant & Nonattainment Designation	*de minimis* level (Tons/Year)
Ozone (Volatile Organic Compounds or Nitrogen Oxides)	
– Serious Nonattainment Areas	50
– Severe Nonattainment Areas	25
– Extreme	10
– Other ozone Nonattainment Areas (outside an ozone transport region)	100
– Marginal and moderate Nonattainment Areas (inside an ozone transport region)	
VOC	50
NO_x	100
Carbon Monoxide (CO):	
– All Nonattainment Areas	100
Sulfur Dioxide (SO_2) or Nitrogen Dioxide (NO_2):	
– All Nonattainment Areas	100
Particulate Matter <10 microns (PM_{10}):	
– Moderate Nonattainment Areas	100
– Serious Nonattainment Areas	70
Lead (Pb):	
– All Nonattainment Areas	25

Source: 40 CFR 51.

C.4.2.1.3.2 Impacts Evaluation for Hazardous (including Radionuclides) and Toxic Air Pollutants

The determination of applicable emissions limits and allowable ambient concentrations for pollutants other than the six criteria pollutants, was performed on a site-by-site basis. This approach was necessary because site-specific information on existing levels of non-criteria contaminants was not readily available from the site or regulatory agencies. Information on ambient concentrations of such substances from DOE

site monitoring and environmental impact statements was used when available and applicable. In addition, the applicable regulations and standards vary considerably from state to state. Detailed procedures were defined on a site-by-site basis and described in the pertinent site air quality analyses section in the PEIS waste-type chapters.

C.4.2.1.3.3 Impacts Evaluation for Ozone Precursor Emissions

Ozone pollution is generally caused by reactions between VOC and NO_x, in the presence of sunlight, and generally reaches its maximum many miles downwind of the sources of these substances. The impacts of the WM alternatives on ambient ozone levels were assessed by comparing changes in emissions of VOC and NO_x with the total rate of emissions of these substances from the DOE site, the county, or the AQCR in which the emissions occur. It was assumed that changes in ozone precursor emissions would result in corresponding changes in downwind ozone levels.

C.4.2.1.3.4 Ozone Depleting Substances (ODS)

The stratospheric ozone layer protects the earth from the penetration of harmful ultraviolet radiation. On the basis of substantial scientific evidence, a national and international consensus currently exists that certain man-made halocarbons (including chlorofluorocarbons [CFCs], halons, carbon tetrachloride, and methyl chloroform), react in the upper atmosphere to deplete the stratospheric ozone layer.

In response to this awareness, the U.S. and 22 other countries in 1987 signed the Montreal Protocol on Substances that Deplete the Ozone Layer. The Montreal Protocol, as originally drafted, called for a freeze on the production CFCs at 1986 levels and for CFCs to be reduced by 50% by 1998.

The Clean Air Act (CAA), as amended, includes requirements for controlling ozone depleting substances that are generally consistent with, but in some cases, more stringent than those contained in the Montreal Protocol. Title VI of the CAA, and the implementing regulations (40 CFR 82), call for a phaseout of CFCs by January 1, 2000. In addition to the phaseout of ODS, Title VI includes a variety of other provisions intended to reduce emissions of ODS and promote the recycling of these substances. In addition, DOE facilities are required to adhere to Executive Order 12843 of April 21, 1993: *Reduction*

of Ozone-Depleting Substances. This Executive Order stipulates that all Federal Agencies must implement cost-effective programs to minimize the procurement of materials and substances that contribute to the depletion of stratospheric ozone; and give preference to the procurement of alternative chemicals, products, and manufacturing processes that reduce overall risks to human health and the environment by reducing the depletion of ozone in the upper atmosphere.

Impacts to the stratospheric ozone layer due to emissions from WM activities were estimated. The analysis was performed at the alternative level since emissions of ozone depleting substances is a global rather than a site issue. The analysis was performed for waste types where treatment of waste containing hazardous constituents occurs (i.e., LLMW, TRUW and HW). The compounds analyzed include the ozone depleting substances identified by EPA in 40 CFR 82. Emissions of ozone depleting substances from incineration were tallied from information supplied by the health risk assessment. The total emissions from each alternative were found to be exceedingly small for all waste types, and in fact were <0.1 pound per year for all LLMW alternatives (DOE, 1995). These minor emissions would not be expected to have any measurable affect on upper atmosphere ozone levels. Emissions of ozone depleting substances from other treatment, storage and disposal operations were assumed to be small due to the nature of these activities, and the mandated phase-out of the use of ozone depleting substances.

C.4.3 Water Resources Impacts Analysis Methods

This section describes the methods used to estimate the impacts of proposed WM alternatives on surface water and groundwater resources. Section C.4.3.1 provides an introduction, C.4.3.2 briefly describes the regulations that limit impacts to water resources, C.4.3.3 lists the assumptions used in the impacts analyses, C.4.3.4 describes impacts that were considered but not evaluated in detail, and C.4.3.5 describes the methods used to assess the impacts on water resources that were evaluated in detail.

C.4.3.1 Introduction

The alternatives analyzed in this PEIS can affect the quantity or the quality of surface water and groundwater. Water availability elements that may be affected include surface water flow, floodplains, groundwater flow, and aquifer water levels. Surface water and groundwater rights, allocations and usage

may also be affected. Water quality elements that may be affected include areas of surface water and groundwater that are already contaminated, and receiving water bodies such as streams, lakes, rivers, and groundwater aquifers. The ROI for water resources is the area encompassed by onsite and offsite surface water and groundwater bodies and their watersheds, which may be affected by site activities.

Water availability is affected when water withdrawal or discharge causes an appreciable change in surface water flow or groundwater levels. Water quality is affected when discharges cause an appreciable increase in the concentration of sediments or contaminants in the receiving water body. In addition, water quality may be affected when activities cause the movement of existing contamination. For example, activities that change the water table gradient could accelerate offsite movement of a plume of groundwater contamination.

Construction, operation, and transportation activities can adversely affect water resources, both during normal operations and when an accident occurs. Waste management activities may adversely affect surface and groundwaters, as a result of increased water use, increased stormwater runoff, increased wastewater discharges, and releases to groundwater from disposal facilities. Transportation of wastes may affect water resources from the deposition of exhausts emitted from the vehicles and from accidental spills into water bodies.

C.4.3.2 Regulatory Considerations

The Clean Water Act (33 USC 1251 et seq.), as amended, requires a permit for all discharges to surface waters (including stormwater discharges) under the National Pollutant Discharge Elimination System (NPDES) program. NPDES permits set discharge limits for contaminants and require periodic monitoring to ensure compliance. In addition, Section 404 of the Clean Water Act regulates the discharge of fill material into navigable waters of the United States.

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 USC 9601 et seq.), as amended, requires the cleanup of contaminated areas and specifies cleanup levels by application of Applicable or Relevant and Appropriate Requirements (ARARs).

The Safe Drinking Water Act (42 USC 300 et seq.) regulates drinking water quality. The maximum contaminant levels established in the implementing regulations (40 CFR 141), although not directly applicable to groundwater quality, are commonly used as ARARs to determine appropriate levels for groundwater cleanup. Since the drinking water standards adequately protect human heath, concentrations of contaminants in groundwater at or below these levels are considered to be acceptable. In addition, DOE derived concentration guides for drinking water (DOE, 1990) are sometimes cited as "to be considered" requirements under CERCLA.

Executive Order 11988 (Floodplain Management) and 10 CFR 1022 (Compliance with Floodplain/Wetland Environmental Review Requirements) require that proposed projects be reviewed to determine their impact on floodplain and wetland areas. Federal agencies are required to avoid, when possible, occupying and modifying floodplains. Floodplain and wetland assessments are required for actions that occur within the 100-year floodplain, and for "critical actions" that occur within 500-year floodplains.

Monitoring of effluents and nearby water bodies for adverse effects from WM facilities is required by a number of statutes and their related regulations. Under the Clean Water Act, the National Pollutant Discharge Elimination System requires that discharges to waters of the United States be monitored and that levels of contaminants in the effluent remain below permitted levels. The Clean Water Act, as amended, also requires stormwater discharges to be monitored. The regulations implementing the RCRA (42 USC 6901 *et seq.*) have extensive requirements for groundwater monitoring at hazardous waste treatment, storage, and disposal facilities. Levels of contaminants in the groundwater must remain below levels described in the regulations. The regulations of the Toxic Substances Control Act (15 USC 2601 *et seq.*) require similar monitoring at treatment, storage, and disposal facilities for asbestos and PCBs. DOE orders (e.g., 5820.2A (DOE, 1988)), require surface water and groundwater monitoring at radioactive waste treatment, storage, and disposal facilities. In addition, EPA regulations (40 CFR 191) require monitoring of treatment, storage, and disposal facilities at DOE sites that dispose of HLW and TRUW.

Monitoring generally involves periodic measurement of characteristics of the effluent or receiving water body including measurement of radionuclide and chemical concentrations, temperature, pH, and flow. Groundwater monitoring usually involves the analysis of samples collected from wells drilled for this purpose. Surface water monitoring generally involves sampling from stations located downstream from

the effluent discharge point. These monitoring stations are located such that they are likely to intercept any releases from a WM facility.

Monitoring provides the opportunity to detect excessive discharges from a WM facility before significant harm is done to human health or the environment. Once the cause of the excessive discharge is located, corrective actions are implemented to contain and then eliminate the source of the problem. DOE will comply with all applicable monitoring requirements.

C.4.3.3 Assumptions

Assumptions for the water resources impacts analysis included the following:

- Current conditions of water resources adequately represent future baseline conditions.

- Water for WM activities would be supplied by current water sources. If water is currently supplied by wells in aquifer X, water for the proposed alternatives would be supplied by wells in aquifer X. If water is currently supplied by a municipal system, then water for the proposed alternatives would be supplied by that system. If water is currently supplied by river Y, water for new facilities would be supplied by river Y.

- Because municipal water is the current source, onsite surface and groundwater resources would not be affected by water withdrawals at Rocky Flats Environmental Technology Site (RFETS), Sandia National Laboratory-New Mexico (SNL-NM), and Waste Isolation Pilot Plant (WIPP). Because groundwater is used as the current source, surface water resources would not be affected by water withdrawals at Argonne National Laboratory–East (ANL-E), Brookhaven National Laboratory (BNL), Fernald Environmental Management Project (FEMP), INEL, Los Alamos National Laboratory (LANL), LLNL Site-300, Nevada Test Site (NTS), Pantex Plant, Portsmouth Gaseous Diffusion Plant (Ports), and SRS. Because surface water is the current source, groundwater resources would not be affected by water withdrawals at Hanford, Oak Ridge Reservation (ORR), Paducah Gaseous Diffusion Plant (PGDP), and WVDP.

- Although some sites under consideration receive water from more than one source, they are assumed to obtain their water as follows: (1) Hanford Site from surface water; and (2) Lawrence Livermore National Laboratory (LLNL)–Site 300; and Savannah River Site (SRS) from groundwater. Since only a small portion of the Hanford Site is supplied by groundwater, it was assumed that all water would be supplied by surface water. At LLNL Site-300 water is supplied by an offsite municipal source and onsite groundwater, but to be conservative, it was assumed that groundwater supplied all the water to the site. At SRS, surface water is generally used only for cooling water. Therefore, it was assumed that groundwater would be used to supply WM facilities.

- During normal operations, no untreated sanitary or process wastewater would be discharged to surface or groundwaters at any site. Wastewater would be recycled to the extent possible, would be treated, and then discharged to existing process or sanitary treatment plants, as appropriate. After the additional treatment, wastewater would be discharged from these plants in compliance with all NPDES and industrial wastewater discharge permits.

- The manner of disposing wastewater would not change. If wastewater is currently discharged to a municipal sewer system, than future wastewater would be discharged to that system. If wastewater is currently discharged to a treatment plant, effluent would continue to be discharged to the treatment plant.

- Since the locations for the WM have not been selected, it was not possible to determine which particular onsite water course(s) would be affected. For this impacts assessment, the major offsite water body was assumed to be the receiving water body.

- Onsite surface water resources would not be affected by effluent discharges at SNL-NM, because wastewaters are discharged to municipal wastewater treatment systems. Surface water resources would not be affected by effluent discharges at Hanford, INEL, LANL, LLNL-Site 300, NTS, Pantex, or WIPP, because wastewaters are not discharged to natural-flowing surface water bodies.

- For municipal water supply systems, withdrawals up to the capacity of the site distribution system are acceptable. It was assumed that, if water is available from the utility, the necessary steps have been taken to ensure that operations meet Federal, State, and local environmental regulations. These steps

may include withdrawal permits, water rights agreements, and environmental impact reports. This same assumption applies to municipal wastewater treatment.

- During normal operation of waste storage facilities, no water (including precipitation, surface water, or groundwater) would be allowed to come into contact with the waste. Therefore, surface and groundwater quality would not be affected because runoff would not be contaminated. During normal operation of waste treatment facilities, no releases directly to groundwater would occur. Therefore, groundwater quality would not be affected.

- Seepage of contaminated groundwater from disposal facilities could contaminate surface water. This contamination would be diluted by surface water flows such that the concentration in the surface water would be less than the concentration in the groundwater. Therefore, the impacts analysis of contaminated groundwater bound the impacts of contaminated surface water.

- As described in Appendix E, for waste transported in U.S. Nuclear Regulatory Commission (NRC) Type B certified containers, the probability of container leakage during an accident would be very low. Therefore, transportation accidents involving Type B containers are not likely to affect surface or groundwater resources.

C.4.3.4 Impacts Considered But Not Evaluated in Detail

This section describes potential impacts to water resources that were not evaluated in detail in the PEIS. These impacts were not evaluated in detail because they: 1) could be evaluated generically rather than for each alternative; 2) are believed to be minor; or 3) require site-specific analyses that are not possible at this time.

Impacts to Floodplains

If possible, new WM facilities would be located outside the 100-year floodplain, and if the facilities are considered "critical actions," would be located outside the 500-year floodplain. Even if the WM facilities are located outside floodplains, access roadways and utility corridors may encroach on floodplains. The impacts of these activities cannot be estimated at this time since the specific locations of the WM facilities have not been selected. Therefore, the requirements of Executive Order 11988 (Floodplain Management)

and 10 CFR 1022 (Compliance with Floodplain/Wetland Environmental Review Requirements) are satisfied, and a floodplain and wetland assessment is not required in the PEIS. Compliance with floodplain and wetland review requirements would be examined in detail when specific locations are proposed in site-specific or project-level NEPA documents.

Impacts from Runoff and Sedimentation

During the construction period, surface water resources could be affected by runoff and sedimentation from site clearing. During operations, water resources could be affected by increased runoff from buildings, parking lots, and cleared areas. Generally, the impacts would be proportional to the amount of land disturbed during construction or occupied during operations. In all cases, the effects would be minimized by implementing the best management practices for stormwater runoff and erosion control. These practices include the use of silt fences, runon and runoff diversion ditches, and stormwater retention and sedimentation ponds. In addition, stormwater discharges would be regulated by the new NPDES stormwater discharge permits. Therefore, impacts from these activities are not expected to be major, and should not influence the choice of alternatives. If necessary these impacts would be evaluated in site-specific or project-level NEPA documents.

During WM operations, stormwater runoff may be contaminated with small quantities of materials deposited from air-borne emissions. Some of the potentially contaminated stormwater runoff would be contained within onsite stormwater collection ponds. The stormwater runoff would evaporate or infiltrate into the ground, although the ponds may discharge to surface water bodies during high flow conditions. The volume of stormwater in the ponds would be expected to change somewhat between the alternatives, depending on the size of the areas drained, but the quality of the water would be expected to be similar. Stormwater runoff would be routinely monitored and any discharges would be in compliance with site-specific permit limits. The impacts of runoff were not evaluated in quantitative fashion, but were assumed to be low due to regulations and practices for erosion control and stormwater management. Impacts from stormwater runoff are highly site-specific and would be evaluated in NEPA documents tiered to the WM PEIS.

Stormwater runoff that is not contained within the stormwater management system, may contaminate surface waters. This runoff may contain small amounts of contamination from airborne emissions. Impacts from contaminated stormwater runoff are expected to be minor, but are highly site-specific and would depend on the design of the stormwater management system, meteorologic conditions, topography, soil,

and the affected surface water body at the site. These impacts should not influence the choice of alternatives, but would be evaluated in site-specific or project-level NEPA documents if necessary.

Impacts from Sanitary Wastewater Discharges

The majority of any new aqueous waste would be sanitary waste generated by the employees needed for the alternative. Sanitary wastes by definition are non-hazardous and would be discharged to existing sanitary wastewater treatment facilities. After treatment, sanitary wastewaters would be recycled, or discharged from these plants in compliance with site-specific NPDES, or industrial wastewater discharge permit limits. Limits on the amount of contaminants in the effluent are set by the regulators after consideration of potential adverse ecological and human health effects in the receiving water body. The impacts on existing sanitary wastewater treatment facilities are discussed in the infrastructure sections of each waste-type chapter.

Although the volume of sanitary wastewater may vary between alternatives, it would remain similar in quality. Therefore, current conditions would not change appreciably unless the discharge volume was a large percentage of the flow in the receiving water body. The impacts of combined sanitary and process wastewater discharges on surface water availability were evaluated for all waste types in the site tables, and show only minor (less than 1%) changes in flow. Since the quality of effluent discharges from sanitary wastewater treatment facilities would not change, and the flow would not be a significant fraction of the average flow in the major receiving water body, current monitoring captures the majority of the water quality effects of sanitary wastewater treatment plant discharges for the alternatives. Therefore, impacts from these activities are not expected to be major, and should not influence the choice of alternatives. If necessary these impacts would be evaluated in site-specific or project-level NEPA documents.

Impacts from Process Wastewater Discharges

Process wastewater (aqueous waste) is wastewater potentially contaminated by hazardous or radioactive constituents during treatment, storage or disposal activities. Process wastewaters from waste treatment facilities would be discharged to existing wastewater treatment facilities, where possible. After treatment, wastewaters would be recycled or discharged from these plants in compliance with site-specific DOE, NPDES, or industrial wastewater discharge permit limits.

The aqueous wastewaters that are currently being managed at the sites are not part of the WM PEIS. The WM PEIS includes only those aqueous wastes generated by the facilities analyzed as part of the PEIS alternatives. These WM facilities were assumed to be very efficient in water use. Process wastewater would be treated and recycled to the extent practicable with little liquid effluent discharge. Therefore there is little process wastewater that would be discharged to surface waters after treatment. Since process wastewater treatment would continue at all the sites where it presently occurs, and the volumes of process wastewater treated at each site would vary only slightly between alternatives. Therefore, the effects of process waste treatment on surface and groundwater quality are already accounted for in the affected environment section. Therefore, impacts from these activities are not expected to be major, and should not influence the choice of alternatives. If necessary these impacts would be evaluated in site-specific or project-level NEPA documents.

Impacts to Small Onsite Streams

Wastewater released by WM facilities may enter small onsite water courses before entering the major surface water body near the site. Additional effluents in these small streams, may cause eroding of parts of the stream channel and sedimentation in other parts of the channel. Water quality may also be affected because the facility effluents may form a large fraction of the natural streamflow. Before NPDES permits are renewed or issued by the EPA or state agencies, water quality in the receiving water body would be considered in setting effluent limits for the facilities. Impacts on small onsite water bodies would be evaluated in detail in site-specific or project-level NEPA documents.

Impacts of Water Withdrawals on the Movement of Groundwater Contamination Plumes

Withdrawals of groundwater for use by WM facilities could cause the movement of existing areas of groundwater contamination. This could occur where water levels are lowered by water withdrawals. Impacts of this sort are unlikely because existing wells would be used to the extent possible and new wells would be located to minimize their impact on the movement of existing contaminant plumes. Impacts on existing areas of contamination would be evaluated in detail in site-specific or project-level NEPA documents.

Impacts from Waste Disposal on Surface Water Quality

Seepage of contaminated groundwater from disposal facilities could contaminate surface water. This would be expected to occur at sites with shallow groundwater, and surface water bodies that are fed by

groundwater discharge (springs). Some sites (INEL, NTS, and Pantex) are located above deep groundwater such that surface water would not be expected to become contaminated. Other sites (LANL, LLNL, SNL-NM, and WIPP) have a low potential for surface water contamination due to the intermittent nature of most of the sites streams. Where contaminated groundwater discharges to the surface, dilution in "clean" surface waters would cause concentrations of contaminants in surface water to be lower than concentrations in groundwater. Therefore the groundwater pathway was assumed to be the major pathway for movement of contaminants beyond the disposal facility boundary, and was the pathway that was examined in detail.

Impacts from Transportation

Routine transportation would involve the intersite movement of waste by truck or rail, and the travel of workers to and from work. Waste materials would not be released during routine transportation of wastes. Therefore, impacts from transportation would be limited to the deposition and runoff of vehicle emissions to surface waters and the infiltration of materials deposited on the surface into groundwaters. As described in Section C.4.2 on air quality, vehicle emissions at any one place from transportation would be small. Therefore, the impacts of routine transportation on surface and ground waters would be minimal.

Impacts from Transportation Accidents

Because the waste would be shipped in sealed NRC or DOT approved containers, impacts to water resources would be unlikely unless a ruptured container fell directly into a surface water body. In the unlikely event that waste was released from a shipping container, cleanup response to the accident would be swift, and the release would be contained and cleaned up as quickly as possible. The spill response and cleanup, and any subsequent remediation, would be conducted in accordance with the CERCLA as amended, the National Oil and Hazardous Substances Pollution Contingency Plan, and DOE emergency response requirements. Since a swift clean-up would occur, long-term impacts to water quality are unlikely.

C.4.3.5 Impact Assessment Methods for Water Resources

The environmental impacts on surface water and groundwater availability and groundwater quality were assessed by determining the potential change from baseline conditions caused by implementing the

Alternatives. A summary of the water resources impacts that were evaluated in detail in the PEIS is shown in Table C.4–7.

First, current conditions at the sites were summarized from data in the Affected Environment Technical Report. Table C.4–8 shows the affected environment information used for each site, which includes the following types of information:

- Source(s) of water for the site
- Current rate of municipal water use (gallons per day)
- Current rate of surface water use (gallons per day)
- Current rate of groundwater use (gallons per day)
- Location of wastewater discharge(s)
- Average streamflow for the major water body (gallons per day)
- The presence of Sole-Source Aquifers in the ROI as defined by the EPA
- The presence of federally designated Wild and Scenic Rivers in the ROI

Then the applicable facility design data for the sites affected by the proposed alternatives were assembled from the data tables in Appendix C, including:

- Water used during construction (total gallons)
- Water used during operations (gallons per year)

Water used during construction was converted to daily usage by dividing by the total number of days of the construction period, assuming 250 work days per year and a 2-year construction period. Water used during operations was converted to daily usage, assuming 250 work days per year. Figures for the number of work days per year for construction and operation and for the duration of the construction period were supplied in the EG&G reports (e.g., EG&G and MK, 1994).

Table C.4-7. Impacts Evaluated in Detail for Water Resources

Impacts Assessed	Relevant Waste Types	Period of Analysis	Activities for Which Impacts are Assessed	Impacts Measure	Presentation of Results
Water Availability	All five waste types	Construction	Estimated for water used: – by personnel – for concrete – for dust suppression	Percent increase in current water use	Tabular and text discussion
				Percent decrease in stream flow	Text discussion
	All five waste types	Operations	Estimated for water used: – by personnel – by treatment and disposal processes	Percent increase in current water use	Tabular and text discussion
				Percent decrease in stream flow	Text discussion
			Estimated for effluent discharged from sanitary and process wastewater treatment facilities	Percent increase in stream flow	Text discussion
Groundwater Quality	LLMW and LLW	Post-Closure	Disposal of waste	Percent of drinking water quality standard	Tabular and text discussion

The following calculations were performed for each alternative by combining the baseline environmental data with the facility design data:

- Percentage of current site water usage for increment added during construction
- Percentage of average streamflow for water usage increment added during construction
- Percentage of current site water usage for increment added during operations
- Percentage of average streamflow for water usage increment added during operations
- Percentage of average streamflow for effluent discharge increment added during operations, assuming that all water used is ultimately discharged as effluent from a wastewater treatment facility

Table C.4-8. Affected Environment Data for Water Resources[a]

Site	Source of Water Supply for Site	Current Use (gpd)			Waste-Water Discharge Location	Average Flow in Major Stream (gpd)
		Municipal Water	Surface Water	Groundwater		
ANL-E	Chicago Sanitary & Ship Canal and Niagara Aquifer	NA	350,000	626,000	City of DuPage Municipal Sewer System, Sawmill Creek & Des Plains River	582,000,000
BNL	Upper Glacial Aquifer & Magothy Aquifer[b]	NA	NA	4,500,000	Onsite Streams & Peconic River	1,000,000
FEMP	Miami Valley Aquifer[b]	NA	NA	400,000	Onsite Streams & Great Miami River	1,823,000,000
Hanford	Columbia River, Deep Wells and City of Richland Municipal System	d	9,567,000	184,000	Onsite Drain Fields, Evaporation Ponds & Columbia River	77,560,000,000
INEL	Snake River Plain Aquifer[b]	NA	NA	5,700,000	Onsite Evaporation Ponds	NA
LANL	Main Aquifer	NA	NA	4,100,000	Onsite Canyons	NA
LLNL Site-300	Deep Groundwater & Hetch Hetchy Aqueduct	e	NA	87,000	Onsite Ponds and Leach Fields	NA
LLNL-L	Hetch Hetchy Aqueduct and Alameda County	717,000	NA	NA	City of Livermore Municipal Sewer System	NA
NTS	Groundwater	NA	NA	1,367,000	Onsite Evaporation Ponds	NA
ORR	Clinch River	NA	18,300,000	NA	Onsite Streams & Clinch River	3,003,000,000
PGDP	Ohio River	NA	15,000,000	NA	Onsite Streams & Ohio River	174,521,000,000
Pantex	Ogallala Aquifer	NA	NA	548,000	Onsite Playas	NA
Ports	Alluvial Aquifer & Scioto River	NA	0	14,000,000	Onsite Streams & Scioto River	3,036,000,000
RFETS	Denver Water Board	272,000	NA	NA	Onsite Streams & Walnut Creek	142,000,000
SNL-NM	City of Albuquerque & Kirtland Air Force Base	1,000,000	NA	NA	City of Albuquerque WWTP	NA
SRS	Groundwater & Savannah River	NA	112,000,000	1,600,000	Onsite Streams & Savannah River	6,463,000,000
WIPP	City of Carlsbad Municipal System	14,400	NA	NA	Onsite Evaporation Ponds	NA
WVDP[c]	Two Onsite Surface Water Reservoirs	NA	70,000	NA	Onsite Streams & Buttermilk Creek	41,000,000

[a] Data from "Affected Environment for the Waste Management Programmatic Environmental Impact Statement Department of Energy Sites"(M/B, 1995b). No Sites have Federally designated Wild & Scenic Rivers in the ROI, although the Hanford Reach of the Columbia River is being considered for inclusion. WWTP = Waste Water Treatment Plant. NA = Not applicable. INEL includes INEL, ANL-W and NRF. LLNL-L includes LLNL-L and SNL-CA. SNL-NM includes SNL-NM and ITRI.
[b] Sole-source aquifer.
[c] Site is upstream from a sole-source aquifer.
[d] Water use rate not available. Municipal water used to supply administrative areas (700, 1100 and 3000 Areas) near the City of Richland, only.
[e] New system that has a capacity of 500,000 gallons/day.

These calculations formed the basis for assessing the impacts of the proposed alternatives on water availability.

Percentages less than or equal to 1% were considered to be negligible and were not discussed further. The 1% threshold is based on the assumption that a change in current conditions of this magnitude is not likely to produce a significant impact. Thus the 1% level was used as a screening level below which impacts were assumed to be minor.

Percentages greater than 1% were examined on a case-by-case basis because impacts would depend on the characteristics of the affected site. At one site a change in groundwater usage of 10% may be problematic, while at another site a change of this magnitude may not be a problem. When necessary, water usage was compared to the capacity of the water supply distribution system, regional water use, or water rights agreements to determine if these values would be exceeded. The effects of projected demands for proposed facilities on existing water supply or wastewater treatment infrastructures are evaluated in the section on infrastructure impacts.

The impacts of waste disposal on groundwater quality were estimated by using the information for the groundwater pathway generated during the health effects modeling. The movement of contaminants was modeled for each site using the Multimedia Environmental Pollutant Assessment System (MEPAS) code, modified to better account for radioactive decay and ingrowth of daughter radionuclides. The model estimated concentrations for radionuclides and hazardous constituents at a hypothetical well located 300 meters from the center of the disposal facility for 70-year increments between the end of institutional control and 10,000 years. Impacts from leakage during operations and institutional control are unlikely since leachate and groundwater monitoring are likely to detect the leak before significant degradation of groundwater quality could occur. Disposal of 36 radionuclides was evaluated for LLMW and LLW; disposal of 15 hazardous constituents was evaluated for LLMW. The maximum concentrations above 0.001 pCi/L for radionuclides and 0.000001 mg/L for hazardous constituents were then tabulated and compared to groundwater quality comparison criteria. The year of the maximum concentration was also included in the tabulation. Values above 25% of the comparison criteria were noted, and the potential impacts of these concentrations were discussed in the PEIS. Appendix D provides more detail on the health effects methodology used to model the groundwater pathway. This appendix states that the uncertainty in the health risk results for the groundwater pathway is approximately 400%.

As shown in Table C.4–9, water quality comparison criteria used in the PEIS include maximum contaminant levels of the EPA National Primary Drinking Water Regulations (40 CFR 141) and standards for drinking water from DOE Order 5400.5 (DOE, 1990). Although not directly applicable to groundwater quality, these criteria are commonly used as ARARs to determine appropriate levels for groundwater cleanup. Since these criteria adequately protect human heath, then groundwater contamination at or below these levels is normally considered to be acceptable. EPA National Secondary Drinking Water Regulation secondary maximum contaminant levels (40 CFR 143) were used as comparison criteria where maximum contaminant levels did not exist, although they focus on qualities of taste and odor rather than protection of health.

Table C.4–9. Water Quality Comparison Criteria[a]

Constituent	EPA Drinking Water Regulations			DOE Derived Concentration Guides for Drinking Water[f]	EPA Quality Criteria for Fresh Water[g]	
	MCL[b]	SMCL[d]	Proposed MCL[e]		Acute	Chronic
1,2-Dichloroethane	0.005				118	20
Actinium-227			1.27	0.4		
Americium-241			6.34	1.2		
Americium-242m			1.27	1.2		
Americium-243			6.37	1.2		
Arsenic	0.05				0.36	0.19
Barium	1					
Benzene	0.005				5.3	
Cadmium	0.005				0.0039	0.0011
Carbon Tetrachloride	0.005				35.2	
Carbon-14			3200	2800		
Cesium-135			794	800		
Cesium-137			119	120		
Chromium +VI	0.1				0.016	0.011
Curium-242			133	40		
Curium-244			9.84	2.4		
Curium-245			6.23	1.2		
Cyanide	0.2				0.022	0.0052
Iodine-129			21	20		
Lead	0.015 c				0.082	0.0032
Mercury	0.002				0.0024	0.000012
Methylene Chloride	0.005					
Neptunium-237			7.06	1.2		
Nickel-59			27000	28000		
Nickel-63			9910	12000		

Table C.4-9. Water Quality Comparison Criteria[a]—Continued

Constituent	EPA Drinking Water Regulations			DOE Derived Concentration Guides for Drinking Water[f]	EPA Quality Criteria for Fresh Water[g]	
	MCL[b]	SMCL[d]	Proposed MCL[e]		Acute	Chronic
Palladium-107			36600	40000		
Plutonium-238			7.02	1.6		
Plutonium-239			62.1	1.2		
Plutonium-240			62.2	1.2		
Plutonium-241			62.6	80		
Potassium-40				280		
Protactinium-231			10.2	0.4		
Radium-226	3 c		20	4		
Samarium-151			14100	16000		
Selenium	0.05				0.26	0.035
Selenium-79				800		
Silver		0.1			0.0041	0.00012
Strontium-90	8		42	40		
Technetium-99			3790	4000		
Thorium-229			49.3	1.6		
Thorium-230			79.2	12		
Thorium-232			88	2		
Tin-126			293	320		
Uranium-233			13.8	20		
Uranium-234			13.9	20		
Uranium-235			14.5	24		
Uranium-236			14.7	20		
Uranium-238			14.6	24		
Zirconium-93			5090	3600		

[a] Chemicals in mg/L. Radionuclides in pCi/L. MCL = maximum contaminant level. SMCL = secondary maximum contaminant level. Comparison criteria for 1,2,2-trichloro-1,1-trifluroethane and acetone were not found.
[b] Source: 40 CFR 141, *National Primary Drinking Water Regulations*, and EPA, 1991, *National Primary Drinking Water Regulations, Synthetic Organic Chemicals and Inorganic Chemicals; Final Rule*, 40 CFR 141 and 142, 57 FR 31776.
[c] Action level.
[d] Source: 40 CFR 143, *National Secondary Drinking Water Regulations*. SMCLs based on taste and odor effects.
[e] Source: EPA, 1991. *National Primary Drinking Water Regulations; Radionuclides, notice of proposed rulemaking*, 56 FR 33050, July 18, 1991. Concentration based on 4 mrem/year dose. Alpha emitters based on lifetime incidence risk of 1×10^{-4}
[f] Source: DOE Order 5400.5 (DOE, 1990), *Radiation Protection of the Public and the Environment*, June 5, 1990. Concentration based on 4 mrem/year effective dose equivalent.
[g] Source: EPA, 1986. *Quality Criteria for Water, 1986*, EPA 440/5-86-001, Office of Water Regulations and Standards, Washington, DC.

The EPA proposed maximum contaminant levels for radionuclides in drinking water (EPA, 1991) were not used because they are proposed regulations that are not yet in effect. Note that most of the EPA proposed drinking water standards for radionuclides are similar to the DOE derived concentration guides

that were used. EPA quality criteria for fresh water (EPA, 1986) were not used since these apply primarily to surface water quality.

It is important to note that DOE Order 5820.2A (DOE, 1988) for radioactive waste management, RCRA for hazardous waste, the Toxic Substances Control Act for waste containing PCBs, and DOE's Performance Assessment process would not allow a disposal facility to be constructed that would cause significant contamination of groundwater outside the facility boundary. If significant groundwater contamination was predicted by the Performance Assessment process, changes in the waste acceptance criteria would be made to limit disposal of the waste causing the problem. The wastes excluded from disposal would then become "special case wastes" that would require additional treatment prior to disposal, would be disposed at another DOE site where the wastes meet the waste acceptance criteria, or would be stored until a method was found to treat or dispose of the waste.

Indirect impacts to water resources were deferred to site-specific or project-level NEPA documents. These include the effects of increased offsite water use caused by in-migrating employees and their families.

C.4.4 Ecological Impacts Analysis Methods

Effects on ecological resources of waste treatment, storage, or disposal activities proposed at the 17 major DOE sites and the impacts of waste transportation were evaluated for each waste type under each alternative for:

- routine activities of constructing and operating WM facilities; and
- accidental releases of transported wastes.

Table C.4–10 lists the ecological impact type, the particular resources affected, the general method used, the waste types to which each method was applied, and the type of presentation format for each ecological impact evaluated.

C.4.4.1 Routine WM Activity Impacts

The ecological impacts of routine WM activities were assessed in terms of potential disturbance or loss of nonsensitive terrestrial habitat resulting from site clearing for construction of WM facilities, the potential for site clearing and WM facility operations to affect nearby sensitive habitats, and the potential for airborne contaminant releases from waste treatment facilities to be toxic to terrestrial wildlife.

C.4.4.1.1 *Direct Nonsensitive Habitat Impacts*

During the construction phase, ecological resources will be affected through disturbance or loss of habitat resulting from site clearing. Terrestrial resources will be directly affected by land clearing through changes in vegetative cover, which will adversely affect the habitat of terrestrial animals.

These changes may be important for individual animals of certain species with limited home ranges, such as small mammals and songbirds. Likely impacts include increased direct mortality and susceptibility to predation. Individual animals with larger home ranges, such as game animals and raptors, may not be adversely affected by the decreases in vegetative cover resulting from site construction. In general, it is not expected that any nonsensitive species populations will be affected by the limited amounts of nonsensitive habitats lost or disturbed in the WM program. The discussion of the potential for these effects in the waste-type chapters draws a comparison between the limited amounts of acreage likely to be disturbed in managing the waste type at individual sites and the extent of the nonsensitive habitats available regionally.

Table C.4-10. Ecological Resources Impacts Analyzed for the WM Alternatives

Ecological Impact Analyzed	Affected Ecological Resource	Impact Analysis Method	Applicable Waste Types	Presentation of Results
Habitat Effects—Routine WM Activities				
Non-sensitive Habitat Loss	Terrestrial plants and animals	Comparison of habitat loss at WM construction sites to general habitat range	All five types	Text discussion
Potential for Sensitive Habitat Effects	Nearby wetlands and other sensitive habitats	Likelihood of impacts to nearby sensitive habitats by comparing construction acreage to available acreage of nonsensitive habitats	All five types	Text discussion
Contaminant Exposures—Routine WM Activities				
Terrestrial Species Exposures	Terrestrial animal species	Comparison of estimated radiation dose of representative species with toxicity standard	LLMW, LLW, TRUW	Text discussion
Habitat Effects or Contaminant Exposures—Routine WM Activities				
Sensitive Species Concerns	Federally and State-listed endangered and threatened species	Numbers of Federally and State-listed species displayed by site/alternative	All five types	Tabular listing
Contaminant Exposures—Accidents				
Effects of Transportation Accidents	Aquatic Species in Streams crossing transportation corridors	Results of scenario-based modeling analysis of accidental spill effects on fish in various size streams	LLMW, LLW, TRUW	Text discussion

C.4.4.1.2 *Indirect Sensitive Habitat Impacts*

Many of the DOE sites contain sensitive habitats. The degree to which those habitats would be unaffected by noise or vibration disturbance, human presence, vehicle or equipment emissions, runoff, or encroachment by nearby WM facility construction or operations activities at any site would depend on DOE's ability to avoid locating the facilities near the sensitive habitats. A measure of this ability is the percentage of available land that facility construction under any WM alternative would require at a site. Available acreage was estimated from site development plans either using land designated for waste operations or subtracting the acreage of existing structures and sensitive habitats, such as wetlands and

wildlife management areas, from the total site acreage. Potential for impacts was assessed by estimating the percentage of available land by site and alternative and listing those that equal or exceed 1% in the waste-type chapters. Further evaluation of those sites where the percentage equals or exceeds 1% is presented in the waste-type chapters in terms of the expectation that DOE will be able to avoid impacts to sensitive habitats.

Aquatic resources may be indirectly affected through increased runoff and sedimentation loadings to surface waters from disturbed terrestrial areas. However, the use of various mitigation techniques should minimize potential facility construction impacts to aquatic ecological resources. Direct discharges of contaminants to surface waters from the routine operation of facilities are expected to be limited by engineering control practices. Therefore, impacts to aquatic organisms are expected to be minimal.

Habitat Effects Data Sources. Estimates of the acreage cleared to build WM facilities were compiled from the engineering analysis outputs described in Section C.3.1 of this appendix. For each waste type and WM alternative, the total disturbed area was estimated by summing the plant area required for all WM facility modules (plus 10-foot buffer zones) and the parking area. Plant area was estimated as a function of waste throughput requirements, whereas, parking area was estimated on the approximate number of full-time plant employees. Available acreage was estimated using site development plans and site environmental reports.

Habitat Effects Data Evaluation. For nonsensitive habitat impacts, the construction acreage requirements at each site under each alternative are compared qualitatively with the general extent of these habitats in the affected regions.

For sensitive habitat impact evaluation, sites where the proposed construction activities would disturb more than 1% of the available WM area are noted in the waste-type chapters and additional discussion is included about whether these greater percentages would indicate that indirect effects to sensitive habitats are likely. Additional investigations of the type that would be conducted as part of the site-specific or project-level NEPA evaluations tiered to the PEIS, would be needed to confirm or refute any presumed significant habitat impacts.

C.4.4.1.3 *Potential Toxicity to Terrestrial Wildlife*

The impacts of airborne releases of radionuclides and hazardous chemicals to terrestrial animals living near waste treatment facilities were estimated using atmospheric emission/deposition modeling. This modeling, which used the same atmospheric emissions estimates as used in the human health risk assessment, provided estimates of doses of radiological and nonradiological contaminants deposited onto near-field and far-field surface soils. The model also estimated uptake from the soils and transfer in a terrestrial food chain leading to exposure of a small mammal used as a model terrestrial receptor.

The white-footed mouse (*Peromyscus leucopus*) was used in this analysis to be representative of most small mammals because it is sensitive to contaminant exposure, it has a varied diet (for example, it eats both plants and insects), and it is a common prey species for a number of predators. In addition, field mice are ubiquitously distributed. These animals have a limited home range relative to estimated contaminant distributions. Therefore, mice live within potentially contaminated areas and can be expected to consume all of their diet from these areas.

Data Sources. Contaminant toxicity evaluations were conducted using the same estimates of waste treatment facility airborne emissions as were used in the human health risk analyses. These annual emission rate estimates, provided by ANL, were assumed to be constant over a 10-year operating period. Contaminants that accounted for up to 80% of total emissions were included in the assessment; trace emissions were not assessed.

Emission estimates were used as inputs to atmospheric dispersion/deposition models, which provided estimates of contaminant concentrations deposited to surface soils. Surface soil contaminants were then modeled for distribution in terrestrial food chains using a number of transfer factors.

Estimates of maximum near-field and far-field contaminant concentrations were developed in order to conservatively assess exposure. The pathways used to estimate internal and external exposure include direct exposure to external radiation, incidental soil ingestion, and uptake of contaminants from soils into terrestrial food chains. Exposure from the inhalation and water ingestion pathways was assumed to be minimal due to dilution.

Surface soil concentration estimates were developed for each contaminant by applying the maximum near-field and far-field deposition rates to the contaminant emission rates. Except for tritium, contaminants were conservatively assumed to accumulate in the soil over the 10-year operation period. Radioactive decay was accounted for in the analysis. Contaminants were assumed to be evenly distributed in the top six inches of soil.

Terrestrial food chain contaminant concentration estimates were made by applying transfer factors to soil concentrations to develop concentration estimates in plant tissues. Since reliable transfer factors were not available for estimating concentrations in insect tissue from plant tissue concentrations, complete (100%) plant to invertebrate transfer was conservatively assumed to estimate invertebrate tissue concentrations (ORNL, 1995b).

Tritium exposure was assessed separately. Tritiated water is the principal form of tritium in the environment. Therefore, tritium can be expected to be incorporated into a great variety of compounds but cannot be assumed to accumulate in soils. For tritium, a simplifying assumption was made that tritium deposition is continuous and uniform over time and that tritium in the receptor mouse has attained a steady state equilibrium with environmental tritium (IAEA, 1992). Transfer factors for tritium were conservatively assumed to be 100% (ORNL, 1995b).

Data Evaluation. The potential toxicity of the radiological contaminants was assessed by comparing the estimated total internal and external doses to a benchmark value of 100 mrad/day, established by the International Atomic Energy Agency (IAEA, 1992). No-observable-adverse-effect levels (NOAELs) were used as benchmarks for the nonradiological (i.e., hazardous chemical) contaminants. The radionuclides selected for each analysis comprised 80% of the total volume of all radionuclides expected to be emitted at a given site. The radionuclides were used in calculating hazard indexes (HI's) for each selected site/alternative combination as composite ratios between the estimated species exposures to each of the contaminants and known, contaminant-specific toxic levels. The resulting ratio, the hazard index (HI), was used to identify WM alternatives that may be of concern for potential ecotoxicity. An HI greater than one would indicate a potential for the combined exposures to adversely affect the health of terrestrial species. Hazardous and toxic chemicals were evaluated using a separate HI in the same way.

C.4.4.1.4 *Potential Impacts to Sensitive Species*

Location-specific analyses would be required to address impacts to sensitive habitats and sensitive species, including species listed by the U.S. Fish and Wildlife Service as endangered or threatened. Those analyses would be part of the impacts analyses in NEPA documents tiered to this PEIS. For comparison of WM program effects on sensitive species, the waste-type chapters list the numbers of Federal and State-listed endangered and threatened species at each site under each alternative where a major action is proposed. Reference is made to the PEIS Chapter 4 on Affected Environment chapter which lists the sensitive species at the 17 major sites.

C.4.4.2 Impacts of Accidental Releases

The ecological impacts of waste transportation accidents were evaluated as consequence assessments of spills into aquatic environments. These assessments estimated the potential ecological impacts of transportation accidents involving varying size releases of radionuclides under certain spill scenarios. However, they do not include estimates of the probability of these events occurring.

Because hazardous constituents would vary so widely in volume and type in any particular mixed or hazardous waste shipment, no attempt was made to quantify the consequences of hazardous constituents in transportation accidents. Where applicable, the PEIS acknowledges that the consequences of those spills may be as severe or more severe than the consequences of spills of radioactive wastes.

Accidental spills in nonsensitive terrestrial environments were not quantified but are expected to have more limited consequences than those estimated for the aquatic scenarios because the extent of the affected area would be more limited to the immediate locality of the spill and cleanup would likely be more effective because of the stable nature of the affected substrate. Airborne contaminants released downwind through such accidents could affect terrestrial species through all routes of exposure. The effects of such releases on nearby exposed humans were evaluated and are presented in the PEIS waste-type chapters and the human health risk appendix D. Terrestrial species would be at similar levels of risk for any acute effects.

Facility accidents would also likely affect terrestrial and aquatic environments on and near the affected site. Such accidents were evaluated for effects on human health. Ecological impacts are likely to be as severe as those shown in the human health effects analysis, however, no separate quantitative analysis of ecological impacts was done.

The transportation accident scenario used involves a rail shipment spill of waste directly into surface waters of different size classes. Assessments were performed for stream size classes ranging from a small second order stream (for example, flow rate of a few meters per second) to a tenth order major continental river (for example, the Mississippi River). Stream order is a method of numbering steams as part of a drainage basin network. The smallest tributary is called first order, the stream receiving the tributary is called second order, and so on. There are about 350,000 second-order streams in the United States and only one tenth-order stream, the Mississippi River.

The environmental fate of the spilled waste was evaluated under two assumptions. In one case, it was assumed that all spilled material remained suspended or dissolved in the water column and was transported downstream. Aquatic organisms present at any given location were assumed to be exposed for a maximum of four days to the maximum concentration of waste material. Contaminant concentrations would be reduced by longitudinal dispersion as the contaminants move downstream. Biota in the water column would receive an external exposure to suspended or dissolved radioisotopes.

In the other case, it was assumed that all of the released material was immediately deposited on the stream sediment at the release site. Aquatic organisms present at the release site were assumed to be exposed over their entire lifetime. Benthic (that is, bottom dwelling) biota would receive an external exposure from radiological waste deposited in sediment. If the deposited materials were allowed to remain in the sediment for a sufficient length of time, many isotopes would become incorporated into aquatic foodchains. Foodchain exposure would produce internal exposures for benthic organisms and for fish or other organisms that feed on them.

Data Sources. Estimates of the potential impacts of transportation accidents to aquatic organisms were conducted by Oak Ridge National Laboratory (ORNL, 1995b). ORNL used the waste load source term data provided by Argonne National Laboratory as inputs to aquatic environmental fate models to estimate maximum credible radiological releases for transportation accidents involving HLW, LLW, and C-H and R-H TRUW. For each waste type, ANL provided information on the radionuclides and total activity

present in a shipment and on the total release in a maximum severity accident. ANL concluded that for HLW and TRUW only a small portion of the total shipment inventory would be released because the only credible accidental release mechanisms for these waste types involve small cracks and seal failures in shipping containers. The entire contents of the LLW shipment were assumed to be released during a maximum severity accident; however, only a small fraction of the release was assumed to be soluble. The analysis of LLMW was based on the LLW results. Effects for HW and the chemical component of LLMW were not quantified as noted above (ANL, 1995).

The source terms used in the assessment were obtained by screening the source terms from all sites for all alternatives for these waste types to identify the waste shipments that would result in the highest releases.

The environmental fate of the spilled contaminants was estimated using a two-dimensional aquatic chemical fate model (EPA, 1985c). It was assumed that all of the spilled material remained in the water column for transport downstream or to sediment (ORNL, 1995b).

Data Evaluation. For aquatic biota, adverse short-term effects (that is, acute toxicity) are assumed to occur if the estimated doses exceeded the maximum safe dose of one rad per day (rad/day) recommended by the National Council on Radiation Protection and Measurements (NCRP, 1991). The results of the water column assessment include estimates of (1) the length (meters) of the stream (for each size class) affected before longitudinal dispersion reduces the exposure below the NCRP threshold; and (2) the time (hours) required for this dispersion to occur.

The results of the sediment assessment include estimates of the amount (kilogram) of clean sediment needed to dilute the spilled material to a sediment activity level corresponding to a one rad/day lifetime dose to a large fish residing at the bottom of the stream and feeding on benthic biota. This value also should be a reasonable estimate of the amount of sediment that would have to be removed during a remedial action taken following the spill.

C.4.5 Economic Impacts Analysis Methods

The economic impact analysis methods were used to estimate the economic impacts of the WM alternatives on the regional and National economies. The impacts assessment addressed potential changes in regional employment, personal income, and industry output due to WM expenditures at the 17 major sites (Table C.4–11). The assessment also addressed changes in National employment, personal income, and industry output due to the sum of spending on WM facility activities at all applicable sites and on waste transportation between sites under each waste type alternative. This section describes the analysis procedures, assumptions, data, evaluation techniques, and the presentation of the results from the economic impacts analysis.

Table C.4–11. Economic Impacts Analyzed for the WM Alternatives

Economic Impact Analyzed	Affected Aspect of Economy	Impact Analysis Method	Presentation of Results
Effect on Regional Employment	Level of Regional Employment at the Major Sites	Proposed site expenditures multiplied by regional employment multiplier at each major site	Tabular or Text-Only depending on Range of Results
Effect on Regional Incomes	Level of Regional Personal Income at the Major Sites	Proposed site expenditures multiplied by regional income multiplier at each major site	Tabular or Text-Only depending on Range of Results
Effect on Regional Industry Output	Value of Regional Industrial Production	Proposed site expenditures multiplied by regional income multiplier at each major site	Presented in Environmental Impacts Technical Report Only
National Economic Effects	National Employment, Personal Income and Industry Output	Proposed site expenditures at all involved sites plus intersite transportation costs multiplied by national employment, income, and industry output multipliers	Text Discussion

C.4.5.1 Focus of the Economic Impact Assessment

The economic impact analyses of the WM alternatives used a methodology that is standard for industrial construction projects, although the WM program presents several unique economic considerations because the WM facilities are designed to treat, store, and/or dispose of radioactive and hazardous waste. Because processing of these wastes requires substantial provisions to decrease the probability of harm to human

health and the environment, special costs apply that include the costs of environmental documentation, for example, under RCRA (42 USC 6901 *et seq.*) and NEPA (42 USC 4231 *et seq.*), for monitoring, and for shielding.

The specific project expenditure categories, as described in Section C.3.3, include design and planning, testing, construction, cold start, O&M, D&D, and transportation. These expenditures and their respective time periods are not uniform across waste types. For example, there is no D&D phase for high-level waste. In the case of the alternatives for hazardous waste, there are expenditures proposed for commercial treatment, storage, and disposal facilities that factor into the National economy. Expenditures were aggregated into three major phases: construction, operations, and transportation. The construction phase encompasses all activities from the design phase through the cold start. The operations phase encompasses the O&M period as well as D&D. The transportation phase generally coincided with the O&M portion of the operations phase. The analysis focused on the economic consequences of spending money on waste management activities within these major project phases. The full economic consequences of waste management activities were assumed to continue for an additional five years beyond the end of each phase (Cuthbertson and Nitzche, 1994).

C.4.5.2 Quantitative Effects

The principal variables selected to characterize the regional and National economics and provide the baseline conditions for the 17 major sites—employment, per capita income, and population—are presented in Chapter 4. Per capita income was multiplied by population to calculate total personal income. Data for these variables are provided for 1990 in 1990 dollars.

The economic impact analysis estimated changes in employment, personal income, and industry output that would result from the direct infusion of project dollars into the regional and national economies and subsequent multiple cycles of spending. The following definitions of these variables apply to both the affected environment and impact chapters of the PEIS.

Employment

One of the variables that the economic impacts generated by the model described below is "job-years." The variable "job-years" is equivalent to person-years, or full-time equivalents. One job-year is equal to

2,080 hours of employment in a twelve month period. Employment is the count of full- and part-time jobs. Job-years is converted to jobs or employment by dividing the number of job-years by the number of years over which the initial expenditures take place, plus the additional time it takes for the successive rounds of expenditure to occur (i.e., five years for each phase).

Employment impacts are presented according to place of work. Employment by place of work shows how many people work in a given region irrespective of where they live. The workforce of a regional economy is considered to be the number of people that work in a given region (as opposed to the number of people that live and work in the region). The economic impact analysis is geared to determine what the change in direct, indirect, and induced employment would be given a change in expenditures in the region. The research question is one of how many jobs will be generated in total, not how many jobs will be generated for the people that live in a given county.

The employment by place of residence shows how many people in a given region (a county or aggregation of counties) have jobs, irrespective of which region their jobs are in. The affected environment chapter in the PEIS (Chapter 4) provides employment by place of residence for the 17 major DOE sites. The ratio of the site workforce to employment by place of residence is an indicator of regional economic dependence on DOE sites. If there were a change in the number of jobs at a site, the change in the unemployment rate would be reported by where people live, not work.

While the data will indicate the direction of change, information on the magnitude of the changes will be more vague. It will be difficult to gauge the change in the unemployment rates due to a change in waste management spending, for example, but estimates of the magnitude of change in employment can be given. The percentage of earnings to labor from each of the "division level" Standard Industrial Classification (SIC) codes gives a useful snapshot of the character of the economy, but it will not be possible to determine how the composition of labor earnings will change given the implementation of one of the alternatives at a site. This is because the programmatic level of analysis must focus on a level of detail that enables a comparison of alternatives across sites and waste types. Analyzing changes in the composition of earnings obscures the importance of variables that facilitate a meaningful comparison of alternatives.

Baseline employment (by place of work) and baseline personal income for every ROI has been extracted from the U.S. Bureau of Economic Analysis' Regional Economic Information System (DOC, 1992a) and is presented in Tables C.4–12 and C.4–13.

Personal Income

Total personal income is defined as pre-tax disposable income to the household sector. It is useful as a measure of the purchasing power available to consumers. The impacts analysis uses a measure of income that subtracts taxes out of the first cycle of spending. While the two measures are not identically defined, the numbers are similar enough that they can be combined.

Industry Output

Output is defined as gross industry receipts (DOC, 1992b), i.e., the number of units of goods and services that are sold times the price per unit. Output is useful in illustrating the magnitude of economic activity in a given region or in the national economy. Output, however, has two important limitations:

- Output includes the revenues for each cycle of expenditure. Therefore, the value of a given good or service may be accumulated several times as an intermediate good before it sold as a final good to the ultimate consumer.

- There are no available baseline measures of output available at the regional level. The model used to determine impacts provides a change in output given a change in initial expenditures, but there is no data available to compute a percent change in the baseline output.

Table C.4-12. Baseline Employment Data

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
AMES	Boone (IA)	10,266	11,351	11,684	11,006	11,205	9.1%
	Hamilton (IA)	8,237	8,969	9,427	9,418	10,210	24.0%
	Hardin (IA)	10,110	10,809	11,822	11,290	11,323	12.0%
	Jasper (IA)	15,997	16,390	16,889	16,770	17,823	11.4%
	Marshall (IA)	20,632	22,377	23,519	21,779	23,065	11.8%
	Polk (IA)	157,758	179,201	206,377	216,637	255,686	62.1%
	Story (IA)	28,296	33,610	40,419	42,245	46,365	63.9%
		251,296	282,707	320,137	329,145	375,677	49.5%
ANL-E	Cook (IL)	2,780,014	2,742,358	2,873,797	2,885,969	3,080,458	10.8%
	Du Page (IL)	154,520	215,484	282,623	382,481	510,994	230.7%
	Kane (IL)	108,159	117,301	131,252	141,234	171,116	58.2%
	Will (IL)	87,178	90,369	100,401	104,134	121,273	39.1%
		3,129,871	3,165,512	3,388,073	3,513,818	3,883,841	24.1%
BCL	Delaware (OH)	15,851	17,914	21,449	23,432	27,026	70.5%
	Fairfield (OH)	27,211	30,877	36,655	35,308	38,948	43.1%
	Franklin (OH)	399,431	447,635	512,397	576,164	680,737	70.4%
	Licking (OH)	41,660	43,642	50,269	52,119	56,828	36.4%
	Madison (OH)	9,124	9,763	10,205	10,262	13,287	45.6%
	Pickaway (OH)	14,546	16,037	17,188	16,031	17,800	22.4%
	Union (OH)	10,672	11,289	12,486	15,042	22,671	112.4%
		518,495	577,157	660,649	728,358	857,297	65.3%
BAPL	Allegheny (PA)	730,822	731,255	765,235	742,910	802,173	9.8%
	Armstrong (PA)	22,139	24,075	24,607	23,111	24,280	9.7%
	Beaver (PA)	81,428	87,386	86,106	64,258	62,093	-23.7%
	Butler (PA)	46,384	49,600	56,201	56,647	67,382	45.3%
	Washington (PA)	71,399	77,275	79,039	73,958	80,823	13.2%
	Westmoreland (PA)	123,374	131,997	147,434	141,501	151,582	22.9%
		1,075,546	1,101,588	1,158,622	1,102,385	1,188,333	10.5%
BNL	Nassau (NY)	556,601	581,113	648,039	749,839	771,414	38.6%
	Suffolk (NY)	317,836	378,992	470,017	586,728	647,626	103.8%
		874,437	960,105	1,118,056	1,336,567	1,419,040	62.3%
Charleston	Berkeley (SC)	12,091	15,250	23,617	27,331	33,869	180.1%
	Charleston (SC)	130,125	147,319	167,296	196,497	226,839	74.3%
	Colleton (SC)	10,507	10,942	11,591	12,568	13,805	31.4%
	Dorchester (SC)	8,701	11,782	15,983	21,662	25,392	191.8%
		161,424	185,293	218,487	258,058	299,905	85.8%
Colonie	Albany (NY)	179,332	183,478	203,657	225,005	256,215	42.9%
	Columbia (NY)	17,950	19,455	20,598	22,942	25,561	42.4%
	Greene (NY)	11,675	13,144	14,306	15,456	17,034	45.9%
	Rensselaer (NY)	44,314	44,726	46,767	52,406	61,152	38.0%
	Saratoga (NY)	30,254	35,894	44,418	54,378	68,058	125.0%
	Schenectady (NY)	71,461	75,442	75,567	75,564	79,628	11.4%
	Schoharie (NY)	7,799	8,514	8,656	9,267	10,655	36.6%
		362,785	380,653	413,969	455,018	518,303	42.9%
ETEC	Kern (CA)	136,096	166,838	198,411	231,191	259,475	90.7%
	Los Angeles (CA)	3,326,115	3,551,891	4,272,799	4,661,161	5,199,569	56.3%
	San Luis Obispo (CA	37,913	48,874	65,028	83,929	103,621	173.3%
	Santa Barbara (CA)	113,665	134,333	163,668	193,381	213,960	88.2%
	Ventura (CA)	131,954	166,800	216,109	259,345	320,927	143.2%
		3,745,743	4,068,736	4,916,015	5,429,007	6,097,552	62.8%
FNAL	Cook (IL)	2,780,014	2,742,358	2,873,797	2,885,969	3,080,458	10.8%
	De Kalb (IL)	31,128	31,702	34,187	35,438	38,832	24.7%
	Du Page (IL)	154,520	215,484	282,623	382,481	510,994	230.7%
	Kane (IL)	108,159	117,301	131,252	141,234	171,116	58.2%
	Kendall (IL)	13,871	16,224	17,041	13,700	10,763	-22.4%
	McHenry (IL)	41,314	46,505	55,262	65,007	81,866	98.2%
	Will (IL)	87,178	90,369	100,401	104,134	121,273	39.1%
		3,216,184	3,259,943	3,494,563	3,627,963	4,015,302	24.8%

Table C.4-12. Baseline Employment Data—Continued

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
FEMP	Butler (OH)	82,804	87,339	99,638	103,659	115,182	39.1%
	Hamilton (OH)	488,962	490,210	540,620	562,639	630,991	29.0%
	Warren (OH)	17,209	21,622	27,641	31,891	44,723	159.9%
	Dearborn (IN)	10,779	11,322	12,629	12,114	13,480	25.1%
		599,754	610,493	680,528	710,303	804,376	34.1%
GA	Imperial (CA)	33,842	41,879	45,988	40,725	52,289	54.5%
	Orange (CA)	531,119	711,851	1,038,731	1,271,121	1,552,291	192.3%
	Riverside (CA)	166,660	192,861	256,835	317,421	438,293	181.8%
	San Diego (CA)	633,738	733,668	963,302	1,154,677	1,396,552	120.4%
		1,365,359	1,680,259	2,304,856	2,783,944	3,437,425	151.8%
GE	Alpine (CA)	200	248	520	707	802	301.0%
	Amador (CA)	4,720	5,839	7,656	9,173	11,974	153.7%
	Calaveras (CA)	4,618	4,743	7,524	8,880	10,610	129.8%
	San Joaquin (CA)	123,076	139,076	162,927	181,349	211,109	71.5%
	Stanislaus (CA)	81,872	98,597	121,735	132,122	166,656	103.6%
	Tuolumne (CA)	7,473	9,570	13,817	16,582	20,641	176.2%
		221,959	258,073	314,179	348,813	421,792	90.0%
GJPO	Delta (CO)	5,515	6,599	8,667	9,155	9,506	72.4%
	Garfield (CO)	5,783	8,747	11,873	14,554	17,224	197.8%
	Gunnison (CO)	2,664	3,979	6,163	6,263	7,041	164.3%
	Mesa (CO)	22,275	29,506	42,466	43,106	48,064	115.8%
	Montrose (CO)	7,025	8,806	11,649	11,460	13,141	87.1%
	Pitkin (CO)	4,231	7,865	11,529	12,764	16,546	291.1%
	Grand (UT)	2,675	3,032	4,045	2,955	3,122	16.7%
		50,168	68,534	96,392	100,257	114,644	128.5%
HANF	Adams (WA)	6,976	7,602	8,076	7,894	8,409	20.5%
	Benton (WA)	27,477	38,013	58,925	54,409	59,910	118.0%
	Franklin (WA)	12,743	15,528	18,414	17,177	21,129	65.8%
	Grant (WA)	18,323	22,333	23,340	23,904	26,950	47.1%
	Yakima (WA)	62,556	71,326	82,024	84,284	97,900	56.5%
		128,075	154,802	190,779	187,668	214,298	67.3%
INEL	Bannock (ID)	20,961	26,185	30,628	30,386	30,078	43.5%
	Bingham (ID)	12,362	14,051	15,150	15,679	16,758	35.6%
	Bonneville (ID)	22,232	26,706	31,452	33,436	38,092	71.3%
	Butte (ID)	4,287	5,347	6,625	7,054	7,934	85.1%
	Clark (ID)	463	539	602	584	679	46.7%
	Jefferson (ID)	4,221	4,953	5,603	5,470	6,151	45.7%
		64,526	77,781	90,060	92,609	99,692	54.5%
KCP	Cass (MO)	13,222	15,139	14,298	17,627	20,904	58.1%
	Clay (MO)	40,959	42,843	51,268	66,683	77,616	89.5%
	Jackson (MO)	385,262	390,795	424,126	430,173	441,174	14.5%
	Johnson (MO)	14,493	16,243	17,867	19,173	21,770	50.2%
	Lafayette (MO)	10,684	11,221	12,036	12,253	13,439	25.8%
	Ray (MO)	4,662	5,357	5,736	6,583	6,784	45.5%
	Johnson (KS)	70,399	98,553	141,148	185,482	242,894	245.0%
	Wyandotte (KS)	81,896	87,583	92,056	93,354	91,892	12.2%
		621,577	667,734	758,535	831,328	916,473	47.4%
KAPL-K	Fulton (NY)	18,714	18,882	19,715	20,262	21,167	13.1%
	Saratoga (NY)	30,254	35,894	44,418	54,378	68,058	125.0%
	Schenectady (NY)	71,461	75,442	75,567	75,564	79,628	11.4%
		120,429	130,218	139,700	150,204	168,853	40.2%
KAPL-N	Albany (NY)	179,332	183,478	203,657	225,005	256,215	42.9%
	Montgomery (NY)	22,062	20,904	22,387	23,284	24,092	9.2%
	Saratoga (NY)	30,254	35,894	44,418	54,378	68,058	125.0%
	Schenectady (NY)	71,461	75,442	75,567	75,564	79,628	11.4%
	Schoharie (NY)	7,799	8,514	8,656	9,267	10,655	36.6%
		310,908	324,232	354,685	387,498	438,648	41.1%

Table C.4-12. Baseline Employment Data—Continued

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
KAPL-W	Hartford (CT)	438,369	452,340	527,904	572,596	615,574	40.4%
	Litchfield (CT)	53,720	56,711	68,844	76,288	85,810	59.7%
	Middlesex (CT)	45,352	51,689	60,868	73,741	82,460	81.8%
	New Haven (CT)	337,150	345,124	380,393	414,784	444,307	31.8%
	Tolland (CT)	26,124	29,700	33,363	39,941	48,387	85.2%
	Hampden (MA)	202,106	198,347	220,977	229,234	240,374	18.9%
		1,102,821	1,133,911	1,292,349	1,406,584	1,516,912	37.5%
LEHR	Colusa (CA)	6,205	7,138	7,112	6,942	7,891	27.2%
	Lake (CA)	6,677	8,708	11,881	15,251	17,218	157.9%
	Napa (CA)	26,918	34,555	42,081	48,591	58,321	116.7%
	Sacramento (CA)	276,010	320,242	396,980	485,139	603,669	118.7%
	Solano (CA)	76,418	82,069	96,464	111,163	134,353	75.8%
	Sutter (CA)	15,427	19,256	22,441	22,643	26,725	73.2%
	Yolo (CA)	34,958	47,963	57,528	64,323	82,075	134.8%
		442,613	519,931	634,487	754,052	930,252	110.2%
LBL	Alameda (CA)	490,578	509,946	588,728	656,286	738,160	50.5%
	Contra Costa (CA)	170,808	202,758	262,043	321,605	396,508	132.1%
		661,386	712,704	850,771	977,891	1,134,668	71.6%
LLNL	Alameda (CA)	490,578	509,946	588,728	656,286	738,160	50.5%
	Contra Costa (CA)	170,808	202,758	262,043	321,605	396,508	132.1%
	San Joaquin (CA)	123,076	139,076	162,927	181,349	211,109	71.5%
	Stanislaus (CA)	81,872	98,597	121,735	132,122	166,656	103.6%
		866,334	950,377	1,135,433	1,291,362	1,512,433	74.6%
LANL	Los Alamos (NM)	8,802	10,950	14,010	16,831	18,066	105.2%
	Rio Arriba (NM)	6,505	7,006	8,303	9,377	10,341	59.0%
	Santa Fe (NM)	22,125	28,707	36,708	46,045	55,088	149.0%
		37,432	46,663	59,021	72,253	83,495	123.1%
Mare Island	Contra Costa (CA)	170,808	202,758	262,043	321,605	396,508	132.1%
	Lake (CA)	6,677	8,708	11,881	15,251	17,218	157.9%
	Marin (CA)	68,350	81,672	105,136	131,293	149,704	119.0%
	Mendocino (CA)	19,826	24,124	32,118	35,191	41,643	110.0%
	Napa (CA)	26,918	34,555	42,081	48,591	58,321	116.7%
	Sonoma (CA)	71,368	93,149	129,858	162,799	200,809	181.4%
		363,947	444,966	583,117	714,730	864,203	137.5%
MSP	Mercer (NJ)	152,536	163,220	180,825	197,963	218,289	43.1%
	Middlesex (NJ)	236,060	264,873	317,105	362,229	410,340	73.8%
	Monmouth (NJ)	156,505	173,172	205,799	247,685	278,379	77.9%
	Somerset (NJ)	73,129	87,696	110,237	138,071	162,850	122.7%
	Union (NJ)	289,170	276,194	298,539	312,241	298,021	3.1%
		907,400	965,155	1,112,505	1,258,189	1,367,879	50.7%
MOUND	Butler (OH)	82,804	87,339	99,638	103,659	115,182	39.1%
	Clark (OH)	54,155	54,702	58,828	58,685	64,883	19.8%
	Darke (OH)	17,601	19,586	20,840	21,516	23,698	34.6%
	Greene (OH)	38,914	41,134	45,604	51,345	61,164	57.2%
	Miami (OH)	33,836	35,269	41,309	41,334	45,711	35.1%
	Montgomery (OH)	310,229	296,176	319,744	336,040	365,015	17.7%
	Preble (OH)	9,686	10,484	11,389	12,650	13,803	42.5%
	Warren (OH)	17,209	21,622	27,641	31,891	44,723	159.9%
		564,434	566,312	624,993	657,120	734,179	30.1%
NTS	Clark (NV)	131,904	171,122	261,135	301,329	441,267	234.5%
	Nye (NV)	7,140	5,794	7,819	11,071	12,763	78.8%
		139,044	176,916	268,954	312,400	454,030	226.5%
Norfolk	Chesapeake city (VA)	22,046	24,449	31,494	41,790	60,021	172.3%
	Hampton city (VA)	49,777	52,385	60,119	69,468	74,278	49.2%
	Newport News city (	74,805	78,736	84,006	96,784	108,988	45.7%
	Norfolk city (VA)	209,849	211,839	225,741	245,270	256,042	22.0%
	Suffolk city (VA)	17,837	19,957	19,391	19,414	20,545	15.2%
	Virginia Beach city (	64,219	77,602	106,903	151,809	182,932	184.9%
	Isle of Wight (VA)	9,222	9,781	11,791	11,380	12,346	33.9%
		447,755	474,749	539,445	635,915	715,152	59.7%

Table C.4-12. Baseline Employment Data—Continued

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
ORR	Anderson (TN)	20,457	24,385	30,785	32,310	39,083	91.0%
	Knox (TN)	123,389	143,530	174,676	187,012	212,347	72.1%
	Loudon (TN)	8,434	9,012	9,966	10,694	12,310	46.0%
	Roane (TN)	21,217	21,211	23,362	22,289	24,234	14.2%
		173,497	198,138	238,789	252,305	287,974	66.0%
PGDP	Ballard (KY)	3,139	3,344	3,812	3,603	3,868	23.2%
	Carlisle (KY)	1,911	1,814	1,768	1,798	1,802	-5.7%
	Graves (KY)	12,550	13,566	13,549	13,552	15,312	22.0%
	Marshall (KY)	9,121	9,125	10,705	10,901	12,773	40.0%
	McCracken (KY)	27,167	31,027	34,536	34,007	41,056	51.1%
	Massac (IL)	4,776	5,078	5,267	4,666	4,945	3.5%
		58,664	63,954	69,637	68,527	79,756	36.0%
Palos	Cook (IL)	2,780,014	2,742,358	2,873,797	2,885,969	3,080,458	10.8%
	Du Page (IL)	154,520	215,484	282,623	382,481	510,994	230.7%
	Kane (IL)	108,159	117,301	131,252	141,234	171,116	58.2%
	Lake (IL)	164,074	177,608	206,965	238,950	292,353	78.2%
	McHenry (IL)	41,314	46,505	55,262	65,007	81,866	98.2%
	Will (IL)	87,178	90,369	100,401	104,134	121,273	39.1%
	Lake (IN)	228,285	227,217	237,925	205,496	228,304	0.0%
		3,563,544	3,616,842	3,888,225	4,023,271	4,486,364	25.9%
Pantex	Carson (TX)	4,536	4,681	4,619	5,279	4,956	9.3%
	Potter (TX)	55,811	68,372	77,990	88,106	78,713	41.0%
	Randall (TX)	9,502	11,954	14,554	18,663	20,585	116.6%
		69,849	85,007	97,163	110,048	104,254	49.3%
Pearl Harbor	Honolulu (HI)	354,084	400,793	454,443	474,056	540,449	52.6%
	Kauai (HI)	13,518	16,252	21,278	23,900	31,820	135.4%
	Maui (HI)	21,023	27,778	38,034	47,507	63,110	200.2%
		388,625	444,823	513,755	545,463	635,379	63.5%
PIN	Hillsborough (FL)	219,555	276,643	334,297	443,567	534,096	143.3%
	Pasco (FL)	17,603	30,096	46,570	66,730	83,624	375.1%
	Pinellas (FL)	185,693	232,451	307,786	400,674	457,517	146.4%
		422,851	539,190	688,653	910,971	1,075,237	154.3%
PORTS	Jackson (OH)	8,995	9,430	9,911	11,328	11,560	28.5%
	Pike (OH)	6,030	7,300	9,135	9,481	9,876	63.8%
	Ross (OH)	23,046	23,172	26,441	27,342	28,598	24.1%
	Scioto (OH)	26,467	24,934	26,633	25,617	27,772	4.9%
		64,538	64,836	72,120	73,768	77,806	20.6%
Portsmouth	Cumberland (ME)	97,734	107,768	126,806	151,907	183,271	87.5%
	Oxford (ME)	17,305	18,085	21,598	20,341	23,304	34.7%
	York (ME)	46,430	48,463	60,765	72,106	83,380	79.6%
	Carroll (NH)	8,070	10,525	14,020	18,809	23,172	187.1%
	Rockingham (NH)	49,342	60,202	89,598	117,970	134,660	172.9%
	Strafford (NH)	30,189	31,769	40,538	44,984	50,420	67.0%
		249,070	276,812	353,325	426,117	498,207	100.0%
PPPL	Burlington (NJ)	135,712	127,481	142,828	175,494	202,936	49.5%
	Hunterdon (NJ)	24,227	27,383	32,991	44,645	52,433	116.4%
	Mercer (NJ)	152,536	163,220	180,825	197,963	218,289	43.1%
	Middlesex (NJ)	236,060	264,873	317,105	362,229	410,340	73.8%
	Monmouth (NJ)	156,505	173,172	205,799	247,685	278,379	77.9%
	Somerset (NJ)	73,129	87,696	110,237	138,071	162,850	122.7%
	Bucks (PA)	137,592	163,917	199,483	234,165	266,078	93.4%
		915,761	1,007,742	1,189,268	1,400,252	1,591,305	73.8%
Puget Sound	Jefferson (WA)	3,628	4,405	6,183	7,114	9,117	151.3%
	King (WA)	537,408	605,581	804,356	901,911	1,131,447	110.5%
	Kitsap (WA)	44,510	50,766	66,838	78,435	95,238	114.0%
	Mason (WA)	6,919	8,067	10,767	11,274	13,333	92.7%
	Pierce (WA)	184,149	178,218	207,284	234,443	269,479	46.3%
		776,614	847,037	1,095,428	1,233,177	1,518,614	95.5%

Table C.4-12. Baseline Employment Data—Continued

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
RMI	Ashtabula (OH)	37,633	38,012	40,731	38,646	38,878	3.3%
	Geauga (OH)	15,640	18,878	23,400	28,035	32,720	109.2%
	Lake (OH)	62,584	72,178	86,842	90,650	103,431	65.3%
	Trumbull (OH)	95,326	102,895	107,783	102,098	105,424	10.6%
	Crawford (PA)	32,380	34,817	36,833	36,586	39,330	21.5%
	Erie (PA)	115,493	129,015	132,838	130,760	143,588	24.3%
		359,056	395,795	428,427	426,775	463,371	29.1%
RFP	Adams (CO)	47,558	72,721	97,335	113,176	126,465	165.9%
	Arapanoe (CO)	48,565	87,125	132,994	191,619	218,287	349.5%
	Boulder (CO)	53,430	76,151	110,011	139,658	157,460	194.7%
	Denver (CO)	379,312	399,634	480,031	510,784	469,920	23.9%
	Jefferson (CO)	68,124	109,812	154,901	207,232	228,393	232.3%
		596,989	745,443	975,272	1,162,469	1,198,525	100.8%
SNLA	Bernalillo (NM)	135,635	176,533	219,901	266,864	304,985	124.9%
	Cibola (NM)	0	0	0	5,358	6,148	NA
	Sandoval (NM)	3,323	4,386	5,495	8,987	12,734	283.2%
	Santa Fe (NM)	22,125	28,707	36,708	46,045	55,088	149.0%
	Torrance (NM)	1,879	2,046	2,182	2,496	2,957	57.4%
	Valencia (NM)	9,110	12,208	17,661	9,695	11,486	26.1%
		172,072	223,880	281,947	339,445	393,398	128.6%
SRS	Aiken (SC)	35,181	38,587	45,585	52,476	73,012	107.5%
	Allendale (SC)	5,399	4,581	4,273	4,128	4,784	-11.4%
	Bamberg (SC)	6,327	6,268	6,691	6,118	6,139	-3.0%
	Barnwell (SC)	7,598	8,627	8,942	9,766	9,242	21.6%
	Burke (GA)	5,833	6,457	7,806	16,144	8,470	45.2%
	Columbia (GA)	21,949	15,629	22,958	26,033	28,284	28.9%
	Richmond (GA)	71,085	79,213	90,877	102,953	119,064	67.5%
	Screven (GA)	4,752	5,392	5,906	5,587	5,782	21.7%
		158,124	165,154	193,038	223,205	254,777	61.1%
SLAC	Alameda (CA)	490,578	509,946	588,728	656,286	738,160	50.5%
	Monterey (CA)	131,810	147,482	158,959	176,632	202,533	53.7%
	San Benito (CA)	7,902	9,020	10,481	11,808	15,212	92.5%
	San Mateo (CA)	227,090	259,528	313,958	349,819	396,533	74.6%
	Santa Clara (CA)	446,473	553,366	790,461	930,931	1,015,759	127.5%
	Santa Cruz (CA)	47,367	61,480	82,228	102,096	122,735	159.1%
	Stanislaus (CA)	81,872	98,597	121,735	132,122	166,656	103.6%
		1,433,092	1,639,419	2,064,550	2,359,694	2,657,588	85.4%
UMo	Audrain (MO)	12,400	12,868	13,518	12,386	12,779	3.1%
	Boone (MO)	39,057	46,023	56,810	63,584	75,366	93.0%
	Callaway (MO)	10,588	11,120	16,920	14,611	16,281	53.8%
	Cole (MO)	28,045	32,876	38,421	42,868	48,500	72.9%
	Cooper (MO)	6,488	6,913	6,965	7,026	7,097	9.4%
	Howard (MO)	4,866	4,555	4,190	4,384	4,421	-9.1%
	Moniteau (MO)	4,796	4,722	5,338	5,752	6,231	29.9%
	Randolph (MO)	8,977	9,883	11,321	12,350	12,666	41.1%
		115,217	128,960	153,483	162,941	183,341	59.1%
WIPP	Chaves (NM)	16,649	19,528	22,695	25,116	26,216	57.5%
	Eddy (NM)	15,825	18,410	21,374	22,298	21,748	37.4%
	Lea (NM)	20,607	23,894	29,280	30,095	25,009	21.4%
	Otero (NM)	19,079	20,526	22,626	25,681	24,956	30.8%
	Culberson (TX)	1,854	1,848	1,897	1,815	1,718	-7.3%
	Loving (TX)	102	175	131	123	60	-41.2%
		74,116	84,381	98,003	105,128	99,707	34.5%
WSSRAP	Franklin (MO)	19,479	22,207	27,656	31,825	38,233	96.3%
	Jefferson (MO)	19,773	21,857	29,787	38,875	47,635	140.9%
	St. Charles (MO)	23,441	29,902	40,985	66,107	83,286	255.3%
	St. Louis (MO)	355,947	393,919	477,764	610,547	695,600	95.4%
	Madison (IL)	97,430	96,639	100,691	99,640	112,247	15.2%
	Monroe (IL)	4,923	5,464	5,742	6,598	7,448	51.3%
	St. Clair (IL)	91,681	94,622	99,354	98,863	105,059	14.6%
		612,674	664,610	781,979	952,455	1,089,508	77.8%
WVDP	Cattaraugus (NY)	31,724	32,991	35,540	35,920	39,434	24.3%
	Erie (NY)	465,799	466,761	477,986	476,411	529,812	13.7%
		497,523	499,752	513,526	512,331	569,246	14.4%
UNITED STATES		89,753	97,177	112,257	123,176	137,160	52.8%

Source: U.S. Department of Commerce, Bureau of Economic Analysis, 1992a.

Table C.4-13. Baseline Personal Income

TOTAL PERSONAL INCOME (In $MM)

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
AMES	Boone (IA)	98.6	168.7	261.4	324.0	402.3	308.1%
	Hamilton (IA)	74.5	128.7	190.3	246.3	314.7	322.6%
	Hardin (IA)	92.0	141.9	215.9	276.2	333.6	262.7%
	Jasper (IA)	142.1	228.1	356.8	485.9	634.1	346.2%
	Marshall (IA)	182.4	290.9	433.1	539.1	692.8	279.8%
	Polk (IA)	1,268.0	2,073.2	3,444.2	4,703.3	6,620.9	422.1%
	Story (IA)	210.3	354.0	633.2	879.5	1,180.8	461.6%
		2,067.9	3,385.5	5,534.9	7,454.2	10,179.3	392.3%
ANL-E	Cook (IL)	27,609.0	39,409.7	60,465.2	82,068.1	110,927.8	301.8%
	Du Page (IL)	2,611.0	4,636.8	9,007.3	13,480.1	21,043.2	706.0%
	Kane (IL)	1,169.8	1,863.4	3,117.7	4,490.1	6,914.2	491.0%
	Will (IL)	1,068.0	1,844.2	3,372.3	4,633.2	6,738.2	530.9%
		32,457.8	47,754.1	75,962.5	104,671.5	145,623.4	348.7%
BCL	Delaware (OH)	159.0	281.1	510.6	799.7	1,279.4	704.5%
	Fairfield (OH)	263.5	456.6	848.7	1,219.1	1,697.2	544.1%
	Franklin (OH)	3,449.1	5,284.4	8,639.7	12,854.9	18,376.0	432.8%
	Licking (OH)	374.3	617.4	1,088.2	1,566.7	2,109.6	463.6%
	Madison (OH)	100.3	169.6	275.1	385.7	580.5	478.6%
	Pickaway (OH)	135.1	221.6	354.5	488.5	666.3	393.2%
	Union (OH)	89.0	155.0	267.8	384.4	618.8	595.2%
		4,570.4	7,185.5	11,984.7	17,698.9	25,327.8	454.2%
BAPL	Allegheny (PA)	7,024.7	10,277.7	16,072.4	20,701.8	27,600.6	292.9%
	Armstrong (PA)	243.3	415.6	691.0	929.1	1,228.3	404.8%
	Beaver (PA)	742.2	1,236.9	2,061.3	2,261.5	2,816.5	279.5%
	Butler (PA)	474.9	785.4	1,384.4	1,834.4	2,626.3	453.0%
	Washington (PA)	759.5	1,246.5	2,066.4	2,584.4	3,396.7	347.2%
	Westmoreland (PA)	1,383.8	2,153.6	3,803.4	4,816.0	6,316.2	356.4%
		10,628.3	16,115.6	26,078.8	33,127.3	43,984.7	313.8%
BNL	Nassau (NY)	8,524.6	11,845.3	18,941.6	28,244.9	40,745.2	378.0%
	Suffolk (NY)	4,876.5	7,924.0	13,650.9	21,596.1	32,091.6	558.1%
		13,401.1	19,769.3	32,592.5	49,840.9	72,836.8	443.5%
Charleston	Berkeley (SC)	145.2	301.4	635.6	1,116.0	1,672.5	1051.5%
	Charleston (SC)	835.3	1,363.4	2,236.8	3,280.0	4,741.6	467.6%
	Colleton (SC)	65.6	110.9	196.7	282.0	407.9	521.6%
	Dorchester (SC)	95.5	201.6	461.7	769.4	1,175.2	1130.0%
		1,141.7	1,977.4	3,530.8	5,447.5	7,997.2	600.4%
Colonie	Albany (NY)	1,378.0	2,028.6	3,027.7	4,382.5	6,147.6	346.1%
	Columbia (NY)	194.8	325.4	564.1	846.2	1,239.0	536.0%
	Greene (NY)	123.8	204.4	341.3	496.2	735.9	494.4%
	Rensselaer (NY)	574.8	827.5	1,306.1	1,907.1	2,745.3	377.7%
	Saratoga (NY)	437.1	738.5	1,374.4	2,153.7	3,435.4	686.0%
	Schenectady (NY)	738.5	1,025.3	1,544.5	2,243.2	3,086.2	317.9%
	Schoharie (NY)	85.1	131.6	210.6	302.6	455.6	435.6%
		3,532.0	5,281.4	8,368.7	12,331.4	17,845.0	405.2%
ETEC	Kern (CA)	1,267.9	2,189.1	4,321.3	6,224.1	8,691.4	585.5%
	Los Angeles (CA)	35,043.2	50,436.0	88,053.0	130,394.8	185,131.4	428.3%
	San Luis Obispo (CA)	388.3	718.0	1,443.5	2,469.8	3,767.8	870.3%
	Santa Barbara (CA)	1,235.4	1,949.3	3,563.0	5,696.0	8,134.3	558.4%
	Ventura (CA)	1,589.4	2,901.8	5,940.7	9,495.6	14,428.4	807.8%
		39,524.2	58,194.3	103,321.5	154,280.3	220,153.3	457.0%
FNAL	Cook (IL)	27,609.0	39,409.7	60,465.2	82,068.1	110,927.8	301.8%
	De Kalb (IL)	264.8	431.7	675.2	935.5	1,286.3	385.8%
	Du Page (IL)	2,611.0	4,636.8	9,007.3	13,480.1	21,043.2	706.0%
	Kane (IL)	1,169.8	1,863.4	3,117.7	4,490.1	6,914.2	491.0%
	Kendall (IL)	122.6	226.6	425.2	549.7	797.7	550.6%
	McHenry (IL)	519.0	895.6	1,677.4	2,509.2	4,032.9	677.1%
	Will (IL)	1,068.0	1,844.2	3,372.3	4,633.2	6,738.2	530.9%
		33,364.2	49,307.9	78,740.3	108,665.9	151,740.3	354.8%

Table C.4-13. Baseline Personal Income—Continued

TOTAL PERSONAL INCOME (In $MM)

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
FEMP	Butler (OH)	870.5	1,386.6	2,508.2	3,473.1	4,902.0	463.1%
	Hamilton (OH)	4,130.7	5,879.9	9,405.5	12,973.0	17,837.8	331.8%
	Warren (OH)	302.0	476.2	890.9	1,271.3	1,973.6	553.6%
	Dearborn (IN)	101.0	162.8	295.4	430.2	594.3	488.4%
		5,404.2	7,905.5	13,099.9	18,147.7	25,307.8	368.3%
GA	Imperial (CA)	299.6	527.9	888.2	1,085.6	1,595.3	432.4%
	Orange (CA)	7,013.6	12,242.3	25,407.5	40,169.6	59,190.7	743.9%
	Riverside (CA)	2,012.5	3,522.1	7,104.1	11,674.0	20,431.5	915.2%
	San Diego (CA)	6,163.1	10,294.5	19,917.7	32,190.3	49,344.3	700.6%
		15,488.9	26,586.7	53,317.4	85,119.4	130,561.8	742.9%
GE	Alpine (CA)	2.1	4.1	9.2	15.4	25.5	1093.0%
	Amador (CA)	49.0	89.4	188.3	292.7	456.0	830.6%
	Calaveras (CA)	51.6	88.1	184.4	294.0	442.3	757.8%
	San Joaquin (CA)	1,215.3	2,033.7	3,634.5	5,215.1	7,484.0	515.8%
	Stanislaus (CA)	766.1	1,335.7	2,577.1	3,743.3	5,699.3	644.0%
	Tuolumne (CA)	81.5	144.9	308.1	481.9	724.9	789.9%
		2,165.5	3,693.8	6,901.6	10,042.2	14,832.0	584.9%
GJPO	Delta (CO)	45.8	84.7	168.8	229.5	278.8	508.9%
	Garfield (CO)	56.6	115.9	236.2	335.4	486.7	759.5%
	Gunnison (CO)	18.1	36.2	80.5	109.7	139.9	674.4%
	Mesa (CO)	183.4	365.3	805.0	1,041.8	1,412.7	670.2%
	Montrose (CO)	53.3	97.5	186.2	253.7	350.9	558.6%
	Pitkin (CO)	36.0	79.9	169.4	249.0	412.7	1047.6%
	Grand (UT)	23.1	37.5	77.9	76.8	88.0	280.6%
		416.3	817.0	1,724.1	2,295.8	3,169.8	661.5%
HANF	Adams (WA)	54.7	122.5	146.2	184.3	230.7	321.6%
	Benton (WA)	269.5	536.2	1,200.8	1,473.4	1,959.2	626.9%
	Franklin (WA)	98.0	197.9	358.6	409.2	553.1	464.6%
	Grant (WA)	148.4	296.4	444.2	601.8	853.8	475.2%
	Yakima (WA)	496.0	929.0	1,549.3	2,046.8	2,920.4	488.8%
		1,066.7	2,082.0	3,699.2	4,715.4	6,517.2	511.0%
INEL	Bannock (ID)	169.4	310.5	554.3	731.3	884.6	422.1%
	Bingham (ID)	93.5	161.6	266.2	353.4	512.5	448.0%
	Bonneville (ID)	189.5	339.7	588.5	837.4	1,203.7	535.2%
	Butte (ID)	9.5	14.0	28.2	32.2	45.8	380.6%
	Clark (ID)	4.7	6.1	10.1	12.7	20.2	327.9%
	Jefferson (ID)	34.6	61.4	106.7	136.6	212.2	512.8%
		501.3	893.2	1,554.0	2,103.7	2,879.0	474.3%
KCP	Cass (MO)	132.6	250.9	484.7	753.2	1,092.3	724.1%
	Clay (MO)	501.9	784.7	1,467.5	2,172.1	2,833.8	464.6%
	Jackson (MO)	2,825.6	4,181.1	6,531.9	9,141.2	11,798.7	317.6%
	Johnson (MO)	104.7	160.3	261.7	381.3	521.4	397.9%
	Lafayette (MO)	103.7	161.5	264.7	381.7	504.7	386.6%
	Ray (MO)	61.0	102.1	187.6	271.4	335.7	450.4%
	Johnson (KS)	1,151.1	1,940.2	3,776.0	5,973.0	9,355.4	712.7%
	Wyandotte (KS)	650.3	944.2	1,479.1	1,941.4	2,284.9	251.4%
		5,530.9	8,525.0	14,453.1	21,015.4	28,726.9	419.4%
KAPL-K	Fulton (NY)	189.8	279.0	448.1	619.9	849.2	347.5%
	Saratoga (NY)	437.1	738.5	1,374.4	2,153.7	3,435.4	686.0%
	Schenectady (NY)	738.5	1,025.3	1,544.5	2,243.2	3,086.2	317.9%
		1,365.4	2,042.7	3,367.0	5,016.7	7,370.7	439.8%
KAPL-N	Albany (NY)	1,378.0	2,028.6	3,027.7	4,382.5	6,147.6	346.1%
	Montgomery (NY)	210.7	290.7	446.5	599.3	835.0	296.4%
	Saratoga (NY)	437.1	738.5	1,374.4	2,153.7	3,435.4	686.0%
	Schenectady (NY)	738.5	1,025.3	1,544.5	2,243.2	3,086.2	317.9%
	Schohane (NY)	85.1	131.6	210.6	302.6	455.6	435.6%
		2,849.3	4,214.7	6,603.7	9,681.2	13,959.8	389.9%

Table C.4-13. Baseline Personal Income—Continued

TOTAL PERSONAL INCOME (In $MM)

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
KAPL-W	Hartford (CT)	4,109.6	5,812.0	9,720.2	14,610.2	21,209.3	416.1%
	Litchfield (CT)	689.5	1,053.0	1,876.1	2,905.6	4,381.3	535.9%
	Middlesex (CT)	535.9	837.8	1,452.3	2,279.9	3,462.3	546.0%
	New Haven (CT)	3,509.0	5,060.5	8,305.2	12,501.4	17,872.5	409.3%
	Tolland (CT)	412.0	622.6	1,167.7	1,626.0	2,631.8	587.3%
	Hampden (MA)	1,866.9	2,696.5	4,323.7	6,220.6	8,706.2	366.4%
		11,122.9	16,082.3	26,845.1	40,343.8	58,473.4	425.7%
LEHR	Colusa (CA)	73.5	143.5	178.3	205.3	276.4	276.7%
	Lake (CA)	77.1	150.6	349.4	559.9	789.4	924.2%
	Napa (CA)	362.2	638.6	1,145.6	1,712.0	2,519.8	595.8%
	Sacramento (CA)	2,766.4	4,613.4	8,310.2	12,912.8	19,873.9	618.4%
	Solano (CA)	695.7	1,252.9	2,402.7	3,749.2	5,935.3	753.2%
	Sutter (CA)	187.1	346.9	557.4	743.3	1,032.1	451.7%
	Yolo (CA)	407.3	734.0	1,239.1	1,775.7	2,801.9	588.0%
		4,569.1	7,779.8	14,182.8	21,658.2	33,230.9	627.3%
LBL	Alameda (CA)	5,187.3	7,674.5	13,092.7	20,275.5	28,453.8	448.5%
	Contra Costa (CA)	2,774.2	4,452.6	8,785.0	13,924.1	20,647.5	644.3%
		7,961.5	12,127.2	21,877.7	34,199.6	49,101.3	516.7%
LLNL	Alameda (CA)	5,187.3	7,674.5	13,092.7	20,275.5	28,453.8	448.5%
	Contra Costa (CA)	2,774.2	4,452.6	8,785.0	13,924.1	20,647.5	644.3%
	San Joaquin (CA)	1,215.3	2,033.7	3,634.5	5,215.1	7,484.0	515.8%
	Stanislaus (CA)	766.1	1,335.7	2,577.1	3,743.3	5,699.3	644.0%
		9,942.9	15,496.5	28,089.2	43,157.9	62,284.6	526.4%
LANL	Los Alamos (NM)	78.1	124.7	221.4	364.4	505.8	547.8%
	Rio Arriba (NM)	53.8	92.1	163.6	240.3	312.1	480.0%
	Santa Fe (NM)	192.8	352.3	677.2	1,140.1	1,704.0	784.0%
		324.7	569.1	1,062.1	1,744.8	2,521.9	676.8%
Mare Island	Contra Costa (CA)	2,774.2	4,452.6	8,785.0	13,924.1	20,647.5	644.3%
	Lake (CA)	77.1	150.6	349.4	559.9	789.4	924.2%
	Marin (CA)	1,229.1	1,945.1	3,813.8	6,056.3	8,657.2	604.3%
	Mendocino (CA)	195.4	329.5	650.2	900.8	1,301.1	565.8%
	Napa (CA)	362.2	638.6	1,145.6	1,712.0	2,519.8	595.8%
	Sonoma (CA)	921.5	1,694.7	3,430.8	5,556.0	8,628.9	836.4%
		5,559.5	9,211.0	18,174.8	28,709.0	42,543.9	665.3%
MSP	Mercer (NJ)	1,475.4	2,314.5	3,647.9	5,707.3	8,491.9	475.6%
	Middlesex (NJ)	2,751.4	4,303.7	7,057.0	11,558.7	16,761.1	509.2%
	Monmouth (NJ)	2,120.8	3,380.2	6,038.3	10,105.8	15,178.4	615.7%
	Somerset (NJ)	1,055.7	1,604.0	2,919.1	4,991.5	8,009.3	658.7%
	Union (NJ)	3,002.8	4,035.9	6,505.8	9,621.6	12,943.0	331.0%
		10,406.1	15,638.3	26,168.1	41,984.8	61,383.7	489.9%
MOUND	Butler (OH)	870.5	1,386.6	2,508.2	3,473.1	4,902.0	463.1%
	Clark (OH)	588.0	853.4	1,331.4	1,832.4	2,461.8	318.7%
	Darke (OH)	175.2	277.8	463.8	641.3	864.6	393.4%
	Greene (OH)	502.0	750.2	1,243.6	1,742.3	2,490.0	396.0%
	Miami (OH)	337.8	502.0	860.2	1,171.6	1,585.3	369.3%
	Montgomery (OH)	2,630.1	3,625.9	5,742.2	7,999.6	10,577.1	302.2%
	Preble (OH)	123.9	188.0	320.9	444.0	598.6	383.0%
	Warren (OH)	302.0	476.2	890.9	1,271.3	1,973.6	553.6%
		5,529.5	8,060.0	13,361.3	18,575.6	25,453.1	360.3%
NTS	Clark (NV)	1,335.2	2,337.6	5,123.0	7,843.2	14,087.5	955.1%
	Nye (NV)	27.6	44.6	100.3	167.9	273.9	892.9%
		1,362.8	2,382.2	5,223.3	8,011.0	14,361.4	953.8%
Norfolk	Chesapeake city (VA)	296.6	537.7	1,025.5	1,672.3	2,593.7	774.4%
	Hampton city (VA)	420.2	648.9	1,006.2	1,513.1	1,979.0	371.0%
	Newport News city (VA)	490.8	753.8	1,281.5	1,985.1	2,613.3	432.5%
	Norfolk city (VA)	1,111.8	1,610.3	2,339.9	3,389.0	4,280.1	285.0%
	Suffolk city (VA)	139.3	244.5	407.5	635.0	878.2	530.3%
	Virginia Beach city (VA)	690.0	1,354.7	2,707.1	4,745.4	7,024.8	918.0%
	Isle of Wight (VA)	57.0	105.1	191.2	313.7	451.6	692.2%
		3,205.7	5,255.0	8,958.9	14,253.5	19,820.6	518.3%

Table C.4-13. Baseline Personal Income—Continued

TOTAL PERSONAL INCOME (in $MM)

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
ORR	Anderson (TN)	203.2	346.8	586.1	801.7	1,121.1	451.6%
	Knox (TN)	923.2	1,562.5	2,788.6	4,045.7	5,844.4	533.1%
	Loudon (TN)	66.9	117.2	218.8	293.0	433.5	547.5%
	Roane (TN)	110.5	199.2	395.6	527.8	727.5	558.2%
		1,303.9	2,225.7	3,989.2	5,668.2	8,126.4	523.2%
PGDP	Ballard (KY)	27.8	41.9	70.6	88.7	122.9	342.3%
	Carlisle (KY)	13.9	22.9	37.5	52.9	66.1	374.1%
	Graves (KY)	93.0	150.4	266.5	355.9	482.0	418.4%
	Marshall (KY)	61.7	107.4	215.1	287.2	398.7	545.8%
	McCracken (KY)	209.4	335.7	588.6	777.3	1,099.4	425.1%
	Massac (IL)	41.4	71.8	113.5	151.3	195.3	372.3%
		447.2	730.2	1,291.8	1,713.3	2,364.5	428.8%
Palos	Cook (IL)	27,609.0	39,409.7	60,465.2	82,068.1	110,927.8	301.8%
	Du Page (IL)	2,611.0	4,636.8	9,007.3	13,480.1	21,043.2	706.0%
	Kane (IL)	1,169.8	1,863.4	3,117.7	4,490.1	6,914.2	491.0%
	Lake (IL)	1,980.9	3,214.4	5,837.8	8,946.3	14,211.2	617.4%
	McHenry (IL)	519.0	895.6	1,677.4	2,509.2	4,032.9	677.1%
	Will (IL)	1,068.0	1,844.2	3,372.3	4,633.2	6,738.2	530.9%
	Lake (IN)	2,159.4	3,257.7	5,187.4	5,916.4	7,758.7	259.3%
		37,117.1	55,121.9	88,665.1	122,043.4	171,626.2	362.4%
Pantex	Carson (TX)	27.2	67.5	63.0	99.1	117.7	332.1%
	Potter (TX)	315.2	512.3	958.9	1,357.7	1,589.1	404.1%
	Randall (TX)	233.3	448.3	768.8	1,295.3	1,598.0	585.0%
		575.7	1,028.2	1,790.7	2,752.0	3,304.7	474.0%
Pearl Harbor	Honolulu (HI)	3,194.4	5,090.3	8,293.1	11,815.8	17,880.7	459.8%
	Kauai (HI)	121.2	207.8	374.4	515.8	884.1	629.5%
	Maui (HI)	193.9	371.9	710.5	1,068.6	1,876.8	867.7%
		3,509.5	5,670.1	9,377.9	13,400.2	20,641.6	488.2%
PIN	Hillsborough (FL)	1,683.7	3,130.5	5,593.9	9,497.0	14,177.8	742.1%
	Pasco (FL)	249.7	650.0	1,562.5	2,703.0	3,960.7	1486.4%
	Pinellas (FL)	2,189.0	4,014.7	7,710.5	12,857.5	18,483.7	744.4%
		4,122.3	7,795.2	14,866.9	25,057.5	36,622.1	788.4%
PORTS	Jackson (OH)	72.1	119.0	201.6	279.2	347.6	382.2%
	Pike (OH)	48.3	81.3	146.2	219.3	291.7	503.6%
	Ross (OH)	194.9	300.8	529.4	737.0	935.8	380.1%
	Scioto (OH)	247.0	364.1	608.4	788.9	1,017.3	311.9%
		562.3	865.1	1,485.6	2,024.4	2,592.4	361.0%
Portsmouth	Cumberland (ME)	766.5	1,192.3	2,041.5	3,270.8	5,211.5	579.9%
	Oxford (ME)	139.9	216.5	391.7	528.2	786.0	462.0%
	York (ME)	399.4	629.7	1,187.1	1,896.6	2,960.5	641.2%
	Carroll (NH)	73.7	134.3	267.1	461.5	780.8	959.5%
	Rockingham (NH)	536.8	904.9	1,957.5	3,566.5	5,369.4	900.3%
	Strafford (NH)	245.0	368.3	735.1	1,195.7	1,794.5	632.5%
		2,161.3	3,446.0	6,580.0	10,919.3	16,902.6	682.1%
PPPL	Burlington (NJ)	1,326.0	2,172.7	3,897.1	6,067.2	9,106.0	586.7%
	Hunterdon (NJ)	344.2	600.8	1,139.9	2,043.2	3,276.3	852.0%
	Mercer (NJ)	1,475.4	2,314.5	3,647.9	5,707.3	8,491.9	475.6%
	Middlesex (NJ)	2,751.4	4,303.7	7,057.0	11,558.7	16,761.1	509.2%
	Monmouth (NJ)	2,120.8	3,380.2	6,038.3	10,105.8	15,178.4	615.7%
	Somerset (NJ)	1,055.7	1,604.0	2,919.1	4,991.5	8,009.3	658.7%
	Bucks (PA)	1,754.2	2,875.8	5,280.3	8,132.8	12,250.6	598.3%
		10,827.6	17,251.7	29,979.6	48,606.4	73,073.7	574.9%
Puget Sound	Jefferson (WA)	39.3	71.1	156.3	226.7	329.2	738.1%
	King (WA)	5,583.1	8,507.6	16,470.2	23,445.3	36,181.4	548.1%
	Kitsap (WA)	430.4	761.3	1,485.0	2,232.2	3,262.1	657.9%
	Mason (WA)	75.2	135.1	279.3	390.6	547.2	628.0%
	Pierce (WA)	1,654.8	2,561.0	4,738.9	6,764.8	9,583.1	479.1%
		7,782.8	12,036.2	23,129.8	33,059.5	49,903.0	541.2%

Table C.4-13. Baseline Personal Income—Continued

TOTAL PERSONAL INCOME (in $MM)

Site	County/City	1970	1975	1980	1985	1990	Percent Change 1970-1990
RMI	Ashtabula (OH)	347.8	526.1	875.2	1,102.7	1,337.9	284.7%
	Geauga (OH)	256.6	415.1	828.7	1,164.4	1,688.0	557.4%
	Lake (OH)	823.6	1,276.0	2,270.5	3,096.6	4,249.0	415.9%
	Trumbull (OH)	935.6	1,494.9	2,400.7	2,937.9	3,673.6	292.7%
	Crawford (PA)	281.0	443.6	715.2	937.7	1,241.6	341.8%
	Erie (PA)	1,016.4	1,623.4	2,544.6	3,358.2	4,499.4	343.1%
		3,660.2	5,779.1	9,633.2	12,597.8	16,689.5	356.0%
RFP	Adams (CO)	659.4	1,151.3	2,288.6	3,461.4	4,274.6	548.2%
	Arapahoe (CO)	805.9	1,704.1	3,826.3	6,567.0	8,850.0	998.2%
	Boulder (CO)	556.6	1,005.4	2,125.7	3,479.2	4,843.5	769.9%
	Denver (CO)	2,469.1	3,830.5	6,029.7	8,610.0	10,334.9	318.6%
	Jefferson (CO)	1,081.0	2,119.6	4,484.6	7,245.9	9,230.5	753.9%
		5,572.1	9,810.9	18,754.9	29,363.5	37,533.5	573.6%
SNLA	Bernalillo (NM)	1,158.1	2,088.6	3,895.3	6,168.0	8,450.7	629.7%
	Cibola (NM)	0.0	0.0	0.0	175.4	195.2	NA
	Sandoval (NM)	40.1	102.1	227.3	488.0	832.9	1974.7%
	Santa Fe (NM)	192.8	352.3	677.2	1,140.1	1,704.0	784.0%
	Torrance (NM)	13.4	25.7	52.6	76.1	107.9	703.1%
	Valencia (NM)	97.1	179.2	436.2	369.9	532.2	448.0%
		1,501.5	2,747.9	5,288.6	8,417.4	11,822.9	687.4%
SRS	Aiken (SC)	308.6	484.2	860.5	1,359.6	2,172.4	608.6%
	Allendale (SC)	21.5	35.1	59.3	88.5	127.5	493.5%
	Bamberg (SC)	36.6	59.8	92.7	134.5	177.3	384.6%
	Barnwell (SC)	46.3	84.1	129.4	209.5	285.8	517.2%
	Burke (GA)	44.7	76.7	120.3	199.7	231.1	417.4%
	Columbia (GA)	70.8	131.7	339.9	694.8	1,120.6	1483.3%
	Richmond (GA)	500.3	820.7	1,369.8	2,233.2	3,023.5	504.3%
	Screven (GA)	28.7	52.3	80.7	130.8	165.9	477.2%
		1,055.4	1,744.5	3,052.6	5,050.6	7,304.0	592.0%
SLAC	Alameda (CA)	5,187.3	7,674.5	13,092.7	20,275.5	28,453.8	448.5%
	Monterey (CA)	1,167.5	1,915.6	3,178.0	4,626.1	6,954.0	495.6%
	San Benito (CA)	73.5	124.1	246.3	391.9	600.5	716.6%
	San Mateo (CA)	3,277.2	4,970.5	8,595.9	13,341.5	18,789.9	473.4%
	Santa Clara (CA)	5,220.4	8,610.2	16,910.5	27,071.3	37,882.5	625.7%
	Santa Cruz (CA)	541.6	1,011.8	2,087.0	3,323.7	5,085.9	839.1%
	Stanislaus (CA)	766.1	1,335.7	2,577.1	3,743.3	5,699.3	644.0%
		16,233.6	25,642.4	46,687.6	72,973.3	103,485.8	537.4%
UMo	Audrain (MO)	91.1	139.7	224.2	288.2	355.5	290.3%
	Boone (MO)	269.9	474.9	890.4	1,320.1	1,935.4	617.1%
	Callaway (MO)	84.6	131.5	268.3	368.3	487.9	476.6%
	Cole (MO)	172.1	286.7	507.7	745.4	1,038.5	503.3%
	Cooper (MO)	51.6	77.6	115.8	161.5	202.6	292.3%
	Howard (MO)	33.8	47.1	72.3	103.1	129.9	284.6%
	Moniteau (MO)	34.2	56.4	97.2	138.3	190.6	456.0%
	Randolph (MO)	73.0	117.4	187.8	266.2	330.5	353.0%
		810.2	1,331.1	2,363.8	3,391.0	4,670.9	476.5%
WIPP	Chaves (NM)	135.7	240.6	416.7	625.9	821.6	505.5%
	Eddy (NM)	130.7	225.6	409.7	585.9	688.8	427.1%
	Lea (NM)	167.1	289.6	558.2	778.5	744.5	345.6%
	Otero (NM)	125.1	200.2	322.4	520.4	651.7	421.0%
	Culberson (TX)	11.1	16.0	27.3	32.5	38.0	242.8%
	Loving (TX)	0.4	1.1	2.1	2.1	2.7	507.2%
		570.1	973.1	1,736.3	2,546.3	2,947.3	417.0%
WSSRAP	Franklin (MO)	189.3	318.9	614.9	956.8	1,323.3	598.9%
	Jefferson (MO)	350.2	549.8	1,271.3	1,923.6	2,737.9	681.7%
	St. Charles (MO)	372.9	606.0	1,454.9	2,610.8	4,036.8	982.5%
	St. Louis (MO)	4,685.5	7,329.9	11,901.7	17,713.2	24,097.6	393.2%
	Madison (IL)	995.1	1,470.2	2,459.0	3,350.6	4,487.0	350.9%
	Monroe (IL)	66.2	109.7	212.4	307.2	466.9	603.5%
	St. Clair (IL)	1,013.4	1,480.5	2,373.8	3,275.2	4,257.3	320.1%
		7,872.7	11,862.9	20,287.9	30,137.3	41,405.8	426.9%
WVDP	Cattaraugus (NY)	289.9	405.5	633.5	850.3	1,152.5	327.1%
	Erie (NY)	4,669.4	6,608.2	10,002.6	13,224.0	17,712.0	279.3%
		4,939.2	7,013.7	10,636.1	14,074.2	18,864.5	281.9%
UNITED STATES		825,534.0	1,308,482.0	2,254,076.0	3,317,545.0	4,664,057.0	465.0%

C.4.5.3 Impacts Analysis Procedures

C.4.5.3.1 *Development of Regional Multipliers*

The economic impact analysis was conducted by first determining how responsive the National economy and the various regional economies were to a change in expenditures. The result of this determination was quantified in what is termed a "multiplier." Each site has a unique ROI (relevant counties as defined below) and each industry within that region has a unique degree of responsiveness to changes in the level of expenditures in the region. Multipliers for disposable income, output, and job-years were developed for 80 industries (industrial sectors) for the aggregate county regions of influence and the national economy. The multipliers were derived from an 80-sector model based on the Regional Input-Output Modeling System (RIMS II) approach developed by the U.S. Department of Commerce, Bureau of Economic Analysis (DOC, 1992b).

The procedure for developing the regional multipliers required establishing an economic ROI for each site. This was done by identifying those counties in the vicinity of the site where economic impacts would be expected to occur. Counties are unique in their ability to provide the labor and other resources necessary to any particular line of production. The demand for intermediate goods (i.e., goods that are used in the production of other goods) is a function of the demand for final goods. The technique used to measure a county's ability to satisfy production requirements was first to establish the relationships between industries for the National economy, and then to estimate the proportion of relationships that are attributable to the regional economy under analysis. The technique involves matrix multiplication of the BEA's 1987 *U.S. Use and Make Tables* that results in a *National Direct Requirements Table*, as shown in the following example:

$$A_N = [USE_N] \times [MAKE_N]$$

where:

A_N = National Direct Requirements Table

USE_N = 1987 U.S. Use Table

$MAKE_N$ = 1987 U.S. Make Table

By using the Consumer Price Index (CPI) and the Producer Price Index (PPI), the 1987 data was updated to 1990 dollar terms. (The detailed PPI was used to update manufacturing and wholesale trade sectors, while the detailed CPI was used to update service and retail sectors.)

Once the interindustry relationships were identified in the *National Direct Requirements Table*, they were regionalized by calculating the location quotient for earnings (i.e., income to labor). The location quotient for output is given by:

$$LQ^R_i = [(X^R_i/X^R)/(X^N_i/X^N)]$$

where:
LQ^R = Location quotient for region "R" and industry "i"
X^R_i and X^R are output for industry "i" and total industry output in the region
X^N_i and X^N are National output for industry "i" and total output for the country (Miller and Blair, 1985)

Similarly, the income (earnings) location quotient matrix for industry "i" in region "R" is given by:

$$LQ^R_i = [(Y^R_i/Y^R)/(Y^N_i/Y^N)]$$

where:
LQ^R = Location quotient for region "R" and industry "i"
Y^n and Y^n are national income for industry "i" and total income for the Nation
Y^R_i and Y^R are income for industry "i" and total industry income in the region

The *National Direct Requirements Table* (from above) was then multiplied by the vector of location quotients for a given region to derive a regional *Direct Requirements Table*. This process was repeated for each ROI.

The regional *Direct Requirements Table* is therefore:

$$A_R = [LQ_R] \times [A_N]$$

where:
A_R = regional Direct Requirements Table for region "R," and
LQ_R = Matrix of location quotients for region "R"

The following calculation resulted in the final matrix of impacts for a given region:

$$M_R = [I - A_R]^{-1}$$

where:
M_R = Matrix of output multipliers for region "R," and
I = the "identity" matrix (a matrix of zeros with ones on the diagonal)

The resulting 80-by-80-sector output multiplier table was then totaled across its rows (except for row 80) to produce a vector of output multipliers. Row 80 is the sum of earnings paid to households and is already incorporated in the multipliers for the first 79 sectors. Therefore, row 80 contains the earnings multipliers for a given region.

A final step was required to determine the employment multipliers for a region. Using County Business Pattern data for the Nation as a whole (DOC, 1993), the relationships between employment and output for all industries were derived.

The standard procedure in applying regional impact models is to calculate the specific multipliers (employment, income, and output as described above) for each of the 80 sectors individually, then multiply each industry multiplier by the costs anticipated for each industry sector. The difficulty with this approach is in transforming the data from an lump sum engineering cost estimate into the 80 industry classifications. The procedure used in this economic impact analysis was to assume that the individual multipliers are normally distributed. The mean multiplier for employment, income, and output was calculated for each region, and multiplied by the initial costs. The product is the change in employment, income, and output. Given a sample size of 80 sectors that are normally distributed, the sample size is large enough to approximate a standard normal distribution.

There is an advantage in using individual multipliers because of their ability to trace impacts on the economic variables through individual industrial sectors. However, because the objective of this analysis was to look at marginal changes in total employment, income, and output—not at the changes in specific industrial sectors—such a detailed analysis was considered unwarranted.

The employment, income, and output multipliers for each region were then applied to the initial waste management project costs for each site under each waste type alternative taken from the analysis described

in Section C.3.3. As discussed above, the cost data were broken out into construction, operations, and transportation phases. When changes in employment and income were calculated for each waste-type alternative, they were weighted by the number of years involved for construction and operations activities. The percent change in employment and income is equal to the total time-weighted dollar change in the variable divided by the 1990 value of the variable, multiplied by 100.

The National-level impacts of waste management activities were calculated by using the National RIMS II multipliers. These impacts help to account for the leakage in expenditures that would occur at the regional level when purchases of goods and services must be made outside a particular ROI due to the inability of the regional economy to provide those goods or services. For example, steel is manufactured only in certain parts of the U.S. When steel is required by a site that is in an ROI that does not have a steel plant, the steel must be brought in from outside of the ROI. This purchase causes money "leakage" out of that ROI to somewhere else in the National economy. The National economy analysis is thus able to "capture" economic activity that is otherwise lost to the individual site ROIs.

Since the transportation expenditures would be made throughout the country, the National multipliers were also used to determine the impacts of transportation expenditures.

The next step was to multiply the respective grand mean multipliers for employment, income, and output respectively by the initial expenditure anticipated for each site and waste type alternative. The product of the initial cost and the multipliers gave the estimated change in personal income, job-years, and output.

C.4.5.3.2 *Analysis Assumptions*

This section identifies the assumptions used in developing the baseline conditions and impacts for the various waste types.

C.4.5.3.3 *Multiplier Analysis*

Baseline conditions for the impacts analysis used a two-tier ROI. The first tier included the 17 sites that contain the vast majority of DOE waste. A detailed ROI was developed based on the residence patterns

of the site employees. Counties were included if they contained 5% or more of the site employees, until the counties selected accounted for 90% or more of the site employees. Contiguous counties were included by exception if there was reason to believe that excluding them might preclude a site-specific determination of where on a site a waste management facility could be located.

The second ROI tier included 37 sites that are anticipated to have relatively low expenditures, irrespective of the waste type or the Alternative. In most cases the second tier sites were waste donor sites. Since these sites will experience small impacts (due to little or no planned activity) they were not given the extensive treatment that the major sites received. The ROIs for each second tier site consists of the host and contiguous counties only.

As indicated above, multipliers were assembled for each of the ROIs associated with each site. The simplifying assumption regarding these multipliers holds that the average (mean) multiplier is an unbiased and efficient estimator of the any of the 80 multipliers.

Each waste type was analyzed using specific timing assumptions. Further, the HLW analysis used different timing assumptions for each alternative. The time frames identified in Table C.4–14 and employed in the analysis should be viewed as representative. Representative time cycles are used to show what would happen if a similar cycle were actually used. The time frame is required to annualize the changes in income and employment both to provide the absolute change in the variable and the percent change over the 1990 baseline. The time frames are proxies for any time period and are not intended to imply that a particular time frame has been selected.

In addition, it was assumed that an additional five years will elapse before the full economic impacts of any given or phase of the operation will occur. The time frame used to calculate impacts then includes the time over which the action is planned to occur plus five years.

Table C.4-14. Duration in Years of WM Activity Phases Assumed for Waste Type Economic Analysis

Waste Type	Construction Phase	Operations Phase	Transportation
LLMW	4	15 (No Action = 25)	10 (No Action = 20)
LLW	4	15 (No Action = 25)	10 (No Action = 20)
TRUW	4	15 (No Action = 25)	10 (No Action = 20)
HLW	3	17 to 43	34
HW	4	12	10

The economic impact analysis was based on standard Keynesian economic theory. This theory holds that aggregate demand is a function of income. When income is generated in the form of a wage, several deductions are made reducing the amount of money that is available for respending. These deductions are given in Table C.4–15.

Table C.4-15. Wage Deductions Used in the Income Multiplier Analysis

Deduction	Percentage of Deduction
Federal Income Tax	18.0
Social Security Tax	7.6
State Unemployment Tax	1.5
Benefits (Health and life insurance)	2.0
Personal Savings	5.0
Total unavailable for respending	34.1
Total available for respending	65.9

A coefficient of variance was calculated for the grand mean multipliers of the ROIs for the 47 sites. The coefficient of variance is equal to the standard deviation of the grand mean multiplier divided by the grand mean multiplier.

The grand mean multipliers and the multipliers' coefficient of variance for the 47 ROIs are reported in Table C.4–16 and Table C.4–17, respectively.

Table C.4-16. Grand Mean Multipliers

Site	Output (1)	Earnings (2)	Employment (3)
AMES	1.6968398	0.2686351	26.1
ANL-E	1.8992364	0.2794387	24.1
BCL	2.0945444	0.2963150	27.2
BAPL	2.0854729	0.2955736	26.8
BNL	1.8928028	0.2825461	24.9
Charleston	1.8486995	0.2632758	24.2
Colonie	1.9521110	0.2755395	26.0
ETEC	2.0860979	0.2918617	26.9
FNAL	2.1277356	0.3000036	27.1
FEMP	2.0115936	0.2992522	26.2
GA	1.9761869	0.2793827	26.2
GE	1.8819248	0.2698297	26.0
GJPO	1.8788433	0.2628304	25.5
Hanford	1.7345193	0.2606101	24.4
INEL	1.6539740	0.2501210	23.2
KCP	2.0661073	0.2920600	26.9
KAPL-K	1.6542548	0.2492809	22.1
KAPL-N	1.8803463	0.2665589	25.2
KAPL-W	2.0211218	0.2872877	26.0
LEHR	1.8814520	0.2667942	25.2
LBL	2.1162016	0.3093407	26.8
LLNL	2.1480631	0.3114184	28.2
LANL	1.7278235	0.2566492	23.6
Mare Island	2.0097511	0.2841494	26.5
MSP	2.0560625	0.2908983	26.2
MOUND	1.7815385	0.2537604	23.7
NTS	1.7526830	0.2633199	23.4
Norfolk	1.7882339	0.2551058	23.9
ORR	2.0175825	0.3014903	26.7
PGDP	1.7091768	0.2612092	23.9
Palos	2.1394955	0.3019226	27.2
Pantex	1.8058253	0.2664281	24.8
Pearl Harbor	1.8166110	0.2560974	24.3
PIN	1.9382666	0.2750944	25.8
PORTS	1.7395320	0.2644895	24.8
Portsmouth	2.0104574	0.2857046	26.3
PPPL	2.0962324	0.2967151	26.8
Puget Sound	1.9194054	0.2736098	25.3
RMI	1.8073449	0.2559203	23.4
RFETS	1.9088693	0.2832914	25.2
SNLA	1.8358633	0.2730185	24.9
SRS	1.8961558	0.2789010	25.8
SLAC	1.7502934	0.2507150	23.3
UMo	1.7537006	0.2497958	24.0
WIPP	1.7094931	0.2559931	23.7
WSSRAP	2.1302335	0.3014761	27.3
WVDP	2.1326031	0.3170268	27.8
NATIONAL	3.0829564	0.8324667	36.8

Notes:

(1) The total dollar change in output that occurs across all industries for each additional dollar of output delivered to final demand.

(2) The total dollar change in earnings of households employed by all industries for each additional dollar of output delivered to final demand.

(3) The total change in number of jobs in all industries for each additional 1 million dollars of output delivered to final demand in a given year.

Table C.4-17. Multipliers' Coefficient of Variance

Site	Output	Earnings	Employment
AMES	0.1282514	0.3232824	0.7017540
ANL-E	0.1514593	0.4842782	0.6223096
BCL	0.1335457	0.3108199	0.5816449
BAPL	0.1423880	0.3197699	0.5657588
BNL	0.1076392	0.4656121	0.6015071
Charleston	0.1350718	0.3236767	0.6538367
Colonie	0.1183233	0.3023482	0.6448926
ETEC	0.1194562	0.3069452	0.5785328
FNAL	0.1395721	0.3117937	0.5540122
FEMP	0.1212080	0.4434402	0.5735707
GA	0.1184384	0.3187351	0.6262334
GE	0.1310743	0.3253468	0.7018351
GJPO	0.1458825	0.3387602	0.7130032
Hanford	0.1291553	0.4987933	0.7501411
INEL	0.1174174	0.5183568	0.7851976
KCP	0.1249323	0.3062415	0.5880993
KAPL-K	0.1055506	0.5082354	0.6985579
KAPL-N	0.1108195	0.3142466	0.6520623
KAPL-W	0.1330296	0.3176867	0.5789079
LEHR	0.1195645	0.3213139	0.6552262
LBL	0.1336941	0.4379207	0.5548303
LLNL	0.1299192	0.4302718	0.6280589
LANL	0.1234926	0.5115640	0.7293250
Mare Island	0.1336816	0.3163528	0.6208246
MSP	0.1337611	0.3137265	0.5703249
MOUND	0.1183593	0.3377189	0.7091450
NTS	0.1305871	0.5074167	0.6517835
Norfolk	0.1225205	0.3380128	0.6498472
ORR	0.1279087	0.4467180	0.5916954
PGDP	0.1297143	0.5055180	0.7517458
Palos	0.1399090	0.3116253	0.5491915
Pantex	0.1236165	0.4922549	0.7415270
Pearl Harbor	0.1267270	0.3324984	0.6697828
PIN	0.1146860	0.3179148	0.6247028
PORTS	0.1408416	0.5007350	0.7359551
Portsmouth	0.1414415	0.3262595	0.5881818
PPPL	0.1343447	0.3116302	0.5635358
Puget Sound	0.1342005	0.3296160	0.6086124
RMI	0.1327751	0.3383731	0.6790840
RFETS	0.1261521	0.4754906	0.6146155
SNLA	0.1197497	0.4900238	0.6760818
SRS	0.1370186	0.4650688	0.7017991
SLAC	0.1079955	0.3308188	0.6862206
UMo	0.1305158	0.3448562	0.7495700
WIPP	0.1205319	0.5070867	0.7579089
WSSRAP	0.1401402	0.3130342	0.5595690
WVDP	0.1362926	0.4282287	0.5648346
NATIONAL	0.1816865	0.2830192	0.3542612

Note: The coefficient of variance is equal to the standard deviation of the mean multiplier divided by the mean.

C.4.5.3.4 *Limitations of the Multiplier Analysis*

The use of the input-output (I-O) system for estimating multipliers has several limitations, including:

- No explicit recognition of prices—relative prices between industries change and the prices are not updated. The most complete table in use today uses 1987 prices; price adjustments are made uniformly and do not capture changes in relative prices within an industry.

- Linear homogeneous production function. If any scale economies or diseconomies exist, they are not captured; expansion of one industry will not have the impacts on downstream industries that the I-O model assumes.

- Constant I-O formation ignores the possibility that capacity will be reached with the effect of changing relative prices and input substitutions.

While these limitations are important, the use of the multipliers is to show relative changes; what would happen if you did a similar thing in different places. While the limitations prevent the determination of the absolute changes in the magnitude of the economic variables, they are instrumental in identifying relative changes.

C.4.5.3.5 *Analysis Data*

Most of the baseline data used in this analysis are from the Bureau of Economic Analysis whose "Regional Economic Information System" provides historical data on employment and personal income.

The cost figures used in the analysis were those described in Section C.3.3 of this appendix. They include the fully loaded costs of setting up a business to build and operate the WM facilities. They also include a set of linear scaler modules that can be assembled on the basis of the type of waste and waste volume. The modules can be placed in any part of the country and either scaled to accommodate the volume of waste, or adjusted in terms of the number of operating years to accommodate different waste volumes. The cost figures include a 30% contingency.

C.4.5.3.6 *Evaluation Techniques*

The economic model outputs included changes in income, output, and job-years. When the timing assumptions were applied, the job-years variable was divided by the number of years to give the number of direct, indirect, and induced jobs in an ROI. All of the ROIs that were evaluated are anticipated to experience an increase in expenditures resulting in increases in employment, income, and output; therefore, all impacts are expected to be positive.

The primary evaluation technique is to identify the magnitude of the change. All of the impact categories are first measured in absolute terms. Then, income and employment inputs are calculated with respect to changes in the baseline income and employment.

C.4.5.3.7 *Presentation of Results*

Data from the analysis are presented in several places in the document. Chapter 4 provides affected environment data for the 17 major sites in text and tables. The additional sites are presented in the Technical Report on the Affected Environment for the DOE Sites Considered in the WM PEIS (M/B SR-01). Chapters 6 through 10 present the results of the impacts analysis for each of the waste types and for each alternative. The primary variable in these chapters is the percent change in the number of jobs. Changes in personal income are also presented. Both variables are presented in terms of absolute numbers as well as percent changes over the 1990 baseline. A 1% change in the number of jobs is considered a substantial positive benefit to the regional or National economy.

C.4.6 Population Impacts

The analysis examined the potential for the waste management alternatives to cause the types of impacts that could result when any large industrial or public works project attracts workers and their families to an area.

C.4.6.1 Regions of Influence

The ROI included the geographic area surrounding the site that would be subject to the changes traditionally associated with large-scale industrial projects (such as changes in employment and demographics). The site-level ROI was defined, as an aggregate of whole counties to include the host county (or counties), any contiguous counties, and other counties within the region that contain at least 5% of the total site workforce (both DOE and contractor personnel). Where these counties did not represent at least 90% of the total site workforce, counties with progressively lower percentages were included until the 90% threshold was met.

The site ROI population was assumed to represent the affected community at each site. It was considered reasonable to expect that the effects of in-migration to a region would be experienced in existing, nearby communities that have the infrastructure and established community support networks necessary for social life.

The analysis quantified population changes that constitute or that may in turn cause a number of related changes in community characteristics and that are likely to affect community services and resources. The likelihood of these latter effects is inferred from the size of the expected temporary and permanent population changes during the construction and operations phases of the waste management projects and the general characteristics of the communities at each site.

C.4.6.1.1 *Potential Impacts of WM Project Labor Requirements*

Population increases and settlement patterns associated with worker in-migration to the ROI are the source of most social effects of the construction and operation of an industrial project. (Halstead, et al., 1984; Cantor, 1977). Sources of change include the introduction of new people into a region in response to new employment; loss of residents in response to a perceived diminished quality of life or loss of employment opportunities; or retention of residents, who might otherwise have left the area, as a result of improvement or enhancement of some social factor.

The construction and operation of waste management facilities can be expected to have some influence on the growth of the population in the regions surrounding the sites. This growth will raise important

concerns based on the potential for changes to certain community characteristics such as size, diversity, stability, and the ability to provide necessary or locally desirable social services. Though the description of the precise nature and detail of these changes is dependent on site specific information regarding the location of any proposed facility, the size and characteristics of the inmigrating workforces and the number of existing site personnel actually employed on the project, some preliminary estimates can be made on the basis of the more general information available at the programmatic level.

Community Characteristics—Size, Diversity, Stability. Conventional effects associated with large industrial facilities include: the economic effects of increased local employment, the demographic effects of increased population growth, the fiscal effects of increased demands for social services, and social effects of perceived changes in the quality of life (Finley, 1983). These changes will usually result in other changes in community life. The temporary in-migration of construction workers and their families and the more permanent settlement of workers during the operations phase of the proposed action are relevant to this analysis.

The central impetus for change rests in the differences, both real and perceived, between the incoming population and those who already reside in the ROI. Important demographic characteristics that could change include age, sex, ethnic and racial composition, and income distribution. Potential disruptions to settlement patterns and relocation of local population are also important (Cantor, 1993). Consequential changes in the patterns of interaction of local residents also can be anticipated (Gramling and Freudenburg, 1992).

Other associated changes include: the level of diversity and complexity—affected when the number and types of social groups in the community are increased; and community cohesion—potentially affected by anything that decreases the desirability of the community itself or the desirability of associating or identifying with the community (Finsterbusch, 1980).

Community Services and Resources. Local community resources and especially the provision of services (health, education, and public safety services) to community residents are susceptible to any change in the size and composition of the local population (Cantor, 1993). Along with community social and welfare services, these social services constitute primary resources to the populations of the affected communities. The mechanisms for providing these services can be disrupted by population growth or change in composition or location of the population. Other social resources, such as available housing

and recreational and cultural resources, may also be affected by temporary or long-term in-migration. Project related growth is expected to increase demands for services provided by local and State governments in the affected regions.

Although it is not feasible to collect data on the capabilities of individual community service delivery systems without specific information regarding the physical location of the designated facility and the corresponding distribution of new population in the ROI, some qualitative prediction of impacts can be made on the basis of general population estimates. Impacts to social services and resources can be inferred from the direct and indirect labor requirements and associated changes in population size and mix anticipated for each of the alternatives. Impacts may be predicted on the basis of the potential for altering service provider to recipient ratios, such as student/teacher or doctor/patient ratios; decreased availability of facilities such as hospital beds or schoolroom seats; or the loss of services to segments of the community as a result of overcrowding or population relocation. A sudden need to provide resources to expand services or an increased capability to provide resources based on an increased population would cause fiscal impacts.

C.4.6.1.2 *Method of Population Analysis*

Because the factors that influence in-migration are multiple and complex, it was impossible to precisely predict the number of in-migrants at each site for the proposed alternatives. However, an estimate was made for each site based on total waste management project workforce requirements. Although this number is not a specific prediction of the actual in-migration into a site's ROI, it provides a basis for comparing potential changes in population across alternatives.

This analysis considered three types of in-migration associated with new requirements for 1) direct construction labor; 2) O&M labor; and 3) secondary labor resulting from new employment at the sites. The level of in-migration would be indirectly influenced by several factors: the current level of unemployment in the region; the economic conditions and the demands for labor (both within the region and in adjacent areas); the ability of the local workforce to provide the necessary skills; the presence and success of worker retraining programs; characteristics of workers and their families; and individual preferences for location and type of residence. The location and the personnel requirements of contractors

who work on the project would also be factors; some may already be located in the region with available staff to meet the work requirement, while others may be located outside the region.

Other factors that would influence in-migration include the size of the project and proximity of the region to urban centers. Indirect employment and induced employment (additional employment in the region that is not directly connected to the project but results from increased expenditures in the region) would also contribute to changes in the resident population and to the general social character of the region.

This approach assumed that the following factors remain constant for all alternatives: worker family characteristics, residential locations, composition of the local workforce, and labor shortages among specific occupational groups in the region. No attempt was made to estimate the potential for in-migration that exceeds the number of jobs provided; only estimates of actual employment, direct and multiplier-based, are used. Estimates of peak employment or singular shortages of particular labor categories at particular sites are not included. The success rates of retraining programs at individual sites may affect the availability of labor, but this factor cannot be correctly appraised for this assessment.

The actual number of in-migrants during any phase of the waste management project could not be precisely determined, but the literature provides empirical data that were used as percentage estimators for the WM project phases based on the phases of similar projects:

- The percentage of construction jobs filled by in-migrants would range from 30 to 60% (Halstead, et al., 1984). The actual figures for specific projects vary according to the following factors:

  - size of the project
  - proximity to urban centers
  - local labor force
  - requirement for specialized skills and crafts
  - Table C.4–18 lists the percentages for each of the 17 major sites based on the characteristics of the site ROI

- Job duration during the construction phase was assumed to be approximately four years, and most (85%) of in-migrant construction workers who are directly related to the project are phased out after this period.

- Local workers occupy 40 to 60% of new O&M jobs. Training or retraining programs may encourage local hiring. Because DOE has plans for a retraining program, it is assumed that no fewer than 40% of the available jobs will go to retrainees, 30% will go to other local workers, and 30% will go to in-migrants.

- Of all induced labor associated with the project, 50% will be hired from the local workforce.

Table C.4–18. Percentage of Construction Workers Expected to in-Migrate to Each of the 17 Major DOE Sites

Percentage	Sites
30	BNL
40	ANL-E, FEMP, LLNL, ORR, RFETS, SNL-NM, WVDP
45	HS, NTS
60	INEL, LANL, PGDP, Pantex, Ports, SRS, WIPP

For the quantitative estimate of population in-migration and associated characteristics, impacts are presented in the waste-type chapters for those sites where ROI population increases (including new workers and their families) were estimated to be 1% or greater than the 1990 population. These sites are assumed by the analysis to experience a greater potential for change to the social environment as a result of the proposed action. Additionally, sites with estimated population increases over one-half of 1% were assumed to have a potential for minor impacts to social characteristics and the provision of social services and are noted in the discussion where appropriate.

Because the precise location of new facilities at a site and the subsequent preferred residential location of in-migrating workers are not known, this assessment serves only as an estimate for the purpose of comparing impacts. Noticeable effects may occur at much lower levels than 1%, if in-migration is concentrated in one or two communities.

C.4.7 Environmental Justice Impacts

In accordance with the requirements of Executive Order 12898, DOE evaluated the potential for the WM PEIS program alternatives to cause disproportionately high and adverse human health or environmental effects to minority and low-income populations. DOE identified and mapped the distribution of minority and low-income populations at the 17 major sites then reviewed the human health effects and environmental impacts associated with alternatives for the five waste types at those sites. The review included potential impacts under each of the major scientific disciplines evaluated for the waste-type alternatives--human health risk, air quality, water resources, ecology, economics, population impacts, land use, infrastructure, and cultural resources impacts. Regarding health effects, both normal facility operations and accident conditions were examined, with accident scenarios evaluated in terms of the risk to the public. Likewise, the examination of transportation included both routine transportation effects and the effects of potential accidents for truck and rail transportation of the waste types. Special exposure pathways were evaluated with respect to subsistence consumption of fish, game, or native plants.

C.4.7.1 Environmental Justice Overview

Environmental justice means the fair treatment of people of all races, cultures, and income levels with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies (EPA, 1994a). Environmental justice impacts refer to adverse effects that result when one or more of a broad range of factors tends to place disproportionate adverse environmental impacts on minority (specifically including Native American) and low-income populations.

C.4.7.1.1 *Studies Supporting Environmental Justice Concerns*

A number of studies, particularly those by the United Church of Christ and the EPA Environmental Equity Workgroup, have indicated a positive correlation between the locations of minority and low-income communities and the location of potentially polluting facilities such as industrial plants and hazardous waste facilities (United Church of Christ, 1987; EPA, 1992b).

The United Church of Christ study found that race was more strongly correlated to residence near a hazardous waste site than to income status (United Church of Christ, 1987). The EPA Environmental Equity Workgroup study found that:

- There are clear differences between racial groups in terms of diseases and death rates; however, there is a general lack of data on environmental health effects by race and income.

- People of color and low-income populations experience higher-than-average exposures to selected air pollutants, hazardous waste facilities, and contaminated fish.

- Data are not routinely collected on health risks posed by multiple industrial facilities, cumulative and synergistic effects, or multiple pathways of exposure.

- American Indians are a unique group with a special relationship to the Federal government and distinct environmental problems. Tribes generally lack physical infrastructure, institutions, trained personnel, and resources necessary to protect their members (EPA, 1994a; EPA, 1992b).

C.4.7.1.2 *Issuance of the Executive Order on Environmental Justice*

As a result of these and other studies, Executive Order 12898, ***Federal Actions to Address Environmental Justice in Minority and Low-Income Populations***, was developed by the administration during 1993 and became effective when signed on February 11, 1994 (Executive Order 12898). The Executive Order requires all Federal agencies to focus attention on the environmental and human health conditions in minority and low-income communities to promote nondiscrimination in federal programs substantially affecting human health and the environment. The Executive Order also requires federal agencies to provide minority and low-income communities access to information and public participation in matters relating to environmental justice.

To accomplish these goals, the Executive Order focuses on the need for all Federal agencies to apply the substantive environmental requirements relating to the enforcement of existing laws in a non-discriminatory manner. The Executive Order also establishes a process for Federal agencies, individually and in concert, to implement these environmental justice requirements. To initiate this process, EPA has

convened an interagency Federal Working Group on Environmental Justice to provide guidance to Federal agencies, and to serve as an information clearinghouse, coordinate research and data collection, disseminate existing data and studies, provide public participation, organize interagency model projects, and deal with other environmental justice issues that require cooperation among Federal agencies. DOE is a member of the Working Group.

Under the Executive Order, agencies are required to develop agency-wide environmental justice strategies to identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of the agency's programs, policies, and activities on minority and low-income populations. Using the strategy, the agency is required to conduct its programs, policies, and activities that "substantially affect human health or the environment" in a manner that insures that they do not subject persons (including populations) to discrimination.

There are significant information-gathering requirements under the Executive Order. The extra dimension of minority and low-income populations is added to existing research, data collection, and analysis requirements to the extent practicable and appropriate. Additionally, to the extent practicable and appropriate, agencies must examine consumption patterns of fish and wildlife where they may be affected by agency activities. Risks inherent in such consumption must be communicated to at-risk populations.

The public participation and information access requirements of the Executive Order are also significant. The public is encouraged to submit recommendations to Federal agencies relating to incorporation of environmental justice principles into agency programs or policies. Federal agencies must convey such recommendations to the Working Group. Whenever practicable and appropriate, agencies must translate relevant communication relating to human health or the environment for limited English speaking populations. Public documents, notices, and hearings relating to human health or the environment must be concise, understandable, and readily accessible to the public. In addition to other minority and low-income groups, Native Americans are specifically identified as requiring agency scrutiny under the requirements of the Executive Order.

Federal agencies are required to implement the Executive Order consistent with and "to the extent permitted by existing law." However, the Executive Order is intended only to improve the internal management of the Executive branch and does not create "any right, benefit, or trust responsibility, substantive or procedural, enforceable at law or equity by a party against the United States, its agencies,

its officers, or any person." The Executive Order is not to be construed to create any right to judicial review involving the compliance or noncompliance of the United States, its agencies, its officers, or any other person. A memorandum for the heads of all departments and agencies, circulated with the Executive Order, underscored the application of Title VI of the Civil Rights Act of 1964, NEPA, the Freedom of Information Act, the Sunshine Act, and the Emergency Planning and Community Right-to-Know Act as existing law particularly applicable to environmental justice (Office of the President, 1994).

"Minority and low-income populations" are not defined under the Executive Order. Generally, as defined by the U. S. Department of Commerce, Bureau of Census, minority populations include Black, American Indian, Asian-Pacific, and Hispanic racial and ethnic categories (DOC, 1992c; DOC, 1992d). Native American populations are specifically identified under the Order. Low-income populations are those whose income level is below the poverty level, also as defined by the Bureau of Census (DOC, 1992e).

C.4.7.1.3 *Status of DOE Guidance on Environmental Justice*

The interagency Federal Working Group on Environmental Justice is directed to provide guidance to Federal agencies on criteria for identifying disproportionately high and adverse human health or environmental effects on minority populations and low-income populations. The Working Group is also directed to coordinate with each Federal agency to develop an environmental justice strategy, if a strategy is required by the proposed activities. At the time of this analysis, the Working Group had not issued final guidance on the approach to be used in analyzing environmental justice, as directed by the Executive Order. The Working Group has issued draft definitions of terms in the Draft Guidance for Federal Agencies on terms in Executive Order 12898, dated November 28, 1994. These definitions, with slight modifications, were used in the PEIS environmental justice analysis. Further, in coordination with the Working Group, DOE is developing internal guidance for the implementation of the Executive Order, which has not yet been finalized. Because both DOE and the Working Group are still in the process of developing guidance, the approach used in this analysis might depart somewhat from whatever guidance is eventually issued.

C.4.7.2 Approach to PEIS Consideration of Environmental Justice Impacts

For the environmental justice assessment, the following effects were evaluated for alternatives under each of the five waste types:

Disproportionately high and adverse human health effects: Adverse health effects are measured in risks and rates that could result in latent cancer fatalities, as well as other fatal or nonfatal adverse impacts to human health. Disproportionately high and adverse human health effects occur when the risk or rate for a minority population or low-income population from exposure to an environmental hazard significantly exceeds the risk or rate to the general population and, where available, to another appropriate comparison group.

Disproportionately high and adverse environmental impacts: An adverse environmental impact is a deleterious environmental impact determined to be unacceptable or above generally accepted norms. A disproportionately high impact refers to an impact (or risk of an impact) to a low-income or minority community that significantly exceeds the same type of impact in the larger community.

C.4.7.2.1 *Identification and Mapping of Minority and Low-Income Populations*

Demographic information obtained from the U.S. Bureau of Census was used to identify minority and low-income populations in the zone of potential impact surrounding each of the sites under consideration. This zone is defined as a circle with origin at the site center and an 80-kilometer (50-mile) radius. This 80-kilometer (50-mile) radius was selected because it was judged to encompass virtually all of the human health risks and environmental impacts that may occur. It was used to specify the offsite population at risk in the human health risk assessment of airborne dispersion of waste management facility emissions. It also encompasses the majority of communities that would be affected socioeconomically by waste management program actions. Transportation impacts are assessed within 800 meters (0.5 miles) of transportation routes for incident-free transportation because impacts beyond this distance are expected to be negligible. For transportation accidents, an 80-kilometer (50-mile) radius was used.

Definitions

Definitions used to develop and map the community characteristics data are as follows:

A ***census tract*** is an area defined for the purpose of monitoring census data that is usually comprised of between 2,500 and 8,000 persons, with 4,000 persons being ideal. When first delineated, census tracts are designed to be homogenous with respect to population characteristics, economic status, and living conditions. Census tracts do not cross county boundaries. The spatial size of census tracts varies widely depending on the density of settlement. Census tract boundaries are delineated with the intention of being maintained over a long period of time so that statistical comparisons can be made from census to census.

A ***minority population*** is a group of people and/or community experiencing common conditions of exposure or impact that consists of persons classified by the U.S. Bureau of the Census as Negro/Black/African-American, Hispanic, Asian and Pacific Islander, American Indian, Eskimo, Aleut, or other nonwhite, based on self-classification by the people according to the race with which they most closely identify. For the purposes of this analysis, a minority populations was defined as any census tract within the 50-mile zone of impact where minority individuals comprise 50% or more of the population. A ***low-income population*** was defined as a census tract with a median income to a family of four equal to or below the national poverty level of $12,674. Census tracts were included in the analysis if 50% of the area of the tract fell within the 80-kilometer (50-mile) radius..

Mapping Procedures

For each of the 17 major WM sites, demographic maps were prepared using 1990 census data available from the U.S. Bureau of the Census. Maps of the minority and low-income populations are shown in Appendix I. Figures I-1 through I-17 and Figures I-18 through I-34 illustrate census tract distributions for minority populations and low-income populations respectively for areas surrounding the 17 DOE sites being considered for the management of the five waste types. These maps are based on an analysis of 1990 United States Bureau of the Census Tiger Line files, which contain political boundaries and geographical features, and Summary Tape Files 3A (as processed by the U.S. Environmental Protection Agency), which contain demographic information (DOC, 1992c; DOC, 1992d; DOC, 1992e). Data were resolved to the census tract group level. A census tract is an area defined for the purpose of monitoring census data that is usually comprised of between 2,500 and 8,000 persons. Native American tribal lands

within 50 miles of each site were also identified and mapped and are included in Appendix I, where applicable, with the minority distribution maps I-1 through I-17

C.4.7.2.2 *Review of High and Adverse Health Risks and Environmental Impacts*

The environmental justice analysis presented in each waste type chapter is based on a review of the findings of the risk assessment for public health effects from proposed WM activities at each site and from transportation of wastes. The analysis focused on risks to the maximally-exposed individual (MEI) members of the offsite population at the sites and in the transportation corridors. The expectation was that the PEIS human health risk assessment findings would indicate that risks to the general population from WM actions at each site would be low. Therefore, only in instances where certain individuals identified as MEIs are at high risk would there be a potential for disproportionately high and adverse health risks to minority or low-income communities. If risks to MEIs were also low then no segment of the population would experience disproportionately high and adverse health risks including any minority or low-income populations.

The analysis also reviewed environmental impacts, focusing on such effects as air quality impacts that are likely to directly affect offsite populations. Special consideration was also given to the potential for effects on subsistence hunters and fishermen in terms of contamination of fish or game and in terms of reductions in game populations caused by vehicle collisions. As was the case with health risk, if environmental impacts in general were low then only in the instance of a specific impact being high at a particular site would there be a potential for disproportionately high and adverse impacts to minority or low-income groups. Where risks or environmental impacts were found to be significant, mitigation measures are described that could minimize impacts and thus eliminate the potential for disproportionately high impacts to any minority or low-income populations that might be affected.

C.4.8 Land Use Impacts

The land use impacts analysis evaluated the potential for the management alternatives for the five waste types to adversely affect land use at the sites by comparing the amount of land required for proposed waste treatment, storage, or disposal facilities with the amount of land designated for future waste

management operations in the site development plans for the 17 major sites. For those of the 17 sites not having a portion of the site designated for waste operations, the land required for waste management activities was compared with an estimated amount of land suitable for development. This estimate was made by subtracting from the total installation acreage the known or estimated acreage of land in existing structures, sensitive habitats including wetlands, topographic and surface water features, and other features such as wildlife management areas and cultural resources. At sites where the land requirement constitutes 1% or more of designated or suitable land, a potential for impacts is noted in the waste type impacts discussion and the percent required is listed in a summary table for the site/alternative. The text then discusses the severity of impacts depending on how great a portion of the available land is required and includes an indication of the likelihood of conflicts with land uses adjacent to the site. Where the land requirements for waste management activities exceeds the amount of land designated or suitable, the analysis indicates that significant land use impacts are likely. Apart from the analysis of the percent of suitable site land used, the analysis also indicates whether the description of future uses at the sites given in the site development plans appears to indicate a potential conflict between those planned uses and the uses proposed under the waste type alternatives.

C.4.9 Infrastructure Impacts Methodology

Construction and operation of waste management facilities at the sites will increase the sites' use of water supply, wastewater treatment facilities, and electrical power systems and will increase traffic on site roads. The impacts of the waste management alternatives on site water, wastewater, and power systems were evaluated using estimates of the percentage of existing system capacity the new requirements represented. Where the new requirements were substantial, they were added to current use rates and the sum compared to the existing supply capacities of those systems. Site transportation infrastructure impacts were assessed indirectly using increased site employment as an indicator of increased stress on the system. Impacts to community infrastructure systems were assessed using estimated waste management project-induced population increases as an indicator of increased demand on those systems. The impacts assessment evaluated the separate effects of the construction and operations phases for each alternative for each waste type.

C.4.9.1 Site Infrastructure Impacts

The site infrastructure impacts analysis focused on the effects of the WM alternatives on the 17 major sites' water supply, wastewater treatment, and electrical power infrastructure systems. Data on new infrastructure requirements under each alternative are described in Section C.3.2 of this appendix. Current use rate and existing capacity data are described in PEIS Chapter 4 on the Affected Environment and in the Affected Environment Technical Report.

New project requirements of less than 5% of existing capacity were considered likely to have negligible or minor impacts on an infrastructure system and were not further evaluated. Moderate or major impacts were considered possible where increases in system requirements were 5% or greater. These cases were further evaluated on a site by site basis. Major impacts were considered possible where new requirements caused system capacity to be approached or exceeded. Therefore, any increase of 5% or greater that caused the total site use rate to exceed 90% of available capacity, was considered to have the potential to cause a major infrastructure impact. In such cases, site infrastructure may require substantial expansion or construction of new systems to meet the added demand. Such projects would have associated costs and environmental impacts beyond the direct impacts of the waste management facilities.

Where site infrastructure capacity information was not available, the new requirements were evaluated as a percentage of current use. In these cases, new requirements of less than 5% of current use were considered likely to have negligible or minor impacts. Increases in requirements from 5 to less than 15% were considered to have the potential to cause moderate impacts, and increases of 15% or greater were considered to have the potential to cause major impacts.

Site transportation infrastructure impacts were evaluated indirectly by comparing new site employment to existing site employment as an indicator of increased stress on site transportation systems. New site employment of less than 5% of current employment was considered likely to have negligible or minor impacts. Site employment increases from 5% to less than 15% were considered to have the potential to cause moderate impacts, and increases of 15% or greater were considered to have the potential to cause major impacts.

C.4.9.2 Community Infrastructure Impacts

Community infrastructure would be affected indirectly by any substantial increase in population caused by the influx of labor to implement the WM alternatives. Community infrastructure impacts were evaluated by comparing estimated population increases with current population levels as an indicator of increased use rates of community infrastructure systems. This analysis was based on the in-migration estimates and 1990 regional population data described in the social impacts analysis (see Section C.4.6). Population increases of less than 5% of current (1990 census) population levels were considered to have the potential to cause negligible or minor impacts. Increases of 5% or greater were considered to have the potential to cause moderate impacts, and increases of 15% or greater were considered to have the potential for major infrastructure impacts.

C.4.9.3 Site and Community Infrastructure Baseline

Baseline water, wastewater, and power information can be found in the Affected Environment chapter and appendix. The information is summarized below. Proposed resource requirements under the alternatives are compared to the current capacity to determine whether increased use will impact the infrastructure systems. Site employment information is provided in the socioeconomic impacts discussion, and is summarized in Table C.4–19. Proposed increases in site employment under the various alternatives is compared to current site employment to determine possible impacts to transportation infrastructure.

Table C.4-19. Baseline Infrastructure Data for the 17 Major DOE Sites

Site	Water (gpd)		Wastewater (gpd)		Power (mw)		Site Employment
	Current Use	Capacity	Current Use	Capacity	Current Use	Capacity	
ANL-E	625,000	1,800,000	434,000	2,600,000	23	NA	4,455
BNL	3,500,000	6,000,000	1,000,000	2,300,000	35	47	3,557
FEMP	400,000	1,600,000	2,180,000	2,270,000	33	NA	1,939
HS	9,510,000	79,060,000	158,000	200,000	550	NA	14,394
INEL	5,242,000	30,630,000	254,000	unlimited	42	NA	11,813
LANL	4,100,000	10,000,000	NA	1,000,000	68	120	6,199
LLNL	717,000	2,520,000	400,000	1,680,000	61	100	8,173
NTS	1,360,000	2,780,000	140,000	338,000	30	45	7,086
ORR	18,300,000	40,200,000	2,000,000	4,100,000	116	660	21,544
PGDP	15,000,000	30,000,000	400,000	1,750,000	1,564	3,040	1,740
Pantex	500,000	1,500,000	275,000	545,000	13	1,523	2,891
PORTS	14,000,000	37,000,000	350,000	1,200,000	1,537	1,929	2,386
RFETS	272,000	1,000,000	150,000	500,000	18	35	7,365
SNL	1,000,000	4,030,000	548,000	NA	35	50	8,596
SRS	1,600,000	5,000,000	500,000	750,000	80	175	17,319
WIPP	14,000	540,000	12,000	185,000	NA	NA	932
WVDP	70,000	110,000	70,000	70,000	3	7	643

C.4.10 Cultural Resources Impacts

The potential for cultural resources to be affected by waste management activities was considered by using the estimated acreage of site disturbance to construct waste management facilities under each waste-type alternative as an estimate of the area of potential cultural resource effects and as a comparative indicator of the extent of the cultural resource survey requirements at each site. Cultural resources impacts were not directly evaluated in the PEIS because the analysis would require identification of specific locations of proposed waste management facilities.

C.4.10.1 Cultural Resources Considered

The cultural resources considered in this analysis include prehistoric and historic resources, and Native American resources. Paleontological resources, though not cultural in origin, are also included because of their recognized value and similar need for protection.

C.4.10.1.1 *Prehistoric and Historic Properties*

A "historic property" is an archeological site, standing structure, or traditional cultural property that is listed or is potentially eligible for listing on the National Register of Historic Places (36 CFR 60). Requirements for the assessment of historic properties for the PEIS are met through compliance with Section 106 of the National Historic Preservation Act of 1966 (16 USC 470), as amended, with implementing regulations contained in 36 CFR 800. In general, Federal agencies are required to determine the effects of proposed actions on significant historic properties within a defined area of potential effects.

C.4.10.1.2 *Native American Resources*

Native American resources refer to structures, regional locations, natural features, native plants, objects and other materials that are considered to be of value to contemporary Native American groups for traditional, religious, or ceremonial purposes. Examples of these resources can include burial grounds, sacred sites, and areas, materials for the production of sacred objects and traditional implements, and botanical, biological, and geological resources of ritual importance. Impacts to these areas include both direct physical impacts (destruction, loss of access) and indirect social and economic effects. Several laws and regulations are specifically applicable to the protection of Native American resources including American Indian Religious Freedom Act of 1978 (42 USC 1996) and the Native American Graves Protection and Repatriation Act of 1990 (25 USC 3001 *et seq.*). Determination of potential impact to these sites is similar to that for other historic properties.

C.4.10.1.3 *Paleontological Resources*

Paleontological materials and features are the physical remains of life forms (fossils) from a former geologic age. These include the remains of animals, plants, or trace fossils such as impressions, burrows or tracks. Although paleontological resources are not treated with the same level of specificity as archeological or historic properties, they are included in several Federal statutes such as the Archeological Resources Protection Act of 1979 (16 USC 470aa-470ll) and the Federal Land Management Policy Act of 1976 (43 USC 1701 *et seq.*).

C.4.10.2 Cultural Resources Protection Procedures

Federal agencies protect cultural resources through compliance with Section 106 of the National Historic Preservation Act of 1966, as amended, which is implemented through regulations contained in 36 CFR 800. These regulations require Federal agencies to consider the existing information, undertake identification activities if the existing information is insufficient, determine whether any cultural resources contained within the agency-defined area of potential effects meet the criteria for eligibility for inclusion in the National Register of Historic Places, determine the effect of the proposed action on significant historic properties, consult with the State Historic Preservation Office (SHPO), and afford the Advisory Council on Historic Preservation (ACHP) the opportunity to comment.

To comply with 36 CFR 800, the lead federal agency defines an "area of potential effects," or project area, for the proposed action. The project area usually comprises the physical limits of disturbance or alteration that will result from the proposed actions, such as construction, demolition, staging, or operation of a facility.

The next step in the process is to identify the presence of absence of historic properties within the area of potential effects (36 CFR 800.4). An "historic property" is an archeological site, standing structure, or traditional cultural property that is listed or is potentially eligible for listing on the National Register of Historic Places (NRHP) (36 CFR 60). Identificational studies can comprise a variety of site-specific archaeological, architectural, or cultural surveys of the undertaking's project area. Other studies may be conducted in order to evaluate an identified resource's eligibility for inclusion on NRHP.

If no cultural resources eligible or potentially eligible for the NRHP are identified during these studies, then, given the concurrence of the SHPO, the project will have no effect on historic properties and the undertaking may proceed. If historic properties are identified within the project area, then the agency in consultation with the SHPO must apply the "criteria or effect and adverse effect" as defined in 36 CFR 800.5 and Part 800.9.

An undertaking is considered to have an adverse effect when the effect on a historic property may diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association. Adverse effects on historic properties include, but are not limited to:

- Physical destruction, damage, or alteration to all or part of the property
- Isolation of the property from or alteration to the character of the property's setting when that character contributes to the property's qualification for the National Register
- Introduction of visual, audible, or atmospheric elements that are out of character with the property or alter its setting
- Neglect of a property resulting in its deterioration or destruction
- Transfer, lease, or sale of the property (36 CFR 800.9.b.1-5)

C.4.10.3 Consideration of Cultural Resources Impacts in the PEIS

Given the various levels of cultural resource information (the number of recorded resources and the size of surveyed areas) associated with DOE facilities across the country and the cultural resource diversity known or presumed to be located at these sites, the specific analysis of impacts must be left to site-specific or project-level NEPA documents. In addition, the locations of the different waste management activities at individual sites have not been identified. Thus, at the programmatic level, both the specific area of potential effects and the presence or absence of National Register eligible historic properties are at present unknown. Therefore, evaluation of potential impacts in this PEIS was limited to providing relevant information on existing cultural resources identified at the sites (see Chapter 4, Affected

Environment) and an estimate of the extent to which potential new site surveys would be required (see the Cultural Impacts sections in the waste-type Chapters 6 - 10).

Chapter 4 identifies the extent to which installations have been surveyed for cultural resources and lists registered cultural properties. Chapters 6 through 10 display acreage requirements for treatment, storage, or disposal construction as estimates of the amount of land that may be disturbed at each site and may therefore require a cultural resource survey. Acreages are given by site and by alternative, and are totaled across sites as estimates of alternative-specific survey requirements. In general, the smaller the total acreage required, the lower the likelihood that National Register eligible properties will be affected by new facility construction. Thus, the waste management alternative that requires the smallest total land area at the individual sites would appear to be preferable from a cultural resources perspective. This may be partially offset by the greater acreages required at the fewer regional or the single centralized sites, although these sites are generally the much larger sites, which gives DOE a greater ability to locate the new waste management facilities so as to avoid affecting cultural resources.

Appendix C
References

CFR: Code of Federal Regulations: 10 CFR 1021 is read "Title 10 of the Code of Federal Regulations, Part 1021."

USC: United States Code of Law: 42 USC 6901 is read "Title 42 of the U.S. Code, Part 6901."

10 CFR 1022. Compliance with Floodplain/Wetland Environmental Review Requirements. 1979.

15 USC 2601 et seq. Toxic Substances Control Act of 1976.

16 USC 470. National Historic Preservation Act of 1966, As Amended.

16 USC 470aa-470ll. Archeological Resources Protection Act of 1979.

25 USC 3001 et seq. Native American Graves Protection and Repatriation Act of 1990.

33 USC 1251 et seq. Clean Water Act.

36 CFR 60. National Register of Historic Places.

36 CFR 800. Protection of Historic Properties.

40 CFR 50. [EPA] National Primary and Secondary Ambient Air Quality Standards.

40 CFR 51, Subpart T. U.S. Conformity to State or Federal Implementation Plans of Transportation Plans, Programs, and Projects Developed, Funded or Approved under Title 23 U.S.C. or the Federal Transit Act.

40 CFR 52.21. Protection of the Environment; Approval and Promulgation of Implementation Plans - Prevention of Significant Deterioration of Air Quality (NESHAP).

40 CFR 61. Protection of the Environment; National Emission Standards for Hazardous Air Pollutants (NESHAP).

40 CFR 81. Protection of the Environment; Designation of Areas for Air Quality Planning Purposes, Subpart C: Section 107 Attainment Status Designations.

40 CFR 82. Stratospheric Ozone Protection Regulations.

40 CFR 93. Determining Conformity of Federal Actions to State or Federal Implementation Plans.

40 CFR 141. National Primary Drinking Water Regulations.

40 CFR 143. National Secondary Drinking Water Regulations.

40 CFR 191. Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes.

40 CFR 1502.15. Environmental Impact Statement: Affected Environment.

40 CFR 1508.27. Terminology and Index: Significantly.

42 USC 300 *et seq.* Safe Drinking Water Act.

42 USC 1996 *et seq.* American Indian Religious Freedom Act of 1978.

42 USC 4231 *et seq.* National Environmental Policy Act of 1969, As Amended.

42 USC 6901 *et seq.* Resource Conservation and Recovery Act of 1976.

42 USC 7401 *et seq.* Clean Air Act of 1977, As Amended.

42 USC 9601 *et seq.* Comprehensive Environmental Response, Compensation, and Liability Act of 1980.

43 USC 1701 *et. seq.* Federal Land Management Policy Act of 1976.

57 FR 31776. 1992. 40 CFR 141 and 142: National Primary Drinking Water Regulations, Synthetic Organic Chemicals and Inorganic Chemicals; Final Rule. July 17.

ANL. *See* Argonne National Laboratory.

Argonne National Laboratory. 1995a. *Supplemental Information Related to Risk Assessment for the Off-Site Transportation of Low-Level Waste for the U.S. Department of Energy Waste Management Programmatic Environmental Impact Statement* by F.A. Monette, B.M. Biwer, D.J. LePoire, and S.Y. Chen. ANL/EAD/TM-23. April 28 Draft. Argonne, Illinois.

Argonne National Laboratory. 1995b. *High-Level Waste Inventory, Characteristics, Generation and Facility Assessment for Treatment, Storage, and Disposal Alternatives Considered in the U.S. Department of Energy Waste Management Programmatic Environmental Impact Statement* by S. M. Folga, G. Conzelmann, J.L. Gillette, P.H. Kier, and L.A. Poch. ANL\EAD\TM-17. April 28 Draft. Argonne, Illinois.

Branch, K., J. Thompson, J. Creighton, and D. Hooper. 1992. *Guide to Social Assessment* prepared by the Bureau of Land Management, Social Effects Project. BLM-YA-PT-82-007-1606. July. Billings, MT: Mountain West Research.

Cantor, L. 1977. *Environmental Impact Assessment*. New York: McGraw Hill.

Cantor, L. 1993. *Environmental Impact Assessment*. Draft. New York: McGraw Hill.

Cuthbertson, K., and D. Nitzsche. 1994. "Macro Systems: The Dynamics of Economic Policy" (Book Review). *Journal of Economic Dynamics and Control*. No. 18, pp. 1937-39.

D'Antonio, M. 1993 . *Atomic Harvest*. New York: Crown Publishers, Inc.

DOC. *See* U.S. Department of Commerce.

DOE. *See* U.S. Department of Energy.

Edelstein, M. 1988. *Contaminated Communities*. Boulder, CO: Westview Press.

EG&G and MK (EG&G Idaho and Morrison Knudsen Corporation). 1994. *Waste Management Facilities Cost Information, Volume II, Socioeconomic Data Package, TRU Case No. 2.* MKES WMF6-R-S-06-743, June 7.

EPA. *See* U.S. Environmental Protection Agency.

Executive Order 11988. *Floodplain Management,* May 24, 1977.

Executive Order 12843. *Procurement Requirements and Policies for Federal Agencies for Ozone-Depleting Substances.*

Executive Order 12898. "Federal Actions to Address Environmental Justice in Minority and Low Income Populations." *Federal Register* (February 1, 1994), p. 7629. Signed February 11, 1994.

Finely, J. 1983. "Federal, State, and Local Socioeconomic Management Dimensions in Nuclear Waste Disposal," *Nuclear Waste: Socioeconomic Dimensions of Long-Term Storage* by S. Murdock, F.L. Leistritz, and R. Hamm, eds. Boulder, CO: Westview Press.

Finsterbusch, K. 1980. *Social Impacts*. Beverly Hills, CA: Sage Publications.

Freudenburg, W. 1993. *Risk and Recreancy: Weber, The Division of Labor, and The Rationality of Risk Perceptions*. Social Forces 71, vol.4. June.

Freudenburg, W. and R. Baxter. 1984. *Host Community Attitudes Toward Nuclear Power Plant: A Reassessment*. Social Science Quarterly 46.

Freudenburg, W. and R. Gramling. 1992. *Community Impacts of Technological Change: Toward a Longitudinal Perspective*. Social Forces 70, vol 4. June.

Gramling, R. and W. Freudenburg. 1992. *Opportunity-Threat Development and Adaptation: Toward a Comprehensive Framework for Social Impact Assessment*. Rural Sociology. 57 (2).

Halstead, J., R. Chase, S. Murdoch, and F. Leistritz. 1984. *Socioeconomic Impact Assessment, Design and Implementation.* Boulder, CO: Westview Press.

IAEA. *See* International Atomic Energy Agency.

Idaho National Engineering Laboratory. 1994. *Data Collection on Existing and Planned/Approved Waste Management Facilities in Support of the EM PEIS* by M. Sherick and D.E. Shropshire. DES-35-94, Revision 2. August. Idaho Falls, Idaho: EG&G Idaho, Inc..

Idaho National Engineering Laboratory. 1995a. *Interim Report: Waste Management Facilities Cost Information for Mixed Low-Level Waste* by D.E. Shropshire, Michael Sherick, and Chuck Biagi. INEL-95/0014 (Formerly EGG-WM-10962) Revision 1. June Draft. Idaho Falls, Idaho.

Idaho National Engineering Laboratory. 1995b. *Waste Management Facilities Cost Information for Transuranic Waste* by D.E. Shropshire, Michael Sherick, and Chuck Biagi. INEL-95/0015 (Formerly EGG-WM-11274) Revision 1. June Draft. Idaho Falls, Idaho.

Idaho National Engineering Laboratory. 1995c. *Waste Management Facilities Cost Information for Hazardous Waste* by D.E. Shropshire, Michael Sherick, and Chuck Biagi. INEL-95/0016 (Formerly EGG-WM-11432) Revision 1. June Draft. Idaho Falls, Idaho.

Idaho National Engineering Laboratory. 1995d. *Waste Management Facilities Cost Information for Low-Level Waste* by D.E. Shropshire, Michael Sherick, and Chuck Biagi. INEL-95/0013 Revision 1. June Draft. Idaho Falls, Idaho.

Idaho National Engineering Laboratory. 1995e. *Waste Management Facilities Cost Information for Transportation of Radioactive and Hazardous Materials* by F.H. Feizollahi, D.E. Shropshire, and D. Burton. Revision 1. INEL-95/0300 (Formerly EGG-WM-10877) Revision 1. June Draft. Idaho Falls, Idaho.

INEL. *See* Idaho National Engineering Laboratory.

International Atomic Energy Agency. 1992. *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards*. Technical Report Series No. 332. Vienna: International Atomic Energy Agency.

Kaiser Engineers Hanford and Westinghouse Hanford Company. 1994. *FY 1993 Annual Report on In-house Energy Management*. January. Richland, Washington.

Kraft, M. and B. Clarey. 1993. "Public Testimony in Nuclear Waste Repository Hearings: A Content Analysis," *Public Reactions to Nuclear Waste: Citizens Views of Repository Siting* by R. Dunlap, M. Kraft and E. Rosa, eds. Durham: Duke University Press.

McClelland, G., H. Gray, William Schulze, and B. Hurd, et al. 1990. *The Effect of Risk Beliefs on Property Values: A Case Study of a Hazardous Waste Site*. Risk Analysis 10, vol.4.

Metz, W. C., 1992. *Perceived Risk and Nuclear Waste in Nevada: A Mixture Leading to Economic Doom*. Impact Assessment Bulletin 10, no. 3.

Miller, R.E., and P.D. Blair. 1985. *Input-Output Analysis: Foundations and Extensions*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

NAC. *See* National Academy of Sciences.

National Council on Radiation Protection and Measurements. 1991. *Effects of Ionizing Radiation on Aquatic Organisms*. NCRP 109.

National Academy of Sciences. 1984. *Social and Economic Aspects of Radioactive Waste Management* by the National Research Council. Washington, DC: National Academy Press.

NCRP. *See* National Council on Radiation Protection and Measurements.

NPS. *See* U.S. National Park Service.

Oak Ridge National Laboratory. 1993a. *Highway 3.1—An Enhanced Highway Routing Model: Program Description, Methodology, and Revised User's Manual* by P.E. Johnson, D.S. Joy, D.B. Clark, and J.M. Jacob. ORNL\TM-12124. March. Oak Ridge, Tennessee.

Oak Ridge National Laboratory. 1993b. *Interline 5.0—An Expanded Railroad Routing Model: Program Description Methodology, and Revised User's Manual* by P.E. Johnson, D.S. Joy, D.B. Clark, and J.M. Jacob. ORNL\TM-12090. March. Oak Ridge, Tennessee.

Oak Ridge National Laboratory. 1995a. *DOE Public and Onsite Population Health Risk Evaluation Methodology for Assessing Risks Associated with Environmental Restoration and Waste Management.* ORNL 6832. April Draft. Oak Ridge, Tennessee: Center for Risk Management.

Oak Ridge National Laboratory. 1995b. *Ecological Risks of the Department of Energy's Programmatic Waste Management Alternatives* prepared by Oak Ridge National Laboratory, Environmental Sciences Division and Advanced Sciences Inc. August 15 Draft. Oak Ridge, Tennessee.

Office of the President. 1994. *Memorandum for Heads of All Departments, Executive Order on Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations.* February 11. Washington, DC.

ORNL. *See* Oak Ridge National Laboratory.

Peters and Timmerhaus. 1968. *Plant Design and Economics for Chemical Engineers.* Chemical Engineering Series. Second Edition, Page 122. New York, NY: McGraw-Hill Book Company.

Rimmer and Chai. 1990. "Estimate Costs of Scaled-Up Process Plants," *Chemical Engineering.* Volume 97, No. 4. Pages 138-175. April. McGraw-Hill Publications.

Slovic, P., M. Laymen and J. Flynn. 1993. "Perceived Risk, Trust, and Nuclear Waste: Lessons from Yucca Mountain," *Public Reactions to Nuclear Waste: Citizens Views of Repository Siting* by R. Dunlap, M. Kraft and E. Rosa, eds. Durham, NC: Duke University Press.

Slovic, P., M. Layman, N. Kraus, J. Flynn, J. Chalmers, and G. Gessell. 1991. *Perceived Risk, Stigma and Potential Economic Impacts of a High-Level Nuclear Waste Repository in Nevada.* Risk Analysis 11, no. 4.

Solley, W.B., C.F. Merk, and R.R. Pierce. 1988. *Estimated Use of Water in the United States in 1985.* U.S. Geological Survey Circular 1004.

United Church of Christ. 1987. *Toxic Wastes and Race in the United States.* Commission for Racial Justice.

U.S. Department of Commerce. 1992a. *Regional Economic Information System (REIS)* (CD-ROM). May. Washington, DC: Bureau of Economic Analysis.

U.S. Department of Commerce. 1992b. *Regional Multipliers: A User Handbook of Regional Input-Output Modeling System (RIMS II).* Second Edition. May. Washington, DC: Bureau of Economic Analysis, Government Printing Office.

U.S. Department of Commerce. 1992c. *1990 Census of Population and Housing*, Summary Tape File 3, Data for Persons of Hispanic Origin. August. Washington, DC: Bureau of the Census.

U.S. Department of Commerce. 1992d. *1990 Census of Population and Housing*, Summary Tape File 3, Data for Persons: Race. August. Washington, DC: Bureau of the Census.

U.S. Department of Commerce. 1992e. *1990 Census of Population and Housing*, Summary Tape File 3, Data for Families: Family Income and Poverty. August. Washington, DC: Bureau of the Census.

U.S. Department of Commerce,. 1993. *1990 County Business Patterns: United States.* Washington, DC: Bureau of the Census, Government Printing Office.

U.S. Department of Energy. 1986. *Environmental Assessment for a Monitored Retrievable Storage Facility, Volume II.* DOE/RW-0035/1. February. Washington, DC.

U.S. Department of Energy. 1988. *Radioactive Waste Management.* DOE Order 5820.2A. September 26. Washington, DC.

U.S. Department of Energy. 1990. *Radiation Protection of the Public and the Environment*, DOE Order 5400.5. June 5. Washington, DC.

U.S. Department of Energy. 1991. *Transportation System Data Base, Reference Transportation Data for the Civilian Radioactive Waste Management Program, Revision 1.* April. Washington, DC.

U.S. Department of Energy. 1992a. *Integrated Data Base for 1992: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics* prepared by Oak Ridge National Laboratory. DOE\RW-006. Rev. 8. October. Washington, DC.

U.S. Department of Energy. 1992b. *Waste Management Information System. Computer Database Maintained by the Hazardous Waste Remedial Actions Program (HAZWRAP).* December. Oak Ridge, TN: Martin Marietta Energy Systems.

U.S. Department of Energy. 1993a. *Interim Mixed Waste Inventory Report.* EM-352. April. Washington, DC.

U.S. Department of Energy. 1993b. "Radiation Protection of the Public and the Environment." Proposed Rule, 10 CFR 834. *Federal Register* (March 25, 1993).

U.S. Department of Energy. 1994a. *Mixed Waste Inventory Report: Final Phase II Mixed Waste Inventory Report Data.* EM-352. May. Washington, DC: Office of Environmental Restoration and Waste Management.

U.S. Department of Energy. 1994b. *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Draft Environmental Impact Statement.* DOE/EIS-0203-D. June. Washington, DC: Idaho Operations Office.

U.S. Department of Energy. 1995a. *Waste Management Environmental and Socioeconomic Impacts Methods and Results* prepared by META/Berger. M/B SR-02. September Draft. Washington, DC: Office of Environmental Management.

U.S. Department of Energy. 1995b. *Affected Environment for the Waste Management Programmatic Environmental Impact Statement Department of Energy Sites* prepared by META/Berger. M/B SR-01. July Draft. Washington, DC: Office of Environmental Management.

U.S. Environmental Protection Agency. 1985a. *Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources.* (AP-42), 4th edition. Washington, DC.

U.S. Environmental Protection Agency. 1985b. *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources.* (AP-42), 4th edition. Washington, DC.

U.S. Environmental Protection Agency. 1985c. *Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water*. Part 1. EPA/600/6-85/002a. Athens, GA: Environmental Research Laboratory, Office of Research and Development.

U.S. Environmental Protection Agency. 1986. *Quality Criteria for Water, 1986*. EPA 440/5-86-001, Washington, DC: Office of Water Regulations and Standards.

U.S. Environmental Protection Agency. 1987. *Industrial Source Complex (ISC) Dispersion Model User's Guide—Second Edition (Revised)*, Vol. I. EPA-450/4-88-002a. December. Washington, DC.

U.S. Environmental Protection Agency. 1990. *The Nations Hazardous Waste Management Program at a Crossroads*. July. Washington, DC.

U.S. Environmental Protection Agency. 1991. "National Primary Drinking Water Regulations; Radionuclides, Notice of Proposed Rulemaking." *Federal Register* (July 18, 1991) p. 33050.

U.S. Environmental Protection Agency. 1992a. *Air Superfund National Technical Guidance Study Series; Screening Procedures for Estimating the Air Impacts of Incineration at Superfund Sites*. EPA-450/1-92-003. February. Research Triangle Park, North Carolina: Office of Air Quality Planning and Standards.

U.S. Environmental Protection Agency. 1992b. *Environmental Equity: Reducing Risk in All Communities*, Vol. 1 & 2. EPA 230-R-92-008. Washington, DC: Environmental Equity Workgroup.

U.S. Environmental Protection Agency. 1993. "Determining Conformity of Federal Actions to State or Federal Implementation Plans," Final Rule, 40 CFR 93. *Federal Register*, (November 30, 1993).

U.S. Environmental Protection Agency. 1994a. *Users Guide to Mobile5a*. EPA-AA-AQAB-94-01. May. Washington, DC: Office of Air & Radiation.

U.S. Environmental Protection Agency. 1994b. *Draft User's Guide to PART5; a Program for Calculating Particle Emissions from Motor Vehicles*. July. Ann Arbor, Michigan: National Motor Vehicle and Fuels Emission Laboratory, Office of Mobile Sources.

U.S. Environmental Protection Agency. 1994c. *Environmental Justice Initiatives*, 1993. EPA 200 R-93 001. February. Washington, DC: Office of Environmental Equity.

U.S. Environmental Protection Agency. 1994d. *Pre-Application Kit for Assistance FY 1995*. Washington, DC: Office of Environmental Justice Small Grants Program.

U.S. National Park Service. 1994. *List of Tribal, Native Alaskan Entity, and Native Hawaiian Organization Contacts*. April 1 (with changes through October 18, 1994).

Appendix D

Waste Management Facility Human Health Risk Estimates

U.S. Department of Energy
Waste Management Programmatic Environmental Impact Statement

August 1995

This page intentionally left blank.

Contents

Tables viii
Figures xxiii
Acronyms and Abbreviations xxiv

D.1 Introduction D-1
D.1.1 Purpose of the Waste Management Human Health Risk Evaluation D-2
D.1.2 Waste Types Evaluated D-2
D.1.3 Waste Consolidation Alternatives D-3

D.2 Evaluating The Risks Associated With Waste Management Activities D-4
D.2.1 Characterizing the Environmental Setting D-5
D.2.2 Identifying Potentially Exposed Populations D-5
D.2.2.1 Populations Not Specifically Evaluated D-7
D.2.3 Identifying Environmental Transport Pathways D-9
D.2.3.1 Transport Pathways Not Evaluated D-10
D.2.4 Identifying Likely Exposure Routes For Populations and Individuals D-12
D.2.4.1 Offsite and Noninvolved Worker Population Exposure Routes D-12
D.2.4.2 Hypothetical Farm Family Exposure Routes D-17
D.2.4.3 Hypothetical Intruder Exposure Routes D-17
D.2.4.4 Worker Exposure Routes D-17
D.2.5 Identifying the Human Health Effects to be Evaluated D-18
D.2.5.1 Factors Excluded from the Analysis D-19
D.2.6 Quantifying Contaminant Intakes, Doses, and Exposures D-20
D.2.6.1 Quantifying Chemical Intake and Exposure D-20
D.2.6.2 Quantifying Radiological Dose and Exposure D-21
D.2.6.3 Comparing Radionuclide Exposures to Chemical Exposures D-22
D.2.7 Calculating Exposures for the PEIS Receptors D-24
D.2.7.1 Calculating Exposures to the Offsite and Noninvolved Populations, the Hypothetical Farm Family, and the Hypothetical Intruder D-24
D.2.7.2 Calculating Exposures to Waste Management Workers D-27
D.2.8 Calculating Risks D-30
D.2.8.1 Scaling Unit Doses and Intakes According to Installation Source Term D-30
D.2.8.2 Calculating Risks from Unit Doses and Intakes D-30
D.2.9 Calculating and Interpreting the Hazard Index D-33
D.2.10 Calculating and Interpreting the Exposure Index D-34
D.2.11 Calculating and Interpreting the IDLH Index for Accidents D-35

D.2.12	Assessing the Risks from Potential Accidents	D-35
D.2.12.1	Predicted Annual Frequency of Accidents	D-37
D.2.13	Contents of the Risk Analysis Tables	D-37
D.2.14	Reading and Interpreting the Risk and Probability Numbers	D-38
D.2.15	Overview of Uncertainties in the PEIS Risk Analysis Process	D-41
D.3	Risk Analysis By Waste Stream	D-42
D.3.1	High-Level Waste	D-43
D.3.1.1	Summary of HLW Alternatives	D-44
D.3.1.2	Special Assumptions and Considerations Used in the HLW Risk Analysis	D-45
D.3.1.3	Results Tables for the HLW Human Health Risk Analysis	D-46
D.3.1.4	Results of the HLW Human Health Risk Analysis for Routine Operations	D-53
D.3.1.5	Special Assumptions and Considerations Used in the HLW Accident Analysis	D-54
D.3.1.6	Results Tables for the Risk Analysis of Potential HLW Accidents	D-55
D.3.1.7	Summary of the HLW Accident Analysis Results	D-57
D.3.2	Low-Level Waste	D-58
D.3.2.1	Summary of LLW Alternatives	D-60
D.3.2.2	Special Assumptions and Considerations Used in the LLW Risk Analysis	D-63
D.3.2.3	Results Tables for the LLW Human Health Risk Analysis	D-63
D.3.2.4	Results of the LLW Human Health Risk Analysis for Routine Operations	D-69
D.3.2.4.1	Program-Wide Trends in Human Health Risks Associated with LLW Management Alternatives	D-69
D.3.2.4.2	Program-Wide Trends in Human Health Risks Associated with LLW Disposal	D-72
D.3.2.4.3	Comparison Among Treatment Options	D-74
D.3.2.4.4	Comparison Among Disposal Scenarios	D-75
D.3.2.4.5	Summary of Results for Routine Treatment and Disposal of LLW	D-76
D.3.2.6	Summary of Alternatives for Potential LLW Accidents	D-126
D.3.2.7	Special Assumptions and Considerations Used in the LLW Accident Analysis	D-126
D.3.2.8	Results Tables for the Risk Analysis of Potential LLW Accidents	D-127
D.3.2.9	Summary of the LLW Accident Analysis Results	D-135
D.3.2.9.1	Risks to the Offsite Population from LLW Accidents	D-136
D.3.2.9.2	Risks to the Noninvolved Worker Population from LLW Accidents	D-136
D.3.2.9.3	Risks to the Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual from LLW Accidents	D-137
D.3.2.9.4	Risks to Waste Management Workers from LLW Accidents	D-137

D.3.2.10	Risks to the Hypothetical Intruder from LLW Disposal	D-138
D.3.2.10.1	Results of the Human Health Risk Analysis for the Intruder	D-142
D.3.3	Hazardous Waste	D-143
D.3.3.1	Summary of HW Alternatives	D-145
D.3.3.2	Special Assumptions and Considerations Used in the HW Risk Analysis	D-146
D.3.3.3	Results Tables for the HW Human Health Risk Analysis	D-148
D.3.3.4	Results of the HW Human Health Risk Analysis for Routine Operations	D-155
D.3.3.4.1	Program-Wide Trends in Human Health Risks Associated with HW Management Alternatives	D-156
D.3.3.4.2	Summary of Results for Routine Treatment of HW	D-157
D.3.3.4.3	Discussion	D-158
D.3.3.5	Summary of Alternatives for Potential HW Accidents	D-159
D.3.3.5.1	Single-Drum Accidents	D-159
D.3.3.5.2	Storage Facility Accidents	D-162
D.3.3.5.3	Treatment Facility Accidents	D-162
D.3.3.6	Special Assumptions and Considerations Used in the HW Accident Analysis	D-162
D.3.3.7	Results Tables for the Risk Analysis of Potential HW Accidents	D-164
D.3.3.8	Summary of the HW Accident Analysis Results	D-170
D.3.3.8.1	Risks to the Offsite Population from Accidents During Storage	D-170
D.3.3.8.2	Risks to the Offsite Population from Accidents During Treatment	D-171
D.3.3.8.3	Risks to the Noninvolved Worker Population from Accidents During Storage	D-172
D.3.3.8.4	Risks to the Noninvolved Worker Population from Accidents During Treatment	D-173
D.3.3.8.5	Risks to the Most-Exposed Offsite Individual from Single-Drum Accidents	D-173
D.3.3.8.6	Risks to the Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual from Storage Facility Accidents	D-173
D.3.3.8.7	Risks to Waste Management Workers from Storage and Treatment Facility Accidents	D-174
D.3.4	Transuranic Waste	D-176
D.3.4.1	Summary of CH-TRUW Alternatives	D-179
D.3.4.2	Special Assumptions and Considerations Used in the TRUW Risk Analysis	D-181
D.3.4.3	Results Tables for the CH-TRUW Human Health Risk Analysis	D-183
D.3.4.4	Results of the CH-TRUW Human Health Risk Analysis for Routine Operations	D-199

D.3.4.4.1	Program-Wide Trends in Human Health Risks Associated with CH-TRUW Management Alternatives	D-199
D.3.4.4.2	Comparison of the Decentralized Alternative and Regionalized Alternative 1: Treatment to WIPP Waste Acceptance Criteria versus Treatment to Reduce Gas Generation	D-203
D.3.4.4.3	Comparison of Regionalized Alternatives 1 and 2: Treatment to Reduce Gas Generation versus Treatment to Land Disposal Restrictions	D-203
D.3.4.4.4	Comparison of the Regionalized 2, 3, and Centralized Alternatives: Differences in Consolidation Configuration	D-204
D.3.4.4.5	Summary of the Human Health Risk Analysis for Routine Management of CH-TRUW	D-207
D.3.4.5	Summary of RH-TRUW Alternatives	D-207
D.3.4.6	Results Tables for the RH-TRUW Human Health Risk Analysis	D-209
D.3.4.7	Results of the RH-TRUW Human Health Risk Analysis	D-218
D.3.4.7.1	Program-Wide Trends in Human Health Risks Associated with RH-TRUW Management Alternatives	D-218
D.3.4.7.2	Comparison of the Decentralized and Regionalized 1 Alternatives: Treatment to WIPP Waste Acceptance Criteria Versus Treatment to Reduce Gas Generation	D-221
D.3.4.7.3	Comparison of the Regionalized 1 Alternative with the Regionalized 2, 3, and Centralized Alternatives: Treatment to Reduce Gas Generation Versus Treatment to Land Disposal Restrictions	D-222
D.3.4.7.4	Summary	D-223
D.3.4.8	Summary of Alternatives for Potential TRUW Accidents	D-223
D.3.5	Low-Level Mixed Waste	D-223
D.3.5.1	Summary of LLMW Alternatives	D-225
D.3.5.2	Special Assumptions and Considerations Used in the LLMW Risk Analysis	D-228
D.3.5.3	Results Tables for the LLMW Human Health Risk Analysis	D-228
D.3.5.4	Results of the LLMW Human Health Risk Analysis for Routine Operations	D-260
D.3.5.4.1	Program-Wide Trends in Human Health Risks Associated with LLMW Management Alternatives	D-260
D.3.5.4.2	Program-Wide Trends in Human Health Risks Associated with LLMW Disposal	D-265
D.3.5.4.3	Comparison Among Treatment Options	D-268
D.3.5.4.4	Comparison Among Disposal Scenarios	D-269
D.3.5.4.5	Summary of Results for Routine Treatment and Disposal of LLMW	D-269

D.3.5.5	Summary of Alternatives for Potential LLMW Accidents	D-270
D.3.5.6	Special Assumptions and Considerations Used in the LLMW Accident Analysis	D-270
D.3.5.7	Results Tables for the Risk Analysis of Potential LLMW Accidents	D-271
D.3.5.8	Summary of the LLMW Accident Analysis Results	D-272
D.3.5.8.1	Risks to the Offsite Population from LLMW Accidents	D-273
D.3.5.8.2	Risks to the Noninvolved Worker Population from LLMW Accidents	D-274
D.3.5.8.3	Risks to the Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual from LLMW Accidents	D-276
D.3.5.8.4	Risks to Waste Management Workers from LLMW Accidents	D-278
D.3.5.9	Risks to the Hypothetical Intruder from LLMW Disposal	D-326
D.3.5.9.1	Results of the Human Health Risk Analysis for the Intruder	D-331
D.4	Uncertainty	D-332
D.4.1	Treatment and Storage Sites	D-334
D.4.1.1	Radionuclides	D-335
D.4.1.1.1	Sensitivity Analysis of GENII	D-335
D.4.1.1.2	Uncertainty Analysis	D-340
D.4.1.2	Hazardous Chemicals	D-340
D.4.1.3	Conclusion for Treatment and Storage Sites	D-341
D.4.2	Disposal Sites	D-341
D.4.2.1	Conclusion for Disposal Sites	D-343
D.4.3	Waste Management Workers	D-344
D.4.3.1	Conclusion for Worker Risk	D-346
D.5	Models Used in the PEIS Human Health Risk Evaluation	D-347
References		D-351

Tables

Table D.2–1	Preliminary Surface Water Analysis Results for Radionuclides	D–11
Table D.2–2	Preliminary Surface Water Analysis Results for Chemicals	D–12
Table D.2–3	ICRP Radiological Risk Factors Used in the PEIS Human Health Risk Evaluation	D–31
Table D.3.1–1	PEIS Waste Consolidation Alternatives for HLW	D–45
Table D.3.1–2	Summary of Program-Wide Risks Associated with Routine Management of HLW: Risks to Worker Population Under Storage Case 1, by Alternative	D–48
Table D.3.1–3	Program-Wide Risks Associated with Managing HLW Under Storage Case 1 of the No Action Alternative, by Health Endpoint	D–48
Table D.3.1–4	Program-Wide Risks Associated with Managing HLW Under Storage Case 1 of the Decentralized Alternative, by Health Endpoint	D–49
Table D.3.1–5	Program-Wide Risks Associated with Managing HLW Under Storage Case 1 of the Regionalized Alternative 1, by Health Endpoint	D–49
Table D.3.1–6	Program-Wide Risks Associated with Managing HLW Under Storage Case 1 of the Regionalized Alternative 2, by Health Endpoint	D–50
Table D.3.1–7	Program-Wide Risks Associated with Managing HLW Under Storage Case 1 of the Centralized Alternative, by Health Endpoint	D–50
Table D.3.1–8	Risks Associated with Managing HLW Under Storage Case 1 of the No Action Alternative, by Installation	D–50
Table D.3.1–9	Risks Associated with Managing HLW Under Storage Case 1 of the Decentralized Alternative, by Installation	D–51
Table D.3.1–10	Risks Associated with Managing HLW Under Storage Case 1 of the Regionalized Alternative 1, by Installation	D–51
Table D.3.1–11	Risks Associated with Managing HLW Under Storage Case 1 of the Regionalized Alternative 2, by Installation	D–51
Table D.3.1–12	Risks Associated with Managing HLW Under Storage Case 1 of the Centralized Alternative, by Installation	D–52
Table D.3.1–13	Storage Case 2: Incremental Annual Exposure Risks Associated with Storage Beyond 2015, in Risk per Year	D–53
Table D.3.1–14	Storage Case 2: Incremental Annual Operational Risks Associated with Storage Beyond 2015, in Risk per Year	D–53
Table D.3.1–15	Storage Case 2: Additional Loading, Unloading, and Construction Risks at Hanford	D–54
Table D.3.1–16	Summary of Risks from Potential HLW Accidents, by Accident Type and Installation	D–57
Table D.3.1–17	Size of Offsite, Noninvolved Worker, and Worker Populations Affected by the Risks from Potential HLW Storage Accidents, by Installation	D–57
Table D.3.1–18	HLW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population, by Accident Type and Installation	D–58
Table D.3.2–1	PEIS Alternatives for LLW	D–62

Table D.3.2-2	Summary of Program-Wide Risks Associated with Treatment of LLW: Risks to Total Populations, by Alternative	D-65
Table D.3.2-3	Summary of Program-Wide Risks Associated with Disposal of LLW: Risks to Hypothetical Farm Family and Waste Management Workers, by Alternative	D-66
Table D.3.2-4	Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Routine Management of LLW, by Alternative	D-67
Table D.3.2-5	Summary of Program-Wide Risks Associated with Treatment of LLW: Risks To the Offsite and Noninvolved Worker Most-Exposed Individuals, by Alternative	D-67
Table D.3.2-6	Radionuclide Contributing the Highest Risk of Cancer Fatality to the Offsite Population for LLW Treatment, by Alternative and Installation	D-68
Table D.3.2-7	Program-Wide Risks Associated with Treatment of LLW Under the No Action Alternative, by Health Endpoint	D-77
Table D.3.2-8	Program-Wide Risks Associated with Treatment of LLW Under the Decentralized Alternative, by Health Endpoint	D-78
Table D.3.2-9	Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 1, by Health Endpoint	D-79
Table D.3.2-10	Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 3, by Health Endpoint	D-80
Table D.3.2-11	Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 6, by Health Endpoint	D-81
Table D.3.2-12	Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 7, by Health Endpoint	D-82
Table D.3.2-13	Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 1, by Health Endpoint	D-83
Table D.3.2-14	Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 2, by Health Endpoint	D-84
Table D.3.2-15	Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 2, by Health Endpoint	D-85
Table D.3.2-16	Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 4, by Health Endpoint	D-86
Table D.3.2-17	Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternatives 3 and 4, by Health Endpoint	D-87
Table D.3.2-18	Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 5, by Health Endpoint	D-88
Table D.3.2-19	Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 5, by Health Endpoint	D-89
Table D.3.2-20	Program-Wide Risks Associated with Treatment of LLW Under the No Action Alternative, by Installation	D-90
Table D.3.2-21	Program-Wide Risks Associated with Treatment of LLW Under the Decentralized Alternative, by Installation	D-91

Table D.3.2–22 Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 1, by Installation D–92
Table D.3.2–23 Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 3, by Installation D–93
Table D.3.2–24 Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 6, by Installation D–94
Table D.3.2–25 Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 7, by Installation D–95
Table D.3.2–26 Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 1, by Installation D–96
Table D.3.2–27 Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 2, by Installation D–97
Table D.3.2–28 Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 2, by Installation D–98
Table D.3.2–29 Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 4, by Installation D–99
Table D.3.2–30 Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternatives 3 and 4, by Installation D–100
Table D.3.2–31 Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 5, by Installation D–101
Table D.3.2–32 Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 5, by Installation D–102
Table D.3.2–33 Program-Wide Risks Associated with Disposal of LLW Under the No Action Alternative, by Health Endpoint D–103
Table D.3.2–34 Program-Wide Risks Associated with Disposal of LLW Under the Decentralized Alternative, by Health Endpoint D–104
Table D.3.2–35 Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 1, by Health Endpoint D–105
Table D.3.2–36 Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 3, by Health Endpoint D–106
Table D.3.2–37 Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 6, by Health Endpoint D–107
Table D.3.2–38 Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 7, by Health Endpoint D–108
Table D.3.2–39 Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 1, by Health Endpoint D–109
Table D.3.2–40 Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 2, by Health Endpoint D–110
Table D.3.2–41 Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 2, by Health Endpoint D–111
Table D.3.2–42 Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 4, by Health Endpoint D–112
Table D.3.2–43 Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 3, by Health Endpoint D–113

Table D.3.2–44	Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 4, by Health Endpoint	D–114
Table D.3.2–45	Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 5, by Health Endpoint	D–115
Table D.3.2–46	Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 5, by Health Endpoint	D–116
Table D.3.2–47	Program-Wide Risks Associated with Disposal of LLW Under the No Action Alternative, by Installation	D–117
Table D.3.2-48	Program–Wide Risks Associated with Disposal of LLW Under the Decentralized Alternative, by Installation	D–118
Table D.3.2–49	Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 1, by Installation	D–119
Table D.3.2–50	Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 3, by Installation	D–120
Table D.3.2–51	Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 6, by Installation	D–120
Table D.3.2–52	Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 7, by Installation	D–121
Table D.3.2–53	Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 1, by Installation	D–121
Table D.3.2–54	Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 2, by Installation	D–122
Table D.3.2–55	Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 2, by Installation	D–123
Table D.3.2–56	Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 4, by Installation	D–124
Table D.3.2–57	Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 3, By Installation	D–124
Table D.3.2–58	Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 4, By Installation	D–125
Table D.3.2–59	Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 5, by Installation	D–125
Table D.3.2–60	Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 5, by Installation	D–126
Table D.3.2–61	Risks from Potential Worst-Case LLW Treatment Facility Accidents, by Alternative and Installation	D–128
Table D.3.2–62	Sizes of the Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Potential LLW Treatment Accidents, by Installation	D–128
Table D.3.2–63	Accident Risks Associated With LLW Treatment at INEL Under the No Action Alternative, by Accident Type	D–129
Table D.3.2–64	Accident Risks Associated With LLW Treatment at SRS Under the No Action Alternative, by Accident Type	D–129
Table D.3.2–65	Accident Risks Associated With LLW Treatment at FEMP Under the Regionalized Alternative 2, by Accident Type	D–130

Table D.3.2-66 Accident Risks Associated With LLW Treatment at Hanford Under the Regionalized Alternative 2, by Accident Type D-130
Table D.3.2-67 Accident Risks Associated With LLW Treatment at INEL Under the Regionalized Alternative 2, by Accident Type D-131
Table D.3.2-68 Accident Risks Associated With LLW Treatment at LLNL Under the Regionalized Alternative 2, by Accident Type D-131
Table D.3.2-69 Accident Risks Associated With LLW Treatment at LANL Under the Regionalized Alternative 2, by Accident Type D-132
Table D.3.2-70 Accident Risks Associated With LLW Treatment at ORR Under the Regionalized Alternative 2, by Accident Type D-132
Table D.3.2-71 Accident Risks Associated With LLW Treatment at PGDP Under the Regionalized Alternative 2, by Accident Type D-133
Table D.3.2-72 Accident Risks Associated With LLW Treatment at Ports Under the Regionalized Alternative 2, by Accident Type D-133
Table D.3.2-73 Accident Risks Associated With LLW Treatment at RFETS Under the Regionalized Alternative 2, by Accident Type D-134
Table D.3.2-74 Accident Risks Associated With LLW Treatment at SRS Under the Regionalized Alternative 2, by Accident Type D-134
Table D.3.2-75 Accident Risks Associated With LLW Treatment at Hanford Under the Centralized Alternative 5, by Accident Type D-135
Table D.3.2-76 Summary Table for the Intruder Scenario for LLW (100 years) D-139
Table D.3.2-77 Summary Table for the Intruder Scenario for LLW (300 years) D-139
Table D.3.2-78 Intruder Scenario Risk Results for the Decentralized Alternative (100 years) D-140
Table D.3.2-79 Intruder Scenario Risk Results for the Decentralized Alternative (300 years) D-140
Table D.3.2-80 Intruder Scenario Risk Results for the Regionalized Alternative 3 (100 years) D-141
Table D.3.2-81 Intruder Scenario Risk Results for the Regionalized Alternative 3 (300 years) D-141
Table D.3.2-82 Intruder Scenario Risk Results for the Centralized Alternative 1 (100 years) D-142
Table D.3.2-83 Intruder Scenario Risk Results for the Centralized Alternative 1 (300 years) D-142
Table D.3.3-1 PEIS Alternatives for HW D-146
Table D.3.3-2 HW Source Term Constituents Derived from Analysis of Deer Park, Texas, Incinerator Flue Gases D-147
Table D.3.3-3 Summary of Program-Wide Risks Associated with Routine Management of HW: Risks to Total Populations, By Alternative D-149
Table D.3.3-4 Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by the Risks from Routine Management of HW, By Alternative D-149
Table D.3.3-5 Summary of Program-Wide Risks Associated with Managing HW to the Offsite and Noninvolved Worker Most-Exposed Individuals, By Alternative D-150

Table D.3.3-6	Program-Wide Risks Associated with the Routine Management of HW Under the No Action Alternative, By Health Endpoint	D-151
Table D.3.3-7	Program-Wide Risks Associated with the Routine Management of HW Under the Regionalized Alternative 1, by Health Endpoint	D-152
Table D.3.3-8	Program-Wide Risks Associated with the Routine Management of HW Under the Regionalized Alternative 2, by Health Endpoint	D-153
Table D.3.3-9	Risks Associated with the Routine Management of HW Under the No Action Alternative, By Installation	D-154
Table D.3.3-10	Risks Associated with the Routine Management of HW Under the Regionalized Alternative 1, By Installation	D-154
Table D.3.3-11	Risks Associated with the Routine Management of HW Under the Regionalized Alternative 2, By Installation	D-155
Table D.3.3-12	Constituents in HW Contributing the Highest Risk of Cancer Incidence to the Offsite Population at Each Installation, By Alternative	D-155
Table D.3.3-13	Summary of Single-Drum Accident Scenarios for HW	D-161
Table D.3.3-14	Chemical Surrogates Used in Risk Analysis for Potential HW Accidents	D-164
Table D.3.3-15	Summary of Risks to the Offsite and Waste Management Worker Populations from Potential Single-Drum HW Accidents, by Alternative and Installation	D-165
Table D.3.3-16	Risks Associated with Potential Facility-Wide HW Storage Accidents Under the Regionalized Alternative 1, By Accident and Installation	D-166
Table D.3.3-17	Risks Associated with Potential Facility-Wide HW Storage Accidents Under the Regionalized Alternative 2, By Accident and Installation	D-167
Table D.3.3-18	Risks Associated with Potential Facility-Wide HW Treatment AccidentsUnder the Regionalized Alternative 1, By Accident and Installation	D-168
Table D.3.3-19	Risks Associated with Potential Facility-Wide HW Treatment AccidentsUnder the Regionalized Alternative 2, By Accident and Installation	D-169
Table D.3.3-20	Size of Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Potential HW Treatment and Storage Accidents, by Installation	D-169
Table D.3.4-1	PEIS Alternatives for CH-TRUW	D-180
Table D.3.4-2	PEIS Consolidation and Treatment Strategies for CH-TRUW	D-181
Table D.3.4-3	Summary of Program-Wide Risks Associated Wtih Routine Management of CH-TRUW: Risks to Total Populations, by Alternative	D-184
Table D.3.4-4	Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Routine Management of CH-TRUW, by Alternative	D-184
Table D.3.4-5	Summary of Program-Wide Risks Associated with Routine Management of CH-TRUW: Risks To the Offsite and Noninvolved Worker Most-Exposed Individuals, by Alternative	D-185

Table D.3.4–6 Program-Wide Risks Associated with Managing CH-TRUW Under the No Action Alternative D–186
Table D.3.4–7 Program-Wide Risks Associated with Managing CH-TRUW Under the Decentralized Alternative D–187
Table D.3.4–8 Program-Wide Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 1 . . . . . D–188
Table D.3.4–9 Program-Wide Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 2 . . . . . D–189
Table D.3.4–10 Program-Wide Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 3 . . . . . D–190
Table D.3.4–11 Program-Wide Risks Associated with Managing CH-TRUW Under the Centralized Alternative D–191
Table D.3.4–12 Risks Associated with Managing CH-TRUW Under the No Action Alternative, by Installation D–192
Table D.3.4–13 Risks Associated with Managing CH-TRUW Under the Decentralized Alternative, by Installation D–193
Table D.3.4–14 Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 1, by Installation D–194
Table D.3.4–15 Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 2, by Installation D–195
Table D.3.4–16 Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 3, by Installation D–196
Table D.3.4–17 Risks Associated with Managing CH-TRUW Under the Centralized Alternative, by Installation D–197
Table D.3.4–18 CH-TRUW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population At Each Installation, By Alternative D–198
Table D.3.4–19 Population Distribution Around SRS, Based on the 1990 U.S. Census D–205
Table D.3.4–20 Population Distribution Around the Waste Isolation Pilot Plant (WIPP), Based on the 1990 U.S. Census D–206
Table D.3.4–21 PEIS Alternatives for RH-TRUW D–208
Table D.3.4–22 PEIS Consolidation and Treatment Strategies for RH-TRUW D–209
Table D.3.4–23 Summary of Program-Wide Risks Associated with Routine Management of RH-TRUW: Risks to Total Populations, by Alternative D–210
Table D.3.4–24 Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Routine Management of RH-TRUW, by Alternative D–210
Table D.3.4–25 Summary of Program-Wide Risks Associated with Routine Management of RH-TRUW: Risks To the Most-Exposed Offsite Individual and Most-Exposed Noninvolved Worker, by Alternative D–211
Table D.3.4–26 Program-Wide Risks Associated with Treatment of RH-TRUW Under the No Action Alternative, by Health Endpoint D–212
Table D.3.4–27 Program-Wide Risks Associated with Treatment of RH-TRUW Under the Decentralized Alternative, by Health Endpoint D–213

Table D.3.4–28	Program-Wide Risks Associated with Treatment of RH-TRUW Under the Regionalized Alternative 1, by Health Endpoint	D–214
Table D.3.4–29	Program-Wide Risks Associated with Treatment of RH-TRUW Under the Regionalized 2, 3, and Centralized Alternatives, by Health Endpoint	D–215
Table D.3.4–30	Risks Associated with Treatment of RH-TRUW Under the No Action Alternative, by Installation	D–216
Table D.3.4–31	Risks Associated with Treatment of RH-TRUW Under the Decentralized Alternative, by Installation	D–216
Table D.3.4–32	Risks Associated with Treatment of RH-TRUW Under the Regionalized Alternative 1, by Installation	D–217
Table D.3.4–33	Risks Associated with Treatment of RH-TRUW Under the Regionalized 2, 3, and Centralized Alternatives, by Installation	D–217
Table D.3.4–34	RH-TRUW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population at Each Installation, By Alternative	D–218
Table D.3.5–1	PEIS Alternatives for LLMW	D–227
Table D.3.5–2	Summary of Program-Wide Risks Associated with Treatment of LLMW: Risks to Total Populations, by Alternative	D–230
Table D.3.5–3	Summary of Program-Wide Risks Associated with Disposal of LLMW: Risks to Hypothetical Farm Family and Waste Management Workers, by Alternative	D–230
Table D.3.5–4	Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Routine Management of LLMW, by Alternative	D–231
Table D.3.5–5	Summary of Program-Wide Risks Associated with Treatment of LLMW: Risks To the Offsite and Noninvolved Worker Most-Exposed Individuals, by Alternative	D–231
Table D.3.5–6	Radionuclide Contributing the Highest Risk of Cancer Fatality to the Offsite Population for LLMW Treatment,by Alternative and Installation	D–232
Table D.3.5–7	Program-Wide Risks Associated with Treatment of LLMW Under the No Action Alternative, by Health Endpoint	D–233
Table D.3.5–8	Program-Wide Risks Associated with Treatment of LLMW Under the Decentralized Alternative, by Health Endpoint	D–234
Table D.3.5–9	Program-Wide Risks Associated with Treatment of LLMW Under the Regionalized Alternative 1, by Health Endpoint	D–235
Table D.3.5–10	Program-Wide Risks Associated with Treatment of LLMW Under the Regionalized Alternative 2, by Health Endpoint	D–236
Table D.3.5–11	Program-Wide Risks Associated with Treatment of LLMW Under the Regionalized Alternative 3, by Health Endpoint	D–237
Table D.3.5–12	Program-Wide Risks Associated with Treatment of LLMW Under the Regionalized Alternative 4, by Health Endpoint	D–238

Table D.3.5–13 Program-Wide Risks Associated with Treatment of LLMW Under the Centralized Alternative, by Health Endpoint D–239
Table D.3.5–14 Program-Wide Risks Associated with Treatment of RH-LLMW Under Each Alternative (Except No Action), by Health Endpoint D–240
Table D.3.5–15 Risks Associated with Treatment of LLMW Under the No Action Alternative, by Installation D–241
Table D.3.5–16 Risks Associated with Treatment of LLMW Under the Decentralized Alternative, by Installation D–242
Table D.3.5–17 Risks Associated with Treatment of LLMW Under the Regionalized Alternative 1, by Installation D–243
Table D.3.5–18 Risks Associated with Treatment of LLMW Under the Regionalized Alternative 2, by Installation D–244
Table D.3.5–19 Risks Associated with Treatment of LLMW Under the Regionalized Alternative 3, by Installation D–245
Table D.3.5–20 Risks Associated with Treatment of LLMW Under the Regionalized Alternative 4, by Installation D–246
Table D.3.5–21 Risks Associated with Treatment of LLMW Under the Centralized Alternative, by Installation D–247
Table D.3.5–22 Risks Associated with Treatment of RH-LLMW Under Each Alternative (Except No Action), by Installation D–248
Table D.3.5–23 Program-Wide Risks Associated with Disposal of LLMW Under the Decentralized Alternative, by Health Endpoint D–249
Table D.3.5–24 Program-Wide Risks Associated with Disposal of LLMW Under the Regionalized Alternative 1, by Health Endpoint D–250
Table D.3.5–25 Program-Wide Risks Associated with Disposal of LLMW Under the Regionalized Alternative 2, by Health Endpoint D–251
Table D.3.5–26 Program-Wide Risks Associated with Disposal of LLMW Under the Regionalized Alternative 3, by Health Endpoint D–252
Table D.3.5–27 Program-Wide Risks Associated with Disposal of LLMW Under the Regionalized Alternative 4, by Health Endpoint D–253
Table D.3.5–28 Program-Wide Risks Associated with Disposal of LLMW Under the Centralized Alternative, by Health Endpoint D–254
Table D.3.5.–29 Program-Wide Risks Associated with Disposal fo RH-LLMW Under Each Alternative (Except No Action), by Health Endpoint D–255
Table D.3.5–30 Risks Associated with Disposal of LLMW Under the Decentralized Alternative, by Installation D–256
Table D.3.5–31 Risks Associated with Disposal of LLMW Under the Regionalized Alternative 1, by Installation D–257
Table D.3.5–32 Risks Associated with Disposal of LLMW Under the Regionalized Alternative 2, by Installation D–258
Table D.3.5–33 Risks Associated with Disposal of LLMW Under the Regionalized Alternative 3, by Installation D–258
Table D.3.5–34 Risks Associated with Disposal of LLMW Under the Regionalized Alternative 4, by Installation D–259

Table D.3.5–35 Risks Associated with Disposal of LLMW Under the Centralized Alternative, by Installation D–259
Table D.3.5–36 Risks Associated with Disposal of RH-LLMW Under Each Alternative (Except No Action), by Installation D–260
Table D.3.5–37 Radionuclide-Related Risks from Potential Worst-Case LLMW Treatment Facility Accidents, by Alternative and Installation D–280
Table D.3.5–38 Chemical-Related Risks from Potential Worst-Case LLMW Treatment Facility Accidents, by Alternative and Installation D–282
Table D.3.5–39 Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the No Action Alternative, by Accident Type D–284
Table D.3.5–40 Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the No Action Alternative, by Accident Type D–284
Table D.3.5–41 Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the No Action Alternative, by Accident Type D–285
Table D.3.5–42 Radionuclide-Related Accident Risks Associated With LLMW Treatment at ANL-E Under the Decentralized Alternative, by Accident Type D–285
Table D.3.5–43 Radionuclide-Related Accident Risks Associated With LLMW Treatment at BNL Under the Decentralized Alternative, by Accident Type D–286
Table D.3.5–44 Radionuclide-Related Accident Risks Associated With LLMW Treatment at FEMP Under the Decentralized Alternative, by Accident Type D–286
Table D.3.5–45 Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Decentralized Alternative, by Accident Type D–287
Table D.3.5–46 Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Decentralized Alternative, by Accident Type D–288
Table D.3.5–47 Radionuclide-Related Accident Risks Associated With LLMW Treatment at KAPL-K Under the Decentralized Alternative, by Accident Type D–289
Table D.3.5–48 Radionuclide-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Decentralized Alternative, by Accident Type D–289
Table D.3.5–49 Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under the Decentralized Alternative, by Accident Type D–290
Table D.3.5–50 Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the Decentralized Alternative, by Accident Type D–290

Table D.3.5–51 Radionuclide-Related Accident Risks Associated With LLMW Treatment at PGDP Under the Decentralized Alternative, by Accident Type D–291
Table D.3.5–52 Radionuclide-Related Accident Risks Associated With LLMW Treatment at Pantex Under the Decentralized Alternative, by Accident Type D–291
Table D.3.5–53 Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Decentralized Alternative, by Accident Type D–292
Table D.3.5–54 Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Decentralized Alternative, by Accident Type D–293
Table D.3.5–55 Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 1, by Accident Type D–294
Table D.3.5–56 Radionuclide-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Regionalized Alternative 1, by Accident Type D–295
Table D.3.5–57 Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 1, by Accident Type D–295
Table D.3.5–58 Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Regionalized Alternative 1, by Accident Type D–296
Table D.3.5–59 Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 1, by Accident Type D–296
Table D.3.5–60 Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 2, by Accident Type D–297
Table D.3.5–61 Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 2, by Accident Type D–297
Table D.3.5–62 Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 2, by Accident Type D–298
Table D.3.5–63 Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 2, by Accident Type D–298
Table D.3.5–64 Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Regionalized Alternative 2, by Accident Type D–299
Table D.3.5–65 Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 2, by Accident Type D–300

Table D.3.5–66 Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 4, by Accident Type D–301
Table D.3.5–67 Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 4, by Accident Type D–302
Table D.3.5–68 Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 4, by Accident Type D–302
Table D.3.5–69 Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 4, by Accident Type D–303
Table D.3.5–70 Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Centralized Alternative, by Accident Type D–304
Table D.3.5–71 Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the No Action Alternative, by Accident Type D–304
Table D.3.5–72 Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the No Action Alternative, by Accident Type D–304
Table D.3.5–73 Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the No Action Alternative, by Accident Type D–305
Table D.3.5–74 Chemical-Related Accident Risks Associated With LLMW Treatment at ANL-E Under the Decentralized Alternative, by Accident Type D–306
Table D.3.5–75 Chemical-Related Accident Risks Associated With LLMW Treatment at BNL Under the Decentralized Alternative, by Accident Type D–306
Table D.3.5–76 Chemical-Related Accident Risks Associated With LLMW Treatment at FEMP Under the Decentralized Alternative, by Accident Type D–307
Table D.3.5–77 Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Decentralized Alternative, by Accident Type D–307
Table D.3.5–78 Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Decentralized Alternative, by Accident Type D–308
Table D.3.5–79 Chemical-Related Accident Risks Associated With LLMW Treatment at KCP Under the Decentralized Alternative, by Accident Type D–308
Table D.3.5–80 Chemical-Related Accident Risks Associated With LLMW Treatment at KAPL-K Under the Decentralized Alternative, by Accident Type D–309

Table D.3.5–81 Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under the Decentralized Alternative, by Accident Type D–309
Table D.3.5–82 Chemical-Related Accident Risks Associated With LLMW Treatment at LBL Under the Decentralized Alternative, by Accident Type D–310
Table D.3.5–83 Chemical-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Decentralized Alternative, by Accident Type D–310
Table D.3.5–84 Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Decentralized Alternative, by Accident Type D–311
Table D.3.5–85 Chemical-Related Accident Risks Associated With LLMW Treatment at PGDP Under the Decentralized Alternative, by Accident Type D–311
Table D.3.5–86 Chemical-Related Accident Risks Associated With LLMW Treatment at Pantex Under the Decentralized Alternative, by Accident Type D–312
Table D.3.5–87 Chemical-Related Accident Risks Associated With LLMW Treatment at Ports Under the Decentralized Alternative, by Accident Type D–312
Table D.3.5–88 Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Decentralized Alternative, by Accident Type D–313
Table D.3.5–89 Chemical-Related Accident Risks Associated With LLMW Treatment at SNL-NM Under the Decentralized Alternative, by Accident Type D–313
Table D.3.5–90 Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Decentralized Alternative, by Accident Type D–314
Table D.3.5–91 Chemical-Related Accident Risks Associated With LLMW Treatment at FEMP Under the Regionalized Alternative 1, by Accident Type D–314
Table D.3.5–92 Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 1, by Accident Type D–315
Table D.3.5–93 Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 1, by Accident Type D–315
Table D.3.5–94 Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 1, by Accident Type D–316
Table D.3.5–95 Chemical-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Regionalized Alternative 1, by Accident Type D–316

Table D.3.5-96 Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 1, by Accident Type D-317
Table D.3.5-97 Chemical-Related Accident Risks Associated With LLMW Treatment at Pantex Under the Regionalized Alternative 1, by Accident Type D-317
Table D.3.5-98 Chemical-Related Accident Risks Associated With LLMW Treatment at PGDP Under the Regionalized Alternative 1, by Accident Type D-318
Table D.3.5-99 Chemical-Related Accident Risks Associated With LLMW Treatment at Ports Under the Regionalized Alternative 1, by Accident Type D-318
Table D.3.5-100 Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Regionalized Alternative 1, by Accident Type D-319
Table D.3.5-101 Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 1, by Accident Type D-319
Table D.3.5-102 Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 2, by Accident Type D-320
Table D.3.5-103 Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 2, by Accident Type D-320
Table D.3.5-104 Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 2, by Accident Type D-321
Table D.3.5-105 Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 2, by Accident Type D-321
Table D.3.5-106 Chemical-Related Accident Risks Associated With LLMW Treatment at Ports Under the Regionalized Alternative 2, by Accident Type D-322
Table D.3.5-107 Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Regionalized Alternative 2, by Accident Type D-322
Table D.3.5-108 Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 2, by Accident Type D-323
Table D.3.5-109 Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 4, by Accident Type D-323
Table D.3.5-110 Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 4, by Accident Type D-324

Table D.3.5–111	Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 4, by Accident Type	D–324
Table D.3.5–112	Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 4, by Accident Type	D–325
Table D.3.5–113	Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Centralized Alternative, by Accident Type	D–325
Table D.3.5–114	Summary Table for the Intruder Scenario for LLMW (100 years)	D–326
Table D.3.5–115	Summary Table for the Intruder Scenario for LLMW (300 years)	D–326
Table D.3.5–116	Intruder Scenario Risk Results for the Decentralized Alternative (100 years)	D–327
Table D.3.5–117	Intruder Scenario Risk Results for the Decentralized Alternative (300 years)	D–328
Table D.3.5–118	Intruder Scenario Risk Results for the Regionalized Alternative 2 (100 years)	D–329
Table D.3.5–119	Intruder Scenario Risk Results for the Regionalized Alternative 2 (300 years)	D–329
Table D.3.5–120	Intruder Scenario Risk Results for the Centralized Alternative (100 years)	D–330
Table D.3.5–121	Intruder Scenario Risk Results for the Centralized Alternative (300 years)	D–330
Table D.3.5–122	Intruder Scenario Risk Results for RH-LLMW (100 years)	D–330
Table D.3.5–123	Intruder Scenario Risk Results for RH-LLMW (300 years)	D–331
Table D.4–1	Descriptive Statistics for Chi/Q from ORR Meteorological Data	D–338
Table D.4–2	Results of GENII Sensitivity Study	D–339
Table D.4–3	Correlation Coefficients for Significant Variables	D–339
Table D.4–4	Descriptive Statistics for AEDE from the Uncertainty Analysis	D–340
Table D.4–5	Uncertainties of Risk Predictions via the Groundwater Pathway	D–344

Figures

Figure D.2–1 Exposure routes for the offiste and noninvolved worker populations for treatment and storage activities D–13

Figure D.2–2 Exposure routes for waste management workers for routine operations and accidents during waste treatment and storage D–14

Figure D.2–3 Exposure routes for the intruder for disposal activities D–15

Figure D.2–4 Exposure routes for the farm family and waste management workers for disposal activities D–16

Acronyms and Abbreviations

Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AEDE	annual effective dose equivalent
ALARA	as low as reasonably achievable
ANL	Argonne National Laboratory
ANL-E	Argonne National Laboratory-East
ANL-W	Argonne National Laboratory-West
ANSI	American National Standards Institute
BNL	Brookhaven National Laboratory
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	cancer fatality
CFR	*Code of Federal Regulations* (indicating citation from)
CH-LLMW	contact-handled low-level mixed waste
CH-TRUW	contact-handled transuranic waste
CI	cancer incidence
C&OF	construction and operational fatalities
D&D	decontamination and decommissioning
DITTY	the Dose-in-Ten-Thousand-Years computational model
DOE	U.S. Department of Energy
DUST	Disposal Unit Source Term computational model
EDE	effective dose equivalent
EI	exposure index
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ER	environmental restoration
ETEC	Energy Technology Engineering Center
FEMP	Fernald Environmental Management Project
Fermi	Fermi National Accelerator Laboratory

FTE	full-time equivalent
GENII	Generation II of the Hanford Environmental Radiation Dosimetry Software System
GENII-S	Sensitivity and Uncertainty Analysis portion of the GENII computational model
GTCC-LLW	greater-than-Class-C low-level waste
Hanford	Hanford Site
HI	hazard index
HLW	high-level waste
HW	hazardous waste
ICRP	International Commission on Radiological Protection
IDLH	immediately dangerous to life and health
INEL	Idaho National Engineering Laboratory
INEXPLC	computational model for simulating close-in atmospheric dispersion, explosive releases, and particle deposition
ISC2	Industrial Source Complex Dispersion Models, Version 2
ITRI	Inhalation Toxicology Research Institute
K-25	Oak Ridge K-25 Site
KAPL-K	Knolls Atomic Power Laboratory-Kesselring
KCP	Kansas City Plant
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
LDRs	land disposal restrictions
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
MEI	most-exposed individual
MEL	most-exposed lifetime of the hypothetical farm family
MEPAS	Multimedia Environmental Pollutant Assessment System
NAS	National Academy of Science
NAS/NRC	National Academy of Sciences/National Research Council
NE	northeast

NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commision
NRF	Naval Reactor Facility
NTS	Nevada Test Site
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
Pantex	Pantex Plant
PCB	polychlorinated biphenyl
PEIS	DOE *Draft Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*
PGDP	Paducah Gaseous Diffusion Plant
Pinellas	Pinellas Plant
PNL	Pacific Northwest Laboratory
Ports	Portsmouth Gaseous Diffusion Plant
PRESTO	series of computational models for assessing the potential human health impacts from the disposal of low-level waste
RCRA	Resource Conservation and Recovery Act
RH-LLMW	remote-handled low-level mixed waste
RH-TRUW	remote-handled transuranic waste
RFETS	Rocky Flats Environmental Technology Site
SNL-CA	Sandia National Laboratory-California
SNL-NM	Sandia National Laboratories-New Mexico
SRS	Savannah River Site
TLV	threshold limit value
TRUPACT II	Transuranic Package Transporter-II
TRUW	transuranic waste
TWA-TLV	time-weighted average threshold limit value
U of Mo	University of Missouri at Columbia
WIPP	Waste Isolation Pilot Plant

WIPP-WAC	Waste Isolation Pilot Plant Waste Acceptance Criteria
WM	of or pertaining to the DOE Waste Management Program
WVDP	West Valley Demonstration Project
Y-12	Oak Ridge Y-12 Plant

Abbreviations

Am	americium
C	carbon
Ci	curie(s)
Cm	curium
cm^2	square centimeter(s)
cm^3	cubic centimeter(s)
Co	cobalt
Cs	cesium
d	day(s)
E	east
ENE	east-northeast
ESE	east-southeast
Fed. Reg.	*Federal Register* (indicating citation from)
ft^3	cubic foot (feet)
g	gram(s)
gal	gallon(s)
h	hour(s)
H-3	tritium
I	iodine
in.	inch
K_d	sorption distribution coefficient (for contaminants in soil)
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
m	meter(s)
m^2	square meter(s)

m^3	cubic meter(s)
mi	mile(s)
min	minute(s)
mph	miles per hour
mrem	milliroentgen equivalent man
N	north
nCi	nanocurie(s)
NNE	north-northeast
NNW	north-northwest
Np	neptunium
NW	northwest
P	phosphorus
pCi	picocurie(s)
Pu	plutonium
qt	quart(s)
rem	roentgen equivalent man
RfC	reference concentration
RfD	reference dose
Ru	ruthenium
S	south
S	sulfur
SE	southeast
Sr	strontium
SSE	south-southeast
SSW	south-southwest
SW	southwest
t	ton(s)
Tc	technetium
Th	thorium
U	uranium

W	west
WNW	west-northwest
WSW	west-southwest
Y	yttrium
yr	year(s)
yd	yard(s)

APPENDIX D
Waste Management Facility Human Health Risk Estimates

D.1 Introduction

This appendix summarizes the human health impacts posed by stationary sources of waste at U.S. Department of Energy (DOE) waste management facilities. The term "stationary source" refers to facilities that process, store, or dispose of various types of waste throughout the DOE complex, in contrast to waste transport. Waste transportation risks are discussed in Appendix E. Supplemental details of this human health risk assessment are available in a separate technical report (ORNL, 1995e).

This appendix is organized as follows:

- Section D.1 defines the purpose and scope of the Waste Management (WM) Program human health risk evaluation including an overview of the five DOE WM Program waste types and waste consolidation alternatives.
- Section D.2 presents general information on the risk assessment process, including a discussion of the potentially exposed populations and health effects evaluated, assumptions used to calculate the risks to the affected populations and individuals, explanations of certain risk calculations, and directions on how to read and interpret the risk results that are presented in Section D.3.
- Section D.3 contains the human health risk evaluations for the five DOE WM Program waste types. It provides definitions of the wastes; identifies the waste consolidation alternatives evaluated; discusses the assumptions used in estimating the human health risks for routine waste management activities and potential accidents by waste type; presents a summary of the human health risk results for routine waste management activities and (where applicable) accidents by waste type; and identifies the waste consolidation options and contaminants that potentially pose the greatest and least risks to human health.
- Section D.4 describes the uncertainties associated with the waste management human health risk evaluation.
- Section D.5 presents a discussion of the mathematical models used to develop the human health risk estimates for this study.

D.1.1 Purpose of the Waste Management Human Health Risk Evaluation

The purpose of this human health risk evaluation is to provide projections of the health risks posed by the waste consolidation options being considered for DOE waste management facilities in this draft programmatic environmental impact statement (hereinafter called the PEIS). This information, in conjunction with other PEIS impacts (e.g., transportation risks, ecological risks, air, water, and socioeconomic impacts) and costs, is intended to aid in determining the advantages and disadvantages of the various waste consolidation options.

The risk estimates presented here are based on various assumptions, best available data, and data generated by fate and transport and exposure modeling (instead of data gathered by monitoring). This was necessary because monitored data were not consistently available for all installations and/or processes have not been demonstrated fully. To maintain consistency with current regulatory approaches to risk assessment, the methodologies used to estimate the various elements of risk for the PEIS were partially adapted from existing accepted risk assessment methods (NAS, 1983; EPA, 1989a, 1991a, 1991b; ICRP, 1977, 1979, 1990) or developed specifically for the PEIS (ORNL, 1995a, 1995b, 1995c). While it is important to recognize the purpose and limitations of this assessment, the same assumptions and methodologies were applied uniformly to all installations. Therefore, when used on a *comparative* basis at the program level, these results should provide a relatively accurate overview of the risks posed by WM Program treatment, storage, and disposal activities. More detailed risk estimates for a particular DOE installation should be performed when necessary in site-specific documents (e.g., environmental impact statements, environmental assessments, risk assessments).

D.1.2 Waste Types Evaluated

Both existing and future waste management facilities were evaluated for the following waste types:

- High-level waste (HLW) (Section D.3.1)
- Low-level waste (LLW) (Section D.3.2)
- Hazardous waste (HW) (Section D.3.3)
- Transuranic waste (TRUW) (Section D.3.4)
- Low-level mixed waste (LLMW) (Section D.3.5)

The risk analysis for each waste type and installation was performed based on data including (1) estimated rates of contaminant release to the air and/or the water in the water table (called "groundwater"), and (2) estimated waste processing rates (which determine a worker's hourly exposure). These two types of release rates are called "source terms." The source terms for the human health risk analysis were developed by Argonne National Laboratory (ANL) based on waste inventory information and characterization data, waste management module characterization information, and the definitions of the various PEIS alternatives. This process, as well as the source terms used in the analysis, are included in Appendix C and supporting technical reports by ANL (ANL, 1995a, 1995b, 1995c, 1995d, 1995e).

Health effects were not evaluated for spent nuclear fuel (from which HLW is derived) because its programmatic issues are assessed in a separate environmental impact statement (see further discussion of this in Chapter 1 of the PEIS).

D.1.3 Waste Consolidation Alternatives

For each of the waste types listed in Section D.1.2, the Oak Ridge National Laboratory (ORNL) estimated the potential health effects posed by up to four general alternatives for consolidating, processing, storing, and disposing of wastes:

- No Action: Wastes are processed and/or disposed at each installation using existing or approved facilities (an approved facility is one for which National Environmental Policy Act [NEPA] review has been completed, appropriate permits received, and the decision made to proceed with the facility).
- Decentralized: Wastes are processed and/or disposed at the installation where they were generated.
- Regionalized: Wastes are consolidated for processing and/or disposal at regional installations.
- Centralized: Wastes are consolidated for processing and/or disposal at one or two installations.

Within each type of alternative, there were often several potentially feasible waste management options. For example, a spectrum of regionalized alternatives was considered for contact-handled TRUW in which wastes are treated and stored at as many as 10 or as few as 3 installations. The rationale for selecting these alternatives is discussed in Chapter 3.

The waste processing and disposal period for the No Action alternatives was assumed to be 20 years. For the remaining alternatives except for HLW, it was assumed that 10 years would be needed for the construction of required waste management facilities and 10 years would be required for waste processing and disposal. The risk analysis for HLW differed in that only interim storage pending final disposal was assessed because a treatment method has already been selected and is being performed at some installations.

Many DOE installations do not currently have facilities for waste management. In the alternatives evaluation, it was necessary to assume that these installations would construct the waste management facilities required under the alternative being evaluated, and that waste processing would begin after construction was completed.

The waste disposal evaluation assessed disposal only for the installations currently storing waste. It did not include federal facilities planned for waste disposal such as Yucca Mountain because these installations will be addressed in site-specific NEPA documents (for more information on this subject, see Chapter 2).

D.2 Evaluating The Risks Associated With Waste Management Activities

This section presents a brief introduction to the concepts and methods used to perform the human health risk analysis for the PEIS including information on the potentially exposed human populations, the means by which people could be exposed to WM Program wastes, the health effects that could result from exposure to the various wastes, and an overview of the process of estimating human health risks. In addition, this section contains a discussion of how to read and interpret the risk analysis results presented in Section D.3.

Risk analysis entails several steps including characterizing the environmental setting of the installation being studied; identifying potential receptors, environmental transport pathways, and exposure routes; identifying potential human health effects to be evaluated; quantifying contaminant intakes, doses, and exposures; and calculating risks. For more detailed information on the risk analysis process used in this study, see the ORNL risk methodologies (ORNL, 1995a, 1995b, 1995c).

D.2.1 CHARACTERIZING THE ENVIRONMENTAL SETTING

The first step in estimating risk is to collect information about the installation's environmental setting including agricultural data (e.g., prevalent livestock and crops, crop yields), geographical location, climatological information (e.g., annual rainfall, storm frequency, temperature range, joint frequency distribution for wind), and land use on and around the installation. The environmental setting information used in the PEIS can be found in the ORNL installation description report (ORNL, 1995d).

D.2.2 IDENTIFYING POTENTIALLY EXPOSED POPULATIONS

The next step is to identify the categories of people (called "receptors" in the analysis) who might be exposed to or affected by waste management processes. The following receptor categories were selected (1) to represent the populations that would most likely be exposed to contaminants during waste management activities or (2) as worst-case receptors for the risk analysis:

- Offsite (general public) population: The offsite population within an 80-km (50-mi) radius of each installation.
- Noninvolved workers: Onsite employees not directly involved in an installation's waste handling activities.
- Most-exposed individual (MEI) of the offsite population.
- MEI of the noninvolved worker population.
- Waste management workers: Onsite employees working in an installation's waste management facilities, including both the workers directly involved in the waste management process and the construction workers who build the waste management facilities.
- Hypothetical farm family: An imaginary family of two adults and two children assumed to live 300 m (approximately 330 yd) downgradient of the center of a waste disposal facility in a period when institutional controls (fences, warning signs, etc.) no longer exist. The farm family engages in farming activities such as growing and consuming their own crops and livestock, and uses groundwater for drinking and for watering the crops and animals.
- Hypothetical intruder: An imaginary adult who drills a well directly through a waste disposal facility down to the water table (groundwater), brings the contaminated soil from within the disposal facility to the surface during drilling, and mixes the contaminated soil into the top 15 cm (5.9 in.) of surface soil of a 2,500-m^2 (0.6-acre) plot of land. The intruder then farms this plot and feeds him- or herself with the crops. The intrusion scenario takes place in a period when institutional controls no longer exist.

Estimates of the offsite population and distribution within an 80-km radius of each installation were obtained from the 1990 U.S. census. The population and distribution of noninvolved workers at each installation were estimated based on installation records, site maps, and best judgment. Because of lack of information, it was necessary at some installations to simply assume an even distribution of workers in all directions around a facility. The offsite and noninvolved worker population size and distribution for each installation and the location of each installation's MEIs can be found in the ORNL installation description report (ORNL, 1995d).

Risks to the offsite and noninvolved worker populations were assumed to result from exposure to airborne contaminants, and were estimated only for the first 70 years after an alternative is implemented (i.e., for the lifetime of a person living during the period when treatment and storage activities take place).

The worst-case risk to an individual member of the offsite and noninvolved worker populations was assessed by considering the MEI in each population. In these scenarios, the MEI receives the highest total chemical intake and/or radiation dose for all exposure routes (e.g., inhalation, ingestion, direct exposure) over the person's lifetime. In considering the results of the TRUW and LLMW alternatives, note that for each *installation* the MEI is one individual; however, for each *alternative* (in which the impacts from all relevant installations are considered together), the MEI is a composite of the worst radiological exposure at any of those installations, the worst chemical carcinogen exposure at any of the installations, and the worst noncarcinogenic chemical exposure.

The hypothetical farm family and hypothetical intruder represent two worst-case exposure situations that occur at a time when institutional controls (fences, warning signs, land records, etc.) no longer exist, and are analyzed to determine upper-bound exposures only. The farm family is assumed to set up residence 300 m downgradient from the center of the disposal facility. The 300-m distance was chosen to ensure that the farm family's groundwater well was beyond the boundary of the disposal site (no matter what type of disposal facility is assumed for a particular installation).

Risks to the hypothetical onsite farm family are evaluated for 143 consecutive 70-year lifetimes (e.g., 10,000 years) in order to determine the upper bound of long-term risks from exposure to groundwater that has been contaminated by the failure of a waste disposal facility. The maximum exposure would presumably occur in the futuren when the peak concentration of contaminant(s) passes the farm family's well, and might be significant over a series of lifetimes. The 10,000-year time period was selected for

the analysis in order to maintain consistency with current performance assessments and the *Guidelines for Radiological Performance Assessment of DOE Low-Level Radioactive Waste Disposal Sites* (Case et al., 1988). To provide some perspective on the timing of health risks predicted to result from disposal, the risk analysis identifies the 70-year lifetime (out of the 143 lifetimes evaluated) during which the highest exposures, hence, risks, are estimated to occur for the hypothetical farm family. This peak-risk lifetime is referred to in the results as the most-exposed lifetime (MEL) of the farm family.

The intruder scenario involves chronic exposure of an individual to contaminated material brought up to the ground surface by drilling a well directly through a waste disposal facility (following guidance on intruder scenarios presented in *Intruder Scenarios for Site-Specific Low-Level Radioactive Waste Classification* [Kennedy, et al., 1988]). The intruder scenario is intended to show the worst-case risk from the disposal technology itself; therefore, only the health effects from direct exposure to contaminated drilling wastes (as opposed to additional exposure to other contaminated media such as groundwater) are evaluated for this scenario. Exposure to an intruder is evaluated for one lifetime for two instances of intrusion: one at 100 years after closure of the disposal facility and one at 300 years after closure.

Worker risks are estimated both for short-term construction activities and for longer term facility operation activities. Worker activities are expected to occur over 10 to 20 years, depending on waste type and alternative, so worker risk is estimated to be a factor only during the first lifetime, or 70 years, after implementation of an alternative. The number of waste management workers involved in the various alternatives was determined as described in Section D.2.7.2.

D.2.2.1 Populations Not Specifically Evaluated

The human health risk analysis did not explicitly include risks to sensitive subpopulations (as defined by the U.S. Environmental Protection Agency [EPA] [EPA, 1989a]) such as children, the elderly, pregnant or nursing women, or people who consume a large quantity of locally-grown produce or fish from local water sources. However, sensitive subpopulations were considered in the development of the toxicity and exposure values that were used in the analysis, hence, are indirectly included.

For radiological exposures, the nominal risk probability coefficients (referred to as "risk factors") used to estimate the risk of cancer and adverse genetic effects from radionuclide exposures are taken from

Volume 60 of the proceedings of the International Commission on Radiological Protection (ICRP), which is referred to as *ICRP 60* (ICRP, 1990). *ICRP 60* states that "[a]lthough there are differences between the sexes and between populations of different age-specific mortality rates, these differences are not so large as to necessitate the use of different nominal probability coefficients." A small difference exists, however, between the risk factors used for workers and those used for the population as a whole. This difference arises principally because the more sensitive younger age groups and pregnant women are included in the whole population (as opposed to the worker population). With regard to the elderly, the radiological risks presented in the PEIS were calculated as the estimated risks a person would sustain over a 70-year lifespan assuming 50 years of radionuclide uptake and commitment (the concept of radionuclide commitment is explained in Section D.2.6). A person who is already elderly when a PEIS alternative is implemented would not likely be exposed for the entire 50 years. Therefore, the use of a 50-year uptake and commitment period should lead to an overestimate of the risks to the elderly. This overestimate would be more pronounced in populations containing a disproportionate number of elderly people.

The EPA slope factors and reference doses (RfDs) or reference concentrations (RfCs) used to evaluate risks from exposures to chemicals are similarly conservative. Slope factors and RfDs or RfCs are generally extrapolated from animal data and include what is termed an "uncertainty factor." This uncertainty factor is an attempt to arithmetically express how well or poorly the pharmacokinetic differences between animals and humans are understood for a particular chemical; it also accounts for the effects of the chemical on various human subpopulations. As such, these slope factors and RfDs or RfCs are considered valid for a wide range of human subpopulations. For more information on this subject, readers may wish to refer to the EPA sources for toxicity factors, the Health Effects Assessment Summary Tables (referred to as HEAST) and the on-line Integrated Risk Information System (called IRIS).

In deciding whether to explicitly consider one or more sensitive subpopulations in the PEIS risk evaluation, it was necessary to determine whether the presence of such subpopulations might affect the exposure parameters used in the study. Certain Native American populations, for example, might consume larger quantities of locally grown produce or fish from local water sources than the population as a whole; this might result in higher risks to these particular people. However, the consumption of fish was eliminated as an exposure route of concern for the PEIS because postulated surface water contamination was found to be minimal (see Section D.2.3.1). In addition, it was assumed that all food grown within 80 km of an installation remained in the area and that all members of the offsite population

have the same dietary habits and consumption rates. On this basis, groups that consume relatively large quantities of locally grown produce or fish from local water sources were not differentiated from other members of the offsite population in this evaluation.

Another issue not explicitly addressed in the human health risk analysis was that of environmental justice impacts. This issue, which involves the consideration of minority and low-income populations in policy-making where negative impacts are expected, is discussed in detail in Appendix C. Executive Order 12898 mandates adding the dimension of minority and low-income populations to research, data collection, and analysis to the extent practicable and appropriate. From the perspective of human health risk, there would be little reason to assess risks differently for minority or low-income populations unless dietary habits or other factors were to cause their exposure to be substantially different from that of the population as a whole. A more comprehensive analysis of environmental justice impacts would require detailed site-level information beyond the scope of this programmatic document.

D.2.3 Identifying Environmental Transport Pathways

The next step in the risk analysis process is to identify the pathways between the sources of contamination and the individuals or populations at risk. These pathways are the actual physical routes along which the contaminants would travel from the source to the exposed individual or population.

Waste management workers working at waste management facilities can come into direct contact with wastes and/or waste containers and with intrafacility airborne contamination during routine treatment, storage, and disposal operations, and during accidents. The remaining receptors become exposed only if contaminants are released from the waste management facility to environmental media such as air or groundwater. For the purposes of the PEIS, it is assumed that contaminants are released (1) to the air during waste treatment operations and accidents, (2) to the groundwater at some point after wastes have been disposed of in engineered disposal facilities, and (3) to the surrounding soil upon intrusion into disposal facilities following institutional control. During treatment operations and accidents, area winds carry released contaminants from the treatment facility toward the offsite and noninvolved worker populations. These airborne contaminants can be inhaled as well as deposited on plants and soil. Wind also transports the contaminated soil that the intruder brings to the surface during drilling and mixes into his/her farm plot. In the waste disposal scenarios, it is assumed that contaminants leach from the facility

to the groundwater and are transported downgradient toward the hypothetical farm family's drinking water well.

D.2.3.1 Transport Pathways Not Evaluated

Deposition of Radionuclides onto Surface Water with Subsequent Ingestion. The deposition of contaminants by an airborne plume on an exposed body of water was eliminated as a pathway from detailed quantitative analysis. Preliminary tests were performed to determine the order-of-magnitude impacts of this secondary exposure pathway. These tests, which involved varying rates of flow of surface water, widths of surface water bodies, and distances from the atmospheric source to the receptor, demonstrated that the contribution of this secondary pathway to the final dose was at least 3 orders of magnitude smaller than the dose resulting from inhalation of the plume. Tests were performed for a hypothetical unit release and atmospheric deposition of several representative radionuclides using parameters associated with the Columbia River near Hanford (Washington) and the Clinch River near ORNL (Tennessee). The Columbia has an average width of 457.2 m, an average depth of 6.1 m, and an average flow speed of 1.2 m/s. The Clinch River has an average width of 124.3 m, an average depth of 9.1 m, and an average flow speed of 0.1 m/s. For the test, the atmospheric source was located at three different distances from both rivers: 10 m, 300 m, and 16.1 km. The receptor was located at the river and drank 1 L (0.9 qt) of contaminated water per day. The cancer incidence risk from inhalation of the plume is compared with the cancer incidence risk from ingestion of the contaminated water. The following table summarizes the results for uranium–238.

Table D.2-1. Preliminary Surface Water Analysis Results for Radionuclides

River	Distance (m)	Ingestion Cancer Incidence Risk	Inhalation Cancer Incidence Risk	Approximate Difference[a]
Contaminant: Uranium-238				
Columbia	10	2.4E-11	4.9E-1	10 orders of magnitude
	300	5.3E-13	3.6E-4	9 orders of magnitude
	16,100	7.7E-15	9.5E-8	7 orders of magnitude
Clinch	10	3.4E-12	3.6E-4	8 orders of magnitude
	300	7.7E-11	2.4E-1	10 orders of magnitude
	16,100	1.0E-13	1.9E-7	6 orders of magnitude

[a] Difference (in orders of magnitude) between cancer incidence risks for ingestion versus inhalation.

Deposition of Chemicals onto Surface Water with Subsequent Ingestion. Tests were performed for exposure to unit releases of chemicals for some of the same scenarios outlined above. Benzene and 1,1,1-trichloroethane were chosen because both are in the PEIS source terms. Benzene is a carcinogen for inhalation and ingestion, and 1,1,1-trichloroethane is a noncarcinogen for inhalation and ingestion. Chemicals that exhibit carcinogenicity for ingestion but not for inhalation (or vice versa) were not examined because an accurate comparison could not be made.

Overland Runoff. Overland runoff involves an additional time delay and dilution factor with respect to direct deposition of contaminants on surface water. Since the latter case involves negligible contributions to risk, the former would pose even less of a contribution to risk. For this reason, the overland runoff pathway was not analyzed in the PEIS.

Table D.2-2. Preliminary Surface Water Analysis Results for Chemicals

Columbia River at 300 m					
Contaminant	Ingestion Hazard Quotient	Inhalation Hazard Quotient	Ingestion Cancer Incidence Risk	Inhalation Cancer Incidence Risk	Approximate Difference
Benzene	--	--	7.5E-19	8.7E-10	9 orders of magnitude
1,1,1-Trichloroethane	1.4E-14	7.8E-6	--	--	8 orders of magnitude

[a] Difference (in orders of magnitude) between hazard indices and cancer incidence risks for ingestion versus inhalation.

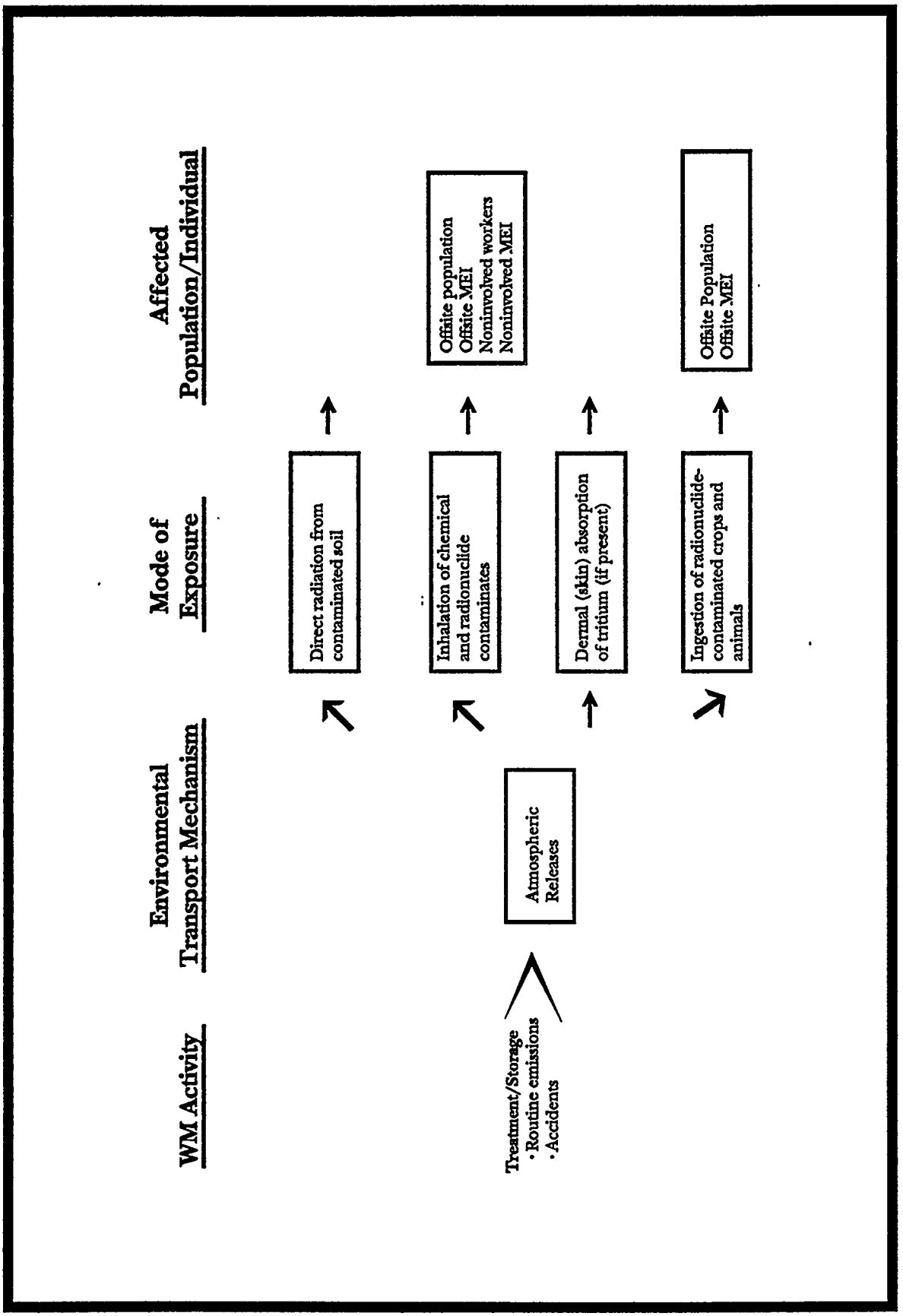
D.2.4 Identifying Likely Exposure Routes For Populations and Individuals

The following sections describe the exposure routes by which the various receptors may come into contact with radiological and chemical contaminants. These exposure routes are illustrated in Figures D.2-1, D.2-2, D.2-3, and D.2-4.

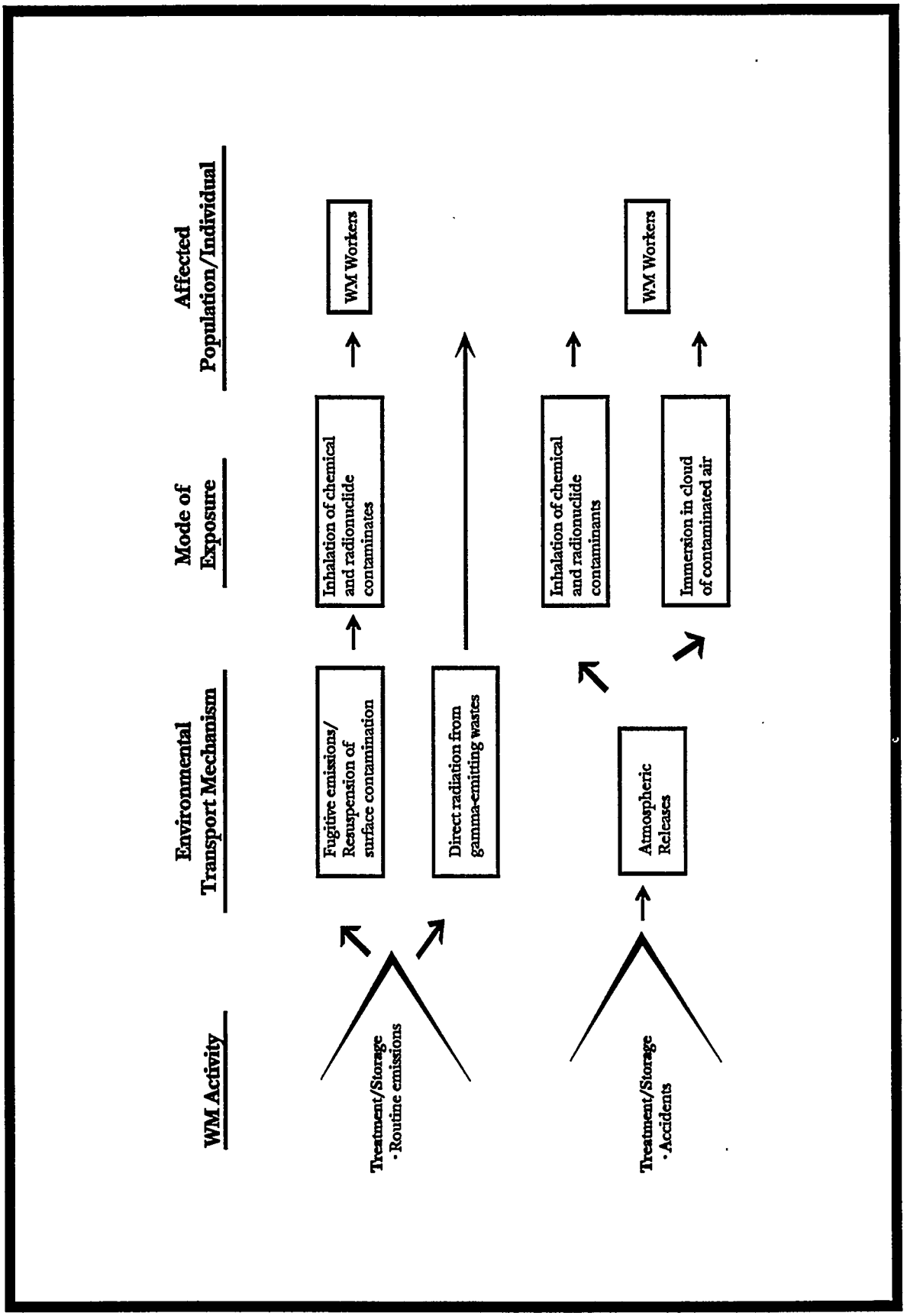
D.2.4.1 Offsite and Noninvolved Worker Population Exposure Routes

It was assumed that the offsite population could be exposed to radionuclides, carcinogenic chemicals, and noncarcinogenic toxic chemicals by coming into contact with contaminated air. Airborne contaminants can be inhaled, taken up by agricultural animals and plants and subsequently ingested, or can cause direct (external) exposure via immersion in a plume of contaminated air or exposure to contaminated soil. Noninvolved workers were assumed to be exposed only to atmospheric releases, because institutional controls should ensure that this population is not exposed to contaminated groundwater or surface water through drinking or showering.

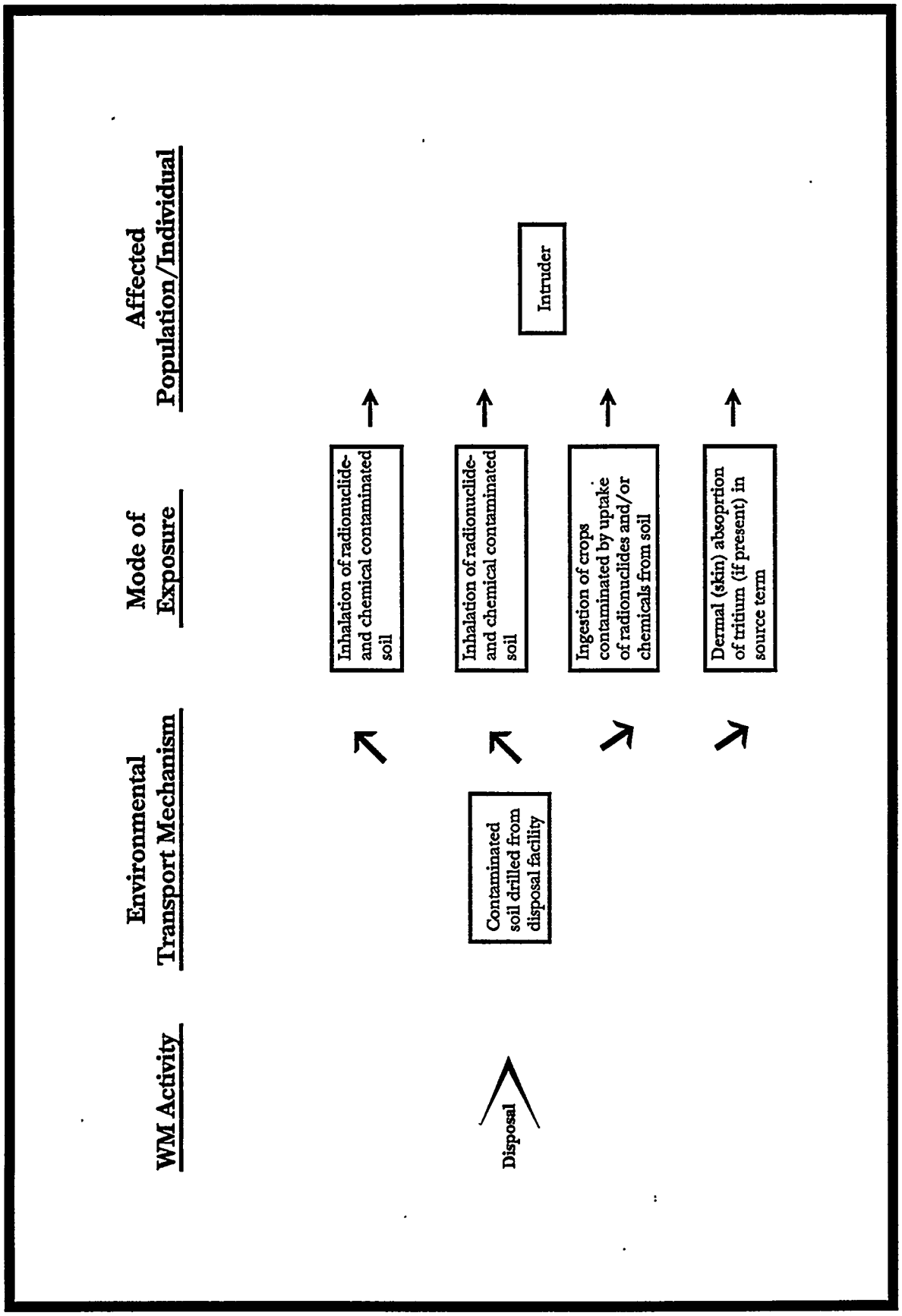
The offsite and noninvolved worker populations were evaluated for dermal exposure to tritium derived from tritiated water in the atmosphere. Both absorption through the skin and the lungs were taken into account; this combined rate of absorption was assumed to be 150% of the inhalation intake rate alone (Napier et al., 1988).



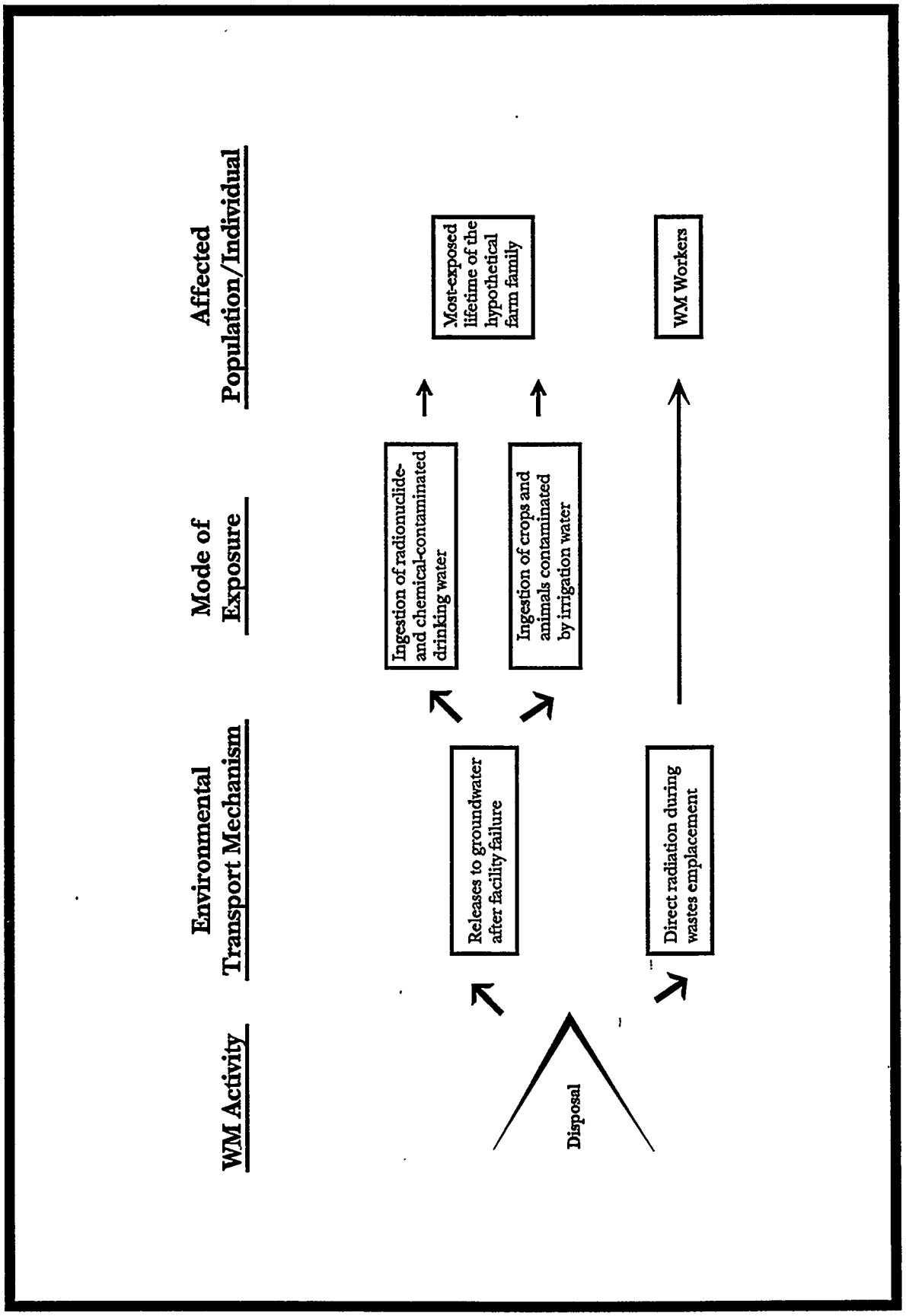
D.2-1. Exposure Routes for the Offsite and Noninvolved Worker Populations for Treatment and Storage Activities



D.2-2. Exposure Routes for Waste Management Workers for Routine Operations and Accidents During Waste Treatment and Storage



D.2-3. Exposure Routes for the Intruder for Disposal Activities



D.2–4. Exposure Routes for the Farm Family and Waste Mangement Workers for Disposal Activities

D.2.4.2 Hypothetical Farm Family Exposure Routes

The risks to the hypothetical farm family were analyzed only for the waste types that will be disposed of in DOE facilities (e.g., LLW and LLMW). It was assumed that the farm family could be exposed directly and indirectly to groundwater contaminated by a release from the disposal facility. Shallow land disposal facilities were assumed to allow immediate releases; tumulus and below-ground vault disposal facilities were assumed to fail and allow release in 300 and 750 years, respectively. The exposure routes evaluated for the farm family include ingestion of contaminated groundwater and ingestion of crops and animals contaminated by exposure to groundwater.

D.2.4.3 Hypothetical Intruder Exposure Routes

Exposure of the intruder was assessed only for LLW and LLMW, the waste types that will be disposed of in DOE facilities. The exposure routes evaluated for the intruder involve exposure to contaminated soil. These exposure routes are direct radiation from the soil, ingestion of plants, inadvertent ingestion of soil, and inhalation of resuspended soil (for radionuclides); and ingestion of plants, inadvertent ingestion of soil, and inhalation of resuspended soil (for chemicals).

D.2.4.4 Worker Exposure Routes

To provide an overview of the program-level health impacts from waste treatment, storage, and disposal activities, the risks to waste management workers include the risks to workers building waste management facilities. Workers directly involved in treatment, storage, and disposal were assumed to be exposed to contaminated air in work areas resulting from fugitive treatment emissions and resuspended surface contamination on waste containers, to receive external exposure from radioactive wastes, and to be at risk of death or injury from industrial-type physical hazards. The worker exposures associated with placing wastes into disposal facilities were assessed separately from treatment risks. Construction workers were assumed to be exposed only to construction-related physical hazards, not to radiological and chemical wastes. The construction and operational risk factors used in this risk analysis are based on current statistics from the U.S. Bureau of Labor Statistics and the National Safety Council, as discussed in the PEIS unit risk methodology (ORNL, 1995c). At sites where no construction was assumed, these risks were not estimated.

D.2.5 Identifying the Human Health Effects to be Evaluated

The PEIS focuses on certain human health impacts as one of the bases for comparing the various waste management alternatives. In this risk evaluation, it was assumed that health effects, which might range from mild clinical symptoms of chemical exposure to bodily injury, illness, or death, could result from exposure to radionuclides, carcinogenic chemicals, and noncarcinogenic toxic chemicals as a result of both routine waste management operations and potential accidents. In addition to exposure-related health problems, waste management workers were assumed to be at risk of on-the-job injuries or deaths from physical trauma (falls, crushing, electrocution, etc.). The following health effects, called "endpoints" in the analysis, were evaluated:

- Cancer incidence from radionuclide and chemical exposures
- Cancer fatalities from radionuclide exposures only
- Adverse genetic effects caused by exposure to radionuclides
- Hazard index for non-workers (an indicator of the likelihood of noncancer toxicity caused by continuous exposure to nonradioactive waste components)
- Exposure index for workers (an indicator of the likelihood of noncancer toxicity caused by work-day exposure to nonradioactive waste components)
- Waste management worker fatalities and injuries associated with the construction and operation of waste management facilities

In addition, in the accident scenarios, an "immediately-dangerous-to-life-and-health (IDLH) index" was calculated for workers as an indicator of the likelihood that contaminant levels might impair escape or be immediately dangerous to life and health.

For the purposes of this evaluation, the concepts of cancer incidence and cancer fatality refer to what are termed "excess cancers," i.e., cancers that would not otherwise have occurred. These terms encompass all types of cancer and any occurrence(s) of cancer over the 70-year lifetime of an individual.

Radiation-Related Health Effects. It was assumed that exposures to radiation can result in cancer incidence, cancer fatality, and adverse genetic effects. Adverse genetic effects include gene mutations (alterations in the elementary units of heredity, the genes) and gross chromosomal aberrations (changes in the structure or number of chromosomes). Because exposure to contaminants in and from DOE sites might occur over many generations, concern exists that the cumulative genetic damage carried benignly

across generations might, at some point, produce disease that is not accounted for in the basic cancer risk calculations.

The frequency with which these three health effects occur was assumed to be directly proportional to the amount of radiation absorbed by the receptor (see the discussions on "effective dose equivalent" and dose "commitment" in Section D.2.6). Moreover, these impacts were assumed to occur in a fixed ratio to one another. For example, for all receptors except waste management workers, the ratio of cancer incidence to cancer fatality to genetic effects was taken to be 17:5:1 (see Section D.2.8.1 for a more detailed discussion of these assumptions).

Chemical-Related Health Effects. It was assumed that exposure to hazardous (nonradioactive) chemicals can cause cancer and/or a spectrum of toxic effects ranging from mild headaches or nasal irritation to more serious impacts such as organ (e.g., liver, kidney) toxicity, neurotoxicity, immunotoxicity, developmental toxicity, reproductive toxicity, and genetic toxicity.

The risk of cancer fatality was calculated for radionuclides but not for chemical carcinogens; this is discussed in more detail in Section D.2.6.3.

D.2.5.1 Factors Excluded from the Analysis

The risks from enhanced or diminished toxicity from interactions among components of a contaminant mixture (termed "synergy" and "antagonism," respectively), or the effects of multiple chemical forms of the same atom ("speciation") or combination of atoms ("complexing") were not evaluated because not enough information exists on these effects. If synergism or antagonism is occurring at a particular installation, the risks there will be accordingly under- or overestimated. Similarly, since complexing and speciation can affect a contaminant's physicochemical and health-related properties including its toxicity, carcinogenicity, reactivity, and water solubility (hence, transportability), the lack of toxicity information on waste complexing and speciation may introduce some additional uncertainty to the risk analysis.

D.2.6 Quantifying Contaminant Intakes, Doses, and Exposures

This section presents a brief overview of how chemical and radiological exposures are measured. For more information, refer to the EPA risk assessment guidelines (EPA, 1989a) and the ORNL risk methodologies (ORNL, 1995a, 1995b).

D.2.6.1 Quantifying Chemical Intake and Exposure

Chemical hazards are generally quantified by an individual's intake of a chemical. Intake is expressed in milligrams of contaminant ingested, inhaled, or absorbed per kilogram of body weight per day. When evaluating health effects from chemical exposure, intake values for noncarcinogenic chemicals are compared to EPA RfDs or RfCs as published in HEAST and IRIS (for all receptors except waste management workers), and intake values for chemical carcinogens are multiplied by EPA cancer slope factors (for all receptors). For workers, American Conference of Government Industrial Hygienists' (ACGIH) time-weighted average threshold limit values (TWA–TLVs, or more simply, TLVs) are used rather than RfDs or RfCs, since TLVs are based on workday exposure concentrations.

There are many uncertainties inherent in the process of formulating RfDs and cancer slope factors. For example, a margin of safety is incorporated into these values (i.e., these values tend to overestimate the risk of the toxicant to some degree to help ensure that human health is protected). In addition, uncertainties are introduced when the findings of dose-response research performed on animals are applied to humans; findings of studies performed at high exposure levels are extrapolated to low exposure levels; results concerning acute exposures are extended to chronic exposures; and findings from occupational conditions are used to characterize toxicity in nonoccupational or environmental conditions.

The magnitude of these uncertainties is not well known; estimates from different studies vary depending upon factors such as the number of studies performed for a particular substance and the receptors and scenarios for which the substance was investigated.

D.2.6.2 Quantifying Radiological Dose and Exposure

A variety of units are used to indicate the amount, intensity, and potential health effects of radiation. The "curie" (abbreviated Ci) is a measure of the amount of radioactive decay occurring in a sample of radioactive material, and is defined as 37 billion disintegrations (individual radioactive decay events) per second. The rate of decay of 1 g of radium is the basis for this unit of measure. Amounts of radionuclides are commonly measured in curies or fractions of curies such as the picocurie (pCi), which is a trillionth of a curie. Emission rates are typically measured in picocuries per year (pCi/year), and concentrations in units such as picocuries per cubic meter (pCi/m^3) or picocuries per gram (pCi/g).

The same dose (absorbed by the human body) of different types of radiation (e.g., alpha, beta, gamma) can produce different health risk outcomes and different effects on living cells. To standardize for these effects, a unit of radiation measure called a "rem" is used as a way of measuring the biological effects of a given dose of any type of radiation. The rem has built-in factors that weight the dose according to each type of radiation's capacity for causing biological damage (this capacity is called the "biological effectiveness" of the radiation). Hence, 1 rem of one type of radiation (for example, gamma radiation) is presumed to have the same biological effects on a given type of tissue as 1 rem of any other type of radiation (say, beta radiation). This unit of measure allows comparison of the biological effects (on a given type tissue) of radionuclides that emit different types of radiation. A millirem (mrem) is one-thousandth of a rem. See the ORNL worker risk methodology (ORNL, 1995b) for a more detailed description of the different types of radiation.

The various organs of the body have different susceptibilities to harm from radiation; for example, the gonads tend to be more sensitive to radiation damage than the cornea of the eye. The unit of measure that takes these different susceptibilities into account to provide a broad indicator of the total effective radiation dose is called an "effective dose equivalent" (or "EDE"). It is obtained by multiplying the dose (or "dose equivalent") in rems in each major organ or tissue by a weighting factor associated with the risk susceptibility of the tissue or organ, then summing the totals. This unit of measure allows comparison of the general adverse consequences to people who are exposed to radiation, regardless of the different susceptibilities of individual types of tissue in different organs to such exposure. For a more detailed discussion of organic and tissue weighting factors, see the ORNL worker risk methodology (ORNL, 1995b).

Three types of radiation doses are calculated in the PEIS: an external dose, an internal dose, and a combined external and internal dose (or total dose). External doses are from sources located outside the body such as a sealed radioactive container or contaminated air, water, or soil. Internal doses arise from sources that have entered the body, usually from eating or drinking contaminated substances or breathing contaminated air.

D.2.6.3 Comparing Radionuclide Exposures to Chemical Exposures

Radionuclide and chemical exposures are, for the most part, very different from one another. A chemical contaminant may be released to groundwater or dispersed into the air, whereupon it is deposited on the ground, vegetables or other crops, or other surfaces. A person becomes exposed by inhaling the contaminant, drinking contaminated water, eating contaminated vegetables, etc. A number of chemicals, such as mercury, lead, and PCBs, bind to or "bioaccumulate" in various body tissues such as bone and fat and may continue to cause toxic effects long after initial exposure. However, quite often, a chemical that has entered the body exerts its toxic or carcinogenic effect over a relatively short period of time and is excreted or otherwise eliminated from the exposed person's body. (The time required for a living organism to eliminate half the amount of an absorbed or ingested chemical substance by natural processes is termed the "biological half-life" of that substance.)

There seems to be an exposure *threshold* for noncancer effects caused by chemicals that do not bioaccumulate. Above this threshold exposure level, these chemicals begin to exert adverse effects; below the threshold, their effects seem to be negligible. A person can be exposed many times to less than the exposure threshold of chemicals that do not bioaccumulate and show no cumulative adverse noncancer effects.

Based on the characteristics of the contaminants of concern in the WM Program waste types, it was assumed in this risk analysis that chemical contaminants of concern do not significantly bioaccumulate. Accordingly, the exposure time for toxic chemicals was assumed to equal the release time. The release time was assumed to be equal to the total processing period for the waste type in question (e.g., 10 or 20 years). While this assumption may be somewhat conservative, it is applied across all installations; hence, the *relative* ranking of installations by risk will likely remain the same.

People are exposed to radionuclides by the same mechanisms as they are to chemicals. However, radionuclides may be present in forms such as simple salts that, when ingested, can be incorporated into body tissues (such as bone) more readily than many hazardous chemicals. Radionuclides may also adhere to particles that, once inhaled, are too small for the lungs to expel. In these circumstances, a radionuclide will stay in the body and continue to deliver a radiation dose long after the exposed person has stopped ingesting or inhaling the radionuclide. (The persistence time of a radionuclide in a living organism is measured in terms of the radionuclide's "effective half-life." This is the period of time required for the amount of radionuclide in an organism to diminish 50% from the combined action of radioactive decay and biological elimination.)

Based on the radionuclides found in the WM waste types and ICRP guidance (ICRP, 1977; 1990), it was assumed that most ingested or inhaled radionuclides remain in the body and continue to expose the person for the rest of his or her life (i.e., the internal dose continues to accumulate). In risk analysis, this continuing, cumulative internal exposure period is referred to as the "commitment period." A commitment period of 50 years was chosen for this study (ICRP, 1990). This time period reflects the average person's working lifetime beginning at age 18, and is a standard time period used in risk assessments. Accordingly, in this study, the risks from radionuclide exposure are calculated not just for the waste treatment time span (10 or 20 years, according to waste type) but as though the internal exposure period persists for a total of 50 years (this does not apply to external exposure to radiation). Therefore, the total EDE deposited in the body over the 50 years after intake of a radionuclide, called the "committed EDE," is used in the PEIS risk calculations.

Because we do not have a clear understanding of the biological processes by which chemicals and radiation cause cancer, a conservative approach (and the one adopted in the PEIS) is to assume that there is *no minimum or threshold value for exposures to carcinogens*. This means that any exposure to a carcinogen increases the lifetime risk of cancer. Consequently, it is assumed that the risk of cancer accumulates with repeated exposures to carcinogens and that the risk of cancer from multiple exposures to multiple sources is additive.

The risk of cancer fatality was calculated for radionuclides but not for chemical carcinogens. This is because research and epidemiological studies have provided enough information to develop risk factors for both cancer incidence and fatality caused by radionuclides; however, there is not yet enough information to develop risk factors for cancer deaths resulting from chemical exposures. These differences

between the amounts of information available about cancers associated with chemical and radionuclide exposures have another implication: The risk of cancer incidence from exposure to hazardous chemicals is not, strictly speaking, directly comparable to the risk of cancer incidence from exposure to radionuclides (this becomes an issue only in the risk analyses for TRUW and LLMW, which contain both radionuclides and hazardous constituents). Readers should bear this in mind when assessing the risk analysis results.

D.2.7 Calculating Exposures for the PEIS Receptors

This section presents a brief introduction to the methods used to model the fate and transport of chemical and radiological contaminants between their initial release and the point at which the various receptors are exposed, and to calculate the unit chemical intakes and radiological doses the receptors receive.

For every potential contaminant in these studies, it was assumed that one unit amount of contaminant is released to various environmental media (e.g., air, soil, or groundwater); or, for worker exposures to radionuclides, is available to cause direct exposure. This unit is 1 Ci for radionuclides and 1 g for chemicals. Appropriate fate and transport models and dose assessment models were then used to estimate the exposures the various receptors sustain from this unit of contaminant. These models use information about the physical and chemical properties of the contaminants and the specific environmental setting in which the contaminants were released to calculate the direction in which the contaminants move; the rate at which they move into different environmental media (for example, air, soil, water); their dilution, dispersion, and degradation or decay; and their movement via the food chain. The models described below are discussed further in Section D.5 and in supporting ORNL technical reports (ORNL, 1995a, 1995b, 1995c).

D.2.7.1 Calculating Exposures to the Offsite and Noninvolved Populations, the Hypothetical Farm Family, and the Hypothetical Intruder

Regulatory Considerations for Public Receptors. While there are regulatory standards governing the maximum permissible radionuclide and chemical exposures to members of the public (i.e., to all receptors other than waste management workers), the doses to these receptors were not limited in this analysis for two reasons. First, a waste management facility is a relatively controlled environment so worker

exposures are somewhat more easily monitored than exposures to the public. Second, leaving the predicted exposures to the offsite and noninvolved worker populations unmodified enables the reader to make a better assessment of the worst-case risks among the various PEIS alternatives. (Applicable environmental requirements would be taken into account in the implementation of a selected alternative).

Estimating Doses from Contaminated Groundwater. For the groundwater pathway, the computer models DUST (Disposal Unit Source Term) (Sullivan, 1992), MEPAS (Multimedia Environmental Pollutant Assessment System) (Droppo et al., 1989), and DITTY (Dose in Ten Thousand Years) (derived from the GENII model) are used to simulate environmental transport of contaminants from the source (waste disposal location) to groundwater to potential receptors. Contaminant-specific unit rate of transfer (flux) rates out of the engineered disposal facility are generated by DUST and are used by MEPAS to simulate the transport of contaminants through the vadose zone (the area above the permanent groundwater level) and into the groundwater. The MEPAS model then predicts the environmental concentration of contaminants at various receptor locations as a function of time. For radionuclides, the 70-year average concentrations from MEPAS are used by DITTY to predict the dose to receptors for each radionuclide. For hazardous chemicals, the 70-year average concentrations are multiplied by standard intake values for water and food to arrive at a contaminant-specific intake, which is multiplied by the size of the drinking water population to give the total contaminant dose for each 70-year period.

Radioactive decay and ingrowth of daughter products are taken into account at several points during the estimation of dose from the groundwater pathway. Radioactive decay that occurs prior to the disposal facility breach is calculated, and the contaminant inventory is modified accordingly. Decay that occurs after the facility breach and during transport to the vadose zone is accounted for prior to the transfer of flux rates to MEPAS. The MEPAS model then accounts for radioactive decay and ingrowth involved in transport through the vadose and saturated zones. All doses from daughter products are attributed to the parent radionuclide in the analysis results.

Estimating Radionuclide Doses from the Atmosphere. For atmospheric transport of radionuclides, doses are estimated by a program called GENII (Generation II of the Hanford Environmental Radiation Dosimetry Software System) (Napier et al., 1988). GENII contains algorithms, data, and methods for calculating radiological doses to various organs and tissues and for calculating EDEs based on ICRP guidance (ICRP, 1977, 1979). To create unit doses for the atmospheric release of radionuclides, GENII is run using an emission rate of 1 Ci per year for each radionuclide in the GENII library. The GENII

program then uses the modeled atmospheric concentrations to predict the unit dose to potential receptors. A separate unit dose is generated for both an acute (i.e., 24-h) release period and a one-year release period. The unit dose calculated for acute releases is used to evaluate the accidental release scenarios. The one-year unit dose is used to project cumulative doses associated with chronic release scenarios. This is accomplished using radionuclide-specific cumulative dose conversion equations, which calculate the cumulative EDE based on the number of years of release. As previously noted, when calculating the cumulative EDE, radioactivity is assumed to be continually deposited in the body for 50 years after exposure occurs. GENII also accounts for radioactive decay and ingrowth of daughter products; all doses from daughter products are attributed to the parent in the analysis results.

Estimating Chemical Intakes from the Atmosphere. For chemicals, ISC2 dispersion models (Industrial Source Complex Dispersion Models, Version 2) (EPA, 1992) are used to estimate exposures to contaminants. To create site-specific unit intakes for the atmospheric release of chemicals, ISC2 is run using an emission rate of 1 g/s with site-specific information for wind distribution. The ISC2 model predicts atmospheric concentrations based on this emission rate for each block in a circular grid comprising 16 directional sectors (e.g., north, north-northeast, northeast, east-northeast, etc.) at 10 radial distances out to 80 km (50 mi) from the point of release, yielding a distribution of unit atmospheric concentrations. The highest concentration in a block with actual population is used to generate the MEI's intake, while the population-weighted average concentration is used to generate the population intake. Recall that, unlike radionuclides, there is no commitment period for chemical exposures. To generate the unit intakes for chemicals, the unit air concentration predicted by ISC2 is converted to a unit intake using standard exposure parameters developed by the EPA, such as how much air an average-sized adult breathes per day (EPA, 1991a).

Estimating Doses and Intakes from Contaminated Soil for the Intruder Scenario. This estimate is based on the inventory of contaminants in the disposal facility. Contaminant concentrations in soil are derived for the intruder by (1) calculating the volume of the cylinder of soil removed from the waste facility during drilling; (2) multiplying the inventory in the disposal facility by the ratio of the well volume to the facility volume to derive the amount of contaminant removed by drilling; and (3) calculating the final concentration of contaminant in the 2,500-m^2 farm plot after the contaminated well-drilling soil is mixed into the top 15 cm of plot soil.

The exposure pathways evaluated for radionuclides are direct radiation from the soil, ingestion of plants, inadvertent ingestion of soil, and inhalation of resuspended soil. The exposure pathways for chemicals are ingestion of plants, inadvertent ingestion of soil, and inhalation of resuspended soil. The GENII computer model is used to calculate the 50-year cumulative EDE for radionuclide exposures. This dose is multiplied by the appropriate risk factors to calculate the resulting potential cancer fatalities, cancer incidence, and genetic effects. Radioactive decay and ingrowth of daughter products are accounted for in both intruder scenarios. An enhanced version of the PRESTO computer model (Fields et al., 1986; Fields and Mellescue, in preparation) is used to calculate the cancer incidence for carcinogenic chemicals and the hazard index for noncarcinogenic chemicals.

D.2.7.2 Calculating Exposures to Waste Management Workers

Characterizing Waste Management Facilities and Treatment Processes. Estimating worker exposures calls for characterizing the various waste management facilities and treatment processes used in each alternative. To make comparative analysis possible, these characterizations are based on the conceptual designs of "generic" waste management facilities developed by EG&G Idaho, Inc., for estimating the costs associated with the various PEIS alternatives, and on consistent assumptions about worker activities and worker protection (EG&G, 1992). Each individual process or step of treating, storing, and disposing of a waste (such as retrieving waste from current storage, receiving and inspection, shredding and compaction, incineration, solidification, interim storage, packaging, shallow land burial, and below-ground vault disposal) is identified and analyzed separately for risk as a "module." Each module serves conceptually as a self-contained "box" within which worker exposures may occur; each can contain several submodules or worker activities (see ORNL, 1995b).

Modules can be arranged to form "treatment trains" that contain all the processes required to treat, store, and dispose of a specific type of waste. A treatment train for solid LLW, for instance, might consist of size reduction (shredding), compaction, packaging, and shallow land burial. These generic modules are interchangeable and can be used as needed to formulate the treatment trains for all the different waste types in the analysis (for example, the incineration module is used in several of the treatment trains for HW, LLW, and LLMW; and the compaction module is used in many of the treatment trains for LLW, LLMW, and TRUW).

Estimating Staffing Requirements. Once the various types of waste management facilities have been characterized, staffing requirements are then estimated. To make it possible to compare estimated worker exposures to regulatory criteria, staffing was expressed as the number of "full-time equivalents" (FTEs). An FTE was assumed to be commensurate to one individual working full-time in a waste management facility. In reality, one FTE could represent several individuals who are not exposed full-time to waste management activities, but whose *cumulative* work time totals one FTE. Because the risk of exposure could be shared by more than one worker working less than full-time in a waste management facility, risks to actual individual workers might be overestimated. When interpreting the risk analysis results, readers may find it useful to think of an FTE as a hypothetical worker or "worker equivalent." Note that radiation doses to workers are expressed in FTE-rem instead of person-rem.

The staffing requirements for facilities of various sizes were estimated using equations developed through linear regression analysis. These equations, which predict the number of FTEs needed according to facility capacity, were based on data points provided by EG&G Idaho, Inc. It was assumed that the facilities operate at 70% availability (i.e., they are not operating the other 30% of the time). Workers are assumed to be exposed by treatment or handling processes 5.6 hours/day, 240 days/year, totaling 1,344 hours/year (EG&G, 1992).

Regulatory Considerations for Waste Management Workers. Regulatory requirements have been established to limit exposures of workers to radionuclides and hazardous chemicals. These requirements are generally considered to be conservative to ensure safe conditions for workers. Code of Federal Regulations, Title 10, Chapter 835 (abbreviated "10 CFR 835") and DOE Order 5480.11 specify that the maximum allowable worker exposure to radionuclides is 5 rem/year. However, DOE installations institute their own additional radioactive waste operations procedures and administrative exposure limits for workers. DOE facilities adhere to the principle that radiological exposures should be kept "as low as reasonably achievable" (the "ALARA" principle). Guidance documents such as the Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, Standard Operating Safety Guides, and Field Standard Operating Procedures provide information oriented toward reducing exposures at hazardous waste sites. One of the primary assumptions of the worker risk analysis is that waste management worker exposures do not routinely exceed occupational exposure limits. This assumption is based on historical occupational exposure data showing that workers involved in routine operations are generally exposed to levels less than these limits. According to the DOE Radiological Control Manual (DOE, 1994), the DOE Administrative Control Level per person is 2,000 mrem. However, the Manual

also states that "an annual facility Administrative Control Level of 500 mrem or less should be challenging and achievable. An annual facility Administrative Control Level above 1,500 mrem is in most cases not sufficiently challenging to meet the goals of this Manual." Therefore, for the worker risk analysis, the radiation exposure guideline of 1,000 mrem/year (1 rem/year) is assumed to be the upper bound of worker exposure to radiation.

Estimated air concentrations are also compared to occupational exposure criteria such as TLVs for chemicals and EPA derived air concentrations for radionuclides to evaluate worker exposure conditions. The methodology used to estimate worker risks assumes the use of good work practices under normal conditions. If a TLV is not available for a particular chemical, estimated air concentrations of that chemical may be compared instead to 10% of the IDLH concentration, as established by the National Institute of Occupational Safety and Health. The IDLH level is defined as the maximum air concentration to which an individual without a respirator can be exposed for 30 min without suffering escape-impairing or irreversible health effects; 10% of that level is considered the boundary between negligible and reversible health effects for a 30-min exposure (ORNL, 1995b).

Estimating Doses from Indoor Air. For indoor scenarios in which individuals work inside treatment, storage, and disposal facilities, air concentrations are estimated using a room model (Jayjock, 1988). Contaminant releases are assumed to be distributed evenly throughout the entire volume of the room where treatment takes place. Intakes or doses from inhalation are estimated for each module, contaminant, and worker classification. For the worker risk evaluation, 10% of the stack emissions are assumed to escape from the module into the room (EPA, 1989b). Stack emission rates from treatment, storage, and disposal facilities are provided by ANL. Dose conversion factors used to calculate committed EDEs for inhalation of radionuclides are obtained from the EPA (EPA, 1988).

Estimating Doses from External Radiation. Doses received by treatment, storage, and disposal workers from exposure to radiation from sources external to the body (not inhaled or ingested) are calculated by taking into account the capacity of each module, worker types and numbers, exposure durations, and available shielding. With the aid of the MicroShield computer model (Grove Engineering, 1992), a "unit" EDE is calculated for workers within each module. MicroShield modeling is performed assuming that a unit concentration (1 Ci/m^3) of each radionuclide is present. Since treatment periods are assumed for a maximum of 10 years, radioactive decay and ingrowth of daughter products are considered for a

five-year time period (average of the treatment period) in order to include external doses from photon-emitting daughter products.

D.2.8 Calculating Risks

This section describes how the unit doses and intakes estimated by modeling (as described in the previous section) are scaled up according to each installation's source term and how the PEIS human health risk estimates are calculated for the various alternatives.

D.2.8.1 Scaling Unit Doses and Intakes According to Installation Source Term

For each installation, a database is created of unit doses and intakes for all known contaminants. The database comprises numerous tables that contain waste-, site-, and exposure pathway-specific information. For radionuclides, the database contains tables of unit doses by site, receptor, contaminant, and pathway. For chemicals, the database contains tables of unit intakes by site, receptor, contaminant, and pathway.

Once unit doses and intakes have been estimated for the contaminants at a particular installation for a particular alternative, they are scaled up based on the waste inventory at that installation. To estimate exposures to the offsite and noninvolved populations, intruder, and farm family posed by a particular contaminant at the installation, the inventory for that contaminant is first multiplied by the fraction of contaminant released during treatment, storage, and disposal activities. This product, the source term, is the estimated amount of contaminant released to the environment that could result in exposure via ingestion or inhalation. To estimate worker exposures, the unit exposure values are scaled by the inventory of contaminant present in each module for a particular installation.

D.2.8.2 Calculating Risks from Unit Doses and Intakes

Calculating Risks for Noncarcinogens. The health risk value for each noncarcinogenic hazardous chemical is estimated by dividing the intake by the appropriate chemical-specific toxicity value (e.g., the EPA RfD) for all receptors but waste management workers. For workers, the estimated air concentration is divided by the ACGIH TLV. The resulting quotients (called the "hazard quotient" and "exposure

ratio," respectively) express how closely the exposure to this toxicant, under the conditions in the exposure scenario, approaches the EPA or ACGIH exposure standard (this concept is explained in greater detail in Sections D.2.9, D.2.10, and D.2.11).

Calculating Risks for Carcinogens. Risks for carcinogens are estimated by multiplying the unit dose or intake by the appropriate cancer risk values from the EPA and the ICRP. For chemical carcinogens, EPA chemical-specific cancer potency factors are used (EPA, 1991b). The risk factors used for radionuclides are published in *ICRP 60* (ICRP, 1990). The radiological risk factors for the public (all receptors except waste management workers) and waste management workers are shown in Table D.2–3.

As stated above, these factors are multiplied by the EDE or committed EDE (for internal radiological exposures) sustained by a receptor or group of receptors to yield risk estimates associated with radiation exposure. The *ICRP 60* risk factors are consistent with the recommendations of the DOE Office of National Environmental Policy Act Oversight and are contained in the preamble to the U.S. Nuclear Regulatory Commission's Standards for Protection Against Radiation, 56 *Fed. Reg.* 23363.

Table D.2–3. ICRP Radiological Risk Factors Used in the PEIS Human Health Risk Evaluation

Endpoint	Risk Factor for Public Receptors	Risk Factor for Workers
Cancer incidence	0.0017/rem-lifetime	0.0014/rem-lifetime[a]
Cancer fatality	0.0005/rem-lifetime	0.0004/rem-lifetime[a]
Genetic effects	0.0001/rem-lifetime[b]	0.00006/rem-lifetime[b]

[a] The nominal probability coefficient for fatal cancers is used to derive the cancer incidence nominal probability coefficient. The probability of fatal cancer, F (which for workers is 80% of F, as described in *ICRP 60*) is divided by the lethality fraction, k, for each organ. The total cancers per organ are then summed over all organs to result in total cancer incidence nominal probability coefficient of 0.0014.
[b] Includes weighting for severity of hereditary effects, but not for years of life lost should harm occur.

Source: ICRP, 1990.

Risk Factors for Construction and Operational Hazards. Construction and operational risks are calculated based on current Bureau of Labor Statistics and National Safety Council statistics for the number of construction fatalities per 100,000 full-time workers; the rate of injuries, illnesses, or lost work days per 100 full-time workers over 200,000 work hours; and the risk of operational fatality,

illness, or injury to sanitary (sewerage and refuse) services workers (including both government and private industry employees).

Calculating Risks to the Public (All Receptors Except Waste Management Workers). The following example summarizes the steps involved in calculating risk for the offsite population:

- **Calculating Unit Dose**—Assuming that 1 Ci of plutonium–238 is released per year from one treatment module in LLW Treatment Facility No. 2 at Installation X, a unit dose of 0.0001 rem/Ci/year is calculated, using the computer model GENII, for inhalation of plutonium–238 by the offsite population.
- **Calculating Exposure to the Offsite Population**—The unit dose of 0.0001 rem/Ci/year is multiplied by the source term, which is the inventory of plutonium–238 (expressed in Ci) released per year. Assuming that the source term for plutonium–238 emissions from one treatment module in LLW Treatment Facility No. 2 at Installation X is 20 Ci/year:

$$0.0001 \text{ rem/Ci/year} \times 20 \text{ Ci/year} = 0.002 \text{ person-rem} \quad (1)$$

- **Calculating Annual Risk of Cancer Fatalities**—The annual risk for cancer fatalities resulting from the release of plutonium–238 from one treatment module in LLW Treatment Facility No. 2 at Installation X is calculated by multiplying the dose calculated in equation (1) above by the risk factor for cancer fatalities for the offsite population (Table D.2–3) to obtain the annual risk for release of plutonium–238 from one treatment module in LLW Treatment Facility No. 2 at Installation X:

$$0.002 \text{ person-rem} \times 0.0005/\text{person-rem} = 0.000001 \text{ (or one in one million)} \quad (2)$$

- **Calculating Cumulative Risk for Entire Release Period**—To calculate the cumulative cancer fatality risk release of plutonium–238 from one treatment module in LLW Treatment Facility No. 2 at Installation X for the entire 20-year release period, the annual risk calculated in equation (2) above is multiplied by 20:

$$0.000001/\text{year} \times 20 \text{ years} = 0.00002 \text{ (or 2 in 100,000) over 20 years} \quad (3)$$

The risks for all of the contaminants in the installation's source term are calculated as described in the four steps above, then summed to yield the total risk for each exposure pathway. The risks for each pathway associated with a treatment module are summed to give a risk for each module. The risks for all modules are summed to give a risk for each waste type. The risks for treatment of each waste type at an installation can then be summed to give the installation's total risk. Population risk estimates represent the estimated number of occurrences of a health effect such as cancer incidence, cancer fatality, or genetic effects within the total population. A risk estimate for an individual (i.e., for the MEIs) is the estimated probability that the individual will develop a particular health effect.

Calculating Risks to Waste Management Workers. Risks to waste management workers from exposure to a unit amount of contaminant are estimated using unit doses similar to the those described above. Worker risks are calculated by the following steps:

- Waste management modules, treatment trains, worker types, and staffing estimates are characterized as described in Section D.2.7.2.
- Unit doses and intakes for each technology or module are then calculated.
- Worker exposures are estimated based on unit intakes and doses, installation/module-specific contaminant inventories and waste throughputs, and module-specific person-hours required to perform the selected technologies or activities.
- The risks of injury and death from physical trauma (crushing, burning, electrocution, etc.) during construction and operation of waste management facilities are calculated based on worker person-hours and current Bureau of Labor Statistics and National Safety Council data, as described in Section D.2.8.1 and the ORNL worker risk methodology (ORNL, 1995b).

For example, assume that a rate of 0.00005 deaths per person-hour from physical trauma is expected for workers involved in heavy construction. If an estimated 20,000 person-hours are required to build a treatment facility, then:

$$20{,}000 \text{ person-hours} \times 0.00005 \text{ deaths/person-hour} = 1 \quad (4)$$

Therefore, one death is estimated to occur during facility construction.

D.2.9 Calculating and Interpreting the Hazard Index

The hazard index is an indicator of the total *additive*, non-cancer toxicity from exposure to mixtures of hazardous chemicals (EPA, 1991a). It is calculated for the offsite and noninvolved worker MEIs at each installation, by alternative, for both routine waste management operations and potential accidents. The highest offsite and noninvolved worker hazard indices for a particular alternative represent the estimated highest noncarcinogenic chemical exposure that an offsite individual and individual noninvolved worker, respectively, would receive at any installation under that scenario.

The first step in calculating the hazard index is to estimate the receptor's predicted exposure to a hazardous chemical in the waste mixture, and divide the predicted exposure level by that chemical's

maximum acceptable level (the level to which a person can be exposed 24 hours/day over a 70-year lifetime without developing adverse effects). These maximum acceptable levels are determined based on EPA RfDs and RfCs.

The resulting number from this calculation is the "hazard quotient." Hazard quotients are calculated for all of the hazardous components in the mixture and the results are summed to yield the hazard index.

Hazard index estimates should be interpreted according to EPA risk assessment guidelines (EPA, 1991a). According to this guidance, if the hazard index is less than or equal to 1.0, the exposure is unlikely to produce adverse toxic affects. However, the closer the hazard index is to 1.0, the more concern about the potential hazard of the chemical mixture increases. If the index exceeds 1.0, the concern is the same as if an individual chemical exposure had exceeded its acceptable level by the same proportion. While the hazard index does not provide a statistical probability that a particular mixture at a particular exposure level will cause a particular adverse effect (recall that below-threshold exposures for single components of a mixture may not contribute to adverse effects), it can serve as an indicator of the *relative potential for causing harm*. For a more detailed explanation of this concept, refer to supporting technical reports by ORNL (1995b, 1995c).

If a contaminant has no RfD, it is excluded from the public risk analysis and the effect of excluding it is discussed in the results.

D.2.10 Calculating and Interpreting the Exposure Index

For routine waste management operations, the exposure index is calculated for the most-exposed FTE ("worker equivalent") instead of the hazard index. Like the hazard index, the exposure index is an estimate of the worst-case, total non-cancer toxicity from exposure to hazardous chemicals (EPA, 1991a). However, it is based on occupational exposure (which is episodic) rather than continuous, residential-type exposure.

The first step in determining the exposure index is to divide the concentration of each hazardous chemical in the workroom air by its TLV to yield an "exposure ratio" for each chemical. TLVs are typically time-weighted average exposure concentrations considered safe for a normal 8-hour (or 10-hour) work day and

a 40-hour work week. The TLVs for an 8-hour work day were used for this analysis when available (ACGIH, 1992).

The exposure ratios for all of the chemicals in the workroom air are summed to determine the exposure index. Results greater than 1.0 indicate exposure at levels higher than recommended and an increased likelihood of adverse health effects. Similar to the hazard index, the exposure index in the results shows the highest chemical exposure to the most-exposed FTE at any installation under a particular alternative.

If no TLV or IDLH concentration has been determined for a particular contaminant, it is not included in the worker risk estimates. If an excluded contaminant comprises a significant percentage of the waste, the results discussion for that waste addresses the effect of excluding it.

D.2.11 Calculating and Interpreting the IDLH Index for Accidents

For *accidents* involving hazardous, noncarcinogenic wastes, the IDLH index, instead of the exposure index, is determined for FTEs. The IDLH index is similar in concept to the exposure index and is calculated similarly for the most-exposed FTE at any installation under a particular alternative. However, it is based on comparison to contaminant air concentrations that impair escape or are immediately dangerous to life and health if exposure lasts more than 30 min. An IDLH index greater than 1.0 indicates an increased likelihood of immediate danger to life and health (whereas an exposure index greater than 1.0 indicates exposure at a level higher than recommended for a safe work environment). The IDLH index is used for accidents based on the assumption that if exposure to a contaminant does not impair escape or threaten health or life for at least 30 min, this exposure does not impair escape or threaten health or life in the few seconds or minutes postulated for the accident scenarios analyzed in this part of the PEIS.

D.2.12 Assessing the Risks from Potential Accidents

This section provides a brief overview of the methodology for calculating accident risks; additional details can be found in (ORNL, 1995b).

There are two general types of accidents likely to affect waste management operations: operational accidents involving waste management workers in the course of routine waste management activities; and external events, which are accidents caused by forces or events outside of waste management operations. Operational accidents include handling mishaps, explosions, uncontrolled reactions, fires, and leaks or spills. External events include those caused by humans (such as airplane crashes) and natural phenomena (such as earthquakes, extreme winds or tornadoes, and volcanoes). One or more of these types of accidents were postulated and evaluated for all WM Program waste types as part of the PEIS human health risk analysis. The rationale for the design and selection of the PEIS accident scenarios can be found in Appendix F. In general, worst-case accidents (such as an earthquake followed by fire and explosion) and accidents that are likely to occur during waste management operations (such as drum-handling accidents) have been selected to represent the spectrum of potential accidents.

In all accident scenarios, one shift of workers is assumed to be present in the facility when the accident occurs. The workers are assumed not to be using personal protective equipment because adequate engineering and administrative controls are assumed to be in place to protect them during routine operations. It is assumed that workers are not blocked or injured by falling or burning debris, and are not so overcome by heat or smoke that they cannot escape from the accident scene. The injuries or fatalities considered in the risk analysis result solely from the radiological and/or chemical exposure the workers receive in the accident.

It is assumed that when an accident occurs, the released contaminants mix uniformly into a specified volume of air. The size and shape of this volume vary according to waste type and accident scenario. The concentration of contaminants in this volume of air is the concentration to which workers are exposed. Exposure durations vary depending on the type of accident and whether it occurs indoors or outdoors.

Any contamination that escapes during the accident is assumed to disperse to the offsite and noninvolved worker populations via the atmosphere. Both populations are at risk from inhaling contaminated air. In addition, the offsite population may be directly exposed by contaminated soils, and by ingesting contaminated water, soil, meat, and agricultural products (ORNL, 1995a). The resulting health effects and their duration depend on the type of contaminant(s) released and the exposure pathway(s) and route(s) (ORNL, 1995a). Because the exposure pathways and routes may be different for the offsite and noninvolved worker populations than for workers, the contaminant of greatest concern to these non-worker populations may be different from the contaminant causing the most risk to workers.

The population distributions and meteorological monitoring data used in the accident analyses can be found in the technical report, "PEIS Installations Descriptions" (ORNL, 1995d). Any additional assumptions used in evaluating accident risks are noted in the text where appropriate.

D.2.12.1 Predicted Annual Frequency of Accidents

Each accident type in the PEIS risk evaluation is assigned an estimated annual frequency of occurrence as follows (see Appendix F):

- Anticipated (greater than 1 chance in 100)
- Unlikely (between 1 chance in 100 and 1 chance in 10,000)
- Very unlikely (between 1 chance in 10,000 and 1 chance in 1,000,000)
- Extremely unlikely (less than 1 in 1,000,000)

For example, incinerator ash explosions during the processing of LLW are considered to be anticipated, while a large aircraft impact with fire and explosion is considered extremely unlikely.

The accident risk estimates presented in the results section reflect only the *consequence* of each accident as though it occurs; the estimated annual frequency is not factored into these results. However, when considering the results, readers should bear both of these parameters in mind. There may be cases in which an accident scenario has extremely serious projected consequences but the probability that it will occur is extremely remote. Conversely, an accident with relatively small consequences may be of substantial concern because it is predicted to occur relatively often.

D.2.13 Contents of the Risk Analysis Tables

The risk analysis results tables in the subsequent sections of this appendix present a breakdown of the total human health risks associated with managing and disposing of that waste under its waste consolidation alternatives. For each of the waste types, the tables show:

- The estimated risk to each total offsite and noninvolved worker population, their respective MEIs, and waste management workers of developing cancer, dying of cancer, or suffering adverse genetic effects from exposure to chemicals and/or radionuclides, by alternative and installation.
- The risks to waste management workers of death or injury from physical trauma during waste management activities and the construction of waste management facilities, by alternative and installation (it is assumed that no contaminants are released during these events so physical hazards can be assessed separately from chemical and radiological hazards).
- A hazard index calculation for the offsite and noninvolved worker MEIs, indicating the greatest likelihood of noncancer toxicity from continuous exposure to chemical contaminants, by alternative.
- An exposure index calculation for the most-exposed FTE (hypothetical worker or "worker equivalent"), indicating the greatest likelihood of noncancer toxicity effects from work-day (episodic) exposure to chemical contaminants, by alternative.
- The risks to waste management workers, the most-exposed generation of the hypothetical farm family, and all generations of the farm family from disposal of LLW and LLMW, by alternative and installation.
- The risks to the hypothetical intruder for intrusion at 100 years and 300 years, by alternative.
- The risks to all populations and MEIs from potential accidents, by alternative.

D.2.14 Reading and Interpreting the Risk and Probability Numbers

The numbers in the results tables are displayed in the standard "scientific" (exponential) notation used in risk assessment and are read as follows. Assume that a table contains the entry 5.0E-1 to represent the total estimated operations fatalities to waste management workers incinerating a particular waste under a regionalized alternative. The notation "E-1" indicates the power of 10 by which the leftmost, two-digit number (in this case, 5.0) is to be multiplied. Therefore, 5.0 is multiplied by 10^{-1} (0.1) to yield 0.5. This result means it is predicted that nationwide operations for that waste type under this regionalized alternative will result in an estimated 0.5 fatality during routine incineration operations over the total processing period for that waste (e.g., 10 or 20 years). Note that the estimate in this example is a fraction of 1, that is, a number less than 1. This means that over the period studied (under the assumptions used in the risk analysis), no waste management workers are estimated to die as a result of routine incinerator operations. (However, note that there is some degree of error in any risk estimate due to uncertainties in the assumptions, data, models, etc., used to perform the analysis; see Sections D.2.15 and D.4).

Probability is expressed as a number between zero and one. If there is no chance that a particular event will occur, it is assigned a probability of zero; if that event is certain to occur, its probability is one. The probability that the offsite and noninvolved worker MEIs will develop or die of cancer, or manifest noncancer toxicity, etc., is expressed in the same notation as risk. Assume that a table contains the entry 3.0E-6 to represent the probability that the noninvolved worker MEI for a particular waste type scenario will develop cancer from exposure to a radioactive waste. The notation 3.0E-6 indicates that 3.0 is multiplied by 10^{-6} (0.000001). Therefore, this probability is 0.000003, which means that there are 3 chances in 1,000,000 that, over the total waste processing period, the noninvolved worker MEI will develop cancer from exposure to that radioactive waste. (Again, note that this estimate will be affected by any uncertainties associated with the risk calculations.)

To place the risk estimates in this appendix in perspective, it may be useful to compare them to the exposure level guidelines in 40 CFR 300.430(e)(2) and (EPA, 1991b). According to those guidelines, the target exposure level (or risk goal) for an individual member of the public to known or suspected carcinogens is generally taken to be that concentration that poses an excess lifetime risk of cancer incidence between 1.0E-4 and 1.0E-6. It follows that individual risks of cancer incidence below 1.0E-6 are generally considered to meet this goal while risks above 1.0E-4 may indicate that action is necessary to reduce risks. Note that these guidelines should be considered as an attempt to define action levels and *not* to represent any value judgements about acceptable or unacceptable risks.

As discussed in preceding sections, the maximum exposure to workers allowed under 10 CFR 835 and DOE Order 5480.11 is 5 rem/year. In contrast, DOE Order 5400.5 states that the maximum annual allowable radiation dose to the members of the public from DOE-operated nuclear facilities is 100 mrem/year. For perspective, it is estimated that the average individual in the United States receives a dose of about 300 mrem (0.3 rem)/year from all sources combined, including medical sources of radiation (such as x-rays) and natural background radiation (such as radon gas). A modern chest x-ray results in a dose of approximately 8 mrem, while a diagnostic hip x-ray results in a dose of approximately 83 mrem. A person must receive an acute (short-term) dose of approximately 600,000 mrem before there is a high probability of near-term death (NAS/NRC, 1990).

Since the offsite and noninvolved worker MEIs at each installation receive the worst-case public exposures to contaminants (the per capita exposure to an entire population is always lower than the MEI's

exposure), readers might wish to compare the risks for these most-exposed receptors to the EPA guidelines above.

Note that the estimated risks of injury to waste management workers take into account all on-the-job injuries from the most minor to the most severe. Similarly, the risks to all receptors of adverse effects from noncarcinogenic, hazardous chemicals (expressed as the hazard and exposure indices) consider all adverse manifestations with no indication of their severity.

Finally, there are two ways to examine and compare the risks between alternatives in this risk analysis: at the *program level* and at the *installation level*. This is illustrated in the following example.

Consider a decentralized alternative (for example, Hypothetical Alternative 1) that affects the populations at 14 installations and a centralized alternative (Hypothetical Alternative 2) that affects the population at only 1 installation. If the total risks across all installations in Hypothetical Alternative 1 are *numerically* higher than the total risks for the one installation in Hypothetical Alternative 2, Hypothetical Alternative 1 is the highest-risk alternative at the *program level*. However, the reader may find it useful in some instances to look at these risks at the *installation level* as well.

Suppose the overall program-wide risk of cancer incidence from radionuclide exposure in Hypothetical Alternative 1 is 8.0E-1, and this total risk is distributed across 23 million people, the sum of the offsite populations at all 14 installations involved in that alternative. If this program-wide risk, 8.0E-1, is divided by the total affected population, 23 million, the resulting number is:

$$8.0E-1 \text{ (total risk for alternative)} \div 23{,}000{,}000 \text{ people affected overall} = 3.5E-8$$

This result, 3.5E-8, might be considered the "average" risk to an individual member of the program-wide offsite population. (Note that this number is *not* the risk to the MEI, and will *in all cases* be less than the risk to the MEI. This is because, on average, individual members of the population receive less exposure, by definition, than the MEI, the most-exposed member of the population.)

If this so-called "average" individual risk is compared to EPA risk assessment guidelines, it is found to be 1.5 orders of magnitude below 1.0E-6, or within what is considered to be the target risk range.

Although this "average" individual risk is *not* a formal construct in risk analysis, it may be useful in helping the reader compare the risks among alternatives or installations. "Average" risks will be brought to the reader's attention in the text and tables as needed to clarify the risks posed by particular alternatives or installations.

D.2.15 Overview of Uncertainties in the PEIS Risk Analysis Process

The results of any human health risk assessment are conditional estimates based on multiple assumptions about exposure, toxicity, release of contaminants into the environment, human behavior patterns, and other variables. Therefore, the uncertainties accompanying the analysis should be evaluated to place these risk estimates in proper perspective. Uncertainties can be classified into three broad categories:

- Model uncertainty
- Scenario uncertainty
- Parameter uncertainty

Model uncertainty can result from the general limitations of mathematical models. Modeling involves trying to simulate a process that is inherently complex using a fixed and relatively small number of variables. Model uncertainty is usually estimated in the verification and validation phase of model development. Model uncertainty can also result from the inappropriate application of a model to a particular scenario (for instance, in situations for which no model has been specifically designed, and existing models must be adapted for use).

Scenario uncertainty may result from a generalized or incorrect conceptualization of a contaminant release or an exposure scenario. For example, there may be errors in the generalized assumptions concerning the amount of contaminants released, the spatial distribution of potential receptors, and the intake parameters considered for the receptors.

Parameter uncertainty may result from sampling errors, natural variability of the parameter, or the use of generic data (data that are not site-specific). The fate and transport models used to estimate risks for the PEIS require large amounts of data, including meteorological measurements, hydrogeologic settings,

and release parameters. Actual data are used where possible, but generic data are often substituted where site-specific data are unavailable.

Keep in mind that the goal of the PEIS risk analyses is to evaluate the *relative* differences in risks among the various waste management alternatives if implemented nationwide. The assumptions made in performing this program-level evaluation were intended to yield reasonably conservative risk estimates (i.e., estimates that tend to overestimate rather than underestimate risk) using the best available data and state-of-the-art models. Given the programmatic nature of the PEIS and the use of the unit approach to risk assessment (ORNL, 1995c), many of the uncertainties associated with the PEIS risk estimates are "systematic." That is, many modeling and scenario assumptions were applied consistently—that is, "systematically"—throughout the analysis (such as facility emission rates for particular types of waste treatment or storage, inhalation rates, etc.). Therefore, the *relative* differences in risk estimates among waste management alternatives should not be affected by errors associated with these systematically applied assumptions. For example, if consumption of contaminated agricultural food products by the offsite population was overestimated for one alternative, it was similarly overestimated for all other alternatives.

Other uncertainties in risk estimates may be specific to assumptions about a particular scenario or installation (such as wind conditions, crop yields, etc.). Section D.4 presents an evaluation of some of these parameter uncertainties associated with the PEIS health risk estimates. In addition, readers may also wish to refer to the modeling literature cited in the reference list (Section D.6).

D.3 Risk Analysis By Waste Stream

This section contains a summary of the risk analysis for both routine waste management operations and potential accidents associated with each of the DOE WM Program waste streams. The information for each waste stream includes a brief definition of the waste, an overview of the alternatives analyzed, the special assumptions and considerations used in the analysis, tables showing the results of the analysis, and results summaries.

D.3.1 HIGH-LEVEL WASTE

High-level waste (HLW) is the highly radioactive material resulting from the reprocessing of spent nuclear fuel. When spent nuclear fuel is reprocessed, reactor fuel elements are divided and dissolved to separate plutonium and uranium from their fission products; the plutonium and uranium can then be reused. The byproduct, HLW, includes liquid waste produced directly in reprocessing as well as any solid waste derived from the liquid, and contains a combination of TRUW and fission products in concentrations requiring careful handling and permanent isolation (DOE, 1988). Because a variety of solvents, acids, and alkaline agents are used in spent nuclear fuel reprocessing as well as in treatment, HLW may also contain hazardous waste components (nonradioactive but hazardous substances subject to Resource Conservation and Recovery Act regulation). However, once HLW has been vitrified (vitrification involves mixing the waste with glass-forming frit; heating the mixture to fuse it into a glass, ceramic, or other noncrystalline solid; and storing the immobilized waste in sealed, decontaminated metal canisters), these are no longer present or are immobilized in the glass matrix and are no longer emitted. DOE has determined that spent nuclear fuel reprocessing will be phased out as soon as possible; therefore, liquid HLW will no longer be generated in the future.

Four installations manage DOE-owned HLW (note that the abbreviations given here are used in the tables in this appendix):

- Hanford Site (Hanford), Richland, Washington
- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Savannah River Site (SRS), Aiken, South Carolina
- West Valley Demonstration Project (WVDP), West Valley, New York

Because DOE has already selected vitrification as the method for immobilizing HLW, evaluations were performed only for the worker risks associated with interim storage of the resulting HLW canisters pending final disposal in a national geologic repository. Public risks were not evaluated for interim storage because the offsite population would be at negligible risk of exposure. However, public risks were calculated for potential accidents; the results are presented in Sections D.3.1.5 through D.3.1.8. Transportation risks are presented in Appendix E.

Chapters 3 and 9 of the PEIS and the HLW technical report (ANL, 1995a) provide more detailed information on this waste including HLW inventories at DOE installations, estimated release rates, treatment categories used in the PEIS, and the process for developing the PEIS HLW alternatives.

D.3.1.1 Summary of HLW Alternatives

The PEIS waste management alternatives (No Action, Decentralized, Regionalized, and Centralized) and the rationale for developing them are discussed rigorously in the main body of the PEIS. Five HLW alternatives (the No Action, Decentralized, Regionalized 1, Regionalized 2, and Centralized alternatives) were analyzed. For each alternative, two cases—designated Storage Cases 1 and 2—were analyzed. In Storage Case 1, it was assumed that a geologic repository would be available in 2015 and would accept HLW canisters at a rate of 800/year. In Storage Case 2, it was assumed that there would be a delay in the availability of a geologic repository past 2015, but that when the repository began accepting HLW, it would accept canisters at a rate of 800/year. For each alternative except the Centralized Alternative, the number of canisters produced and stored at each installation is identical between Storage Cases 1 and 2. In Storage Case 1 of the Centralized Alternative, Hanford stores only the portion of canisters produced by SRS and INEL until 2015; and in Storage Case 2 of the Centralized Alternative, Hanford stores all of the SRS and INEL canisters.

- In the No Action Alternative, HLW canisters are stored in existing and approved interim storage facilities at Hanford, SRS, and WVDP. No interim storage facility exists or has been approved for INEL; therefore, no risks are calculated for INEL under the No Action Alternative.
- In the Decentralized Alternative, each of the four installations continues to store its own inventory of immobilized HLW awaiting ultimate disposal in a national geologic repository.
- In the Regionalized Alternative 1, 300 vitrified canisters of HLW from WVDP are shipped to SRS to be stored there until final disposition. Hanford and INEL store their own HLW.
- In the Regionalized Alternative 2, 300 canisters of HLW from WVDP are shipped to Hanford for interim storage. SRS and INEL store their own HLW.
- In Storage Case 1 of the Centralized Alternative, 2,373 canisters from SRS, 327 from INEL, and 300 from WVDP are transported to Hanford for interim storage until a geologic repository is available. The remaining canisters produced at SRS (2,199) and INEL (8,173) are stored onsite until the geologic repository is in operation. In Storage Case 2, Hanford stores all SRS and INEL canisters (a total of 28,372) and would require additional storage capacity.

Construction hazards were analyzed for the installations where additional storage facilities would be needed until the opening of a national geologic repository in the year 2015 or later.

Table D.3.1-1 depicts the five HLW alternatives and shows which installations ship their wastes to regional or central consolidation sites for interim storage. The numbers in parentheses are the numbers of canisters stored at the installation. For each alternative, Storage Cases 1 and 2 are identical to one another except in the Centralized Alternative, in which Hanford would store all of the SRS and INEL canisters (making a total of 28,372 HLW canisters at Hanford).

Table D.3.1-1. PEIS Waste Consolidation Alternatives for HLW

Alternative		Hanford	INEL	SRS	WVDP
No Action (both storage cases)	Ship	—	—	—	—
	Store	Hanford (750)	—	SRS[a] (4,572)	WVDP (300)
Decentralized (both storage cases)	Ship	—	—	—	—
	Store	Hanford[a] (15,000)	INEL[a] (8,500)	SRS[a] (4,572)	WVDP (300)
Regionalized 1 (both storage cases)	Ship	—	—	—	Store temporarily for 6 years then ship 300 to SRS
	Store	Hanford[a] (15,000)	INEL[a] (8,500)	SRS[a] (4,872)	
Regionalized 2 (both storage cases)	Ship	—	—	—	Store temporarily for 16 years then ship 300 to Hanford
	Store	Hanford[a] (15,300)	INEL[a] (8,500)	SRS[a] (4,572)	
Centralized—Storage Case 1	Ship	—	Ship 327 to Hanford	Ship 2,373 to Hanford	Ship 300 to Hanford
	Store	Hanford[a] (18,000)	INEL[a] (8,173)	SRS (2,199)	—
Centralized—Storage Case 2	Ship	—	Ship 8,500 to Hanford	Ship 4,572 to Hanford	Ship 300 to Hanford
	Store	Hanford[a] (28,372)	—	—	—

[a] Construction of a new storage facility is required.

D.3.1.2 Special Assumptions and Considerations Used in the HLW Risk Analysis

Once HLW has been vitrified, sealed in stainless steel canisters, decontaminated, and moved into dedicated storage, there is expected to be very little risk of exposing the public to these materials under routine (nonaccident) conditions; therefore, only routine operational worker risks associated with interim storage of treated HLW were evaluated. These include risks associated with exposure to radiation and with operational or construction hazards. Risk estimates were based on expected worker person-hours associated with loading and storage activities. Potential exposures and health risks to the public and

workers from accidental releases during HLW storage are considered in Sections D.3.1.5, D.3.1.6, and D.3.1.7.

Interim storage is defined as long-term storage prior to disposal in a geologic repository. Temporary storage is defined as more short-term storage prior to shipment to another installation for interim storage pending disposal in a geologic repository. For the purposes of this analysis, all shipments of HLW are assumed to be by truck.

It was assumed that the canisters are thoroughly decontaminated before they are transported to interim storage; this would remove any radioactive residue from the outside of a canister that could be inhaled, ingested, or transferred to the skin. Therefore, WM workers would be subject only to radiation that penetrates the HLW canister wall (this is termed "external" or "direct" radiation) and to the physical hazards associated with construction and routine facility operations. It was also assumed that HLW treatment would remove or immobilize any hazardous, nonradioactive components; therefore, there would be little or no risk of chemical carcinogenesis or toxic effects.

D.3.1.3 Results Tables for the HLW Human Health Risk Analysis

This section contains the results tables for the HLW human health risk analysis. A discussion of the results is presented in Section D.3.1.4. The fatality and cancer incidence numbers in the tables are displayed in the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.1–2 presents an overview, by alternative (for Storage Case 1 only), of the *total*, program-wide risks of cancer fatalities, cancer incidence, and construction and operational fatalities to waste management workers. This table provides the estimated *total number* of workers involved in storage and handling activities who will develop or die of cancers caused by exposure to HLW over the next 50 years if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities associated with storage and handling of HLW.
- Tables D.3.1–3 through D.3.1–7 show the program-wide worker risks by health effect and Storage Case 1 alternative.
- Tables D.3.1–8 through D.3.1–12 present the worker population risks for each installation, by Storage Case 1 alternative.

- Tables D.3.1–13 and D.3.1–14 present the incremental annual risk for each Storage Case 2 alternative (where the repository opening is delayed past 2015). These risk numbers show the additional risk per year from storage past 2015.
- Table D.3.1–15 presents the additional risks at Hanford for the Storage Case 2 Centralized Alternative. This alternative requires Hanford to accept all canisters of HLW produced at WVDP, INEL, and SRS which will result in more loading and unloading risks and additional construction risks.

Table D.3.1–2. Summary of Program-Wide Risks Associated with Routine Management of HLW: Risks to Worker Population Under Storage Case 1, by Alternative

Storage Case 1 Alternative	Total Fatalities[a]	CF[b]	CI[c]	C&OF[d]
No Action	1.7	1.8	6.4	5.0E-1
Decentralized	3.7	2.7	9.8	9.8E-1
Regionalized 1	3.8	2.8	9.9	9.9E-1
Regionalized 2	3.7	2.8	9.9	9.2E-1
Centralized	4.0	3.0	1.0E1	9.9E-1

[a] Sum of fatalities from construction, operation, and cancer associated with exposure to radionuclides.
[b] CF—Cancer fatality associated with exposure to radionuclides.
[c] CI—Cancer incidence.
[d] C&OF—Construction and operational fatalities.

Table D.3.1–3. Program-Wide Risks Associated with Managing HLW Under Storage Case 1 of the No Action Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
WM Workers	Dose (FTE-rem)	4.5E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.4	
	Genetic Effects	2.7E-1	
	Construction Fatalities		2.4E-2
	Construction Injuries		1.0E1
	Operation Fatalities		4.7E-1
	Operation Injuries		4.0E2

Table D.3.1–4. Program-Wide Risks Associated with Managing HLW Under Storage Case 1 of the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
WM Workers	Dose (FTE-rem)	7.0E3	
	Cancer Fatalities	2.7	
	Cancer Incidence	9.8	
	Genetic Effects	4.2E-1	
	Construction Fatalities		2.0E-1
	Construction Injuries		8.8E1
	Operation Fatalities		7.7E-1
	Operation Injuries		6.5E2

Table D.3.1–5. Program-Wide Risks Associated with Managing HLW Under Storage Case 1 of the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
WM Workers	Dose (FTE-rem)	7.1E3	
	Cancer Fatalities	2.8	
	Cancer Incidence	9.9	
	Genetic Effects	4.2E-1	
	Construction Fatalities		2.0E-1
	Construction Injuries		8.9E1
	Operation Fatalities		7.8E-1
	Operation Injuries		6.6E2

Table D.3.1-6. Program-Wide Risks Associated with Managing HLW Under Storage Case 1 of the Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
WM Workers	Dose (FTE-rem)	7.0E3	
	Cancer Fatalities	2.8	
	Cancer Incidence	9.9	
	Genetic Effects	4.2E-1	
	Construction Fatalities		2.0E-1
	Construction Injuries		8.8E1
	Operation Fatalities		7.1E-1
	Operation Injuries		6.0E2

Table D.3.1-7. Program-Wide Risks Associated with Managing HLW Under Storage Case 1 of the Centralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
WM Workers	Dose (FTE-rem)	7.5E3	
	Cancer Fatalities	3.0	
	Cancer Incidence	1.0E1	
	Genetic Effects	4.5E-1	
	Construction Fatalities		2.2E-1
	Construction Injuries		9.5E1
	Operation Fatalities		7.6E-1
	Operation Injuries		6.4E2

Table D.3.1-8. Risks Associated with Managing HLW Under Storage Case 1 of the No Action Alternative, by Installation

Installation	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	3.4E-1	2.8
INEL	0.0	0.0
SRS	1.3	3.4
WVDP	6.6E-2	1.7E-1
TOTAL	1.7	6.4

[a] Includes fatalities associated with both radiation exposures and physical hazards.

Table D.3.1-9. Risks Associated with Managing HLW Under Storage Case 1 of the Decentralized Alternative, by Installation

Installation	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	1.8	4.7
INEL	5.7E-1	1.5
SRS	1.3	3.4
WVDP	6.6E-2	1.7E-1
TOTAL	3.7	9.8

[a] Includes fatalities associated with both radiation exposures and physical hazards.

Table D.3.1-10. Risks Associated with Managing HLW Under Storage Case 1 of the Regionalized Alternative 1, by Installation

Installation	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	1.8	4.7
INEL	5.7E-1	1.5
SRS	1.4	3.6
WVDP	4.0E-2	1.1E-1
TOTAL	3.8	9.9

[a] Includes fatalities associated with both radiation exposures and physical hazards.

Table D.3.1-11. Risks Associated with Managing HLW Under Storage Case 1 of the Regionalized Alternative 2, by Installation

Installation	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	1.9	4.8
INEL	5.7E-1	1.5
SRS	1.2	3.4
WVDP	5.8E-2	1.5E-1
TOTAL	3.7	9.9

[a] Includes fatalities associated with both radiation exposures and physical hazards.

Table D.3.1-12. Risks Associated with Managing HLW Under Storage Case 1 of the Centralized Alternative, by Installation

Installation	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	2.3	6.1
INEL	5.6E-1	1.5
SRS	1.0	2.7
WVDP	5.8E-2	1.5E-1
TOTAL	4.0	1.0E1

[a] Includes fatalities associated with both radiation exposures and physical hazards.

Table D.3.1-13. Storage Case 2: Incremental Annual Exposure Risks Associated with Storage Beyond 2015, in Risk per Year

Storage Case 2 Alternative	Hanford			INEL			SRS			WVDP		
	CF[a]	CI[b]	GE[c]	CF	CI	GE	CF	CI	GE	CF	CI	GE
No Action	7.2E-3	2.5E-2	1.1E-3	0.0	0.0	0.0	7.6E-3	2.7E-2	1.1E-3	1.2E-3	4.2E-3	1.8E-4
Decentralized	7.2E-3	2.5E-2	1.1E-3	8.0E-4	2.8E-3	1.2E-4	7.6E-3	2.7E-2	1.1E-3	1.2E-3	4.2E-3	1.8E-4
Regionalized 1	7.2E-3	2.5E-2	1.1E-3	8.0E-4	2.8E-3	1.2E-4	7.6E-3	2.7E-2	1.1E-3	0.0	0.0	0.0
Regionalized 2	7.2E-3	2.5E-2	1.1E-3	8.0E-4	2.8E-3	1.2E-4	7.6E-3	2.7E-2	1.1E-3	0.0	0.0	0.0
Centralized	7.6E-3	2.7E-2	1.1E-3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]CF—Cancer fatalities.
[b]CI—Cancer incidence.
[c]GE—Genetic effects.

Table D.3.1-14. Storage Case 2: Incremental Annual Operational Risks Associated with Storage Beyond 2015, in Risk per Year

Storage Case 2 Alternative	Hanford		INEL		SRS		WVDP	
	OF[a]	OI[b]	OF	OI	OF	OI	OF	OI
No Action	3.2E-3	2.8	0.0	0.0	3.4E-3	2.9	5.4E-4	4.6E-1
Decentralized	3.2E-3	2.8	3.6E-4	3.1E-1	3.4E-3	2.9	5.4E-4	4.6E-1
Regionalized 1	3.2E-3	2.8	3.6E-4	3.1E-1	3.4E-3	2.9	0.0	0.0
Regionalized 2	3.2E-3	2.8	3.6E-4	3.1E-1	3.4E-3	2.9	0.0	0.0
Centralized	3.4E-3	2.9	0.0	0.0	0.0	0.0	0.0	0.0

[a]OF—Operational fatalities.
[b]OI—Operational injuries and illnesses.

Table D.3.1-15. Storage Case 2: Additional Loading, Unloading, and Construction Risks at Hanford

Storage Case 2 Alternative	Hanford						
	CF[a]	CI[b]	GE[c]	OF[d]	OI[e]	CnF[f]	CnI[g]
Centralized	1.1	3.9	1.7E-1	3.9E-2	3.3E1	6.7E-2	2.9E1

[a]CF—Cancer fatalities.
[b]CI—Cancer incidence.
[c]GE—Genetic effects.
[d]OF—Operational fatalities.
[e]OI—Operational injuries and illnesses.
[f]CnF—Construction fatalities.
[g]CnI—Construction injuries and illnesses.

D.3.1.4 Results of the HLW Human Health Risk Analysis for Routine Operations

In general, there are only slight differences in estimated worker cancer and physical hazard risks among the Storage Case 1 alternatives (in which the repository is assumed to be available in 2015; see Table D.3.1-2 and Tables D.3.1-3 through D.3.1-12). Program-wide fatalities from cancer and physical hazards range from 1.7 to 4.0. The risks for each health endpoint differ by about a factor of two. The factors influencing the risks among the alternatives are: (1) the duration of interim storage; (2) the construction of new interim storage facilities at SRS, Hanford, and INEL; and (3) the volumes of HLW at SRS and Hanford. In the Storage Case 2 alternatives, for every year that operation of the repository is delayed past 2015, there are additional storage risks at certain installations depending on the alternative (see Tables D.3.1-13 and D.3.1-14). Table D.3.1-15 shows the additional risks at Hanford as a result of the increased number of canisters being shipped there for storage in the Storage Case 2 Centralized Alternative.

The lowest estimated cancer fatality risks are for the No Action Alternative in Storage Case 1. This is because there are fewer canisters at Hanford and the risks are zero at INEL. The risks for the Storage Case 1 consolidation alternatives (Decentralized, Regionalized, and Centralized) are higher by slightly more than a factor of two. This increased risk is due to the relatively long time that SRS, Hanford, and INEL store their canisters—42 to 45 years at all three installations. These long storage periods are based on the assumption that the national geologic repository accepts 800 canisters/year; therefore, canister shipping rates to the repository are about 400 canisters/year at Hanford and 200 canisters/year at the other sites. Note that in each of these consolidation alternatives, the canisters are moved from one installation

to another but the total number of canisters at all installations, hence, the total associated risk, stays approximately the same.

The risk of fatalities from physical hazards follows the same trend as the risk of cancer fatalities; Storage Case 1 risks for the Decentralized, Regionalized, and Centralized alternatives (9.2E-1 to 9.9E-1) are about two times higher than the risks for Storage Case 1 of the No Action Alternative (5.0E-1). These higher risks are due to the extended loading and storage periods at Hanford and INEL; this means that more person-hours are devoted to storage activities in these alternatives than in the No Action Alternative. Because more HLW is present at SRS and Hanford, the highest estimated risks of total fatalities are associated with these two installations (see Tables D.3.1–8 through D.3.1–12).

D.3.1.5 Special Assumptions and Considerations Used in the HLW Accident Analysis

This section presents an overview of the types of potential accidents analyzed for the interim storage of immobilized HLW. For this analysis, ANL estimated source terms for the HLW facilities at Hanford, SRS, and WVDP for accidents involving a canister breach due to dropping, collision, or both. These accident source terms are site-specific but do not differ by alternative (i.e., a glass canister breach at a particular installation is considered to have the same consequences regardless of the alternative under which the accident occurs). The probability or frequency of HLW accidents is not addressed. Instead, consequences are presented as if each accident occurs once over the course of HLW interim storage. However, this should *not* be construed as indicating the actual probability or frequency of the postulated storage accidents.

Two accident scenarios were evaluated to determine the risks from radiological exposure to the offsite population and MEI, the noninvolved worker population and MEI, and waste management workers. In both, it was assumed that one canister of vitrified HLW is breached inside the storage facility and produces a cloud of pulverized, radioactive material. One shift of four waste management workers is assumed to be inside the facility when the accident occurs.

When the canister is breached, the contaminants are assumed to disperse in a hemispherical mixing volume with a radius of 5 m. The four waste management workers are 1 m away from the canister when it is breached and walk away at 1 m/s; therefore, the workers are exposed for 4 sec. It is assumed that

the workers do not hold their breath while walking away. While immersed in the resulting cloud of contaminated air, the workers are subject to external radiation and to internal radiation exposure by inhalation.

In the first accident, the storage facility's high-efficiency particulate air (HEPA) filtration system is assumed to be fully functional when the canister is breached and only a small amount of the cloud of contaminated air escapes from the building. This material is atmospherically dispersed and presents a risk of internal and external exposure to the offsite and noninvolved worker populations and their respective MEIs.

In the second accident, the storage facility's HEPA filtration system is assumed to be completely disabled when the canister is breached. The entire cloud of contaminated air escapes from the building, is atmospherically dispersed, and presents a risk of internal and external exposure to the offsite and noninvolved worker populations and their respective MEIs.

For the worker exposure assessment, it was assumed that workers are always exposed to unfiltered releases, thus, the same unfiltered source term was used for both accident scenarios. As a result, worker risks are the same for both accident types at a particular installation. The methodology and models for estimating worker risks are different from those used to estimate the risks that noninvolved worker and offsite receptors might receive from atmospheric releases (ORNL, 1995b). Because of this, air concentrations are different for workers than for nonworkers; controlling contaminants and exposure routes may also differ.

D.3.1.6 Results Tables for the Risk Analysis of Potential HLW Accidents

Table D.3.1–16 presents a program-wide summary of the risks of cancer incidence and cancer fatality to all receptors, by accident type and installation. Table D.3.1–17 provides the sizes of the offsite, noninvolved worker, and worker populations for each installation. Table D.3.1–18 lists the contaminant contributing the most risk to the total offsite population and the dose contributed by that contaminant.

Table D.3.1–16. Summary of Risks from Potential HLW Accidents, by Accident Type and Installation

Accident	Installation	Offsite Population		Offsite MEI[a]		Noninvolved Worker Population		Noninvolved Worker MEI		Workers[b]	
		CF[c]	CI[d]	CF	CI	CF	CI	CF	CI	CF	CI
Filtered Canister Breach	Hanford	1.4E-3	4.7E-3	3.3E-8	1.1E-7	1.2E-7	4.1E-7	1.2E-9	4.0E-9	3.7E-4	1.3E-3
	SRS	1.2E-7	4.0E-7	3.6E-12	1.2E-11	9.4E-9	3.2E-8	4.0E-11	1.4E-10	1.3E-3	4.6E-3
	WVDP	4.9E-7	1.7E-6	1.8E-10	6.2E-10	4.2E-9	1.4E-8	2.4E-11	8.1E-11	3.3E-4	1.2E-3
Unfiltered Canister Breach	Hanford	1.3E-1	4.3E-1	3.0E-6	1.0E-5	4.0E-3	1.3E-2	3.9E-5	1.3E-4	3.7E-4	1.3E-3
	SRS	5.8E-2	2.0E-1	1.8E-6	6.1E-6	4.7E-3	1.6E-2	2.0E-5	6.9E-5	1.3E-3	4.6E-3
	WVDP	2.4E-1	8.3E-1	9.1E-5	3.1E-4	2.1E-3	7.1E-3	1.2E-5	4.0E-5	3.3E-4	1.2E-3

[a] MEI—Most-exposed individual.
[b] Worker exposures for a particular installation are the same in both accidents.
[c] CF—Risk of cancer fatality associated with radiological exposure.
[d] CI—Risk of cancer incidence associated with radiological exposure.

Table D.3.1–17. Size of Offsite, Noninvolved Worker, and Worker Populations Affected by the Risks from Potential HLW Storage Accidents, by Installation

Installation	Offsite Population	Noninvolved Worker Population	Worker Population
Hanford	377,645	8,674	4
SRS	620,618	15,996	4
WVDP	1,698,391	960	4

Table D.3.1–18. HLW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population, by Accident Type and Installation

Accident Type	Radionuclide and Dose, by Installation		
	Hanford	SRS	WVDP
Filtered Canister Breach	Iodine–129 2.8 person-rem	Strontium–90 7.8E-5 person-rem	Cesium–137 3.9E-4 person-rem
Unfiltered Canister Breach	Cesium–137 108 person-rem	Strontium–90 39.2 person-rem	Cesium–137 197 person-rem

Note: All exposures received via internal exposure (inhalation and ingestion).

D.3.1.7 Summary of the HLW Accident Analysis Results

As expected, the risks to all offsite and noninvolved worker receptors from the accident in which HEPA filtration is lost are markedly higher than the risks from the accident in which filtration is retained. As shown in Table D.3.1–16, estimated cancer incidence and fatalities for both populations and MEIs are 2 to 6 orders of magnitude greater for the unfiltered canister breach than for the filtered accident.

Recall that cancer incidence risks to the MEI between 1.0E-4 and 1.0E-6 are generally regarded as within the target risk range according to EPA risk assessment guidelines (see Section D.2.14). In the filtered canister breach, cancer incidence and fatality risks to all offsite and noninvolved worker receptors are 1 to 5 orders of magnitude below 1.0E-6. In the unfiltered canister breach, cancer incidence and fatality risks exceed 1.0E-4 for the offsite MEI at WVDP and the noninvolved worker MEI at Hanford, and are in the E-6 to E-5 range for all remaining offsite and noninvolved worker MEIs.

At Hanford, the filtered canister breach accident risks for both the offsite population and MEI are 2 to 4 orders of magnitude greater than the analogous risks at SRS and WVDP (see Table D.3.1–16). This is because Hanford has iodine–129 in its inventory. Iodine–129 is a volatile gas, not a particulate, so HEPA filtration is not highly effective in removing it. In addition, iodine–129 is very biologically dangerous when taken into the body because it bioaccumulates in the thyroid and can severely damage thyroid tissue. However, while iodine–129 contributes equally to the risks in both the filtered and unfiltered accident scenarios at Hanford, its contribution to the unfiltered canister breach accident risks are outweighed by the risks from cesium–137.

In both accident scenarios, strontium-90 contributes most of the offsite population risk at SRS and cesium-137 is the major contributor at WVDP (see Table D.3.1-18). At Hanford, the controlling radionuclides are iodine-129 in the filtered canister breach scenario and cesium-137 in the unfiltered breach scenario. In all circumstances, the predominant exposure routes are inhalation and, to a lesser extent, ingestion.

Worker exposure is the same in both accident scenarios (see Table D.3.1-16). Worker risks do not differ appreciably among installations, and are highest at SRS by less than 0.5 orders of magnitude. The controlling radionuclides for worker exposure are plutonium-238 at SRS and americium-241 at Hanford and WVDP; inhalation is the principal exposure route.

D.3.2 Low-Level Waste

This section contains the human health risk analysis results for low-level waste (LLW). LLW includes all radionuclide-containing wastes not classified as high-level waste, transuranic waste with an activity greater than 100 nanocuries (billionths of a curie) per gram, spent nuclear fuel, or byproduct material as defined in Section 11e(2) of the Atomic Energy Act of 1954 (such as tailings containing uranium or thorium). Waste designated as LLW contains source, special nuclear, or byproduct material that is acceptable for disposal in a land disposal facility and does not contain hazardous components regulated under the Resource Conservation and Recovery Act (RCRA). LLW that contains hazardous components is classified as low-level mixed waste, which is addressed in Section D.3.5.

DOE generates LLW primarily in research and development, defense activities, uranium enrichment operations, and the naval nuclear propulsion program. More than 30 installations within the DOE complex generate LLW; following are the installations considered in the PEIS (note the abbreviations used in this section):

- Argonne National Laboratory-East (ANL-E), Argonne, Illinois
- Argonne National Laboratory-West (ANL-W), Idaho Falls, Idaho
- Brookhaven National Laboratory (BNL), Brookhaven, New York
- Fernald Environmental Management Project (FEMP), Fernald, Ohio
- Hanford Site (Hanford), Richland, Washington

- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Kansas City Plant (KCP), Kansas City, Missouri
- Lawrence Berkeley Laboratory (LBL), Berkeley, California
- Lawrence Livermore National Laboratory (LLNL), Livermore, California
- Los Alamos National Laboratory (LANL), Los Alamos, New Mexico
- Mound Plant (Mound), Miamisburg, Ohio
- Naval Reactors Facility (NRF), Idaho Falls, Idaho
- Nevada Test Site (NTS), Las Vegas, Nevada
- Oak Ridge Institute for Science and Education (ORISE), Oak Ridge, Tennessee
- Oak Ridge Reservation (ORR), Oak Ridge, Tennessee (comprises the Oak Ridge K–25 Site [K–25], the Oak Ridge National Laboratory [ORNL], and the Oak Ridge Y–12 Plant [Y–12])
- Paducah Gaseous Diffusion Plant (PGDP), Paducah, Kentucky
- Pantex Plant (Pantex), Amarillo, Texas
- Pinellas Plant (Pinellas), Largo, Florida
- Portsmouth Gaseous Diffusion Plant (Ports), Piketon, Ohio
- Rocky Flats Environmental Technology Site (RFETS), Golden, Colorado
- Sandia National Laboratories–New Mexico (SNL–NM), Albuquerque, New Mexico
- Sandia National Laboratory–California (SNL–CA), Livermore, California
- Savannah River Site (SRS), Aiken, South Carolina

Note that treatment risks were estimated separately for the three sites comprising ORR (e.g., ORNL, Y–12, and K–25), whereas disposal risks were calculated for the combined three sites (i.e., for the ORR as a single, overall installation). Treatment risks were calculated separately based on the assumption that Y–12 and K–25 perform only the packaging and certification/shipment modules, while ORNL undertakes these plus additional modules such as aqueous treatment, solidification, tumulus disposal, and incineration (where applicable). Disposal risks were combined based on the assumption that disposal of LLW from all three sites takes place at one central ORR facility.

LLW may contain a wide range of radionuclides at activities ranging from trace amounts to thousands of curies. Depending on its chemical and physical properties, LLW can be grouped into waste stream categories according to the type of treatment needed, such as dilute and aqueous wastes; organic wastes; combustible wastes; noncombustible, compactible or noncompactible wastes; surface-contaminated bulk

metal or equipment; activated bulk metal or equipment; sludges and resins; and remote-handled LLW (RH–LLW), a high-activity waste requiring special handling.

Currently, Hanford, INEL, LANL, NTS, ORR, and SRS are authorized to dispose of DOE-generated LLW. Low-activity wastes can be disposed of by shallow, engineered land disposal; higher-activity wastes require disposal technologies offering greater confinement.

Chapters 3 and 7 of the PEIS and the LLW technical report (ANL, 1995c) provide more detailed information on this waste, including LLW inventories at DOE installations, estimated release rates, treatment categories used in the PEIS, the process for developing PEIS LLW alternatives, and the various waste consolidation alternatives.

D.3.2.1 Summary of LLW Alternatives

The PEIS waste management alternatives (No Action, Decentralized, Regionalized 1 and 2, and Centralized) and the rationale for developing them are discussed rigorously in the main body of the PEIS. A broad range of alternatives are analyzed for this waste type:

- The No Action Alternative: All installations transport LLW to six installations (Hanford, INEL, LANL, NTS, ORR, and SRS) for disposal under current arrangements. All installations use existing treatment facilities.
- The Decentralized Alternative: Twelve installations dispose of all LLW projected to be generated over the next 20 years. Minimum treatment at each installation is assumed.
- The Regionalized Alternatives (seven alternatives): 2, 6, or 10 installations dispose of all LLW projected to be generated over the next 20 years. In three of these alternatives, treatment to reduce waste volume (by shredding, compaction, and incineration) is performed.
- The Centralized Alternatives (five alternatives): One installation (Hanford or NTS) disposes of all LLW projected to be generated over the next 20 years. In three of these alternatives, treatment to reduce volume is performed.

This series of alternatives makes it possible to compare the risks of minimum treatment versus minimum treatment plus volume reduction, the risks of using volume reduction at varying numbers of installations, and the risks associated with various disposal configurations.

Table D.3.2–1 depicts the overall treatment and storage schemes for the LLW alternatives.

Table D.3.2–1. PEIS Alternatives for LLW

Alternative	Treat	Dispose	ANL-E	BNL	FEMP	Hanford	INEL	LANL	LLNL	NTS	ORR	PGDP	Pantex	Ports	RFETS	SNL-NM	SRS
No Action	10[b]	6				TD[c]	TD	D	T	D	TD	T			T		TD
Dec.[a]		16	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Reg. 1		12			D	D	D	D	D	D	D	D	D	D	D		D
Reg. 2	11	12			TD	TD	TD	TD	TD	D	TD	TD	TD	TD	TD		TD
Reg. 3		6				D	D	D		D	D						D
Reg. 4	7	6				TD	TD	TD		D	TD			T	T		TD
Reg. 5	4	6				TD	TD	D		D	TD						TD
Reg. 6		2				D											D
Reg. 7		2								D							D
Cen. 1		1				D											
Cen. 2		1								D							
Cen. 3	7	1				TD	T	T			T			T	T		T
Cen. 4	7	1		-		T	T	T		D	T			T	T		T
Cen. 5	1	1			-	TD											

[a] Alternative abbreviations are: Dec. = Decentralized; Reg. = Regionalized; and Cen. = Centralized.
[b] Ten installations use existing facilities for volume reduction. Three sites not listed as major installations above (LBL, RMI, and Mound) include volume reduction facilities.
[c] T—Treatment installation. In this context, treatment entails volume reduction using thermal organic destruction, size reduction (shredding, etc.), and compaction followed by solidification. All installations perform minimum treatment in all alternatives; this consists of solidifying liquids and powdered material, packaging, and shipment.
[d] D—Disposal installation. Each of the 6-installation disposal alternatives uses the same installations, and each of the 12-installation disposal alternatives uses the same 12 installations.

Note that for the purposes of this risk analysis, the waste loads from four smaller generators have been added to the inventories of larger generators. Specifically, the ORISE waste load is combined with the ORNL inventory; the ANL-W and NRF waste loads are added to the INEL inventory; and the SNL-CA waste load is combined with the LLNL inventory.

D.3.2.2 Special Assumptions and Considerations Used in the LLW Risk Analysis

For all disposal scenarios, it is assumed that shallow land burial will be used at installations west of the Mississippi River and tumulus (above-ground vault) disposal will be used at eastern installations. The exceptions are RFETS, which disposes in tumulus vaults, and SRS, which disposes in below-ground vaults.

Some LLW waste streams will already be disposed of onsite and are not considered in the consolidation alternatives. In particular, grout waste at Hanford and saltstone waste at SRS are not included in the LLW disposal inventories at their respective installations. Disposal of these waste forms is assumed to cause no risk to workers because the waste is piped directly into underground disposal facilities; therefore, worker risks have not been assessed for these situations.

It is assumed that, except in the No Action Alternative, LLW disposal capacity at each installation will be expanded as required to meet disposal demands.

In estimating worker radiological risks, it is assumed that management and disposal of the "activated metals" and "remote-handled" categories of LLW require greater shielding for workers than the other categories because these two waste streams emit higher levels of external radiation; a remote shielding scenario was used to estimate worker radiation exposure, as described in ORNL unit risk methodology (ORNL, 1995c).

D.3.2.3 Results Tables for the LLW Human Health Risk Analysis

This section contains tables that summarize the results for the LLW human health risk analysis. A discussion of the results and the remainder of the results tables are presented in Section D.3.2.4. The

fatality and cancer incidence numbers in the tables are displayed in the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.2–2 presents an overview, by alternative, of the *total*, program-wide risks associated with treatment of LLW. Included are the risks of cancer fatalities and cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers associated with waste treatment. This table provides the estimated *total number* of people in the three populations who will develop or die of cancer caused by exposure to LLW if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities. The results in this table are drawn from Tables D.3.2–7 through D.3.2–19, which can be found at the end of Section D.3.2.4.
- Table D.3.2–3 presents an overview, by alternative, of the program-wide risks associated with disposal of LLW. This table summarizes the risks of cancer fatalities and cancer incidence for the most-exposed lifetime (MEL) of the hypothetical farm family; the total risks to members of all 143 lifetimes of the farm family; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers associated with waste disposal. The results in this table are drawn from Tables D.3.2–33 through D.3.2–46, located at the end of Section D.3.2.4.
- Table D.3.2–4 shows the sizes of the total affected populations for each alternative.
- Table D.3.2–5 summarizes the risks to the noninvolved worker and offsite MEIs for each LLW alternative. The numbers in this table are the estimated *probabilities* that the offsite and noninvolved worker MEIs will die of cancer or develop cancer from radionuclide exposure. These results are drawn from Tables D.3.2–7 through D.3.2–19 and Tables D.3.2–33 through D.3.2–46.
- Table D.3.2–6 lists the radionuclides that contribute most of the risk of cancer fatality to the offsite population, by installation and alternative.

Table D.3.2-2. Summary of Program-Wide Risks Associated with Treatment of LLW: Risks to Total Populations, by Alternative

Alternative	Offsite Population		Noninvolved Worker Population		WM Workers		
	CF[a]	CI[b]	CF	CI	CF	CI	C&OF[c]
No Action	1.3E-2	4.5E-2	4.3E-4	1.5E-3	1.1	3.7	2.9
Minimum Treatment Alternatives							
Decentralized	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.5E-1	2.6	2.1
Regionalized 1	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.5E-1	2.5	2.1
Regionalized 3	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.5E-1	2.5	2.3
Regionalized 6	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.7E-1	2.7	2.6
Regionalized 7	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.7E-1	2.7	2.6
Centralized 1	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.7E-1	2.7	2.6
Centralized 2	2.9E-2	9.8E-2	1.9E-4	6.4E-4	7.7E-1	2.7	2.6
Volume Reduction Alternatives							
Regionalized 2	6.4E-1	2.2	6.6E-3	2.2E-2	1.1	3.8	4.8
Regionalized 4	9.7E-2	3.3E-1	1.9E-3	6.5E-3	1.2	4.3	4.8
Centralized 3	1.0E-1	3.4E-1	2.1E-3	7.3E-3	1.2	4.3	4.8
Centralized 4	1.0E-1	3.4E-1	2.1E-3	7.3E-3	1.2	4.3	4.8
Regionalized 5	1.2E-1	4.0E-1	1.4E-3	4.8E-3	1.4	4.8	4.8
Centralized 5	9.8E-2	3.33E-1	1.1E-3	3.7E-3	2.2	7.5	4.3

[a] CF—cancer fatality associated with radionuclide exposure.
[b] CI—cancer incidence associated with exposure to radionuclides.
[c] C&OF—fatalities due to the physical hazards of constructing and operating waste management facilities.

Table D.3.2–3. Summary of Program-Wide Risks Associated with Disposal of LLW: Risks to Hypothetical Farm Family and Waste Management Workers, by Alternative

Alternative	MEL of Farm Family		All (143) Lifetimes of Farm Family		WM Workers		
	CF[a]	CI[b]	CF	CI	CF	CI	C&OF[c]
No Action	5.7E-3	2.0E-2	7.6E-2	2.6E-1	3.0	10	3.8
Decentralized Disposal							
Decentralized	6.4E-2	2.2E-1	1.2	3.9	2.3	7.9	5.9
Regionalized Disposal							
Regionalized 1	1.5E-3	5.1E-3	2.2E-2	7.4E-2	2.2	7.6	5.7
Regionalized 2	5.2E-3	1.8E-2	7.2E-2	2.5E-1	1.8	6.3	4.2
Regionalized 3	1.3E-3	4.3E-3	1.7E-2	5.8E-2	2.4	8.3	5.3
Regionalized 4	1.4E-2	4.8E-2	1.9E-1	6.3E-1	1.8	6.3	3.9
Regionalized 5	1.4E-2	4.8E-2	1.9E-1	6.3E-1	1.8	6.3	3.9
Regionalized 6	1.6E-2	5.6E-2	2.2E-1	7.3E-1	1.8	6.2	6.4
Regionalized 7	1.7E-4	5.9E-4	1.8E-4	6.3E-3	1.8	6.2	6.3
Centralized Disposal							
Centralized 1	4.8E-3	1.6E-2	6.4E-2	2.2E-1	2.8	9.7	1.4
Centralized 2	0.00	0.00	0.00	0.00	2.8	9.7	1.3
Centralized 3	9.2E-3	3.1E-2	1.2E-1	4.2E-1	1.8	6.1	7.5E-1
Centralized 4	0.00	0.00	0.00	0.00	1.8	6.2	8.5E-1
Centralized 5	9.2E-3	3.1E-2	1.2E-1	4.2E-1	1.8	6.2	8.8E-1

[a] CF—Risk of cancer fatality associated with exposure to radionuclides.
[b] CI—Risk of cancer incidence associated with exposure to radionuclides.
[c] C&OF—Estimated construction and operational fatalities from physical hazards.

Table D.3.2–4. Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Routine Management of LLW, by Alternative

Alternative	Offsite Population	Noninvolved Worker Population	WM Workers
No Action	32,597,069	115,729	16,656
Decentralized	38,321,357	115,729	9,640
Regionalized 1	32,582,803	115,729	9,663
Regionalized 3	32,582,803	115,729	10,321
Regionalized 6	32,582,803	115,729	11,579
Regionalized 7	32,582,803	115,729	11,845
Centralized 1	32,582,803	115,729	11,601
Centralized 2	32,582,803	115,729	11,867
Regionalized 2	35,347,392	118,185	22,483
Regionalized 4	32,582,803	115,729	22,469
Centralized 3	32,597,069	119,485	22,489
Centralized 4	32,597,069	119,485	22,489
Regionalized 5	32,582,803	115,729	22,602
Centralized 5	32,582,803	115,729	19,855

Table D.3.2–5. Summary of Program-Wide Risks Associated with Treatment of LLW: Risks To the Offsite and Noninvolved Worker Most-Exposed Individuals, by Alternative

Alternative	Offsite MEI[a]		Noninvolved Worker MEI	
	CF[b]	CI[c]	CF	CI
No Action	3.5E-7	1.2E-6	3.4E-7	1.2E-6
Decentralized	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Regionalized 1	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Regionalized 3	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Regionalized 6	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Regionalized 7	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Centralized 1	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Centralized 2	2.9E-7	9.7E-7	4.7E-8	1.6E-7
Regionalized 2	6.3E-6	2.1E-5	1.8E-6	6.2E-6
Regionalized 4	2.3E-6	7.9E-6	8.5E-7	2.9E-6
Centralized 3	2.3E-6	7.9E-6	1.1E-6	3.6E-6
Centralized 4	2.3E-6	7.9E-6	1.1E-6	3.6E-6
Regionalized 5	1.4E-6	4.9E-6	8.5E-7	2.9E-6
Centralized 5	1.5E-6	5.2E-6	1.7E-6	5.8E-6

[a] MEI—Most-exposed individual.
[b] CF—Risk of cancer fatality associated with exposure to radionuclides.
[c] CI—Risk of cancer incidence associated with exposure to radionuclides.

Table D.3.2–6. Radionuclide Contributing the Highest Risk of Cancer Fatality to the Offsite Population for LLW Treatment, by Alternative and Installation

Alt.[a]	Installation																				
	ANL-E	BNL	FEMP	Hanford	INEL	KCP	KAPL-K	LBL	LLNL	LANL	Mound	NTS	K-25	ORNL	Y-12	PGDP	Pantex	Pinellas	Ports	RFETS	SNL/NM	SRS
No Action	Pu-238[b] 7.0E-7[c]			Pu-238 2.3E-7	Co-60 1.3E-6	U-238 5.5E-10	Co-60 5.3E-4	H-3 7.6E-4	U-238 2.4E-7	Pu-238 1.1E-4	Pu-238 4.3E-8		U-238 1.2E-9	Pu-238 1.0E-1	U-238 1.8E-8	U-238 1.8E-8	H-3 1.6E-7	H-3 1.8E-8	U-238 1.6E-9	Pu-238 4.9E-8	U-238 8.8E-7	H-3 4.1E-4
Dec.	Pu-238 7.6E-7			Pu-238 1.5E-6	Co-60 7.6E-7	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 8.0E-9	Pu-238 3.3E-6	U-238 1.9E-8	U-238 2.8E-7	H-3 8.0E-8	H-3 1.8E-8	U-238 2.8E-10	Pu-238 1.4E-7	U-238 8.9E-7	H-3 6.2E-6
Reg. 1	Pu-238 7.6E-7			Pu-238 1.5E-6	Co-60 7.6E-7	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 8.0E-9	Pu-238 3.3E-6	U-238 1.9E-8	U-238 2.8E-7	H-3 8.0E-8	H-3 1.8E-8	U-238 2.8E-10	Pu-238 1.4E-7	U-238 9.1E-7	H-3 6.2E-6
Reg. 3	Pu-238 7.6E-7			Pu-238 1.5E-6	Co-60 7.6E-7	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 8.0E-9	Pu-238 3.3E-6	U-238 1.9E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	H-3 6.2E-6
Reg. 6	Pu-238 7.6E-7			Pu-238 1.5E-6	Co-60 1.2E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 1.1E-7	Pu-238 3.3E-6	U-238 7.8E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	H-3 6.2E-6
Reg. 7	Pu-238 7.6E-7			Pu-238 2.2E-6	Co-60 1.2E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 1.1E-7	Pu-238 3.3E-6	U-238 7.8E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	H-3 6.2E-6
Cen. 1	Pu-238 7.6E-7			Pu-238 1.5E-6	Co-60 1.2E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 1.1E-7	Pu-238 3.3E-6	U-238 7.8E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	H-3 6.2E-6
Cen. 2	Pu-238 7.6E-7			Pu-238 2.2E-6	Co-60 1.2E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 1.0E-1	Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 1.1E-7	Pu-238 3.3E-6	U-238 7.8E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	H-3 6.2E-6
Reg. 2	Pu-238 7.6E-7		H-3 2.0E-1	Pu-238 1.9E-6	Co-60 1.3E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1	H-3 3.8E-1	U-238 1.0E-1	Pu-238 4.7E-8		U-238 8.0E-9	C-14 4.9E-6	U-238 1.9E-8	U-238 1.6E-6	H-3 8.1E-8	H-3 1.8E-8	Co-60 5.8E-5	Pu-238 7.4E-5	U-238 9.1E-7	H-3 4.1E-4
Reg. 4	Pu-238 7.6E-7			H-3 5.0E-1	Co-60 1.3E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1		U-238 1.0E-1	Pu-238 4.7E-8		U-238 8.0E-9	U-238 5.6E-6	U-238 1.9E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	H-3 2.0E-1	Pu-238 7.4E-5	U-238 9.1E-7	H-3 4.1E-4
Cen. 3 Cen. 4	Pu-238 7.6E-7			H-3 5.0E-1	Co-60 1.3E-6	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1		U-238 1.0E-1	Pu-238 4.7E-8	Pu-238 4.8E-5	U-238 8.0E-9	U-238 5.6E-6	U-238 1.9E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	H-3 2.0E-1	Pu-238 7.4E-5	U-238 9.1E-7	H-3 4.1E-4
Reg. 5	Pu-238 7.6E-7			H-3 5.0E-1	U-238 3.4E-4	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1		Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 8.0E-9	H-3 5.0E-1	U-238 1.9E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	H-3 4.1E-4
Cen. 5	Pu-238 7.6E-7			H-3 7.0E-1	Co-60 7.6E-7	U-238 5.7E-10	Co-60 5.2E-4	H-3 2.0E-1		Pu-238 1.2E-4	Pu-238 4.7E-8		U-238 8.0E-9	Pu-238 3.3E-6	U-238 1.9E-8	U-238 1.8E-8	H-3 8.0E-8	H-3 1.8E-8	U-238 1.6E-9	Pu-238 1.6E-7	U-238 9.1E-7	Co-60 5.0E-6

[a] Alternative abbreviations are: Alt. = Alternative; Dec. = Decentralized; Reg. = Regionalized; and Cen. = Centralized.
[b] Radionuclide contributing most risk.
[c] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this installation.

D.3.2.4 Results of the LLW Human Health Risk Analysis for Routine Operations

D.3.2.4.1 *Program-Wide Trends in Human Health Risks Associated with LLW Management Alternatives*

In general, No Action presents the lowest health risks for all public populations and for all health risk endpoints. For the offsite population the risks of cancer fatality due to the treatment of LLW are within 1.5 orders of magnitude for all alternatives (1.3E–2 to 6.4E–1). Risks to the noninvolved worker population and to MEIs follow the same general trend. Regionalized Alternative 2 (regionalized volume reduction at 11 installations) produces the highest risk of cancer fatalities, though it is still within an order of magnitude of all the other alternatives. The health risks tend to increase as the level of treatment increases and where a treatment installation is situated in a highly populated area.

Overall, estimated worker health risks associated with management of LLW are similar among alternatives; however, the highest worker risks tend to be for installations with waste consolidation (i.e., larger waste loads) for treatment and for installations with more treatment facility construction.

Estimated impacts to each of the receptor populations are presented below.

Offsite Population. The lowest risks of cancer fatality to the offsite population are from the No Action Alternative (1.3E-2), the Decentralized Alternative, Regionalized Alternatives 1, 3, 6, 7, and Centralized Alternatives 1 and 2. All are in the E–2 order of magnitude and affect a total population of 32 million to 38 million people. All of these installations perform minimum treatment (although some volume reduction is performed in the No Action Alternative); the only variation is in the various disposal configurations. The risks of cancer fatality associated with Regionalized Alternatives 4 and 5 and Centralized Alternatives 3, 4, and 5 are similar to one another (ranging from 9.7E-2 to 1.2E-1 over a total affected population of approximately 32.5 million) and are about 0.5 to 1 order of magnitude higher than for the other alternatives.

Regionalized 2 poses the highest risks to the offsite population by approximately 0.5 orders of magnitude (an estimated 6.4E-1 cancer fatalities over 32.5 million people). This is because the largest combined population (11 sites totaling about 14.8 million people) is affected by volume reduction (which includes

incineration). The highest installation-specific risks are associated with LLNL (an estimated 3.9E-1 cancer fatalities over a population of approximately 6.3 million); the radionuclide contributing the most risk is tritium, via inhalation and ingestion. The lowest risks to an offsite population at a particular installation are at Ports in both the Decentralized and Regionalized 1 Alternatives.

Inspection of Table D.3.2–6 shows that for all alternatives in which incineration is the major volume-reduction treatment (Regionalized 2, 4, and 5, and Centralized 3, 4, and 5), cancer fatality risks in the E-1 order of magnitude are attributable to tritium except in Regionalized 4, and Centralized 3 and 4. In these three alternatives, both tritium and uranium–238 contribute cancer fatality risks on the order of E-1.

Noninvolved Worker Population. The trends in program-wide health risks to the noninvolved worker population are similar to those observed for the offsite population; both the program-wide risks and the total affected population are lower by approximately 2 orders of magnitude.

The estimated risk of cancer fatality to the noninvolved worker population in Regionalized 2 (6.6E-3 cancer fatalities in a population of 118,185) are about three to six times higher than in the other volume reduction alternatives.

The risks in the No Action, Decentralized, Regionalized 1, 3, 6, 7, and Centralized 1 and 2 Alternatives are nearly identical to one another (ranging from approximately 2E-4 to 4E-4) because the treatment is the same at all sites. The risks to the noninvolved worker population are 1 to 1.5 orders of magnitude higher in Regionalized 4, and 5 and Centralized 3, 4, and 5 than in the minimum treatment alternatives.

Most-Exposed Noninvolved Workers and Most-Exposed Offsite Individuals. Radiological exposure risks to the noninvolved worker and offsite MEIs are lowest in the No Action, Decentralized, Regionalized 1, 3, 6, 7, and Centralized 1 and 2 Alternatives; slightly higher in Regionalized 4 and 5 and Centralized 3, 4, and 5; and highest in Regionalized 2. This trend generally parallels that seen for the overall noninvolved worker and offsite populations.

The program-wide risk of cancer incidence for both MEIs is in the E-5 to E-6 range in Regionalized 2, 4, and 5 and Centralized 3, 4, and 5 (see Table D.3.2–5), and are considered to meet target exposure levels according to EPA guidelines. Across the program, the highest risk of cancer fatality for both MEIs is in Regionalized 2 (an estimated risk of 6.3E-6 for the offsite MEI and 1.8E-6 for the noninvolved

worker MEI). At the installation level, the highest risks of cancer fatality to the offsite MEI are at FEMP (4.4E-6) and LLNL (6.3E-6) in Regionalized 2; Ports (2.3E-6) in Regionalized 4; Hanford (1.0E-6) and Ports (2.3E-6) in Centralized 3 and 4; ORNL (1.4E-6) in Regionalized 5; and Hanford (1.5E-6) in Regionalized 5. These elevated risks are the result of volume reduction (including incineration) of relatively large volumes of volatile waste containing tritium. All cancer fatality risks to both MEIs for minimum treatment alternatives are below E-6.

Workers. The program-wide estimated risks of cancer fatality to workers vary by no more than a factor of three across all alternatives. The risks for the minimum treatment alternatives (Decentralized, Regionalized 1, 3, 6, and 7 and Centralized 1 and 2) are nearly identical to one another (approximately 7.5E-1 cancer fatalities across 9,640 to 11,867 FTEs), and are slightly higher in the No Action Alternative and volume reduction alternatives Regionalized 2, 4, and 5, and Centralized 3 and 4). The highest program-wide cancer fatality risk is incurred in Centralized Alternative 5 (2.2 over a total population of 19,855 FTEs), in which all waste is treated by volume reduction at Hanford.

Estimated construction fatality risks for workers are lowest in the No Action Alternative (8.5E-1), in which no new treatment facilities are to be built. New facilities will be required at several installations in the volume reduction alternatives (Regionalized 2, 4, and 5, and Centralized 3, 4, and 5); however, the risks in these alternatives are higher than in the remaining alternatives by only a factor of two. Estimated operational fatalities are slightly higher (by about a factor of two or less) for the No Action Alternative (2.01) and the volume reduction alternatives (2.4 to 2.73) than for the minimum treatment alternatives (1.17 to 1.44). This is because more worker person-hours are required for the 20-year No Action treatment period and for the more extensive treatment in the volume reduction alternatives.

Although worker risks are very similar across alternatives, some differences in installation risks are notable. The estimated total fatalities (cancer fatalities plus construction and operational fatalities) in the No Action and minimum treatment alternatives are consistently very similar among installations (E-2 to E-1 range) except at KCP and Pinellas (E-3 order of magnitude), which have much smaller waste loads to treat and employ fewer workers (21 to 26 and 11 to 13 FTEs, respectively) than are needed at other installations.

By a slight margin, ORNL poses the highest total worker fatality risks in the Regionalized 2, 4, and 5, and Centralized 3 and 4 volume reduction alternatives (total fatalities range from 1.15 to 1.77) however

the risks among installations in these alternatives are within approximately 1 order of magnitude except at KCP and Pinellas, at which worker fatality risks are 1 to 2 orders of magnitude lower in all alternatives. The slight elevation in risks at ORNL in the volume-reduction alternatives reflects consolidation of waste loads at ORNL for treatment, additional construction of treatment facilities, and the presence of 10 times more FTEs at ORNL in these scenarios. Total fatalities also increase slightly at INEL (1.34) in Regionalized Alternative 5, in which volume reduction is performed at four installations; this is due mainly to larger consolidated waste loads in treatment and a larger exposed work force than for other alternatives. The highest estimated total fatalities are in Centralized Alternative 5 at Hanford (3.65 in 9,856 FTEs), where all volume reduction is performed and the treatment work force is greatly increased compared to other alternatives.

D.3.2.4.2 *Program-Wide Trends in Human Health Risks Associated with LLW Disposal*

For the MEL of the hypothetical farm family, the health risks associated with the LLW disposal alternatives show no discernable trends. The risk of cancer fatality to all 143 farm family lifetimes across alternatives ranges from 0.0 to 1.2 cancer fatalities over 10,000 years. Estimated cancer fatalities for workers during disposal are very similar across alternatives, ranging from 1.8 to 3.0; worker risks tend to increase as the waste load to be disposed of becomes larger and as more disposal facility construction is required.

Most-Exposed Lifetime of the Hypothetical Farm Family. For each alternative, with the exception of Centralized alternatives 2 and 4 (single site disposal at NTS), the risk of cancer incidence to the MEL of the farm family is greater than 1E-4, indicating exposure levels that might be considered above the target exposure level if compared with the EPA guidelines discussed in Section D.2.14. For the "average" individual member of the farm family, the risk of cancer incidence (determined by dividing the cancer incidence risk in Table D.3.2–3 by the number of family members, four, times the number of disposal sites for that alternative), may be considered above the target exposure level in all alternatives except Centralized 2 and 4.

The highest cancer fatality risks to the MEL are in Decentralized (in which wastes receive minimum treatment and are then disposed of at 12 installations). Estimated program-wide cancer fatality risks are 6.4E-2 in Decentralized.

The lowest risks of cancer fatality to the MEL are in Centralized 2 (minimum treatment and disposal at NTS) and Centralized 4 (volume reduction at seven installations and disposal at NTS). The program-wide risks of cancer fatality for the four-member farm family are 0.0 in Centralized 2 and in Centralized 4.

At the installation level, the lowest disposal risks are at LANL in the No Action, Decentralized, Regionalized 1, 2, 3, 4, and 5 Alternatives; at NTS in the No Action, Regionalized 3, 4, and 7, and Centralized 2 and 4 Alternatives; at Pantex in the Decentralized and Regionalized 1 and 2 Alternatives; and at INEL in the No Action, Decentralized, and Regionalized 1, 2, 3, 4, and 5 Alternatives. The estimated radiological risks at these installations are zero because the wastes being disposed of contain low concentrations of radionuclides and the migration of the contaminants into the groundwater is very slow (all four installations receive little annual rainfall).

The highest "average" disposal installation risk to a farm family member is at SNL-NM in the Decentralized Alternative (average individual risk of cancer fatality is 1.6E-2). The MEL is lifetime 15 at SNL-NM, where uranium-238 contributes over 99% of the dose received by farm family members.

Workers Placing Wastes into Disposal. The estimated worker risks from disposal are very similar across alternatives, ranging from 1.8 to 3.0 for cancer fatality and 6.1 to 10 for cancer incidence. However, the estimated risk of fatality from construction is more than 1 order of magnitude lower for the one-installation disposal alternatives (the five Centralized Alternatives) than for the other alternatives. In the Centralized scenarios, Hanford and NTS are the single-disposal installations; both have large amounts of existing disposal capacity compared to other installations and, therefore, require less new construction.

The highest construction fatality risks occur in Regionalized 6 and 7; these alternatives involve two-installation disposal at Hanford and SRS. The majority of the construction-related worker risks are at SRS, which has a relatively small amount of existing disposal capacity and, based on the large amount of LLW to be sent there for disposal in these disposal scenarios, would require extensive construction.

The estimated number of operational fatalities is within 1 order of magnitude among alternatives (ranging from 5.3E-1 to 2.1). In general, operational fatalities are slightly higher for scenarios in which multiple installations dispose (the No Action, Decentralized, and Regionalized 1 and 3 Alternatives), and are slightly lower where only one installation disposes (the Centralized Alternatives). This is because the

fewer the disposal installations, the fewer the number of FTEs needed to operate them (therefore, fewer workers are around to be involved in operational accidents).

Although overall risks to workers from disposal do not differ appreciably among alternatives, some trends are apparent in the installation-specific risks associated with disposal. In the multiple-installation disposal alternatives (the No Action, Decentralized, and Regionalized Alternatives), the same four installations, Hanford, INEL, SRS, and LANL, have the highest cancer risks by approximately 0.5 to 2 orders of magnitude; all four are consolidation installations for LLW disposal in these alternatives. The controlling contaminants are cobalt-60 at Hanford, INEL, and SRS, and cesium-137 and daughter products at LANL; external radiation is the predominant exposure route. In the two-installation disposal alternatives (Hanford and SRS in Regionalized 6; NTS and SRS in Regionalized 7), Hanford and NTS cancer risks are approximately twice as high as those for disposal at SRS. The controlling contaminant for disposal at Hanford and NTS in Regionalized 6 and 7 is cobalt-60; the primary exposure route is external radiation. However, there are more estimated fatalities at SRS due to physical hazards because of the construction of new disposal facilities.

D.3.2.4.3 *Comparison Among Treatment Options*

For workers, comparison of minimum treatment and volume reduction scenarios shows very little difference in cancer risks associated with LLW treatment. In all alternatives, estimated worker cancer fatality risks from treatment are very similar, ranging between 7.5E-1 and 2.2. Overall, worker risks at particular installations seem to be driven primarily by waste consolidation and facility construction.

The program-wide risk of cancer fatality for all of the minimum treatment alternatives are identical for all receptors. The overall risks associated with the volume reduction alternatives are approximately 0.5 to 1.5 orders of magnitude higher than the risks associated with minimum treatment only. This can be seen at the installation level as well as at the program level; for example, at RFETS, cancer fatalities in the offsite population increase from 4.0E-7 in Regionalized Alternative 5 (which involves minimum treatment) to 1.9E-4 in Regionalized Alternative 4 (which involves volume reduction). This is attributable to increased atmospheric releases associated with the incineration of LLW.

Comparison of the risks for the volume reduction alternatives shows that the risks for all receptors vary by no more than a factor of six between volume reduction at 11 installations and volume reduction at 7, 4, or 1 installation(s).

D.3.2.4.4 *Comparison Among Disposal Scenarios*

Comparisons can be made between the alternatives in which treatment is the same but the number of disposal sites varies from 12 installations to 1. For the minimum treatment alternatives, the cancer fatality risks to all farm family lifetimes range from 1.6E-3 to 8.2E-2. There are no apparent trends as the number of disposal facilities changes. The cancer fatality risks in the single-installation disposal alternatives (Centralized 1 and 2) are within 0.5 orders of magnitude (1.6E-3 at NTS and 4.8E-3 at Hanford).

Comparison of disposal risks among alternatives that have the same disposal scenarios but different treatment options shows that the type of LLW treatment has little effect on the cancer risks to all farm family lifetimes or to the MEL. For example, in the 10-installation disposal alternatives (Regionalized 1 and Regionalized 2), the major difference is that minimum treatment is performed at all installations in Regionalized 1, while additional volume reduction is performed at 11 installations in Regionalized 2. Risks of cancer fatality to all farm family lifetimes from disposal are higher in Regionalized 2 by less than a factor of three. This small difference is found for both the MEL and for all lifetimes across Regionalized 3, 4, and 5 (the six-installation disposal alternatives); Centralized 1, 3, and 5 (the alternatives in which disposal takes place at Hanford); and Centralized 2 and 4 (in which LLW is disposed of at NTS).

As previously noted for worker risks associated with LLW treatment, the disposal risks to workers do not differ appreciably among alternatives; however, certain installation-specific risks tend to be higher where waste loads are consolidated for disposal or where more construction of disposal facilities is required.

D.3.2.4.5 *Summary of Results for Routine Treatment and Disposal of LLW*

Treatment by volume reduction slightly increases the cancer risks to offsite and noninvolved worker populations at a particular installation in comparison to minimum treatment. However, the type of treatment does not affect the subsequent disposal risks to the farm family as much as the amount of waste consolidated at an installation or the hydrogeology and meteorology of the disposal installation (both of which can markedly affect the migration of contaminants into groundwater). Volume reduction tends to concentrate waste producing slightly higher estimated risks to the farm family.

In all but two disposal alternatives (Centralized 2 and 4), the program-wide risks of cancer incidence to the MEL of the hypothetical farm family exceed the target exposure levels if comparison is made to EPA risk assessment guidelines (Section D.2.14). Recall that this is a worst-case disposal scenario in which the farm family residence and drinking water well are situated 300 m downgradient from the center of a disposal facility, and that the well serves as the sole source of water for the family, their livestock, and crops.

Worker risks are very similar across all alternatives, regardless of treatment type or disposal scenario; program-wide risks are within 1 order of magnitude across all treatment alternatives and all disposal alternatives. Fatalities associated with radiation exposure are usually fewer than those due to the physical hazards of constructing and operating treatment and disposal facilities, except in the one-site disposal alternatives at NTS and Hanford. As discussed above, these installations have relatively large existing disposal facility capacities and require less construction. Overall, however, worker risks at specific installations seem to be driven primarily by the amount of waste consolidated for treatment and/or disposal and the amount of facility construction needed.

Table D.3.2–7. Program-Wide Risks Associated with Treatment of LLW Under the No Action Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	8.5E-1	
	Cancer Fatalities	4.3E-4	
	Cancer Incidence	1.5E-3	
	Genetic Effects	8.5E-5	
Noninvolved Worker MEI	Dose (rem)	6.8E-4	
	Cancer Fatalities	3.4E-7	
	Cancer Incidence	1.2E-6	
	Genetic Effects	6.8E-8	
	Hazard Index		
Offsite Population	Dose (person-rem)	2.7E1	
	Cancer Fatalities	1.3E-2	
	Cancer Incidence	4.5E-2	
	Genetic Effects	2.7E-3	
Offsite MEI	Dose (rem)	7.0E-4	
	Cancer Fatalities	3.5E-7	
	Cancer Incidence	1.2E-6	
	Genetic Effects	7.0E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	2.6E3	
	Cancer Fatalities	1.1	
	Cancer Incidence	3.7	
	Genetic Effects	1.6E-1	
	Exposure Index		
	Construction Fatalities		8.5E-1
	Construction Injuries		3.7E2
	Operation Fatalities		2.0
	Operation Injuries		1.7E3

Table D.3.2-8. Program-Wide Risks Associated with Treatment of LLW Under the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.7E-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.9E3	
	Cancer Fatalities	7.5E-1	
	Cancer Incidence	2.6	
	Genetic Effects	1.1E-1	
	Exposure Index		
	Construction Fatalities		9.6E-1
	Construction Injuries		4.2E2
	Operation Fatalities		1.2
	Operation Injuries		9.9E2

Table D.3.2–9. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.7E-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.8E3	
	Cancer Fatalities	7.3E-1	
	Cancer Incidence	2.5	
	Genetic Effects	1.1E-1	
	Exposure Index		
	Construction Fatalities		9.6E-1
	Construction Injuries		4.2E2
	Operation Fatalities		1.2
	Operation Injuries		9.9E2

Table D.3.2–10. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.7E-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.8E3	
	Cancer Fatalities	7.3E-1	
	Cancer Incidence	2.5	
	Genetic Effects	1.1E-1	
	Exposure Index		
	Construction Fatalities		1.0
	Construction Injuries		4.5E2
	Operation Fatalities		1.3
	Operation Injuries		1.1E3

Table D.3.2-11. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 6, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.7E-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.9E3	
	Cancer Fatalities	7.7E-1	
	Cancer Incidence	2.7	
	Genetic Effects	1.2E-1	
	Exposure Index		
	Construction Fatalities		1.2
	Construction Injuries		5.0E2
	Operation Fatalities		1.4
	Operation Injuries		1.2E3

Table D.3.2–12. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 7, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.7E-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.9E3	
	Cancer Fatalities	7.7E-1	
	Cancer Incidence	2.7	
	Genetic Effects	1.2E-1	
	Exposure Index		
	Construction Fatalities		1.2
	Construction Injuries		5.2E2
	Operation Fatalities		1.4
	Operation Injuries		1.2E3

Table D.3.2–13. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.7E-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.9E3	
	Cancer Fatalities	7.7E-1	
	Cancer Incidence	2.7	
	Genetic Effects	1.2E-1	
	Exposure Index		
	Construction Fatalities		1.2
	Construction Injuries		5.0E2
	Operation Fatalities		1.4
	Operation Injuries		1.2E3

Table D.3.2-14. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.7E-1	
	Cancer Fatalities	1.9E-4	
	Cancer Incidence	6.4E-4	
	Genetic Effects	3.7E-5	
Noninvolved Worker MEI	Dose (rem)	9.4E-5	
	Cancer Fatalities	4.7E-8	
	Cancer Incidence	1.6E-7	
	Genetic Effects	9.4E-9	
	Hazard Index		
Offsite Population	Dose (person-rem)	5.8E1	
	Cancer Fatalities	2.9E-2	
	Cancer Incidence	9.8E-2	
	Genetic Effects	5.8E-3	
Offsite MEI	Dose (rem)	5.7E-4	
	Cancer Fatalities	2.9E-7	
	Cancer Incidence	9.7E-7	
	Genetic Effects	5.7E-8	
	Hazard Index		
WM Workers	Dose (FTE-rem)	1.9E3	
	Cancer Fatalities	7.7E-1	
	Cancer Incidence	2.7	
	Genetic Effects	1.2E-1	
	Exposure Index		
	Construction Fatalities		1.2
	Construction Injuries		5.2E2
	Operation Fatalities		1.4
	Operation Injuries		1.2E3

Table D.3.2-15. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	1.3E1	
	Cancer Fatalities	6.6E-3	
	Cancer Incidence	2.2E-2	
	Genetic Effects	1.3E-3	
Noninvolved Worker MEI	Dose (rem)	3.6E-3	
	Cancer Fatalities	1.8E-6	
	Cancer Incidence	6.2E-6	
	Genetic Effects	3.6E-7	
	Hazard Index		
Offsite Population	Dose (person-rem)	1.3E3	
	Cancer Fatalities	6.4E-1	
	Cancer Incidence	2.2	
	Genetic Effects	1.3E-1	
Offsite MEI	Dose (rem)	1.3E-2	
	Cancer Fatalities	6.3E-6	
	Cancer Incidence	2.1E-5	
	Genetic Effects	1.3E-6	
	Hazard Index		
WM Workers	Dose (FTE-rem)	2.7E3	
	Cancer Fatalities	1.1	
	Cancer Incidence	3.8	
	Genetic Effects	1.7E-1	
	Exposure Index		
	Construction Fatalities		2.1
	Construction Injuries		9.2E2
	Operation Fatalities		2.7
	Operation Injuries		2.3E3

Table D.3.2-16. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	3.8	
	Cancer Fatalities	1.9E-3	
	Cancer Incidence	6.5E-3	
	Genetic Effects	3.8E-4	
Noninvolved Worker MEI	Dose (rem)	1.7E-3	
	Cancer Fatalities	8.5E-7	
	Cancer Incidence	2.9E-6	
	Genetic Effects	1.7E-7	
	Hazard Index		
Offsite Population	Dose (person-rem)	2.0E2	
	Cancer Fatalities	9.7E-2	
	Cancer Incidence	3.3E-1	
	Genetic Effects	2.0E-2	
Offsite MEI	Dose (rem)	4.6E-3	
	Cancer Fatalities	2.3E-6	
	Cancer Incidence	7.9E-6	
	Genetic Effects	4.6E-7	
	Hazard Index		
WM Workers	Dose (FTE-rem)	3.1E3	
	Cancer Fatalities	1.2	
	Cancer Incidence	4.3	
	Genetic Effects	1.8E-1	
	Exposure Index		
	Construction Fatalities		2.1
	Construction Injuries		9.3E2
	Operation Fatalities		2.7
	Operation Injuries		2.3E3

Table D.3.2-17. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternatives 3 and 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	4.3	
	Cancer Fatalities	2.1E-3	
	Cancer Incidence	7.3E-3	
	Genetic Effects	4.3E-4	
Noninvolved Worker MEI	Dose (rem)	2.1E-3	
	Cancer Fatalities	1.1E-6	
	Cancer Incidence	3.6E-6	
	Genetic Effects	2.1E-7	
	Hazard Index		
Offsite Population	Dose (person-rem)	2.0E2	
	Cancer Fatalities	1.0E-1	
	Cancer Incidence	3.4E-1	
	Genetic Effects	2.0E-2	
Offsite MEI	Dose (rem)	4.6E-3	
	Cancer Fatalities	2.3E-6	
	Cancer Incidence	7.9E-6	
	Genetic Effects	4.6E-7	
	Hazard Index		
WM Workers	Dose (FTE-rem)	3.1E3	
	Cancer Fatalities	1.2	
	Cancer Incidence	4.3	
	Genetic Effects	1.9E-1	
	Exposure Index		
	Construction Fatalities		2.1
	Construction Injuries		9.3E2
	Operation Fatalities		2.7
	Operation Injuries		2.3E3

Table D.3.2-18. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 5, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	2.8	
	Cancer Fatalities	1.4E-3	
	Cancer Incidence	4.8E-3	
	Genetic Effects	2.8E-4	
Noninvolved Worker MEI	Dose (rem)	1.7E-3	
	Cancer Fatalities	8.5E-7	
	Cancer Incidence	2.9E-6	
	Genetic Effects	1.7E-7	
	Hazard Index		
Offsite Population	Dose (person-rem)	2.4E2	
	Cancer Fatalities	1.2E-1	
	Cancer Incidence	4.0E-1	
	Genetic Effects	2.4E-2	
Offsite MEI	Dose (rem)	2.9E-3	
	Cancer Fatalities	1.4E-6	
	Cancer Incidence	4.9E-6	
	Genetic Effects	2.9E-7	
	Hazard Index		
WM Workers	Dose (FTE-rem)	3.5E3	
	Cancer Fatalities	1.4	
	Cancer Incidence	4.8	
	Genetic Effects	2.1E-1	
	Exposure Index		
	Construction Fatalities		2.1
	Construction Injuries		9.1E2
	Operation Fatalities		2.7
	Operation Injuries		2.3E3

Table D.3.2–19. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 5, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved Worker Population	Dose (person-rem)	2.2	
	Cancer Fatalities	1.1E-3	
	Cancer Incidence	3.7E-3	
	Genetic Effects	2.2E-4	
Noninvolved Worker MEI	Dose (rem)	3.4E-3	
	Cancer Fatalities	1.7E-6	
	Cancer Incidence	5.8E-6	
	Genetic Effects	3.4E-7	
	Hazard Index		
Offsite Population	Dose (person-rem)	2.0E2	
	Cancer Fatalities	9.8E-2	
	Cancer Incidence	3.3E-1	
	Genetic Effects	2.0E-2	
Offsite MEI	Dose (rem)	3.1E-3	
	Cancer Fatalities	1.5E-6	
	Cancer Incidence	5.2E-6	
	Genetic Effects	3.1E-7	
	Hazard Index		
WM Workers	Dose (FTE-rem)	5.4E3	
	Cancer Fatalities	2.2	
	Cancer Incidence	7.5	
	Genetic Effects	3.2E-1	
	Exposure Index		
	Construction Fatalities		1.9
	Construction Injuries		8.5E2
	Operation Fatalities		2.4
	Operation Injuries		2.0E3

Table D.3.2-20. Program-Wide Risks Associated with Treatment of LLW Under the No Action Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
INEL	153061 2169	1.4E-6	1.7E-10	6.1E-1	4.7E-6	5.8E-10	8.7E-1
Hanford	377645 997	4.2E-7	8.6E-12	3.2E-1	1.4E-6	2.9E-11	5.4E-1
KAPL-K	1290172 925	5.3E-4	1.2E-8	1.7E-1	1.8E-3	4.0E-8	1.8E-2
LBL	5856829 236	7.6E-4	1.2E-8	5.1E-2	2.6E-3	4.1E-8	2.9E-2
LANL	159152 920	1.9E-4	2.0E-8	3.3E-1	6.6E-4	6.9E-8	6.2E-1
NTS	14266 0	0.00	0.00	0.00	0.00	0.00	0.00
ORNL	881652 914	1.1E-2	3.5E-7	2.3E-1	3.8E-2	1.2E-6	2.0E-1
SNL-NM	610714 277	1.7E-6	6.8E-11	5.1E-2	5.8E-6	2.3E-10	1.8E-3
SRS	620618 3032	5.9E-4	5.6E-9	8.5E-1	2.0E-3	1.9E-8	1.2
KCP	1729833 13	1.0E-9	4.6E-14	2.4E-3	3.4E-9	1.6E-13	1.3E-4
LLNL	6324234 426	3.5E-7	5.8E-12	7.0E-2	1.2E-6	2.0E-11	4.1E-3
Mound	3032983 710	9.4E-8	5.5E-12	1.4E-1	3.2E-7	1.9E-11	7.2E-3
K-25	871406 708	1.3E-9	2.8E-14	1.2E-1	4.4E-9	9.6E-14	1.5E-2
Y-12	895379 1101	1.9E-8	7.2E-13	1.9E-1	6.6E-8	2.4E-12	2.3E-2
PGDP	500502 654	2.0E-8	2.3E-12	1.2E-1	6.9E-8	7.6E-12	7.8E-3
Pantex	265185 1040	1.8E-7	1.6E-11	1.8E-1	6.3E-7	5.3E-11	1.2E-2
Pinellas	2532174 26	1.8E-8	3.8E-13	4.7E-3	6.0E-8	1.3E-12	2.4E-4
Ports	639602 1450	1.7E-9	2.1E-13	2.5E-1	5.7E-9	7.2E-13	2.0E-2
RFETS	2171877 656	1.2E-7	1.7E-12	1.2E-1	4.1E-7	5.6E-12	6.5E-3
ANL-E	7939785 402	2.3E-6	1.3E-11	1.1E-1	8.0E-6	4.4E-11	1.5E-1
TOTAL		1.3E-2	3.5E-7	3.9	4.5E-2	1.2E-6	3.7

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.2-21. Program-Wide Risks Associated with Treatment of LLW Under the Decentralized Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
Hanford	377645 / 577	2.7E-6	5.5E-11	2.2E-1	9.1E-6	1.9E-10	3.5E-1
INEL	153061 / 677	8.0E-7	9.9E-11	3.2E-1	2.7E-6	3.4E-10	5.8E-1
KAPL-K	1290172 / 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 / 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LLNL	6324234 / 191	1.0E-2	1.6E-7	5.0E-2	3.4E-2	5.5E-7	8.9E-3
LANL	159152 / 653	2.1E-4	2.2E-8	2.8E-1	7.1E-4	7.5E-8	4.9E-1
ORNL	881652 / 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
SNL-NM	610714 / 187	1.8E-6	7.1E-11	6.5E-2	6.1E-6	2.4E-10	7.6E-2
SRS	620618 / 1986	1.9E-5	1.7E-10	6.6E-1	6.3E-5	5.9E-10	7.9E-1
BNL	5738554 / 0	0.00	0.00	0.00	0.00	0.00	0.00
KCP	1729833 / 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
Mound	3032983 / 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 / 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 / 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 / 501	3.2E-7	3.6E-11	1.1E-1	1.1E-6	1.2E-10	5.2E-3
Pantex	265185 / 446	8.3E-8	7.1E-12	9.8E-2	2.8E-7	2.4E-11	8.9E-3
Pinellas	2532174 / 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 / 730	2.4E-10	3.1E-14	1.5E-1	8.3E-10	1.1E-13	1.6E-2
RFETS	2171877 / 298	3.6E-7	4.9E-12	7.1E-2	1.2E-6	1.7E-11	4.0E-3
TOTAL		2.9E-2	2.9E-7	2.9	9.8E-2	9.7E-7	2.6

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.2-22. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 1, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 577	2.7E-6	5.5E-11	2.2E-1	9.1E-6	1.9E-10	3.5E-1
INEL	153061 677	8.0E-7	9.9E-11	3.2E-1	2.7E-6	3.4E-10	5.8E-1
KAPL-K	1290172 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LLNL	6324234 191	1.0E-2	1.6E-7	5.0E-2	3.4E-2	5.5E-7	8.9E-3
LANL	159152 653	2.1E-4	2.2E-8	2.8E-1	7.1E-4	7.5E-8	4.9E-1
ORNL	881652 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
Ports	639602 730	2.4E-10	3.1E-14	1.5E-1	8.3E-10	1.1E-13	1.6E-2
SNL-NM	610714 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 1986	1.9E-5	1.7E-10	6.6E-1	6.3E-5	5.9E-10	7.9E-1
ANL-E	7939785 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
Mound	3032983 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 501	3.2E-7	3.6E-11	1.1E-1	1.1E-6	1.2E-10	5.2E-3
Pantex	265185 446	8.3E-8	7.1E-12	9.8E-2	2.8E-7	2.4E-11	8.9E-3
Pinellas	2532174 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
RFETS	2171877 298	3.6E-7	4.9E-12	7.1E-2	1.2E-6	1.7E-11	4.0E-3
TOTAL		2.9E-2	2.9E-7	2.9	9.8E-2	9.7E-7	2.5

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.2-23. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 3, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 577	2.7E-6	5.5E-11	2.2E-1	9.1E-6	1.9E-10	3.5E-1
INEL	153061 677	8.0E-7	9.9E-11	3.2E-1	2.7E-6	3.4E-10	5.8E-1
KAPL-K	1290172 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 653	2.1E-4	2.2E-8	2.8E-1	7.1E-4	7.5E-8	4.9E-1
NTS	14266 0	0.00	0.00	0.00	0.00	0.00	0.00
ORNL	881652 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
SNL-NM	610714 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 1986	1.9E-5	1.7E-10	6.6E-1	6.3E-5	5.9E-10	7.9E-1
ANL-E	7939785 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 227	1.0E-2	1.6E-7	5.9E-2	3.4E-2	5.5E-7	8.9E-3
Mound	3032983 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 503	2.1E-8	2.3E-12	1.1E-1	7.1E-8	8.0E-12	5.2E-3
Pantex	265185 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 1075	1.8E-9	2.2E-13	2.3E-1	6.0E-9	7.5E-13	1.6E-2
RFETS	2171877 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
TOTAL		2.9E-2	2.9E-7	3.0	9.8E-2	9.7E-7	2.5

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.2-24. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 6, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 577	2.7E-6	5.5E-11	2.2E-1	9.1E-6	1.9E-10	3.5E-1
KAPL-K	1290172 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 902	2.1E-4	2.2E-8	3.3E-1	7.1E-4	7.5E-8	4.9E-1
ORNL	881652 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
SNL-NM	610714 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 1986	1.9E-5	1.7E-10	6.6E-1	6.3E-5	5.9E-10	7.9E-1
INEL	153061 1032	1.3E-6	1.6E-10	4.3E-1	4.4E-6	5.4E-10	7.2E-1
ANL-E	7939785 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 227	1.0E-2	1.6E-7	5.9E-2	3.4E-2	5.5E-7	8.9E-3
Mound	3032983 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 867	1.1E-7	2.5E-12	1.9E-1	3.9E-7	8.6E-12	1.3E-2
Y-12	895379 1222	8.4E-8	3.1E-12	2.7E-1	2.9E-7	1.1E-11	1.9E-2
PGDP	500502 503	2.1E-8	2.3E-12	1.1E-1	7.1E-8	8.0E-12	5.2E-3
Pantex	265185 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 1075	1.8E-9	2.2E-13	2.3E-1	6.0E-9	7.5E-13	1.6E-2
RFETS	2171877 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
TOTAL		2.9E-2	2.9E-7	3.3	9.8E-2	9.7E-7	2.7

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.2-25. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 7, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 843	4.2E-6	8.5E-11	2.9E-1	1.4E-5	2.9E-10	3.6E-1
KAPL-K	1290172 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 902	2.1E-4	2.2E-8	3.3E-1	7.1E-4	7.5E-8	4.9E-1
NTS	14266 0	0.00	0.00	0.00	0.00	0.00	0.00
ORNL	881652 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
SNL-NM	610714 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 1986	1.9E-5	1.7E-10	6.6E-1	6.3E-5	5.9E-10	7.9E-1
INEL	153061 1032	1.3E-6	1.6E-10	4.3E-1	4.4E-6	5.4E-10	7.2E-1
ANL-E	7939785 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 227	1.0E-2	1.6E-7	5.9E-2	3.4E-2	5.5E-7	8.9E-3
Mound	3032983 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 867	1.1E-7	2.5E-12	1.9E-1	3.9E-7	8.6E-12	1.3E-2
Y-12	895379 1222	8.4E-8	3.1E-12	2.7E-1	2.9E-7	1.1E-11	1.9E-2
PGDP	500502 503	2.1E-8	2.3E-12	1.1E-1	7.1E-8	8.0E-12	5.2E-3
Pantex	265185 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 1075	1.8E-9	2.2E-13	2.3E-1	6.0E-9	7.5E-13	1.6E-2
RFETS	2171877 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
TOTAL		2.9E-2	2.9E-7	3.4	9.8E-2	9.7E-7	2.7

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.2–26. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 1, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 577	2.7E-6	5.5E-11	2.2E-1	9.1E-6	1.9E-10	3.5E-1
KAPL–K	1290172 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 902	2.1E-4	2.2E-8	3.3E-1	7.1E-4	7.5E-8	4.9E-1
ORNL	881652 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
SNL–NM	610714 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 2008	1.9E-5	1.8E-10	6.7E-1	6.3E-5	5.9E-10	8.0E-1
INEL	153061 1032	1.3E-6	1.6E-10	4.3E-1	4.4E-6	5.4E-10	7.2E-1
KCP	1729833 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 227	1.0E-2	1.6E-7	5.9E-2	3.4E-2	5.5E-7	8.9E-3
Mound	3032983 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 867	1.1E-7	2.5E-12	1.9E-1	3.9E-7	8.6E-12	1.3E-2
Y-12	895379 1222	8.4E-8	3.1E-12	2.7E-1	2.9E-7	1.1E-11	1.9E-2
PGDP	500502 503	2.1E-8	2.3E-12	1.1E-1	7.1E-8	8.0E-12	5.2E-3
Pantex	265185 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 1075	1.8E-9	2.2E-13	2.3E-1	6.0E-9	7.5E-13	1.6E-2
RFETS	2171877 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
ANL-E	7939785 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
TOTAL		2.9E-2	2.9E-7	3.3	9.8E-2	9.7E-7	2.7

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.2-27. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 2, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 843	4.2E-6	8.5E-11	2.9E-1	1.4E-5	2.9E-10	3.6E-1
KAPL-K	1290172 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 902	2.1E-4	2.2E-8	3.3E-1	7.1E-4	7.5E-8	4.9E-1
NTS	14266 0	0.00	0.00	0.00	0.00	0.00	0.00
ORNL	881652 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
SNL-NM	610714 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 2008	1.9E-5	1.8E-10	6.7E-1	6.3E-5	5.9E-10	8.0E-1
INEL	153061 1032	1.3E-6	1.6E-10	4.3E-1	4.4E-6	5.4E-10	7.2E-1
ANL-E	7939785 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 227	1.0E-2	1.6E-7	5.9E-2	3.4E-2	5.5E-7	8.9E-3
Mound	3032983 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 867	1.1E-7	2.5E-12	1.9E-1	3.9E-7	8.6E-12	1.3E-2
Y-12	895379 1222	8.4E-8	3.1E-12	2.7E-1	2.9E-7	1.1E-11	1.9E-2
PGDP	500502 503	2.1E-8	2.3E-12	1.1E-1	7.1E-8	8.0E-12	5.2E-3
Pantex	265185 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 1075	1.8E-9	2.2E-13	2.3E-1	6.0E-9	7.5E-13	1.6E-2
RFETS	2171877 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
TOTAL		2.9E-2	2.9E-7	3.4	9.8E-2	9.7E-7	2.7

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.2-28. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 2, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Fernald	2764589 461	2.3E-1	4.4E-6	1.2E-1	7.9E-1	1.5E-5	2.3E-2
Hanford	377645 1569	3.6E-6	7.3E-11	5.2E-1	1.2E-5	2.5E-10	6.9E-1
INEL	153061 1809	1.4E-6	1.7E-10	5.4E-1	4.6E-6	5.7E-10	5.8E-1
KAPL-K	1290172 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LLNL	6324234 483	3.9E-1	6.3E-6	1.5E-1	1.3	2.1E-5	1.7E-1
LANL	159152 1362	7.8E-3	8.2E-7	4.9E-1	2.7E-2	2.8E-6	6.5E-1
ORNL	881652 4756	1.5E-5	4.6E-10	1.2	5.1E-5	1.6E-9	4.6E-1
Ports	639602 3434	5.3E-5	6.6E-9	7.4E-1	1.8E-4	2.2E-8	9.6E-2
SNL-NM	610714 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 2598	6.1E-4	5.7E-9	8.3E-1	2.1E-3	2.0E-8	9.6E-1
KCP	1729833 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
Mound	3032983 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
RFETS	2171877 800	1.9E-4	2.5E-9	2.2E-1	6.3E-4	8.6E-9	4.0E-3
K-25	871406 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
Pinellas	2532174 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Pantex	265185 1251	1.1E-7	9.1E-12	2.6E-1	3.7E-7	3.1E-11	9.5E-3
ANL-E	7939785 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
PGDP	500502 800	1.9E-6	2.1E-10	1.9E-1	6.4E-6	7.1E-10	5.8E-3
TOTAL		6.4E-1	6.3E-6	5.9	2.2	2.1E-5	3.8

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.2-29. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 4, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 1634	4.7E-2	9.6E-7	5.4E-1	1.6E-1	3.3E-6	7.2E-1
INEL	153061 1809	1.4E-6	1.7E-10	5.4E-1	4.6E-6	5.7E-10	5.8E-1
KAPL-K	1290172 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 2731	7.8E-3	8.2E-7	9.3E-1	2.7E-2	2.8E-6	1.2
ORNL	881652 4855	1.9E-5	5.7E-10	1.2	6.3E-5	1.9E-9	4.5E-1
Ports	639602 3483	1.9E-2	2.3E-6	7.6E-1	6.4E-2	7.9E-6	1.3E-1
SNL-NM	610714 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 2598	6.1E-4	5.7E-9	8.3E-1	2.1E-3	2.0E-8	9.6E-1
KCP	1729833. 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 227	4.4E-3	7.1E-8	5.9E-2	1.5E-2	2.4E-7	8.9E-3
Mound	3032983 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
NTS	14266 0	0.00	0.00	0.00	0.00	0.00	0.00
K-25	871406 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 497	2.1E-8	2.4E-12	1.1E-1	7.2E-8	8.0E-12	5.2E-3
Pantex	265185 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
RFETS	2171877 800	1.9E-4	2.5E-9	2.2E-1	6.3E-4	8.6E-9	4.0E-3
ANL-E	7939785 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
TOTAL		9.7E-2	2.3E-6	6.1	3.3E-1	7.9E-6	4.3

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.2-30. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternatives 3 and 4, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 1634	5.0E-2	1.0E-6	5.4E-1	1.7E-1	3.5E-6	7.2E-1
INEL	153061 1809	1.4E-6	1.7E-10	5.4E-1	4.6E-6	5.7E-10	5.8E-1
KAPL-K	1290172 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 2731	7.8E-3	8.2E-7	9.3E-1	2.7E-2	2.8E-6	1.2
NTS	14266 0	0.00	0.00	0.00	0.00	0.00	0.00
ORNL	881652 4855	1.9E-5	5.7E-10	1.2	6.3E-5	1.9E-9	4.5E-1
Ports	639602 3481	1.9E-2	2.3E-6	7.6E-1	6.4E-2	7.9E-6	1.3E-1
SNL-NM	610714 232	1.8E-6	7.2E-11	7.7E-2	6.2E-6	2.4E-10	7.6E-2
SRS	620618 2598	6.1E-4	5.7E-9	8.3E-1	2.1E-3	2.0E-8	9.6E-1
ANL-E	7939785 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 227	4.4E-3	7.1E-8	5.9E-2	1.5E-2	2.4E-7	8.9E-3
Mound	3032983 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 497	2.1E-8	2.4E-12	1.1E-1	7.2E-8	8.0E-12	5.2E-3
Pantex	265185 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
RFETS	2171877 800	1.9E-4	2.5E-9	2.2E-1	6.3E-4	8.6E-9	4.0E-3
TOTAL		1.0E-1	2.3E-6	6.1	3.4E-1	7.9E-6	4.3

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.2-31. Program-Wide Risks Associated with Treatment of LLW Under the Regionalized Alternative 5, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 1634	4.7E-2	9.6E-7	5.4E-1	1.6E-1	3.3E-6	7.2E-1
INEL	153061 3954	4.1E-4	5.1E-8	1.3	1.4E-3	1.7E-7	1.9
KAPL-K	1290172 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 902	2.1E-4	2.2E-8	3.3E-1	7.1E-4	7.5E-8	4.9E-1
ORNL	881652 7524	4.6E-2	1.4E-6	1.8	1.6E-1	4.9E-6	5.6E-1
SNL-NM	610714 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 2598	6.1E-4	5.7E-9	8.3E-1	2.1E-3	2.0E-8	9.6E-1
ANL-E	7939785 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
KCP	1729833 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
LLNL	6324234 227	4.4E-3	7.1E-8	5.9E-2	1.5E-2	2.4E-7	8.9E-3
Mound	3032983 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
NTS	14266 0	0.00	0.00	0.00	0.00	0.00	0.00
K-25	871406 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 497	2.1E-8	2.4E-12	1.1E-1	7.2E-8	8.0E-12	5.2E-3
Pantex	265185 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 1087	1.8E-9	2.2E-13	2.4E-1	5.9E-9	7.5E-13	1.6E-2
RFETS	2171877 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
TOTAL		1.2E-1	1.4E-6	6.2	4.0E-1	4.9E-6	4.8

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.2-32. Program-Wide Risks Associated with Treatment of LLW Under the Centralized Alternative 5, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 9856	7.5E-2	1.5E-6	3.7	2.5E-1	5.2E-6	5.3
KAPL-K	1290172 650	5.3E-4	1.2E-8	1.5E-1	1.8E-3	4.0E-8	2.0E-2
LBL	5856829 174	1.8E-2	2.9E-7	5.1E-2	6.2E-2	9.7E-7	2.7E-2
LANL	159152 902	2.1E-4	2.2E-8	3.3E-1	7.1E-4	7.5E-8	4.9E-1
SNL-NM	610714 210	1.8E-6	7.2E-11	5.1E-2	6.2E-6	2.4E-10	1.5E-3
SRS	620618 1986	1.2E-5	1.2E-10	6.6E-1	4.2E-5	3.9E-10	7.9E-1
INEL	153061 677	8.0E-7	9.9E-11	3.2E-1	2.7E-6	3.4E-10	5.8E-1
ORNL	881652 444	5.7E-6	1.8E-10	1.5E-1	1.9E-5	6.0E-10	9.1E-2
KCP	1729833 11	1.1E-9	4.8E-14	2.6E-3	3.6E-9	1.6E-13	1.0E-4
ANL-E	7939785 224	2.5E-6	1.4E-11	8.3E-2	8.5E-6	4.7E-11	1.1E-1
LLNL	6324234 227	4.4E-3	7.1E-8	5.9E-2	1.5E-2	2.4E-7	8.9E-3
Mound	3032983 435	1.0E-7	5.9E-12	1.1E-1	3.5E-7	2.0E-11	4.7E-3
K-25	871406 582	8.6E-9	1.9E-13	1.2E-1	2.9E-8	6.4E-13	1.2E-2
Y-12	895379 853	2.0E-8	7.5E-13	1.8E-1	6.9E-8	2.6E-12	1.8E-2
PGDP	500502 497	2.1E-8	2.4E-12	1.1E-1	7.2E-8	8.0E-12	5.2E-3
Pantex	265185 675	1.1E-7	9.2E-12	1.5E-1	3.7E-7	3.1E-11	9.0E-3
Pinellas	2532174 21	1.8E-8	3.8E-13	5.1E-3	6.0E-8	1.3E-12	2.0E-4
Ports	639602 1087	1.8E-9	2.2E-13	2.4E-1	5.9E-9	7.5E-13	1.6E-2
RFETS	2171877 344	4.0E-7	5.4E-12	8.1E-2	1.4E-6	1.8E-11	4.0E-3
TOTAL		9.8E-2	1.5E-6	6.5	3.3E-1	5.2E-6	7.5

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.2-33. Program-Wide Risks Associated with Disposal of LLW Under the No Action Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	1.2E1	
	Cancer Fatalities	5.7E-3	
	Cancer Incidence	2.0E-2	
	Genetic Effects	1.2E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	1.5E2	
	Cancer Fatalities	7.6E-2	
	Cancer Incidence	2.6E-1	
	Genetic Effects	1.5E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	7.4E3	
	Cancer Fatalities	3.0	
	Cancer Incidence	1.0E1	
	Genetic Effects	4.5E-1	
	Exposure Index		
	Construction Fatalities		1.7
	Construction Injuries		7.5E2
	Operation Fatalities		2.1
	Operation Injuries		1.8E3

Table D.3.2-34. Program-Wide Risks Associated with Disposal of LLW Under the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	1.3E2	
	Cancer Fatalities	6.4E-2	
	Cancer Incidence	2.2E-1	
	Genetic Effects	1.3E-2	
	Hazard Index		
All Lifetimes	Dose (person-rem)	2.3E3	
	Cancer Fatalities	1.2	
	Cancer Incidence	4.0	
	Genetic Effects	2.3E-1	
	Hazard Index		
WM Workers	Dose (FTE-rem)	5.6E3	
	Cancer Fatalities	2.2	
	Cancer Incidence	7.9	
	Genetic Effects	3.4E-1	
	Exposure Index		
	Construction Fatalities		3.9
	Construction Injuries		1.7E3
	Operation Fatalities		1.8
	Operation Injuries		1.5E3

Table D.3.2–35. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	3.0	
	Cancer Fatalities	1.5E-3	
	Cancer Incidence	5.1E-3	
	Genetic Effects	3.0E-4	
	Hazard Index		
All Lifetimes	Dose (person-rem)	4.4E1	
	Cancer Fatalities	2.2E-2	
	Cancer Incidence	7.4E-2	
	Genetic Effects	4.4E-3	
	Hazard Index		
WM Workers	Dose (FTE-rem)	5.4E3	
	Cancer Fatalities	2.2	
	Cancer Incidence	7.6	
	Genetic Effects	3.2E-1	
	Exposure Index		
	Construction Fatalities		3.9
	Construction Injuries		1.7E3
	Operation Fatalities		1.8
	Operation Injuries		1.5E3

Table D.3.2–36. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	2.5	
	Cancer Fatalities	1.2E-3	
	Cancer Incidence	4.3E-3	
	Genetic Effects	2.5E-4	
	Hazard Index		
All Lifetimes	Dose (person-rem)	3.4E1	
	Cancer Fatalities	1.7E-2	
	Cancer Incidence	5.8E-2	
	Genetic Effects	3.4E-3	
	Hazard Index		
WM Workers	Dose (FTE-rem)	5.9E3	
	Cancer Fatalities	2.4	
	Cancer Incidence	8.3	
	Genetic Effects	3.5E-1	
	Exposure Index		
	Construction Fatalities		3.7
	Construction Injuries		1.6E3
	Operation Fatalities		1.6
	Operation Injuries		1.3E3

Table D.3.2–37. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 6, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	3.3E1	
	Cancer Fatalities	1.6E-2	
	Cancer Incidence	5.6E-2	
	Genetic Effects	3.3E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	4.3E2	
	Cancer Fatalities	2.2E-1	
	Cancer Incidence	7.3E-1	
	Genetic Effects	4.3E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.4E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.2	
	Genetic Effects	2.6E-1	
	Exposure Index		
	Construction Fatalities		5.1
	Construction Injuries		2.2E3
	Operation Fatalities		1.3
	Operation Injuries		1.1E3

Table D.3.2-38. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 7, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	3.4E-1	
	Cancer Fatalities	1.7E-4	
	Cancer Incidence	5.9E-4	
	Genetic Effects	3.4E-5	
	Hazard Index		
All Lifetimes	Dose (person-rem)	3.7	
	Cancer Fatalities	1.8E-3	
	Cancer Incidence	6.3E-3	
	Genetic Effects	3.7E-4	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.4E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.2	
	Genetic Effects	2.6E-1	
	Exposure Index		
	Construction Fatalities		5.0
	Construction Injuries		2.2E3
	Operation Fatalities		1.3
	Operation Injuries		1.1E3

Table D.3.2–39. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	9.6	
	Cancer Fatalities	4.8E-3	
	Cancer Incidence	1.6E-2	
	Genetic Effects	9.6E-4	
	Hazard Index		
All Lifetimes	Dose (person-rem)	1.3E2	
	Cancer Fatalities	6.4E-2	
	Cancer Incidence	2.2E-1	
	Genetic Effects	1.3E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	6.9E3	
	Cancer Fatalities	2.8	
	Cancer Incidence	9.7	
	Genetic Effects	4.2E-1	
	Exposure Index		
	Construction Fatalities		4.0E-1
	Construction Injuries		1.7E2
	Operation Fatalities		9.6E-1
	Operation Injuries		8.1E2

Table D.3.2–40. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	0.0	
	Cancer Fatalities	0.0	
	Cancer Incidence	0.0	
	Genetic Effects	0.0	
	Hazard Index		
All Lifetimes	Dose (person-rem)	0.0	
	Cancer Fatalities	0.0	
	Cancer Incidence	0.0	
	Genetic Effects	0.0	
	Hazard Index		
WM Workers	Dose (FTE-rem)	6.9E3	
	Cancer Fatalities	2.8	
	Cancer Incidence	9.7	
	Genetic Effects	4.2E-1	
	Exposure Index		
	Construction Fatalities		3.7E-1
	Construction Injuries		1.6E2
	Operation Fatalities		9.6E-1
	Operation Injuries		8.1E2

Table D.3.2–41. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	1.0E1	
	Cancer Fatalities	5.2E-3	
	Cancer Incidence	1.8E-2	
	Genetic Effects	1.0E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	1.5E2	
	Cancer Fatalities	7.2E-2	
	Cancer Incidence	2.5E-1	
	Genetic Effects	1.5E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.5E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.3	
	Genetic Effects	2.7E-1	
	Exposure Index		
	Construction Fatalities		3.0
	Construction Injuries		1.3E3
	Operation Fatalities		1.2
	Operation Injuries		1.0E3

Table D.3.2–42. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	2.8E1	
	Cancer Fatalities	1.4E-2	
	Cancer Incidence	4.8E-2	
	Genetic Effects	2.8E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	3.7E2	
	Cancer Fatalities	1.9E-1	
	Cancer Incidence	6.3E-1	
	Genetic Effects	3.7E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.5E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.3	
	Genetic Effects	2.7E-1	
	Exposure Index		
	Construction Fatalities		2.8
	Construction Injuries		1.2E3
	Operation Fatalities		1.1
	Operation Injuries		9.0E2

Table D.3.2–43. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	1.8E1	
	Cancer Fatalities	9.2E-3	
	Cancer Incidence	3.1E-2	
	Genetic Effects	1.8E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	2.5E2	
	Cancer Fatalities	1.2E-1	
	Cancer Incidence	4.2E-1	
	Genetic Effects	2.5E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.4E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.2	
	Genetic Effects	2.7E-1	
	Exposure Index		
	Construction Fatalities		2.5E-1
	Construction Injuries		1.1E2
	Operation Fatalities		6.3E-1
	Operation Injuries		5.4E2

Table D.3.2–44. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	0.0	
	Cancer Fatalities	0.0	
	Cancer Incidence	0.0	
	Genetic Effects	0.0	
	Hazard Index		
All Lifetimes	Dose (person-rem)	0.0	
	Cancer Fatalities	0.0	
	Cancer Incidence	0.0	
	Genetic Effects	0.0	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.4E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.2	
	Genetic Effects	2.7E-1	
	Exposure Index		
	Construction Fatalities		2.2E-1
	Construction Injuries		9.6E1
	Operation Fatalities		6.3E-1
	Operation Injuries		5.4E2

Table D.3.2–45. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 5, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	2.8E1	
	Cancer Fatalities	1.4E-2	
	Cancer Incidence	4.8E-2	
	Genetic Effects	2.8E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	3.7E2	
	Cancer Fatalities	1.8E-1	
	Cancer Incidence	6.3E-1	
	Genetic Effects	3.7E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.5E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.3	
	Genetic Effects	2.7E-1	
	Exposure Index		
	Construction Fatalities		2.8
	Construction Injuries		1.2E3
	Operation Fatalities		1.1
	Operation Injuries		9.0E2

Table D.3.2-46. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 5, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Most-Exposed Farm Family	Dose (person-rem)	1.8E1	
	Cancer Fatalities	9.2E-3	
	Cancer Incidence	3.1E-2	
	Genetic Effects	1.8E-3	
	Hazard Index		
All Lifetimes	Dose (person-rem)	2.5E2	
	Cancer Fatalities	1.2E-1	
	Cancer Incidence	4.2E-1	
	Genetic Effects	2.5E-2	
	Hazard Index		
WM Workers	Dose (FTE-rem)	4.4E3	
	Cancer Fatalities	1.8	
	Cancer Incidence	6.2	
	Genetic Effects	2.6E-1	
	Exposure Index		
	Construction Fatalities		2.5E-1
	Construction Injuries		1.1E2
	Operation Fatalities		6.3E-1
	Operation Injuries		5.3E2

Table D.3.2–47. Program-Wide Risks Associated with Disposal of LLW Under the No Action Alternative, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
LANL (0)	0.00	0.00	1.2	0.00	0.00	2.9
NTS (0)	0.00	0.00	4.9E-1	0.00	0.00	2.8E-1
SRS (153)	1.5E-4	2.2E-3	2.8	5.0E-4	7.3E-3	2.5
ORR 225)	8.2E-8	1.2E-6	3.5E-1	2.8E-7	4.0E-6	1.3E-1
Hanford (18)	5.6E-3	8E-2	1.1	1.9E-2	2.7E-1	2.3
INEL (0)	0.00	0.00	8.5E-1	0.00	0.00	2.2
TOTAL	5.7E-3	7.6E-2	6.8	2.0E-2	2.6E-1	1.0E1

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-48. Program-Wide Risks Associated with Disposal of LLW Under the Decentralized Alternative, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
INEL (0)	0.00	0.00	6.6E-1	0.00	0.00	1.5
LLNL (142)	4.4E-6	6.8E-5	2.3E-1	1.5E-5	2.3E-4	5.6E-1
LANL (0)	0.00	0.00	8.8E-1	0.00	0.00	2.0
ORR (22)	1.0E-7	1.4E-5	4.6E-1	3.4E-6	4.6E-5	1.0E-1
SNL-NM (15)	6.3E-2	1.1	9.5E-2	2.1E-1	3.9	2.2E-1
PGDP (42)	3.7E-4	6.1E-3	1.5E-1	1.3E-3	2.1E-2	1.1E-2
Pantex (0)	0.00	0.00	1.4E-1	0.00	0.00	9.8E-3
RFETS (38)	1.1E-7	2.1E-6	1.4E-1	3.7E-7	7.0E-6	9.9E-3
SRS (153)	1.1E-4	1.7E-3	4.1	3.8E-4	5.6E-3	2.0
Ports (37)	2.4E-7	4.5E-6	4.4E-1	8.2E-7	1.5E-5	4.6E-2
ANL-E (64)	1.1E-4	5.1E-3	1.1E-1	3.9E-4	1.7E-2	1.5E-1
Hanford (18)	1.0E-3	1.4E-2	5.6E-1	3.4E-3	4.7E-2	1.3
TOTAL	6.4E-2	1.2	7.9	2.2E-1	3.9	7.9

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–49. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 1, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.0E-3	1.4E-2	5.6E-1	3.4E-3	4.7E-2	1.3
INEL (0)	0.00	0.00	6.6E-1	0.00	0.00	1.5
LLNL (142)	4.4E-6	6.8E-5	2.3E-1	1.5E-5	2.3E-4	5.6E-1
LANL (0)	0.00	0.00	8.9E-1	0.00	0.00	2.0
ORR (22)	1.0E-7	1.4E-5	4.6E-1	3.4E-6	4.6E-5	1.0E-1
Ports (145)	2.0E-6	7.7E-5	5.2E-1	6.9E-6	2.6E-4	1.1E-1
PGDP (42)	3.7E-4	6.1E-3	1.5E-1	1.3E-3	2.1E-2	1.1E-2
Pantex (0)	0.00	0.00	1.4E-1	0.00	0.00	9.8E-3
SRS (153)	1.2E-4	1.8E-3	4.1	4.1E-4	6.0E-3	2.0
RFETS (38)	1.1E-7	2.1E-6	1.4E-1	3.7E-7	7.0E-6	9.9E-3
TOTAL	1.5E-3	2.2E-2	7.8	5.1E-3	7.4E-2	7.6

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–50. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 3, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.0E-3	1.4E-2	5.6E-1	3.4E-3	4.7E-2	1.3
INEL (0)	0.00	0.00	6.6E-1	0.00	0.00	1.5
LANL (0)	0.00	0.00	1.2	0.00	0.00	2.7
NTS (0)	0.00	0.00	2.3E-1	0.00	0.00	5.7E-1
ORR (22)	1.2E-4	1.5E-3	8.8E-1	4.2E-4	5.2E-3	1.8E-1
SRS (153)	1.2E-4	1.8E-3	4.1	4.1E-4	6.0E-3	2.0
TOTAL	1.3E-3	1.7E-2	7.6	4.3E-3	5.8E-2	8.3

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–51. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 6, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.6E-2	2.2E-1	1.8	5.5E-2	7.3E-1	4.0
SRS (23)	1.7E-4	1.9E-3	6.4	5.9E-4	6.6E-3	2.1
TOTAL	1.6E-2	2.2E-1	8.2	5.6E-2	7.4E-1	6.2

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–52. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 7, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
NTS (0)	0.00	0.00	1.7	0.00	0.00	4.1
SRS (23)	1.7E-4	1.9E-3	6.4	5.9E-4	6.3E-3	2.1
TOTAL	1.7E-4	1.9E-3	8.1	5.9E-4	6.3E-3	6.2

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–53. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 1, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	4.8E-3	6.4E-2	4.1	1.6E-2	2.2E-1	9.7
TOTAL	4.8E-3	6.4E-2	4.1	1.6E-2	2.2E-1	9.7

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-54. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 2, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
NTS (0)	0.00	0.00	4.1	0.00	0.00	9.7
TOTAL	0.00	0.00	4.1	0.00	0.00	9.7

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–55. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 2, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	4.5E-3	6.2E-2	4.3E-1	1.5E-2	2.1E-1	1,1
INEL (0)	0.00	0.00	4.9E-1	0.00	0.00	1.2
LLNL (142)	4.4E-6	6.8E-5	1.9E-1	1.5E-5	2.3E-4	4.7E-1
LANL (0)	0.00	0.00	5.3E-1	0.00	0.00	1.3
ORR (22)	4.6E-6	6.3E-5	2.0E-1	1.6E-5	2.1E-4	1.7E-1
Ports (145)	3.5E-6	1.3E-4	3.2E-1	1.2E-5	4.5E-4	9.3E-2
PGDP (42)	5.0E-4	8.1E-3	1.3E-1	1.7E-3	2.8E-2	9.7E-3
Pantex (0)	0.00	0.00	6.3E-2	0.00	0.00	4.7E-3
SRS (153)	1.4E-4	2.1E-3	3.5	4.9E-4	7.2E-3	2.0
RFETS (38)	3.2E-7	6.2E-6	6.8E-2	1.1E-6	2.1E-5	5.6E-3
TOTAL	5.2E-3	7.2E-2	6.0	18E-2	2.5E-1	6.3

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-56. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 4, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
LANL (0	0.00	0.00	5.7E-1	0.00	0.00	1.4
ORR (22)	2.8E-4	3.6E-3	4.7E-1	9.6E-4	1.2E-2	1.7E-1
NTS (0)	0.00	0.00	1.6E-1	0.00	0.00	3.9E-1
SRS (153)	1.4E-4	2.1E-3	3.5	4.9E-4	7.2E-3	2.0
INEL (0)	0.00	0.00	5.2E-1	0.00	0.00	1.3
Hanford (18)	1.4E-2	1.8E-1	4.3E-1	4.6E-2	6.1E-1	1.1
TOTAL	1.4E-2	1.9E-1	5.7	4.8E-2	6.3E-1	6.3

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-57. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 3, By Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	9.2E-3	1.2E-1	2.7	3.1E-2	4.2E-1	6.2
TOTAL	9.2E-3	1.2E-1	2.7	3.1E-2	4.2E-1	6.2

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-58. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 4, By Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
NTS (0)	0.00	0.00	2.6	0.00	0.00	6.2
TOTAL	0.00	0.00	2.6	0.00	0.00	6.2

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-59. Program-Wide Risks Associated with Disposal of LLW Under the Regionalized Alternative 5, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.4E-2	1.8E-1	4.3E-1	4.6E-2	6.1E-1	1.1
LANL (0)	0.00	0.00	5.9E-1	0.00	0.00	1.4
ORR (22)	2.8E-4	3.5E-3	4.7E-1	9.6E-4	1.2E-2	1.7E-1
NTS (0)	0.00	0.00	1.6E-1	0.00	0.00	3.9E-1
SRS (153)	1.4E-4	2.1E-3	3.5	4.9E-4	7.2E-3	2.0
INEL (0)	0.00	0.00	4.9E-1	0.00	0.00	1.2
TOTAL	1.4E-2	1.9E-1	5.7	4.8E-2	6.3E-1	6.3

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-60. Program-Wide Risks Associated with Disposal of LLW Under the Centralized Alternative 5, by Installation

Installation (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	9.2E-3	1.2E-1	2.6	3.1E-2	4.2E-1	6.2
TOTAL	9.2E-3	1.2E-1	2.6	3.1E-2	4.2E-1	6.2

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

D.3.2.6 Summary of Alternatives for Potential LLW Accidents

For LLW, health risks from potential incinerator accidents were evaluated for the No Action, Regionalized 2, and Centralized 5 Alternatives (see Section D.3.2.1); no storage-related accidents were analyzed. The types of accidents evaluated were (1) a baghouse area facility fire; (2) an earthquake leading to a fire in the incinerator facility; (3) the crash of a large aircraft (at INEL, SRS, and Hanford) or a small aircraft (at RFETS and PGDP) resulting in fire and explosion; and (4) an incinerator explosion. Accidents in "alpha facilities" (incinerators that process LLW contaminated with alpha-emitting radionuclides) were evaluated for RFETS in Regionalized 2 and for Hanford in Centralized 5.

Aircraft impacts were not evaluated for FEMP, LANL, LLNL, Mound Plant, PGDP, or ORR.

For more detailed information on accident scenarios, see Appendix F.

D.3.2.7 Special Assumptions and Considerations Used in the LLW Accident Analysis

All accident releases from incinerator facilities to the outside (i.e., to the offsite and noninvolved worker populations) are assumed to be at ground level with dispersion starting at a lower level rather than from a facility stack. In the incinerator explosion accident scenario, it is assumed that the efficiency of the facility's high-efficiency particulate air filtration system drops to 99.9%. In the assessment of worker

risks from incineration accidents, it is assumed that the air in the work area is not ventilated or filtered; the intra-facility source term for this accident is, therefore, 1000 times higher than the atmospheric source term used to calculate risks to the offsite and noninvolved worker populations.

During all accidents, one shift of waste management workers is assumed to be inside the facility. Shift size varies from one to eight workers (see Table D.3.2–64).

Incineration accidents are assumed to result in releases into the operating gallery where the workers are located. Half of the operating gallery (e.g., an area 32 m long × 6 m wide × 6 m high) is assumed to fill with contaminated air. Exposure duration is 1 min, the time necessary for workers to avoid any obstructions and leave the scene.

Each accident type has an associated estimated annual frequency of occurrence as determined by Argonne National Laboratory (see Section D.2.12.1). However, the probability of occurrence is not taken into account in the risk calculations. Risks estimates associated with each accident should be interpreted as the consequences if the accident occurred. The incinerator explosion is considered to be "anticipated" (greater than 1E-2); the baghouse area facility fire is considered "unlikely" (1E-4 to 1E-2); the earthquake resulting in an incinerator facility fire is considered "very unlikely" (1E-6 to 1E-4); and the aircraft impact is regarded as "extremely unlikely" (less than 1E-6) (see Appendix F).

D.3.2.8 Results Tables for the Risk Analysis of Potential LLW Accidents

Table D.3.2–61 presents a summary of the worst-case accident risks to the offsite and noninvolved worker populations, their respective MEIs, and waste management worker populations for treatment facility accidents, by installation and alternative. Table D.3.2–62 provides the sizes of the offsite, noninvolved worker, and worker populations at each installation. Tables D.3.2–63 through D.3.2–75 present more detailed results by health endpoint and installation.

Table D.3.2–61. Risks from Potential Worst-Case LLW Treatment Facility Accidents, by Alternative and Installation

Installation	Offsite Population		Offsite MEI		Noninvolved Worker Population		Noninvolved Worker MEI[a]		Worker Population	
	CF[b]	CI[c]	CF	CI	CF	CI	CF	CI	CF	CI
No Action										
INEL	5.9E-5	2.0E-4	6.7E-9	2.3E-8	2.2E-5	7.5E-5	1.3E-8	4.5E-8	1.5E-5	5.4E-5
SRS	4.6E-2	1.6E-1	1.4E-6	4.9E-6	9.6E-3	3.3E-2	4.2E-5	1.4E-4	9.5E-3	3.3E-2
Regionalized 2										
FEMP	6.0E-5	2.1E-4	1.6E-8	5.4E-8	2.2E-6	7.6E-6	1.5E-8	5.1E-8	3.6E-7	1.3E-6
Hanford	2.4E-3	8.1E-3	5.5E-8	1.9E-7	1.2E-4	4.2E-4	1.3E-6	4.2E-6	1.0E-5	3.5E-5
INEL	5.9E-5	2.0E-4	6.7E-9	2.3E-8	2.2E-5	7.5E-5	1.3E-8	4.5E-8	1.9E-5	6.7E-5
LANL	8.7E-1	3.0	4.1E-4	1.4E-3	2.5E-1	8.6E-1	7.4E-4	2.5E-3	2.5E-1	8.7E-1
LLNL	2.9	9.8	4.0E-4	1.4E-3	2.1E-1	7.1E-1	3.6E-4	1.2E-3	7.3E-3	2.6E-2
ORR	1.1E-2	3.9E-2	9.7E-7	3.3E-6	8.2E-3	2.8E-2	9.1E-6	3.1E-5	2.5E-4	8.6E-4
PGDP	2.5E-4	8.6E-4	7.4E-8	2.5E-7	4.9E-5	1.7E-4	4.3E-7	1.5E-6	3.8E-5	1.3E-4
Ports	2.5E-5	8.6E-5	1.7E-8	5.9E-8	1.1E-5	3.8E-5	1.7E-8	5.7E-8	5.2E-6	1.8E-5
RFETS	2.8E-2	9.4E-2	9.8E-7	3.3E-6	4.8E-3	1.6E-2	1.4E-5	4.8E-5	2.1E-3	7.3E-3
SRS	4.6E-2	1.6E-1	1.4E-6	4.9E-6	9.6E-3	3.3E-2	4.2E-5	1.4E-4	1.2E-2	4.1E-2
Centralized 5										
Hanford	4.8	1.6E1	1.1E-4	3.8E-4	9.1E-1	3.1	9.2E-3	3.1E-2	6.0E-1	2.1

[a] MEI—most-exposed individual; each value represents the highest *single* risk (not the sum of all risks) to the MEI from among all accidents at an installation.
[b] CF—risk of cancer fatality associated with exposure to radionuclides.
[c] CI—risk of cancer incidence associated with exposure to radionuclides.

Table D.3.2–62. Sizes of the Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Potential LLW Treatment Accidents, by Installation

Installation	Offsite Population	Noninvolved Worker Population	WM Worker Population		
			No Action	Regionalized 2	Centralized 5
Hanford	377,645	8,674		1	8
FEMP	2,764,589	2,456		4	
INEL	153,061	8,451	4	5	
LANL	159,152	11,552		6	
LLNL	6,324,234	9,504		1	
ORR	881,652	3,809		2	
PGDP	500,502	1,952		4	
Ports	639,602	3,226		5	
RFETS	2,171,877	6,993		8	
SRS	620,618	15,996	4	5	

Table D.3.2-63. Accident Risks Associated With LLW Treatment at INEL Under the No Action Alternative, by Accident Type

Accident		Cancer Fatalities[a]			Cancer Incidence[a]		
		Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake	(VU)[c]	3.9E-5	4.5E-9	1.0E-5	1.3E-4	1.5E-8	3.6E-5
Incineration, Incinerator Explosion	(A)	2.4E-8	2.7E-12	6.1E-6	8.0E-8	9.1E-12	2.2E-5
Incineration, Baghouse Facility Fire	(U)	5.9E-7	6.7E-11	1.5E-7	2.0E-6	2.3E-10	5.4E-7
Incineration, Large Aircraft Crash	(EU)	5.9E-5	6.7E-9	1.5E-5	2.0E-4	2.3E-8	5.4E-5
WORST-CASE ACCIDENT		5.9E-5	6.7E-9	1.5E-5	2.0E-4	2.3E-8	5.4E-5

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.2-64. Accident Risks Associated With LLW Treatment at SRS Under the No Action Alternative, by Accident Type

Accident		Cancer Fatalities[a]			Cancer Incidence[a]		
		Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Large Aircraft Crash	(EU)[c]	4.6E-2	1.4E-6	9.5E-3	1.6E-1	4.9E-6	3.3E-2
Incineration, Earthquake	(VU)	3.1E-2	9.6E-7	6.3E-3	1.0E-1	3.3E-6	2.2E-2
Incineration, Incinerator Explosion	(A)	1.8E-5	5.8E-10	3.8E-3	6.2E-5	2.0E-9	1.3E-2
Incineration, Baghouse Facility Fire	(U)	4.6E-4	1.4E-8	9.5E-5	1.6E-3	4.9E-8	3.3E-4
WORST-CASE ACCIDENT		4.6E-2	1.4E-6	9.5E-3	1.6E-1	4.9E-6	3.3E-2

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.2-65. Accident Risks Associated With LLW Treatment at FEMP Under the Regionalized Alternative 2, by Accident Type

Accident		Cancer Fatalities[a]			Cancer Incidence[a]		
		Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake	(VU)[c]	6.0E-5	1.6E-8	3.6E-7	2.1E-4	5.4E-8	1.3E-6
Incineration, Incinerator Explosion	(A)	3.6E-8	9.5E-12	2.1E-7	1.2E-7	3.2E-11	7.5E-7
Incineration, Baghouse Facility Fire	(U)	9.1E-7	2.4E-10	5.4E-9	3.1E-6	8.1E-10	1.9E-8
WORST-CASE ACCIDENT		6.0E-5	1.6E-8	3.6E-7	2.1E-4	5.4E-8	1.3E-6

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.2-66. Accident Risks Associated With LLW Treatment at Hanford Under the Regionalized Alternative 2, by Accident Type

Accident		Cancer Fatalities[a]			Cancer Incidence[a]		
		Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake	(VU)[c]	1.6E-3	3.7E-8	6.7E-6	5.4E-3	1.3E-7	2.3E-5
Incineration, Incinerator Explosion	(A)	9.5E-7	2.2E-11	4.0E-6	3.2E-6	7.5E-11	1.4E-5
Incineration, Baghouse Facility Fire	(U)	2.4E-5	5.5E-10	1.0E-7	8.1E-5	1.9E-9	3.5E-7
Incineration, Large Aircraft Crash	(EU)	2.4E-3	5.5E-8	1.0E-5	8.1E-3	1.9E-7	3.5E-5
WORST-CASE ACCIDENT		2.4E-3	5.5E-8	1.0E-5	8.1E-3	1.9E-7	3.5E-5

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.2-67. Accident Risks Associated With LLW Treatment at INEL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Large Aircraft Crash (EU)[c]	5.9E-5	6.7E-9	1.9E-5	2.0E-4	2.3E-8	6.7E-5
Incineration, Earthquake (VU)	3.9E-5	4.5E-9	1.3E-5	1.3E-4	1.5E-8	4.5E-5
Incineration, Incinerator Explosion (A)	2.4E-8	2.7E-12	7.7E-6	8.0E-8	9.1E-12	2.7E-5
Incineration, Baghouse Facility Fire (U)	5.9E-7	6.7E-11	1.9E-7	2.0E-6	2.3E-10	6.7E-7
WORST-CASE ACCIDENT	5.9E-5	6.7E-9	1.9E-5	2.0E-4	2.3E-8	6.7E-5

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.2-68. Accident Risks Associated With LLW Treatment at LLNL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake (VU)[c]	2.9	4.0E-4	7.3E-3	9.8	1.4E-3	2.6E-2
Incineration, Incinerator Explosion (A)	1.7E-3	2.4E-7	4.4E-3	5.9E-3	8.1E-7	1.5E-2
Incineration, Baghouse Facility Fire (U)	4.3E-2	6.0E-6	1.1E-4	1.5E-1	2.0E-5	3.8E-4
WORST-CASE ACCIDENT	2.9	4.0E-4	7.3E-3	9.8	1.4E-3	2.6E-2

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.2-69. Accident Risks Associated With LLW Treatment at LANL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake (VU)[c]	8.7E-1	4.1E-4	2.5E-1	3.0	1.4E-3	8.7E-1
Incineration, Incinerator Explosion (A)	5.2E-4	2.5E-7	1.5E-1	1.8E-3	8.4E-7	5.2E-1
Incineration, Baghouse Facility Fire (U)	1.3E-2	6.2E-6	3.7E-3	4.4E-2	2.1E-5	1.3E-2
WORST-CASE ACCIDENT	8.7E-1	4.1E-4	2.5E-1	3.0	1.4E-3	8.7E-1

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.2-70. Accident Risks Associated With LLW Treatment at ORR Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake (VU)[c]	1.1E-2	9.7E-7	2.5E-4	3.9E-2	3.3E-6	8.6E-4
Incineration, Incinerator Explosion (A)	6.9E-6	5.8E-10	1.5E-4	2.3E-5	2.0E-9	5.2E-4
Incineration, Baghouse Facility Fire (U)	1.7E-4	1.5E-8	3.7E-6	5.8E-4	4.9E-8	1.3E-5
WORST-CASE ACCIDENT	1.1E-2	9.7E-7	2.5E-4	3.9E-2	3.3E-6	8.6E-4

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.2-71. Accident Risks Associated With LLW Treatment at PGDP Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Earthquake (VU)[c]	2.5E-4	7.4E-8	3.8E-5	8.6E-4	2.5E-7	1.3E-4
Incineration, Incinerator Explosion (A)	1.5E-7	4.4E-11	2.3E-5	5.2E-7	1.5E-10	7.9E-5
Incineration, Baghouse Facility Fire (U)	3.8E-6	1.1E-9	5.6E-7	1.3E-5	3.8E-9	2.0E-6
Incineration, Small Aircraft Crash (EU)	6.3E-5	1.8E-8	9.4E-6	2.2E-4	6.3E-8	3.3E-5
WORST-CASE ACCIDENT	2.5E-4	7.4E-8	3.8E-5	8.6E-4	2.5E-7	1.3E-4

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.2-72. Accident Risks Associated With LLW Treatment at Ports Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Baghouse Facility Fire (U)[c]	3.8E-7	2.6E-10	7.8E-8	1.3E-6	8.8E-10	2.7E-7
Incineration, Earthquake (VU)	2.5E-5	1.7E-8	5.2E-6	8.6E-5	5.9E-8	1.8E-5
Incineration, Incinerator Explosion (A)	1.5E-8	1.0E-11	3.1E-6	5.1E-8	3.5E-11	1.1E-5
WORST-CASE ACCIDENT	2.5E-5	1.7E-8	5.2E-6	8.6E-5	5.9E-8	1.8E-5

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.2–73. Accident Risks Associated With LLW Treatment at RFETS Under the Regionalized Alternative 2, by Accident Type

Accident		Cancer Fatalities[a]			Cancer Incidence[a]		
		Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Small Aircraft Crash (alpha)	(EU)[c]	6.9E-3	2.5E-7	5.2E-4	2.4E-2	8.3E-7	1.8E-3
Incineration, Baghouse Facility Fire (alpha)	(U)	4.2E-4	1.5E-8	3.1E-5	1.4E-3	5.0E-8	1.1E-4
Incineration, Earthquake (alpha)	(VU)	2.8E-2	9.8E-7	2.1E-3	9.4E-2	3.3E-6	7.3E-3
Incineration, Incinerator Explosion (alpha)	(A)	1.7E-5	5.9E-10	1.3E-3	5.7E-5	2.0E-9	4.4E-3
WORST-CASE ACCIDENT		2.8E-2	9.8E-7	2.1E-3	9.4E-2	3.3E-6	7.3E-3

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.2–74. Accident Risks Associated With LLW Treatment at SRS Under the Regionalized Alternative 2, by Accident Type

Accident		Cancer Fatalities[a]			Cancer Incidence[a]		
		Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Large Aircraft Crash	(EU)[c]	4.6E-2	1.4E-6	1.2E-2	1.6E-1	4.9E-6	4.1E-2
Incineration, Earthquake	(VU)	3.1E-2	9.6E-7	7.9E-3	1.0E-1	3.3E-6	2.8E-2
Incineration, Incinerator Explosion	(A)	1.8E-5	5.8E-10	4.7E-3	6.2E-5	2.0E-9	1.7E-2
Incineration, Baghouse Facility Fire	(U)	4.6E-4	1.4E-8	1.2E-4	1.6E-3	4.9E-8	4.1E-4
WORST-CASE ACCIDENT		4.6E-2	1.4E-6	1.2E-2	1.6E-1	4.9E-6	4.1E-2

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[a] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.2-75. Accident Risks Associated With LLW Treatment at Hanford Under the Centralized Alternative 5, by Accident Type

Accident		Cancer Fatalities[a]			Cancer Incidence[a]		
		Population[b]	MEI[b]	Workers	Population[b]	MEI[b]	Workers
Incineration, Large Aircraft Crash (non-alpha)	(EU)[c]	4.8	1.1E-4	6.0E-1	1.6E1	3.8E-4	2.1
Incineration, Large Aircraft Crash (alpha)	(EU)	2.4E-2	5.6E-7	3.1E-3	8.0E-2	1.9E-6	1.1E-2
Incineration, Earthquake (non-alpha)	(VU)	3.2	7.5E-5	4.0E-1	1.1E1	2.5E-4	1.4
Incineration, Earthquake (alpha)	(VU)	1.6E-2	3.7E-7	2.1E-3	5.4E-2	1.3E-6	7.3E-3
Incineration, Incinerator Explosion (non-alpha)	(A)	1.9E-3	4.5E-8	2.4E-1	6.5E-3	1.5E-7	8.5E-1
Incineration, Incinerator Explosion (alpha)	(A)	9.5E-6	2.2E-10	1.3E-3	3.2E-5	7.6E-10	4.4E-3
Incineration, Baghouse Facility Fire (non-alpha)	(U)	4.8E-2	1.1E-6	6.0E-3	1.6E-1	3.8E-6	2.1E-2
Incineration, Baghouse Facility Fire (alpha)	(U)	2.4E-4	5.6E-9	3.1E-5	8.0E-4	1.9E-8	1.1E-4
WORST-CASE ACCIDENT		4.8	1.1E-4	6.0E-1	1.6E1	3.8E-4	2.1

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

D.3.2.9 Summary of the LLW Accident Analysis Results

For all receptors, the dominating accidents are those involving a large airplane crash or an earthquake during incineration (non-alpha). At any installation where both of these accident types are analyzed, the risks associated with them differ by less than a factor of two for offsite and noninvolved worker populations, offsite and noninvolved worker MEIs, and workers. The risks to all receptors from alpha facility accidents are generally lower than the comparable non-alpha facility accident risks at a given installation by about 2 orders of magnitude. This is due to a much smaller inventory of alpha LLW and therefore, much smaller releases associated with alpha incinerator accidents.

D.3.2.9.1 *Risks to the Offsite Population from LLW Accidents*

The lowest installation-specific health risks associated with accidents are for the incinerator explosion at INEL in No Action and Regionalized 2 (2.4E-8 cancer fatalities) and for the same accident at FEMP (3.4E-8 cancer fatalities) and Ports (1.5E-8 cancer fatalities) in Regionalized 2. The highest accident risks are at Hanford in Centralized 5 for the large airplane crash during incineration (4.8 cancer fatalities) and for the earthquake during incineration (3.2 cancer fatalities) and at LLNL and LANL in Regionalized 2 for the earthquake during incineration (2.9 and 8.7E-1 cancer fatalities, respectively). The comparatively high risks to these populations are due to the combination of population distribution and waste inventory at each installation. The cancer fatality risk from the worst-case accident at Hanford in Centralized 5 increases about 3 orders of magnitude compared to that in Regionalized 2 due to waste consolidation.

In general, the airplane crash (small and large) and the earthquake resulting in a fire are the worst-case accidents in all alternatives and vary by less than 1 order of magnitude at all installations where both accident types are postulated. The associated annual frequencies for these accidents differ somewhat in that an airplane crash is considered "extremely unlikely" (less than 1E-6) and an earthquake is considered "very unlikely" (1E-6 to 1E-4).

The principal contributors to risk are uranium-238 at FEMP, Hanford (Centralized 5), LANL, PGDP, Ports, and SRS; thorium-232 at LLNL and ORR; cesium-137 at Hanford (Regionalized 2); cobalt-60 at INEL; and plutonium-238 at Hanford (alpha incineration only in Centralized 5) and RFETS. The primary exposure route is internal exposure in all alternatives.

D.3.2.9.2 *Risks to the Noninvolved Worker Population from LLW Accidents*

Noninvolved worker risks are slightly lower than offsite population risks, but are distributed over a much smaller affected population. The general trend in risks by accident type, dominating accident type, controlling contaminants and exposure route, and highest-risk installations are the same as for offsite population.

D.3.2.9.3 *Risks to the Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual from LLW Accidents*

Radiological risks to the offsite and noninvolved worker MEIs generally parallel the trends for their respective populations but are 2 to 5 orders of magnitude lower. For the noninvolved worker MEI, the highest worst-case cancer fatality risks are at Hanford in Centralized 5 (9.2E-3) and at LLNL and LANL in Regionalized 2 (3.6E-4 and 7.4E-4, respectively). The highest cancer fatality risks to the offsite MEI are at LLNL and LANL in Regionalized 2 (4.0E-4 and 4.1E-4, respectively) and at Hanford in Centralized 5 (1.1E-4). The cancer risks to the offsite population in Regionalized 2 are among the highest primarily because of the relatively large contaminant releases in the accidents at LANL and LLNL combined with the relatively large number of residents living very close to each of these installations (ORNL, 1995d). The cancer risks in Centralized 5 are among the highest primarily because of the large volume of waste consolidated at Hanford (higher than the cancer risks to MEIs in Regionalized 2 by almost 4 orders of magnitude).

Controlling contaminants for both MEIs at these three installations are the same as for their respective populations, uranium-238 at LANL and Hanford and thorium-232 at LLNL. The exposure route is internal exposure for both receptors at all installations.

D.3.2.9.4 *Risks to Waste Management Workers from LLW Accidents*

The cancer fatality risks to workers from worst-case accidents range from 3.6E-7 to 6.0E-1; shift size varies from one to eight workers. In all alternatives, the large aircraft crash into an incinerator and an earthquake at an incinerator are the highest-risk accidents. For any installation where both of these accident types were analyzed, the difference in risks between them is less than a factor of two. The next highest accident risks to workers are associated with the incinerator explosion scenario. (If the large aircraft crash is not postulated for an installation, then the earthquake and incinerator explosion scenarios are the highest-risk accident types; cancer risks differ by less than a factor of two for these two scenarios.) Risks from the baghouse fire scenario are generally 1 or more orders of magnitude lower than those associated with the aircraft crash, earthquake, and incinerator explosion scenarios. The accident types that result in higher risks to workers involve larger releases of radionuclides than the baghouse fire scenario. Recall that the estimated annual frequency of the aircraft crash accidents occurring is "extremely

unlikely" (less than 1E-6); the earthquake scenario is considered "very unlikely" (1E-6 to 1E-4); the baghouse fire is considered "unlikely" (1E-4 to 1E-2); and the incinerator explosion is "anticipated" (greater than 1E-2).

The highest worker cancer fatality risk is for the worst-case accident at Hanford in Centralized 5. The cancer fatality risk at Hanford in Centralized 5 is about 5 orders of magnitude higher than at Hanford in Regionalized 2 due to the consolidation of LLW for treatment at Hanford (which would result in a larger release in the event of an accident). Exposure to uranium-238 via inhalation is the risk driver at Hanford in Centralized 5. The highest-risk installations in No Action and Regionalized 2 are SRS and LANL (Regionalized 2 only). Worker cancer fatality risks at the other installations are lower by 1 to 6 orders of magnitude. Inhalation of uranium-238 is also the driving contributor to worker risk at SRS and LANL in No Action and Regionalized 2.

D.3.2.10 Risks to the Hypothetical Intruder from LLW Disposal

The health risks to the hypothetical intruder who drills a well through an LLW disposal facility were evaluated for the Decentralized, Regionalized 3, and Centralized 1 Alternatives, for intrusion 100 years and 300 years after the cessation of disposal activities at each installation.

Tables D.3.2–76 and D.3.2–77 present summaries of the risk evaluations at 100 and 300 years, respectively. Tables D.3.2–78 through D.3.2–83 contain the health risks by health endpoint and installation for each alternative in both time frames.

Table D.3.2–76. Summary Table for the Intruder Scenario for LLW (100 years)

Alternative	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Decentralized	160	8.0E-2	2.7E-1	1.6E-2
Regionalized 3	110	5.3E-2	1.8E-1	1.1E-2
Centralized 1	1.7	8.3E-3	2.8E-2	1.7E-3

Table D.3.2–77. Summary Table for the Intruder Scenario for LLW (300 years)

Alternative	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Decentralized	1.7	8.4E-4	2.8E-3	1.7E-4
Regionalized 3	1.1	5.7E-4	1.9E-3	1.1E-4
Centralized 1	1.7E-1	8.4E-5	2.9E-4	1.7E-5

Table D.3.2-78. Intruder Scenario Risk Results for the Decentralized Alternative (100 years)

Installation	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
ANL-E	6.6E-1	3.3E-4	1.1E-3	6.6E-5
Hanford	6.8	3.4E-3	1.2E-2	6.8E-4
INEL	7.0E-1	3.5E-4	1.2E-3	7.0E-5
LANL	142	7.1E-2	2.4E-1	1.4E-2
LLNL	5.8	2.9E-3	9.8E-3	5.8E-4
ORR	1.3	6.6E-4	2.2E-3	1.3E-4
PGDP	6.7E-3	3.3E-6	1.1E-5	6.7E-7
Pantex	5.2E-3	2.6E-6	8.9E-6	5.2E-7
PORTS	4.8E-1	2.4E-4	8.2E-4	4.8E-5
RFETS	2.4E-3	1.2E-6	4.1E-6	2.4E-7
SNL-NM	1.5	7.3E-4	2.5E-3	1.5E-4
SRS	2.3	1.2E-3	4.0E-3	2.3E-4
TOTAL	160	8.0E-2	2.7E-1	1.6E-2

Table D.3.2-79. Intruder Scenario Risk Results for the Decentralized Alternative (300 years)

Installation	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
ANL-E	7.6E-3	3.8E-6	1.3E-5	7.6E-7
Hanford	5.8E-2	2.9E-5	9.9E-5	5.8E-6
INEL	1.3E-1	6.6E-5	2.2E-4	1.3E-5
LANL	1.2	5.9E-4	2.0E-3	1.2E-4
LLNL	1.0E-1	5.0E-5	1.7E-4	1.0E-5
ORR	1.1E-2	5.3E-6	1.8E-5	1.1E-6
PGDP	6.6E-3	3.3E-6	1.1E-5	6.6E-7
Pantex	5.2E-3	2.6E-6	8.9E-6	5.2E-7
PORTS	1.2E-1	6.0E-5	2.0E-4	1.2E-5
RFETS	1.9E-3	9.5E-7	3.2E-6	1.9E-7
SNL-NM	2.6E-2	1.3E-5	4.4E-5	2.6E-6
SRS	2.6E-2	1.3E-5	4.5E-5	2.6E-6
TOTAL	1.7	8.4E-4	2.8E-3	1.7E-4

Table D.3.2-80. Intruder Scenario Risk Results for the Regionalized Alternative 3 (100 years)

Installation	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Hanford	6.8	3.4E-3	1.2E-2	6.8E-4
INEL	7.0E-1	3.5E-4	1.2E-3	7.0E-5
LANL	91	4.5E-2	1.5E-1	9.1E-3
NTS	5.8	2.9E-3	9.8E-3	5.8E-4
ORR	8.1E-1	4.1E-4	1.4E-3	8.1E-5
SRS	2.3	1.2E-3	4.0E-3	2.3E-4
TOTAL	110	5.3E-2	1.8E-1	1.1E-2

Table D.3.2-81. Intruder Scenario Risk Results for the Regionalized Alternative 3 (300 years)

Installation	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Hanford	5.8E-2	2.9E-5	9.9E-5	5.8E-6
INEL	1.3E-1	6.6E-5	2.2E-4	1.3E-5
LANL	7.6E-1	3.8E-4	1.3E-3	7.6E-5
NTS	1.0E-1	5.0E-5	1.7E-4	1.0E-5
ORR	6.1E-2	3.0E-5	1.0E-4	6.1E-6
SRS	2.6E-2	1.3E-5	4.5E-5	2.6E-6
TOTAL	1.1	5.7E-4	1.9E-3	1.1E-4

Table D.3.2-82. Intruder Scenario Risk Results for the Centralized Alternative 1 (100 years)

Installation	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Hanford	1.7	8.3E-3	2.8E-2	1.7E-3
TOTAL	1.7	8.3E-3	2.8E-2	1.7E-3

Table D.3.2-83. Intruder Scenario Risk Results for the Centralized Alternative 1 (300 years)

Installation	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Hanford	1.7E-1	8.4E-5	2.9E-4	1.7E-5
TOTAL	1.7E-1	8.4E-5	2.9E-4	1.7E-5

D.3.2.10.1 Results of the Human Health Risk Analysis for the Intruder

In the Decentralized Alternative, LLW is disposed of at 12 installations. One hundred years after the end of disposal operations, the highest intruder cancer fatality risk is at LANL (7.1E-2). This is due to both the large volume of waste disposed at LANL in this alternative and the presence of Sr-90 in the inventory. Strontium is a bone-seeking radionuclide, hence, its internal dose conversion factors are high. The lowest intruder cancer fatality risk is at RFETS (1.2E-6), which disposes only of its own waste in this alternative. Three hundred years after disposal operations end, the highest and lowest intruder risks are still at LANL (5.9E-4) and RFETS (9.5E-7), respectively; Sr-90 continues to be the driving contaminant at LANL.

In the Regionalized Alternative 3, LLW is consolidated and disposed of at six installations. One hundred years after the completion of disposal operations, the highest intruder cancer fatality risk is at LANL (4.5E-2). Again, this is due to the large volume of waste disposed and the presence of Sr-90 in the inventory. In Regionalized 3, LANL receives waste from SNL-NM, Pantex, and RFETS. The lowest intruder cancer fatality risk is at INEL (3.5E-4), which disposes only of its own waste. Three hundred

years after the end of disposal operations, the highest intruder cancer fatality risk remains at LANL (3.8E-4). The lowest intruder cancer fatality risk is at SRS (1.3E-5), which receives waste from Pinellas. INEL is no longer the lowest-risk installation because of the accumulation of higher-risk daughter (radioactive decay) products at this installation during the intervening 200 years.

In the Centralized Alternative 1, all LLW is consolidated and disposed of at Hanford. One hundred years after disposal operations end, the intruder's risk of cancer fatality is 8.3E-3. Three hundred years after disposal operations, the risks are 2 orders of magnitude lower.

Overall, Centralized 1 results in the lowest collective risks to the intruder among the three alternatives. This result may seem counterintuitive. However, when relatively low-activity wastes from other installations are added to the higher-activity Hanford wastes, the resulting *average* waste concentration at Hanford is lower than in Decentralized and Regionalized 3. Consequently, the risks to the intruder are lowest in Centralized 1.

D.3.3 Hazardous Waste

Hazardous waste (HW) is broadly defined in the Resource Conservation and Recovery Act (RCRA) as

> a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may: (1) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or (2) pose a substantial or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

The EPA has more specifically defined and identified HW according to considerations such as acute and chronic toxicity, persistence, and degradability in nature; potential for bioaccumulation; and other characteristics such as ignitability, corrosiveness, and reactivity. Based on these factors, the EPA promulgated regulations under 40 CFR 261, classifying HW as "listed" waste, "characteristic" waste, or "other" waste. Listed wastes are those specifically identified on one of the lists in 40 CFR 261, Subpart D. These include wastes from non-specific sources, wastes from specific sources or industries, and a rigidly defined list of commercial chemical products. Examples of listed wastes are spent solvents, spent

sludges, and discarded commercial chemicals such as cyanides, benzene, and chloroform. Characteristic wastes are defined by 40 CFR 261, Subpart C, as exhibiting ignitability, corrosiveness, reactivity, or toxicity. Other HW includes mixtures that contain HW and residues from HW treatment. HW contains no radioactive component; wastes that meet the RCRA definition of HW and are also radioactive are addressed as low-level mixed waste (see Section D.3.5).

HW is generated by a variety of DOE activities including those associated with defense, nuclear energy, and energy research programs. The following 11 installations generate the majority of the DOE inventory of HW and are considered in this human health risk evaluation (note that the abbreviations given here are used throughout this appendix):

- Argonne National Laboratory–East (ANL–E), Argonne, Illinois
- Hanford Site, (Hanford), Richland, Washington
- Fermi National Accelerator Laboratory (Fermi), Batavia, Illinois
- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Kansas City Plant (KCP), Kansas City, Missouri
- Los Alamos National Laboratory (LANL), Los Alamos, New Mexico
- Lawrence Livermore National Laboratory (LLNL), Livermore, California
- Oak Ridge Reservation (ORR), Oak Ridge, Tennessee
- Pantex Plant (Pantex), Amarillo, Texas
- Sandia National Laboratories–New Mexico (SNL–NM), Albuquerque, New Mexico
- Savannah River Site (SRS), Aiken, South Carolina

The quantities and types of HW generated vary throughout the DOE complex. Laboratory facilities generate wastes (e.g., laboratory solutions, acids, and caustics) as a result of research and development activities, processing operations, and other activities associated with their mission. Production facilities generate HW as a result of manufacturing weapons and weapons materials, nuclear fuel, and other production operations. Many installations also generate reportable quantities of industrial solvents, paints, oils, rags, and wipes contaminated with hazardous cleaning compounds, and other hazardous materials that are byproducts of routine maintenance, degreasing, and machine-shop operations (ANL, 1995d). The current HW management strategy is based on minimizing (or eliminating) HW generation, and on proper characterization, treatment, and disposal.

Environmental restoration activities also contribute substantially to HW generation. While an installation may produce very little HW in the course of routine operations, remediation of environmental problems such as leaking petroleum underground storage tanks may generate thousands of pounds of HW-contaminated soil.

For more detailed information on HW, including HW inventories at DOE installations, estimated release rates, treatment categories used in the PEIS, and the process for developing PEIS HW alternatives, see Chapters 3 and 10 of the PEIS and the HW technical report (ANL, 1995d).

D.3.3.1 Summary of HW Alternatives

The PEIS waste management alternatives (No Action, Regionalized 1 and 2) and the rationale for developing the various HW analysis alternatives are discussed rigorously in the main body of the PEIS.

- The No Action Alternative demonstrates the baseline risks of treating some of the DOE inventory of HW by incineration only (no waste fuel burning) at existing facilities at INEL and the ORR, while the remainder is treated and disposed of by permitted commercial facilities.
- In the Regionalized Alternative 1, approximately 50% of the complex-wide, commercially treated HW is instead treated by incineration and waste fuel burning at Hanford, INEL, LANL, ORR, and SRS. The remaining HW is treated and disposed of by permitted commercial facilities.
- In the Regionalized Alternative 2, approximately 80% to 90% of the complex-wide, commercially treated HW is instead treated by incineration and waste fuel burning at INEL and ORR. The remainder is treated and disposed of by a limited number of permitted commercial facilities.

Table D.3.3–1 presents the consolidation and treatment schemes for these three alternatives.

Table D.3.3-1. PEIS Alternatives for HW

Alternative	ANL-E	Hanford	Fermi	INEL	KCP	LANL	LLNL	ORR	Pantex	SNL-NM	SRS
No Action—Treatment of own HW (by incineration) at current 2 installations; remainder treated commercially				T[a]				T			
Regionalized 1—50% of DOE HW treated (by incineration and fuel burning) at 5 installations; remainder treated commercially		T		T		T		T			T
Regionalized 2—80-90% of DOE HW treated (by incineration and fuel burning) at 2 installations; remainder treated commercially				T				T			

[a] T—Treatment installation

D.3.3.2 Special Assumptions and Considerations Used in the HW Risk Analysis

The source term for chlorinated organics and inorganics emitted in incinerator flue gases was developed from a set of RCRA trial burn data from the Rollins Deer Park, Texas, waste incinerator (one of the commercial facilities that currently processes DOE-generated HW); the constituents in the flue gases are shown in Table D.3.3-2. Although the chemistry of the industrial wastes used in the trial burn was unknown, they were waste types generally typical of DOE HW and were assumed to be reasonably similar to DOE HW in organic composition (ANL, 1995d). The results of those burns were scaled up based on each installation's HW waste volume.

Table D.3.3-2 HW Source Term Constituents Derived from Analysis of Deer Park, Texas, Incinerator Flue Gases

Constituents in HW Source Term	
Bromodichloromethane	Chlorine
Chlorobenzene	Vinyl chloride
Chloromethane	Cadmium
Chloroform	Chromium (VI)
Dibromochloromethane	Copper
1,2-Dichloroethane	Lead
Methylene chloride	Mercury
1,1,2,2-Tetrachloroethane	Nickel
1,1,1-Trichloroethane	Zinc
1,1,2-Trichloroethane	Arsenic
Trichlorofluoromethane	Dioxins (PCDD)
Hydrogen chloride	Furans (PCDF)

It was assumed that the composition of HW and the relative proportions of its components are the same at all installations. Because of this, the controlling contaminants and their percentage contribution to risk are the same across all installations and alternatives.

Consistent with the other waste streams, the duration of the No Action Alternative is assumed to be 20 years. For the Regionalized 1 and 2 Alternatives, construction of treatment facilities is assumed to take place for 10 years and HW treatment for 10 years.

The RfDs and cancer potency factors for the various HW constituents, where available, were obtained from the EPA's Health Effects Assessment Summary Tables and Integrated Risk Information System. If the EPA values were not available, toxicity values derived by PNL were used (Droppo et al., 1989).

It was assumed that an FTE (see Section D.2) would not be exposed to concentrations of hazardous chemicals that exceed the time-weighted average threshold limit value (TWA-TLV) for full-time workers exposed 8 hours/day, 40 hours/week (ACGIH, 1992).

The chemicals used as surrogates in evaluating the health effects to the public from polychlorinated dibenzodioxins and polychlorinated dibenzofurans were hexachlorodibenzo-p-dioxin and hexachlorodibenzofuran, respectively. Due to the lack of better information, it was also assumed that the chromium in the source term was present as 100% chromium (VI), an inhalation carcinogen,. This is a conservative assumption; therefore, health risks associated with chromium in the HW source term may be overestimated.

No TLVs or immediately-dangerous-to-life-and-health (IDLH) values were found for bromodichloromethane, dibromochloromethane, hexachlorodibenzofuran, or hexachlorodibenzo-p-dioxin; therefore, the health effects to workers associated with these chemicals were not evaluated. However, the first two compounds comprise only 0.01% each of the source term, the third is 2.6E-5% of the source term, and the fourth is 3E-6% of the source term. The offsite and noninvolved worker populations were evaluated for all chemicals in the source term.

Note that the human health risks for commercial treatment are not addressed in this analysis. Therefore, the greater the percentage of waste treated commercially, the lower the human health risk estimates for the DOE complex and the less information this analysis can supply about the overall risks to human health from combined public and private HW waste management activities.

D.3.3.3 Results Tables for the HW Human Health Risk Analysis

This section contains the results tables for the HW human health risk analysis. A discussion of the results is presented in Section D.3.4.4. The risks in the tables are displayed in the standard scientific (exponential) notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.3-3 presents an overview, by alternative, of the *total*, program-wide risks of cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer incidence and construction and operational fatalities for waste management workers. These tables provide the estimated *total number* of people in the three receptor populations who will develop cancers from exposure to HW over a lifetime if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities.
- Table D.3.3-4 shows the sizes of the total affected populations for each alternative.

- Table D.3.3-5 summarizes the risks to the offsite and noninvolved worker MEIs for each HW alternative. The numbers in this table are the estimated *probabilities* that the offsite and noninvolved worker MEIs will develop cancer from chemical exposure or are indicators that the MEIs will suffer adverse health effects from exposure to noncarcinogenic, hazardous constituents.
- Tables D.3.3-6 through D.3.3-8 show the program-wide risks for all receptors and health effect endpoints, by alternative.
- Tables D.3.3-9 through D.3.3-11 present offsite and worker population risks for each installation, by alternative.
- Table D.3.3-12 lists the hazardous constituents that contribute most of the risk of cancer incidence to the offsite population, by installation and alternative.

Table D.3.3-3 Summary of Program-Wide Risks Associated with Routine Management of HW: Risks to Total Populations, By Alternative

Alternative	Offsite Population	WM Workers		Noninvolved Worker Population
	Chem CI[a]	Chem CI	C&OF[b]	Chem CI
No Action	7.5E-3	9.4E-2	8.2E-3	2.5E-3
Regionalized 1	6.0E-2	1.2	6.9E-2	2.5E-2
Regionalized 2	9.6E-2	1.8	7.3E-2	3.3E-2

[a] Chem CI—cancer incidence associated with exposure to hazardous chemicals.
[b] C&OF—Fatalities due to physical hazards during construction and operation of waste treatment facilities.

Table D.3.3-4 Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by the Risks from Routine Management of HW, By Alternative

Alternative	Offsite Population	WM Workers	Noninvolved Worker Population
No Action	1,034,713	52	12,260
Regionalized 1	2,192,128	355	48,482
Regionalized 2	1,034,713	372	12,260

Table D.3.3-5 Summary of Program-Wide Risks Associated with Managing HW to the Offsite and Noninvolved Worker Most-Exposed Individuals, By Alternative

Alternative	Offsite MEI[a]		Noninvolved Worker MEI	
	Chem CI[b]	HI[c]	Chem CI	HI
No Action	3.9E-7	2.6E-3	2.4E-6	1.6E-2
Regionalized 1	2.4E-6	3.2E-2	1.1E-5	5.1E-1
Regionalized 2	5.0E-6	6.6E-2	3.1E-5	4.1E-1

[a] MEI—Most-exposed individual
[b] Chem CI—cancer incidence associated with exposure to hazardous chemicals
[c] HI—Hazard index

Table D.3.3-6 Program-Wide Risks Associated with the Routine Management of HW Under the No Action Alternative, By Health Endpoint

Receptor	Endpoint	Hazardous Chemicals		Physical Hazards
		Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem) Cancer Fatalities Cancer Incidence Genetic Effects	2.5E-3		
Noninvolved Worker MEI	Dose (rem) Cancer Fatalities Cancer Incidence Genetic Effects Hazard Index	2.4E-6	 1.6E-2	
Offsite Population	Dose (person-rem) Cancer Fatalities Cancer Incidence Genetic Effects	7.5E-3		
Offsite MEI	Dose (rem) Cancer Fatalities Cancer Incidence Genetic Effects Hazard Index	3.9E-7	 2.6E-3	
WM Workers	Dose (FTE-rem) Cancer Fatalities Cancer Incidence Genetic Effects Exposure Index Construction Fatalities Construction Injuries Operation Fatalities Operation Injuries	9.4E-2	 4.3	 1.9E-3 8.4E-1 6.3E-3 5.3

Table D.3.3–7. Program-Wide Risks Associated with the Routine Management of HW Under the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Hazardous Chemicals		Physical Hazards
		Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem) Cancer Fatalities Cancer Incidence Genetic Effects	2.5E-2		
Noninvolved Worker MEI	Dose (rem) Cancer Fatalities Cancer Incidence Genetic Effects Hazard Index	1.1E-5	 1.5E-1	
Offsite Population	Dose (person-rem) Cancer Fatalities Cancer Incidence Genetic Effects	6.0E-2		
Offsite MEI	Dose (rem) Cancer Fatalities Cancer Incidence Genetic Effects Hazard Index	2.4E-6	 3.2E-2	
WM Workers	Dose (FTE-rem) Cancer Fatalities Cancer Incidence Genetic Effects Exposure Index Construction Fatalities Construction Injuries Operation Fatalities Operation Injuries	1.2	 6.1	 2.6E-2 1.2E1 4.3E-2 3.7E1

Table D.3.3–8. Program-Wide Risks Associated with the Routine Management of HW Under the Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Hazardous Chemicals		Physical Hazards
		Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem) Cancer Fatalities Cancer Incidence Genetic Effects	3.3E-2		
Noninvolved Worker MEI	Dose (rem) Cancer Fatalities Cancer Incidence Genetic Effects Hazard Index	3.1E-5	4.1E-1	
Offsite Population	Dose (person-rem) Cancer Fatalities Cancer Incidence Genetic Effects	9.6E-2		
Offsite MEI	Dose (rem) Cancer Fatalities Cancer Incidence Genetic Effects Hazard Index	5.0E-6	6.6E-2	
WM Workers	Dose (FTE-rem) Cancer Fatalities Cancer Incidence Genetic Effects Exposure Index Construction Fatalities Construction Injuries Operation Fatalities Operation Injuries	1.8	6.2	2.8E-2 1.2E1 4.5E-2 3.8E1

Table D.3.3-9. Risks Associated with the Routine Management of HW Under the No Action Alternative, By Installation

Installation	Population[a]	Fatalities[b]	Cancer Incidence				
		Workers	Offsite Population	Offsite MEI[c]	Noninvolved Worker Population	Noninvolved Worker MEI[c]	Workers
INEL	153061 / 16	2.6E-3	3.4E-5	4.6E-9	4.4E-5	3.7E-8	1.8E-2
ORR	881652 / 36	5.6E-3	7.4E-3	3.9E-7	2.5E-3	2.4E-6	7.6E-2
TOTAL		8.2E-3	7.5E-3	3.9E-7	2.5E-3	2.4E-6	9.4E-2

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for waste management workers involved in both construction and operation activities.
[b] Risk of cancer fatality from exposure to hazardous chemicals cannot be assessed; worker fatality risks reflect risks from physical hazards only.
[c] MEI—Most-exposed individual.

Table D.3.3-10. Risks Associated with the Routine Management of HW Under the Regionalized Alternative 1, By Installation

Installation	Population[a]	Fatalities[b]	Cancer Incidence				
		Workers	Offsite Population	Offsite MEI[c]	Noninvolved Worker Population	Noninvolved Worker MEI[c]	Workers
Hanford	377645 / 91	1.8E-2	4.3E-3	1.4E-7	2.6E-3	5.0E-6	2.9E-1
INEL	153061 / 35	6.8E-3	1.0E-4	1.4E-8	1.4E-4	1.1E-7	7.6E-2
LANL	159152 / 88	1.7E-2	1.9E-2	2.4E-6	9.5E-3	5.9E-6	3.0E-1
ORR	881652 / 101	2.0E-2	3.6E-2	1.8E-6	1.1E-2	1.1E-5	4.2E-1
SRS	620618 / 40	7.9E-3	1.2E-3	1.5E-8	5.9E-4	6.7E-7	9.3E-2
TOTAL		6.9E-2	6.0E-2	2.4E-6	2.5E-2	1.1E-5	1.2

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for waste management workers involved in both construction and operation activities.
[b] Risk of cancer fatality from exposure to hazardous chemicals cannot be assessed; worker fatality risks reflect risks from physical hazards only.
[c] MEI—Most-exposed individual.

Table D.3.3-11. Risks Associated with the Routine Management of HW Under the Regionalized Alternative 2, By Installation

Installation	Population[a]	Fatalities[b]	Cancer Incidence				
		Workers	Offsite Population	Offsite MEI[c]	Noninvolved Worker Population	Noninvolved Worker MEI[c]	Workers
INEL	153061 160	3.1E-2	9.7E-4	1.3E-7	1.3E-3	1.1E-6	7.4E-1
ORR	881652 212	4.1E-2	9.5E-2	5.0E-6	3.2E-2	3.1E-5	1.1
TOTAL		7.3E-2	9.6E-2	5.0E-6	3.3E-2	3.1E-5	1.8

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for waste management workers involved in both construction and operation activities.
[b] Risk of cancer fatality from exposure to hazardous chemicals cannot be assessed; worker fatality risks reflect risks from physical hazards only.
[c] MEI—Most-exposed individual.

Table D.3.3-12. Constituents in HW Contributing the Highest Risk of Cancer Incidence to the Offsite Population at Each Installation, By Alternative

Alternative	Installation				
	Hanford	INEL	LANL	ORR	SRS
No Action	—	chromium (VI)[a] 2.7E-5[b]	—	chromium (VI) 5.9E-3	—
Regionalized 1	chromium (VI) 3.5E-3	chromium (VI) 8.3E-5	chromium (VI) 1.5E-2	chromium (VI) 2.9E-2	chromium (VI) 9.4E-4
Regionalized 2	—	chromium (VI) 7.8E-4	—	chromium (VI) 7.7E-2	—

[a] Chromium in the source term was assumed to be 100% chromium (VI).
[b] Risk of cancer incidence contributed by this constituent.

D.3.3.4 Results of the HW Human Health Risk Analysis for Routine Operations

The following sections present a summary of the estimated program-wide impacts to each receptor population and a discussion of the overall results of the HW human health risk analysis.

D.3.3.4.1 *Program-Wide Trends in Human Health Risks Associated with HW Management Alternatives*

Offsite Population. For the offsite population, the program-wide risk of cancer incidence associated with routine treatment of HW is lowest for No Action (7.5E-3 cancer incidences distributed over a total affected population of approximately 1 million), and slightly higher for Regionalized 1 and 2 (6.0E-2 over a total population of approximately 2 million and 9.6E-2 over approximately 1 million, respectively).

As would be expected based on the waste consolidation and treatment scenarios, cancer incidence risks at INEL and ORR are slightly higher in Regionalized 2 than Regionalized 1 (recall that in Regionalized 2, 80% to 90% of the DOE inventory of commercially treatable HW is consolidated and treated at these two installations).

Noninvolved Worker Population. The program-wide risk of cancer incidence to the noninvolved worker population follows the same pattern as for the offsite population: Regionalized 1 and 2 risks are similar to one another (both are in the E-2 order of magnitude) and approximately 1 order of magnitude higher than in No Action. However, the total affected noninvolved worker populations (approximately 12,260 in No Action and Regionalized 2 and 48,482 in Regionalized 1) are substantially smaller than the total offsite populations. Therefore, the relative risks "per capita" (the risks to an average member of the noninvolved worker population compared to an average member of the offsite population) are concomitantly higher. This higher individual risk to members of the noninvolved worker population is also reflected in the results for the offsite and noninvolved worker MEIs.

Most-Exposed Noninvolved Worker and Offsite Individual. For the offsite and noninvolved worker MEIs, risk of cancer incidence follows the same pattern as for their respective populations. However, the risks of cancer incidence for both of these receptors in Regionalized 1 and 2 are in the E-5 to E-6 range. Following EPA guidance developed for evaluating cancer incidence (see Section D.2.14), the risks to the MEIs in Regionalized 1 and 2 are within target exposure levels. Most of the risk in these alternatives is attributable to the presence of the inhalation carcinogen chromium (VI) in the source term (ANL, 1995d).

The hazard indices for both MEIs (indicating the worst-case individual exposure to noncarcinogenic chemicals per scenario) follow the trend for cancer incidence but are less than 1.0 in all alternatives. This

indicates a low probability that these receptors will suffer adverse effects from exposure to noncarcinogenic, toxic contaminants.

Workers. Program-wide health risks to workers follow the same general trends as for the offsite and noninvolved worker populations. The total risks of cancer incidence in Regionalized 1 and 2 are slightly more than 1 order of magnitude higher than in No Action, and range from 1.8E-2 to 1.1. While the air concentrations of each HW constituent component are estimated to be at or below TLVs, the sum of the exposures from those concentrations yields exposure indices that are consistently above 1.0 (ranging from 4.1 to 8.2) in all alternatives. This indicates that the worker receiving the worst-case exposure is potentially at risk of adverse health effects from the daily inhalation of fugitive chemical emissions in all three alternatives. These results indicate that the risk of cancer incidence to the total worker population increases as a greater percentage of the DOE HW inventory is treated and as treatment is performed at fewer consolidation installations, while the worst-case individual exposure to hazardous, noncarcinogenic chemicals differs little from alternative to alternative.

As can be seen in Tables D.3.3-9 through D.3.3-11, the highest risks of cancer incidence to workers result at INEL and ORR under Regionalized 2, in which these two installations treat 80% to 90% of the DOE inventory of commercially treatable HW. The difference in risks at these installations between Regionalized 1 and 2 is about 0.5 to 1 order of magnitude.

Construction and operational injuries and fatalities follow the same pattern as exposure risks to workers and other populations (see Tables D.3.3-6 through D.3.3-8). No Action involves the least construction, the smallest volume of waste in treatment, and the fewest workers. Accordingly, the No Action risks from physical hazards are the lowest among the three alternatives. The risks from physical hazards in Regionalized 1 and 2 are almost identical to one another and reflect increased person-hours spent building and operating waste processing facilities compared to No Action.

D.3.3.4.2 *Summary of Results for Routine Treatment of HW*

For the offsite population, ORR poses the highest risk of cancer incidence in No Action and Regionalized 2; ORR and LANL pose the highest risks in Regionalized 1 (see Tables D.3.3-9 through D.3.3-11). INEL presents the lowest cancer incidence risks in all alternatives. Inhaled chromium (VI) contributes

the most risk of cancer incidence to the offsite population at all installations across all alternatives (see Table D.3.3–12). Cancer incidence risks to the offsite MEI are in the E-6 order of magnitude at LANL in Regionalized 1 and ORR in Regionalized 1 and 2.

Risks to the various noninvolved worker populations tend to parallel the risks to the installation-specific offsite populations. ORR presents the highest risk of cancer incidence in No Action and Regionalized 2; and ORR, LANL, and Hanford pose the highest risks in Regionalized 1. Inhalation of chromium (VI) contributes most of the cancer incidence risk at all installations in all alternatives (ORNL, 1995e).

The cancer incidence risk to the noninvolved worker MEI is between 1E-6 and 1E-4 at ORR in No Action; ORR, LANL, and Hanford in Regionalized 1; and ORR and INEL in Regionalized 2. Hazard indices for both MEIs are below 1.0 in all alternatives, indicating a low probability of adverse effects from exposure to noncarcinogenic, toxic contaminants.

The highest installation cancer incidence risks are always at ORR for workers, although differences between installations in cancer incidence for workers are consistently less than 1 order of magnitude. The controlling contaminants at ORR for worker cancer incidence are chromium (VI) in No Action and vinyl chloride and chromium (VI) in Regionalized 1 and 2. In No Action, the exposure index at ORR is slightly higher than at INEL; the controlling contaminants at ORR are chlorine and cadmium. In Regionalized 1 and 2, exposure indices at all installations are approximately equal; controlling contaminants are hydrogen chloride, chlorine, cadmium, copper, lead, and nickel.

D.3.3.4.3 *Discussion*.

As noted in the summary of HW alternatives (Section D.3.3.1), No Action involves only the incineration of the INEL and ORR inventories of HW, while Regionalized 1 and 2 involve treatment of consolidated HW waste loads (50% and 80 to 90%, respectively) by incineration and waste fuel burning. Accordingly, risks to the various receptors would be expected to increase as the amount of waste treated at DOE installations and the degree of consolidation increase. While the differences among alternatives are relatively small, this trend is apparent. Health risks associated with Regionalized 1 and 2 are slightly higher than those associated with No Action by about 1 order of magnitude. The risks for Regionalized 1 and 2 are approximately the same for all populations and health effects endpoints. In other words,

treating 50% of the DOE inventory of HW at five installations and treating 80% to 90% at two installations result in nearly the same overall health risks to all populations. Within each alternative, the highest-risk installations for exposure are also the highest-risk installations for construction and operational risks. This indicates that the volume of waste being treated and, consequently, the number of hours workers spend constructing facilities and processing the waste, are the determining factors for health risks.

Comparison of the risks to the overall populations and MEIs in Regionalized 1 and 2 (see Tables D.3.3–10 and D.3.3–11) shows that risks generally differ by less than a factor of 2 between the two alternatives (which is reasonable since the difference in the amount of waste processed does not quite double between the alternatives). However, the risks in Regionalized 1 are distributed over twice as many members of the offsite population and four times as many members of the noninvolved worker population as in Regionalized 2.

D.3.3.5 Summary of Alternatives for Potential HW Accidents

Three categories of potential HW accidents were analyzed for Regionalized 1 and 2: single-drum, single-contaminant accidents occurring during storage; multiple-contaminant storage facility accidents; and multiple-contaminant treatment facility accidents.

D.3.3.5.1 *Single-Drum Accidents*

Thirty-one storage accidents involving the release of a single chemical (either a carcinogen or a hazardous noncarcinogen) from a single drum were postulated for each installation and each alternative. Thsee single-drum accident scenarios are summarized in Table D.3.3–13.

There were three general types of single-drum accidents: a spill; a spill plus fire; and other combinations of events (spill plus explosion, fire only, fire plus explosion, etc.). Because of the large number of accidents to be analyzed, only the results of the four worst-case accidents (i.e., those for which the attendant risks are highest) at each installation for each alternative are reported in Table D.3.3–15. These results are:

- The estimated cancer incidence in the installation's offsite population for an accident involving a carcinogen.
- The hazard index for the offsite MEI for an accident involving a hazardous noncarcinogen.
- The estimated cancer incidence for the shift of six FTEs (hypothetical workers) working during an accident involving a carcinogen.
- The IDLH index (see Section D.2.11) for the most-exposed FTE working during an accident involving a hazardous noncarcinogen.

The consequences of a single-drum accident release (if the accident occurred) do not differ among alternatives. However, the estimated annual frequency of the accident may differ among alternatives (i.e., an accident may become more likely as more drums are stored at an installation).

The risks to noninvolved workers from single-drum accidents are not reported in this appendix; those results can be found in ORNL (1995e).

Note that the single-drum accident that poses the highest risks to the offsite population may not be the same as the worst-case accident for workers (because exposure scenarios and pathways often differ between workers and the other receptors).

Table D.3.3–13. Summary of Single-Drum Accident Scenarios for HW

Scenario	Accident Category	Toxic Gases Released
Spill	1A	Ammonia
	1B	Hydrogen chloride
	1C	Hydrogen fluoride
	1D	Sulfur oxides
Spill and fire	2A	Polyaromatic hydrocarbon soot, unburnt hydrocarbons and carbon monoxide
	2B	Hydrogen fluoride
	2C	Cyanide
	2D	Mercury vapor
Spill, fire, and gas cylinder explosion	3A	Ammonia
Fire and gas cylinder breach	3B	Ammonia
Fire and gas cylinder breach	3C	Ammonia
Spill and explosion	3D	Ammonia
Fire and explosion	3E	Ammonia
Spill	4A	Ammonia
	4B	Hydrogen chloride
	4C	Hydrogen fluoride
	4D	Sulfur oxides
	4E	Acetic acid
	4F	Carbon disulfide
	4G	1,1,1-Trichloroethane
Fire	5A	Polyaromatic hydrocarbon soot and unburnt hydrocarbons
	5B	Hydrogen fluoride
	5C	Cyanide
	5D	Mercury vapor
	5E	Cadmium fumes
	5F	Dust from burnt and unburnt potassium and sodium dichromate salts
Spill, fire, and gas cylinder explosion	6A	Ammonia
Fire and gas cylinder breach	6B	Ammonia
Fire and gas cylinder breach	6C	Ammonia
Spill and explosion	6D	Ammonia
Fire and gas cylinder explosion	6E	Ammonia

D.3.3.5.2 *Storage Facility Accidents*

Potential storage facility HW accidents include (1) a facility fire that engulfs a significant fraction of the containers in storage, releasing some or all of these contaminants: 2A, 2B, 2C, 2D, 5E, and 5F (see Table D.3.3-13); (2) an earthquake that ruptures a significant number of drums, releasing some or all of these contaminants: 1A, 1B, 1C, 1D, 4E, 4F, and 4G in Table D.3.3-13; and (3) the crash of a large aircraft (at Hanford, INEL, and SRS) or small aircraft (at LANL and ORR) resulting in a fire that burns a significant portion of the storage drums releasing some or all of these contaminants: 2A, 2B, 2C, 2D, 3A, 3D, 5E, and 5F in Table D.3.3-13. Earthquake-related storage accidents were postulated for Hanford and LANL only in Regionalized 1 and for INEL and ORR in Regionalized 2.

D.3.3.5.3 *Treatment Facility Accidents*

The treatment facility accidents analyzed for HW include (1) an incinerator explosion and resulting feedstock fire; (2) an earthquake followed by an incinerator facility fire; and (3) a large or small aircraft impact (assuming the same scenarios as for the storage facility accidents) and resulting incinerator facility fire. All three types of incinerator accidents involve a fire and a release of some or all of these contaminants: 2A, 2B, 2C, 2D, 5E, and 5F.

D.3.3.6 Special Assumptions and Considerations Used in the HW Accident Analysis

The source terms for the HW accidents include the period of time over which a particular accident release occurs. For assessing risks to offsite and noninvolved worker receptors from single-drum and facility-wide accidents, all releases have been averaged for a 1-h release (i.e., for contaminant releases greater than 60 min in duration, the amount released was scaled to reflect a 60-min release; for contaminant releases of less than 60 min in duration, the total amount of contaminant is assumed to be released in 60 min).

In estimating the risks to the offsite and noninvolved worker populations, releases from storage facility accidents are assumed to be ground releases without flow (i.e., releases at ground level); releases from

incinerator facility accidents are assumed to be stack releases with flow (i.e., release from the stack of an operating facility).

All storage accidents are assumed to involve six workers, the average number of workers needed to place waste in storage facilities (EG&G, 1992). For treatment (incineration) accidents, one shift of workers is assumed to be present in the facility when the accident occurs; shift size varies with the waste processing rate. For HW, from one to five workers are present during treatment accidents (see Table D.3.3-20) (EG&G, 1992).

All releases from storage accidents are assumed to take place outside at an outdoor storage facility. A 5-min worker exposure duration is assumed for outdoor exposures to accidents that are readily visually detectable (fires, explosions, spills plus fire, etc.). For spills alone (which may not be noticed as quickly), a 10-min exposure period is assumed. Outdoor worker exposure concentrations were calculated using the INEXPLC model for close-in atmospheric dispersion, explosive releases, and particle deposition (ORNL, 1993), using the following assumptions:

- The worker is standing directly downwind of the release.
- The release height is 0 m (i.e., at ground level).
- The receptor height is 1.5 m (i.e., the height of the person's nose).
- The radius of the source is 1.5 m.
- Receptor distances were varied from 1 m to 25 m at 1-m intervals and concentrations calculated at each interval; an average of these concentrations was used as the exposure concentration.
- Simple gas dispersion with no particle settling takes place.

Incineration accidents are accompanied by releases into an indoor operating gallery where the workers are located. Half the gallery (e.g., an area 32 m long × 6 m wide × 6 m high) is assumed to fill with contaminated air. An exposure duration of 1 min is assumed, during which workers avoid any obstructions and leave the scene. Indoor worker exposure concentrations are estimated using a room model with no ventilation.

Cancer potency factors from the EPA Integrated Risk Information System and Health Effects Assessment Summary Tables were used for determining the cancer incidence resulting from accidents that released carcinogenic chemicals. RfCs and lethality concentrations for acute exposure to toxic chemicals are

derived from the methodology developed by Hartmann et al. (1994). Cadmium and benzene are considered to be the carcinogens in the HW accident source terms. Cadmium is toxic as well as carcinogenic, so it is incorporated into both the IDLH index and cancer incidence risk for workers. For the offsite and noninvolved worker populations exposed to cadmium, only the risk of cancer incidence is evaluated because no acute RfD is available to calculate a hazard index. The toxicity and slope factors and IDLH values for cadmium dust are used for accident subcategory 5E because no analogous values are available for cadmium fumes.

The chemical surrogates in Table D.3.3–14 are used in the HW accident risk estimates for all receptors.

Table D.3.3–14. Chemical Surrogates Used in Risk Analysis for Potential HW Accidents

Chemical Hypothetically Released in Accident	Surrogate Used in Risk Analysis
Cyanides (hydrogen, potassium, etc.)	Hydrogen cyanide
Dichromate salts (potassium, sodium, etc.)	Potassium dichromate
Polyaromatic hydrocarbon soot and unburnt hydrocarbons	Benzene
Sulfur oxides	Sulfur dioxide

There is an associated estimated annual frequency of occurrence for each accident type (see Section D.2.12.1). However, the probability of occurrence is not taken into account in the risk calculations. Risk estimates associated with each accident should be interpreted as the consequences if the accident occurred. The various single drum accidents have estimated annual frequencies of occurrence ranging from "unlikely" (1E-4 to 1E-2) to "very unlikely"(1E-6 to 1E-4). The incinerator explosion and fire is considered to be "anticipated" (greater than 1E-2); the earthquake causing a storage facility spill or an incinerator fire is considered "unlikely" to "very unlikely," depending on the location of the installation; and aircraft impact is regarded as "extremely unlikely" (less than 1E-6), depending on installation location (see Appendix F).

D.3.3.7 Results Tables for the Risk Analysis of Potential HW Accidents

Table D.3.3–15 shows a summary of the risks to the offsite and waste management worker populations from worst-case single-drum, single-contaminant releases, by installation and alternative. Tables D.3.3–16

through D.3.3–19 present a summary of risks to the offsite, noninvolved worker, and waste management worker populations for treatment and storage facility accidents, by installation and alternative. Table D.3.3–20 provides the sizes of the offsite, noninvolved worker, and worker populations at each installation.

Table D.3.3–15. Summary of Risks to the Offsite and Waste Management Worker Populations from Potential Single-Drum HW Accidents, by Alternative and Installation

Installation	Alternative	Receptor and Endpoint							
		Offsite Population		Offsite MEI[b]		Worker Population		Most-Exposed Worker	
		Accident[c]	CI[d]	Accident	HI[e]	Accident	CI	Accident	IDLH Index
Hanford	Reg. 1[a]	5E (U)[f]	3.2E-4	2D (U)	8.1E-2	5E (U)	2.5E-3	5F (VU)	6.4E1
INEL	Reg. 1	5E (U)	2.1E-4	2D (U)	5.3E-1	5E (U)	2.5E-3	5F (U)	6.4E1
LANL	Reg. 1	5E (U)	3.0E-4	2D (U)	9.9E-1	5E (U)	2.5E-3	5F (U)	6.4E1
ORR	Reg. 1	5E (VU)	5.9E-3	2D (U)	5.8	5E (VU)	2.5E-3	5F (VU)	6.4E1
SRS	Reg. 1	5E (U)	2.6E-5	2D (U)	8.1E-2	5E (U)	2.5E-3	5F (0)[g]	6.4E1
INEL	Reg. 2[a]	5E (U)	2.1E-4	2D (U)	5.3E-1	5E (U)	2.5E-3	5F (U)	6.4E1
ORR	Reg. 2	5E (U)	5.9E-3	2D (U)	5.8	5E (U)	2.5E-3	5F (U)	6.4E1

[a] Reg.1—Regionalized Alternative 1; Reg. 2—Regionalized Alternative 2.
[b] MEI—most-exposed individual.
[c] Worst-case single-drum accident type.
[d] CI—risk of cancer incidence associated with exposure to chemical carcinogens.
[e] HI—hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[f] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).
[g] The annual frequency of this accident occurring at SRS is 0.

Table D.3.3-16. Risks Associated with Potential Facility-Wide HW Storage Accidents Under the Regionalized Alternative 1, By Accident and Installation

Installation	Offsite Pop CI[a]	Offsite MEI[b] HI[c]	Noninvolved Worker Pop CI	Noninvolved Worker MEI HI	Worker CI	Worker IDLH Index
Storage Facility Fire						
Hanford (U)[d]	2.8E-3	1.1	1.5E-5	5.6	1.8E-2	9.0E2
INEL (U)	1.7E-3	1.5	6.8E-3	1.4E1	2.0E-2	5.1E2
LANL (U)	8.3E-3	3.1E1	1.8E-3	4.4E2	6.6E-2	2.4E3
ORR (U)	1.8E-2	7.6E1	2.3E-2	8.4E2	5.3E-3	6.0E2
SRS (U)	5.6E-4	1.7	2.8E-3	1.1E2	5.4E-2	1.3E3
Large or Small Aircraft Impact and Storage Facility Fire						
Hanford (EU) (large)	2.8E-3	1.2	1.4E-5	6.2	1.8E-2	1.4E3
INEL (EU) (large)	1.7E-3	1.6	6.9E-3	1.4E1	2.0E-2	5.3E2
LANL (EU) (small)	8.3E-3	3.2E1	1.8E-3	4.5E2	6.6E-2	2.7E3
ORR (EU) (small)	1.8E-2	7.7E1	2.3E-2	8.5E2	5.3E-3	6.8E2
SRS (EU) (large)	5.9E-4	1.7	2.8E-3	1.1E2	5.4E-2	1.3E3
Earthquake and Resulting Spill of Multiple Storage Containers						
Hanford (VU)	0.0[e]	1.6E-3	0.0[e]	8.5E-3	0.0[e]	1.2
LANL (U)	0.0[e]	2.0E-2	0.0[e]	2.8E-1	0.0[e]	1.2

[a] CI—risk of cancer incidence associated with exposure to chemical carcinogens.
[b] MEI—most-exposed individual.
[c] HI—hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).
[e] Zero indicates that no carcinogen is released in accident scenario.

Table D.3.3-17. Risks Associated with Potential Facility-Wide HW Storage Accidents Under the Regionalized Alternative 2, By Accident and Installation

Installation	Offsite Pop CI[a]	Offsite MEI[b] HI[c]	Noninvolved Worker Pop CI	Noninvolved Worker MEI HI	Worker CI	Worker IDLH Index
Storage Facility Fire						
INEL (U)[d]	1.2E-2	3.6E1	4.8E-2	3.2E2	1.4E-1	5.1E3
ORR (U)	1.6E-1	2.4E2	2.1E-1	2.6E3	6.1E-2	2.2E3
Large or Small Aircraft Impact and Storage Facility Fire						
INEL (EU) (large)	1.2E-2	3.7E1	4.8E-2	3.3E2	1.4E-1	6.2E3
ORR (EU) (small)	1.6E-1	2.4E2	2.1E-1	2.6E3	6.1E-2	2.3E3
Earthquake and Resulting Spill of Multiple Storage Containers						
INEL (U)	0.0[e]	1.9E-1	0.0[e]	1.7	0.0[e]	8.0
ORR (U)	0.0[e]	1.1E-1	0.0[e]	1.3	0.0[e]	1.2

[a] CI—risk of cancer incidence associated with exposure to chemical carcinogens.
[b] MEI—most-exposed individual.
[c] HI—hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).
[e] Zero indicates that no carcinogen is released in accident scenario.

Table D.3.3-18. Risks Associated with Potential Facility-Wide HW Treatment Accidents Under the Regionalized Alternative 1, By Accident and Installation

Installation		Offsite Pop CI[a]	Offsite MEI[b] HI[c]	Noninvolved Worker Pop CI	Noninvolved Worker MEI HI	Worker CI	Worker IDLH Index
Incinerator Explosion and Fire							
Hanford	(A)[d]	1.9E-5	8.0E-2	9.8E-8	4.3E-1	1.0E-6	3.9E1
INEL	(A)	2.0E-4	0.0[e]	4.7E-4	0.0[e]	2.5E-4	7.9E1
LANL	(A)	3.1E-4	9.5E-1	6.1E-5	7.3	7.5E-4	1.2E2
ORR	(A)	5.5E-3	3.5	4.8E-4	3.7	1.0E-3	2.0E2
SRS	(A)	7.6E-7	8.0E-2	3.4E-6	4.4	5.0E-7	3.9E1
Large or Small Aircraft Impact and Incinerator Facility Fire							
Hanford (large)	(EU)	5.6E-5	1.8E-1	2.9E-7	9.8E-1	3.0E-6	3.6E2
INEL (large)	(EU)	4.1E-4	8.3E-2	9.4E-4	4.6E-1	5.0E-4	2.3E2
LANL (small)	(EU)	3.4E-4	1.3	6.6E-5	9.9	7.6E-4	4.8E2
ORR (small)	(EU)	1.1E-2	6.8	9.7E-4	7.1	2.0E-3	3.2E2
SRS (large)	(EU)	2.9E-5	8.1E-2	1.3E-4	4.4	5.0E-4	1.2E2
Earthquake and Incinerator Facility Fire							
Hanford	(VU)	3.7E-5	1.0E-1	2.0E-7	5.5E-1	2.0E-6	3.2E2
INEL	(VU)	2.1E-4	8.3E-2	4.8E-4	4.6E-1	2.5E-4	1.6E2
LANL	(VU)	3.5E-4	1.0	6.8E-5	7.8	7.8E-4	2.0E2
ORR	(VU)	1.1E-2	6.8	9.7E-4	7.1	2.0E-3	3.2E2
SRS	(VU)	2.7E-5	8.1E-2	1.2E-4	4.4	5.0E-4	1.2E2

[a] CI—risk of cancer incidence associated with exposure to chemical carcinogens.
[b] MEI—most-exposed individual.
[c] HI—hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).
[e] Zero indicates that no acute RfD was available for contaminant; cancer incidence only was calculated.

Table D.3.3-19. Risks Associated with Potential Facility-Wide HW Treatment Accidents Under the Regionalized Alternative 2, By Accident and Installation

Installation		Offsite Pop CI[a]	Offsite MEI[b] HI[c]	Noninvolved Worker Pop CI	Noninvolved Worker MEI HI	Worker CI	Worker IDLH Index
Incinerator Explosion and Fire							
INEL	(A)[d]	2.3E-4	4.9E-1	5.2E-4	2.7	1.3E-3	2.0E2
ORR	(A)	6.0E-3	6.6	5.2E-4	6.9	1.3E-3	1.6E2
Large or Small Aircraft Impact and Incinerator Facility Fire							
INEL (large)	(EU)	4.5E-4	1.5	1.0E-3	8.5	2.5E-3	6.4E2
ORR (small)	(EU)	1.2E-2	1.1E1	1.0E-3	1.1E1	2.5E-3	5.6E2
Earthquake and Incinerator Facility Fire							
INEL	(VU)	8.6E-4	2.1	2.0E-3	1.2E1	5.0E-3	9.9E2
ORR	(VU)	1.2E-2	1.1E1	1.0E-3	1.1E1	2.5E-3	5.6E2

[a] CI—risk of cancer incidence associated with exposure to chemical carcinogens.
[b] MEI—most-exposed individual.
[c] HI—hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.3-20. Size of Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Potential HW Treatment and Storage Accidents, by Installation

Installation	Offsite Population	Noninvolved Worker Population	Storage Worker Population		Treatment Worker Population	
			Regionalized 1	Regionalized 2	Regionalized 1	Regionalized 2
Hanford	377,645	8,674	6		2	
INEL	153,061	8,451	6	6	1	5
LANL	159,152	11,552	6		3	
ORR	881,652	3,809	6	6	4	5
SRS	620,618	15,996	6		2	

D.3.3.8 Summary of the HW Accident Analysis Results

In general, the accident analyses indicate the same trend as seen in routine waste management operations: as the volume of waste is increased at an installation, the risks to the public and workers during treatment and storage increase. In Regionalized Alternative 2, approximately 80% of DOE-generated HW is treated at two installations, while treatment of 50% of DOE HW is distributed across five installations in Regionalized 1. Accordingly, the accident risks to all receptors at INEL and ORR in Regionalized 2 tend to be higher than the Regionalized 1 risks at these installations by roughly 1 order of magnitude for storage accidents and by only a slight margin for treatment accidents.

The worst-case single-drum storage accidents for the offsite population and MEI involve releases of cadmium and mercury vapor. The worst-case single-drum accidents for workers involve releases of cadmium and dichromate salts. The facility-wide storage accidents that would produce the highest risks to all receptors are the storage facility fire and the crash of an aircraft into a storage facility followed by fire. However, the storage facility fire is considered "unlikely" (1E-4 to 1E-2) whereas the aircraft impact scenario is designated "extremely unlikely" (less than 1E-6). For treatment facility accidents, consequences are generally similar among accident types at a given installation; however, the incinerator explosion is considered much more likely (greater than 1E-2 or "anticipated") than other scenarios. The most common controlling contaminants in HW accident scenarios are cadmium and mercury vapor. The highest-risk installations are usually INEL, ORR, and LANL.

D.3.3.8.1 *Risks to the Offsite Population from Accidents During Storage*

Single-Drum Accidents. For the offsite population at each installation, the highest cancer incidence risks are associated with a forklift accident resulting in a spill and fire involving a release of cadmium fumes (5E) (see Table D.3.3–15). These risks of cancer incidence range from 2.6E-5 to 5.9E-3 in Regionalized 1 and from 2.1E-4 to 5.9E-3 in Regionalized 2. The highest cancer incidence is at ORR in both Regionalized 1 and 2 (5.9E-3 occurrences affecting a population of 881,652). The next highest risks of cancer incidence are at Hanford and LANL in Regionalized 1 and at INEL in both alternatives (3.2E-4, 3.0E-4, and 2.1E-4, respectively). The lowest cancer incidence risks are at SRS in Regionalized 1 (2.6E-5). The consequences at an installation of the worst-case single-drum accident (if it occurred) do not differ between alternatives. However, the estimated annual frequency of the accident increases almost 2 orders

of magnitude at ORR from "very unlikely" (1E-6 to 1E-4) to "unlikely" (1E-4 to 1E-2) in Regionalized 2. The accident is considered "unlikely" at all other installations in both alternatives.

Storage Facility Accidents. For the offsite population, storage facility fires and aircraft impacts with subsequent fires would pose about the same risks of cancer incidence if they occurred at an installation (see Tables D.3.3-16 and D.3.3-17). However, facility fires are projected to occur more frequently than airplane crashes ("unlikely" [1E-4 to 1E-2] versus "extremely unlikely" [less than 1E-6], respectively). In general, the risks at each installation are 1 order of magnitude higher in Regionalized 2 than in Regionalized 1. This is because approximately 80% of DOE-generated HW is treated at two installations in Regionalized 2 while treatment of 50% of DOE HW is distributed across five installations in Regionalized 1.

The highest cancer incidence risks from a storage facility fire or an airplane impact affecting a storage facility are at ORR in Regionalized 1 and 2 (1.8E-2 and 1.6E-1, respectively, in an affected population of 881,652), INEL in Regionalized 2 (1.2E-2 in a population of 153,061), and LANL in Regionalized 1 (8.3E-3 in a population of 159,152). At all three installations, the controlling contaminant is cadmium. In earthquake scenarios, no carcinogens are assumed to be released (source terms contain noncarcinogens only).

D.3.3.8.2 *Risks to the Offsite Population from Accidents During Treatment*

The risks of cancer incidence to the offsite population from facility-wide accidents during incineration range from 7.6E-7 to 1.1E-2 in Regionalized 1 and from 2.3E-4 to 1.2E-2 in Regionalized 2. In Regionalized 1, cancer incidence risks to the offsite population are similar among accident types (incinerator explosion, aircraft crash into a incinerator facility, and earthquake and fire affecting an incinerator facility) at a given installation, differing by only a factor of three or less in most instances. One exception is the incinerator explosion scenario at SRS, which results in a cancer incidence to the offsite population (7.6E-7) that is more than 1 order of magnitude lower than other accident types at SRS. (This is because the carcinogen cadmium is released in the other accident types, but not in the incinerator explosion scenario.) Cancer incidence risks to the offsite population are also similar among accident types at INEL and ORR in Regionalized 2, differing by less than a factor of four. However, in both alternatives, the estimated annual frequency associated with each of the three treatment facility accident

scenarios is different: the incinerator explosion is considered "anticipated" (estimated annual frequency greater than 1E-2); the aircraft impact scenario is "extremely unlikely" (less than 1E-6); and the earthquake scenario is "very unlikely" (1E-6 to 1E-4).

ORR is the highest-risk installation for all accident types and alternatives. The highest cancer incidence risks are for the aircraft impact or the earthquake at ORR in both alternatives (1.1E-2 in Regionalized 1 and 1.2E-2 in Regionalized 2). The driving contaminant at ORR for these accident types is cadmium.

D.3.3.8.3 *Risks to the Noninvolved Worker Population from Accidents During Storage*

The risks to noninvolved workers from single-drum accidents are not presented in this appendix, but can be found in a separate ORNL technical report (1995e).

The risk of cancer incidence in the noninvolved worker population due to accident-related releases follows a similar pattern to that for the offsite population. At each installation, storage facility fires and aircraft impacts with subsequent fires pose about the same risks of cancer incidence (see Tables D.3.3–16 and D.3.3–17); however, facility fires are projected to occur more frequently than airplane crashes ("unlikely" versus "extremely unlikely," respectively). Accident risks in Regionalized 2 are approximately 1 order of magnitude higher than those in Regionalized 1 for each installation. This is due to a greater number of breached containers involved in the Regionalized 2 accident scenarios. Cancer incidence due to storage accidents ranges from 1.4E-5 to 2.3E-2 in Regionalized 1 and from 4.8E-2 to 2.1E-1 in Regionalized 2.

For the airplane impact affecting a storage facility and the storage facility fire, the highest cancer incidence risks are at ORR in Regionalized 1 and 2 (2.3E-2 and 2.1E-1, respectively, in an affected population of 3,809). The next highest cancer incidence risks are from an airplane impact or storage facility fire at INEL (approximately 7.0E-3 in Regionalized 1 and 4.8E-2 in Regionalized 2). Cadmium is the controlling contaminant at both installations. The installation with the lowest cancer incidence risks to noninvolved workers from storage accidents is Hanford in Regionalized 1.

D.3.3.8.4 *Risks to the Noninvolved Worker Population from Accidents During Treatment*

The risks of cancer incidence to the noninvolved worker population from facility-wide accidents during incineration range from 9.8E-8 to 9.7E-4 in Regionalized 1 and from 5.2E-4 to 2.0E-3 in Regionalized 2. In both alternatives, cancer incidence risks to noninvolved workers are similar among accident types at a given installation, differing by only a factor of three or less in most instances. One exception is the incinerator explosion scenario at SRS which results in a cancer incidence (3.4E-6) that is nearly 2 orders of magnitude lower than other accident types at SRS. (This is because the carcinogen cadmium is released in the other accident types, but not in the incinerator explosion scenario.)

The highest installation risks of cancer incidence are at ORR and INEL for all accident types. Cancer incidence risks to noninvolved workers at INEL range from 4.7E-4 to 9.4E-4 in Regionalized 1 and from 5.2E-4 to 2.0E-3 in Regionalized 2. ORR cancer incidence risks are very similar to those at INEL, ranging from 4.8E-4 to 9.7E-4 in Regionalized 1 and from 5.2E-4 to 1.0E-3 in Regionalized 2. The controlling contaminant is cadmium at both installations.

D.3.3.8.5 *Risks to the Most-Exposed Offsite Individual from Single-Drum Accidents*

The worst-case single-drum accident involving the release of a noncarcinogenic chemical is a forklift accident that results in a spill and fire with release of mercury vapor (2D) (see Table D.3.3-15). The highest hazard index is at ORR in both alternatives (5.8), indicating an increased likelihood of adverse health effects. The next highest hazard index resulting from this accident type is 9.9E-1 at LANL in Regionalized 1; this value approaches the threshold value of 1.0 beyond which adverse health effects become more likely. All other hazard indices are below 1.0. The estimated annual frequency of occurrence for this accident type is "unlikely" for all installations and alternatives.

D.3.3.8.6 *Risks to the Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual from Storage Facility Accidents*

Accidents During Storage. The highest hazard indices for the offsite MEI from an airplane impact affecting a storage facility or a storage facility fire are at ORR in Regionalized 1 and 2 (approximately

7.7E1 and 2.4E2, respectively); INEL in Regionalized 2 (approximately 3.7E1); and LANL in Regionalized 1 (approximately 3.2E1). The same trend holds true for the noninvolved worker MEI. At all three installations the controlling contaminant is mercury vapor.

Hazard indices associated with earthquake scenarios that affect storage facilities are usually less than 1.0 with the exception of the noninvolved worker MEI at ORR and INEL in Regionalized 2 (1.3 and 1.7, respectively). The hazard index from an earthquake-related accident is generally 2 to 3 orders of magnitude less than those associated with other storage facility accidents at the same installation. In terms of annual accident frequency, earthquake and facility fire scenarios are considered "unlikely" (with the exception of the earthquake scenario at Hanford in Regionalized 1 which is considered "very unlikely"), while aircraft impacts are "extremely unlikely" to happen.

Accidents During Treatment. The highest hazard indices to the offsite MEI for all accident types are at ORR in Regionalized 1 and 2 (ranging from 3.5 to 1.1E1); the aircraft impact and earthquake scenarios at INEL in Regionalized 2 (1.5 and 2.1, respectively); and the aircraft impact and earthquake scenarios at LANL in Regionalized 1 (1.3 and 1.0, respectively). The controlling contaminant at these installations is mercury vapor. The highest hazard indices to the noninvolved worker MEI are for all accident types at ORR in both alternatives (ranging from 3.7 to 1.1E1); LANL in Regionalized 1 (ranging from 7.3 to 9.9); SRS in Regionalized 1 (4.4 for all accident types); and INEL in Regionalized 2 (ranging from 2.7 to 12). Each of these accidents, were it to occur, would result in exposures that might lead to adverse health effects to the MEIs. Recall, however, that the incinerator explosions are considered "anticipated," while the earthquake and aircraft impact scenarios are considered "very unlikely" and "extremely unlikely," respectively.

D.3.3.8.7 *Risks to Waste Management Workers from Storage and Treatment Facility Accidents*

Accidents During Storage. The single-drum accident scenario resulting in the highest cancer incidence risk to workers (2.5E-3) is 5E, the forklift accident leading to a spill and fire with release of cadmium fumes (see Table D.3.3-13). (This scenario was also the worst-case single-drum accident involving a carcinogen for the offsite population.) The worst-case single-drum accident for workers involving the release of a noncarcinogen is 5F, a forklift accident resulting in a spill and fire with a release of dust from burnt and unburnt dichromate salts (analyzed as potassium dichromate). The IDLH index associated

with this accident is 6.4E1, which is 64 times the exposure concentration that could cause irreversible health effects if exposure were to last as long as 30 min. However, the accident scenario assumes a much shorter exposure duration, which could reduce the severity of health effects. For each installation, the consequences of the worst-case single-drum accidents for workers are the same across alternatives. However, the estimated annual frequency of accident types 5E and 5F increases at ORR from "very unlikely" in Regionalized 1 to "unlikely" in Regionalized 2. Note that the estimated annual frequency of 5F is zero (i.e., 5F is assumed not to occur) at SRS in Regionalized 1.

Storage facility fires and aircraft impacts with subsequent fires would pose very similar risks of cancer incidence and IDLH indices were they to occur at an installation (see Tables D.3.3-16 and D.3.3-17). However, facility fires are projected to occur more frequently than airplane crashes ("unlikely" versus "extremely unlikely," respectively). Both cancer incidence risk and IDLH index increase by about 1 order of magnitude at INEL and ORR from Regionalized 1 to Regionalized 2 due to centralization of waste loads. The highest risk of cancer incidence is associated with the storage facility fire or aircraft crash at INEL in Regionalized 2 (1.4E-1 for each accident). The highest IDLH indices are also for the storage facility fire and aircraft crash at INEL in Regionalized 2 (5.1E3 and 6.2E3, respectively). These IDLH indices indicate that, were one of these accidents to occur, contaminant concentrations would greatly exceed the level considered immediately dangerous to life and health for exposures of 30 min. However, the accident scenarios assume a much shorter exposure duration, which could reduce the severity of health effects. The controlling contaminants at INEL are cadmium and mercury vapor.

Earthquake-related accidents result in IDLH indices greater than 1.0, but 2 to 3 orders of magnitude less than those resulting from other storage facility accidents. The highest IDLH index for earthquake-related releases from storage is also at INEL in Regionalized 2 (8.0). No carcinogens are assumed to be released in earthquake scenarios.

Accidents During Treatment. In both alternatives, cancer incidence risks to workers are similar among treatment accident types at a given installation. However, similar to the trend for offsite and noninvolved worker populations, there is one exception: the incinerator explosion at SRS in Regionalized 1 results in a cancer incidence risk to workers of 5.0E-7; this is 3 orders of magnitude lower than other treatment facility accidents at SRS. As previously discussed, this is because there is no cadmium in the source term for the incinerator explosion. The highest installation risks are for all accident types at ORR in both

alternatives (ranging from 1.0E-3 to 2.0E-3) and INEL in Regionalized 2 (ranging from 1.3E-3 to 5.0E-3). The controlling contaminant is cadmium at both installations.

IDLH indices are similar among accident types at a given installation in both alternatives. One notable exception is the incinerator explosion at Hanford in Regionalized 1, which results in an IDLH index approximately 1 order of magnitude lower than for other accident types. This is primarily because there is no cyanide in the incinerator explosion source term (in contrast to the other accident types). All IDLH indices associated with treatment facility accidents are greater than 1.0 by 1 to 3 orders of magnitude, indicating exposures to workers that could lead to irreversible health effects.

D.3.4 TRANSURANIC WASTE

DOE Order 5820.2A defines transuranic waste (TRUW) as, "[w]ithout regard to source or form, waste that is contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years, and concentrations greater than 100 nCi/gm [nanocuries per gram] at the time of assay" (DOE, 1988). This lower activity limit is interpreted as being per gram of actual waste matrix, excluding the weight of added external shielding, liners, or packaging. By definition, TRUW includes neptunium, plutonium, americium, curium, and californium. DOE Order 5820.2A also provides for the management of some other alpha-contaminated wastes as TRUW, such as wastes containing uranium-233 and radium-226, as necessary. In this appendix the term "TRUW" refers to all materials meeting the DOE definition including TRUW that contain hazardous constituents regulated by the Resource Conservation and Recovery Act (RCRA). The principal focus of the PEIS is on TRUW generated since 1970, which has been packaged and retrievably stored in various trench, pit, vault, and pad configurations. (TRUW generated before 1970 was buried onsite in shallow landfills and may be addressed through environmental restoration activities.)

TRUW is generated primarily in research and development, weapons manufacturing, and plutonium recovery; some TRUW is also retrieved during environmental restoration and decontamination and decommissioning. Following are the DOE installations that generate or store TRUW (note that the abbreviations given here are used throughout this appendix):

- Argonne National Laboratory-East (ANL-E), Argonne, Illinois
- Argonne National Laboratory-West (ANL-W), Idaho Falls, Idaho
- Energy Technology Engineering Center (ETEC), Canoga Park, California
- Hanford Site (Hanford), Richland, Washington
- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Inhalation Toxicology Research Institute (ITRI), Albuquerque, New Mexico
- Lawrence Berkeley Laboratory (LBL), Berkeley, California
- Lawrence Livermore National Laboratory (LLNL), Livermore, California
- Los Alamos National Laboratory (LANL), Los Alamos, New Mexico
- Mound Plant (Mound), Miamisburg, Ohio
- Nevada Test Site (NTS), Las Vegas, Nevada
- Oak Ridge Reservation (ORR), Oak Ridge, Tennessee
- Paducah Gaseous Diffusion Plant (PGDP), Paducah, Kentucky
- Rocky Flats Environmental Technology Site (RFETS), Golden, Colorado
- Sandia National Laboratories-New Mexico (SNL-NM), Albuquerque, New Mexico
- Sandia National Laboratory-California (SNL-CA), Livermore, California
- Savannah River Site (SRS), Aiken, South Carolina
- University of Missouri at Columbia (U of Mo), Columbia, Missouri
- West Valley Demonstration Project (WVDP), West Valley, New York

Most TRUW is solid waste (such as contaminated tools, machine parts, protective clothing, and laboratory glassware) but some is in liquid or sludge forms. Perhaps 50 to 60 % of the DOE inventory of TRUW is mixed waste, containing both radioactive and hazardous constituents regulated under RCRA. Examples of this mixed waste include sludges contaminated with spent solvents, debris contaminated with solvents and radionuclides, and discarded contaminated lead shielding. Depending on its chemical and physical properties, TRUW can be grouped into waste stream categories, such as aqueous liquids, organic liquids, solid process residues, soils, or debris, according to the type of treatment needed.

Packaged TRUW with a surface dose rate of less than 200 mrem/h is categorized as contact-handled TRUW (CH-TRUW). Packaged TRUW with a surface dose rate greater than 200 mrem/h emits sufficient penetrating beta, gamma, or neutron radiation to require remote handling, and is classified as remote-handled TRUW (RH-TRUW). The handling category determines the level of protective shielding needed to store and process the waste safely. The distinction between CH-TRUW and RH-TRUW is maintained

in the human health risk analysis for both routine operations and accidents. Therefore, the results for CH-TRUW are presented separately from the results for RH-TRUW.

The DOE Waste Isolation Pilot Plant (WIPP), located near Carlsbad, New Mexico, has been identified as the permanent disposal installation for DOE-generated TRUW. To ensure that TRUW can be disposed of safely at WIPP, DOE has developed a set of waste acceptance criteria (referred to as "WIPP-WAC" in the risk analysis tables) that waste generators and treatment and storage installations must meet before shipping TRUW to WIPP. These waste acceptance criteria were taken into account in developing the PEIS alternatives. However, because the final WIPP disposal criteria will likely be more stringent than current criteria, two additional treatment standards were evaluated in this analysis. The first of these was treatment to an intermediate waste form that generates less gas from the degradation of organic chemicals and corrodible metals than is mandated by current WIPP waste acceptance criteria. This is accomplished mainly by shredding and grouting the wastes and packaging them in containers that are not expected to release significant amounts of gases when disposed of at WIPP. The second was treatment to meet RCRA land disposal restrictions (LDRs) as promulgated in 1986 in Title 40, Chapter 268 of the Code of Federal Regulations. This is the most extensive of the three treatment standards; wastes are incinerated to destroy most of the hazardous organic chemical components.

Chapters 3 and 8 of the PEIS and the TRUW technical report (ANL, 1995b) provide more detailed information on this waste, including TRUW inventories at DOE installations, estimated release rates, treatment categories used in the PEIS, and the process for developing PEIS TRUW alternatives.

D.3.4.1 Summary of CH-TRUW Alternatives

The PEIS waste management alternatives (No Action, Decentralized, Regionalized, and Centralized) and the rationale for developing the various CH-TRUW analysis alternatives are discussed rigorously in the main body of the PEIS.

- The No Action Alternative demonstrates the baseline risks of CH-TRUW retrieval, packaging, certification, and indefinite interim storage at all generator installations. Treatment is not considered, and it is assumed that TRUW will not be disposed of at WIPP, although it will be prepared as though it were going to WIPP.
- The Decentralized Alternative presents the risks of treating wastes to WIPP waste acceptance criteria and storing them at 10 installations.
- In Regionalized Alternative 1, CH-TRUW is consolidated, treated to minimize gas generation, and stored at five installations.
- In Regionalized Alternatives 2 and 3, CH-TRUW is consolidated, treated to meet RCRA LDRs, and stored at five and three installations, respectively.
- In the Centralized Alternative, CH-TRUW is consolidated, treated to meet RCRA LDRs, and stored at one installation.

In Regionalized 1 and 2, consolidation, treatment, and storage take place at the same five installations. Comparison of these alternatives makes it possible to contrast the risks of treatment to minimize gas generation versus treatment to meet RCRA LDRs. Comparison of Regionalized 2, 3, and the Centralized Alternative demonstrates the differences in risks when the same treatment method is used but treatment and storage are performed at five, three, and one installation(s), respectively.

Table D.3.4-1 presents the overall treatment and storage schemes for these six alternatives. Table D.3.4-2 shows which installations ship their wastes to regionalized or centralized consolidation installations for treatment and storage. Note that for the purposes of this risk analysis, the waste loads from three smaller generators were added to the inventories of larger generators. Specifically, the ITRI waste load was combined with the SNL-NM inventory; the ANL-W waste load was added to the INEL inventory; and the SNL-CA waste load was combined with the LLNL inventory. Also, source terms were not available for ETEC, U of Mo, and the WVDP so risks at these installations were not evaluated (ANL, 1995b).

Table D.3.4-1. PEIS Alternatives for CH-TRUW

Alternative	ANL-E	ETEC[a]	Hanford	INEL[b]	LANL	LBL	LLNL[c]	Mound	NTS	ORR	PGDP	RFETS	SNL-NM[d]	SRS	U of Mo[a]	WVDP[f]	WIPP
No Action Alternative	T[g]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	
No treatment/store at 16	S[h]	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	
Decentralized Alternative	T		T	T	T		T	T	T	T		T		T			
Treat to WIPP-WAC/store at 10	S		S	S	S		S	S	S	S		S		S			
Regionalized Alternative 1			T	T	T							T		T			
Treat to reduce gas/store at 5			S	S	S							S		S			
Regionalized Alternative 2			T	T	T							T		T			
Treat to LDRs/store at 5			S	S	S							S		S			
Regionalized Alternative 3			T	T										T			
Treat to LDRs/store at 3			S	S										S			
Centralized Alternative																	T
Treat to LDRs/store at 1																	S

[a,c,f] Data for ETEC, U of Mo, and WVDP were not available so risks at these installations were not evaluated.
[b] Includes CH-TRUW from ANL-W.
[c] Includes CH-TRUW from SNL-CA.
[d] Includes CH-TRUW from ITRI.
[g] T—treatment installation.
[h] S—storage installation.

Table D.3.4-2. PEIS Consolidation and Treatment Strategies for CH-TRUW

Alternative	Origin	Treatment and Storage Destination
No Action Alternative No treatment; store at 16 installations	All installations	Generators store own waste
Decentralized Alternative Treat to WIPP-WAC and store at 10 installations	ANL-E Hanford, LBL INEL/ANL-W[a] LANL, SNL-NM/ITRI[b] LLNL/SNL-CA[c] Mound, WVDP[d] NTS, ETEC[e] ORR, PGDP, U of Mo[f] RFETS SRS	ANL-E Hanford INEL LANL LLNL Mound NTS ORR RFETS SRS
Regionalized Alternative 1 Treat to minimize gas generation and store at 5 installations	Hanford, LBL, LLNL/SNL-CA INEL/ANL-W, ETEC, NTS LANL, SNL-NM/ITRI RFETS SRS, ANL-E, Mound, ORR, PGDP, U of Mo, WVDP	Hanford INEL LANL RFETS SRS
Regionalized Alternative 2 Treat to RCRA LDRs and store at 5 installations	Hanford, LBL, LLNL/SNL-CA INEL/ANL-W, ETEC, NTS LANL, SNL-NM/ITRI RFETS SRS, ANL-E, Mound, ORR, PGDP, U of Mo, WVDP	Hanford INEL LANL RFETS SRS
Regionalized Alternative 3 Treat to RCRA LDRs and store at 3 installations	Hanford, LBL, LLNL/SNL-CA INEL/ANL-W, ETEC, LANL, NTS, RFETS, SNL-NM/ITRI SRS, ANL-E, Mound, ORR, PGDP, U of Mo, WVDP	Hanford INEL SRS
Centralized Alternative Treat to RCRA LDRs and store at WIPP	All installations	WIPP

[a,b,c] For the purpose of the human health risk analysis, the ANL-W waste load is added to the INEL inventory, the ITRI waste load is added to the SNL-NM inventory, and the SNL-CA waste load is added to the LLNL inventory.
[d,e,f] Source terms for WVDP, ETEC, and U of Mo were not available so risks at these installations were not evaluated.

D.3.4.2 Special Assumptions and Considerations Used in the TRUW Risk Analysis

For all alternatives except the No Action Alternative (for CH-TRUW and RH-TRUW), it is assumed that design and construction of new facilities will begin in 1995, and new facilities will be operational in the year 2003. All current inventory, retrievably stored waste, and waste generated between 1993 to 2013 will be treated from approximately 2003 to 2013. Waste generated after 2013 will be treated as necessary (ANL, 1995b). Therefore, all alternatives except No Action were evaluated to estimate human health risks

for a 10-year period of treatment and storage, while No Action was evaluated for a 20-year period. Disposal risks were not estimated for TRUW since it is assumed that all TRUW will be disposed of at WIPP.

It is assumed that WIPP will accept TRUW for disposal from 1998 to 2018. The acceptance rate for waste will average 7080 m^3/year (250,000 ft^3/year) for 20 years. Because WIPP waste acceptance criteria may change over time, the human health risk assessment was performed for treatment to three increasingly stringent standards to obtain a clearer picture of the full range of potential impacts, (current WIPP waste acceptance criteria, treatment for reduced gas generation, and RCRA LDRs).

In the No Action Alternative, wastes are retrieved where necessary, packaged, certified for shipment to WIPP, and placed in interim storage. There is no treatment of waste other than packaging, but health risks to public receptors and WM workers are assessed for retrieval and packaging operations. Retrieval potentially poses exposure risk due to emissions from corroding waste containers. Therefore, contaminant emissions during both retrieval and packaging were considered as part of routine waste management for TRUW.

Waste containers were assumed to be 55-gal drums for CH-TRUW; 6-in.-wall concrete casks for RH-TRUW; and Transuranic Package Transporter-II (TRUPACT II) containers for packaging wastes to be shipped to WIPP.

A hazard index is reported for the noninvolved worker MEI and offsite MEI, while an exposure index is reported for workers. The HI reflects the worst-case exposure of the noninvolved worker MEI and offsite MEI to noncarcinogenic, hazardous chemicals. The EI indicates the analogous worst-case exposure to an individual FTE.

Staffing requirements, expressed as FTEs, were estimated for the TRUW module for polymer solidification using the FTE data for grout solidification; and for the TRUW module for wet-air oxidation using the FTE data for wet-air oxidation of alpha-contaminated low-level and low-level mixed waste. For more information on the treatment modules, see ORNL (1994b).

D.3.4.3 Results Tables for the CH-TRUW Human Health Risk Analysis

This section contains the results tables for the CH-TRUW human health risk analysis. A discussion of the results is presented in Section D.3.4.4. The fatality and cancer incidence numbers in the tables are displayed in the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.4–3 presents an overview, by alternative, of the *total*, program-wide risks of cancer fatalities and cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers. This table provides the estimated *total number* of people in the three populations who will develop or die of cancers caused by exposure to CH-TRUW over the next 50 years if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities.
- Table D.3.4–4 shows the sizes of the total affected populations for each alternative.
- Table D.3.4–5 summarizes the risks to the noninvolved worker MEI and offsite MEI for each CH-TRUW alternative. The numbers in this table are the estimated *probabilities* that the offsite and noninvolved worker MEIs will die of cancer or develop cancer from radionuclide or chemical exposure, and indicators of the likelihood of suffering adverse health effects from exposure to noncarcinogenic, hazardous constituents.
- Tables D.3.4–6 through D.3.4–11 show the program-wide risks for all receptors and health effect endpoints, by alternative.
- Tables D.3.4–12 through D.3.4–17 present offsite and worker population risks for each installation, by alternative.
- Table D.3.4–18 lists the radionuclides that contribute most of the risk of cancer fatality to the offsite population, by installation and alternative.

Table D.3.4–3. Summary of Program-Wide Risks Associated with Routine Management of CH-TRUW: Risks to Total Populations, by Alternative

Alternative	Offsite Population		Noninvolved Worker Population		WM Workers		
	CF[a]	CI[b]	CF	CI	CF	CI	C&OF[c]
No Action Alternative	2.3E-5	7.8E-5	2.1E-6	7.1E-6	9.6E-3	3.4E-2	3.5E-1
Decentralized Alternative	1.2E-4	4.2E-4	1.1E-5	3.9E-5	6.0E-1	2.1	2.1
Regionalized Alternative 1	1.7E-4	5.9E-4	1.6E-5	5.5E-5	6.3E-1	2.2	2.7
Regionalized Alternative 2	3.3	11.3	3.4E-1	1.2	6.1E-1	2.1	4.4
Regionalized Alternative 3	2.6	8.9	2.9E-1	9.9E-1	6.6E-1	2.3	3.6
Centralized Alternative	6.1E-1	2.1	5.0E-2	1.7E-1	6.8E-1	2.4	3.1

[a] CF—cancer fatality associated with radionuclide exposure.
[b] CI—cancer incidence associated with exposure to radionuclides and carcinogenic chemicals.
[c] C&OF—fatalities due to the physical hazards of constructing and operating waste management facilities.

Table D.3.4–4. Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Routine Management of CH-TRUW, by Alternative

Alternative	Offsite	Noninvolved Worker	WM Worker
No Action	19,333,201	70,681	1,690
Decentralized	24,373,318	92,462	6,473
Regionalized 1	23,491,666	88,653	8,439
Regionalized 2	23,491,666	88,653	14,569
Regionalized 3	23,491,666	88,653	11,991
Centralized	24,473,207	89,713	10,237

Table D.3.4-5. Summary of Program-Wide Risks Associated with Routine Management of CH-TRUW: Risks To the Offsite and Noninvolved Worker Most-Exposed Individuals, by Alternative

Alternative	Offsite MEI				Noninvolved Worker MEI			
	CF[a]	Rad CI[b]	Chem CI[c]	HI[d]	CF	Rad CI	Chem CI	HI
No Action	4.4E-10	1.5E-9	3.1E-13	2.6E-11	1.3E-9	4.4E-9	9.9E-13	2.7E-10
Decentralized	5.7E-9	1.9E-8	2.8E-12	1.5E-10	4.8E-9	1.6E-8	8.9E-12	1.4E-9
Regionalized 1	6.9E-9	2.3E-8	4.8E-12	2.2E-10	7.7E-9	2.6E-8	1.5E-11	2.5E-9
Regionalized 2	6.7E-5	2.3E-4	4.8E-12	1.1E-8	2.4E-4	8.2E-4	1.5E-11	1.3E-7
Regionalized 3	2.4E-5	8.2E-5	4.8E-12	3.0E-9	2.4E-4	8.2E-4	1.5E-11	1.3E-7
Centralized	1.6E-4	5.4E-4	4.8E-12	7.6E-8	1.9E-4	6.5E-4	1.5E-11	4.6E-7

[a] CF—cancer fatality associated with exposure to radionuclides.
[b] Rad CI—cancer incidence associated with exposure to radionuclides.
[c] Chem CI—cancer incidence associated with exposure to carcinogenic chemicals.
[d] HI—hazard index associated with exposure to noncarcinogenic, toxic chemicals.

Table D.3.4-6. Program-Wide Risks Associated with Managing CH-TRUW Under the No Action Alternative

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	4.2E-3			
	Cancer Fatalities	2.1E-6			
	Cancer Incidence	7.1E-6	3.5E-9		
	Genetic Effects	4.2E-7			
Noninvolved Worker MEI	Dose (rem)	2.6E-6			
	Cancer Fatalities	1.3E-9			
	Cancer Incidence	4.4E-9	9.9E-13		
	Genetic Effects	2.6E-10			
	Hazard Index			2.7E-10	
Offsite Population	Dose (person-rem)	4.6E-2			
	Cancer Fatalities	2.3E-5			
	Cancer Incidence	7.8E-5	1.4E-8		
	Genetic Effects	4.6E-6			
Offsite MEI	Dose (rem)	8.7E-7			
	Cancer Fatalities	4.4E-10			
	Cancer Incidence	1.5E-9	3.1E-13		
	Genetic Effects	8.7E-11			
	Hazard Index			2.6E-11	
WM Workers	Dose (FTE-rem)	2.4E1			
	Cancer Fatalities	9.6E-3			
	Cancer Incidence	3.4E-2	3.8E-7		
	Genetic Effects	1.4E-3			
	Exposure Index			2.6E-6	
	Construction Fatalities				1.4E-1
	Construction Injuries				6.2E1
	Operation Fatalities				2.0E-1
	Operation Injuries				1.7E2

Table D.3.4-7. Program-Wide Risks Associated with Managing CH-TRUW Under the Decentralized Alternative

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	2.3E-2			
	Cancer Fatalities	1.1E-5			
	Cancer Incidence	3.9E-5	3.4E-8		
	Genetic Effects	2.3E-6			
Noninvolved Worker MEI	Dose (rem)	9.5E-6			
	Cancer Fatalities	4.8E-9			
	Cancer Incidence	1.6E-8	8.9E-12		
	Genetic Effects	9.5E-10			
	Hazard Index			1.4E-9	
Offsite Population	Dose (person-rem)	2.4E-1			
	Cancer Fatalities	1.2E-4			
	Cancer Incidence	4.2E-4	1.3E-7		
	Genetic Effects	2.4E-5			
Offsite MEI	Dose (rem)	1.1E-5			
	Cancer Fatalities	5.7E-9			
	Cancer Incidence	1.9E-8	2.8E-12		
	Genetic Effects	1.1E-9			
	Hazard Index			1.5E-10	
WM Workers	Dose (FTE-rem)	1.5E3			
	Cancer Fatalities	6.0E-1			
	Cancer Incidence	2.1	1.0E-5		
	Genetic Effects	9.0E-2			
	Exposure Index			3.1E-5	
	Construction Fatalities				1.4
	Construction Injuries				5.9E2
	Operation Fatalities				7.8E-1
	Operation Injuries				6.7E2

Table D.3.4-8. Program-Wide Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 1

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	3.2E-2			
	Cancer Fatalities	1.6E-5			
	Cancer Incidence	5.5E-5	5.8E-8		
	Genetic Effects	3.2E-6			
Noninvolved Worker MEI	Dose (rem)	1.5E-5			
	Cancer Fatalities	7.7E-9			
	Cancer Incidence	2.6E-8	1.5E-11		
	Genetic Effects	1.5E-9			
	Hazard Index			2.5E-9	
Offsite Population	Dose (person-rem)	3.4E-1			
	Cancer Fatalities	1.7E-4			
	Cancer Incidence	5.9E-4	2.3E-7		
	Genetic Effects	3.4E-5			
Offsite MEI	Dose (rem)	1.4E-5			
	Cancer Fatalities	6.9E-9			
	Cancer Incidence	2.3E-8	4.8E-12		
	Genetic Effects	1.4E-9			
	Hazard Index			2.2E-10	
WM Workers	Dose (FTE-rem)	1.6E3			
	Cancer Fatalities	6.3E-1			
	Cancer Incidence	2.2	2.0E-5		
	Genetic Effects	9.4E-2			
	Exposure Index			3.1E-5	
	Construction Fatalities				1.7
	Construction Injuries				7.5E2
	Operation Fatalities				1.0
	Operation Injuries				8.7E2

Table D.3.4-9. Program-Wide Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 2

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	6.9E2			
	Cancer Fatalities	3.4E-1			
	Cancer Incidence	1.2	5.6E-8		
	Genetic Effects	6.9E-2			
Noninvolved Worker MEI	Dose (rem)	4.9E-1			
	Cancer Fatalities	2.4E-4			
	Cancer Incidence	8.2E-4	1.5E-11		
	Genetic Effects	4.9E-5			
	Hazard Index			1.3E-7	
Offsite Population	Dose (person-rem)	6.7E3			
	Cancer Fatalities	3.3			
	Cancer Incidence	1.1E1	2.2E-7		
	Genetic Effects	6.7E-1			
Offsite MEI	Dose (rem)	1.3E-1			
	Cancer Fatalities	6.7E-5			
	Cancer Incidence	2.3E-4	4.8E-12		
	Genetic Effects	1.3E-5			
	Hazard Index			1.1E-8	
WM Workers	Dose (FTE-rem)	1.5E3			
	Cancer Fatalities	6.1E-1			
	Cancer Incidence	2.1	2.5E-5		
	Genetic Effects	9.2E-2			
	Exposure Index			8.6E-4	
	Construction Fatalities				2.6
	Construction Injuries				1.1E3
	Operation Fatalities				1.8
	Operation Injuries				1.5E3

Table D.3.4-10. Program-Wide Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 3

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	5.8E2			
	Cancer Fatalities	2.9E-1			
	Cancer Incidence	9.9E-1	5.7E-8		
	Genetic Effects	5.8E-2			
Noninvolved Worker MEI	Dose (rem)	4.9E-1			
	Cancer Fatalities	2.4E-4			
	Cancer Incidence	8.2E-4	1.5E-11		
	Genetic Effects	4.9E-5			
	Hazard Index			1.3E-7	
Offsite Population	Dose (person-rem)	5.2E3			
	Cancer Fatalities	2.6			
	Cancer Incidence	8.9	2.2E-7		
	Genetic Effects	5.2E-1			
Offsite MEI	Dose (rem)	4.8E-2			
	Cancer Fatalities	2.4E-5			
	Cancer Incidence	8.2E-5	4.8E-12		
	Genetic Effects	4.8E-6			
	Hazard Index			3.0E-9	
WM Workers	Dose (FTE-rem)	1.6E3			
	Cancer Fatalities	6.6E-1			
	Cancer Incidence	2.3	3.6E-5		
	Genetic Effects	9.8E-2			
	Exposure Index			8.6E-4	
	Construction Fatalities				2.2
	Construction Injuries				9.4E2
	Operation Fatalities				1.5
	Operation Injuries				1.2E3

Table D.3.4-11. Program-Wide Risks Associated with Managing CH-TRUW Under the Centralized Alternative

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	9.9E1			
	Cancer Fatalities	5.0E-2			
	Cancer Incidence	1.7E-1	6.6E-8		
	Genetic Effects	9.9E-3			
Noninvolved Worker MEI	Dose (rem)	3.8E-1			
	Cancer Fatalities	1.9E-4			
	Cancer Incidence	6.5E-4	1.5E-11		
	Genetic Effects	3.8E-5			
	Hazard Index			4.6E-7	
Offsite Population	Dose (person-rem)	1.2E3			
	Cancer Fatalities	6.1E-1			
	Cancer Incidence	2.1	2.3E-7		
	Genetic Effects	1.2E-1			
Offsite MEI	Dose (rem)	3.2E-1			
	Cancer Fatalities	1.6E-4			
	Cancer Incidence	5.4E-4	4.8E-12		
	Genetic Effects	3.2E-5			
	Hazard Index			7.6E-8	
WM Workers	Dose (FTE-rem)	1.7E3			
	Cancer Fatalities	6.8E-1			
	Cancer Incidence	2.4	8.6E-5		
	Genetic Effects	1.0E-1			
	Exposure Index			1.1E-3	
	Construction Fatalities				1.8
	Construction Injuries				7.9E2
	Operation Fatalities				1.2
	Operation Injuries				1.1E3

Table D.3.4–12. Risks Associated with Managing CH-TRUW Under the No Action Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 404	3.5E-7	7.2E-12	8.9E-2	1.2E-6	2.5E-11	2.5E-2
INEL	153061 55	2.6E-9	3.3E-13	1.1E-2	8.9E-9	1.1E-12	3.8E-6
LBL	5856829 0	4.8E-10	7.0E-15	3.4E-5	1.7E-9	2.5E-14	3.2E-12
LLNL	6324234 148	1.1E-6	1.8E-11	3.0E-2	3.8E-6	6.1E-11	2.5E-5
LANL	159152 257	4.1E-6	4.4E-10	5.3E-2	1.4E-5	1.5E-9	1.2E-3
PGDP	500502 0	0.00	0.00	0.00	0.00	0.00	0.00
Mound	3032983 0	0.00	0.00	0.00	0.00	0.00	0.00
NTS	14266 0	0.00	0.00	0.00	0.00	0.00	0.00
RFETS	2171877 353	3.0E-6	4.1E-11	7.3E-2	1.0E-5	1.4E-10	2.9E-4
SNL-NM	610714 0	0.00	0.00	0.00	0.00	0.00	0.00
SRS	620618 367	1.4E-5	1.3E-10	7.6E-2	4.7E-5	4.4E-10	7.4E-3
ANL-E	7939785 106	5.5E-7	3.1E-12	2.2E-2	1.9E-6	1.0E-11	3.3E-6
TOTAL		2.3E-5	4.4E-10	3.6E-1	7.8E-5	1.5E-9	3.4E-2

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.4-13. Risks Associated with Managing CH-TRUW Under the Decentralized Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 275	1.8E-6	9.9E-12	1.0E-1	6.1E-6	3.4E-11	3.0E-2
INEL	153061 2303	1.1E-6	1.4E-10	1.0	3.8E-6	4.8E-10	8.7E-1
LBL	5856829 1	6.3E-9	9.4E-14	8.4E-3	2.1E-8	3.2E-13	7.6E-9
LLNL	6324234 354	3.5E-6	5.7E-11	1.1E-1	1.2E-5	2.0E-10	2.0E-3
LANL	159152 1064	5.4E-5	5.7E-9	4.9E-1	1.8E-4	1.9E-8	5.0E-1
ORR	881652 2	0.00	0.00	4.7E-4	0.00	0.00	7.9E-14
Mound	3032983 84	8.4E-7	4.8E-11	3.2E-2	2.9E-6	1.6E-10	4.8E-4
NTS	14266 204	1.1E-10	3.0E-14	6.8E-2	3.9E-10	1.0E-13	7.3E-4
PGDP	500502 15	3.5E-9	3.9E-13	1.3E-2	1.2E-8	1.3E-12	1.6E-6
RFETS	2171877 664	9.3E-6	1.3E-10	2.2E-1	3.2E-5	4.3E-10	2.7E-2
SNL-NM	610714 2	2.7E-9	1.1E-13	8.7E-3	9.1E-9	3.6E-13	2.1E-8
SRS	620618 790	5.1E-5	4.8E-10	3.5E-1	1.7E-4	1.6E-9	3.1E-1
Hanford	377645 715	1.4E-6	2.9E-11	3.3E-1	4.8E-6	9.9E-11	3.6E-1
TOTAL		1.2E-4	5.7E-9	2.7	4.2E-4	1.9E-8	2.1

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.4-14. Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 1, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 121	1.5E-6	8.5E-12	4.5E-2	5.2E-6	2.9E-11	3.0E-2
Hanford	377645 1232	2.3E-6	4.7E-11	5.3E-1	7.7E-6	1.6E-10	4.5E-1
INEL	153061 3100	1.4E-6	1.8E-10	1.2	4.9E-6	6.0E-10	8.7E-1
LBL	5856829 1	9.8E-9	1.5E-13	1.8E-4	3.4E-8	5.0E-13	7.5E-9
LLNL	6324234 186	3.6E-6	5.9E-11	5.7E-2	1.3E-5	2.1E-10	2.0E-3
LANL	159152 1502	6.5E-5	6.9E-9	6.4E-1	2.2E-4	2.3E-8	5.0E-1
PGDP	500502 8	5.3E-9	5.9E-13	2.5E-3	1.8E-8	2.0E-12	1.7E-6
Mound	3032983 47	1.5E-6	8.6E-11	1.4E-2	5.1E-6	2.9E-10	4.7E-4
NTS	14266 137	1.5E-10	3.9E-14	4.2E-2	5.1E-10	1.3E-13	7.0E-4
RFETS	2171877 989	1.5E-5	2.0E-10	3.4E-1	5.1E-5	6.9E-10	2.7E-2
SNL-NM	610714 1	3.5E-9	1.4E-13	4.5E-4	1.2E-8	4.8E-13	2.1E-8
SRS	620618 1115	8.1E-5	7.7E-10	4.6E-1	2.8E-4	2.6E-9	3.1E-1
TOTAL		1.7E-4	6.9E-9	3.4	5.9E-4	2.3E-8	2.2

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.4-15. Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 2, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 121	1.5E-6	8.5E-12	4.5E-2	5.2E-6	2.9E-11	3.0E-2
Hanford	377645 2184	4.5E-3	9.4E-8	8.1E-1	1.6E-2	3.2E-7	4.9E-1
INEL	153061 5364	7.3E-3	9.1E-7	1.8	2.5E-2	3.1E-6	8.3E-1
LBL	5856829 1	9.8E-9	1.5E-13	1.8E-4	3.4E-8	5.0E-13	7.5E-9
LLNL	6324234 186	3.6E-6	5.9E-11	5.7E-2	1.3E-5	2.1E-10	2.0E-3
LANL	159152 2772	6.4E-1	6.7E-5	9.6E-1	2.2	2.3E-4	4.8E-1
PGDP	500502 8	5.3E-9	5.9E-13	2.5E-3	1.8E-8	2.0E-12	1.7E-6
Mound	3032983 47	1.5E-6	8.6E-11	1.4E-2	5.1E-6	2.9E-10	4.7E-4
NTS	14266 137	1.5E-10	3.9E-14	4.2E-2	5.1E-10	1.3E-13	7.0E-4
RFETS	2171877 1852	1.1E-1	1.5E-6	5.7E-1	3.7E-1	5.0E-6	2.5E-2
SNL-NM	610714 1	3.5E-9	1.4E-13	4.5E-4	1.2E-8	4.8E-13	2.1E-8
SRS	620618 1896	2.6	2.4E-5	6.8E-1	8.8	8.2E-5	3.0E-1
TOTAL		3.3	6.7E-5	5.0	1.1E1	2.3E-4	2.1

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.4-16. Risks Associated with Managing CH-TRUW Under the Regionalized Alternative 3, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 121	1.5E-6	8.5E-12	4.5E-2	5.2E-6	2.9E-11	3.0E-2
Hanford	377645 2184	4.5E-3	9.4E-8	8.1E-1	1.6E-2	3.2E-7	4.9E-1
INEL	153061 6277	4.1E-2	5.1E-6	2.1	1.4E-1	1.7E-5	8.7E-1
LBL	5856829 1	9.8E-9	1.5E-13	1.8E-4	3.4E-8	5.0E-13	7.5E-9
LLNL	6324234 186	3.6E-6	5.9E-11	5.7E-2	1.3E-5	2.1E-10	2.0E-3
LANL	159152 713	7.1E-5	7.4E-9	3.8E-1	2.4E-4	2.5E-8	5.0E-1
PGDP	500502 8	5.3E-9	5.9E-13	2.5E-3	1.8E-8	2.0E-12	1.7E-6
Mound	3032983 47	1.5E-6	8.6E-11	1.4E-2	5.1E-6	2.9E-10	4.7E-4
NTS	14266 137	1.5E-10	3.9E-14	4.2E-2	5.1E-10	1.3E-13	7.0E-4
RFETS	2171877 420	1.2E-5	1.6E-10	1.6E-1	4.1E-5	5.6E-10	1.0E-1
SNL-NM	610714 1	3.5E-9	1.4E-13	4.5E-4	1.2E-8	4.8E-13	2.1E-8
SRS	620618 1896	2.6	2.4E-5	6.8E-1	8.8	8.2E-5	3.0E-1
TOTAL		2.6	2.4E-5	4.3	8.9	8.2E-5	2.3

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.4-17. Risks Associated with Managing CH-TRUW Under the Centralized Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
WIPP	99889 6125	6.1E-1	1.6E-4	1.8	2.1	5.4E-4	2.3E-1
ANL-E	7939785 121	1.5E-6	8.5E-12	4.5E-2	5.2E-6	2.9E-11	3.0E-2
Hanford	377645 476	1.3E-6	2.7E-11	2.4E-1	4.4E-6	9.1E-11	3.3E-1
INEL	153061 1586	1.6E-6	2.0E-10	7.6E-1	5.3E-6	6.6E-10	8.5E-1
LBL	5856829 1	9.8E-9	1.5E-13	1.8E-4	3.4E-8	5.0E-13	7.5E-9
LLNL	6324234 186	3.6E-6	5.9E-11	5.7E-2	1.3E-5	2.1E-10	2.0E-3
LANL	159152 713	7.1E-5	7.4E-9	3.8E-1	2.4E-4	2.5E-8	5.0E-1
PGDP	500502 8	5.3E-9	5.9E-13	2.5E-3	1.8E-8	2.0E-12	1.7E-6
Mound	3032983 47	1.5E-6	8.6E-11	1.4E-2	5.1E-6	2.9E-10	4.7E-4
NTS	14266 137	1.5E-10	3.9E-14	4.2E-2	5.1E-10	1.3E-13	7.0E-4
RFETS	2171877 420	1.2E-5	1.6E-10	1.6E-1	4.1E-5	5.6E-10	1.0E-1
SNL-NM	610714 1	3.5E-9	1.4E-13	4.5E-4	1.2E-8	4.8E-13	2.1E-8
SRS	620618 416	6.4E-5	6.0E-10	2.2E-1	2.2E-4	2.0E-9	3.3E-1
TOTAL		6.1E-1	1.6E-4	3.7	2.1	5.4E-4	2.4

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.4–18. CH-TRUW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population At Each Installation, By Alternative

Alternative	Installation													
	ANL-E	Hanford	INEL	LANL	LBL	LLNL	Mound	NTS	PGDP	RFETS	SNL-NM	SRS	ORR	WIPP
No Action	Pu-239[a] 4.21E-7[b]	Pu-238 2.45E-7	Am-241 1.34E-9	Am-241 2.14E-6	Pu-239 2.53E-10	Pu-239 5.68E-7	Pu-238 0.00	Pu-242 0.00	Pu-242 0.00	Am-241 1.59E-6	Pu-242 0.00	Pu-238 1.32E-5		
Decentralized	Pu-239 1.37E-6	Pu-238 9.81E-7	Am-241 5.84E-7	Am-241 2.80E-5	Pu-239 3.25E-9	Pu-239 1.79E-6	Pu-238 8.38E-7	Pu-239 2.29E-10	Pu-239 1.82E-9	Am-241 4.94E-6	Pu-239 1.38E-9	Pu-238 4.85E-5	Pu-242 0.00	
Regionalized 1	Pu-239 1.18E-6	Pu-238 1.29E-6	Am-241 7.39E-7	Am-241 3.42E-5	Pu-239 5.11E-9	Pu-239 1.88E-6	Pu-238 1.50E-6	Pu-239 3.01E-10	Pu-239 2.76E-9	Am-241 7.94E-6	Pu-239 1.81E-9	Pu-238 7.81E-5		
Regionalized 2	Pu-239 1.18E-6	Pu-239 1.78E-3	Am-241 3.80E-3	Am-241 3.33E-1	Pu-239 5.11E-9	Pu-239 1.88E-6	Pu-238 1.50E-6	Pu-239 3.01E-10	Pu-239 2.76E-9	Am-241 5.82E-2	Pu-239 1.81E-9	Pu-238 2.47		
Regionalized 3	Pu-239 1.18E-6	Pu-239 1.78E-3	Am-241 2.13E-2	Am-241 3.68E-5	Pu-239 5.11E-9	Pu-239 1.88E-6	Pu-238 1.50E-6	Pu-239 3.01E-10	Pu-239 2.76E-9	Am-241 6.45E-6	Pu-239 1.81E-9	Pu-238 2.47		
Centralized	Pu-239 1.18E-6	Pu-238 9.02E-7	Am-241 8.11E-7	Am-241 3.68E-5	Pu-239 5.11E-9	Pu-239 1.88E-6	Pu-238 1.50E-6	Pu-239 3.01E-10	Pu-239 2.76E-9	Am-241 6.45E-6	Pu-239 1.81E-9	Pu-238 6.10E-5		Pu-238 5.19E-1

[a] Radionuclide contributing most risk.
[b] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this installation.

D.3.4.4 Results of the CH-TRUW Human Health Risk Analysis for Routine Operations

In general, No Action presents the lowest health risks for all public and worker populations and for all health risk endpoints because no waste treatment is performed other than packaging. For offsite and noninvolved worker receptors, the health risks associated with the other CH-TRUW alternatives generally increase as more extensive waste treatment is assumed; the alternatives with the highest estimated health risks are those involving treatment to meet RCRA LDRs. For workers, all alternatives that include waste treatment involve similar health risks. Overall, the health risks from exposure to chemicals in CH-TRUW are considerably lower than from exposure to radionuclides. In addition, the probability of adverse effects from noncarcinogenic, hazardous chemicals is very low.

Estimated impacts to each receptor population are summarized below.

D.3.4.4.1 *Program-Wide Trends in Human Health Risks Associated with CH-TRUW Management Alternatives*

Offsite Population. Radiological and chemical exposure risks to the offsite population are lowest for No Action in which CH-TRUW is stored, without treatment, at the 16 generator installations in existing or approved facilities. The program-wide risk of cancer fatality for this alternative is 2.3E-5 distributed over a total affected offsite population of approximately 19 million (see Tables D.3.4–3 and D.3.4–4). The exposure risks to offsite populations in Decentralized (in which wastes are treated to WIPP waste acceptance criteria and stored at 10 installations) and Regionalized 1 (in which wastes are treated to reduce gas generation and stored at 5 installations) are slightly higher than those for No Action and are distributed over a similar total population. Regionalized 2, 3, and Centralized, the three alternatives in which CH-TRUW receives the extensive treatment necessary to meet RCRA LDRs, show markedly higher risks to offsite populations than other alternatives, with 0.61 to 3.3 estimated cancer fatalities over a total population of approximately 24 million people.

The highest risks to the offsite population are associated with Regionalized 2 and 3 (in which wastes are treated to RCRA LDRs and stored at five and three installations, respectively). Estimated program-wide cancer fatalities for all 12 installations in Regionalized 2 and 3 are 3.3 and 2.6, respectively, for a total offsite population of approximately 23 million. Tables D.3.4–15 and D.3.4–16 show that the predominant

portion of the estimated cancer risks in Regionalized 2 and 3 are attributed to SRS, where, in both alternatives, 2.6 cancer fatalities in a population of 620,618 are estimated to occur over a 10-year treatment period. The higher estimated cancer risks at this installation are linked to its relatively large inventory of plutonium-238 (the larger the contaminant inventory with respect to other installations, the larger the amount of contaminant assumed to be released during treatment).

The risks of radionuclide-related cancer incidence and genetic effects follow the same general trend as for cancer fatalities. Estimated program-wide risk of cancer incidence due to exposure to carcinogenic chemicals remains fairly consistent (in the E-7 order of magnitude) across alternatives except for No Action in which this estimated risk is slightly lower by approximately 1 order of magnitude.

Noninvolved Worker Population. The program-wide health risks to noninvolved worker populations parallel the trends observed for offsite populations but are slightly lower and involve much smaller affected populations (see Table D.3.4–4). Regionalized 2 poses the highest program-wide risk to noninvolved worker populations (0.34 total estimated cancer fatalities); however, the estimated cancer fatality risk for Regionalized 3 (0.29) is only slightly lower than for Regionalized 2. The program-wide risk of cancer incidence due to exposure to carcinogenic chemicals is in the E-7 order of magnitude in all except No Action, where it is slightly lower (by approximately 1 order of magnitude).

Most-Exposed Noninvolved Worker and Offsite Individual. As shown in Table D.3.4–5, radiological exposure risks to the noninvolved worker and offsite MEIs are lowest for No Action, slightly higher for Decentralized and Regionalized 1, and highest by approximately 4 to 5 orders of magnitude for Regionalized 2, 3, and Centralized. This trend generally parallels that seen for noninvolved worker and offsite populations. The risk of cancer fatality for an MEI in Regionalized 2 and 3 are in the E-5 to E-4 range, and the highest risk of cancer fatality for an MEI is in the Centralized Alternative (1.9E-4 for the noninvolved worker MEI and 1.6E-4 for the offsite MEI). As discussed previously in this appendix, the EPA considers that risks of cancer incidence to an individual between 1.0E-4 and 1.0E-6 are within target risk levels (EPA, 1991b). In the alternatives involving treatment to LDRs (Regionalized 2, 3, and Centralized), the risks of cancer incidence to the noninvolved worker (Regionalized 2, 3, and Centralized) and offsite (Regionalized 2 and Centralized) MEIs from radionuclides exceed target risk levels.

Tables D.3.4–15 through D.3.4–17 show that the highest risks of cancer fatality to the offsite MEI are at SRS, LANL, and RFETS in Regionalized 2; SRS and INEL in Regionalized 3; and WIPP in the Centralized Alternative. The elevated risks to the MEIs at these installations are due to two factors. First, in Regionalized 2 and 3, elevated cancer risks to the MEIs at SRS, LANL, and RFETS result from increased exposure to emissions during treatment to LDRs. Second, in Regionalized 3 and Centralized, elevated cancer risks to the MEIs at INEL and WIPP result from a combination of increased emissions from treatment to LDRs and increased waste loads from consolidation.

All health risks due to chemical exposures are relatively low compared to radiation risks. Estimated risk of cancer incidence to each MEI due to chemical exposure is similar among alternatives and does not exceed the E-11 order of magnitude. In addition, the hazard indices for both MEIs are at least 7 orders of magnitude below 1.0 in all alternatives, indicating that adverse health effects from noncarcinogenic chemicals are unlikely.

Workers. As observed for public receptor populations, program-wide radiological and chemical exposure risks to workers are lowest in No Action. Worker health risks for No Action are lower than for the other alternatives by more than 1 order of magnitude (9.6E-3 estimated cancer fatalities over a population of 1,690 FTEs). No treatment is performed and fewer FTEs are required than in the other alternatives, resulting in less collective exposure. The estimated risk of cancer fatality (approximately 6E-1) and cancer incidence (approximately 2.0) due to radiation exposure are approximately equal in all but No Action, indicating that collective worker radiation exposure is relatively independent of the type of CH-TRUW treatment involved.

Worker health risks associated with chemical exposure vary slightly among alternatives. The exposure index, or worst-case individual worker exposure to noncarcinogenic chemicals, follows the trend for the noninvolved worker and offsite MEIs (No Action is the lowest; Decentralized and Regionalized 1 are slightly higher; and Regionalized 2, 3, and Centralized are substantially higher). However, the exposure indices in all alternatives are at least 3 orders of magnitude below 1.0, indicating a low probability of adverse health effects from noncarcinogenic, hazardous constituents. The risk of worker cancer incidence from chemical exposure rises gradually across alternatives (lowest in No Action and slightly higher in the other alternatives). As seen with public receptor populations, chemical exposure contributes much less to worker health risk estimates than radiation exposure.

Estimated construction and operational fatalities are always higher than those associated with radiation exposure, regardless of alternative. No Action results in lower worker health risks from physical hazards because fewer person-hours are spent in construction and operation of facilities; therefore, injuries and fatalities are less likely. Regionalized 2 poses the highest risk of construction and operation fatalities of all the alternatives (4.4), reflecting the greatest number of person-hours devoted to these activities (see Table D.3.4–4).

Discussion. Radiation exposure risks from the routine management of CH-TRUW are substantially greater for all populations than chemical exposure risks; in addition, risks of worker fatalities due to physical hazards are always greater than those due to exposure.

For the offsite population, SRS consistently poses the highest estimated cancer fatalities except in the Centralized Alternative, where the highest risk to the offsite population is at WIPP. The radionuclides contributing the most risk to the offsite population at SRS in Regionalized 2 and 3 are americium and plutonium isotopes through inhalation and ingestion (see Table D.3.4–18). The controlling radionuclides are the same at WIPP in the Centralized Alternative, reflecting the consolidation of SRS's CH-TRUW at WIPP. Note that the cancer fatality risk to the offsite population is more than four times higher when SRS treats its own waste than when its waste is treated at WIPP. This reflects the larger size and higher density of the population surrounding SRS (compare the population distributions for SRS and WIPP as shown in Tables D.3.4–19 and D.3.4–20).

For workers, the highest estimated total fatalities (cancer fatalities plus construction and operational fatalities) are associated with INEL in every alternative except No Action, where Hanford has the highest worker fatality risks, and Centralized, where WIPP has the highest number of total fatalities. As might be expected, for each alternative, the installation with the highest worker risk also has the highest number of FTEs involved in CH-TRUW management. The radionuclides contributing the most risk for workers at these installations are uranium-238 and uranium-235 at INEL via inhalation; and cesium-137 at Hanford and WIPP via external exposure.

D.3.4.4.2 *Comparison of the Decentralized Alternative and Regionalized Alternative 1: Treatment to WIPP Waste Acceptance Criteria versus Treatment to Reduce Gas Generation*

A comparison of the Decentralized Alternative, in which CH-TRUW is stored and treated to WIPP waste acceptance criteria at 10 installations, and Regionalized 1, in which CH-TRUW is stored and treated to reduce gas generation at five installations, shows few differences in the health risks associated with these two treatment and consolidation options. The major difference between treating to WIPP waste acceptance criteria and treating to reduce gas generation is the addition of a waste shredding step in Regionalized 1, therefore, treatment risks should not be substantially different. The number of installations at which waste is consolidated also does not greatly affect the overall health risks.

D.3.4.4.3 *Comparison of Regionalized Alternatives 1 and 2: Treatment to Reduce Gas Generation versus Treatment to Land Disposal Restrictions*

A more controlled comparison of treatment risks can be made between Regionalized 1 and 2 since consolidation schemes are identical (wastes are treated and stored at the same five installations in both alternatives) but treatments differ (treatment to reduce gas generation in Regionalized 1 versus treatment to LDRs in Regionalized 2). As previously noted, the program-wide risks of cancer fatalities, cancer incidence, and genetic effects from radiation exposure associated with treatment to LDRs in Regionalized 2 are approximately 4 orders of magnitude greater for the offsite and noninvolved worker populations and MEIs than the risks from treatment for minimization of gas generation in Regionalized 1. While these radionuclide-related health effects differ between the two alternatives, the contribution of chemical carcinogens to cancer incidence is almost the same in each alternative for each population.

The program-wide risks to workers from radionuclide exposure are nearly the same in Regionalized 1 and 2. In addition, the risk of chemical-related cancer incidence in workers is nearly identical between alternatives. This reflects the fact that collective worker exposure is similar between the alternatives, regardless of the different treatment options.

The offsite and noninvolved worker MEI hazard indices for Regionalized 2 are approximately two orders of magnitude higher than in Regionalized 1, and the Regionalized 2 worker exposure index is about 1 order of magnitude higher than in Regionalized 1. This trend reflects the potential for higher worst-case

individual exposure to noncarcinogenic hazardous chemicals when CH-TRUW is treated to LDRs. However, in all alternatives, exposures to noncarcinogenic, hazardous chemicals yield hazard indices well below 1.0.

D.3.4.4.4 *Comparison of the Regionalized 2, 3, and Centralized Alternatives: Differences in Consolidation Configuration*

Examination of the Regionalized 2, 3, and Centralized Alternatives provides a comparison of consolidation and interim storage configurations; in these three alternatives, wastes are treated to LDRs but are consolidated and stored at five, three, and one installation(s), respectively. As discussed above, the program-wide radiation exposure risks to all populations are very similar across all three alternatives with certain exceptions: In the Centralized Alternative, the risk of cancer fatality, cancer incidence, and genetic effects to offsite populations is 1 order of magnitude lower than the risks in Regionalized 2 and 3 because of the smaller population size and lower population density at WIPP compared to installations such as SRS, INEL, and Hanford. Also, the population at only one installation, rather than several, is being exposed. However, the risks to the offsite and noninvolved worker MEIs are slightly higher in the Centralized Alternative than in Regionalized 2 and 3. These higher risks could be due to a combination of factors including the proximity of neighboring ranches to WIPP and the influence of weather conditions such as wind speed and direction. As previously noted, the estimated cancer incidence risks to the offsite and noninvolved worker MEIs exceed EPA target risk levels (offsite MEI cancer fatality risk 1.6E-4; noninvolved worker MEI cancer fatality risk 1.9E-4).

Table D.3.4–19. Population Distribution Around SRS, Based on the 1990 U.S. Census

Direction from Installation	Distance from Installation										
	0.8 km	2.4 km	4.0 km	5.6 km	7.2 km	12 km	24 km	40 km	56 km	72 km	Total
S	0.00	0.00	0.00	0.00	0.00	0.00	618.00	1,291.00	7,146.00	3,060.00	12,115.00
SSW	0.00	0.00	0.00	0.00	0.00	0.00	496.00	2,197.00	5,795.00	2,844.00	11,332.00
SW	0.00	0.00	0.00	0.00	0.00	0.00	1,283.00	6,379.00	898.00	2,077.00	10,637.00
WSW	0.00	0.00	0.00	0.00	0.00	4.00	1,201.00	3,580.00	1,491.00	6,157.00	12,433.00
W	0.00	0.00	0.00	0.00	0.00	45.00	6,431.00	7,295.00	3,050.00	8,251.00	25,072.00
WNW	0.00	0.00	0.00	0.00	0.00	1,980.00	2,529.00	141,404.00	32,376.00	16,308.00	194597.00
NW	0.00	0.00	0.00	0.00	0.00	475.00	14,925.00	87,876.00	6,296.00	2,327.00	111,899.00
NNW	0.00	0.00	0.00	0.00	0.00	786.00	18,188.00	11,409.00	7,099.00	2,700.00	40,182.00
N	0.00	0.00	0.00	0.00	0.00	3,137.00	21,804.00	10,819.00	6,626.00	10,148.00	52,534.00
NNE	0.00	0.00	0.00	0.00	0.00	12.00	1,431.00	1,777.00	3,117.00	15,556.00	21,893.00
NE	0.00	0.00	0.00	0.00	0.00	0.00	1,522.00	2,030.00	4,951.00	11,660.00	20,163.00
ENE	0.00	0.00	0.00	0.00	0.00	0.00	4,187.00	4,222.00	5,293.00	31,334.00	45,036.00
E	0.00	0.00	0.00	0.00	0.00	0.00	5,294.00	4,027.00	12,122.00	4,551.00	25,994.00
ESE	0.00	0.00	0.00	0.00	0.00	0.00	2,730.00	2,218.00	1,999.00	2,817.00	9,764.00
SE	0.00	0.00	0.00	0.00	0.00	0.00	593.00	5,773.00	5,699.00	11,579.00	23,644.00
SSE	0.00	0.00	0.00	0.00	0.00	0.00	179.00	482.00	551.00	2,111.00	3,323.00
Total	0.00	0.00	0.00	0.00	0.00	6,439.00	83,411.00	292,779.00	104,509.00	133,480.00	620618.00

Table D.3.4–20. Population Distribution Around the Waste Isolation Pilot Plant (WIPP), Based on the 1990 U.S. Census

Direction from Installation	Distance from Installation										
	0.8 km	2.4 km	4.0 km	5.6 km	7.2 km	12 km	24 km	40 km	56 km	72 km	Total
S	0.00	0.00	0.00	0.00	0.00	0.00	3.00	2.00	46.00	20.00	71.00
SSW	9.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	43.00	8.00	62.00
SW	0.00	0.00	0.00	0.00	0.00	0.00	37.00	57.00	0.00	5.00	99.00
WSW	0.00	0.00	0.00	0.00	0.00	0.00	1,622.00	191.00	57.00	62.00	1,932.00
W	0.00	0.00	0.00	0.00	0.00	0.00	138.00	25,291.00	197.00	3.00	25,629.00
WNW	0.00	0.00	0.00	0.00	0.00	0.00	38.00	5,765.00	242.00	63.00	6,108.00
NW	0.00	0.00	0.00	0.00	0.00	0.00	6.00	7.00	14.00	12,401.00	12,428.00
NNW	0.00	0.00	0.00	0.00	0.00	9.00	4.00	66.00	104.00	56.00	239.00
N	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	63.00	12.00	78.00
NNE	0.00	0.00	0.00	0.00	0.00	0.00	4.00	3.00	122.00	7,353.00	7,482.00
NE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00	37.00	9,115.00	9,163.00
ENE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	282.00	30,877.00	31,169.00
E	0.00	0.00	0.00	0.00	0.00	0.00	6.00	5.00	2,982.00	19.00	3,012.00
ESE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	2,173.00	97.00	2,286.00
SE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	20.00	35.00
SSE	0.00	0.00	0.00	0.00	0.00	1.00	3.00	14.00	5.00	73.00	96.00
TOTAL	9.00	0.00	0.00	0.00	0.00	10.00	1,864.00	31,440.00	6,382.00	60,184.00	99,889.00

Risk of cancer incidence due to chemical exposure is within the same order of magnitude for all public receptor populations in all three alternatives. The hazard index for the offsite MEI in Regionalized 3 is slightly lower than the Regionalized 2 or Centralized estimates.

Worker radiation and chemical exposure risks are similar among the Regionalized 2, 3, and Centralized Alternatives.

D.3.4.4.5 *Summary of the Human Health Risk Analysis for Routine Management of CH-TRUW*

In summary, the No Action Alternative presents the fewest health risk to all populations. Health risks generally increase for the public receptors as more extensive treatment of CH-TRUW is assumed. Overall health risks to workers do not differ appreciably with different treatment options. The primary risk drivers for the public receptor populations are radiation exposure (as opposed to chemical exposure) and treatment option. For workers, the primary risk drivers are the size of the waste load and the person-hours necessary to process it.

D.3.4.5 Summary of RH-TRUW Alternatives

The PEIS waste management alternatives (No Action, Decentralization, Regionalization, and Centralization) and the rationale for developing the various RH-TRUW analysis alternatives are discussed rigorously in the main body of the PEIS. Four alternatives are analyzed for the RH-TRUW human health risk analysis:

- The No Action Alternative demonstrates the baseline risks of RH-TRUW retrieval, packaging, certification, and indefinite interim storage at ANL-E, Hanford, INEL, LANL, and ORR. Treatment is not considered and it is assumed that TRUW will not be disposed of at WIPP.
- In the Decentralized Alternative, risks are estimated for building additional treatment facilities as required, treating wastes to WIPP waste acceptance criteria, and storing them at the five installations pending disposal at WIPP.
- In the Regionalized Alternative 1, RH-TRUW is consolidated, treated to minimize gas generation, and stored at Hanford and ORR.

- In the Regionalized 2, 3, and Centralized Alternatives, RH-TRUW is consolidated, treated to meet RCRA LDRs, and stored at Hanford and ORR. (This scenario makes it possible to contrast the risks of different levels of treatment of RH-TRUW by comparison with Regionalized Alternative 1.)

Table D.3.4–21 presents the overall treatment and storage schemes for these RH-TRUW alternatives. Table D.3.4–22 shows which installations will ship their wastes to regionalized or centralized consolidation installations for treatment and storage. Note that for the purposes of this risk analysis, the waste load from a smaller generator, ANL-W, was added to the inventory of INEL, a larger generator (ANL, 1995b), as the two installations are in close proximity to one another.

The discussion of the risk analysis results will address the overall health risk trends across the alternatives discussed above, comparisons among alternatives, higher-risk installations and alternatives, and major factors driving the estimated risks.

Table D.3.4–21. PEIS Alternatives for RH-TRUW

Alternative	ANL-E	Hanford	INEL	LANL	ORR
No Action Alternative	T[a]	T	T	T	T
No treatment; store at 5 installations	S[b]	S	S	S	S
Decentralized Alternative	T	T	T	T	T
Treat to WIPP-WAC and store at 5 installations	S	S	S	S	S
Regionalized Alternative 1		T			T
Treat to reduce gas and store at 2 installations		S			S
Regionalized Alternatives 2, 3, and Centralized Alternative		T			T
Treat to RCRA LDRs and store at 2 installations		S			S

[a] T—treatment installation.
[b] S—storage installation.

Table D.3.4-22. PEIS Consolidation and Treatment Strategies for RH-TRUW

Alternative	Origin	Treatment and Storage Destination
No Action Alternative No treatment; store at 5 installations	All installations	Generators store own waste
Decentralized Alternative Treat to WIPP-WAC and store at 5 installations	All installations	Generators treat and store own waste
Regionalized Alternative 1 Treat to minimize gas generation and store at 2 installations	Hanford, INEL/ANL-W[a], LANL, ORR, ANL-E	Hanford ORR
Regionalized Alternatives 2, 3, and Centralized Alternative Treat to RCRA LDRs and store at 2 installations	Hanford, INEL/ANL-W[a], LANL, ORR, ANL-E	Hanford ORR

[a] For the purpose of the human health risk analysis, the ANL-W waste load is added to the INEL waste load.

D.3.4.6 Results Tables for the RH-TRUW Human Health Risk Analysis

This section contains the results tables for the RH-TRUW human health risk analysis. A discussion of the results is presented in Section D.3.4.7. The fatality and cancer incidence numbers in the tables are displayed in the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.4-23 presents an overview, by alternative, of the *total*, program-wide risks of cancer fatalities and cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers. These tables provide the estimated *total number* of people in the three populations who will develop or die of cancers caused by exposure to RH-TRUW if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities.
- Table D.3.4-24 shows the sizes of the total affected populations for each alternative.
- Table D.3.4-25 summarizes the risks to the noninvolved worker MEI and offsite MEI for each RH-TRUW alternative. The numbers in this table are the estimated *probabilities* that the noninvolved worker and offsite MEIs will die of or develop cancer from radionuclide or chemical exposure, or indicators of the likelihood of suffering adverse health effects from exposure to noncarcinogenic, hazardous constituents.
- Tables D.3.4-26 through D.3.4-29 show the program-wide risks for all receptors and health effect endpoints, by alternative.
- Tables D.3.4-30 through D.3.4-33 present offsite and worker population risks for each installation, by alternative.

- Table D.3.4–34 lists the radionuclides that contribute most of the risk to the offsite population, by installation and alternative.

Table D.3.4–23. Summary of Program-Wide Risks Associated with Routine Management of RH-TRUW: Risks to Total Populations, by Alternative

Alternative	Offsite Population		Noninvolved Worker Population		WM Workers		
	CF[a]	CI[b]	CF	CI	CF	CI	C&OF[c]
No Action	8.8E-7	3.0E-6	3.7E-8	1.3E-7	1.7E-4	5.9E-4	8.6E-2
Decentralized	5.3E-6	1.8E-5	2.3E-7	8.2E-7	4.9E-3	1.7E-2	4.2E-1
Regionalized 1	5.6E-6	1.9E-5	2.4E-7	8.6E-7	5.1E-3	1.8E-2	4.2E-1
Regionalized 2, 3, and Centralized	5.2E-2	1.8E-1	1.8E-3	6.1E-3	9.3E-2	3.3E-1	8.5E-1

[a] CF—cancer fatality associated with radionuclide exposure.
[b] CI—cancer incidence associated with exposure to radionuclides and carcinogenic chemicals.
[c] C&OF—fatalities due to the physical hazards of constructing and operating waste management facilities.

Table D.3.4–24. Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Routine Management of RH-TRUW, by Alternative

Alternative	Offsite	Noninvolved Worker	WM Worker
No Action	9,511,295	38,057	417
Decentralized	9,511,295	38,057	1,234
Regionalized 1	9,511,295	38,057	1,261
Regionalized 2, 3, and Centralized	9,511,295	38,057	2,544

Table D.3.4-25. Summary of Program-Wide Risks Associated with Routine Management of RH-TRUW: Risks To the Most-Exposed Offsite Individual and Most-Exposed Noninvolved Worker, by Alternative

Alternative	Offsite MEI				Noninvolved Worker MEI			
	CF[a]	Rad CI[b]	Chem CI[c]	HI[d]	CF	Rad CI	Chem CI	HI
No Action	1.5E-11	5.2E-11	4.0E-13	3.3E-12	5.8E-11	2.0E-10	2.5E-12	2.0E-11
Decentralized	8.8E-11	3.0E-10	8.1E-12	1.3E-10	3.4E-10	1.1E-9	5.0E-11	8.0E-10
Regionalized 1	9.3E-11	3.2E-10	8.1E-12	1.3E-10	3.5E-10	1.2E-9	5.0E-11	8.1E-10
Regionalized 2, 3, and Centralized	1.4E-6	4.8E-6	5.7E-12	1.9E-9	1.4E-6	4.8E-6	3.5E-11	1.2E-8

[a] CF—cancer fatality associated with exposure to radionuclides.
[b] Rad CI—cancer incidence associated with exposure to radionuclides.
[c] Chem CI—cancer incidence associated with exposure to carcinogenic chemicals.
[d] HI—hazard index associated with exposure to noncarcinogenic, toxic chemicals.

Table D.3.4-26. Program-Wide Risks Associated with Treatment of RH-TRUW Under the No Action Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	7.4E-5			
	Cancer Fatalities	3.7E-8			
	Cancer Incidence	1.3E-7	2.6E-9		
	Genetic Effects	7.4E-9			
Noninvolved Worker MEI	Dose (rem)	1.2E-7			
	Cancer Fatalities	5.8E-11			
	Cancer Incidence	2.0E-10	2.5E-12		
	Genetic Effects	1.2E-11			
	Hazard Index			2.0E-11	
Offsite Population	Dose (person-rem)	1.8E-3			
	Cancer Fatalities	8.8E-7			
	Cancer Incidence	3.0E-6	8.1E-9		
	Genetic Effects	1.8E-7			
Offsite MEI	Dose (rem)	3.0E-8			
	Cancer Fatalities	1.5E-11			
	Cancer Incidence	5.2E-11	4.0E-13		
	Genetic Effects	3.0E-12			
	Hazard Index			3.3E-12	
WM Workers	Dose (FTE-rem)	4.2E-1			
	Cancer Fatalities	1.7E-4			
	Cancer Incidence	5.9E-4	8.7E-8		
	Genetic Effects	2.5E-5			
	Exposure Index			3.0E-6	
	Construction Fatalities				3.5E-2
	Construction Injuries				1.5E1
	Operation Fatalities				5.1E-2
	Operation Injuries				4.3E1

Table D.3.4-27. Program-Wide Risks Associated with Treatment of RH-TRUW Under the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	4.5E-4			
	Cancer Fatalities	2.3E-7			
	Cancer Incidence	7.7E-7	5.2E-8		
	Genetic Effects	4.5E-8			
Noninvolved Worker MEI	Dose (rem)	6.7E-7			
	Cancer Fatalities	3.4E-10			
	Cancer Incidence	1.1E-9	5.0E-11		
	Genetic Effects	6.7E-11			
	Hazard Index			8.0E-10	
Offsite Population	Dose (person-rem)	1.1E-2			
	Cancer Fatalities	5.3E-6			
	Cancer Incidence	1.8E-5	1.6E-7		
	Genetic Effects	1.1E-6			
Offsite MEI	Dose (rem)	1.8E-7			
	Cancer Fatalities	8.8E-11			
	Cancer Incidence	3.0E-10	8.1E-12		
	Genetic Effects	1.8E-11			
	Hazard Index			1.3E-10	
WM Workers	Dose (FTE-rem)	1.2E1			
	Cancer Fatalities	4.9E-3			
	Cancer Incidence	1.7E-2	3.0E-6		
	Genetic Effects	7.3E-4			
	Exposure Index			3.0E-5	
	Construction Fatalities				2.7E-1
	Construction Injuries				1.2E2
	Operation Fatalities				1.5E-1
	Operation Injuries				1.3E2

Table D.3.4-28. Program-Wide Risks Associated with Treatment of RH-TRUW Under the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	4.8E-4			
	Cancer Fatalities	2.4E-7			
	Cancer Incidence	8.1E-7	5.2E-8		
	Genetic Effects	4.8E-8			
Noninvolved Worker MEI	Dose (rem)	7.0E-7			
	Cancer Fatalities	3.5E-10			
	Cancer Incidence	1.2E-9	5.0E-11		
	Genetic Effects	7.0E-11			
	Hazard Index			8.1E-10	
Offsite Population	Dose (person-rem)	1.1E-2			
	Cancer Fatalities	5.6E-6			
	Cancer Incidence	1.9E-5	1.6E-7		
	Genetic Effects	1.1E-6			
Offsite MEI	Dose (rem)	1.9E-7			
	Cancer Fatalities	9.3E-11			
	Cancer Incidence	3.2E-10	8.1E-12		
	Genetic Effects	1.9E-11			
	Hazard Index			1.3E-10	
WM Workers	Dose (FTE-rem)	1.3E1			
	Cancer Fatalities	5.1E-3			
	Cancer Incidence	1.8E-2	3.4E-6		
	Genetic Effects	7.6E-4			
	Exposure Index			3.0E-5	
	Construction Fatalities				2.6E-1
	Construction Injuries				1.2E2
	Operation Fatalities				1.5E-1
	Operation Injuries				1.3E2

Table D.3.4–29. Program-Wide Risks Associated with Treatment of RH-TRUW Under the Regionalized 2, 3, and Centralized Alternatives, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	3.6			
	Cancer Fatalities	1.8E-3			
	Cancer Incidence	6.1E-3	3.7E-8		
	Genetic Effects	3.6E-4			
Noninvolved Worker MEI	Dose (rem)	2.8E-3			
	Cancer Fatalities	1.4E-6			
	Cancer Incidence	4.8E-6	3.5E-11		
	Genetic Effects	2.8E-7			
	Hazard Index			1.2E-8	
Offsite Population	Dose (person-rem)	1.0E2			
	Cancer Fatalities	5.2E-2			
	Cancer Incidence	1.8E-1	1.1E-7		
	Genetic Effects	1.0E-2			
Offsite MEI	Dose (rem)	2.8E-3			
	Cancer Fatalities	1.4E-6			
	Cancer Incidence	4.8E-6	5.7E-12		
	Genetic Effects	2.8E-7			
	Hazard Index			1.9E-9	
WM Workers	Dose (FTE-rem)	2.3E2			
	Cancer Fatalities	9.3E-2			
	Cancer Incidence	3.3E-1	5.2E-6		
	Genetic Effects	1.4E-2			
	Exposure Index			3.0E-5	
	Construction Fatalities				5.4E-1
	Construction Injuries				2.4E2
	Operation Fatalities				3.1E-1
	Operation Injuries				2.6E2

Table D.3.4–30. Risks Associated with Treatment of RH-TRUW Under the No Action Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 30	7.4E-8	4.1E-13	6.1E-3	2.5E-7	1.4E-12	1.0E-7
Hanford	377645 / 264	7.4E-7	1.5E-11	5.4E-2	2.5E-6	5.2E-11	5.8E-4
INEL	153061 / 77	4.1E-9	5.1E-13	1.6E-2	1.4E-8	1.7E-12	1.0E-5
LANL	159152 / 5	6.7E-10	7.0E-14	1.1E-3	2.3E-9	2.4E-13	3.5E-9
ORR	881652 / 41	6.6E-8	2.1E-12	8.4E-3	2.3E-7	7.4E-12	1.3E-6
TOTAL		8.8E-7	1.5E-11	8.6E-2	3.0E-6	5.2E-11	5.9E-4

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.4–31. Risks Associated with Treatment of RH-TRUW Under the Decentralized Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 62	1.9E-7	1.1E-12	2.6E-2	6.5E-7	3.6E-12	5.8E-4
Hanford	377645 / 683	4.3E-6	8.8E-11	2.3E-1	1.5E-5	3.0E-10	2.7E-3
INEL	153061 / 168	1.2E-8	1.6E-12	5.9E-2	4.2E-8	5.3E-12	3.7E-3
LANL	159152 / 51	2.0E-8	2.1E-12	2.3E-2	6.7E-8	7.1E-12	4.8E-4
ORR	881652 / 270	8.0E-7	2.5E-11	9.3E-2	2.9E-6	9.2E-11	9.5E-3
TOTAL		5.3E-6	8.8E-11	4.3E-1	1.8E-5	3.0E-10	1.7E-2

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with radiation exposure and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.4-32. Risks Associated with Treatment of RH-TRUW Under the Regionalized Alternative 1, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 29	2.0E-7	1.1E-12	8.9E-3	6.9E-7	3.8E-12	5.2E-4
Hanford	377645 778	4.5E-6	9.3E-11	2.6E-1	1.5E-5	3.2E-10	3.5E-3
INEL	153061 105	1.6E-8	2.0E-12	3.3E-2	5.4E-8	6.7E-12	3.5E-3
LANL	159152 35	2.5E-8	2.6E-12	1.1E-2	8.5E-8	9.0E-12	4.6E-4
ORR	881652 314	8.3E-7	2.6E-11	1.1E-1	3.0E-6	9.5E-11	9.7E-3
TOTAL		5.6E-6	9.3E-11	4.2E-1	1.9E-5	3.2E-10	1.8E-2

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with radiation exposure and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.4-33. Risks Associated with Treatment of RH-TRUW Under the Regionalized 2, 3, and Centralized Alternatives, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
LANL	159152 35	2.5E-8	2.6E-12	1.1E-2	8.5E-8	9.0E-12	4.6E-4
ORR	881652 682	4.6E-2	1.4E-6	3.0E-1	1.6E-1	4.8E-6	3.2E-1
ANL-E	7939785 29	2.0E-7	1.1E-12	8.9E-3	6.9E-7	3.8E-12	5.2E-4
Hanford	377645 1693	6.3E-3	1.3E-7	5.9E-1	2.2E-2	4.5E-7	5.6E-3
INEL	153061 105	1.6E-8	2.0E-12	3.3E-2	5.4E-8	6.7E-12	3.5E-3
TOTAL		5.2E-2	1.4E-6	9.5E-1	1.8E-1	4.8E-6	3.3E-1

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with radiation exposure and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.
[d] Offsite.

Table D.3.4-34. RH-TRUW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population at Each Installation, By Alternative

Alternative	Installation				
	ANL-E	Hanford	INEL	LANL	ORR
No Action	Pu-239[a] 3.13E-8[b]	Pu-238 4.31E-7	Pu-241 2.13E-9	Pu-239 3.53E-10	Cm-244 3.22E-8
Decentralized	Pu-239 8.02E-8	Pu-238 2.50E-6	Pu-241 6.64E-9	Pu-239 1.04E-8	Cm-244 3.75E-7
Regionalized 1	Pu-239 8.53E-8	Pu-238 2.51E-6	Pu-241 8.46E-9	Pu-239 1.31E-8	Cm-244 3.75E-7
Regionalized 2, 3, and Centralized	Pu-239 8.53E-8	Pu-241 2.57E-3	Pu-241 8.46E-9	Pu-239 1.31E-8	Cm-244 2.11E-2

[a] Radionuclide contributing most risk of cancer fatality.
[b] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this installation.

D.3.4.7 Results of the RH-TRUW Human Health Risk Analysis

D.3.4.7.1 *Program-Wide Trends in Human Health Risks Associated with RH-TRUW Management Alternatives*

In general, the overall risks associated with managing RH-TRUW are somewhat lower than the risks from managing CH-TRUW. No Action presents the lowest health risks for all public and worker populations and for all health risk endpoints because there is no waste treatment other than packaging. For the offsite, noninvolved worker, and worker populations, the health risks associated with the remaining RH-TRUW alternatives generally increase as more extensive waste treatment is employed; the highest estimated health risks are for the RH-TRUW scenario associated with the Regionalized 2, 3, and Centralized Alternatives, which involves incinerating RH-TRUW to destroy organic chemicals to meet RCRA LDRs. For workers, health risks are similar among the alternatives that include waste treatment. Overall, the health risks from exposure to chemicals in RH-TRUW are lower than from exposure to radionuclides, and the probability of adverse effects from noncarcinogenic, hazardous chemicals is very low.

Estimated impacts to each receptor population are summarized below.

Offsite Population. Radiological and chemical exposure risks to the offsite population are lowest for No Action in which RH-TRUW is stored, without treatment, at the five generator installations in existing or approved facilities. The program-wide risk of cancer fatality for this alternative is 8.8E-7 distributed over a total affected offsite population of approximately 9.5 million (see Tables D.3.4–23 and D.3.4–24). The exposure risks to offsite populations in Decentralized (in which wastes are treated to WIPP waste acceptance criteria and stored at five installations) and Regionalized 1 (in which wastes are treated to reduce gas generation and stored at two installations) are slightly higher than those for No Action and are distributed over a similar total population. Treatment of RH-TRUW to LDRs and storage at two installations (Regionalized 2, 3, and Centralized Alternatives) results in markedly higher risks to offsite populations than in the other alternatives, with 5.2E-2 estimated cancer fatalities over a total population of approximately 9.5 million people.

Table D.3.4–33 shows that the predominant portion of the estimated cancer risks when RH-TRUW is treated to meet LDRs and stored at Hanford and ORR (Regionalized 2, 3, and Centralized Alternatives) is attributed to ORR, where 4.6E-2 cancer fatalities in a population of 881,652 are estimated to occur over the 10-year treatment period. The higher estimated cancer risks at this installation are linked to its relatively large inventory of curium-244 (the larger the contaminant inventory with respect to other installations, the larger the amount of contaminant assumed to be released during treatment).

Estimated program-wide risks of cancer incidence from exposure to carcinogenic chemicals remain fairly consistent across alternatives, in the E-7 order of magnitude in all alternatives except No Action, in which cancer incidence risk is 8.1E-9 for the offsite population.

Noninvolved Worker Population. The program-wide health risks to noninvolved worker populations parallel the trends observed for offsite populations but are slightly lower and involve a smaller affected population of 38,052 (see Table D.3.4–24). Treatment of RH-TRUW to LDRs and storage at two installations (Regionalized 2, 3, and Centralized Alternatives) poses the highest program-wide risk to noninvolved worker populations (1.8E-3 total estimated cancer fatalities). The risk of cancer incidence due to exposure to carcinogenic chemicals is in the E-8 order of magnitude in all except No Action, where it is lower by approximately 1 order of magnitude (see Tables D.3.4–26 through D.3.4–29).

Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual. As shown in Table D.3.4–25, radiological risks to the noninvolved worker and offsite MEIs are lowest in No Action, slightly

higher in Decentralized and Regionalized 1, and highest by approximately 4 orders of magnitude in the other alternatives (where RH-TRUW is treated to LDRs and stored at ORR and Hanford). Risks from chemical exposure follow a similar pattern. These trends generally parallel that seen for the total noninvolved worker and offsite populations.

Tables D.3.4–30 through D.3.4–33 show that the highest risks of cancer fatality to the offsite MEI are at Hanford and ORR in the Regionalized 2, 3, and Centralized Alternatives. These elevated risks are due to increased exposure from emissions during treatment to LDRs.

On the program level, estimated risk of cancer incidence due to chemical exposure is similar among alternatives and does not exceed the E-11 order of magnitude. While both MEI hazard indices are approximately 3 orders of magnitude higher in Regionalized 2, 3, and Centralized than in No Action, the hazard indices in all alternatives are well below 1.0, indicating a low probability of adverse health effects from noncarcinogenic, hazardous constituents.

Workers. All exposures to FTEs are below regulatory limits. As was the case for CH-TRUW, RH-TRUW worker exposure and physical hazard risks generally increase as treatment increases in extent. Estimated construction and operational fatalities are always higher than those associated with radiation exposure, regardless of alternative. No Action results in lower worker health risks from physical hazards because fewer person-hours are spent in construction and operation of facilities, therefore injuries and fatalities are less likely. The risks from physical hazards are highest for the alternatives involving treatment (all except No Action) and are similar among these alternatives. Program-wide radiological risks to workers are lowest in No Action (1.7E-4 estimated cancer fatalities over a population of 417 FTEs), somewhat higher in Decentralized and Regionalized 1 (approximately 5E-3 in both alternatives), and increase almost to the E-1 order of magnitude in the other alternatives.

Worker health risks associated with chemical exposure vary slightly among alternatives. The exposure index, or worst-case individual worker exposure to noncarcinogenic chemicals, is approximately 1 order of magnitude lower in No Action than for the alternatives that involve treatment. However, in all alternatives the exposure indices are well below 1.0, indicating a low probability of adverse health effects from noncarcinogenic, hazardous constituents. The risk of worker cancer incidence from chemical exposure rises gradually across alternatives (lowest in No Action and slightly higher in the Decentralized,

Regionalized, and Centralized Alternatives). Chemical exposure contributes much less to worker health risk estimates than radiation exposure.

Discussion. As stated above, radiation exposure risks are greater than chemical exposure risks for RH-TRUW for all populations by several orders of magnitude. The risks of worker fatalities due to physical hazards are always greater than those due to exposure.

For the offsite population, Hanford poses the highest estimated cancer fatalities in all alternatives except Regionalized 2, 3, and Centralized, where the highest risk is at ORR. The radionuclides contributing the most risk to the offsite population are plutonium-238 at Hanford in No Action, Decentralized, and Regionalized 1; plutonium-241 at Hanford in Regionalized 2, 3, and Centralized; and curium-244 at ORR in Regionalized 2, 3, and Centralized (see Table D.3.4–34).

For workers, the highest estimated total fatalities (cancer fatalities plus construction and operational fatalities) in all alternatives are associated with Hanford, where the most FTEs are involved in RH-TRUW management. Total fatality risks (as well as numbers of FTEs) are only slightly lower at INEL in No Action, and at ORR in all other alternatives. In No Action, the radionuclides contributing the most worker risk are plutonium-241 at INEL, through inhalation; and plutonium-238 at Hanford, through inhalation. The controlling radionuclides for worker risks in Decentralized are uranium-236 at Hanford, through inhalation; and europium-152 and its radioactive decay products at ORR, through external exposure. In Regionalized 1 at Hanford, and in Regionalized 2, 3, and Centralized at ORR and Hanford, the controlling radionuclide is uranium-233, through inhalation.

D.3.4.7.2 *Comparison of the Decentralized and Regionalized 1 Alternatives: Treatment to WIPP Waste Acceptance Criteria Versus Treatment to Reduce Gas Generation*

A comparison of Decentralized (in which RH-TRUW is treated to WIPP waste acceptance criteria and stored at five installations) and Regionalized 1 (in which RH-TRUW is treated to reduce gas generation and stored at two installations) shows few differences in the health risks associated with these two treatment and consolidation options. The major difference between treating to WIPP waste acceptance criteria and treating to reduce gas generation is the addition of a waste shredding step in Regionalized 1,

therefore, treatment risks should not be substantially different. The number of installations at which waste is consolidated also does not greatly affect the overall health risks.

D.3.4.7.3 *Comparison of the Regionalized 1 Alternative with the Regionalized 2, 3, and Centralized Alternatives: Treatment to Reduce Gas Generation Versus Treatment to Land Disposal Restrictions*

A more controlled comparison of treatment risks can be made between the Regionalized 1 and the Regionalized 2 and 3, and Centralized Alternatives since consolidation schemes are identical (wastes are treated and stored at the same two installations in all of these alternatives) but treatments differ (treatment to reduce gas generation in Regionalized 1 versus treatment to LDRs in the other three alternatives). As previously noted, the program-wide risks of cancer fatalities, cancer incidence, and genetic effects from radiation exposure associated with treatment of RH-TRUW to LDRs (in the Regionalized 2, 3, and Centralized Alternatives) are approximately 4 orders of magnitude greater for the offsite and noninvolved worker populations and MEIs than the risks from treatment to minimize gas generation in Regionalized 1.

The offsite and noninvolved worker MEI hazard indices associated with treatment of RH-TRUW to LDRs are approximately 1 order of magnitude higher than in Regionalized 1. This trend reflects the potential for higher worst-case individual exposure to noncarcinogenic hazardous chemicals when RH-TRUW undergoes treatment to meet LDRs rather than to reduce gas generation. However, in all alternatives, exposures to noncarcinogenic, hazardous chemicals yield hazard indices well below 1.0, indicating a very low probability of adverse effects from these contaminants.

The program-wide risks to workers from radionuclide exposure are more than 1 order of magnitude higher in the alternatives involving treatment to LDRs than in Regionalized 1. However, the risk of chemical-related cancer incidence is similar between alternatives.

D.3.4.7.4 *Summary*

In summary, the No Action Alternative presents the fewest health risk to all populations. Health risks generally increase for the public receptors as more extensive treatment of RH-TRUW is employed. Radionuclide- and construction/operational-related health risks to workers increase somewhat as more extensive treatment is employed. Chemical-related risks for all receptors are slightly higher in the alternatives that involve treatment (all except No Action) than in No Action, but are relatively independent of treatment type.

The primary risk drivers for the offsite and noninvolved worker populations are radiation exposure (as opposed to chemical exposure) and treatment option. For workers, the primary risk drivers are the size of the waste load and the person-hours necessary to process it.

D.3.4.8 Summary of Alternatives for Potential TRUW Accidents

At the time of this writing the analyses for postulated TRUW facility accidents were incomplete. Current safety analysis reports (as developed in accordance with DOE Order 5481.1B, *Safety Analysis and Review System*) and site-specific DOE environmental impact statements contain predictions of the consequences and frequency of occurrence of selected waste storage accident scenarios. A brief summary of some of the accident scenarios from these safety analysis reports and environmental impact statements, the assumptions used by the various sites in preparing their analyses, and the estimated release or health effects are presented in Appendix F. The PEIS analyses for TRUW storage accidents can be expected to use similar assumptions and produce similar results. TRUW treatment-related accident scenarios will be similar to those analyzed for LLW and LLMW. Accidents associated with contact-handled TRUW will be analyzed similarly to contact-handled LLW and LLMW. These storage and treatment accident results will be published in a supplement to this draft PEIS and will be included in the final PEIS.

D.3.5 Low-Level Mixed Waste

Low-level mixed waste (LLMW) is waste that contains both low-level radioactivity and hazardous components regulated under the Resource Conservation and Recovery Act in sufficient quantities to

render the waste hazardous per the guidelines of 40 CFR 261. Although asbestos-containing wastes are not considered hazardous under the Resource Conservation and Recovery Act, friable asbestos waste is considered a hazardous waste in several states. For the purposes of the PEIS, low-level radioactive waste contaminated with asbestos is considered LLMW. High-level waste, transuranic waste, or spent nuclear fuel that may be contaminated with hazardous components regulated by the Resource Conservation and Recovery Act are not classified as LLMW and are not evaluated for human health risks in this portion of the appendix (high-level waste is considered in Section D.3.1 and transuranic wastes containing hazardous constituents are addressed in Section D.3.4).

Like low-level waste, LLMW may contain a wide range of radionuclides at activities ranging from trace amounts to thousands of curies. Packaged LLMW with a surface dose rate of less than 200 mrem/h is categorized as contact-handled LLMW (CH-LLMW). Packaged LLMW with a surface dose rate greater than 200 mrem/h emits sufficient penetrating beta, gamma, or neutron radiation to require remote handling, and is classified as remote-handled LLMW (RH-LLMW). The handling category determines the level of protective shielding needed to store and process the waste safely. The distinction between CH-LLMW and RH-LLMW is maintained in the human health risk analyses for both routine operations and accidents. The risks associated with each category are estimated and discussed separately.

LLMW is also categorized according to its content of alpha-emitting radionuclides (e.g., alpha LLMW or non-alpha LLMW) and polychlorinated biphenyls (PCBs) (e.g., PCB LLMW or non-PCB LLMW).

More than 50 installations within the DOE complex generate LLMW; following are the installations considered in this portion of the PEIS (note that the abbreviations given here are used in the tables in this appendix):

- Argonne National Laboratory–East (ANL–E), Argonne, Illinois
- Brookhaven National Laboratory (BNL), Brookhaven, New York
- Fernald Environmental Management Project (FEMP), Fernald, Ohio
- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Inhalation Toxicology Research Institute (ITRI), Albuquerque, New Mexico
- Kansas City Plant (KCP), Kansas City, Missouri
- Knolls Atomic Power Laboratory–Kesselring (KAPL–K), Schenectady, New York

- Lawrence Berkeley Laboratory (LBL), Berkeley, California
- Lawrence Livermore National Laboratory (LLNL), Livermore, California
- Los Alamos National Laboratory (LANL), Los Alamos, New Mexico
- Mound Plant (Mound), Miamisburg, Ohio
- Nevada Test Site (NTS), Las Vegas, Nevada
- Oak Ridge Reservation (ORR), Oak Ridge, Tennessee
- Paducah Gaseous Diffusion Plant (PGDP), Paducah, Kentucky
- Pantex Plant (Pantex), Amarillo, Texas
- Portsmouth Gaseous Diffusion Plant (Ports), Piketon, Ohio
- Rocky Flats Environmental Technology Site (RFETS), Golden, Colorado
- Sandia National Laboratories–New Mexico (SNL–NM), Albuquerque, New Mexico
- Savannah River Site (SRS), Aiken, South Carolina
- West Valley Demonstration Project (WVDP), West Valley, New York

Depending on its chemical and physical properties, LLMW can be grouped into waste stream categories according to the type of treatment needed, such as aqueous wastes, organic liquids, inorganic or organic sludges, contaminated soil with or without debris, or special wastes.

Chapters 3 and 6 of the PEIS and the LLMW technical report (ANL, 1995e) provide more detailed information on this waste, including LLMW inventories at DOE installations, estimated release rates, treatment categories used in the PEIS, considerations regarding disposal, and the process for developing PEIS LLMW alternatives.

D.3.5.1 Summary of LLMW Alternatives

The PEIS waste management alternatives (No Action, Decentralized, Regionalized, and Centralized) and the rationale for developing the various LLMW analysis alternatives are discussed rigorously in the main body of the PEIS. A broad range of decentralized, regionalized, and centralized alternatives are analyzed for this waste stream:

- The No Action Alternative: In this alternative, all installations treat CH-LLMW and RH-LLMW using existing capabilities and store the treated waste onsite (there is no disposal scenario for this alternative).

- The Decentralized Alternative: In this alternative, 49 installations treat CH-LLMW and 15 installations dispose of it.
- The Regionalized Alternatives: Regionalized 1 involves treatment of CH-LLMW at 11 installations and disposal at 12. In Regionalized 2 and 3, CH-LLMW is treated at seven installations and disposed of at six and one installation(s), respectively. Regionalized 4 entails treating CH-LLMW at four installations and disposing of it at six.
- The Centralized Alternative: Hanford treats and disposes of CH-LLMW in this alternative.
- The RH-LLMW management scenario (for all alternatives except No Action): four installations treat this waste and dispose of it onsite.

This series of alternatives makes it possible to compare the relative risks of consolidating CH-LLMW and treating it at varying numbers of installations, and the risks associated with a broad range of disposal configurations.

Table D.3.5-1 depicts the overall treatment and storage schemes for the LLMW alternatives; detailed information on waste consolidation scenarios can be found in the LLMW technical report (ANL, 1995e).

Note that for the purposes of this risk analysis, the waste load from the ITRI has been added to the waste load for SNL-NM.

Table D.3.5–1. PEIS Alternatives for LLMW

Alternative	Scenario	ANL-E	FEMP	Hanford	INEL	LANL	LLNL	NTS	ORR	Pantex	PGDP	Ports	RFETS	SNL-NM	SRS	WVDP	BNL	LBL	Mound	KCP	KAPL-K
No Action (CH and RH) All installations treat using existing capabilities and store onsite	Treat at all	T[a]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	Store at all	S[b]	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Decentralized CH Treatment	CH treatment at 49	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	Dispose at 15	D[c]	D	D	D	D	D	D	D	D	D	D	D	D	D		D				
Regionalized 1 CH Treatment	CH treatment at 11		T	T	T	T	T		T	T	T	T	T		T						
	Dispose at 12		D	D	D	D	D	D	D	D	D	D	D		D						
Regionalized 2 CH Treatment	CH treatment at 7			T	T	T			T			T	T		T						
	Dispose at 6			D	D	D		D	D						D						
Regionalized 3 CH Treatment	CH treatment at 7			T	T	T			T			T	T		T						
	Dispose at 1							D													
Regionalized 4 CH Treatment	CH treatment at 4			T	T				T						T						
	Dispose at 6			D	D	D		D	D						D						
Centralized CH Treatment	CH treatment at 1			T																	
	Dispose at 1			D																	
(All alternatives except No Action) RH Treatment	RH treatment at 4			T	T				T						T						
	Dispose at 4			D	D				D						D						

[a] T—treatment installation.
[b] S—storage installation.
[c] D—disposal installation.

D.3.5.2 Special Assumptions and Considerations Used in the LLMW Risk Analysis

The following chemicals were used as representatives of generic classes of chemical contaminants in the risk evaluation for the offsite and noninvolved worker populations: 1,2-dichloroethane (to represent compounds containing two chlorine atoms), 1,1,1-trichloroethane (to represent compounds containing three chlorine atoms), carbon tetrachloride (to represent compounds containing four chlorine atoms), 1,2,2-trichloro 1,1,2-trifluoroethane (to represent chlorofluorocarbons), benzene (to represent water-insoluble organic compounds), and acetone (to represent water-soluble organic compounds). It was also assumed that any chromium in the source term was the inhalation carcinogen, chromium (VI) (100%), due to lack of better information. This is a conservative assumption, and health risks associated with chromium (VI) may be overestimated.

For all disposal scenarios, it is assumed that shallow land burial will be used at installations west of the Mississippi River and tumulus (above-ground vault) disposal will be used at eastern installations. The exceptions are RFETS, which disposes in tumulus vaults, and SRS, which disposes in below-ground vaults.

It is assumed that, except in the No Action Alternative, LLMW disposal capacity at each installation will be expanded as required to meet disposal demands.

The waste containers for CH-LLMW are assumed to be 55-gal drums; RH-LLMW is assumed to be packaged in concrete casks with 6-in. walls.

For the purposes of estimating the human health risks associated with treatment and disposal of LLMW, no distinction is made between PCB-contaminated LLMW and non-PCB LLMW. If an installation is postulated to possess PCB-LLMW, the source term for that mixed waste is combined with all the other LLMW source terms for that installation.

D.3.5.3 Results Tables for the LLMW Human Health Risk Analysis

This section contains the results tables for the LLMW human health risk analysis. A discussion of the results is presented in Section D.3.5.4. The risk numbers in the tables are displayed in the standard

exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.5–2 presents an overview, by alternative, of the *total*, program-wide risks associated with treatment of LLMW. Included are the risks of cancer fatalities and cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers associated with waste treatment. This table provides the estimated *total number* of people in the three populations who will develop or die of cancers caused by exposure to LLMW if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed during construction and operational activities. The results in this table are drawn from Tables D.3.5–7 through D.3.5–14.
- Table D.3.5–3 presents an overview, by alternative, of the program-wide risks associated with disposal of LLMW. This table summarizes the risks of cancer fatalities and cancer incidence for the MEL of the hypothetical farm family; the likelihood of adverse heath effects to the MEL from exposure to noncarcinogenic, hazardous chemicals; the total risks to members of all 143 lifetimes of the farm family; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers associated with waste disposal. The results in this table are drawn from Tables D.3.5–23 through D.3.5–29.
- Table D.3.5–4 shows the sizes of the total affected populations for each alternative.
- Table D.3.5–5 summarizes the risks to the noninvolved worker and offsite MEIs for each LLMW alternative. The numbers in this table are the estimated *probabilities* that the offsite and noninvolved worker MEIs will die of or develop cancer from radionuclide and chemical exposure and indicators of the likelihood of adverse health effects to the MEIs from exposure to noncarcinogenic, hazardous chemicals. These results are drawn from Tables D.3.5–7 through D.3.5–14 and Tables D.3.5–23 through D.3.5–29.
- Table D.3.5–6 lists the radionuclides that contribute most of the risk of cancer fatality to the offsite population for LLMW treatment, by installation and alternative.

The following tables are located at the end of Section D.3.5.4:

- Tables D.3.5–7 through D.3.5–14 provide more detailed information on the program-wide health risks to all receptors from treatment of LLMW, by alternative and health endpoint.
- Tables D.3.5–15 through D.3.5–22 present summaries of the health risks for the offsite and worker populations, by alternative and installation.
- Tables D.3.5–23 through D.3.5–29 provide more detailed information on the program-wide health risks to the MEL of the hypothetical farm family of four, all 143 lifetimes of the farm family, and waste disposal workers, by alternative and health endpoint.
- Tables D.3.5–30 through D.3.5–36 present summaries of the health risks to the farm family and workers and an indication of which farm family lifetime is most exposed, by installation.

Table D.3.5-2. Summary of Program-Wide Risks Associated with Treatment of LLMW: Risks to Total Populations, by Alternative

Alternative	Offsite Population		Noninvolved Worker Population		WM Workers		
	CF[a]	CI[b]	CF	CI	CF	CI	C&OF[c]
No Action	3.1E-1	1.1	1.3E-2	4.3E-2	8.7E-1	3.1	1.8
Decentralized	1.7E-1	5.8E-1	2.4E-3	8.0E-3	5.2E-1	1.8	4.0
Regionalized 1	1.6E-1	5.5E-1	2.4E-3	8.0E-3	5.7E-1	2.0	3.7
Regionalized 2	1.8E-2	6.1E-2	3.6E-4	1.2E-3	5.8E-1	2.0	3.4
Regionalized 3	1.8E-2	6.1E-2	3.6E-4	1.2E-3	5.8E-1	2.0	3.4
Regionalized 4	1.8E-2	5.9E-2	3.6E-4	1.2E-3	6.3E-1	2.2	3.1
Centralized	2.5E-2	8.6E-2	3.3E-4	1.1E-3	6.4E-1	2.2	2.6
RH-LLMW	1.3E-3	4.5E-3	4.2E-5	1.4E-4	2.3E-2	8.1E-2	4.5E-1

[a] CF—cancer fatality associated with radionuclide exposure.
[b] CI—cancer incidence associated with exposure to radionuclides and carcinogenic chemicals.
[c] C&OF—fatalities due to the physical hazards of constructing and operating waste management facilities.

Table D.3.5-3. Summary of Program-Wide Risks Associated with Disposal of LLMW: Risks to Hypothetical Farm Family and Waste Management Workers, by Alternative

Alternative	MEL of Farm Family				All (143) Lifetimes of Farm Family			WM Workers		
	CF[a]	Rad CI[b]	Chem CI[c]	HI[d]	CF	Rad CI	Chem CI	CF	CI	C&OF[e]
Decentralized	1.8E-3	6.1E-3	1.1E-2	3.0	5.0E-2	1.7E-1	5.0E-1	5.5E-1	1.9	4.8E-1
Regionalized 1	1.2E-3	4.1E-3	1.0E-2	3.0	2.4E-2	8.0E-2	5.0E-1	5.5E-1	1.9	4.5E-1
Regionalized 2	1.4E-3	4.8E-3	1.3E-2	2.7	2.4E-2	8.0E-2	8.3E-1	5.2E-1	1.8	4.2E-1
Regionalized 3	0.00	0.00	2.8E-3	3.1E-1	0.00	0.00	5.4E-2	3.7E-1	1.3	1.8E-1
Regionalized 4	1.5E-3	5.1E-3	1.3E-2	2.7	2.5E-2	8.5E-2	8.2E-1	6.4E-1	2.2	4.1E-1
Centralized	1.9E-2	6.6E-2	9.5E-4	2.4	2.5E-1	8.6E-1	8.5E-3	3.6E-1	1.3	1.5E-1
RH-LLMW	8.5E-5	2.9E-4	1.4E-5	1.3E-2	1.3E-3	4.5E-3	5.8E-4	1.5E-3	5.2E-3	3.0E-2

[a] CF—Risk of cancer fatality associated with exposure to both radionuclides and carcinogenic chemicals.
[b] Rad CI—Risk of cancer incidence associated with exposure to radionuclides.
[c] Chem CI—Risk of cancer incidence associated with exposure to chemical carcinogens.
[d] HI—Hazard Index.
[e] C&OF—Estimated construction and operational fatalities from physical hazards.

Table D.3.5–4. Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Routine Management of LLMW, by Alternative

Alternative	Offsite Population	Noninvolved Worker Population	WM Workers
No Action	38,499,644	113,752	9,218
Decentralized	38,499,644	113,752	15,082
Regionalized 1	38,499,644	113,752	14,052
Regionalized 2	38,499,644	113,752	13,300
Regionalized 3	38,499,644	113,752	13,300
Regionalized 4	38,499,644	113,752	12,031
Centralized	38,499,644	113,752	9,756
RH-LLMW	2,032,976	36,930	1,312

Table D.3.5–5. Summary of Program-Wide Risks Associated with Treatment of LLMW: Risks To the Offsite and Noninvolved Worker Most-Exposed Individuals, by Alternative

Alternative	Offsite MEI[a]				Noninvolved Worker MEI[a]			
	CF[b]	Rad CI[c]	Chem CI[d]	HI[e]	CF	Rad CI	Chem CI	HI
No Action	7.0E-6	2.4E-5	2.0E-8	2.3E-5	8.7E-6	3.0E-5	2.1E-7	4.5E-5
Decentralized	2.5E-6	8.5E-6	1.2E-9	1.4E-6	7.3E-7	2.5E-6	7.1E-9	8.8E-6
Regionalized 1	2.6E-6	8.7E-6	1.0E-9	1.4E-6	7.4E-7	2.5E-6	6.2E-9	8.7E-6
Regionalized 2	2.7E-7	9.2E-7	1.0E-9	1.4E-6	3.1E-7	1.0E-6	6.2E-9	8.8E-6
Regionalized 3	2.7E-7	9.2E-7	1.0E-9	1.4E-6	3.1E-7	1.0E-6	6.2E-9	8.8E-6
Regionalized 4	2.7E-7	9.3E-7	1.5E-9	2.0E-6	3.1E-7	1.1E-6	9.3E-9	1.3E-5
Centralized	5.2E-7	1.8E-6	4.1E-10	4.5E-7	5.8E-7	2.0E-6	1.4E-8	1.6E-5
RH-LLMW	3.4E-8	1.2E-7	2.9E-12	4.8E-9	2.3E-8	7.8E-8	1.8E-11	3.8E-8

[a] MEI—Most-exposed individual.
[b] CF—Risk of cancer fatality associated with exposure to radionuclides.
[c] Rad CI—Risk of cancer incidence associated with exposure to radionuclides.
[d] Chem CI—Risk of cancer incidence associated with exposure to chemical carcinogens.
[e] HI—Hazard Index.

Table D.3.5–6. Radionuclide Contributing the Highest Risk of Cancer Fatality to the Offsite Population for LLMW Treatment, by Alternative and Installation

Alt.[a]	Installation																		
	ANL-E	Hanford	INEL	KAPL-K	KCP	LANL	LBL	LLNL	NTS	ORR	Pantex	Ports	PGDP	RFETS	SNL/NM	SRS	WVDP	FEMP	BNL	Mound
No Action	U-238[b] 1.24E-2[c]	Pu-238 1.11E-2	Pu-238 3.85E-4	Co-60 4.87E-4	Co-60 4.61E-6	Pu-238 8.81E-5	U-238 3.45E-5	Pu-238 7.55E-4	U-238 7.81E-11	U-238 1.09E-1	Pu-238 1.45E-6	U-238 5.92E-5	U-238 3.32E-3	Pu-238 1.63E-2	Pu-238 3.13E-5	H-3 2.60E-3	Pu-238 2.03E-4	U-238 5.90E-4	U-238 1.08E-4	Pu-238 1.38E-5
Dec.	U-238 5.94E-4	Pu-238 9.84E-4	H-3 3.50E-5	H-3 1.98E-4	H-3 2.30E-6	H-3 5.86E-4	H-3 1.02E-2	H-3 1.54E-1	U-238 1.75E-14	U-238 4.86E-4	H-3 3.41E-5	U-238 2.49E-6	U-238 1.10E-4	Pu-238 4.09E-5	H-3 1.30E-4	H-3 1.68E-3	Pu-238 1.08E-7	U-238 2.39E-5	U-238 5.32E-6	H-3 1.26E-4
Reg. 1	U-238 2.77E-6	Pu-238 9.03E-4	H-3 3.50E-5	Co-60 1.05E-7	Co-60 9.90E-10	H-3 6.02E-4	U-238 7.74E-9	H-3 1.57E-1	U-238 1.75E-14	U-238 4.19E-4	H-3 3.41E-5	H-3 3.03E-5	U-238 1.10E-4	Pu-238 4.08E-5	Pu-238 7.30E-9	H-3 1.68E-3	H-3 1.06E-7	U-238 3.30E-4	U-238 2.43E-8	Pu-238 3.22E-9
Reg. 2	U-238 2.77E-6	H-3 1.20E-2	H-3 6.10E-4	Co-60 1.05E-7	Co-60 9.90E-10	H-3 8.52E-4	U-238 7.74E-9	Pu-238 1.76E-7	U-238 1.75E-14	U-238 6.56E-4	H-3 2.34E-6	H-3 3.15E-5	U-238 7.48E-7	Pu-238 4.09E-5	Pu-238 7.30E-9	H-3 1.68E-3	H-3 1.06E-7	U-238 1.33E-7	U-238 2.43E-8	Pu-238 3.22E-9
Reg. 3	U-238 2.77E-6	H-3 1.20E-2	H-3 6.10E-4	Co-60 1.05E-7	Co-60 9.90E-10	H-3 8.52E-4	U-238 7.74E-9	Pu-238 1.76E-7	U-238 1.75E-14	U-238 6.56E-4	H-3 2.34E-6	H-3 3.15E-5	U-238 7.48E-7	Pu-238 4.09E-5	Pu-238 7.30E-9	H-3 1.68E-3	H-3 1.06E-7	U-238 1.33E-7	U-238 2.43E-8	Pu-238 3.22E-9
Reg. 4	U-238 2.77E-6	H-3 1.20E-2	H-3 6.51E-4	Co-60 1.05E-7	Co-60 9.90E-10	H-3 3.79E-5	U-238 7.74E-9	Pu-238 1.76E-7	U-238 1.75E-14	U-238 8.04E-4	H-3 2.34E-6	U-238 1.65E-8	U-238 7.48E-7	Pu-238 8.15E-7	Pu-238 7.30E-9	H-3 1.68E-3	H-3 1.06E-7	U-238 1.33E-7	U-238 2.43E-8	Pu-238 3.24E-9
Cen.	U-238 2.77E-6	H-3 2.30E-2	H-3 4.83E-6	Co-60 1.05E-7	Co-60 9.90E-10	H-3 3.79E-5	U-238 7.74E-9	Pu-238 1.76E-7	U-238 1.75E-14	U-238 2.18E-6	H-3 2.34E-6	U-238 1.65E-8	U-238 7.48E-7	Pu-238 8.15E-7	Pu-238 7.30E-9	H-3 9.81E-7	H-3 1.06E-7	U-238 1.33E-7	U-238 2.43E-8	Pu-238 3.24E-9
RH		Pu-238 3.08E-7	H-3 1.95E-4							H-3 7.66E-4						H-3 2.80E-5				

[a] Alternative abbreviations are: Alt. = Alternative; Dec. = Decentralized; Reg. = Regionalized; Cen. = Centralized; RH = RH-LLMW.
[b] Radionuclide contributing most risk.
[c] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this installation.

Table D.3.5–7. Program-Wide Risks Associated with Treatment of LLMW Under the No Action Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	2.5E1			
	Cancer Fatalities	1.3E-2			
	Cancer Incidence	4.3E-2	5.8E-4		
	Genetic Effects	2.5E-3			
Noninvolved Worker MEI	Dose (rem)	1.7E-2			
	Cancer Fatalities	8.7E-6			
	Cancer Incidence	3.0E-5	2.1E-7		
	Genetic Effects	1.7E-6			
	Hazard Index			4.5E-5	
Offsite Population	Dose (person-rem)	6.2E2			
	Cancer Fatalities	3.1E-1			
	Cancer Incidence	1.1	2.9E-3		
	Genetic Effects	6.2E-2			
Offsite MEI	Dose (rem)	1.4E-2			
	Cancer Fatalities	7.0E-6			
	Cancer Incidence	2.4E-5	2.0E-8		
	Genetic Effects	1.4E-6			
	Hazard Index			2.3E-5	
WM Workers	Dose (FTE-rem)	2.2E3			
	Cancer Fatalities	8.7E-1			
	Cancer Incidence	3.0	1.1E-2		
	Genetic Effects	1.3E-1			
	Exposure Index			1.2E-2	
	Construction Fatalities				6.2E-1
	Construction Injuries				2.7E2
	Operation Fatalities				1.1
	Operation Injuries				9.7E2

Table D.3.5-8. Program-Wide Risks Associated with Treatment of LLMW Under the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	4.7			
	Cancer Fatalities	2.4E-3			
	Cancer Incidence	8.0E-3	1.4E-5		
	Genetic Effects	4.7E-4			
Noninvolved Worker MEI	Dose (rem)	1.5E-3			
	Cancer Fatalities	7.3E-7			
	Cancer Incidence	2.5E-6	7.1E-9		
	Genetic Effects	1.5E-7			
	Hazard Index			8.8E-6	
Offsite Population	Dose (person-rem)	3.4E2			
	Cancer Fatalities	1.7E-1			
	Cancer Incidence	5.8E-1	6.2E-5		
	Genetic Effects	3.4E-2			
Offsite MEI	Dose (rem)	5.0E-3			
	Cancer Fatalities	2.5E-6			
	Cancer Incidence	8.5E-6	1.2E-9		
	Genetic Effects	5.0E-7			
	Hazard Index			1.4E-6	
WM Workers	Dose (FTE-rem)	1.3E3			
	Cancer Fatalities	5.2E-1			
	Cancer Incidence	1.8	9.9E-3		
	Genetic Effects	7.8E-2			
	Exposure Index			1.2E-2	
	Construction Fatalities				2.2
	Construction Injuries				9.4E2
	Operation Fatalities				1.9
	Operation Injuries				1.6E3

Table D.3.5-9. Program-Wide Risks Associated with Treatment of LLMW Under the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	4.7			
	Cancer Fatalities	2.4E-3			
	Cancer Incidence	8.0E-3	1.3E-5		
	Genetic Effects	4.7E-4			
Noninvolved Worker MEI	Dose (rem)	1.5E-3			
	Cancer Fatalities	7.4E-7			
	Cancer Incidence	2.5E-6	6.2E-9		
	Genetic Effects	1.5E-7			
	Hazard Index			8.7E-6	
Offsite Population	Dose (person-rem)	3.3E2			
	Cancer Fatalities	1.6E-1			
	Cancer Incidence	5.5E-1	4.6E-5		
	Genetic Effects	3.3E-2			
Offsite MEI	Dose (rem)	5.1E-3			
	Cancer Fatalities	2.6E-6			
	Cancer Incidence	8.7E-6	1.0E-9		
	Genetic Effects	5.1E-7			
	Hazard Index			1.4E-6	
WM Workers	Dose (FTE-rem)	1.4E3			
	Cancer Fatalities	5.7E-1			
	Cancer Incidence	2.0	9.2E-3		
	Genetic Effects	8.5E-2			
	Exposure Index			1.2E-2	
	Construction Fatalities				2.0
	Construction Injuries				8.6E2
	Operation Fatalities				1.7
	Operation Injuries				1.5E3

Table D.3.5–10. Program-Wide Risks Associated with Treatment of LLMW Under the Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	7.2E-1			
	Cancer Fatalities	3.6E-4			
	Cancer Incidence	1.2E-3	1.5E-5		
	Genetic Effects	7.2E-5			
Noninvolved Worker MEI	Dose (rem)	6.1E-4			
	Cancer Fatalities	3.1E-7			
	Cancer Incidence	1.0E-6	6.2E-9		
	Genetic Effects	6.1E-8			
	Hazard Index			8.8E-6	
Offsite Population	Dose (person-rem)	3.6E1			
	Cancer Fatalities	1.8E-2			
	Cancer Incidence	6.1E-2	3.8E-5		
	Genetic Effects	3.6E-3			
Offsite MEI	Dose (rem)	5.4E-4			
	Cancer Fatalities	2.7E-7			
	Cancer Incidence	9.2E-7	1.0E-9		
	Genetic Effects	5.4E-8			
	Hazard Index			1.4E-6	
WM Workers	Dose (FTE-rem)	1.4E3			
	Cancer Fatalities	5.8E-1			
	Cancer Incidence	2.0	9.6E-3		
	Genetic Effects	8.6E-2			
	Exposure Index			1.3E-2	
	Construction Fatalities				1.8
	Construction Injuries				7.7E2
	Operation Fatalities				1.6
	Operation Injuries				1.4E3

Table D.3.5-11. Program-Wide Risks Associated with Treatment of LLMW Under the Regionalized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	7.2E-1			
	Cancer Fatalities	3.6E-4			
	Cancer Incidence	1.2E-3	1.2E-5		
	Genetic Effects	7.2E-5			
Noninvolved Worker MEI	Dose (rem)	6.1E-4			
	Cancer Fatalities	3.1E-7			
	Cancer Incidence	1.0E-6	6.2E-9		
	Genetic Effects	6.1E-8			
	Hazard Index			8.8E-6	
Offsite Population	Dose (person-rem)	3.6E1			
	Cancer Fatalities	1.8E-2			
	Cancer Incidence	6.1E-2	3.2E-5		
	Genetic Effects	3.6E-3			
Offsite MEI	Dose (rem)	5.4E-4			
	Cancer Fatalities	2.7E-7			
	Cancer Incidence	9.2E-7	1.0E-9		
	Genetic Effects	5.4E-8			
	Hazard Index			1.4E-6	
WM Workers	Dose (FTE-rem)	1.4E3			
	Cancer Fatalities	5.8E-1			
	Cancer Incidence	2.0	9.6E-3		
	Genetic Effects	8.6E-2			
	Exposure Index			1.3E-2	
	Construction Fatalities				1.8
	Construction Injuries				7.7E2
	Operation Fatalities				1.6
	Operation Injuries				1.4E3

Table D.3.5-12. Program-Wide Risks Associated with Treatment of LLMW Under the Regionalized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	7.1E-1			
	Cancer Fatalities	3.6E-4			
	Cancer Incidence	1.2E-3	1.3E-5		
	Genetic Effects	7.1E-5			
Noninvolved Worker MEI	Dose (rem)	6.3E-4			
	Cancer Fatalities	3.1E-7			
	Cancer Incidence	1.1E-6	9.3E-9		
	Genetic Effects	6.3E-8			
	Hazard Index			1.3E-5	
Offsite Population	Dose (person-rem)	3.5E1			
	Cancer Fatalities	1.8E-2			
	Cancer Incidence	5.9E-2	3.4E-5		
	Genetic Effects	3.5E-3			
Offsite MEI	Dose (rem)	5.5E-4			
	Cancer Fatalities	2.7E-7			
	Cancer Incidence	9.3E-7	1.5E-9		
	Genetic Effects	5.5E-8			
	Hazard Index			2.0E-6	
WM Workers	Dose (FTE-rem)	1.6E3			
	Cancer Fatalities	6.3E-1			
	Cancer Incidence	2.2	1.2E-2		
	Genetic Effects	9.5E-2			
	Exposure Index			1.6E-2	
	Construction Fatalities				1.6
	Construction Injuries				6.9E2
	Operation Fatalities				1.5
	Operation Injuries				1.3E3

Table D.3.5–13. Program-Wide Risks Associated with Treatment of LLMW Under the Centralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	6.6E-1			
	Cancer Fatalities	3.3E-4			
	Cancer Incidence	1.1E-3	7.9E-6		
	Genetic Effects	6.6E-5			
Noninvolved Worker MEI	Dose (rem)	1.2E-3			
	Cancer Fatalities	5.8E-7			
	Cancer Incidence	2.0E-6	1.4E-8		
	Genetic Effects	1.2E-7			
	Hazard Index			1.6E-5	
Offsite Population	Dose (person-rem)	5.0E1			
	Cancer Fatalities	2.5E-2			
	Cancer Incidence	8.6E-2	1.5E-5		
	Genetic Effects	5.0E-3			
Offsite MEI	Dose (rem)	1.0E-3			
	Cancer Fatalities	5.2E-7			
	Cancer Incidence	1.8E-6	4.1E-10		
	Genetic Effects	1.0E-7			
	Hazard Index			4.5E-7	
WM Workers	Dose (FTE-rem)	1.6E3			
	Cancer Fatalities	6.4E-1			
	Cancer Incidence	2.2	1.8E-2		
	Genetic Effects	9.6E-2			
	Exposure Index			2.6E-2	
	Construction Fatalities				1.4
	Construction Injuries				6.0E2
	Operation Fatalities				1.2
	Operation Injuries				1.0E3

Table D.3.5–14. Program-Wide Risks Associated with Treatment of RH-LLMW Under Each Alternative (Except No Action), by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved Worker Population	Dose (person-rem)	8.4E-2			
	Cancer Fatalities	4.2E-5			
	Cancer Incidence	1.4E-4	3.9E-8		
	Genetic Effects	8.4E-6			
Noninvolved Worker MEI	Dose (rem)	4.6E-5			
	Cancer Fatalities	2.3E-8			
	Cancer Incidence	7.8E-8	1.8E-11		
	Genetic Effects	4.6E-9			
	Hazard Index			3.8E-8	
Offsite Population	Dose (person-rem)	2.7			
	Cancer Fatalities	1.3E-3			
	Cancer Incidence	4.5E-3	7.2E-8		
	Genetic Effects	2.7E-4			
Offsite MEI	Dose (rem)	6.8E-5			
	Cancer Fatalities	3.4E-8			
	Cancer Incidence	1.2E-7	2.9E-12		
	Genetic Effects	6.8E-9			
	Hazard Index			4.8E-9	
WM Workers	Dose (FTE-rem)	5.8E1			
	Cancer Fatalities	2.3E-2			
	Cancer Incidence	8.1E-2	6.7E-5		
	Genetic Effects	3.5E-3			
	Exposure Index			4.6E-4	
	Construction Fatalities				2.9E-1
	Construction Injuries				1.3E2
	Operation Fatalities				1.6E-1
	Operation Injuries				1.4E2

Table D.3.5–15. Risks Associated with Treatment of LLMW Under the No Action Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
FEMP	2764589 268	6.3E-4	1.2E-8	5.2E-2	2.2E-3	4.3E-8	2.2E-3
KAPL-K	1290172 21	1.2E-3	2.6E-8	6.6E-3	3.9E-3	8.7E-8	9.0E-3
LBL	5856829 18	4.3E-5	6.5E-10	3.6E-3	1.6E-4	2.4E-9	1.5E-4
LANL	159152 221	1.5E-4	1.6E-8	4.4E-2	5.2E-4	5.5E-8	7.7E-3
LLNL	6324234 329	1.9E-3	3.1E-8	6.5E-2	6.6E-3	1.1E-7	6.5E-3
Mound	3032983 11	2.5E-5	1.5E-9	2.1E-3	8.8E-5	5.0E-9	8.7E-5
NTS	14266 0	3.2E-11	8.0E-15	4.4E-5	1.1E-10	2.8E-14	1.8E-6
Pantex	265185 74	2.2E-6	1.8E-10	1.5E-2	7.7E-6	6.4E-10	1.5E-3
Ports	639602 534	6.4E-5	8.0E-9	1.1E-1	3.3E-4	4.7E-8	5.7E-3
SNL-NM	610714 12	7.7E-5	3.0E-9	2.4E-3	2.6E-4	1.0E-8	1.8E-4
Hanford	377645 585	1.5E-2	3.1E-7	2.5E-1	5.2E-2	1.1E-6	4.5E-1
RFETS	2171877 931	2.6E-2	3.6E-7	2.1E-1	9.2E-2	1.2E-6	7.8E-3
WVDP	1698391 15	2.7E-4	4.1E-9	2.9E-3	9.3E-4	1.4E-8	2.4E-4
KCP	1729833 1	1.1E-5	5.0E-10	1.2E-4	3.7E-5	1.7E-9	7.9E-6
SRS	620618 1358	3.1E-3	2.9E-8	4.6E-1	1.1E-2	1.0E-7	7.9E-1
ORR	881652 3072	2.3E-1	7.0E-6	8.2E-1	7.8E-1	2.4E-5	9.5E-1
PGDP	500502 89	3.6E-3	4.0E-7	1.7E-2	1.2E-2	1.4E-6	1.3E-3
INEL	153061 1156	1.1E-3	1.4E-7	4.1E-1	3.8E-3	4.8E-7	6.5E-1
BNL	5738554 39	2.3E-4	3.1E-9	7.6E-3	7.9E-4	1.1E-8	5.2E-4
ANL-E	7939785 484	2.6E-2	1.4E-7	1.4E-1	8.9E-2	4.9E-7	1.6E-1
TOTAL		3.1E-1	7.0E-6	2.6	1.1	2.4E-5	3.1

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.5-16. Risks Associated with Treatment of LLMW Under the Decentralized Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
BNL	5738554 / 62	1.2E-5	1.6E-10	1.6E-2	4.1E-5	5.5E-10	4.3E-4
FEMP	2764589 / 533	2.6E-5	4.9E-10	1.6E-1	9.1E-5	1.7E-9	1.1E-3
KAPL-K	1290172 / 44	3.0E-4	6.7E-9	1.3E-2	1.0E-3	2.3E-8	6.2E-3
LBL	5856829 / 40	1.0E-2	1.6E-7	1.0E-2	3.5E-2	5.5E-7	1.3E-4
LANL	159152 / 590	5.9E-4	6.2E-8	2.0E-1	2.0E-3	2.1E-7	5.5E-3
LLNL	6324234 / 831	1.5E-1	2.5E-6	2.7E-1	5.2E-1	8.5E-6	2.8E-2
ORR	881652 / 2530	1.1E-3	3.3E-8	7.7E-1	3.7E-3	1.2E-7	6.2E-1
Mound	3032983 / 7	1.3E-4	7.4E-9	2.1E-3	4.3E-4	2.5E-8	4.7E-5
NTS	14266 / 0	7.0E-15	0.00	2.4E-5	1.8E-9	4.8E-13	9.1E-7
Pantex	265185 / 145	3.5E-5	2.9E-9	3.9E-2	1.2E-4	1.0E-8	1.2E-3
Ports	639602 / 1853	2.7E-6	3.4E-10	4.8E-1	1.2E-5	1.5E-9	5.6E-3
SNL-NM	610714 / 20	1.4E-4	5.4E-9	5.4E-3	4.7E-4	1.9E-8	1.2E-3
SRS	620618 / 1289	1.7E-3	1.7E-8	4.3E-1	5.9E-3	5.6E-8	3.7E-1
RFETS	2171877 / 2305	6.7E-5	9.1E-10	6.3E-1	2.3E-4	3.1E-9	4.1E-3
WVDP	1698391 / 11	2.5E-7	3.8E-12	6.8E-3	8.6E-7	1.3E-11	8.6E-3
KCP	1729833 / 1	3.9E-6	1.8E-10	2.6E-4	1.3E-5	6.0E-10	1.2E-4
INEL	153061 / 1588	5.2E-5	6.5E-9	5.3E-1	1.8E-4	2.2E-8	3.6E-1
Hanford	377645 / 2196	1.5E-3	3.0E-8	6.2E-1	5.0E-3	1.0E-7	3.6E-1
PGDP	500502 / 144	1.2E-4	1.3E-8	4.7E-2	4.1E-4	4.5E-8	8.4E-4
ANL-E	7939785 / 886	1.3E-3	7.2E-9	2.3E-1	4.5E-3	2.5E-8	6.7E-2
TOTAL		1.7E-1	2.5E-6	4.5	5.8E-1	8.5E-6	1.8

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.5-17. Risks Associated with Treatment of LLMW Under the Regionalized Alternative 1, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
BNL	5738554 16	5.2E-8	7.0E-13	4.0E-3	1.9E-7	2.5E-12	2.0E-4
FEMP	2764589 1233	7.0E-4	1.3E-8	3.5E-1	2.4E-3	4.5E-8	9.5E-2
KAPL-K	1290172 9	2.6E-7	5.8E-12	2.8E-3	8.9E-7	2.0E-11	2.2E-3
LBL	5856829 8	9.8E-9	1.5E-13	1.9E-3	4.9E-8	8.3E-13	7.4E-5
LANL	159152 597	6.1E-4	6.4E-8	2.0E-1	2.1E-3	2.2E-7	6.4E-3
LLNL	6324234 915	1.6E-1	2.6E-6	3.1E-1	5.3E-1	8.7E-6	8.1E-2
ORR	881652 2162	9.3E-4	2.9E-8	5.9E-1	3.2E-3	9.8E-8	3.9E-1
Mound	3032983 5	5.9E-9	3.4E-13	1.1E-3	7.3E-8	2.9E-12	4.3E-5
NTS	14266 1	7.0E-15	0.00	1.2E-4	1.8E-9	4.8E-13	1.6E-5
Pantex	265185 145	3.5E-5	2.9E-9	3.9E-2	1.2E-4	1.0E-8	1.2E-3
Ports	639602 1353	4.9E-5	6.0E-9	4.0E-1	1.7E-4	2.1E-8	2.1E-1
SNL-NM	610714 5	1.8E-8	7.1E-13	1.2E-3	6.1E-8	2.4E-12	6.1E-5
SRS	620618 1290	1.8E-3	1.7E-8	4.4E-1	6.0E-3	5.7E-8	3.8E-1
RFETS	2171877 2307	6.7E-5	9.0E-10	6.3E-1	2.3E-4	3.1E-9	4.1E-3
WVDP	1698391 10	1.7E-7	2.6E-12	3.2E-3	5.9E-7	8.9E-12	9.7E-5
KCP	1729833 0	2.5E-9	1.1E-13	5.9E-5	8.4E-9	3.8E-13	2.8E-6
Hanford	377645 2065	1.4E-3	2.8E-8	6.0E-1	4.7E-3	9.6E-8	4.2E-1
INEL	153061 1587	5.2E-5	6.5E-9	5.3E-1	1.8E-4	2.2E-8	3.6E-1
PGDP	500502 144	1.2E-4	1.3E-8	4.7E-2	4.1E-4	4.5E-8	1.4E-3
ANL-E	7939785 200	6.0E-6	3.3E-11	5.7E-2	2.1E-5	1.1E-10	3.6E-2
TOTAL		1.6E-1	2.6E-6	4.3	5.5E-1	8.7E-6	2.0

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.5-18. Risks Associated with Treatment of LLMW Under the Regionalized Alternative 2, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 200	6.0E-6	3.3E-11	5.7E-2	2.1E-5	1.1E-10	3.6E-2
BNL	5738554 16	5.2E-8	7.0E-13	4.0E-3	1.9E-7	2.5E-12	2.0E-4
FEMP	2764589 269	1.4E-7	2.7E-12	8.8E-2	5.8E-7	1.2E-11	8.8E-4
KAPL-K	1290172 9	2.6E-7	5.8E-12	2.8E-3	8.9E-7	2.0E-11	2.2E-3
LBL	5856829 8	9.8E-9	1.5E-13	1.9E-3	4.9E-8	8.3E-13	7.4E-5
LANL	159152 679	8.6E-4	9.1E-8	2.2E-1	2.9E-3	3.1E-7	8.2E-3
LLNL	6324234 136	4.4E-7	7.2E-12	3.3E-2	1.9E-6	3.5E-11	2.2E-3
ORR	881652 2177	1.2E-3	3.6E-8	6.0E-1	4.1E-3	1.3E-7	4.2E-1
Mound	3032983 5	5.9E-9	3.4E-13	1.1E-3	7.3E-8	2.9E-12	4.3E-5
NTS	14266 0	7.0E-15	0.00	2.4E-5	2.5E-14	0.00	9.1E-7
Pantex	265185 48	2.3E-6	2.0E-10	1.5E-2	8.0E-6	6.8E-10	5.8E-4
Ports	639602 1951	1.1E-4	1.3E-8	5.4E-1	3.6E-4	4.5E-8	2.7E-1
SNL-NM	610714 5	1.8E-8	7.1E-13	1.2E-3	6.1E-8	2.4E-12	6.1E-5
SRS	620618 1290	1.8E-3	1.7E-8	4.4E-1	6.0E-3	5.7E-8	3.8E-1
RFETS	2171877 2307	6.8E-5	9.2E-10	6.3E-1	2.4E-4	3.2E-9	4.6E-3
WVDP	1698391 10	1.7E-7	2.6E-12	3.2E-3	5.8E-7	8.9E-12	9.7E-5
KCP	1729833 0	2.5E-9	1.1E-13	5.9E-5	8.4E-9	3.8E-13	2.8E-6
INEL	153061 2010	6.3E-4	7.8E-8	6.6E-1	2.1E-3	2.7E-7	3.9E-1
Hanford	377645 2132	1.3E-2	2.7E-7	6.4E-1	4.5E-2	9.2E-7	5.0E-1
PGDP	500502 48	8.1E-7	9.0E-11	1.3E-2	2.8E-6	3.1E-10	5.2E-4
TOTAL		1.8E-2	2.7E-7	4.0	6.1E-2	9.2E-7	2.0

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.5-19. Risks Associated with Treatment of LLMW Under the Regionalized Alternative 3, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 200	6.0E-6	3.3E-11	5.7E-2	2.1E-5	1.1E-10	3.6E-2
BNL	5738554 16	5.2E-8	7.0E-13	4.0E-3	1.9E-7	2.5E-12	2.0E-4
FEMP	2764589 269	1.4E-7	2.7E-12	8.8E-2	5.8E-7	1.2E-11	8.8E-4
KAPL-K	1290172 9	2.6E-7	5.8E-12	2.8E-3	8.9E-7	2.0E-11	2.2E-3
LBL	5856829 8	9.8E-9	1.5E-13	1.9E-3	4.9E-8	8.3E-13	7.4E-5
LANL	159152 679	8.6E-4	9.1E-8	2.2E-1	2.9E-3	3.1E-7	8.2E-3
LLNL	6324234 136	4.4E-7	7.2E-12	3.3E-2	1.9E-6	3.5E-11	2.2E-3
ORR	881652 2177	1.2E-3	3.6E-8	6.0E-1	4.1E-3	1.3E-7	4.2E-1
Mound	3032983 5	5.9E-9	3.4E-13	1.1E-3	7.3E-8	2.9E-12	4.3E-5
NTS	14266 0	7.0E-15	0.00	2.4E-5	7.1E-8	1.8E-11	9.1E-7
Pantex	265185 48	2.3E-6	2.0E-10	1.5E-2	8.0E-6	6.8E-10	5.8E-4
Ports	639602 1951	1.1E-4	1.3E-8	5.4E-1	3.6E-4	4.5E-8	2.7E-1
SNL-NM	610714 5	1.8E-8	7.1E-13	1.2E-3	6.1E-8	2.4E-12	6.1E-5
SRS	620618 1290	1.8E-3	1.7E-8	4.4E-1	6.0E-3	5.7E-8	3.8E-1
RFETS	2171877 2307	6.8E-5	9.2E-10	6.3E-1	2.4E-4	3.2E-9	4.6E-3
WVDP	1698391 10	1.7E-7	2.6E-12	3.2E-3	5.8E-7	8.9E-12	9.7E-5
KCP	1729833 0	2.5E-9	1.1E-13	5.9E-5	8.4E-9	3.8E-13	2.8E-6
Hanford	377645 2132	1.3E-2	2.7E-7	6.4E-1	4.5E-2	9.2E-7	5.0E-1
INEL	153061 2010	6.3E-4	7.8E-8	6.6E-1	2.1E-3	2.7E-7	3.9E-1
PGDP	500502 48	8.1E-7	9.0E-11	1.3E-2	2.8E-6	3.1E-10	5.2E-4
TOTAL		1.8E-2	2.7E-7	4.0	6.1E-2	9.2E-7	2.0

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.5-20. Risks Associated with Treatment of LLMW Under the Regionalized Alternative 4, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 / 200	6.0E-6	3.3E-11	5.7E-2	2.1E-5	1.1E-10	3.6E-2
BNL	5738554 / 16	5.2E-8	7.0E-13	4.0E-3	1.9E-7	2.5E-12	2.0E-4
FEMP	2764589 / 269	1.4E-7	2.7E-12	8.8E-2	5.8E-7	1.2E-11	8.8E-4
KAPL-K	1290172 / 9	2.6E-7	5.8E-12	2.8E-3	8.9E-7	2.0E-11	2.2E-3
LBL	5856829 / 8	9.8E-9	1.5E-13	1.9E-3	4.9E-8	8.3E-13	7.4E-5
LANL	159152 / 146	3.8E-5	4.0E-9	4.4E-2	1.3E-4	1.4E-8	2.4E-3
LLNL	6324234 / 136	4.4E-7	7.2E-12	3.3E-2	1.9E-6	3.5E-11	2.2E-3
ORR	881652 / 3116	1.6E-3	5.0E-8	9.5E-1	5.6E-3	1.7E-7	8.5E-1
Mound	3032983 / 5	6.0E-9	3.5E-13	1.2E-3	7.4E-8	2.9E-12	4.6E-5
NTS	14266 / 0	7.0E-15	0.00	2.4E-5	2.5E-14	0.00	9.1E-7
Pantex	265185 / 48	2.3E-6	2.0E-10	1.5E-2	8.0E-6	6.8E-10	5.8E-4
Ports	639602 / 405	1.8E-8	2.3E-12	1.2E-1	1.1E-7	1.6E-11	2.9E-3
SNL-NM	610714 / 5	1.8E-8	7.1E-13	1.2E-3	6.1E-8	2.4E-12	6.1E-5
SRS	620618 / 1291	1.8E-3	1.7E-8	4.4E-1	6.0E-3	5.7E-8	3.8E-1
RFETS	2171877 / 769	1.3E-6	1.8E-11	2.1E-1	4.9E-6	6.4E-11	3.5E-3
WVDP	1698391 / 11	1.7E-7	2.6E-12	3.3E-3	6.0E-7	9.1E-12	1.0E-4
KCP	1729833 / 0	2.5E-9	1.1E-13	5.9E-5	8.4E-9	3.8E-13	2.8E-6
INEL	153061 / 3281	6.7E-4	8.4E-8	1.0	2.3E-3	2.8E-7	4.2E-1
Hanford	377645 / 2268	1.3E-2	2.7E-7	6.9E-1	4.5E-2	9.3E-7	5.2E-1
PGDP	500502 / 48	8.1E-7	9.0E-11	1.3E-2	2.8E-6	3.1E-10	5.2E-4
TOTAL		1.8E-2	2.7E-7	3.7	5.9E-2	9.3E-7	2.2

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.5-21. Risks Associated with Treatment of LLMW Under the Centralized Alternative, by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
ANL-E	7939785 200	6.0E-6	3.3E-11	5.7E-2	2.1E-5	1.1E-10	3.6E-2
BNL	5738554 16	5.2E-8	7.0E-13	4.0E-3	1.9E-7	2.5E-12	2.0E-4
FEMP	2764589 269	1.4E-7	2.7E-12	8.8E-2	5.8E-7	1.2E-11	8.8E-4
KAPL-K	1290172 9	2.6E-7	5.8E-12	2.8E-3	8.9E-7	2.0E-11	2.2E-3
LBL	5856829 8	9.8E-9	1.5E-13	1.9E-3	4.9E-8	8.3E-13	7.4E-5
LANL	159152 146	3.8E-5	4.0E-9	4.4E-2	1.3E-4	1.4E-8	2.4E-3
LLNL	6324234 136	4.4E-7	7.2E-12	3.3E-2	1.9E-6	3.5E-11	2.2E-3
ORR	881652 490	6.8E-6	2.1E-10	1.6E-1	2.4E-5	7.7E-10	8.4E-2
Mound	3032983 5	6.0E-9	3.5E-13	1.2E-3	7.4E-8	2.9E-12	4.6E-5
NTS	14266 0	7.0E-15	0.00	2.4E-5	2.5E-14	0.00	9.1E-7
Pantex	265185 48	2.3E-6	2.0E-10	1.5E-2	8.0E-6	6.8E-10	5.8E-4
Ports	639602 405	1.8E-8	2.3E-12	1.2E-1	1.1E-7	1.6E-11	2.9E-3
SNL-NM	610714 5	1.8E-8	7.1E-13	1.2E-3	6.1E-8	2.4E-12	6.1E-5
SRS	620618 207	1.3E-6	1.3E-11	8.1E-2	4.6E-6	4.4E-11	1.1E-1
RFETS	2171877 769	1.3E-6	1.8E-11	2.1E-1	4.9E-6	6.4E-11	3.5E-3
WVDP	1698391 11	1.7E-7	2.6E-12	3.3E-3	5.9E-7	9.1E-12	1.0E-4
KCP	1729833 0	2.5E-9	1.1E-13	5.9E-5	8.4E-9	3.8E-13	2.8E-6
INEL	153061 278	4.9E-6	6.1E-10	1.5E-1	1.7E-5	2.1E-9	2.5E-1
Hanford	377645 6706	2.5E-2	5.2E-7	2.2	8.5E-2	1.8E-6	1.8
PGDP	500502 48	8.1E-7	9.0E-11	1.3E-2	2.8E-6	3.1E-10	5.2E-4
TOTAL		2.5E-2	5.2E-7	3.2	8.6E-2	1.8E-6	2.3

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.5-22. Risks Associated with Treatment of RH-LLMW Under Each Alternative (Except No Action), by Installation

Installation	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Population[d]	MEI[d]	Workers	Population[d]	MEI[d]	Workers
Hanford	377645 1	4.4E-7	9.1E-12	1.7E-4	1.5E-6	3.1E-11	2.4E-9
ORR	881652 725	1.1E-3	3.4E-8	3.0E-1	3.7E-3	1.2E-7	7.5E-2
INEL	153061 569	2.1E-4	2.6E-8	1.7E-1	7.0E-4	8.7E-8	6.9E-3
SRS	620618 17	3.0E-5	2.8E-10	5.1E-3	1.0E-4	9.6E-10	4.8E-6
TOTAL		1.3E-3	3.4E-8	4.7E-1	4.5E-3	1.2E-7	8.1E-2

[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.
[d] Offsite.

Table D.3.5–23. Program-Wide Risks Associated with Disposal of LLMW Under the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	3.6			
	Cancer Fatalities	1.8E-3			
	Cancer Incidence	6.1E-3	1.1E-2		
	Genetic Effects	3.6E-4			
	Hazard Index			3.0	
All Lifetimes	Dose (person-rem)	1.0E2			
	Cancer Fatalities	5.0E-2			
	Cancer Incidence	1.7E-1	5.1E-1		
	Genetic Effects	1.0E-2			
	Hazard Index			3.0	
WM Workers	Dose (FTE-rem)	1.4E3			
	Cancer Fatalities	5.5E-1			
	Cancer Incidence	1.9			
	Genetic Effects	8.3E-2			
	Exposure Index				
	Construction Fatalities				1.3E-1
	Construction Injuries				5.9E1
	Operation Fatalities				3.4E-1
	Operation Injuries				2.9E2

Table D.3.5-24. Program-Wide Risks Associated with Disposal of LLMW Under the Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	2.4			
	Cancer Fatalities	1.2E-3			
	Cancer Incidence	4.1E-3	1.0E-2		
	Genetic Effects	2.4E-4			
	Hazard Index			3.0	
All Lifetimes	Dose (person-rem)	4.7E1			
	Cancer Fatalities	2.4E-2			
	Cancer Incidence	8.0E-2	5.0E-1		
	Genetic Effects	4.7E-3			
	Hazard Index			3.0	
WM Workers	Dose (FTE-rem)	1.4E3			
	Cancer Fatalities	5.5E-1			
	Cancer Incidence	1.9			
	Genetic Effects	8.3E-2			
	Exposure Index				
	Construction Fatalities				1.2E-1
	Construction Injuries				5.4E1
	Operation Fatalities				3.3E-1
	Operation Injuries				2.8E2

Table D.3.5–25. Program-Wide Risks Associated with Disposal of LLMW Under the Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	2.8			
	Cancer Fatalities	1.4E-3			
	Cancer Incidence	4.8E-3	1.3E-2		
	Genetic Effects	2.8E-4			
	Hazard Index			2.7	
All Lifetimes	Dose (person-rem)	4.7E1			
	Cancer Fatalities	2.4E-2			
	Cancer Incidence	8.0E-2	8.3E-1		
	Genetic Effects	4.7E-3			
	Hazard Index			2.7	
WM Workers	Dose (FTE-rem)	1.3E3			
	Cancer Fatalities	5.2E-1			
	Cancer Incidence	1.8			
	Genetic Effects	7.8E-2			
	Exposure Index				
	Construction Fatalities				1.1E-1
	Construction Injuries				4.7E1
	Operation Fatalities				3.1E-1
	Operation Injuries				2.6E2

Table D.3.5-26. Program-Wide Risks Associated with Disposal of LLMW Under the Regionalized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	0.00			
	Cancer Fatalities	0.00			
	Cancer Incidence	0.00	2.8E-3		
	Genetic Effects	0.00			
	Hazard Index			3.1E-1	
All Lifetimes	Dose (person-rem)	0.00			
	Cancer Fatalities	0.00			
	Cancer Incidence	0.00	5.4E-2		
	Genetic Effects	0.00			
	Hazard Index			3.1E-1	
WM Workers	Dose (FTE-rem)	9.2E2			
	Cancer Fatalities	3.7E-1			
	Cancer Incidence	1.3			
	Genetic Effects	5.5E-2			
	Exposure Index				
	Construction Fatalities				5.2E-2
	Construction Injuries				2.3E1
	Operation Fatalities				1.3E-1
	Operation Injuries				1.1E2

Table D.3.5-27. Program-Wide Risks Associated with Disposal of LLMW Under the Regionalized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	3.0			
	Cancer Fatalities	1.5E-3			
	Cancer Incidence	5.1E-3	1.3E-2		
	Genetic Effects	3.0E-4			
	Hazard Index			2.7	
All Lifetimes	Dose (person-rem)	5.0E1			
	Cancer Fatalities	2.5E-2			
	Cancer Incidence	8.5E-2	8.2E-1		
	Genetic Effects	5.0E-3			
	Hazard Index			2.7	
WM Workers	Dose (FTE-rem)	1.6E3			
	Cancer Fatalities	6.4E-1			
	Cancer Incidence	2.2			
	Genetic Effects	9.5E-2			
	Exposure Index				
	Construction Fatalities				1.0E-1
	Construction Injuries				4.4E1
	Operation Fatalities				3.1E-1
	Operation Injuries				2.7E2

Table D.3.5-28. Program-Wide Risks Associated with Disposal of LLMW Under the Centralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	3.9E1			
	Cancer Fatalities	1.9E-2			
	Cancer Incidence	6.6E-2	9.5E-4		
	Genetic Effects	3.9E-3			
	Hazard Index			2.4	
All Lifetimes	Dose (person-rem)	5.0E2			
	Cancer Fatalities	2.5E-1			
	Cancer Incidence	8.6E-1	8.5E-3		
	Genetic Effects	5.0E-2			
	Hazard Index			2.4	
WM Workers	Dose (FTE-rem)	9.1E2			
	Cancer Fatalities	3.6E-1			
	Cancer Incidence	1.3			
	Genetic Effects	5.4E-2			
	Exposure Index				
	Construction Fatalities				1.9E-2
	Construction Injuries				8.1
	Operation Fatalities				1.3E-1
	Operation Injuries				1.1E2

Table D.3.5-29. Program-Wide Risks Associated with Disposal of RH-LLMW Under Each Alternative (Except No Action), by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Most-Exposed Farm Family	Dose (person-rem)	1.7E-1			
	Cancer Fatalities	8.5E-5			
	Cancer Incidence	2.9E-4	1.4E-5		
	Genetic Effects	1.7E-5			
	Hazard Index			1.3E-2	
All Lifetimes	Dose (person-rem)	2.7			
	Cancer Fatalities	1.3E-3			
	Cancer Incidence	4.5E-3	5.8E-4		
	Genetic Effects	2.7E-4			
	Hazard Index			1.3E-2	
WM Workers	Dose (FTE-rem)	3.7			
	Cancer Fatalities	1.5E-3			
	Cancer Incidence	5.2E-3			
	Genetic Effects	2.2E-4			
	Exposure Index				
	Construction Fatalities				9.4E-3
	Construction Injuries				4.1
	Operation Fatalities				2.1E-2
	Operation Injuries				1.8E1

Table D.3.5-30. Risks Associated with Disposal of LLMW Under the Decentralized Alternative, by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	9.4E-4	1.8E-2	2.8E-1	3.7E-3	6.5E-2	7.1E-1
INEL (0)	0.00	0.00	1.9E-1	3.0E-5	4.1E-5	4.9E-1
LLNL (142)	1.3E-6	2.0E-5	6.3E-2	7.8E-6	2.6E-4	1.4E-1
LANL (0)	0.00	0.00	1.3E-2	3.1E-4	5.5E-3	5.5E-3
NTS (0)	0.00	0.00	1.2E-2	2.2E-4	3.5E-3	1.9E-3
ORR (22)	3.8E-6	5.9E-5	1.3E-1	6.4E-3	4.5E-1	2.8E-1
PGDP (146)	7.8E-6	6.6E-5	3.1E-3	2.8E-5	2.4E-4	4.8E-4
Pantex (96)	2.7E-6	8.6E-5	5.1E-3	1.4E-5	3.6E-4	1.1E-3
Ports (145)	3.1E-5	1.1E-3	6.6E-2	5.4E-4	8.8E-3	1.3E-1
RFETS (38)	1.6E-6	3.1E-5	7.1E-2	1.1E-3	2.5E-2	8.2E-3
SNL-NM (92)	1.8E-4	9.3E-3	7.7E-4	6.2E-4	3.2E-2	1.2E-4
SRS (153)	9.7E-5	1.3E-3	1.4E-1	1.3E-3	7.2E-3	1.4E-1
ANL-E (64)	3.4E-4	1.5E-2	5.2E-2	2.1E-3	6.5E-2	4.3E-2
BNL (78)	4.2E-5	2.6E-3	1.6E-3	1.8E-4	9.0E-3	2.1E-4
FEMP (53)	1.5E-4	2.5E-3	9.3E-3	7.8E-6	2.6E-4	1.0E-3
TOTAL	1.8E-3	5.0E-2	1.0	1.7E-2	6.8E-1	1.9

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5–31. Risks Associated with Disposal of LLMW Under the Regionalized Alternative 1, by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
FEMP (53)	1.5E-4	2.5E-3	9.3E-3	5.7E-4	8.7E-3	1.0E-3
INEL (0)	0.00	0.00	1.9E-1	3.0E-5	4.1E-5	4.9E-1
LLNL (142)	1.3E-6	2.0E-5	6.3E-2	7.8E-6	2.6E-4	1.4E-1
LANL (0)	0.00	0.00	1.3E-2	3.1E-4	5.5E-3	6.7E-3
NTS (0)	0.00	0.00	1.4E-2	2.2E-4	3.5E-3	1.9E-3
ORR (22)	3.0E-6	4.7E-5	1.2E-1	6.4E-3	4.5E-1	2.5E-1
PGDP (146)	7.8E-6	6.6E-5	3.1E-3	2.8E-5	2.4E-4	4.8E-4
Pantex (96)	2.7E-6	8.6E-5	5.1E-3	1.4E-5	3.6E-4	1.1E-3
Ports (145)	8.5E-5	3.1E-3	1.1E-1	8.5E-4	1.7E-2	2.0E-1
RFETS (38)	1.6E-6	3.1E-5	7.1E-2	1.1E-3	2.5E-2	8.2E-3
SRS (153)	9.7E-5	1.3E-3	1.4E-1	1.3E-3	7.2E-3	1.4E-1
Hanford (18)	8.6E-4	1.7E-2	2.7E-1	3.4E-3	6.1E-2	7.0E-1
TOTAL	1.2E-3	2.4E-2	1.0	1.4E-2	5.8E-1	1.9

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-32. Risks Associated with Disposal of LLMW Under the Regionalized Alternative 2, by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.3E-3	2.2E-2	2.9E-1	4.9E-3	8.0E-2	7.4E-1
INEL (0)	0.00	0.00	2.2E-1	3.0E-5	4.2E-5	5.8E-1
LANL (0)	0.00	0.00	1.4E-1	1.7E-4	3.2E-3	4.0E-2
NTS (0)	0.00	0.00	3.9E-4	1.4E-9	2.1E-8	2.5E-5
ORR (22)	3.6E-6	5.8E-5	1.5E-1	1.2E-2	8.1E-1	3.3E-1
SRS (153)	9.7E-5	1.3E-3	1.4E-1	1.3E-3	7.2E-3	1.4E-1
TOTAL	1.4E-3	2.4E-2	9.4E-1	1.8E-2	9.1E-1	1.8

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-33. Risks Associated with Disposal of LLMW Under the Regionalized Alternative 3, by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
NTS (0)	0.00	0.00	5.5E-1	2.8E-3	5.4E-2	1.3
TOTAL	0.00	0.00	5.5E-1	2.8E-3	5.4E-2	1.3

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-34. Risks Associated with Disposal of LLMW Under the Regionalized Alternative 4, by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
INEL (0)	0.00	0.00	4.0E-1	1.7E-5	2.2E-5	1.0
LANL (0)	0.00	0.00	7.6E-2	4.7E-7	8.4E-6	5.5E-3
NTS (0)	0.00	0.00	3.3E-4	1.4E-9	2.1E-8	2.5E-5
ORR (22)	4.3E-6	7.0E-5	1.5E-1	1.2E-2	8.2E-1	3.3E-1
SRS (153)	9.7E-5	1.3E-3	1.4E-1	1.3E-3	7.2E-3	1.4E-1
Hanford (18)	1.4E-3	2.4E-2	2.9E-1	5.2E-3	8.5E-2	7.4E-1
TOTAL	1.5E-3	2.5E-2	1.1	1.8E-2	9.1E-1	2.2

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-35. Risks Associated with Disposal of LLMW Under the Centralized Alternative, by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.9E-2	2.5E-1	5.1E-1	6.7E-2	8.7E-1	1.3
TOTAL	1.9E-2	2.5E-1	5.1E-1	6.7E-2	8.7E-1	1.3

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-36. Risks Associated with Disposal of RH-LLMW Under Each Alternative (Except No Action), by Installation

Installation (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Most-Exposed Farm Family	All Farm Family Lifetimes	WM Workers
INEL (0)	0.00	0.00	2.1E-2	7.6E-7	1.2E-6	3.5E-3
Hanford (18)	2.4E-7	5.0E-6	2.5E-5	8.5E-7	1.7E-5	3.2E-11
ORR (22)	8.3E-5	1.3E-3	9.7E-3	2.9E-4	5.0E-3	1.8E-3
SRS (153)	2.1E-6	2.9E-5	1.2E-3	1.2E-5	1.1E-4	2.2E-6
TOTAL	8.5E-5	1.3E-3	3.2E-2	3.0E-4	5.1E-3	5.2E-3

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

D.3.5.4 Results of the LLMW Human Health Risk Analysis for Routine Operations

D.3.5.4.1 *Program-Wide Trends in Human Health Risks Associated with LLMW Management Alternatives*

For the offsite and noninvolved worker populations and their respective MEIs, the cancer fatality risks associated with CH-LLMW treatment Regionalized Alternatives 2, 3, 4, and the Centralized Alternative are generally lower than for No Action, Decentralized, and Regionalized 1, due to reduction in the number of treatment installations and the transfer of waste to installations where offsite populations are smaller and/or farther away from treatment facilities. However, for the offsite population and both MEIs, cancer fatality risks in the Centralized Alternative are slightly higher (less than a factor of two) than those associated with Regionalized 2, 3, and 4. In all alternatives, radiological risks to offsite and noninvolved worker receptors are higher than risks from chemical exposure.

Risk of cancer incidence to offsite and noninvolved worker populations and offsite MEIs from chemical exposure follows a similar trend, decreasing as fewer installations treat LLMW. However, for the noninvolved worker MEI, chemical-related cancer incidence risk increases slightly when all treatment is

performed at only one installation. All hazard indices are all well below 1.0, indicating a low probability of adverse health effects due to noncarcinogenic, toxic chemicals.

For workers, the No Action Alternative (which entails treatment of RH- and CH-LLMW) and all CH-LLMW treatment alternatives are very similar for all health risk endpoints. However, the cancer incidence risks due to chemical exposure are 1 to 2 orders of magnitude lower than the cancer incidence risks due to radionuclide exposure. All exposure indices are well below 1.0, indicating a low probability of adverse health effects due to noncarcinogenic, toxic chemicals.

For all receptors, cancer risks associated with RH-LLMW treatment (in all alternatives except No Action) are greater at ORR and INEL than at other installations because these two installations treat substantially larger waste loads.

Offsite Population. The No Action, 49-installation treatment, and 11-installation treatment alternatives (No Action, Decentralized, and Regionalized 1, respectively) produce risks of cancer fatality to the offsite population approximately 1 order of magnitude higher than the 7-, 4-, and 1-installation treatment alternatives (Regionalized 2, 3, 4, and Centralized). This is because CH-LLMW is being transferred for treatment from LLNL (which has a population of 6.3 million located relatively close to the facility) to Hanford (which has a population of 380,000 located farther from the facility). Total cancer fatality risks for No Action, Decentralized, and Regionalized 1 range from 1.6E-1 to 3.1E-1 over a total affected population of approximately 38.5 million; whereas the risks in Regionalized 2, 3, 4, and Centralized range from 1.8E-2 to 2.5E-2 for the same affected population.

For No Action and the alternatives involving treatment of CH-LLMW, most of the estimated cancer fatality risk can be attributed to exposure to uranium-238 at ORR (No Action), tritium at LLNL (Decentralized and Regionalized 1), and tritium at Hanford (Regionalized 2, 3, 4, and Centralized). The installations that pose the highest risk, by alternative, are ORR in No Action; LLNL in Decentralized and Regionalized 1; and Hanford in Regionalized 2, 3, 4, and Centralized. (As discussed in Chapter 6, the risk estimates in this section are based on the assumption that LLMW will be incinerated. The highest health risks to the offsite population are estimated to result from releases of tritium during incineration of wastes containing tritium. It should be noted that DOE is exploring alternative technologies for treating LLMW where incineration is determined to be unacceptable based on potential health risks.)

Cancer incidence risk to offsite populations from exposure to carcinogenic chemicals follows the trends for radiological risks, generally decreasing from No Action to Centralized. The highest chemical-related cancer incidence risk is in No Action (2.9E-3) by approximately 1 to 2 orders of magnitude over other alternatives. The lowest estimated cancer incidence due to chemical exposure is in the Centralized Alternative (1.5E-5).

The treatment of RH-LLMW at four installations presents a program-wide risk of cancer fatality to the offsite population of 1.3E-3 over a total affected population of approximately 2 million (in all alternatives except No Action). The highest installation-specific cancer fatality risk associated with RH-LLMW treatment is at ORR due to tritium emissions during management of a relatively large waste volume. The estimated program-wide risk of cancer incidence from chemical exposure is 7.2E-8 for the RH-LLMW treatment scenario.

Noninvolved Worker Population. The program-wide health risks to noninvolved worker populations parallel the trends observed for the offsite populations. Cancer fatality risks in No Action, Decentralized, and Regionalized 1 are approximately 1 to 2 orders of magnitude higher than in Regionalized 2, 3, 4, and Centralized. The risk of cancer fatality to noninvolved worker populations ranges from 3.3E-4 (Centralized) to 1.3E-2 (No Action) for CH-LLMW.

The No Action Alternative presents the highest risk of cancer fatality (1.3E-2) to the noninvolved worker population and is approximately 1 order of magnitude higher than the next-highest alternative. The 49-installation and 11-installation CH-LLMW treatment alternatives (Decentralized and Regionalized 1) produce risks of cancer fatality (2.4E-3 in each alternative) for the noninvolved worker population approximately 1 order of magnitude higher than for the 7-, 4-, and 1-installation treatment alternatives (Regionalized 2, 3, 4, and Centralized) (3.3E-4 to 3.6E-4), because at LLNL, a larger population of noninvolved workers is located closer to the facility than at Hanford. (There are 9,500 noninvolved workers located 800 m from the facility at LLNL compared to 160 people at Hanford).

The risk of cancer incidence to noninvolved worker populations from exposure to carcinogenic chemicals in CH-LLMW ranges from 7.9E-6 (Centralized) to 5.8E-4 (No Action), following the same general trend as for offsite populations.

The treatment of RH-LLMW at four installations (all alternatives except No Action) results in a risk to noninvolved worker populations of 4.2E-5 for cancer fatality and a risk of 3.9E-8 for cancer incidence due to chemical exposure.

Most-Exposed Noninvolved Workers and Most-Exposed Offsite Individuals. For CH-LLMW, the trends in cancer fatality risks to offsite MEIs are similar to those for offsite and noninvolved worker populations in that Regionalized 2, 3, 4, and Centralized generally have lower risks than No Action, Decentralized, and Regionalized 1. Risk of cancer incidence to offsite and noninvolved worker populations and offsite MEIs due to chemical exposure follows a similar trend, decreasing as fewer installations treat LLMW. However, both cancer fatality risks and chemical-related cancer incidence risks to the noninvolved worker MEI increase slightly (less than a factor of two) in the Centralized Alternative (compared to Regionalized 2, 3, and 4), reflecting increased exposure of the noninvolved worker MEI with consolidation of waste and treatment at one installation.

The No Action Alternative has the highest risk of cancer fatality for the offsite and noninvolved worker MEIs, (7.0E-6 and 8.7E-6, respectively). The risk of cancer incidence due to chemicals is about 2 or more orders of magnitude less than the risk of cancer incidence due to radionuclides for both MEIs. The hazard index for the offsite MEI ranges from 4.8E-9 to 2.3E-5, whereas the hazard index for the noninvolved worker MEI ranges from 3.8E-8 to 4.5E-5. The hazard indices for all MEIs are well below 1.0 in all alternatives, indicating a low probability of health effects from noncarcinogenic constituents.

Treatment of RH-LLMW at four installations results in cancer fatality risks to the offsite and noninvolved worker MEIs of 3.4E-8 and 2.3E-8 respectively, and risks of cancer incidence from chemical exposure of 2.9E-12 and 1.8E-11, respectively.

Workers. Total estimated risks of cancer incidence and cancer fatalities to workers due to radionuclide exposure are very similar among alternatives, differing by less than a factor of two. Estimated cancer fatalities for No Action and the CH treatment alternatives range from 5.2E-1 to 8.7E-1 out of a total population ranging from about 9,200 to 15,100 FTEs). Risk of cancer incidence due to radiation exposure ranges from 1.8 to 3.0 for the same alternatives. Risks of cancer fatalities and incidence to workers due to radionuclide exposure in the RH treatment scenario are 2.3E-2 and 8.1E-2, respectively, out of a total worker population of 1,312 FTEs.

Worker health risks due to chemical exposure are also similar among alternatives (No Action and CH-LLMW treatment). The highest cancer incidence (1.8E-2 out of a total population of 9,756 FTEs) and the highest exposure index (2.6E-2) due to chemical exposure are for the Centralized Alternative where all waste is treated at Hanford. In this alternative, chemical waste loads are substantially larger at Hanford, and more workers are processing more waste at a time to complete treatment over the 10-year period. However, chemical exposure risks associated with the Centralized Alternative are higher only by about a factor of two over other alternatives. For RH-LLMW, cancer incidence risk due to chemical exposure is 6.7E-5, and the exposure index is 4.6E-4 (in each alternative except No Action).

All worker cancer incidence risks due to chemical exposure are 1 to 2 orders of magnitude lower than cancer incidence risks due to radionuclide exposure. All exposure indices are well below 1.0.

Estimated construction fatality risks for CH treatment are also very similar among alternatives, ranging from 1.4 to 2.2 (in the Regionalized and Centralized Alternatives). Construction fatality risks are slightly lower in No Action (6.2E-1). Construction fatality risk associated with RH treatment is 2.9E-1. Risk of operational fatality ranges from 1.1 to 1.9 for No Action and CH treatment alternatives, and is 1.6E-1 for the RH treatment scenario. Estimated operational fatalities are slightly lower (by about a factor of two or less) for No Action (1.1) than for other alternatives; this is due to less worker person-hours associated with treatment in No Action. Estimated construction and operational injuries follow the same patterns as fatalities.

Although, worker risks associated with CH-LLMW treatment are very similar across alternatives, some differences in installation risks are notable. The estimated total fatalities (cancer fatalities plus construction and operational fatalities) at KCP and NTS (E-5 to E-4 range) are lower by 1 or more orders of magnitude because these installations have much smaller waste loads to treat and fewer workers than other installations (1 or less FTEs in all alternatives). The same trend is seen for total cancer incidence due to radionuclide and chemical exposure at NTS and KCP (see Table D.3.5–15).

The highest total fatality and cancer incidence (from radionuclides and chemicals) risks associated with CH treatment are at Hanford in the Centralized Alternative (2.2 and 1.8, respectively). All risks at Hanford increase about 0.5 to 1 order of magnitude in the Centralized Alternative where Hanford is the only treatment installation (compared to No Action and other CH-LLMW alternatives).

The highest total fatalities and cancer incidence risks for RH treatment are at ORR (3.0E-1 and 7.5E-2, respectively) and INEL (1.7E-1 and 6.9E-3, respectively) due to much larger RH-LLMW volumes and much larger exposed work forces (725 at ORR and 569 at INEL compared to 1 at Hanford and 17 at SRS).

D.3.5.4.2 *Program-Wide Trends in Human Health Risks Associated with LLMW Disposal*

In general, Regionalized 3 (single-installation disposal of CH-LLMW at NTS) poses the lowest total health risks to all farm family lifetimes for cancer fatalities and cancer incidence. Estimated risk of cancer incidence (from radiological and chemical exposure) associated with all other CH-LLMW disposal alternatives is higher by approximately 1 order of magnitude. The estimated risk of cancer incidence to all farm family lifetimes from radionuclides ranges from zero (Regionalized 3) to 8.6E-1 (Centralized); and the estimated cancer incidence risk from carcinogenic chemicals ranges from 8.5E-3 (Centralized) to 8.3E-1 (Regionalized 2). The hazard indices (for a member of the MEL of the farm family) range from 3.1E-1 in Regionalized 3 to 3.0 in Decentralized and Regionalized 1.

Only one scenario (all alternatives except No Action) was analyzed for RH-LLMW with four installations (Hanford, INEL, ORR, and SRS) treating and disposing of all waste onsite. The risks of cancer incidence to all farm family lifetimes from radionuclides range from zero (INEL) to 4.4E-3 (ORR). The risks of cancer incidence posed by chemicals range from 2.6E-7 (Hanford) to 5.7E-4 (ORR). The hazard indices (to a member of the MEL of the farm family) range from 7.2E-5 (Hanford) to 1.3E-2 (SRS).

Most-Exposed Lifetime of the Hypothetical Farm Family. The lowest risks of cancer incidence due to radionuclide exposure to the MEL of the farm family are for Regionalized 3 in which all LLMW is disposed of at NTS. The risk of cancer incidence is zero for the farm family of four. This lack of risk is primarily due to the greater depth of the groundwater, the small amount of rainfall, and the lack of volatile radionuclides (such as carbon-14) in the waste at NTS. This results in retarded migration of contaminants into the groundwater (slow-moving, long-lived radionuclides have not yet reached the groundwater during the 10,000-year analysis period).

The highest risks of cancer incidence due to radionuclide exposure to the MEL of the farm family are for the Centralized Alternative in which all CH-LLMW is disposed of at Hanford. The risk of cancer incidence is 6.6E-2 (average individual risk of cancer incidence is 1.7E-2) during lifetime 18 with

uranium-238 as the controlling radionuclide. The elevated risks are probably due to a higher level of contaminant migration into the groundwater.

The lowest disposal installation risks are at INEL, LANL, and NTS for Decentralized and Regionalized 1, 2, and 4 and at NTS for Regionalized 3. The estimated risk of cancer incidence due to radionuclide exposure to the MEL of the farm family for each of these alternatives is zero. This is due to the lack of volatile radionuclides in the waste at installations with a greater depth to groundwater and a small amount of rainfall.

The lowest estimated risks of cancer incidence due to chemical exposure to the MEL of the farm family are for the Centralized Alternative in which CH-LLMW is disposed of at Hanford. The program-wide risk of cancer incidence is 9.5E-4 for the MEL of the farm family (individual cancer incidence risk is 2.4E-4) during lifetime 18 where 1,2-dichloroethane is the controlling contaminant.

The highest risks of cancer incidence due to chemical exposure to the MEL of the farm family are for Decentralized (15-installation disposal), Regionalized 1 (12-installation disposal), and Regionalized 2 and 4 (both 6-installation disposal). The chemical-related cancer incidence risk for each of these alternatives is very similar, ranging from 1.0E-2 to 1.3E-2. For each of these alternatives, the risk of chemical-related cancer incidence at ORR ranges from 6.4E-3 to 1.2E-2 during lifetime 61, and the controlling contaminant is 1,2-dichloroethane. The higher risk at this installation is due to a much higher concentration of volatile, potentially carcinogenic contaminants in the groundwater.

The lowest hazard index for a member of the MEL of the farm family occurs at NTS for Regionalized 2 and 4 (6.4E-8) during lifetime 37. The controlling contaminant is methylene chloride, which accounts for more than 90% of the hazard index. The hazard index is well below 1.0, therefore, exposure to noncarcinogenic, hazardous chemicals presents very few health hazards to any of the farm family lifetimes at NTS in this alternative.

The highest hazard index occurs at ORR for Regionalized 4 (1.1) during lifetime 22. The controlling contaminant is acetone, which accounts for over 70% of the hazard index. As this hazard index is greater than 1.0, it indicates a risk of toxicity to the most-exposed farm family.

For RH-LLMW disposal, the lowest estimated risks of cancer incidence due to radionuclides is at INEL where the risk to the MEL of the farm family is zero. As observed for NTS, the low amount of rainfall, the depth to groundwater, and a lack of volatile radionuclides in the waste lead to a greatly reduced risk due to retarded migration of contaminants. Estimated risk of radionuclide-related cancer incidence to the MEL of the farm family is highest at ORR with a risk of 2.8E-4 (individual cancer risk of 7.0E-5) during lifetime 22, and the driving radionuclide is neptunium-237.

The lowest risks of cancer incidence posed by chemicals in RH-LLMW is at Hanford (2.6E-8) where carbon tetrachloride is the controlling contaminant during lifetime 34. The highest estimated risk of cancer incidence due to chemicals is at SRS (4.7E-6) during lifetime 5; carbon tetrachloride is the controlling contaminant. All hazard indices are below 1.0, indicating that adverse health effects associated with noncarcinogenic chemicals are estimated to be unlikely for RH-LLMW disposal.

Workers Placing Wastes into Disposal. The estimated worker cancer fatality and incidence risks due to radionuclide exposure during disposal are very similar among alternatives, ranging from 3.6E-1 to 6.4E-1 and from 1.3 and 2.2, respectively, for the CH-LLMW treatment alternatives. However, the estimated risk of fatality from construction is lower for the one-installation disposal alternatives (Regionalized 3 and Centralized) than for other alternatives. Hanford and NTS are the single disposal installations in these alternatives and both have a large amount of existing disposal capacity compared to other installations; therefore, these two installations would require less construction of disposal facilities. The construction risks for the other CH-LLMW alternatives (Decentralized and Regionalized 1, 2, 4) are very similar. Construction fatality risk for the RH-LLMW disposal scenario is 3.0E-2. Trends in risk of construction injury follow those seen for risk of construction fatality.

The estimated number of operational fatalities is within an order of magnitude among the CH disposal alternatives (ranging from 3.4E-1 to 1.3E-1). The RH disposal scenario has an estimated operational fatality risk of 2.1E-2. In general, operational fatalities are slightly higher for alternatives where multiple installations dispose (Decentralized and Regionalized 1, 2, 4) and are slightly lower where only one installation disposes (Regionalized 3 and Centralized). This trend is due to fewer total worker person-hours associated with fewer disposal installations. Risk of operational injury to workers follows the same trend as operational fatalities.

Though overall risks to workers from disposal do not differ appreciably among CH treatment alternatives, some trends are apparent among installation risks associated with disposal. In the multiple-installation disposal alternatives (Decentralized and Regionalized 1, 2, 4), the same two installations, Hanford and INEL, have the highest cancer risks by about 0.5 to 2 orders of magnitude. These installations are consolidation installations for disposal of CH-LLMW in these alternatives. The controlling contaminants are cesium-137 at Hanford for Decentralized and cobalt-60 at Hanford and INEL for Regionalized 1, 2, and 4; external radiation is the predominant exposure route. In the one-installation disposal alternatives, the controlling contaminant at Hanford in Centralized and NTS in Regionalized 3 is cobalt-60; the primary exposure route is external radiation. Risks increase approximately 3 to 5 orders of magnitude at NTS where it is the only installation disposing in Regionalized 3; and risks go up only slightly at Hanford when it is the only disposal installation in the Centralized Alternative.

For RH-LLMW disposal, estimated risk of cancer fatality and cancer incidence from radionuclide exposure are 1.5E-3 and 5.2E-3, respectively. INEL and ORR have the greatest estimated risks to workers by 2 to 7 orders of magnitude with total estimated fatalities (exposure plus physical hazards) of 2.1E-2 and 9.7E-3 and cancer incidence (from radionuclides and chemicals) of 3.5E-3 and 1.8E-3, respectively, over Hanford and SRS. This difference in risk is attributed to the large amounts of remote-handled LLMW at INEL and ORR versus the comparatively small amounts at Hanford and SRS. The controlling radionuclide at INEL and ORR is cobalt-60 and external radiation is the primary exposure route.

D.3.5.4.3 *Comparison Among Treatment Options*

A comparison of CH-LLMW treatment options (No Action and 49-, 11-, 7-, 4-, and 1-installation treatment options) indicates that treatment risks (radiological and chemical) to offsite and noninvolved worker populations generally decrease as the number of treatment installations are reduced. This trend is due in part to transfer of waste to installations where offsite populations are smaller and/or farther away from treatment facilities. Worker risks associated with treatment are very similar for all alternatives. Radiological risks associated with treatment are consistently higher than chemical exposure risks associated with treatment for all receptors.

D.3.5.4.4 *Comparison Among Disposal Scenarios*

Direct comparisons can be made between the two CH-LLMW alternatives that involve disposal at a single installation. Regionalized 3 involves disposal at NTS, and Centralized involves disposal at Hanford. The estimated risk of cancer incidence due to radionuclide exposure is higher for Hanford (6.6E-2) than for NTS (zero). The risk of cancer incidence due to exposure to carcinogenic chemicals is slightly higher at NTS than at Hanford (2.8E-3 versus 9.5E-4, respectively). However, the hazard index at Hanford is higher by approximately one order of magnitude (3.1E-1 at NTS versus 2.4 at Hanford). Though both NTS and Hanford are in arid environments, the level of the groundwater at NTS is much deeper than at Hanford, and radionuclide contaminants migrate at a much slower rate.

Comparisons can also be made between Regionalized 2 (treat CH-LLMW at seven installations, dispose at six installations) and Regionalized 4 (treat CH-LLMW at four installations, dispose at six installations). There is no appreciable difference in the estimated risk of cancer incidence due to chemicals (4.2) or in the hazard indices (2.7). The risks of cancer incidence due to radionuclides show also little variation (8.0E-2 for Regionalized 2 and 8.5E-2 for Regionalized 4).

All worker risks associated with CH-LLMW disposal are similar among alternatives.

D.3.5.4.5 *Summary of Results for Routine Treatment and Disposal of LLMW*

In summary, the No Action Alternative presents the highest treatment health risks to the offsite and noninvolved worker populations. For treatment, radiological risks are consistently higher than chemical exposure risks for all receptors.

Since the types of treatment do not change for any of the LLMW alternatives, treatment is not a consideration for LLMW disposal. The risks are largely affected by the amount and type of waste load as well as the groundwater characteristics of the disposal installation. Geographical location of the disposal installation and the characteristics of the soil affecting the migration of contaminants into the groundwater affect the risks as well.

Worker risks are very similar across all CH-LLMW alternatives, regardless of number of treatment installations or disposal scenario. However, as might be expected, consolidation of CH-LLMW at fewer installations for treatment or disposal tends to elevate worker risks at those installations.

D.3.5.5 Summary of Alternatives for Potential LLMW Accidents

The following LLMW alternatives were evaluated for potential treatment facility (incinerator) accidents: No Action, Decentralized, Regionalized 1, Regionalized 2, Regionalized 4, and Centralized. Health risks associated with accidental releases of radionuclides and those associated with accidental releases of chemicals were analyzed separately from one another and are discussed separately in this section. In addition, the risks from accidents affecting facilities that manage alpha-emitting radionuclides were analyzed separately from the accident risks for facilities that manage non-alpha-emitting radionuclides (these two categories of radionuclides are referred to as "alpha" and "non-alpha" in the analysis). Note that incineration accident scenarios postulated for Regionalized 1 only include installations with alpha facilities.

The treatment facility accidents analyzed include (1) an incinerator explosion and resulting fire; (2) a feedstock staging area fire; and (3) an earthquake followed by an incinerator facility fire. For accidents involving chemical releases during incineration, only the feedstock staging area fire scenario is evaluated.

D.3.5.6 Special Assumptions and Considerations Used in the LLMW Accident Analysis

All accidental releases from incinerator facilities to the outside (i.e., to the offsite and noninvolved worker populations) are assumed to be at ground level with dispersion starting at a lower level rather than from a facility stack. In the incinerator explosion accident scenario, it is assumed that the efficiency of the facility's high-efficiency particulate air filtration system drops only to 99.9%. In the assessment of worker risks from incineration accidents, it is assumed that the air in the work area is not ventilated or filtered; the intra-facility source term for this accident is, therefore, 1,000 times higher than the atmospheric source term used to calculate risks to the offsite and noninvolved worker populations.

Incineration accidents are assumed to cause releases into the operating gallery where the workers are located. Half of the operating gallery (e.g., an area 32 m long × 6 m wide × 6 m high) is assumed to fill with contaminated air. Exposure duration is 1 min, the time necessary for workers to avoid any obstructions and leave the scene. During all accidents, one shift of waste management workers is assumed to be inside the incinerator facility. Shift size varies from 1 to 14 workers.

Each accident type has an associated estimated annual frequency of occurrence as determined by Argonne National Laboratory (see Section D.2.7.1). However, the probability of occurrence is not taken into account in the risk calculations. Risk estimates associated with each accident should be interpreted as the consequences if the accident occurred. Estimated annual frequencies vary by accident type and contaminant type.

For radionuclide-related accidents, the incinerator explosion is considered to be "anticipated" (greater than 1E-2); the feedstock staging area fire is considered "unlikely" (1E-4 to 1E-2); and the earthquake resulting in an incinerator facility fire is considered "very unlikely" (1E-6 to 1E-4). For chemical-related accidents, the incinerator feedstock staging area fire is considered "anticipated" (greater than 1E-2) (see Appendix W).

All "chromium" listed in the source term was assumed to be 100% chromium (VI) due to lack of more specific information. This is a conservative assumption, and health risks associated with chromium (VI) may be overestimated.

D.3.5.7 Results Tables for the Risk Analysis of Potential LLMW Accidents

Because of the volume of results tables for potential LLMW accidents, the following results tables are presented at the end of Section D.3.5.8:

- Tables D.3.5-37 and D.3.5-38 present the worst-case radionuclide- and chemical-related accidents for the offsite and noninvolved worker populations, their respective MEIs, and waste management workers for treatment facility accidents, by installation and alternative.
- Tables D.3.5-39 through D.3.5-70 present the radionuclide-related risks associated with LLMW treatment for the offsite population, offsite MEI, and worker population by alternative, installation, and accident type.

- Tables D.3.5-71 through D.3.5-113 present the chemical-related risks associated with LLMW treatment for the offsite population, offsite MEI, and worker population by alternative, installation, and accident type.

While the risk analysis results for the noninvolved worker population and noninvolved worker MEI are discussed below, the risk results for these receptors are not included in Tables D.3.5-39 through D.3.5-113. The results for the noninvolved worker receptors can be found in the supplementary risk analysis results technical document (ORNL, 1995e).

D.3.5.8 Summary of the LLMW Accident Analysis Results

Accidents Involving Releases of Radiological Contaminants. For radionuclide-related incineration accidents in all alternatives, the dominant accident type for all receptors is the earthquake resulting in a fire. The highest installation-specific cancer fatality risks are consistently associated with Hanford and/or ORR for all receptors. Cancer fatality risks associated with incineration accidents in alpha facilities are usually higher than those associated with similar accidents in non-alpha facilities by 2 times to 3 orders of magnitude (for all receptors at INEL, LANL, and RFETS in Decentralized, Regionalized 2, and Regionalized 4). However, at SRS (in all alternatives where SRS is evaluated) and at Hanford (in the Centralized Alternative), alpha facility accident risks are lower than those from similar accidents in non-alpha facilities by 1 to 2 orders of magnitude.

Accidents Involving Releases of Chemical Contaminants. For chemical-related incineration accidents in all alternatives except Centralized (where Hanford treats all LLMW), ORR is consistently the highest-risk installation for all receptors. In the Centralized Alternative, however, Hanford has the highest worker cancer incidence risk and IDLH index of all alternatives due to a greater number of exposed workers. At installations where both alpha and non-alpha LLMW are incinerated, the accident risks vary depending on contaminant inventories. At a given installation, the estimated cancer incidence risks and hazard/IDLH indices for accidents occurring in alpha incineration facilities are usually higher (in some instances by more than 2 orders of magnitude) than those estimated for similar non-alpha facility accidents. The exceptions to this are: SRS (Decentralized and Regionalized 1, 2, and 4) and Hanford (Centralized) where the risks from non-alpha incineration accidents are approximately 1 order of magnitude higher than those from alpha facility accidents; and LLNL (Decentralized and Regionalized 1) where non-alpha

incineration accident risks are only slightly higher (less than a factor of two) than similar alpha facility accident risks.

D.3.5.8.1 *Risks to the Offsite Population from LLMW Accidents*

Accidents Involving Releases of Radiological Contaminants. For incineration accidents involving releases of radionuclides from non-alpha facilities, cancer fatality risks to the offsite population range from 9.5E-9 to 4.0E-1 in population sizes ranging from 153,061 to 10,453,402. Cancer fatality risks from alpha facility incinerator accidents range from 5.4E-7 to 1.1E-2 in population sizes ranging from 153,061 to 6,324,234. Incineration accident risks at a given installation do not differ greatly among alternatives. Risks associated with a particular accident either remain the same at an installation across alternatives or increase only slightly with waste consolidation.

The incineration accident type resulting in the highest risks to offsite populations is the earthquake resulting in a fire. In each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and aircraft impact) are approximately 2 to 3 orders of magnitude lower than those associated with the earthquake scenario at a given installation. However, the estimated annual frequency of the earthquake scenario affecting the incinerator facility is "very unlikely" (1E-6 to 1E-4) for all installations and alternatives, while the feedstock staging area fire and incinerator explosion are considered "unlikely" (1E-4 to 1E-2) and "anticipated" (greater than 1E-2), respectively.

Hanford has the highest cancer fatality risks to the offsite population from incineration accidents in all alternatives (where Hanford is evaluated) because of relatively high releases of plutonium-238 and/or uranium-238. The highest cancer fatality risk at Hanford is 4.0E-1 (distributed over a population of 377,645) for the non-alpha earthquake scenario in the Centralized Alternative. ORR has the next highest cancer fatality risks to the offsite population from non-alpha incineration accidents. The controlling contaminant at ORR is uranium-238. Internal exposure is the primary route for both installations. The highest alpha facility accident risks are at LLNL in Decentralized and Regionalized 1 and at RFETS in Decentralized and Regionalized 1 and 2. The controlling contaminant at both installations is plutonium-238; the primary exposure route is internal.

Accidents Involving Releases of Chemical Contaminants. For incineration accidents that involve chemical releases from non-alpha facilities (feedstock staging area fire), the estimated risks of cancer incidence range from 2.1E-7 to 1.1E-2 in population sizes ranging from 153,061 to 10,453,402. Estimated risks of cancer incidence from alpha incinerator facility feedstock staging area fire accidents range from 1.5E-6 to 4.7E-4 in population sizes ranging from 153,061 to 6,324,234. All chemical-related feedstock staging area fire scenarios are considered "anticipated" (estimated annual frequency greater than 1E-2).

The highest estimated risk of cancer incidence from an accidental chemical release associated with incineration at an installation is at ORR in Regionalized 4 (1.1E-2 in a population of 881,652). In all alternatives except Centralized (in which all treatment is performed at Hanford), ORR poses the greatest risks of cancer incidence from incineration accidents, ranging from 7.3E-3 to 1.1E-2 in a population of 881,652. This is approximately 1 to 5 orders of magnitude higher than the risks at all other installations. The higher estimated cancer risk at ORR is due to a relatively large release of chromium (VI) during an incinerator accident. The alpha incineration accident with the highest risk of cancer incidence to the offsite population is the feedstock staging area fire at RFETS; the risk of cancer incidence is 4.7E-4 in a population of 2,171,877 for Decentralized and Regionalized 1 and 2. The controlling contaminant at RFETS is also chromium (VI).

Worst-case incineration accident risks do not differ much among alternatives at most installations (remain approximately equal or increase slightly with greater waste consolidation). However, cancer incidence risk to the offsite population from the worst-case accident in Decentralized and Regionalized 1, 2, and 4 is higher than for No Action at INEL by 1 to 2 orders of magnitude. In addition, cancer incidence risk from the worst-case accident at Hanford in the Centralized Alternative is higher than for Hanford in other alternatives by an order of magnitude or more due to centralized consolidation of waste loads.

D.3.5.8.2 *Risks to the Noninvolved Worker Population from LLMW Accidents*

Accidents Involving Releases of Radiological Contaminants. For radionuclide-related accidents, the trends in risk to the noninvolved worker population follow the trends for the offsite population. For incineration accidents involving releases of radionuclides from non-alpha facilities, cancer fatality risks range from 3.5E-10 to 1.2E-1 in population sizes ranging from 128 to 15,996. Cancer fatality risks from

alpha facility incinerator accidents range from 1.1E-7 to 2.0E-3 in population sizes ranging from 6,993 to 15,996. Incineration accident risks at a given installation do not differ greatly among alternatives. Risks associated with a particular accident either remain the same at an installation across alternatives or increase only slightly with waste consolidation.

The incineration accident type resulting in the highest risks to noninvolved worker populations is the earthquake resulting in a fire. For each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and aircraft impact) are approximately 1 to 3 orders of magnitude lower than those associated with the earthquake scenario at a given installation. Recall, however, that the estimated annual frequency of the earthquake scenario affecting the incinerator facility is the lowest of the three accident types.

For the non-alpha facility earthquake scenario, ORR produces the greatest risk of cancer fatalities, with worst-case accident risks ranging from 8.3E-2 to 1.2E-1 in Decentralized and Regionalized 2 and 4, distributed over a population of 3,809. The next highest non-alpha accident risks are at Hanford in all alternatives (where Hanford is evaluated), with cancer fatality risks ranging from 2.2E-2 to 3.8E-2 in a population of 8,674. The controlling contaminants at ORR and Hanford are uranium-238 and plutonium-238, respectively. For alpha facility incinerator accidents, the highest-risk installations are INEL and RFETS in Decentralized and Regionalized 1 and 2 and INEL in Regionalized 4. In these alternatives, cancer fatality risk associated with the worst-case incinerator accident (earthquake) is 2.0E-3 for INEL in a population of 8,451 and 1.0E-3 for RFETS in a population of 6,993; the controlling contaminant is plutonium-238 at both installations.

Accidents Involving Releases of Chemical Contaminants. For chemical-related incineration accidents occurring in non-alpha facilities, the estimated risks of cancer incidence range from 5.1E-10 to 9.7E-4 in population sizes ranging from 128 to 15,996. Estimated risks of cancer incidence from alpha facility incinerator accidents range from 4.3E-6 to 1.7E-4 in population sizes ranging from 6,993 to 15,996. The incinerator accident resulting in the highest estimated risk of cancer incidence is the non-alpha feedstock staging area fire at ORR in Regionalized 4 (9.7E-4 in a population of 3,809). In all alternatives except Centralized (all installations treat at Hanford), ORR poses the greatest risks of cancer incidence. Incineration accident risks to noninvolved worker populations at other installations are 1 to 6 orders of magnitude lower. The controlling contaminant at ORR is chromium (VI). The alpha incineration accident with the highest risk of cancer incidence to the noninvolved worker population is the feedstock staging

area fire at INEL in Regionalized 4 (1.7E-4 in a population of 8,451). The controlling contaminant at INEL is also chromium (VI).

Worst-case accident risks of cancer incidence do not differ much among alternatives at most installations (remain approximately equal or increase slightly with greater waste consolidation). However, cancer incidence risk to the noninvolved worker population from the worst-case accident in Decentralized and Regionalized 1, 2, and 4 is higher than for No Action at INEL by 1 to 2 orders of magnitude. In addition, cancer incidence risk from the worst-case accident at Hanford in the Centralized Alternative is higher than for Hanford in other alternatives by about an order of magnitude due to centralized consolidation of waste loads.

D.3.5.8.3 *Risks to the Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual from LLMW Accidents*

Accidents Involving Releases of Radiological Contaminants. For radionuclide-related accidents, the trends in risk to the offsite MEI and noninvolved worker MEI generally follow those for their respective populations. Incineration accident risks at a given installation do not differ greatly among alternatives. Risks to the MEIs associated with a particular accident either remain the same at an installation across alternatives or increase only slightly with waste consolidation. Differences in cancer risks between non-alpha facility accidents and alpha facility accidents parallel those estimated for the offsite and noninvolved worker populations.

The highest-risk incineration accident type for both MEIs is the earthquake resulting in a fire. The highest-risk installations for the offsite MEI differ somewhat from those observed for the offsite population. The highest installation-specific cancer fatality risk to the offsite MEI is from the non-alpha facility earthquake scenario at ORR in No Action, Decentralized, and Regionalized 2 and 4 (ranging from 1.4E-5 to 1.6E-5). The controlling contaminant at ORR is uranium-238; the primary exposure route is internal. The next highest installation risks are for the non-alpha facility earthquake scenarios at Hanford in Centralized (9.4E-6) and PGDP in Decentralized (9.0E-6). The controlling contaminants at Hanford and PGDP are plutonium-238 and uranium-238, respectively; exposure is primarily internal.

The highest cancer fatality risk to the noninvolved worker MEI from an earthquake scenario is at Hanford (for non-alpha facilities) in Decentralized, Regionalized 2 and 4, and Centralized (ranging from 2.2E-4 to 3.9E-4). The contaminant contributing the most to risk at Hanford is plutonium-238 by internal exposure. The next highest risk to the noninvolved worker MEI is from the non-alpha earthquake scenario at ORR in Regionalized 2 and 4 (1.4E-4 and 1.1E-4 cancer fatalities, respectively). The controlling contaminant at ORR is uranium-238; exposure is primarily internal.

Accidents Involving Releases of Chemical Contaminants. For chemical-related accidents, the trends in risks to the offsite MEI and the noninvolved worker MEI tend to generally follow those for their respective populations. As observed for the offsite and noninvolved worker populations, risks and hazard indices do not differ greatly among alternatives at an installation with the exception of INEL (lower in No Action than other alternatives by about 2 orders of magnitude) and Hanford (greater in the Centralized Alternative with centralized consolidation by an order of magnitude or more).

For incineration accidents (i.e., feedstock staging area fire), the highest risks of cancer incidence to the offsite MEI (7.3E-7) and the noninvolved worker MEI (7.7E-7) occur at ORR in Regionalized 4. The cancer incidence risks to both MEIs are higher at ORR than those at other installations by 2 times to 4 orders of magnitude. The controlling carcinogenic contaminant at ORR is chromium (VI).

The highest hazard indices associated with incineration accidents are also at ORR in all alternatives (ranging from 7.8 to 9.4 for the offsite MEI and from 8.1 to 1.3E1 for the noninvolved worker MEI). For both MEIs, the hazard index is greater than 1.0 at Ports in Decentralized and Regionalized 1 and 2 (ranging from 1.3 to 1.5 for the offsite MEI and from 2.1 to 2.4 for the noninvolved worker MEI). In addition, for the noninvolved worker MEI, hazard indices are greater than 1.0 at SRS in all alternatives where SRS treats LLMW (ranging from 4.4 to 4.7) and at INEL in Regionalized 2 and 4 (ranging from 1.1 to 1.6). The controlling noncarcinogenic chemical is hydrogen chloride at ORR, Ports, SRS, and INEL. All other hazard indices are below 1.0, indicating less likelihood of harmful effects from exposure to noncarcinogens.

D.3.5.8.4 *Risks to Waste Management Workers from LLMW Accidents*

Accidents Involving Releases of Radiological Contaminants. For incineration accidents involving releases of radionuclides, installation-specific worker risks are similar among alternatives, increasing only very slightly at installations where LLMW is consolidated for treatment, most notably in the Centralized Alternative, in which estimated cancer fatalities at Hanford from all incineration accidents increase approximately half an order of magnitude. Estimated worker cancer fatalities associated with accident scenarios in non-alpha facilities range from 7.9E-8 to 1.6E-2. For alpha facility accident scenarios, estimated worker cancer fatalities range from 1.3E-4 to 3.5E-3. Shift size varies from 1 to 14 workers. In all alternatives, the earthquake and incinerator explosion scenarios produce the higher worker risks by about 1 to 2 orders of magnitude over the feedstock staging area fire scenario.

The highest installation-specific cancer fatality risks associated with non-alpha incinerator accidents are for the earthquake scenarios at ORR in No Action (9.8E-3), at ORR and Hanford in Decentralized (1.1E-2 at both installations), at ORR and Hanford in Regionalized 2 (1.6E-2 and 1.1E-2, respectively), at ORR and Hanford in Regionalized 4 (1.4E-2 and 1.1E-2, respectively), and at Hanford in the Centralized Alternative (4.4E-2). The controlling contaminants are uranium-238 at ORR and plutonium-238 at Hanford; the primary exposure route is inhalation. For alpha incinerator accidents, the highest installation cancer fatality risks are for the earthquake scenario at INEL in Decentralized and Regionalized 1, 2, and 4 (ranging from 3.1E-3 to 3.5E-3). The controlling contaminant at this installation is plutonium-238, and the primary exposure route is inhalation. Recall that the radionuclide-related earthquake scenario affecting the incinerator is considered to be "very unlikely".

Accidents Involving Releases of Chemical Contaminants. Estimated risks of cancer incidence to workers from non-alpha incineration accidents (feedstock staging area fires) range from 2.7E-12 to 7.5E-4 across alternatives. Alpha facility accident risks range from 3.2E-6 to 5.7E-5. Worker population size (shift size) varies from 1 to 14 workers. Chemical emissions from an incinerator feedstock staging area fire in a non-alpha facility are assumed to be identical regardless of installation or alternative; the same assumption was made for alpha facility accidents. Because of this, cancer incidence risk estimates for workers only vary by facility type and in direct proportion to the number of workers assumed to be present during the accident at each installation (which depends on the waste volume being incinerated at each installation).

The highest cancer incidence risk to workers from a non-alpha incinerator feedstock staging area fire is at Hanford in the Centralized Alternative (7.5E-4) due to the consolidated waste load and a greater number of workers necessary to operate the incinerator. The next highest cancer incidence risks to workers from non-alpha feedstock staging area fires are at ORR in all alternatives where ORR treats LLMW (ranging from 1.9E-4 to 3.6E-4). The highest alpha facility risks are also associated with Hanford in the Centralized Alternative (5.7E-5). The IDLH index is equal to or greater than 1.0 for all installations and alternatives, indicating a danger of irreversible health effects due to exposure to toxic chemicals. The controlling contaminants are the same at each installation, chromium (VI) and carbon monoxide.

As observed for the offsite and noninvolved worker populations and their respective MEIs, risks and IDLH indices do not differ greatly among alternatives at an installation with the exception of INEL (lower in No Action than other alternatives by about 2 orders of magnitude) and Hanford (greater in the Centralized Alternative with waste consolidation by an order of magnitude or more).

Table D.3.5-37. Radionuclide-Related Risks from Potential Worst-Case LLMW Treatment Facility Accidents, by Alternative and Installation

Installation	Offsite Population		Offsite MEI		Noninvolved Worker Population		Noninvolved Worker MEI[a]		Worker Population	
	CF[b]	CI[c]	CF	CI	CF	CI	CF	CI	CF	CI
No Action										
INEL	1.3E-3	4.4E-3	1.5E-7	5.0E-7	7.2E-4	2.4E-3	4.3E-7	1.5E-6	1.4E-4	5.0E-4
ORR	1.6E-1	5.5E-1	1.4E-5	4.7E-5	8.3E-2	2.8E-1	9.2E-5	3.1E-4	9.8E-3	3.4E-2
SRS	2.0E-2	6.7E-2	6.1E-7	2.1E-6	2.2E-3	7.3E-3	9.4E-6	3.2E-5	3.2E-3	1.1E-2
Decentralized										
ANL-E	6.1E-2	2.1E-1	1.8E-6	6.2E-6	7.9E-4	2.7E-3	5.9E-6	2.0E-5	8.8E-4	3.1E-3
BNL	1.0E-2	3.5E-2	9.2E-7	3.1E-6	8.1E-5	2.8E-4	7.5E-7	2.5E-6	9.3E-6	3.2E-5
FEMP	1.6E-5	5.4E-5	4.1E-9	1.4E-8	5.9E-7	2.0E-6	4.0E-9	1.3E-8	7.0E-8	2.5E-7
Hanford	2.7E-1	9.1E-1	6.3E-6	2.1E-5	2.2E-2	7.5E-2	2.2E-4	7.6E-4	1.1E-2	3.8E-2
INEL	2.1E-3	7.1E-3	2.4E-7	8.1E-7	2.0E-3	6.8E-3	1.2E-6	4.1E-6	3.1E-3	1.1E-2
KAPL-K	4.1E-3	1.4E-2	2.1E-7	7.0E-7	6.9E-5	2.4E-4	2.8E-7	9.5E-7	5.7E-6	2.0E-5
LANL	9.1E-4	3.1E-3	4.3E-7	1.5E-6	2.6E-4	8.8E-4	7.7E-7	2.6E-6	1.7E-4	6.0E-4
LLNL	1.1E-2	3.8E-2	1.6E-6	5.3E-6	9.5E-4	3.2E-3	1.7E-6	5.6E-6	1.3E-4	4.7E-4
ORR	1.6E-1	5.5E-1	1.4E-5	4.7E-5	8.3E-2	2.8E-1	9.2E-5	3.1E-4	1.1E-2	3.9E-2
PGDP	3.1E-2	1.1E-1	9.0E-6	3.1E-5	6.1E-3	2.1E-2	5.4E-5	1.8E-4	2.3E-3	8.2E-3
Pantex	5.1E-4	1.7E-3	5.6E-8	1.9E-7	1.1E-5	3.7E-5	1.9E-7	6.4E-7	5.2E-6	1.8E-5
RFETS	5.9E-3	2.0E-2	2.1E-7	7.1E-7	1.0E-3	3.5E-3	3.1E-6	1.0E-5	3.9E-4	1.4E-3
SRS	2.0E-2	6.7E-2	6.1E-7	2.1E-6	2.2E-3	7.3E-3	9.4E-6	3.2E-5	3.2E-3	1.1E-2
Regionalized 1										
INEL	2.1E-3	7.1E-3	2.4E-7	8.1E-7	2.0E-3	6.8E-3	1.2E-6	4.1E-6	3.1E-3	1.1E-2
LANL	9.1E-4	3.1E-3	4.3E-7	1.5E-6	2.6E-4	8.8E-4	7.7E-7	2.6E-6	1.7E-4	6.0E-4
LLNL	1.1E-2	3.8E-2	1.6E-6	5.3E-6	9.5E-4	3.2E-3	1.7E-6	5.6E-6	1.3E-4	4.7E-4
RFETS	5.9E-3	2.0E-2	2.1E-7	7.1E-7	1.0E-3	3.5E-3	3.1E-6	1.0E-5	3.9E-4	1.4E-3
SRS	1.7E-3	5.9E-3	5.3E-8	1.8E-7	1.9E-4	6.5E-4	8.2E-7	2.8E-6	1.4E-4	4.9E-4
Regionalized 2										
Hanford	2.7E-1	9.1E-1	6.3E-6	2.1E-5	2.2E-2	7.5E-2	2.2E-4	7.6E-4	1.1E-2	3.8E-2
INEL	2.1E-3	7.1E-3	2.4E-7	8.1E-7	2.0E-3	6.9E-3	1.2E-6	4.1E-6	3.1E-3	1.1E-2
LANL	9.1E-4	3.1E-3	4.3E-7	1.5E-6	2.6E-4	8.8E-4	7.7E-7	2.6E-6	1.7E-4	6.0E-4
ORR	1.8E-1	6.1E-1	1.5E-5	5.1E-5	1.2E-1	4.2E-1	1.4E-4	4.6E-4	1.6E-2	5.7E-2
RFETS	5.9E-3	2.0E-2	2.1E-7	7.1E-7	1.0E-3	3.5E-3	3.1E-6	1.0E-5	3.9E-4	1.4E-3
SRS	2.0E-2	6.7E-2	6.1E-7	2.1E-6	2.2E-3	7.4E-3	9.4E-6	3.2E-5	3.2E-3	1.1E-2

Table D.3.5-37. Radionuclide-Related Risks from Potential Worst-Case LLMW Treatment Facility Accidents, by Alternative and Installation—Continued

Installation	Offsite Population		Offsite MEI		Noninvolved Worker Population		Noninvolved Worker MEI[a]		Worker Population	
	CF[b]	CI[c]	CF	CI	CF	CI	CF	CI	CF	CI
Regionalized 4										
Hanford	2.7E-1	9.1E-1	6.3E-6	2.1E-5	2.2E-2	7.5E-2	2.2E-4	7.6E-4	1.1E-2	3.8E-2
INEL	2.1E-3	7.1E-3	2.4E-7	8.1E-7	2.0E-3	6.9E-3	1.2E-6	4.1E-6	3.5E-3	1.2E-2
ORR	1.8E-1	6.2E-1	1.6E-5	5.3E-5	9.6E-2	3.3E-1	1.1E-4	3.6E-4	1.4E-2	5.0E-2
SRS	2.0E-2	6.7E-2	6.1E-7	2.1E-6	2.2E-3	7.4E-3	9.4E-6	3.2E-5	3.2E-3	1.1E-2
Centralized										
Hanford	4.0E-1	1.4	9.4E-6	3.2E-5	3.8E-2	1.3E-1	3.9E-4	1.3E-3	4.4E-2	1.6E-1

[a] MEI—most-exposed individual; each value represents the highest *single* risk (not the sum of all risks) to the MEI from among all accidents at an installation.
[b] CF—risk of cancer fatality associated with exposure to radionuclides.
[c] CI—risk of cancer incidence associated with exposure to radionuclides.

Table D.3.5-38. Chemical-Related Risks from Potential Worst-Case LLMW Treatment Facility Accidents, by Alternative and Installation

Installation	Offsite Population	Offsite MEI		Noninvolved Worker Population	Noninvolved Worker MEI[a]		Workers	
	CI[b]	CI	HI[c]	CI	CI	HI	CI	IDLH[d]
No Action								
INEL	8.9E-7	2.1E-10	3.5E-3	2.0E-6	1.2E-9	1.9E-2	7.5E-8	1.1
ORR	7.3E-3	4.7E-7	7.8	6.3E-4	5.0E-7	8.1	1.9E-4	3.0E1
SRS	1.5E-5	4.9E-9	8.1E-2	6.9E-5	2.7E-7	4.4	6.0E-5	1.4E1
Decentralized								
ANL-E	9.3E-6	2.6E-10	4.2E-3	1.4E-7	7.6E-10	1.3E-2	3.3E-7	1.1
BNL	3.2E-5	5.8E-10	9.5E-3	2.4E-8	1.9E-10	3.1E-3	1.8E-8	1.0
FEMP	2.3E-4	1.0E-8	1.6E-1	1.5E-6	9.6E-9	1.6E-1	2.1E-6	1.9
Hanford	6.5E-5	1.7E-9	2.8E-2	3.4E-7	9.1E-9	1.5E-1	2.1E-5	5.3
INEL	3.5E-5	8.2E-9	1.3E-1	7.9E-5	4.5E-8	7.4E-1	1.9E-5	4.7
KCP	2.7E-7	1.2E-11	2.0E-4	3.4E-9	1.2E-11	2.0E-4	7.7E-12	1.0
KAPL-K	3.6E-6	6.1E-10	1.0E-2	1.5E-7	6.1E-10	1.0E-2	9.3E-9	1.0
LANL	2.2E-5	7.5E-9	1.2E-1	4.3E-6	5.8E-8	9.4E-1	4.5E-6	2.6
LBL	5.6E-6	5.1E-10	8.4E-3	1.4E-7	5.3E-10	8.7E-3	3.9E-9	1.0
LLNL	8.8E-5	2.4E-8	4.0E-1	2.0E-5	3.4E-8	5.6E-1	6.0E-6	3.2
ORR	8.7E-3	5.6E-7	9.2	7.5E-4	5.9E-7	9.6	2.5E-4	3.6E1
PGDP	1.3E-4	1.9E-8	3.2E-1	1.4E-6	1.2E-8	1.9E-1	9.9E-7	1.8
Pantex	6.5E-6	4.5E-10	7.4E-3	7.8E-7	8.6E-9	1.4E-1	7.0E-7	1.9
Ports	1.1E-4	7.9E-8	1.3	4.6E-5	1.3E-7	2.1	3.4E-5	9.5
RFETS	4.7E-4	9.5E-9	1.6E-1	4.6E-6	1.2E-8	1.9E-1	4.5E-6	1.8
SNL-NM	3.5E-6	1.0E-9	1.7E-2	3.6E-7	1.0E-9	1.7E-2	4.6E-8	1.1
SRS	1.6E-5	5.2E-9	8.5E-2	7.3E-5	2.8E-7	4.7	5.9E-5	1.4E1
Regionalized 1								
FEMP	2.5E-4	1.1E-8	1.8E-1	1.6E-6	1.1E-8	1.7E-1	3.8E-6	2.0
Hanford	6.6E-5	1.7E-9	2.8E-2	3.5E-7	9.3E-9	1.5E-1	2.2E-5	5.4
INEL	3.5E-5	8.2E-9	1.3E-1	7.9E-5	4.5E-8	7.4E-1	1.9E-5	4.7
LANL	2.2E-5	7.5E-9	1.2E-1	4.3E-6	5.8E-8	9.4E-1	4.5E-6	2.6
LLNL	9.1E-5	2.5E-8	4.1E-1	2.1E-5	3.6E-8	5.8E-1	6.4E-6	3.3
ORR	8.7E-3	5.6E-7	9.2	7.6E-4	5.9E-7	9.6	2.5E-4	3.6E1
PGDP	1.3E-4	1.9E-8	3.2E-1	1.4E-6	1.2E-8	1.9E-1	9.9E-7	1.8
Pantex	6.5E-6	4.5E-10	7.4E-3	7.8E-7	8.6E-9	1.4E-1	7.0E-7	1.9
Ports	1.1E-4	8.1E-8	1.3	4.7E-5	1.3E-7	2.2	3.5E-5	9.8
RFETS	4.7E-4	9.5E-9	1.6E-1	4.6E-6	1.2E-8	1.9E-1	4.5E-6	1.8
SRS	1.6E-5	5.2E-9	8.6E-2	7.3E-5	2.9E-7	4.7	5.9E-5	1.4E1

Table D.3.5-38. Chemical-Related Risks from Potential Worst-Case LLMW Treatment Facility Accidents, by Alternative and Installation—Continued

Installation	Offsite Population	Offsite MEI		Noninvolved Worker Population	Noninvolved Worker MEI[a]		Workers	
	CI[b]	CI	HI[c]	CI	CI	HI	CI	IDLH[d]
Regionalized 2								
Hanford	1.0E-4	2.6E-9	4.3E-2	5.3E-7	1.4E-8	2.3E-1	3.4E-5	7.7
INEL	5.0E-5	1.2E-8	1.9E-1	1.1E-4	6.6E-8	1.1	3.1E-5	6.3
LANL	2.2E-5	7.5E-9	1.2E-1	4.3E-6	5.8E-8	9.4E-1	4.5E-6	2.6
ORR	8.9E-3	5.7E-7	9.4	7.6E-4	6.0E-7	9.8	2.5E-4	3.6E1
Ports	1.2E-4	9.0E-8	1.5	5.2E-5	1.5E-7	2.4	4.7E-5	1.1E1
RFETS	4.7E-4	9.5E-9	1.6E-1	4.6E-6	1.2E-8	1.9E-1	4.5E-6	1.8
SRS	1.6E-5	5.2E-9	8.6E-2	7.3E-5	2.9E-7	4.7	5.9E-5	1.4E1
Regionalized 4								
Hanford	1.0E-4	2.6E-9	4.3E-2	5.3E-7	1.4E-8	2.3E-1	3.2E-5	7.7
INEL	7.2E-5	1.7E-8	2.8E-1	1.7E-4	9.5E-8	1.6	4.9E-5	8.7
ORR	1.1E-2	7.3E-7	1.2E1	9.7E-4	7.7E-7	1.3E1	3.6E-4	4.6E1
SRS	1.6E-5	5.2E-9	8.6E-2	7.3E-5	2.9E-7	4.7	6.4E-5	1.4E1
Centralized								
Hanford	1.0E-3	2.6E-8	4.3E-1	5.2E-6	1.4E-7	2.3	7.5E-4	6.8E1

[a] MEI—most-exposed individual; each value represents the highest *single* risk (not the sum of all risks) to the MEI from among all accidents at an installation.
[b] CI—risk of cancer incidence associated with exposure to carcinogenic chemicals.
[c] HI—hazard index.
[d] IDLH—worker IDLH index.

Table D.3.5–39. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the No Action Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (A)[d] Incinerator Explosion	7.8E-7	8.9E-11	8.6E-5	2.7E-6	3.0E-10	3.0E-4
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	2.0E-5	2.2E-9	2.1E-6	6.6E-5	7.6E-9	7.5E-6
Non-Alpha Incineration, (VU) Earthquake	1.3E-3	1.5E-7	1.4E-4	4.4E-3	5.0E-7	5.0E-4
WORST-CASE ACCIDENT	1.3E-3	1.5E-7	1.4E-4	4.4E-3	5.0E-7	5.0E-4

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–40. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the No Action Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (VU)[d] Earthquake	1.6E-1	1.4E-5	9.8E-3	5.5E-1	4.7E-5	3.4E-2
Non-Alpha Incineration, (A) Incinerator Explosion	9.7E-5	8.2E-9	5.9E-3	3.3E-4	2.8E-8	2.1E-2
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	2.4E-3	2.1E-7	1.5E-4	8.2E-3	7.0E-7	5.1E-4
WORST-CASE ACCIDENT	1.6E-1	1.4E-5	9.8E-3	5.5E-1	4.7E-5	3.4E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–41. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the No Action Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (VU)[d] Earthquake	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2
Non-Alpha Incineration, (A) Incinerator Explosion	1.2E-5	3.6E-10	1.9E-3	4.0E-5	1.2E-9	6.7E-3
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	3.0E-4	9.1E-9	4.8E-5	1.0E-3	3.1E-8	1.7E-4
WORST-CASE ACCIDENT	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–42. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ANL-E Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (A)[d] Incinerator Explosion	3.7E-5	1.1E-9	5.3E-4	1.2E-4	3.7E-9	1.8E-3
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	9.1E-4	2.7E-8	1.3E-5	3.1E-3	9.3E-8	4.6E-5
Non-Alpha Incineration, (VU) Earthquake	6.1E-2	1.8E-6	8.8E-4	2.1E-1	6.2E-6	3.1E-3
WORST-CASE ACCIDENT	6.1E-2	1.8E-6	8.8E-4	2.1E-1	6.2E-6	3.1E-3

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–43. Radionuclide-Related Accident Risks Associated With LLMW Treatment at BNL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (A)[d] Incinerator Explosion	6.1E-6	5.5E-10	5.6E-6	2.1E-5	1.9E-9	1.9E-5
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	1.5E-4	1.4E-8	1.4E-7	5.2E-4	4.7E-8	4.9E-7
Non-Alpha Incineration, (VU) Earthquake	1.0E-2	9.2E-7	9.3E-6	3.5E-2	3.1E-6	3.2E-5
WORST-CASE ACCIDENT	1.0E-2	9.2E-7	9.3E-6	3.5E-2	3.1E-6	3.2E-5

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–44. Radionuclide-Related Accident Risks Associated With LLMW Treatment at FEMP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (VU)[d] Earthquake	1.6E-5	4.1E-9	7.0E-8	5.4E-5	1.4E-8	2.5E-7
Non-Alpha Incineration, (A) Incinerator Explosion	9.5E-9	2.5E-12	4.2E-8	3.2E-8	8.4E-12	1.5E-7
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	2.4E-7	6.2E-11	1.1E-9	8.1E-7	2.1E-10	3.7E-9
WORST-CASE ACCIDENT	1.6E-5	4.1E-9	7.0E-8	5.4E-5	1.4E-8	2.5E-7

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–45. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, Earthquake (VU)[d]	2.7E-1	6.3E-6	1.1E-2	9.1E-1	2.1E-5	3.8E-2
Non-Alpha Incineration, Incinerator Explosion (A)	1.6E-4	3.8E-9	6.5E-3	5.5E-4	1.3E-8	2.3E-2
Non-Alpha Incineration, Feedstock Staging Area Fire (U)	4.0E-3	9.5E-8	1.6E-4	1.4E-2	3.2E-7	5.7E-4
WORST-CASE ACCIDENT	2.7E-1	6.3E-6	1.1E-2	9.1E-1	2.1E-5	3.8E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–46. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (VU)[d] Earthquake	2.1E-3	2.4E-7	3.1E-3	7.1E-3	8.1E-7	1.1E-2
Alpha Incineration, (A) Incinerator Explosion	1.3E-6	1.4E-10	1.8E-3	4.3E-6	4.9E-10	6.4E-3
Alpha Incineration, (U) Feedstock Staging Area Fire	3.1E-5	3.6E-9	4.6E-5	1.1E-4	1.2E-8	1.6E-4
Non-Alpha Incineration, (VU) Earthquake	1.3E-3	1.5E-7	1.4E-4	4.5E-3	5.1E-7	5.1E-4
Non-Alpha Incineration, (A) Incinerator Explosion	7.9E-7	9.0E-11	8.7E-5	2.7E-6	3.1E-10	3.0E-4
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	2.0E-5	2.3E-9	2.2E-6	6.7E-5	7.7E-9	7.6E-6
WORST-CASE ACCIDENT	2.1E-3	2.4E-7	3.1E-3	7.1E-3	8.1E-7	1.1E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (> 1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (< 1E-6).

Table D.3.5–47. Radionuclide-Related Accident Risks Associated With LLMW Treatment at KAPL-K Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (VU)[d] Earthquake	4.1E-3	2.1E-7	5.7E-6	1.4E-2	7.0E-7	2.0E-5
Non-Alpha Incineration, (A) Incinerator Explosion	2.5E-6	1.2E-10	3.4E-6	8.4E-6	4.2E-10	1.2E-5
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	6.2E-5	3.1E-9	8.6E-8	2.1E-4	1.1E-8	3.0E-7
WORST-CASE ACCIDENT	4.1E-3	2.1E-7	5.7E-6	1.4E-2	7.0E-7	2.0E-5

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–48. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (VU)[d] Earthquake	1.1E-2	1.6E-6	1.3E-4	3.8E-2	5.3E-6	4.7E-4
Alpha Incineration, (A) Incinerator Explosion	6.8E-6	9.3E-10	8.0E-5	2.3E-5	3.2E-9	2.8E-4
Alpha Incineration, (U) Feedstock Staging Area Fire	1.7E-4	2.3E-8	2.0E-6	5.8E-4	7.9E-8	7.0E-6
WORST-CASE ACCIDENT	1.1E-2	1.6E-6	1.3E-4	3.8E-2	5.3E-6	4.7E-4

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–49. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (VU)[d] Earthquake	9.1E-4	4.3E-7	1.7E-4	3.1E-3	1.5E-6	6.0E-4
Alpha Incineration, (A) Incinerator Explosion	5.4E-7	2.6E-10	1.0E-4	1.9E-6	8.8E-10	3.6E-4
Alpha Incineration, (U) Feedstock Staging Area Fire	1.4E-5	6.5E-9	2.6E-6	4.6E-5	2.2E-8	9.0E-6
WORST-CASE ACCIDENT	9.1E-4	4.3E-7	1.7E-4	3.1E-3	1.5E-6	6.0E-4

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–50. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (VU)[d] Earthquake	1.6E-1	1.4E-5	1.1E-2	5.5E-1	4.7E-5	3.9E-2
Non-Alpha Incineration, (A) Incinerator Explosion	9.7E-5	8.2E-9	6.6E-3	3.3E-4	2.8E-8	2.3E-2
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	2.4E-3	2.1E-7	1.7E-4	8.2E-3	7.0E-7	5.8E-4
WORST-CASE ACCIDENT	1.6E-1	1.4E-5	1.1E-2	5.5E-1	4.7E-5	3.9E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–51. Radionuclide-Related Accident Risks Associated With LLMW Treatment at PGDP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (VU)[d] Earthquake	3.1E-2	9.0E-6	2.3E-3	1.1E-1	3.1E-5	8.2E-3
Non-Alpha Incineration, (A) Incinerator Explosion	1.9E-5	5.4E-9	1.4E-3	6.3E-5	1.8E-8	4.9E-3
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	4.6E-4	1.4E-7	3.5E-5	1.6E-3	4.6E-7	1.2E-4
WORST-CASE ACCIDENT	3.1E-2	9.0E-6	2.3E-3	1.1E-1	3.1E-5	8.2E-3

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–52. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Pantex Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (VU)[d] Earthquake	5.1E-4	5.6E-8	5.2E-6	1.7E-3	1.9E-7	1.8E-5
Non-Alpha Incineration, (A) Incinerator Explosion	3.1E-7	3.3E-11	3.1E-6	1.0E-6	1.1E-10	1.1E-5
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	7.7E-6	8.3E-10	7.8E-8	2.6E-5	2.8E-9	2.7E-7
WORST-CASE ACCIDENT	5.1E-4	5.6E-8	5.2E-6	1.7E-3	1.9E-7	1.8E-5

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-53. Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (VU)[d] Earthquake	5.9E-3	2.1E-7	3.9E-4	2.0E-2	7.1E-7	1.4E-3
Alpha Incineration, (A) Incinerator Explosion	3.5E-6	1.3E-10	2.4E-4	1.2E-5	4.3E-10	8.3E-4
Alpha Incineration, (U) Feedstock Staging Area Fire	8.8E-5	3.1E-9	5.9E-6	3.0E-4	1.1E-8	2.1E-5
WORST-CASE ACCIDENT	5.9E-3	2.1E-7	3.9E-4	2.0E-2	7.1E-7	1.4E-3

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–54. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (VU)[d] Earthquake	1.7E-3	5.3E-8	1.4E-4	5.9E-3	1.8E-7	4.9E-4
Alpha Incineration, (A) Incinerator Explosion	1.0E-6	3.2E-11	8.4E-5	3.5E-6	1.1E-10	2.9E-4
Alpha Incineration, (U) Feedstock Staging Area Fire	2.6E-5	8.0E-10	2.1E-6	8.8E-5	2.7E-9	7.3E-6
Non-Alpha Incineration, (VU) Earthquake	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2
Non-Alpha Incineration, (A) Incinerator Explosion	1.2E-5	3.6E-10	1.9E-3	4.0E-5	1.2E-9	6.7E-3
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	3.0E-4	9.1E-9	4.8E-5	1.0E-3	3.1E-8	1.7E-4
WORST-CASE ACCIDENT	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–55. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (A)[d] Incinerator Explosion	1.3E-6	1.4E-10	1.8E-3	4.3E-6	4.9E-10	6.4E-3
Alpha Incineration, (U) Feedstock Staging Area Fire	3.1E-5	3.6E-9	4.6E-5	1.1E-4	1.2E-8	1.6E-4
Alpha Incineration, (VU) Earthquake	2.1E-3	2.4E-7	3.1E-3	7.1E-3	8.1E-7	1.1E-2
WORST-CASE ACCIDENT	2.1E-3	2.4E-7	3.1E-3	7.1E-3	8.1E-7	1.1E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-56. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (VU)[d] Earthquake	1.1E-2	1.6E-6	1.3E-4	3.8E-2	5.3E-6	4.7E-4
Alpha Incineration, (A) Incinerator Explosion	6.8E-6	9.3E-10	8.0E-5	2.3E-5	3.2E-9	2.8E-4
Alpha Incineration, (U) Feedstock Staging Area Fire	1.7E-4	2.3E-8	2.0E-6	5.8E-4	7.9E-8	7.0E-6
WORST-CASE ACCIDENT	1.1E-2	1.6E-6	1.3E-4	3.8E-2	5.3E-6	4.7E-4

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-57. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (VU)[d] Earthquake	9.1E-4	4.3E-7	1.7E-4	3.1E-3	1.5E-6	6.0E-4
Alpha Incineration, (A) Incinerator Explosion	5.4E-7	2.6E-10	1.0E-4	1.9E-6	8.8E-10	3.6E-4
Alpha Incineration, (U) Feedstock Staging Area Fire	1.4E-5	6.5E-9	2.6E-6	4.6E-5	2.2E-8	9.0E-6
WORST-CASE ACCIDENT	9.1E-4	4.3E-7	1.7E-4	3.1E-3	1.5E-6	6.0E-4

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-58. Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (VU)[d] Earthquake	5.9E-3	2.1E-7	3.9E-4	2.0E-2	7.1E-7	1.4E-3
Alpha Incineration, (A) Incinerator Explosion	3.5E-6	1.3E-10	2.4E-4	1.2E-5	4.3E-10	8.3E-4
Alpha Incineration, (U) Feedstock Staging Area Fire	8.8E-5	3.1E-9	5.9E-6	3.0E-4	1.1E-8	2.1E-5
WORST-CASE ACCIDENT	5.9E-3	2.1E-7	3.9E-4	2.0E-2	7.1E-7	1.4E-3

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-59. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (VU)[d] Earthquake	1.7E-3	5.3E-8	1.4E-4	5.9E-3	1.8E-7	4.9E-4
Alpha Incineration, (A) Incinerator Explosion	1.0E-6	3.2E-11	8.4E-5	3.5E-6	1.1E-10	2.9E-4
Alpha Incineration, (U) Feedstock Staging Area Fire	2.6E-5	8.0E-10	2.1E-6	8.8E-5	2.7E-9	7.3E-6
WORST-CASE ACCIDENT	1.7E-3	5.3E-8	1.4E-4	5.9E-3	1.8E-7	4.9E-4

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–60. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (VU)[d] Earthquake	2.7E-1	6.3E-6	1.1E-2	9.1E-1	2.1E-5	3.8E-2
Non-Alpha Incineration, (A) Incinerator Explosion	1.6E-4	3.8E-9	6.5E-3	5.5E-4	1.3E-8	2.3E-2
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	4.0E-3	9.5E-8	1.6E-4	1.4E-2	3.2E-7	5.7E-4
WORST-CASE ACCIDENT	2.7E-1	6.3E-6	1.1E-2	9.1E-1	2.1E-5	3.8E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–61. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (A)[d] Incinerator Explosion	1.3E-6	1.4E-10	1.8E-3	4.3E-6	4.9E-10	6.4E-3
Alpha Incineration, (U) Feedstock Staging Area Fire	3.1E-5	3.6E-9	4.6E-5	1.1E-4	1.2E-8	1.6E-4
Non-Alpha Incineration, (A) Incinerator Explosion	7.9E-7	9.0E-11	1.7E-4	2.7E-6	3.1E-10	6.1E-4
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	2.0E-5	2.3E-9	4.3E-6	6.7E-5	7.7E-9	1.5E-5
Alpha Incineration, (VU) Earthquake	2.1E-3	2.4E-7	3.1E-3	7.1E-3	8.1E-7	1.1E-2
Non-Alpha Incineration, (VU) Earthquake	1.3E-3	1.5E-7	2.9E-4	4.5E-3	5.1E-7	1.0E-3
WORST-CASE ACCIDENT	2.1E-3	2.4E-7	3.1E-3	7.1E-3	8.1E-7	1.1E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-62. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (A)[d] Incinerator Explosion	5.4E-7	2.6E-10	1.0E-4	1.9E-6	8.8E-10	3.6E-4
Alpha Incineration, (U) Feedstock Staging Area Fire	1.4E-5	6.5E-9	2.6E-6	4.6E-5	2.2E-8	9.0E-6
Non-Alpha Incineration, (VU) Earthquake	4.8E-4	2.3E-7	9.3E-6	1.7E-3	7.8E-7	3.3E-5
Non-Alpha Incineration, (A) Incinerator Explosion	2.9E-7	1.4E-10	5.6E-6	9.9E-7	4.7E-10	2.0E-5
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	7.3E-6	3.5E-9	1.4E-7	2.5E-5	1.2E-8	4.9E-7
Alpha Incineration, (VU) Earthquake	9.1E-4	4.3E-7	1.7E-4	3.1E-3	1.5E-6	6.0E-4
WORST-CASE ACCIDENT	9.1E-4	4.3E-7	1.7E-4	3.1E-3	1.5E-6	6.0E-4

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-63. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (VU)[d] Earthquake	1.8E-1	1.5E-5	1.6E-2	6.1E-1	5.1E-5	5.7E-2
Non-Alpha Incineration, (A) Incinerator Explosion	1.1E-4	9.0E-9	9.8E-3	3.6E-4	3.1E-8	3.4E-2
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	2.7E-3	2.3E-7	2.4E-4	9.1E-3	7.6E-7	8.5E-4
WORST-CASE ACCIDENT	1.8E-1	1.5E-5	1.6E-2	6.1E-1	5.1E-5	5.7E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-64. Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (VU)[d] Earthquake	1.5E-4	5.5E-9	4.0E-7	5.3E-4	1.9E-8	1.4E-6
Alpha Incineration, (A) Incinerator Explosion	3.5E-6	1.3E-10	2.4E-4	1.2E-5	4.3E-10	8.3E-4
Alpha Incineration, (U) Feedstock Staging Area Fire	8.8E-5	3.1E-9	5.9E-6	3.0E-4	1.1E-8	2.1E-5
Alpha Incineration, (VU) Earthquake	5.9E-3	2.1E-7	3.9E-4	2.0E-2	7.1E-7	1.4E-3
Non-Alpha Incineration, (A) Incinerator Explosion	9.3E-8	3.3E-12	2.4E-7	3.2E-7	1.1E-11	8.5E-7
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	2.3E-6	8.3E-11	6.0E-9	7.9E-6	2.8E-10	2.1E-8
WORST-CASE ACCIDENT	5.9E-3	2.1E-7	3.9E-4	2.0E-2	7.1E-7	1.4E-3

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (> 1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (< 1E-6).

Table D.3.5-65. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (VU)[d] Earthquake	1.7E-3	5.3E-8	1.4E-4	5.9E-3	1.8E-7	4.9E-4
Alpha Incineration, (A) Incinerator Explosion	1.0E-6	3.2E-11	8.4E-5	3.5E-6	1.1E-10	2.9E-4
Alpha Incineration, (U) Feedstock Staging Area Fire	2.6E-5	8.0E-10	2.1E-6	8.8E-5	2.7E-9	7.3E-6
Non-Alpha Incineration, (VU) Earthquake	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2
Non-Alpha Incineration, (A) Incinerator Explosion	1.2E-5	3.7E-10	1.9E-3	4.0E-5	1.3E-9	6.7E-3
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	3.0E-4	9.2E-9	4.8E-5	1.0E-3	3.1E-8	1.7E-4
WORST-CASE ACCIDENT	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-66. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (VU)[d] Earthquake	2.7E-1	6.3E-6	1.1E-2	9.1E-1	2.1E-5	3.8E-2
Non-Alpha Incineration, (A) Incinerator Explosion	1.6E-4	3.8E-9	6.5E-3	5.5E-4	1.3E-8	2.3E-2
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	4.0E-3	9.5E-8	1.6E-4	1.4E-2	3.2E-7	5.7E-4
WORST-CASE ACCIDENT	2.7E-1	6.3E-6	1.1E-2	9.1E-1	2.1E-5	3.8E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-67. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (VU)[d] Earthquake	2.1E-3	2.4E-7	3.5E-3	7.1E-3	8.1E-7	1.2E-2
Alpha Incineration, (A) Incinerator Explosion	1.3E-6	1.4E-10	2.1E-3	4.3E-6	4.9E-10	7.4E-3
Alpha Incineration, (U) Feedstock Staging Area Fire	3.1E-5	3.6E-9	5.3E-5	1.1E-4	1.2E-8	1.9E-4
Non-Alpha Incineration, (VU) Earthquake	1.3E-3	1.5E-7	4.4E-4	4.5E-3	5.1E-7	1.5E-3
Non-Alpha Incineration, (A) Incinerator Explosion	7.9E-7	9.0E-11	2.6E-4	2.7E-6	3.1E-10	9.1E-4
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	2.0E-5	2.3E-9	6.5E-6	6.7E-5	7.7E-9	2.3E-5
WORST-CASE ACCIDENT	2.1E-3	2.4E-7	3.5E-3	7.1E-3	8.1E-7	1.2E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-68. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Non-Alpha Incineration, (VU)[d] Earthquake	1.8E-1	1.6E-5	1.4E-2	6.2E-1	5.3E-5	5.0E-2
Non-Alpha Incineration, (A) Incinerator Explosion	1.1E-4	9.4E-9	8.5E-3	3.7E-4	3.2E-8	3.0E-2
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	2.8E-3	2.3E-7	2.1E-4	9.3E-3	8.0E-7	7.4E-4
WORST-CASE ACCIDENT	1.8E-1	1.6E-5	1.4E-2	6.2E-1	5.3E-5	5.0E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-69. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (VU)[d] Earthquake	1.7E-3	5.3E-8	1.4E-4	5.9E-3	1.8E-7	4.9E-4
Alpha Incineration, (A) Incinerator Explosion	1.0E-6	3.2E-11	8.4E-5	3.5E-6	1.1E-10	2.9E-4
Alpha Incineration, (U) Feedstock Staging Area Fire	2.6E-5	8.0E-10	2.1E-6	8.8E-5	2.7E-9	7.3E-6
Non-Alpha Incineration, (VU) Earthquake	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2
Non-Alpha Incineration, (A) Incinerator Explosion	1.2E-5	3.7E-10	1.9E-3	4.0E-5	1.3E-9	6.7E-3
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	3.0E-4	9.2E-9	4.8E-5	1.0E-3	3.1E-8	1.7E-4
WORST-CASE ACCIDENT	2.0E-2	6.1E-7	3.2E-3	6.7E-2	2.1E-6	1.1E-2

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–70. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Centralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI[c]	Workers	Population[c]	MEI[c]	Workers
Alpha Incineration, (VU)[d] Earthquake	3.4E-3	8.0E-8	4.5E-4	1.2E-2	2.7E-7	1.6E-3
Non-Alpha Incineration, (VU) Earthquake	4.0E-1	9.4E-6	4.4E-2	1.4	3.2E-5	1.6E-1
Non-Alpha Incineration, (A) Incinerator Explosion	2.4E-4	5.7E-9	2.7E-2	8.2E-4	1.9E-8	9.3E-2
Non-Alpha Incineration, (U) Feedstock Staging Area Fire	6.0E-3	1.4E-7	6.7E-4	2.1E-2	4.8E-7	2.3E-3
Alpha Incineration, (A) Incinerator Explosion	2.0E-6	4.8E-11	2.7E-4	6.9E-6	1.6E-10	9.4E-4
Alpha Incineration, (U) Feedstock Staging Area Fire	5.1E-5	1.2E-9	6.7E-6	1.7E-4	4.1E-9	2.4E-5
WORST-CASE ACCIDENT	4.0E-1	9.4E-6	4.4E-2	1.4	3.2E-5	1.6E-1

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–71. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the No Action Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Worker
Non-Alpha Incineration, (A)[c] Feedstock Staging Area Fire	8.9E-7	2.1E-10	7.5E-8	3.5E-3	1.1
WORST-CASE ACCIDENT	8.9E-7	2.1E-10	7.5E-8	3.5E-3	1.1

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–72. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the No Action Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Worker
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	7.3E-3	4.7E-7	1.9E-4	7.8	3.0E1
WORST-CASE ACCIDENT	7.3E-3	4.7E-7	1.9E-4	7.8	3.0E1

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–73. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the No Action Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Worker
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.5E-5	4.9E-9	6.0E-5	8.1E-2	1.4E1
WORST-CASE ACCIDENT	1.5E-5	4.9E-9	6.0E-5	8.1E-2	1.4E1

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–74. Chemical-Related Accident Risks Associated With LLMW Treatment at ANL-E Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Worker
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	9.3E-6	2.6E-10	3.3E-7	4.2E-3	1.1
WORST-CASE ACCIDENT	9.3E-6	2.6E-10	3.3E-7	4.2E-3	1.1

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–75. Chemical-Related Accident Risks Associated With LLMW Treatment at BNL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Worker
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	3.2E-5	5.8E-10	1.8E-8	9.5E-3	1.0
WORST-CASE ACCIDENT	3.2E-5	5.8E-10	1.8E-8	9.5E-3	1.0

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-76. Chemical-Related Accident Risks Associated With LLMW Treatment at FEMP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	2.3E-4	1.0E-8	2.1E-6	1.6E-1	1.9
WORST-CASE ACCIDENT	2.3E-4	1.0E-8	2.1E-6	1.6E-1	1.9

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-77. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	6.5E-5	1.7E-9	2.1E-5	2.8E-2	5.3
WORST-CASE ACCIDENT	6.5E-5	1.7E-9	2.1E-5	2.8E-2	5.3

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-78. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, (A)[c] Feedstock Staging Area Fire	2.8E-6	6.8E-10	3.1E-7	1.1E-2	1.3
Alpha Incineration, (A) Feedstock Staging Area Fire	3.5E-5	8.2E-9	1.9E-5	1.3E-1	4.7
WORST-CASE ACCIDENT	3.5E-5	8.2E-9	1.9E-5	1.3E-1	4.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-79. Chemical-Related Accident Risks Associated With LLMW Treatment at KCP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, (A)[c] Feedstock Staging Area Fire	2.7E-7	1.2E-11	7.7E-12	2.0E-4	1.0
WORST-CASE ACCIDENT	2.7E-7	1.2E-11	7.7E-12	2.0E-4	1.0

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–80. Chemical-Related Accident Risks Associated With LLMW Treatment at KAPL-K Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	3.6E-6	6.1E-10	9.3E-9	1.0E-2	1.0
WORST-CASE ACCIDENT	3.6E-6	6.1E-10	9.3E-9	1.0E-2	1.0

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–81. Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	2.6E-6	8.7E-10	7.9E-8	1.4E-2	1.2
Alpha Incineration, Feedstock Staging Area Fire (A)	2.2E-5	7.5E-9	4.5E-6	1.2E-1	2.6
WORST-CASE ACCIDENT	2.2E-5	7.5E-9	4.5E-6	1.2E-1	2.6

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–82. Chemical-Related Accident Risks Associated With LLMW Treatment at LBL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, (A)[c] Feedstock Staging Area Fire	5.6E-6	5.1E-10	3.9E-9	8.4E-3	1.0
WORST-CASE ACCIDENT	5.6E-6	5.1E-10	3.9E-9	8.4E-3	1.0

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–83. Chemical-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, (A)[c] Feedstock Staging Area Fire	8.8E-5	2.4E-8	6.0E-6	4.0E-1	3.2
Alpha Incineration, (A) Feedstock Staging Area Fire	6.4E-5	1.8E-8	4.7E-6	2.9E-1	2.6
WORST-CASE ACCIDENT	8.8E-5	2.4E-8	6.0E-6	4.0E-1	3.2

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-84. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	8.7E-3	5.6E-7	2.5E-4	9.2	3.6E1
WORST-CASE ACCIDENT	8.7E-3	5.6E-7	2.5E-4	9.2	3.6E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-85. Chemical-Related Accident Risks Associated With LLMW Treatment at PGDP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.3E-4	1.9E-8	9.9E-7	3.2E-1	1.8
WORST-CASE ACCIDENT	1.3E-4	1.9E-8	9.9E-7	3.2E-1	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–86. Chemical-Related Accident Risks Associated With LLMW Treatment at Pantex Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	6.5E-6	4.5E-10	7.0E-7	7.4E-3	1.9
WORST-CASE ACCIDENT	6.5E-6	4.5E-10	7.0E-7	7.4E-3	1.9

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–87. Chemical-Related Accident Risks Associated With LLMW Treatment at Ports Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.1E-4	7.9E-8	3.4E-5	1.3	9.5
WORST-CASE ACCIDENT	1.1E-4	7.9E-8	3.4E-5	1.3	9.5

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–88. Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Alpha Incineration, Feedstock Staging Area Fire (A)[c]	4.7E-4	9.5E-9	4.5E-6	1.6E-1	1.8
WORST-CASE ACCIDENT	4.7E-4	9.5E-9	4.5E-6	1.6E-1	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–89. Chemical-Related Accident Risks Associated With LLMW Treatment at SNL-NM Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	3.5E-6	1.0E-9	4.6E-8	1.7E-2	1.1
WORST-CASE ACCIDENT	3.5E-6	1.0E-9	4.6E-8	1.7E-2	1.1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–90. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, (A)[c] Feedstock Staging Area Fire	1.6E-5	5.2E-9	5.9E-5	8.5E-2	1.4E1
Alpha Incineration, (A) Feedstock Staging Area Fire	1.5E-6	4.7E-10	3.2E-6	7.6E-3	2.2
WORST-CASE ACCIDENT	1.6E-5	5.2E-9	5.9E-5	8.5E-2	1.4E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–91. Chemical-Related Accident Risks Associated With LLMW Treatment at FEMP Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, (A)[c] Feedstock Staging Area Fire	2.5E-4	1.1E-8	3.8E-6	1.8E-1	2.0
WORST-CASE ACCIDENT	2.5E-4	1.1E-8	3.8E-6	1.8E-1	2.0

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-92. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	6.6E-5	1.7E-9	2.2E-5	2.8E-2	5.4
WORST-CASE ACCIDENT	6.6E-5	1.7E-9	2.2E-5	2.8E-2	5.4

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-93. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	2.8E-6	6.8E-10	3.1E-7	1.1E-2	1.3
Alpha Incineration, Feedstock Staging Area Fire (A)	3.5E-5	8.2E-9	1.9E-5	1.3E-1	4.7
WORST-CASE ACCIDENT	3.5E-5	8.2E-9	1.9E-5	1.3E-1	4.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–94. Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	3.4E-6	1.2E-9	1.1E-7	1.9E-2	1.3
Alpha Incineration, Feedstock Staging Area Fire (A)	2.2E-5	7.5E-9	4.5E-6	1.2E-1	2.6
WORST-CASE ACCIDENT	2.2E-5	7.5E-9	4.5E-6	1.2E-1	2.6

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–95. Chemical-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	9.1E-5	2.5E-8	6.4E-6	4.1E-1	3.3
Alpha Incineration, Feedstock Staging Area Fire (A)	6.4E-5	1.8E-8	4.7E-6	2.9E-1	2.6
WORST-CASE ACCIDENT	9.1E-5	2.5E-8	6.4E-6	4.1E-1	3.3

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-96. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	8.7E-3	5.6E-7	2.5E-4	9.2	3.6E1
WORST-CASE ACCIDENT	8.7E-3	5.6E-7	2.5E-4	9.2	3.6E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-97. Chemical-Related Accident Risks Associated With LLMW Treatment at Pantex Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	6.5E-6	4.5E-10	7.0E-7	7.4E-3	1.9
WORST-CASE ACCIDENT	6.5E-6	4.5E-10	7.0E-7	7.4E-3	1.9

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-98. Chemical-Related Accident Risks Associated With LLMW Treatment at PGDP Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.3E-4	1.9E-8	9.9E-7	3.2E-1	1.8
WORST-CASE ACCIDENT	1.3E-4	1.9E-8	9.9E-7	3.2E-1	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-99. Chemical-Related Accident Risks Associated With LLMW Treatment at Ports Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.1E-4	8.1E-8	3.5E-5	1.3	9.8
WORST-CASE ACCIDENT	1.1E-4	8.1E-8	3.5E-5	1.3	9.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–100. Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	2.1E-7	4.2E-12	2.7E-12	6.9E-5	1.0
Alpha Incineration, Feedstock Staging Area Fire (A)	4.7E-4	9.5E-9	4.5E-6	1.6E-1	1.8
WORST-CASE ACCIDENT	4.7E-4	9.5E-9	4.5E-6	1.6E-1	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–101. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.6E-5	5.2E-9	5.9E-5	8.6E-2	1.4E1
Alpha Incineration, Baghouse Are Facility Fire (A)	1.5E-6	4.7E-10	3.2E-6	7.6E-3	2.2
WORST-CASE ACCIDENT	1.6E-5	5.2E-9	5.9E-5	8.6E-2	1.4E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–102. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.0E-4	2.6E-9	3.4E-5	4.3E-2	7.7
WORST-CASE ACCIDENT	1.0E-4	2.6E-9	3.4E-5	4.3E-2	7.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–103. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	2.9E-6	7.0E-10	5.2E-7	1.1E-2	1.3
Alpha Incineration, Feedstock Staging Area Fire (A)	5.0E-5	1.2E-8	3.1E-5	1.9E-1	6.3
WORST-CASE ACCIDENT	5.0E-5	1.2E-8	3.1E-5	1.9E-1	6.3

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-104. Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, (A)[c] Feedstock Staging Area Fire	1.6E-5	5.5E-9	1.2E-6	9.0E-2	2.2
Alpha Incineration, (A) Feedstock Staging Area Fire	2.2E-5	7.5E-9	4.5E-6	1.2E-1	2.6
WORST-CASE ACCIDENT	2.2E-5	7.5E-9	4.5E-6	1.2E-1	2.6

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-105. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, (A)[c] Feedstock Staging Area Fire	8.9E-3	5.7E-7	2.5E-4	9.4	3.6E1
WORST-CASE ACCIDENT	8.9E-3	5.7E-7	2.5E-4	9.4	3.6E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–106. Chemical-Related Accident Risks Associated With LLMW Treatment at Ports Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, (A)[c] Feedstock Staging Area Fire	1.2E-4	9.0E-8	4.7E-5	1.5	1.1E1
WORST-CASE ACCIDENT	1.2E-4	9.0E-8	4.7E-5	1.5	1.1E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–107. Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, (A)[c] Feedstock Staging Area Fire	8.0E-7	1.6E-11	2.1E-11	2.6E-4	1.0
Alpha Incineration, (A) Feedstock Staging Area Fire	4.7E-4	9.5E-9	4.5E-6	1.6E-1	1.8
WORST-CASE ACCIDENT	4.7E-4	9.5E-9	4.5E-6	1.6E-1	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-108. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.6E-5	5.2E-9	5.9E-5	8.6E-2	1.4E1
Alpha Incineration, Feedstock Staging Area Fire (A)	1.5E-6	4.7E-10	3.2E-6	7.6E-3	2.2
WORST-CASE ACCIDENT	1.6E-5	5.2E-9	5.9E-5	8.6E-2	1.4E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-109. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.0E-4	2.6E-9	3.2E-5	4.3E-2	7.7
WORST-CASE ACCIDENT	1.0E-4	2.6E-9	3.2E-5	4.3E-2	7.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-110. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.4E-5	3.4E-9	3.6E-6	5.5E-2	2.5
Alpha Incineration, Feedstock Staging Area Fire (A)	7.2E-5	1.7E-8	4.9E-5	2.8E-1	8.7
WORST-CASE ACCIDENT	7.2E-5	1.7E-8	4.9E-5	2.8E-1	8.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5-111. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.1E-2	7.3E-7	3.6E-4	1.2E1	4.6E1
WORST-CASE ACCIDENT	1.1E-2	7.3E-7	3.6E-4	1.2E1	4.6E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–112. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Regionalized Alternative 4, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.6E-5	5.2E-9	6.4E-5	8.6E-2	1.4E1
Alpha Incineration, Feedstock Staging Area Fire (A)	1.5E-6	4.7E-10	3.8E-6	7.6E-3	2.2
WORST-CASE ACCIDENT	1.6E-5	5.2E-9	6.4E-5	8.6E-2	1.4E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

Table D.3.5–113. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Centralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Population[b]	MEI[b]	Workers	MEI[b]	Most-Exposed Workers
Non-Alpha Incineration, Feedstock Staging Area Fire (A)[c]	1.0E-3	2.6E-8	7.5E-4	4.3E-1	6.8E1
Alpha Incineration, Feedstock Staging Area Fire (A)	1.3E-4	3.5E-9	5.7E-5	5.7E-2	9.8
WORST-CASE ACCIDENT	1.0E-3	2.6E-8	7.5E-4	4.3E-1	6.8E1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Offsite.
[c] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-6).

D.3.5.9 Risks to the Hypothetical Intruder from LLMW Disposal

The health risks to the hypothetical intruder who drills a well through an LLMW disposal facility were evaluated for the Decentralized, Regionalized 2, and Centralized Alternatives, and for remote-handled LLMW (RH-LLMW) disposal (disposal at four installations in the Decentralized, Regionalized, and Centralized Alternatives). Intrusion was evaluated 100 years and 300 years after the cessation of disposal activities at each installation.

Tables D.3.5–114 and D.3.5–115 present summaries of the risk evaluations at 100 and 300 years, respectively. Tables D.3.5–116 through D.3.5–123 contain the health risks by health endpoint and installation for each alternative in both time frames.

Table D.3.5–114. Summary Table for the Intruder Scenario for LLMW (100 years)

Alternative	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Decentralized	34	1.7E-2	5.8E-2	3.4E-3	1.8E-13	1.1E-7
Regionalized 2	33	1.6E-2	5.5E-2	3.3E-3	1.8E-13	1.4E-7
Centralized	7.1	3.6E-3	1.2E-2	7.1E-4	5.1E-14	9.6E-8
RH-LLMW	68	3.3E-2	1.2E-1	6.8E-3	1.2E-14	8.8E-9

Table D.3.5–115. Summary Table for the Intruder Scenario for LLMW (300 years)

Alternative	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Decentralized	7.2E-1	3.5E-4	1.2E-3	7.2E-5	1.8E-13	1.1E-7
Regionalized 2	6.1E-1	3.0E-4	1.0E-3	6.1E-5	1.8E-13	1.4E-7
Centralized	1.5E-1	7.3E-5	2.5E-4	1.5E-5	5.1E-14	9.6E-8
RH-LLMW	2.2	1.1E-3	3.7E-3	2.2E-4	1.2E-14	8.8E-9

Table D.3.5-116. Intruder Scenario Risk Results for the Decentralized Alternative (100 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
ANL-E	6.6E-1	3.3E-4	1.1E-3	6.6E-5	1.4E-14	1.6E-8
BNL	1.5E-2	7.4E-6	2.5E-5	1.5E-6	0.0	1.3E-9
FEMP	1.4E-3	6.8E-7	2.3E-6	1.4E-7	0.0	6.8E-9
Hanford	19	9.4E-3	3.2E-2	1.9E-3	3.1E-14	4.0E-8
INEL	7.5	3.8E-3	1.3E-2	7.5E-4	2.2E-14	6.2E-8
LANL	5.2E-2	2.6E-5	8.8E-5	5.2E-6	0.0	1.0E-8
LLNL	3.2E-1	1.6E-4	5.4E-4	3.2E-5	0.0	1.6E-8
NTS	4.9E-2	2.4E-5	8.3E-5	4.9E-6	0.0	6.7E-9
ORR	2.6	1.3E-3	4.4E-3	2.6E-4	4.8E-14	1.1E-7
PGDP	1.3E-1	6.4E-5	2.2E-4	1.3E-5	0.0	2.5E-9
Pantex	1.9E-2	9.4E-6	3.2E-5	1.9E-6	0.0	8.6E-10
PORTS	4.8E-1	2.4E-4	8.2E-4	4.8E-5	2.7E-14	2.9E-8
RFETS	1.6E-2	7.8E-6	2.6E-5	1.6E-6	1.3E-14	5.4E-9
SNL-NM	1.1E-2	5.6E-6	1.9E-5	1.1E-6	0.0	4.9E-11
SRS	3.1	1.6E-3	5.4E-3	3.1E-4	2.8E-14	1.0E-7
TOTAL	34	1.7E-2	5.8E-2	3.4E-3	1.8E-13	1.1E-7

Table D.3.5–117. Intruder Scenario Risk Results for the Decentralized Alternative (300 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
ANL–E	2.3E-2	1.1E-5	3.9E-5	2.3E-6	1.4E-14	1.6E-8
BNL	5.0E-4	2.5E-7	8.6E-7	5.0E-8	0.0	1.3E-9
FEMP	1.4E-3	6.8E-7	2.3E-6	1.4E-7	0.0	6.8E-9
Hanford	1.5E-1	7.7E-5	2.6E-4	1.5E-5	3.1E-14	4.0E-8
INEL	2.5E-1	1.2E-4	4.2E-4	2.5E-5	2.2E-14	6.2E-8
LANL	1.9E-3	9.3E-7	3.2E-6	1.9E-7	0.0	1.0E-8
LLNL	9.3E-3	4.6E-6	1.6E-5	9.3E-7	0.0	1.6E-8
NTS	3.1E-3	1.6E-6	5.3E-6	3.1E-7	0.0	6.7E-9
ORR	8.5E-2	4.2E-5	1.4E-4	8.5E-6	4.8E-14	1.1E-7
PGDP	1.3E-1	6.4E-5	2.2E-4	1.3E-5	0.0	2.5E-9
Pantex	1.9E-4	9.3E-8	3.2E-7	1.9E-8	0.0	8.6E-10
PORTS	6.0E-3	3.0E-6	1.0E-5	6.0E-7	2.7E-14	2.9E-8
RFETS	1.1E-2	5.7E-6	1.9E-5	1.1E-6	1.3E-14	5.4E-9
SNL–NM	1.6E-4	8.2E-8	2.8E-7	1.6E-8	0.0	4.9E-11
SRS	4.6E-2	2.3E-5	7.9E-5	4.6E-6	2.8E-14	1.0E-7
TOTAL	7.2E-1	3.5E-4	1.2E-3	7.2E-5	1.8E-13	1.1E-7

Table D.3.5-118. Intruder Scenario Risk Results for the Regionalized Alternative 2 (100 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	19	9.4E-3	3.2E-2	1.9E-3	3.4E-14	4.7E-8
INEL	7.9	3.9E-3	1.3E-2	7.9E-4	2.7E-14	6.9E-8
LANL	4.6E-2	2.3E-5	7.9E-5	4.6E-6	1.7E-14	1.1E-8
NTS	1.4E-4	7.1E-8	2.4E-7	1.4E-8	0.0	2.8E-12
ORR	2.5	1.2E-3	4.2E-3	2.5E-4	7.1E-14	1.4E-7
SRS	3.1	1.6E-3	5.4E-3	3.1E-4	2.7E-14	1.0E-7
TOTAL	33	1.6E-2	5.5E-2	3.3E-3	1.8E-13	1.4E-7

Table D.3.5-119. Intruder Scenario Risk Results for the Regionalized Alternative 2 (300 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	1.4E-1	7.1E-5	2.4E-4	1.4E-5	3.4E-14	4.7E-8
INEL	2.6E-1	1.3E-4	4.4E-4	2.6E-5	2.7E-14	6.9E-8
LANL	1.4E-2	6.8E-6	2.3E-5	1.4E-6	1.7E-14	1.1E-8
NTS	3.4E-4	1.7E-8	5.8E-8	3.4E-9	0.0	2.8E-12
ORR	1.5E-1	7.4E-5	2.5E-4	1.5E-5	7.1E-14	1.4E-7
SRS	4.6E-2	2.3E-5	7.9E-5	4.6E-6	2.7E-14	1.0E-7
TOTAL	6.1E-1	3.0E-4	1.0E-3	6.1E-5	1.8E-13	1.4E-7

Table D.3.5–120. Intruder Scenario Risk Results for the Centralized Alternative (100 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	7.1	3.6E-3	1.2E-2	7.1E-4	5.1E-14	9.6E-8
TOTAL	7.1	3.6E-3	1.2E-2	7.1E-4	5.1E-14	9.6E-8

Table D.3.5–121. Intruder Scenario Risk Results for the Centralized Alternative (300 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	1.5E-1	7.3E-5	2.5E-4	1.5E-5	5.1E-14	9.6E-8
TOTAL	1.5E-1	7.3E-5	2.5E-4	1.5E-5	5.1E-14	9.6E-8

Table D.3.5–122. Intruder Scenario Risk Results for RH-LLMW (100 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	6.2E-3	3.1E-6	1.0E-5	6.2E-7	0.0	5.9E-13
INEL	13	6.4E-3	2.2E-2	1.3E-3	1.2E-14	8.8E-9
ORR	55	2.7E-2	9.3E-2	5.5E-3	0.0	2.3E-10
SRS	7.0E-2	3.5E-5	1.2E-4	7.0E-6	0.0	6.8E-11
TOTAL	68	3.3E-2	1.2E-1	6.8E-3	1.2E-14	8.8E-9

Table D.3.5-123. Intruder Scenario Risk Results for RH-LLMW (300 years)

Installation	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	4.7E-5	2.4E-8	8.1E-8	4.7E-9	0.0	5.9E-13
INEL	2.8E-1	1.4E-4	4.8E-4	2.8E-5	1.2E-14	8.8E-9
ORR	1.9	9.5E-4	3.2E-3	1.9E-4	0.0	2.3E-10
SRS	1.0E-3	5.2E-7	1.8E-6	1.0E-7	0.0	6.8E-11
TOTAL	2.2	1.1E-3	3.7E-3	2.2E-4	1.2E-14	8.8E-9

D.3.5.9.1 *Results of the Human Health Risk Analysis for the Intruder*

For the Decentralized Alternative (which entails disposal at 15 installations), 100 years after the end of disposal operations, the installation with the highest intruder cancer fatality risk is Hanford (9.4E-3) and the lowest cancer fatality risk is at FEMP (6.8E-7). The high dose at Hanford is due to large inventories of Sr-90 and Cs-137. Three hundred years after waste disposal is completed, the highest intruder cancer fatality risk is at INEL (1.2E-4), due primarily to a large inventory of Ni-63, and the lowest risk is at SNL-NM (8.2E-8).

For Regionalized Alternative 2 (involving disposal at six installations), 100 years following the end of disposal, the highest intruder cancer fatality risk is at Hanford (9.4E-3) due to Sr-90 and Cs-137; the lowest intruder risk is at NTS (7.1E-8). Three hundred years after disposal, the highest intruder cancer fatality risk is at INEL (1.3E-4), where Ni-63 is the driving radionuclide; the lowest risk is at NTS (1.7E-8).

The Centralized Alternative (in which all waste is disposed at Hanford) poses an intruder cancer fatality risk of 3.6E-3 at 100 years, following the end of disposal activities. The controlling radionuclide is Sr-90. Three hundred years after disposal, the cancer fatality risk to the intruder decreases to 7.3E-5. The risks at Hanford under this single-installation consolidation alternative are nearly three times lower than the risks at Hanford under the 15- or 6-installation disposal options. While this may seem counterintuitive at first, it derives from the reduction in *average* waste concentration at Hanford that

results when the waste volumes of low-activity wastes from other installations are added to the relatively higher-activity Hanford wastes.

For the RH-LLMW disposal scenario, 100 years after disposal operations cease, the highest cancer fatality risk is at ORR (2.7E-2) due to the presence of Sr–90 in the inventory. The lowest cancer fatality risk occurs at Hanford (3.1E-6). Three hundred years after the end of disposal operations, the highest intruder cancer fatality risk remains at ORR (9.5E-4), due to Th–232, and the lowest risk remains at Hanford (2.4E-8). The driving radionuclide at ORR changes between the 100- and 300-year intrusions because Sr–90 decays through about 10 half-lives in the intervening 200 years whereas, Th–232 has a half-life of approximately 14.1 billion years. As such, more than 99.99% of the material that was present at the close of disposal activities has decayed to lower-risk daughter products.

In general, the risks associated with intrusion at 300 years after closure of the disposal facility are less than those at 100 years due to the decay of radionuclides with time. The incidence of cancer associated with chemical exposures is eight to 12 eight orders of magnitude lower than the risk from exposure to radionuclides, and is well below levels of risk considered to be tolerable. The highest hazard index for any installation is in the E-7 range, so exposure to noncarcinogenic chemicals is unlikely to lead to adverse health effects.

D.4 Uncertainty

The risks presented in the preceding sections of the PEIS will be used to rank the alternatives based on cost, health risk reduction, and environmental and socioeconomic impacts. These risks were calculated based on assumptions about the amount of contaminants released into the environment (source terms), the transport of the contaminants through the air and groundwater to various populations, and the health effects to man resulting from the intake of these contaminants by inhalation or ingestion. These assumptions are necessary because the actual processes may be too complex to simulate or insufficient information is available to properly model the system. Because exact system definition is not possible, a *range* of possible values can be estimated; the most likely value (based on available data) is then chosen for calculating the risk. This range of possible values and the frequency with which these values occur are referred to as the "distribution." The model can be run using this distribution of input parameters to determine the range of risk estimates. This range is known as the risk uncertainty.

The risk uncertainty can be applied to the risk values given in the PEIS to get an estimated range of risks for each alternative. If part of the range of risks for one alternative overlaps the range for another alternative, it may not be possible to make a distinction between the two alternatives to determine which alternative poses the lower risk.

The standard method for determining risk uncertainties is quantitative, and involves estimating the range and distribution of each input parameter, producing a large number of input data sets that simulate those ranges and distributions, then running the model to determine the range of risks that result. However, the PEIS uses too many involves too many parameters and data sets for such an uncertainty analysis. Therefore, a qualitative uncertainty analysis was performed to assess the general accuracy of the PEIS risk estimates. This was done by performing an uncertainty analysis on a limited amount of data, then applying the results across all installations and alternatives.

As noted in previous sections, the uncertainties associated with risk analyses depend to a large degree on the various assumptions that are made when determining model methodologies, scenario definitions, and input parameters. Model uncertainties vary according to the model being used and how applicable that model is to the scenario; they are estimated during the verification and validation phase of model development. Usually, the model developers provide the model uncertainties and/or limitations of model applicability.

Scenario uncertainties include overlooking important receptors, not fully considering receptor activities (which could, for instance, lead to under- or overestimates of exposure), and so forth. Since the PEIS defines the scenarios to be analyzed for risk, these types of uncertainties do not apply in the alternative comparisons and, therefore, were not included in the uncertainty analysis.

Parameter uncertainties are caused by errors in measurements of the independent variables involved in the risk calculations and/or the representativeness of the samples taken for measurement. Since the PEIS is concerned with the comparison of *relative* risk estimates, only the parameters that cause a *relative* uncertainty between alternatives should be included. These parameters generally include all site-specific variables such as wind conditions or crop yields, as opposed to parameters that are common across all facilities, such as the breathing rate of humans and toxicity-related measures such as dose conversion factors.

The first step in this uncertainty analysis requires determining which parameters are significant, that is, which ones have the greatest influence on risk. Parameters that do not contribute to relative errors have been excluded from this uncertainty analysis, and are discussed in greater detail where appropriate in the following sections. The second step involves determining the uncertainty of each significant parameter. The third and final step is calculating the total risk uncertainty. Since different mathematical models are used for treatment and storage sites, disposal facilities, and waste management workers, the analysis will vary for each alternative. Uncertainties are presented in the following text, first for treatment and storage sites, then for disposal sites, and finally for waste management workers.

D.4.1 Treatment and Storage Sites

Atmospheric transport and subsequent inhalation, ingestion, and external exposure to contaminants were considered to be the only significant exposure pathways for treatment and storage sites (the groundwater and surface water transport pathways were excluded). To determine unit doses for the PEIS for radionuclides, the GENII code (Napier et al., 1988) was used. For hazardous chemicals, the ISC2 dispersion models (EPA, 1992) were used. The risk uncertainty from using each of these codes had to be evaluated separately. To determine the general trends and magnitudes in risk uncertainty, a single, quantitative uncertainty analysis was performed using representative data from various sites. The results of this analysis are discussed according to their applicability across all installations.

To perform the uncertainty analysis for the PEIS, the measurement uncertainty and/or representativeness of the samples of all parameters having a significant influence on risk are needed. One significant variable is the source term. However, the uncertainties of the source terms for the PEIS were not provided by ANL at the time of this study and were, therefore, not included in this uncertainty analysis.

The uncertainties of other parameters, such as dose conversion factors, risk factors, and RfDs are associated with a high level of uncertainty. However, these parameters are determined apart from the PEIS and remain constant; therefore, any error associated with them is systematically applied across all facilities. In addition, although the health effects vary for each individual for a given exposure, the overall effects averaged across an entire population should be similar from one facility to another if that population is sufficiently large. Since the assumption that the populations were sufficiently large at all facilities was considered appropriate for a qualitative uncertainty analysis, the uncertainties from these

parameters were not included in this study. The breathing rate of humans was also not considered in this analysis for similar reasons. Other parameters such as particle deposition velocity, resuspension parameters, stack flow rate, and stack exhaust gas temperature were assumed to be identical at all treatment and storage facilities since the facilities are not yet built and are hypothetical in nature. Therefore, these parameters were not included in this uncertainty analysis.

D.4.1.1 Radionuclides

To calculate the uncertainty associated with the estimated exposure caused by radionuclides, a sensitivity analysis of the GENII model was performed first, then the uncertainty analysis was made using only the significant parameters. The results are presented in the following subsections.

D.4.1.1.1 *Sensitivity Analysis of GENII*

A sensitivity analysis was performed to determine the variables that have a significant influence on the model's predictions of risk. Variables that were included in the sensitivity study included average air concentrations from a unit source for a specific area and population (called "Chi/Q"), agricultural yields, and what are termed "dietary fractions" (the rates at which a receptor consumes various nutrients such as water, grain, etc.). As noted in Section D.4.1, other variables such as breathing rates, particle deposition velocities, etc., were not included.

The GENII-S code (Leigh et al., 1992), developed by SNL-NM specifically for sensitivity and uncertainty analysis, was used to perform the sensitivity studies. The uncertainty associated with the annual effective dose equivalent (AEDE) due to the uncertainties associated with input parameters was determined. Latin Hypercube sampling (Iman and Shortencarier, 1984) was used to generate a total of 300 input data sets that represent the distributions of the input variables. The results were subjected to regression analysis so that the statistically significant predictor variables could be determined. The regression equation simply fits a linear curve to the outputs from the Latin Hypercube samples:

$$Y = b + c_1 x_1 + c_2 x_2 + \cdots + c_i x_i$$

where Y is the predicted variable, b is the y intercept, x is the predictor variable, and c is the coefficient of the predictor variable in the linear formula. The null hypothesis that a coefficient was zero was tested to within the 95% confidence level; in other words, any coefficient that had a probability less than 0.05 of being zero was considered a significant parameter.

The parameters used in the sensitivity study included Chi/Q, 11 crop yields, and dietary fractions of cattle. To perform the sensitivity study, the range and distribution of each parameter had to be determined. To initialize input parameters, SRS was chosen as the installation and a representative source term consisting of 1 Ci of each of the following radionuclides was used: tritium, carbon–14, phosphorus–32, sulfur–35, cobalt–60, strontium–90, yttrium–90, technetium–99), ruthenium–106, iodine–125, iodine–129), iodine–135, cesium–137, neptunium–237, thorium–229, uranium–238, americium–242, plutonium–238, and curium–245.

GENII–S uses Chi/Q as an input parameter. However, Chi/Q is actually a derived variable based on the joint frequency data, anemometer height, exhaust stack height, stack flow rate, stack diameter, and stack exhaust gas temperature; therefore, the uncertainty of Chi/Q had to be determined. Only the uncertainty in the site-specific joint frequency data was included in determining the uncertainty of Chi/Q, since the other parameters were not addressed (refer to Section D.4.1).

The joint frequency data for the 26 installations analyzed in the PEIS were collected from the MEPAS code (Droppo et al., 1989) (21 sites), the National Climatic Data Center (4 sites), and an environmental impact statement report (1 site). The joint frequency data comprise six wind speed ranges, seven stability classes per wind speed range (these stability classes indicate the number and intensity of wind gusts for a particular average wind speed range), and 16 wind directions (16 sectors of 22.5 degrees per sector; e.g., north, north-northeast, northeast, east-northeast, etc.). The uncertainties associated with each joint frequency data set are the measurement uncertainties for wind speed and direction and the representativeness of that data set relative to average wind conditions at the site over a specified period of time. The time period of interest may differ for the release scenario. For a chronic release, the joint frequency data should represent wind speeds and directions averaged over the longest possible time period since the exposure period used in the human health risk analysis is equivalent to the average life span of an individual. However, for acute releases, such as would result from accidents, the data should be

representative of a 1-year release since a 1-year constant release was assumed for acute release scenarios. The uncertainty of the joint frequency data is therefore a function of the variability of the wind on an annual basis and of how many years of data were used to estimate the average annual wind conditions.

To estimate the uncertainty in Chi/Q caused by the variations in atmospheric conditions, one site was chosen for which sufficient wind profile data were available to perform the analysis. (However, for a more complete uncertainty analysis, every site would have to be analyzed individually since the method for obtaining the data, the instrumentation used, the location of the meteorological tower relative to the facility, and the number of samples taken vary from installation to installation.) The meteorological data at the ORNL–East Tower were used since the data are readily available, fairly extensive, and measurement uncertainties are negligibly small compared to wind condition variability. The meteorological data are taken each hour, with measurement uncertainties of one degree for wind directions and 0.1 mph for wind speeds. Since GENII uses 16 wind directions of 22.5 degrees per directional sector, a 1-degree uncertainty in wind direction would have a negligible effect on the wind velocity profiles used for modeling (these profiles present wind velocity as a function of direction, by degree). GENII also uses only six wind speed ranges separated by approximately 2 mph and only seven stability classes. Therefore, wind speed uncertainties of 0.1 mph are negligible relative to model input capabilities for both mean wind speeds and stability classes.

The only uncertainty that must be considered is the representativeness of the joint frequency data to the "actual" conditions one would experience during exposure. To estimate this uncertainty for one site, the hourly data taken at the ORNL–East Tower were averaged over 1 year to produce one joint frequency data set for that year. Since data have been acquired since 1987, seven yearly data sets could then be constructed (1987–1993). The GENII code was run for each of these joint frequency data sets to determine a Chi/Q with all other parameters being constant. The results presented in Table D.4–1 show that the standard deviation for Chi/Q for this set of data is 1.27E-12. Two standard deviations are typically used to bound data within the 95% confidence level. Using two standard deviations, the uncertainty of the resultant Chi/Q is approximately $\pm 10\%$. Therefore, the joint frequency data averaged over 7 years would also be expected to have an uncertainty of no more than $\pm 10\%$.

Table D.4-1. Descriptive Statistics for Chi/Q from ORR Meteorological Data

Statistic	Value
Mean	2.34E-11
Standard deviation	1.27E-12
Two standard deviations	2.54E-12 (10% of mean value)

Shor et al. (1982) (the source of the agricultural yield data) report that the margin of error for the agricultural yields is ±10%; the distribution had to be determined from the data in that study. From evaluating various yields from counties surrounding SRS, it was determined that a normal distribution was appropriate for the crop yields.

After the range and distribution of the input parameters were established, 300 input data sets were developed using the Latin Hypercube sampling technique. The regression analysis was then performed on the 300 model outputs. The coefficients resulting from the regression analysis and the probability of a coefficient being zero from the test of the null hypothesis are presented in Table D.4-2.

Table D.4–2. Results of GENII Sensitivity Study

Variable	Coefficient	Probability
Chi/Q	113,787.87	0.000
Yield Rate—Grain for Human Consumption	326.36	0.00
Yield Rate—Fresh Forage for Beef Cattle	202.11	0.05
Beef Dietary Fraction for Stored Feed	100.51	0.17
Yield Rate—Stored Feed for Milk Cows	74.28	0.09
Yield Rate—Stored Feed for Poultry	31.17	0.73
Yield Rate—Root Vegetables	27.57	0.62
Yield Rate—Stored Feed for Beef Cattle	25.37	0.56
Yield Rate—Leafy Vegetables	-6.58	0.68
Yield Rate—Fruit	-18.43	0.45
Yield Rate—Fresh Forage for Milk Cows	-32.35	0.75
Milk Dietary Fraction for Stored Feed	-42.69	0.56
Yield Rate—Stored Feed for Laying Hens	-102.27	0.25

Of all the variables considered in the analysis, only Chi/Q, the yield of grain for human consumption, and the yield of fresh forage for beef cattle were below the 0.05 probability level of having a zero coefficient. This means that the AEDE was most sensitive to variations in these three variables. Latin Hypercube sampling and regression analysis were performed again using these three variables only. The resulting partial correlations (which indicate the strength of the linear dependence of a parameter and factor out the first-order correlations between input variables) are presented in Table D.4–3.

Table D.4–3. Correlation Coefficients for Significant Variables

Variable	Partial Correlation
Chi/Q	0.99
Yield Rate—Grain for Human Consumption	0.17
Yield Rate—Fresh Foliage for Beef Cattle	0.12

Table D.4–3 reveals that the most sensitive variable was Chi/Q with a correlation coefficient of 0.99. This means that the uncertainty in Chi/Q will probably affect the uncertainties in risk much more than the uncertainties in the other two parameters. This is similar to the results found in an uncertainty study

by Lyon et al. (1992), in which the Chi/Q correlation coefficient was 0.95. Despite the small contributions from the other two variables (grain yield for humans and fresh forage yield for beef cattle), the uncertainty analysis was performed using all three variables to ensure the thoroughness of the analysis.

D.4.1.1.2 *Uncertainty Analysis*

The uncertainty analysis was performed using the GENII–S code again, along with the three parameters shown in Table D.4–3. The results presented in Table D.4–4 show that the deviations in AEDE were ±9%. This is nearly the same uncertainty as that of Chi/Q (which, the reader will recall from preceding discussion, was ±10%); this is as expected, since the correlation coefficient of Chi/Q is 0.99.

Table D.4–4. Descriptive Statistics for AEDE from the Uncertainty Analysis

Statistic	Value
Mean	2.5E+4
Deviation (Max-Mean)	2.15E+3 (9% of mean value)

D.4.1.2 Hazardous Chemicals

The ISC2 code (EPA, 1992) was used in the PEIS to estimate atmospheric fate and transport of hazardous chemicals. ISC2 estimates unit air concentrations for each block in a circular grid comprising 16 directional sectors (e.g., north, north-northeast, northeast, east-northeast, etc.) at 10 radial distances out to 80 km (50 mi) from the point of release, similar to the Chi/Q calculation in GENII. Because of the simplicity of the approach in ISC2, the Chi/Q, cancer potency factors, and RfDs are the only parameters used in modeling, and all are sensitive parameters on risk. However, recall from Section D.4.1 that the uncertainties in cancer potency factors and RfDs were not considered applicable in the PEIS uncertainty analysis since only relative, not absolute, uncertainties were being sought. Therefore, Chi/Q was the only sensitive variable in the ISC2 model for the purposes of this uncertainty analysis. Since the calculation for Chi/Q in ISC2 is almost identical to that in GENII, the uncertainties in Chi/Q are ±10%.

D.4.1.3 Conclusion for Treatment and Storage Sites

The relative uncertainty of risk for the PEIS for comparison purposes could not be determined since the uncertainties in source terms were not available for this analysis. For the parameters pertaining to ingestion or inhalation, including Chi/Q, crop yields, and dietary fractions of humans and animals, the only significant parameter was Chi/Q, which had an uncertainty of $\pm 10\%$.

Because the uncertainties for parameters other than the source term are relatively low, the overall risk uncertainties should be of approximately the same order of magnitude as the source term uncertainties determined by ANL.

If the critically exposed population in the PEIS is relatively small, the uncertainties in the breathing rates of humans, dose conversion factors, risk factors, and RfDs become significant, and the uncertainties in risk increase accordingly.

D.4.2 Disposal Sites

Groundwater transport was considered the only significant environmental transport pathway for disposal sites. Three computer codes were used to estimate disposal risks. The DUST code (Sullivan, 1992) was used to estimate the amount leached from the disposal site; MEPAS (Droppo et al., 1989) was used to calculate fate and transport of the contaminants; and the DITTY portion of the GENII code (Napier et al., 1988) was used for the ingestion and exposure assessment. The uncertainty in these disposal risk calculations was estimated based on a sensitivity and uncertainty analysis of the MEPAS code conducted in April 1992 by ORNL and PNL (Lyon et al., 1992).

The applicability of the sensitivity and uncertainty analysis of the MEPAS code to the PEIS was evaluated. The locations studied by Lyon et al. were chosen to encompass high-risk sites (sites for which population fatalities were estimated at greater than 1), medium-risk sites (where population fatalities were predicted to range between 1 and 0.0001), and low-risk sites (with population fatalities estimated at less than 0.0001). Of the six contaminated sites studied, four involved the groundwater pathway. These four were ORNL Waste Area Grouping 6, the Hanford Nonradioactive Dangerous Waste Landfill Site, LLNL Site 300 Landfill 6, and FEMP Operable Unit 1. Because these four sites are located

at four installations that were included in the PEIS health risk analyses, the results from the 1992 study were considered applicable to the PEIS.

Before relating the results of the study by Lyon et al. to the PEIS results, two differences must be pointed out. First, the PEIS used the DUST model instead of MEPAS to input the rate of contaminant release from the disposal site; however, the methodology used in the PEIS was identical to that used in the MEPAS study by Lyon et al. Second, the risk estimates in the study by Lyon et al. were time-weighted such that health effects that occurred sooner were weighted more heavily than those occurring later; the PEIS risks were not time-weighted. However, the contaminants in the Lyon study—uranium-238, strontium-90, benzene, and trichloroethene—moved through the groundwater at relatively similar rates and relatively fast; therefore, time-weighting the results would have a neglible effect on the uncertainties. Moreover, these contaminants are some of the primary constituents in the PEIS source terms. Because of these factors, the variations in risk estimates determined by Lyon et al. should provide a reasonable estimate of the uncertainties in the PEIS.

Latin Hypercube sampling was used to perform the sensitivity and uncertainty studies. The sensitivity analysis was performed by PNL, which used the time-weighted number of health effects as the dependent variable. The initial sensitivity rankings of the inputs were based on the partial correlation coefficients (indicating the strength of the linear dependence of the parameters). Typically, only three to six parameters showed sufficient sensitivity to be considered for the uncertainty analysis at the various sites. The null hypothesis that a coefficient was zero was tested to the 95% confidence level (i.e., parameters were considered sufficiently sensitive if there was a probability of 0.05 or less that a parameter's coefficient in the regression equation was zero).

Table D.4–5 presents the input parameters with significant correlation coefficients and the number of orders of magnitude difference between the 95th percentile upper and lower confidence levels. The significant parameters are listed in order of the highest to lowest correlation coefficients. The authors concluded that the most vital components of the risk characterization process are the initial concentrations of contaminants, contaminant inventories, and contaminant flux rates at the site. In many cases, the final risk estimate is directly proportional to these values. Uncertainties in the subsurface partitioning coefficient, K_ds, were determined to be insignificant relative to these other components.

Table D.4-5 shows that the differences in population risk estimates between the upper and lower 95th-percentile confidence bands ranged from 0.2 to 12.2 orders of magnitude. Note that the uncertainty at Hanford was very high in relation to the other three sites (12 orders of magnitude compared to 0.2, 1.5, and 2.1). This was because of a large decrease in population risk from the lower 80th percentile to the lower 95th percentile, accounting for approximately 10 orders of magnitude of uncertainty; there is only a difference of 2.2 orders of magnitude of uncertainty between the upper 95th percentile to the lower 80th percentile. Excluding the lower 80th to 95th percentile of the uncertainty for Hanford from consideration (because this behavior appears to be unique to Hanford and is extremely uncharacteristic of the other sites), the most reasonable estimate of the uncertainty with respect to disposal risks in the PEIS would be between 1 and 2 orders of magnitude.

This uncertainty estimate does not take into account uncertainties in the waste inventories provided by ANL. If the uncertainties in the inventories are provided by ANL, the risk uncertainty estimated in the preceding paragraph can be adjusted accordingly.

D.4.2.1 Conclusion for Disposal Sites

The most reasonable estimate of the uncertainty in the risk predictions in the PEIS for the disposal sites was expected to be approximately one to two orders of magnitude, based on the study by Lyon et al. (1992). If ANL provides source term uncertainties in the future, the uncertainties in risk in the PEIS can be adjusted accordingly.

Table D.4-5. Uncertainties of Risk Predictions via the Groundwater Pathway

Site	Significant Parameters (from highest to lowest correlation coefficient)	Population Risk Orders of Magnitude Difference[a]
ORR—Waste Area Group 6	1) Contaminant inventory 2) Surface K_d 3) Subsurface K_d 4) Discharge rate of White Oak Lake into the Clinch River	1.5
Hanford—Nonradioactive Dangerous Waste Landfill Site	1) Thickness of saturated zone 2) Waste leaching rate 3) Transverse dispersivity in saturated zone 4) K_d in saturated zone 5) K_d in partially saturated zone 6) Population drinking contaminated groundwater	12
LLNL—Site 300 Landfill 6	1) Flux rate 2) Leaching rate 3) K_d in first partially saturated zone 4) K_d in second partially saturated zone 5) K_d in saturated zone 6) Population drinking contaminated groundwater	2.1
FEMP—Operable Unit 1	1) Contaminant inventory 2) Pore water velocity in saturated zone 3) K_d in first partially saturated zone 4) K_d in second partially saturated zone 5) K_d in saturated zone 6) Travel distance in saturated zone to receptor	0.2

[a] Orders of magnitude difference between the 95th percentile upper and lower confidence levels.

D.4.3 Waste Management Workers

The MicroShield code (Grove Engineering, Inc., 1992) was used to calculate external radiation exposure to waste management workers for the waste management portion of the PEIS. MicroShield is capable of performing sensitivity studies for the shield thickness, distance-from-source-to-shield, and distance-from-source-to-receptor parameters. Sensitivity studies on other parameters such as material density and source strength must be performed manually.

For the comparison of PEIS alternatives, only the parameters that cause relative error, not absolute error, are the ones desired in determining the risk uncertainties. Since the PEIS treatment facilities and operational equipment were hypothetical in nature and were all assumed to be identical for the various treatments required, many parameters could be excluded from this uncertainty study. These included the shielding material and thickness, and the distances of the shield and receptor from the source.

Uncertainties were introduced in the PEIS risk estimates from relating waste throughputs to source volumes (volumes of waste in treatment vessels) and unit dose methodologies. For the PEIS, the throughput of waste for each treatment module for each alternative was provided by ANL. Since MicroShield requires input of the source (or waste) volume rather than the waste throughput, regression equations were used to relate throughputs to treatment vessel volumes using known values for existing facilities, derived from facility data provided by Morrison Knudsen Corporation (1993, 1994). The treatment modules that have variable capacities included feed waste bins, shredders, evaporators, high pressure spray/blast booths, solidification units, aqueous tanks, neutralization tanks, ion exchange tanks, oxidation reactor tanks, incinerators, metal melters, thermal desorption units, mercury roasting kilns, metal deactivation units, lead melting tanks, soil washing tanks, sludge washing tanks, debris washing tanks, and polymer blending tanks. (The size of some modules, such as drum compactors, did not change since the drum sizes remain the same for various throughputs; only the number of drums changed.)

There were two sources of error in the worker exposure calculations. First, the known throughputs and volumes consisted of three or four sizes categorized as extra-small, small, medium, and large. Since only three or four sizes existed to derive the regression equations for each treatment module, the maximum error of the three or four known values was used, regardless of throughput.

The second source of error resulted from using the unit dose methodology, in which the unit dose to a worker is calculated based on exposure to 1 m^3 of waste in a 1-m^3 container. Since the capacity of some of the treatment modules varied, the unit doses had to be scaled to reflect the doses for the correct waste volumes in these cases. To derive this relationship, MicroShield was executed for each of the variable-size modules for a range of waste volumes, and a regression equation was used to relate the dose from the various waste volumes to the unit dose.

To estimate the uncertainty in risk predictions from these two sources of error, an alternative was chosen in which the treatment train consisted of throughputs and treatment modules for which larger errors on

the regression curves existed. The management of LLMW at INEL in Regionalized Alternative 3 was chosen. Since the throughput changed with each of the 57 treatment modules for this alternative, and the number of workers changed with throughput, the actual dose for each treatment module had to be determined. The total actual dose was then calculated in an EXCEL spreadsheet and compared to that in the PEIS, resulting in an approximate ±6% error.

The shielding materials used for the PEIS included air, concrete, iron, and water. Since the construction, operation, and maintenance of all the facilities were assumed to be identical because the facilities are hypothetical in nature, any variations in the densities of concrete, iron, or water that might occur would cause absolute errors in risk predictions but would not cause relative errors (the type of errors sought for comparison purposes). The only site-specific parameter that might cause relative error would be air density since it is a function of the altitude of the treatment site. Because the sea-level air density of 0.00122 g/cm^3 was used for all locations in the PEIS, the error would be the difference between the average density at a specific location and the density at sea level. The altitudes for the facility locations in the PEIS ranged from sea level to approximately 5,300 feet at RFETS in Golden, Colorado. Therefore, the corresponding air densities ranged from 0.00122 to 0.00127 g/cm^3. This variability would have little effect on the shielding properties of air, so its effect on risk estimates would be negligible.

D.4.3.1 Conclusion for Worker Risk

Variability in parameters such as shield thickness, the distance-from-source-to-shield, and distance-from-source-to-receptor would be the major source of absolute error in risk estimates. However, these parameters would not have contributed to *relative* error since they were hypothetical in nature and were assigned identical values at all facilities. Uncertainties in the source terms and waste throughputs are significant for alternative comparisons in the PEIS since they are site-specific parameters. However, as with the source terms for the treatment and storage sites and disposal sites, ANL had not provided the uncertainties in source terms for WM workers at the time of this study; therefore, uncertainties for worker risks could not be determined. Because the uncertainties for parameters, other than source term, that contribute to relative error are relatively low (±6%), the overall risk uncertainties should be approximately of the same order of magnitude as the source term uncertainties determined by ANL.

D.5 Models Used in the PEIS Human Health Risk Evaluation

The ORNL Center for Risk Management used a number of computer codes to generate the PEIS human health risk estimates; these included numerous in-house codes based on established outside models for application of the unit risk approach.

GENII (Generation II of the Hanford Environmental Radiation Dosimetry Software System) (Napier et al., 1988) was used to assess the exposures to the offsite and noninvolved populations resulting from atmospheric releases of radioactive contaminants during routine facility operations and accidents, and to assess the intruder's radiological exposure to contaminated soil.

GENII is the second generation of a model developed for DOE at PNL to incorporate internal dosimetry models recommended by the ICRP into Hanford's existing environmental pathway analysis models. GENII analyzes environmental contamination resulting from both acute and chronic radionuclide releases by calculating radiation doses to individuals or populations from inhalation, ingestion of contaminated food and water, and external exposure through soil, water, and air. The GENII codes were developed under a stringent quality assurance plan based on American National Standards Institute (ANSI) standard NQA-1 as implemented in the *PNL QA Manual* (PNL-MA-70). It includes the DITTY (Dose Integrated Over Ten Thousand Years) code, which was used to calculate doses to the hypothetical farm family in the disposal scenarios as described below.

GENII has been used worldwide by several hundred users. Some noted applications include the Hanford Defense Waste EIS, Hanford's annual reports, the Hanford Safety Analysis, the Reactor Retirement EIS for PNL, and the ANL New Production Reactor Study. It has also been accepted by the State of Washington.

EPA's ISC2 (Industrial Source Complex Dispersion Models, Version 2) (EPA, 1992) was used to model atmospheric exposure modeling to chemical contaminants for the offsite and noninvolved worker populations. The code was designed specifically to support the EPA's regulatory modeling programs, and has EPA approval.

The DUST (Disposal Unit Source Term), MEPAS (Multimedia Environmental Pollutant Assessment System), and DITTY models were used in series to estimate exposures to contaminated groundwater.

DUST was used to calculate the flux of contaminants released and transported to the disposal facility boundary; these fluxes were then used as the input to MEPAS. The transport portion of MEPAS was used for the vadose and saturated zone plume migration calculations; the output concentrations from MEPAS were then used as input to DITTY. The DITTY code was then used for dose assessment calculations.

DUST was developed at Brookhaven National Laboratory (BNL) (Sullivan, 1992). This code models the release and transport of radionuclides through a shallow land disposal facility. DUST contains models to predict fluid flow, container degradation, waste form leaching, and radionuclide transport. DUST is useful for screening to determine which radionuclide is released at the highest rate, and for parameter sensitivity analysis. It has been extensively tested and verified, and the code predictions have been compared to known analytical solutions and to other code predictions; several verification tests are provided in the *Data Input Guide* (Sullivan, 1992). An important application of DUST was the modeling of field lysimeter release data collected at ORNL and ANL over a 7-year period.

MEPAS (Droppo et al., 1989) was originally developed in 1986 by PNL to assist the DOE Office of Environmental Safety and Health in prioritizing sites for remedial activities. This model is an objective, physics-based, PC-platform system that uses mathematical algorithms and a pathway analysis to evaluate the release of contaminants into the environment; the movement of these contaminants through and between multiple environmental media; exposure to surrounding human populations via inhalation, ingestion, dermal contact, and external dose; and the human health effects due to exposure to both chemicals and radionuclides.

MEPAS has been the subject of numerous technical reviews and has been widely used. Applications include the identification and prioritization of areas of existing environmental problems and risk at DOE's defense production facilities, and the assessment of potential risks for a number of commercial clients, the Hanford Site Single-Shell Tank Waste Characterization Program, the Hanford grout studies of hazardous waste risks, and 20 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites.

DITTY was used in the PEIS analysis to calculate radiological doses to the hypothetical farm family. DITTY was developed to calculate long-term population exposures from waste disposal sites; the time frame for calculations in DITTY is 10,000 years, divided into 143 periods of 70 years each. DITTY

calculates the lifetime cumulative dose equivalent for each time period and the EDE for the period of maximum dose.

The risks due to chemicals for the intruder scenario and the surface water deposition study were estimated using an upgraded version of the PRESTO-II risk assessment code (Fields et al., 1986). PRESTO-II was developed at ORNL to assist EPA in assessing the potential human health impacts from the disposal of LLW. PRESTO-II, originally written for a mainframe computer, was based on methodologies presented in the U.S. Nuclear Regulatory Commission *Reg. Guide 1.109* (NRC, 1977) for the release, transport, uptake, and human health risk assessment of radionuclides released from a shallow land burial trench. The PRESTO-II code was downloaded to a PC and augmented with a windows interface; this version of the code is called PRESTO-W (Fields and Melescue, in preparation). Further code development included adding the capability to simulate near-field scenarios where the contaminant concentrations of the environmental media are known at the receptor location. PRESTO-W was also upgraded to estimate human health risks from chemicals. The chemical database in MEPAS was incorporated into PRESTO-W for initializing chemical properties, cancer slope factors, and RfDs. The hazard index and cancer risks from chemicals were calculated in PRESTO-W using the methodologies presented in the EPA Superfund risk assessment guidelines (EPA, 1989a).

The MicroShield 4 computer code (Grove Engineering, Inc., 1992) was used for assessing external radiation exposure to waste management workers. MicroShield 4 was developed for designing shields and containers, assessing radiation exposure to people and materials, making source strength calculations based on radiation measurements, and teaching shielding principles. This model uses a highly structured ANSI standard programming language with good numerical precision. Data for attenuation coefficients, buildup factors, and buildup factor coefficients are taken from information distributed by the Radiation Shielding Information Center and included in ANSI/ANS 6.4.3.

MicroShield is currently being used by 400 organizations worldwide. For example, MicroShield was used in assessments of the Chernobyl accident in the former Soviet Union (Grove Engineering, Inc., 1992) and of various commercial nuclear utilities. Numerous universities including Kansas State University, Pennsylvania State University, the Massachusetts Institute of Technology, the Georgia Institute of Technology, and Renesselaer Polytechnic Institute use MicroShield for teaching shielding principles.

INEXPLC is a QuickBASIC program designed by ORNL System Safety Engineering (Bloom, 1993). The code includes relatively simple models that simulate close-in (i.e., less than 50 m downwind from the

source) atmospheric dispersion, explosive releases, and particle deposition. These models are based on exact solutions to the differential equation of a convection, turbulent-diffusion model for a point source and a semicircular, finite-area source. In this model, it is assumed that simple gas dispersion takes place with no effects from nearby structures (building wake effects or downwash). The INEXPLC code was used in the WM PEIS worker risk analysis to estimate outdoor air concentrations from accidental chemical releases.

References

ACGIH. *See* American Conference of Governmental Industrial Hygienists.

American Conference of Governmental Industrial Hygienists (ACGIH). 1992. *Guide to Occupational Exposure Values—1992.* Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists.

ANL. *See* Argonne National Laboratory.

Argonne National Laboratory (ANL). 1995a. *High Level Waste Inventory, Characteristics, Generation, and Facility Assessment for Treatment, Storage, and Disposal Alternatives Considered in the U.S. Department of Energy Waste Management Programmatic Environmental Impact Statement,* ANL/EAD/TM-17 (Draft). S.M Folga, J.L. Gillette, P.H. Kier, L.A. Poch, and G. Conzelman.

Argonne National Laboratory. 1995b. *Transuranic Waste Inventory, Characteristics, Generation, and Facility Assessment for Treatment, Storage, and Disposal Alternatives Considered in the U.S. Department of Energy Waste Management Programmatic Environmental Impact Statement.* ANL/EAD/TM-22 (Draft). K.J. Hong, T.J. Kotek, B.L. Koebnick, Y. Wang, and C.M. Kalcher.

Argonne National Laboratory. 1995c. *Low-Level Waste Inventory, Characteristics, Generation, and Facility Assessment for Treatment, Storage, and Disposal Alternatives Considered in the U.S. Department of Energy Waste Management Programmatic Environmental Impact Statement.* ANL/EAD/TM-20 (Draft). M.L. Goyette.

Argonne National Laboratory. 1995d. *Hazardous Waste Inventory, Characteristics, Generation, and Facility Assessment for Treatment, Storage, and Disposal Alternatives Considered in the U.S. Department of Energy Waste Management Programmatic Environmental Impact Statement.* ANL/EAD/TM-25 (Draft). M.A. Lazaro, A.J. Policastro, and A.A. Antonopoulos.

Argonne National Laboratory. 1995e. *Low-Level Mixed Waste Inventory, Characteristics, Generation, and Facility Assessment for Treatment, Storage, and Disposal Alternatives Considered by the U.S. Department of Energy Waste Management Programmatic Environmental Impact Statement.* ANL/EAD/TM-32 (Draft). B.D. Wilkins, Y.Y. Wang, D.A. Dolak, and N.K. Meshkov.

Case, M. J. and M. D. Otis. 1988. *Guidelines for Radiological Performance Assessment of DOE Low-Level Radioactive Waste Disposal Sites.* DOE/LLW-62T. U.S. Department of Energy. July 1988.

DOE. *See* U.S. Department of Energy.

Droppo, J. G., Jr., et al. 1989. *Multimedia Environmental Pollutant Assessment System, Application Guidance, Volume 1: User's Guide.* PNL-7216 Vol. 1/UC-602,630. Richland, Wash.: Pacific Northwest Laboratory.

EG&G Idaho, Inc. (EG&G). 1992. *Waste Management Facilities Cost Information Report.* EGG-WTD-10443. October 1992. Idaho Falls, Id.: EG&G Idaho, Inc.

EPA. *See* U.S. Environmental Protection Agency.

Fields, D.E., et al. 1986. *PRESTO-II: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code.* ORNL-5970. Oak Ridge, Tenn.: Oak Ridge National Laboratory.

Fields, D.E. and J.J. Melescue. In preparation. *PRESTO-W—Prediction of Radiation Effects from Shallow Trench Operations—Personal Computer/Windows Version.* Oak Ridge, Tenn.: Oak Ridge National Laboratory.

Grove Engineering, Inc. 1992. *MicroShield Version 4 User's Manual.* Rockville, Md.: Grove Engineering, Inc.

Hartmann, H.M., A.J. Policastro, and M.A. Lazaro. 1994. "Hazardous Waste Transportation Risk Assessment for the U.S. Department of Energy Environmental Restoration and Waste Management Programmatic Environmental Impact Statement—Human Health Endpoints," Draft submitted to the Waste Management '94 Conference, Tucson, Ariz.

Henry, K. 1994. EG&G Idaho, Inc. Personal communication with M. A. Simek, ORNL Center for Risk Management. May 16, 1994.

ICRP. *See* International Commission on Radiological Protection.

Iman, R.L. and M.J. Shortencarier, 1984. *A Fortran 77 Program and User's Guide for the Generation of Latin Hypercube and Random Samples for Use with Computer Models.* SAND83-2365. Albuquerque, N.M.: Sandia National Laboratories.

International Commission on Radiological Protection (ICRP). 1977. *Recommendations of the International Commission on Radiological Protection.* ICRP Pub. 26. New York: Pergammon Press.

International Commission on Radiological Protection. 1979. *Limits for Intakes of Radionuclides by Workers, Part 1.* ICRP Pub. 30. Oxford, G.B.: Pergammon Press.

International Commission on Radiological Protection. 1990. *Recommendations of the International Commission on Radiological Protection.* ICRP Pub. 60. New York: Pergammon Press.

Jayjock, M.A. 1988. "Assessment of inhalation exposure potential from vapors in the workplace." *Am. Ind. Hyg. Assoc. J.* 49, no. 8: 380-385.

Kennedy, W.E., Jr. and R.R. Peloquin. 1988. *Intruder Scenarios for Site-Specific Low-Level Radioactive Waste Classification.* DOE/LLW-70T. U.S. Department of Energy. September 1988.

Leigh, C.D., et al. 1992. *User's Guide for GENII-S: A Code for Statistical and Deterministic Simulations of Radiation Doses to Humans from Radionuclides in the Environment.* SAND91-0561A. Albuquerque, N.M.: Sandia National Laboratories.

Lyon, B.F., et al. 1992. *Sensitivity and Uncertainty Analysis for the U.S. Office of Management and Budget Pilot Study*. Oak Ridge, Tenn.: Oak Ridge National Laboratory.

Morrison Knudsen Corporation. 1993. Communication MKES Doc. No. WMF6-L-S-07-152.

Morrison Knudsen Corporation. 1994. Facility information data package, MKES Doc. No. WMF6-L-S-07-539.

Napier, B.A., et al. 1988. *GENII—The Hanford Environmental Radiation Dosimetry Software System.* PNL-6584. Richland, Wash.: Pacific Northwest Laboratory.

NAS. *See* National Academy of Sciences.

NAS/NRC. *See* National Academy of Sciences/National Research Council.

National Academy of Sciences (NAS). 1983. *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation. NAS Committee on the Biological Effects of Ionizing Radiation.* Washington, D.C.: National Research Council.

National Academy of Sciences/National Research Council (NAS/NRC). 1990. *Committee on the Biological Effects of Ionizing Radiations, Health Effects of Exposure to Low Levels of Ionizing Radiation, BEIR V*, Washington, D.C.: National Academy Press.

NRC. *See* U.S. Nuclear Regulatory Commission.

ORNL. *See* Oak Ridge National Laboratory.

Oak Ridge National Laboratory (ORNL). 1993. *Models for Close-In Atmospheric Dispersion, Explosive Releases, and Particle Deposition,* by S. Bloom. ORNL/TM-12452. Oak Ridge, Tenn.: Oak Ridge National Laboratory. October.

Oak Ridge National Laboratory. 1995a. *DOE Public and Onsite Population Health Risk Evaluation Methodology for Assessing Risks Associated with Environmental Restoration and Waste Management*, ORNL–6832, prepared by the ORNL Center for Risk Management for the U.S. Department of Energy.

Oak Ridge National Laboratory. 1995b. *DOE Worker Health Risk Evaluation Methodology for Assessing Risks Associated with Environmental Restoration and Waste Management,* ORNL–6833, prepared by the ORNL Center for Risk Management for the U.S. Department of Energy.

Oak Ridge National Laboratory. 1995c. *WM PEIS Methodology for Estimating Human Health Risks Associated with Waste Management*, ORNL–6864, prepared by the ORNL Center for Risk Management for the U.S. Department of Energy.

Oak Ridge National Laboratory. 1995d. *Programmatic Environmental Impact Statement Installation Descriptions,* ORNL–6841, prepared by the ORNL Center for Risk Management for the U.S. Department of Energy.

Oak Ridge National Laboratory. 1995e. *Supplemental Results of the Human Health Risk Analysis for the U.S. Department of Energy Draft Waste Management Programmatic Environmental Impact Statement*, ORNL–6867, prepared by the ORNL Center for Risk Management for the U.S. Department of Energy.

Shor, R.W., C.F. Baes, and R.D. Sharp. 1982. *Agricultural Production in the United States by County: A Compilation of Information from the 1974 Census of Agriculture for Use in Terrestrial Food-Chain Transport and Assessment Models.* ORNL–5768. Oak Ridge, Tenn.: Oak Ridge National Laboratory.

Sullivan, T.M., 1992. *Disposal Unit Source Term (DUST): Data Input Guide.* WM–1409–6. Upton, New York: Brookhaven National Laboratory.

U.S. Department of Energy (DOE). 1988. DOE Order 5820.2A, *DOE Radioactive Waste Management.*

U.S. Department of Energy. 1994. *Radiological Control Manual.* DOE/EH–0245T. Washington, D.C.: Office of Assistant Secretary for Environment, Safety, and Health.

U.S. Environmental Protection Agency (EPA). 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion,* Federal Guidance Report No. 11. Washington, D.C.

U.S. Environmental Protection Agency. Office of Emergency and Remedial Response. 1989a. *Risk Assessment Guidance for Superfund (Vol. 1), Human Health Evaluation Manual (Part A), Interim Final.* EPA/540/1-89/002.

U.S. Environmental Protection Agency. 1989b. *Air/Superfund National Technical Guidance Study Series, Volume III: Estimation of Air Emissions from Cleanup Acitivities at Superfund Sites.* EPA 450/1-89-003. Research Triangle Park, N.C.: Office of Air Quality Planning and Standards.

U.S. Environmental Protection Agency. Office of Emergency and Remedial Response. 1991a. *Risk Assessment Guidance for Superfund (Vol. 1), Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors, Interim Final.* OSWER DIRECTIVE 9285.6-03.

U.S. Environmental Protection Agency. Office of Emergency and Remedial Response. 1991b. *Risk Assessment Guidance for Superfund (Vol. 1), Human Health Evaluation Manual (Part B), Interim Final.* Publication 9285.7-01B.

U.S. Environmental Protection Agency. 1992. *User's Guide For the Industrial Source Complex (ISC2) Dispersion Models*, EPA-450/4-92-008. (no place)

U.S. Nuclear Regulatory Commission (NRC). 1977. *Regulatory Guide 1.109. Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix 1.* (no place)