# AR TARGET SHEET

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EDMC#: 0000003
SECTION: 2 OF 11

DOCUMENT #: DOE/EIS-0113

TITLE: Final EIS Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes

# CHAPTER 5.0

## POSTULATED IMPACTS AND POTENTIAL ENVIRONMENTAL CONSEQUENCES

## 5.0 POSTULATED IMPACTS AND POTENTIAL ENVIRONMENTAL CONSEQUENCES

Potential environmental consequences that could result from implementation of the waste disposal alternatives described in Chapter 3 are discussed in this chapter. The consequences described and evaluated in this chapter are believed to bound the range of consequences that could reasonably be expected from the adoption of any of the alternatives.

The waste disposal alternatives are as follows:

1. Geologic Disposal of most (98% of activity) Hanford high-level (HLW), transuranic (TRU) and tank wastes
2. In-Place Stabilization and Disposal of all Hanford high-level, transuranic and tank wastes
3. Reference Alternative (combination disposal) that combines features of geologic disposal and in-place stabilization and disposal
4. Preferred Alternative that consists of disposal of some waste according to the reference alternative and postpones disposal decision and continues present storage and maintainence activities for the remaining wastes until further development and evaluation are completed.

The potential environmental consequences of no disposal action (i.e., continued storage and monitoring) are also evaluated and discussed for the purpose of comparison with the consequences of the disposal alternatives.

### 5.1 INTRODUCTION

Environmental impacts for each of the disposal alternatives and the no disposal action (continued storage) were assessed for the disposal (operational) and postdisposal periods.

Impacts from disposal operations include the following:

- Radiation doses to the work force and public during routine operations
- Radiation doses to the public in the event of postulated radiological accidents
- Consequences of nonradiological accidents (potential injuries and fatalities) to the work force associated with industrial and transportation activities
- Consequences of nonradiological pollutants released to the environment
- Ecological impacts
- Socioeconomic impacts
- Resource requirements
- Costs.

Operational impacts were assessed for 100 years of continued storage to provide a comparable time period for waste disposal plus additional time for surveillance of waste disposal performance. In addition, estimates of impacts of continued storage for each century following the initial 100-year period were developed to provide a basis for estimating accumulated impacts if no disposal action were undertaken. It should be noted that the no disposal action alternative described in this EIS is intended to represent the no action alternative, an analysis of which is required by Council on Environmental Quality Regulations (40 CFR 1500-1517). The no disposal action alternative involves continuous monitoring and surveillance of defense wastes stored at the Hanford Site. The wastes exist, and the current action at the Site must continue until final disposal plans are implemented. An absolute no action alternative is not a reasonable course of action; however, a no disposal action alternative can provide useful information to the decision-making process. Although DOE does not intend to adopt the no disposal action as a long-term alternative, this alternative meets the intent of the National Environmental Policy Act requirement to estimate the impact of taking no action.

Postdisposal impacts considered include:

- Impacts from disposed-of waste under present climatic and otherwise undisturbed conditions where disposal systems perform as planned
- Impacts from disposed-of waste under changed climatic conditions where disposal systems perform as planned
- Radiation doses to the public following postulated performance failures of the disposal systems, compounding effects of changed climatic conditions.

To describe postdisposal impacts in terms of public health and safety, an assessment is required for the safe performance of the disposal systems. Toward this purpose, this study identified and evaluated plausible human-induced events and natural processes that could affect the performance of the disposal systems and result in release of radionuclides. The likelihood of occurrence of such events was not assessed (except for human intrusion), but their potential radiological impacts are reported.

In assessing postdisposal impacts, it is assumed that active institutional controls are absent at the Hanford Site after the year 2150. This is in accord with the Environmental Protection Agency rules (EPA 1985) that active institutional control cannot be relied upon to assure safety from disposed of wastes after 100 years beyond disposal. Absence of active institutional control of the Hanford Site is assumed for analysis and comparison purposes only and does not represent a present or projected DOE plan.

### 5.1.1 General Observations and Findings

The environmental consequences analyses conducted in this EIS cover all major environmental impact sources, pathways, or significant events. Principal observations of the analysis are as follows:

- In terms of human health and safety, any of the disposal alternatives could be safely implemented.

- The geologic disposal alternative is the most costly, with about 13 billion dollars added cost over the reference alternative for HLW disposed of on site and TRU waste disposed of in the Waste Isolation Pilot Plant (WIPP); offsite disposal of HLW would add another 0.7 billion dollars. Some construction fatalities could be expected with this alternative. The geologic disposal alternative also results in the largest collective radiation dose to workers.
- The in-place stabilization and disposal alternative has low environmental impacts and also provides the lowest overall cost.
- The reference alternative provides a balance between cost and environmental impacts and accords with the Defense Waste Management Plan (DOE 1983a).
- Preferred alternative costs would be about $3 billion to proceed with disposal of the waste for which adequate information is available on which to base disposal decisions. Disposal of the remaining three waste classes would cost an additional $0.5 billion to $12 billion.
- Continued storage is an acceptable short-term option, but no disposal action (continued storage) is not a reasonable long-term disposal option.
- Most potential natural events and human activities on or near the waste disposal sites are not expected to significantly affect disposal system performance. Some events, such as assumed catastrophic floods associated with glaciation, could result in low contamination levels [about 0.05 nCi(Pu)/g] within the Pasco Basin; however these floods would in themselves create such an overwhelming environmental impact as to obscure these impacts.
- For the disposal alternatives discussed, all wastes postulated to be buried near the ground surface are covered by a protective barrier. Fires and subsequent wind erosion therefore would not effect the atmospheric release of radioactive waste, but could affect the performance of the protective barrier, whose purpose is to prevent or minimize water infiltration.

### 5.1.2 Waste Types Considered in Determining Environmental Consequences

Waste types and quantities considered in determining the environmental consequences reported in this chapter are presented in Chapter 3 and described in more detail in Appendices A and P.

### 5.1.3 Topics Covered in This Chapter

Results of the environmental impact analysis are reported as follows:

- Environmental impacts from implementation of the geologic disposal alternative — Section 5.2
- Environmental impacts from implementation of the in-place stabilization and disposal alternative — Section 5.3

- Environmental impacts from implementation of the reference (combination disposal) alternative — Section 5.4
- Environmental impacts of no disposal action (continued storage) — Section 5.5
- Environmental impacts from implementation of the preferred alternative — Section 5.6

Topics required to be addressed by the NEPA [Section 102(c)] are discussed within each section. These topics include:

- Irreversible and irretrievable commitment of resources
- Unavoidable adverse impacts
- Relationship of alternatives to land-use plans, policies and controls [required by 40 CFR 1502.16(c)]
- Relationship between near-term use of the environment and enhancement of long-term productivity.

### 5.1.4 Cumulative Impacts

Activities taking place or reasonably anticipated to take place on the Hanford Site that were not within the scope of the action being analyzed in this EIS and that might combine with the proposed action for a cumulative impact are as follows:

- Ongoing characterization and potential construction and operation of a deep geologic repository for commercial and/or commingled defense high-level and commercial transuranic waste
- Operation of the dual-purpose N Reactor for production of special nuclear materials and steam used by the Washington Public Power Supply System (WPPSS) for the production of electrical power
- Operation of PUREX and related facilities
- Construction and operation of the Process Facility Modification project
- Operation of the Supply System's Number 2 nuclear power plant and possible operation of one or more additional units
- Operation of U.S. Ecology's commercial low-level waste disposal site
- Previous and continued disposal of low-level liquid wastes to ground and cribs, and low-level waste disposed of in near-surface burial grounds, including decommissioned defueled naval submarine reactors
- Decontamination and decommissioning of eight surplus reactors
- Eventual decontamination and decommissioning of the remainder of Hanford's surface facilities.

A discussion of cumulative radiological impacts associated with the above activities is presented in this section. In addition to the potential for cumulative radiological impacts, the potential for impacts associated with storage and disposal of chemicals also exists. Location, species and inventories of many chemicals, particularly as may be distributed in soil columns, are not well known and are to be developed. As a consequence, cumulative chemical impacts are not presented but would be additive to the radiation impacts. Socioeconomic impacts of characterization and construction and operation of a deep geologic repository or other major construction would not be expected to adversely impact present community capacity for services; the recent loss of a major work force with termination/mothballing of additional commercial power reactors left the community with excess capacity for services.

#### 5.1.4.1 Cumulative Radiological Impacts in the Near Term

For purposes of this analysis, projected radiological impacts in the near term are derived principally from the Hanford-wide monitoring program. Radiological monitoring data from 1984[a] operations at Hanford are presented in Section 4.1 of this EIS. The overall radiological impact of 1984 operations was calculated to be 0.002 rem total-body dose to a hypothetical maximally exposed individual residing off site and 5 man-rem to the offsite population within 80 km (Price et al. 1985). These small impacts are in addition to those occurring from natural background radiation, which approximate doses of about 0.1 rem per year total body to an individual and about 34,000 man-rem per year to the same 80-km population. The major component of this radiological impact originates from the remaining production facility, N Reactor, located at the 100-N Area on the Hanford Site.

In 1984, airborne concentrations of all radionuclides that could be attributed to Hanford site-wide operations were projected to result in a dose of less than 0.00001 rem/yr to the average person living in the Hanford Site vicinity (within 80 km). This dose rate is substantially below the EPA Standard 40 CFR 61 of 0.025 rem/yr for airborne pathways. Very low levels of radionuclides attributable to Hanford operations were detected in the Columbia River; however, downstream concentrations of these radionuclides were projected to result in a dose of 0.00001 rem/yr, well below the EPA Standard 40 CFR 141 of 0.004 rem/yr for community drinking water systems.

Samples of agricultural foodstuffs grown in the vicinity of the Hanford Site have been examined annually for radioactivity since the mid 1950s. The low levels of radionuclides observed in most foodstuff samples collected in 1984 from farms around Hanford are attributable to worldwide fallout and natural radioactivity (Price et al 1985).

Samples of deer, rabbits, game birds, waterfowl and fish were also collected in 1984 near operating facilities and at locations where the potential for radionuclide uptake from operations was most likely. Although $^{60}Co$, $^{90}Sr$ and $^{137}Cs$, probably from Hanford operations,

(a) Radiological monitoring data are available for 1986 (Jaquish and Mitchell 1987); however, dose calculations presented for 1986 data employ the ICRP 26/30 dosimetry method, which gives effective dose equivalent that is not strictly comparable with dose equivalent used elsewhere in this EIS.

were detected in some of these samples, concentrations were low enough that any radiation dose resulting from consumption of such fish or animals would be within applicable radiation protection standards (Price et al. 1985).

Projected radiological impacts from on-going Hanford operations, reasonably anticipated operations and those specified in this EIS as associated with the implementation of disposal or continued storage of high-level, transuranic and tank waste are summarized in Table 5.1.

**TABLE 5.1. Cumulative Near-Term Radiological Impacts for Hanford Site-Wide Operations and Reasonably Forecasted Operations**

| | Maximum Annual Individual Total-Body Cumulative Dose,[a] rem | Annual Population Total-Body Dose,[b] man-rem |
|---|---|---|
| On-going Hanford Site-Wide Operations[c] | | |
| N Reactor, PUREX, Defense LLW Disposal | 0.002 | 5 |
| WPPSS #2[d] | 0.002 | 1 |
| U.S. Ecology LLW Disposal[e] | ~0 | ~0 |
| Additions from Reasonably Forecasted Operations | | |
| Geologic Repository[f] | <0.001 | 9 |
| Process Facility Modifications[g] Project | ~0 | ~0 |
| Additional WPPSS Nuclear Power Units[d] | 0.002 | 1 |
| Implementation of HDW-EIS Alternatives | | |
| Geologic | <0.001 | 30 |
| In-Place | <0.001 | 0.03 |
| Reference | <0.001 | 0.05 |
| Preferred | <0.001 | 0.03-30 |
| No Disposal Action | <0.001 | 0.006 |

(a) For perspective, the annual dose to such an individual from natural background would be 0.1 rem.
(b) For perspective, the dose to the same population for the same period from natural background would amount to about 34,000 man-rem.
(c) Based on Environmental Monitoring of Hanford 1984 (Price et al. 1985).
(d) Performance of additional units assumed to be the same as reported for WPPSS #2, PFMP EIS, p. 5.53.
(e) Average annual dose rate including background at U.S. Ecology site fence was 0.18 rem, at corners of site 0.11 rem; hence, dose due to facility at Hanford Site boundary would be essentially zero.
(f) See DOE/ET-0029 (DOE 1979), pp. 9.1.7 through 9.1.9; for 122,000 MTHM repository in basalt and an 80-km-radius population of 2 million people. On a basis of 70,000 MTHM repository and 340,000 people the dose should be substantially less.
(g) DOE/EIS-0115D (DOE 1986, p. 5.53).

As shown in Table 5.1, if all present and reasonably forecasted activities are included, cumulative radiological impacts are projected to be substantially less than those permitted by the EPA (40 CFR 61 or 191; 0.025 rem/yr) and small in comparison with natural background radiation (0.1 rem/yr). No health effects would be expected from population doses such as those presented in Table 5.1.

#### 5.1.4.2 Cumulative Radiological Impacts in the Long Term

Long-term cumulative radiological impacts are those that might occur in the distant future after operating plants have been decommissioned and long after the year 2150 (100 years after disposal) when active institutional control is assumed to be absent. For purposes of this analysis, it is assumed that disposal sites not in the scope of this EIS are not provided with protective barriers. Impacts would be expected to be associated principally with leaching of waste components into groundwater and on into the Columbia River.

The principal source of impacts in addition to those presented for implementation of the disposal alternatives and the no disposal action alternative (continued storage) is believed to be that from defense low-level waste disposal sites. "Low-level wastes" as used here includes all radioactive defense waste (some 400 individual sites), exclusive of decontamination and decommissioning wastes, not included in high-level, transuranic and tank waste or in the secondary wastes such as grouted waste produced during waste processing. Long-term cumulative radiological impacts associated with the disposal alternatives and low-level waste are presented in Table 5.2. Impacts presented are those calculated to result among downstream users of Columbia River water for two assumed average annual recharges of groundwater, (from infiltrating precipitation) and for conditions where protective barriers are effective and where they partially fail.

As shown in Table 5.2, long-term impacts associated with low-level waste disposal are larger than those for high-level, transuranic and tank wastes when disposed of according to the alternatives presented in this EIS. Low-level waste disposal impacts, however, are smaller than those associated with the no disposal action (the principal reason for large impacts in the no disposal action alternative is the assumption of tank waste remaining in liquid form).

Impacts from decontamination and decommissioning of the eight surplus reactors will be provided in an environmental impact statement now in preparation that addresses alternative strategies for their disposal. Similarly, impacts from decommissioning other surface facilities currently in operation at the Hanford Site will receive separate environmental reviews. In both cases, impacts will depend upon the decommissioning method ultimately selected.

A waste repository, if it were to be located at Hanford, would also constitute a source of cumulative impacts. Because the repository is largely conceptual at this time, estimated impacts are based on permissible levels of operation over the 10,000-year period of interest. The EPA has indicated in the preamble to 40 CFR 191 that when the release limits specified in Table I of 40 CFR 191 are met, the number of premature cancer deaths over 10,000 years from disposal of wastes from 100,000 t of reactor fuel is not expected to exceed 1,000. Based on that relationship, a geologic repository with a capacity of 70,000 t of

**TABLE 5.2. Cumulative Long-Term Radiological Impacts for Hanford Site-Wide Operations and Reasonable Forecasted Operations**

| On-Going Hanford Site-Wide Operations | Integrated Population Total-Body Dose Over 10,000 yr, man-rem[a]: Barriers[b] Effective/ Current Climate[c] | Integrated Population Total-Body Dose Over 10,000 yr, man-rem[a]: Barrier[b] Failure Scenario/ Wetter Climate[d] |
|---|---|---|
| N Reactor, PUREX, WPPSS #2 | (e) | (e) |
| Defense LLW Disposal (no barriers) | 2,000 | 6,000 |
| U.S. Ecology LLW Disposal, etc, | (f) | (f) |
| **Additions from Reasonably Forecasted Operations** | | |
| Geologic Repository | (g) | |
| Process Facility Modifications Project | (e) | |
| Additional WPPSS Nuclear Power Units | (e) | (e) |
| **HDW-EIS Disposal Alternatives** | | |
| Geologic | 2 | 200 |
| In-Place | 10 | 600 |
| Reference | 10 | 600 |
| Preferred[h] | 2-10 | 300-600 |
| No Disposal Action (no barriers) | 20,000 | 4,000,000 |

(a) All values rounded to one significant figure. For perspective, if the population within 80 km of Hanford remained constant for 10,000 years, the integrated population dose from natural background would amount to 340,000,000 man-rem.
(b) Barriers only for HDW-EIS disposal alternatives.
(c) Assumed average groundwater recharge rate of 0.5 cm/yr for unbarriered areas.
(d) Assumed average groundwater recharge rate of 5 cm/yr for unbarriered areas.
(e) Long-term impacts, if any, would be associated with decommissioning residuals for which no basis is presently available. However, residuals would be small compared to defense low-level waste.
(f) Values not known, but would be expected to be small fractions of defense low-level waste.
(g) A 70,000-MTHM repository operating in compliance with EPA standard 40 CFR 191 would result in no more than 700 health effects over 10,000 years. Using the dose-to-health-effects conversion factors of 100 to 1000 health effects per million man-rem, the integrated population dose would range from 700,000 to 7,000,000 man-rem. This should not be construed as a prediction of long-term impacts from such a repository at Hanford. Long-term impacts would be developed and presented in an EIS addressing such a repository if it were chosen.
(h) Impacts are shown as a range since disposal decisions have not been made for single-shell tank waste, TRU contaminated soil sites, or pre-1970 buried TRU solid waste.

commercial waste would not be expected to result in more than 700 premature cancer deaths over 10,000 years. Based on this same relationship, if all Hanford waste within the scope of this EIS were to be disposed of in such a repository, no more than 180[(a)] premature cancer deaths would be expected over 10,000 years from these wastes. The upper bound of impacts from other new DOE facilities and operations, including decommissioning of existing facilities, will be required as a minimum to fall within applicable regulations.

#### 5.1.4.3 Cumulative Impacts Associated with Transportation of TRU Wastes

The impacts of shipping Hanford TRU wastes to the Waste Isolation Pilot Plant (WIPP) were calculated in this EIS (see Appendix I). Other federal sites will also be shipping their TRU wastes to the WIPP. The cumulative impacts of transporting TRU wastes to the WIPP from all federal sites, including Hanford, have been studied (JIO 1985). The cumulative risk analysis developed in JIO (1985) for transporting TRU wastes to the WIPP evaluated both radiological and nonradiological impacts.

In considering the cumulative impacts of transporting TRU wastes, the Transuranic Waste Transportation Assessment and Guidance Report examined several existing documents. For example, risk analyses in NUREG-0170 (NRC 1977) concluded that the risk of transporting radioactive material over the nation's highways and rails is small. This generic transportation risk assessment evaluated both commercial and defense related shipments of radioactive material. Additional analyses in the final environmental impact statement (FEIS) for WIPP (DOE 1980b) address specific risks associated with the transportation of transuranic waste and high-level waste (for repository experiments) to WIPP. This assessment considered both the radiological and the nonradiological impacts of contact-handled TRU waste shipments from the Idaho National Engineering Laboratory (INEL) and the Rocky Flats Plant, remotely handled TRU waste shipments from INEL, and experimental high-level waste from the Hanford vicinity (Pacific Northwest Laboratory). The WIPP/FEIS did not address transportation of waste from all generating and storage sites to the WIPP, although typical routes and estimated transportation distances from various origin sites to WIPP were identified.

Using a dose rate value of 2 mrem/hr at the outside surface of the TRUPACT (assumed in this EIS for calculation purposes to be the transportation container), the WIPP/FEIS analysis (DOE 1980b) concluded that the radiological impact of incident-free transportation to the public is many times smaller than the effects from natural background radiation. The analysis further concluded that the probability of accidents involving TRU waste shipments which would result in radiological consequences is also small--between 1 in 40,000 years and 1 in 4 million years. And even if such an event should occur in a small or large urban area, its

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(a) EPA 40 CFR 191 provides a method (note 4 of Table I) for apportioning release limits according to fuel burnup level. Although much of Hanford's fuel was irradiated to substantially less than 5,000 MWd/t, EPA permits this as a minimum value for apportionment. Using 5,000 MWd/t results in a total fuel equivalent for comparison with EPA 40 CFR 191 of 18,000 t. (This is a higher value than the amount of commercial fuel equivalent (3,100 MTHM), derived from the typical defense fuel exposure, for purposes of estimating geologic repository capacity needed for Hanford defense waste.)

impact would be less than the 50-year total-body dose commitment (or less than the 10-year dose to lungs) from natural background radiation.

At the present time, no definite estimates of transportation mode mix ratios have been established. Therefore, to allow for the dynamics of transportation costs and the Defense TRU Waste Program, two bounding cumulative transportation analyses were performed: a 100% truck case and a "maximum rail" case. The maximum rail case acknowledges that not all sites have rail access and in those instances waste shipments will be limited to the truck transport mode.

Calculations were made to determine the hypothetical maximum exposure to an individual from incident-free transportation of waste from each of the storage and generator sites. The cumulative value of all site shipments represents the maximum radiological exposure to an individual living near the WIPP facility. Radiological risks were computed as a function of both the transportation mode mix and the Transport Index (TI) value. Nonoccupational risks from annual contact-handled TRU waste shipments range from 6.7 to 140 man-rem, while occupational risks are relatively constant and vary from 21 to 28 man-rem. Estimated nonoccupational impacts are dominated by radiation exposure to the public during stop-over time; i.e., the period when the waste package is stationary for an extended period of time.

The risk contributed from potential accidents which may result in the release of radioactive waste is very small and ranges from 0.03% to 0.20% of the total radiological risk.

The significance of the population doses can be determined by comparing the impact with doses received by the same population from natural background radiation. Estimating the affected population size as that segment of the public living within a half mile of the shipping routes, a total of approximately 6.25 million persons could be affected by transportation of TRU wastes. If each person along the routes receives an average of 0.1 rem annually from natural background radiation sources, as discussed in the WIPP/FEIS (Appendix O of DOE 1980b), the population dose resulting from natural radioactivity would be 625,000 man-rem. Thus, in comparison, the upper limit of incremental risk to the same population exposed to contact-handled TRU waste shipments is approximately 0.03% of the dose that population would receive from natural sources. The radiological aspects of transportation would not result in any health effects (cancer fatalities or genetic effects).

Pollutants are emitted during normal transport by the combustion of diesel fuel, by the passage of a shipment over a dusty road surface, and by tire abrasion. Combustion of diesel fuel generates sulfur dioxide, carbon monoxide, hydrocarbons, nitrogen dioxide and particulates. The passage of a shipment over a roadbed or highway produces fugitive dust, and tire particulates are generated from the abrasion of tires on the pavement. Each pollutant has a unique character, and each may affect health. Pollutant emissions could result in zero to one health effect (latent cancer fatality), depending upon whether the geologic repository is on the Hanford Site or off site.

Injuries and fatalities would be the nonradiological impacts expected from accidents during transport of Hanford defense wastes to assumed repository locations. These injuries and fatalities are not directly related to the radioactive cargo being transported; however, they would not be incurred if the cargo were not being transported. Thus the number of estimated injuries and fatalities would be the same even if the cargo were not radioactive material. Traffic accidents could result in 1 to 2 fatalities and 10 to 21 injuries, depending upon whether the geologic repository is on the Hanford Site or off site.

### 5.1.5 Supporting Material Used in Determining Environmental Impacts

The appendices (Volumes 2 and 3) provide the supporting detail for this EIS. A guide to their contents and relationship is given in Figure 1 of the Introduction to the Appendices. Details of methods used for calculating radiation dose and conversion to health effects are given in Appendices F and N, respectively. Postulated operational accidents are described in Appendix H, and impacts from transportation are given in Appendix I. The long-term performance of waste disposal systems is assessed in Appendices R and S.

The Hanford Waste Vitrification Plant, Transportable Grout Facility, and Waste Receiving and Processing facility are discussed in Appendices C, D and E, respectively.

A description and anticipated performance of a conceptual protective barrier and marker system is presented in Appendices B and M.

The status of geohydrologic modeling of the Hanford Site is described in Appendix O. Information on releases of radionuclides in the long term from various waste forms is presented in Appendix Q. Modeling of nuclide movement in the unsaturated and saturated zones beneath the waste sites is discussed in Appendix P. The groundwater transport of chemicals from single-shell tanks is discussed in Appendix U. Methods for estimating air-quality impacts are described in Appendix T. Inventories by nuclide of various waste forms and their disposition by alternative are presented in Appendix A.

Details of methods for calculating nonradiological injuries, illnesses and fatalities are given in Appendix G. Details of nonradiological impacts from construction and operational activities are presented in Appendix L, and socioeconomic impacts are provided in detail in Appendix K. The method used for calculating repository costs is discussed in Appendix J.

## 5.2 GEOLOGIC DISPOSAL ALTERNATIVE

In the geologic disposal alternative, it is assumed that at least 95% (by activity) of single-shell tank waste, at least 99.95% (by activity) of double-shell tank waste, all encapsulated strontium and cesium, and all transuranic (TRU) wastes would be removed and placed in either an onsite or offsite geologic repository. Some low-activity waste fractions resulting from processing the tank wastes would be incorporated into grout, disposed of in near-surface grout vaults and covered by the protective barrier and marker system.

### 5.2.1 Waste Disposal Procedures

Representative procedures for treating and disposing of the six waste classes for the geologic disposal alternative are described in Chapter 3, Section 3.3.1 and Appendix B in detail.

### 5.2.2 Summary of Operational Impacts Associated with Geologic Disposal Alternative

Operational impacts associated with geologic disposal are summarized for disposal of all waste classes in either a hypothetical onsite or hypothetical offsite repository. Strontium/cesium currently in capsules and tank waste would be disposed of in either a hypothetical onsite or hypothetical offsite geologic repository and TRU waste would be disposed of in the WIPP in New Mexico. The distinction among repository alternatives is limited to that associated with transportation of waste to the repositories and proration of repository costs based on the fraction of the repository occupied by Hanford wastes.

#### 5.2.2.1 Radiological Consequences from Routine Operations

Radiation doses calculated to result from geologic disposal of Hanford defense wastes are summarized in Table 5.3 for all waste classes. An estimated total of about 28,000 worker-years of radiation work would be required for geologic disposal of all waste classes. A total occupational total-body dose of about 15,000 man-rem (including repository emplacement) would result.[a] Over 60% of the occupational dose total would be received from disposing of existing tank waste.

Geologic disposal of all waste classes would release to the atmosphere small amounts of radionuclides from the waste sites and surrounding potentially contaminated soil that could result in radiation doses to members of the offsite general public. The calculated dose commitment in any one year to a maximally exposed individual[b] is $4 \times 10^{-4}$ rem, and the calculated individual lifetime total-body dose is $8 \times 10^{-4}$ rem. The collective dose to the 80-km population in any one year is calculated to total about 30 man-rem, and the total dose to the public from all operations including transportation to an offsite repository is calculated to be about 140 man-rem. For comparison the 70-year dose to the population within 80 km from natural background radiation would amount to 3,000,000 man-rem.

#### 5.2.2.2 Radiological Consequences from Postulated Accidents

Handling and processing of Hanford defense wastes for disposal would create the possibility of accidents. A range of postulated abnormal occurrences has been analyzed for each waste class, and for each process. Of these occurrences, the accident with the largest potential consequences was determined (Appendix H). The postulated operational accidents that would result in the largest radiation doses to the public for each waste class and associated process are summarized in Table 5.4.

(a) Regardless of the large differences in operations taking place on the Hanford Site over the last several decades, the average annual dose to radiation workers has been about 0.5 rem (DOE 1983b).
(b) The maximally exposed individual is a hypothetical member of the public whose habits tend to maximize radiation dose to a given organ. For the case where exposure to airborne radionuclides results in the highest contribution to dose, this individual is assumed to reside continuously at the location of highest airborne radionuclide concentration and to eat food grown there.

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**TABLE 5.3. Estimated Total-Body Radiation Doses from Routine Operations for the Geologic Disposal Alternative**

| | Occupational Doses, man-rem | | Maximum Individual Dose Commitments, rem | | Population Dose Commitments,[a] man-rem | | |
|---|---|---|---|---|---|---|---|
| Waste Class | Operations | Repository Emplacement | 1-yr Exposure | 70-yr Exposure[b] | 1-yr Exposure | 70-yr Exposure[b] | Transportation (offsite) |
| Existing Tank Waste | 9,600 | 870 | $3 \times 10^{-8}$ | $5 \times 10^{-6}$ | $3 \times 10^{-3}$ | 0.3 | 30 |
| Future Tank Waste | 1,100 | 150 | $6 \times 10^{-7}$ | $9 \times 10^{-6}$ | 0.05 | 0.7 | 8 |
| Sr/Cs Capsules | 70 | 78 | $6 \times 10^{-10}$ | $4 \times 10^{-8}$ | $6 \times 10^{-5}$ | $2 \times 10^{-3}$ | 0.8 |
| Retrievably Stored and Newly Generated TRU | 140 | 110 | $1 \times 10^{-6}$ | $1 \times 10^{-4}$ | 0.09 | 9 | 40 |
| TRU-Contaminated Soil[c] | 750 | 52 | $2 \times 10^{-6}$ | $2 \times 10^{-4}$ | 0.1 | 10 | 2 |
| Pre-1970 Buried TRU Solid Waste[c] | 2,300 | 180 | $4 \times 10^{-4}$ | $5 \times 10^{-4}$ | 30 | 30 | 6 |
| Totals | 14,000 | 1,400 | $4 \times 10^{-4}$ | $8 \times 10^{-4}$ | 30 | 50 | 90 |

(a) All dose commitment values have been rounded to one significant figure.
(b) "70-year exposure" implies a lifetime accumulated dose from all operations.
(c) Geologic disposal is taken as an additional protective measure for these previously disposed-of wastes.

**TABLE 5.4. Summary of Upper-Bound Accidents and Calculated Total-Body Radiation Doses for the Geologic Disposal Alternative[a]**

| Waste Class | Description of Upper-Bound Accident | Maximum Individual Dose Commitments, rem | | Population Dose Commitments, man-rem | |
|---|---|---|---|---|---|
| | | 1-yr Dose | 70-yr Dose Commitment | 1-yr Dose | 70-yr Dose Commitment[a] |
| Existing Tank Waste | Explosion of ferrocyanide precipitates in single-shell tank during mechanical retrieval operations. | 0.2 | 3 | 400 | 7,000 |
| Future Tank Waste | Pressurized release of liquid waste due to failure of a diversion box valve during hydraulic retrieval operations. | 0.09 | 0.9 | 300 | 2,000 |
| Sr/Cs Capsules | Rupture of a strontium capsule by improper handling during retrieval operations. | $2 \times 10^{-7}$ | $3 \times 10^{-6}$ | $6 \times 10^{-4}$ | 0.01 |
| Retrievably Stored and Newly Generated TRU | Pressurized release from waste drum rupture due to buildup of radiolytic gases. | $1 \times 10^{-3}$ | 0.05 | 3 | 100 |
| TRU-Contaminated Soil[b] | Deflagration of contaminated material due to process malfunction in slagging pyrolysis incinerator. | $5 \times 10^{-7}$ | $2 \times 10^{-5}$ | $1 \times 10^{-3}$ | 0.04 |
| Pre-1970 Buried TRU Solid Waste[b] | Deflagration of contaminated material due to process malfunction in slagging pyrolysis incinerator. | $5 \times 10^{-6}$ | $1 \times 10^{-4}$ | 0.01 | 0.3 |

(a) See Appendix H for details.
(b) Previously disposed-of wastes.

The impacts to members of the public from accidents shown in Table 5.4 are not severe. The total 70-year population dose from the most severe accident amounted to 7,000 man-rem, a small fraction of the dose this same population would receive from naturally occurring background radiation i.e., 3,000,000 man-rem.

#### 5.2.2.3 Nonradiological Consequences

Nonradiological consequences include generation of dust from waste retrieval, site preparation, site stabilization, and handling of mined material; combustion products from operation of surface vehicles, operation of equipment, and transportation of waste; and injuries and fatalities associated with retrieval, transportation, and disposal of the waste. Details are presented in Appendices G, L and T.

Releases of nonradiological pollutants (i.e., dust and combustion products) resulting from geologic disposal are detailed in Appendix L (Table L.1) and are summarized in Table 5.5. Releases shown in Table 5.5 include those generated on site during waste retrieval and processing.

**TABLE 5.5. Summary of Nonradiological Emissions for the Geologic Disposal Alternative** (over a 20-year time span)

| Pollutant | Emissions, t |
|---|---|
| Particulates | 58,000 |
| $SO_x$ | 3,800 |
| CO | 4,800 |
| HC | 590 |
| $NO_x$ | 3,400 |

Air-quality impacts are estimated in terms of maximum ground-level pollutant concentrations at the site boundary or at publicly accessible locations within the Hanford fenceline and are summarized in Table 5.6 (Appendix T). Pollutant concentrations are based on historical meteorological conditions and expected maximum releases of pollutants and thus are only an indication of what conditions might be. In any case, the values calculated are sufficiently small compared to the standards to suggest that these pollutants would not result in a significant impact.

Nonradiological pollutant concentrations resulting from transportation of waste to WIPP or another offsite repository would be extremely small and well below standards shown in Table 5.6. Transportation emissions are based on round-trip shipping distances of 20 km for an onsite repository, 5,000 km for the WIPP repository, and 10,000 km for an offsite repository. For details on transportation-related air-quality impacts, refer to Appendix I.

The calculated number of injuries and fatalities associated with geologic disposal of Hanford defense waste is described in detail in Appendix L (Table L.2) and is summarized in Table 5.7. The number of injuries and fatalities is based on accident statistics for similar activities and on estimates of manpower requirements.

TABLE 5.6. **Comparison of Estimated Concentrations of Nonradiological Pollutants in Air for the Geologic Disposal Alternative with Ambient Air-Quality Standards**[a]

| Pollutant | Concentration, $\mu g/m^3$ | | | | |
|---|---|---|---|---|---|
| | 1 hr | 3 hr | 8 hr | 24 hr | Annual |
| CO | 560 (40,000) | --[b] | 170 (10,000) | -- | -- |
| $NO_x$ | -- | -- | -- | -- | 1.3 (100) |
| $SO_x$ | 390 (665) | 260 (1,300) | -- | 16 (260) | 1.3 (52) |
| Particulates[c] (including dust) | -- | -- | -- | 6.9 (120) | 0.3 (40) |

(a) Ambient air-quality standards are given in parentheses. See Appendix T.
(b) Dashes indicate there is no applicable standard.
(c) Allowable concentration in excess of background.

TABLE 5.7. **Summary of Estimated Nonradiological Injuries, Illnesses and Fatalities Associated with the Geologic Disposal Alternative**

| | Injuries and Illnesses[a] | | Fatalities | |
|---|---|---|---|---|
| | TRU to WIPP | | TRU to WIPP | |
| Process | HLW Onsite | HLW Offsite | HLW Onsite | HLW Offsite |
| Waste Processing and Stabilization | 520 | 520 | 2 | 2 |
| Repository Emplacement | 380 | 340 | 2 | 2 |
| Transportation | 13 | 21 | 1 | 2 |
| Total | 910 | 880 | 5 | 6 |

(a) Injuries and illnesses that result in lost work days.

#### 5.2.2.4 Ecological Impacts

Onsite ecological impacts from geologic disposal of all waste classes would be minimal since much of the area under consideration has already been disturbed as a result of radioactive waste management and other nuclear-energy-related activities. The construction requirement with the greatest ecological implication is the need for 7 million $m^3$ of fill material (soils, gravel and basalt), primarily for protective barr :r construction. Selection of the borrow area site for barrier construction soil will be conducted in accordance with procedures designed to comply with the requirements relating to protection of archaeological and native American religious sites. The borrow area will be rehabilitated, following removal of material, using state-of-the-art revegetation practices. These include site-specific soil cultural practices (e.g., tilling and inoculation) and seeding with native and other species of grasses.

The onsite areas of present radioactive waste storage at Hanford have already undergone some environmental modification, and the additional impact on plants and wildlife from waste retrieval and deposition in repositories is judged to be temporary and small.

Soil for backfilling and barriers, gravel for tank fill and basalt for barrier construction would be obtained on site from previously established sources or other onsite areas. About three miles of new road would be required in conjunction with the basalt quarry location on site. Noise, dust, and human activity associated with the implementation of the geologic disposal alternative would extend for about 20 years (Rockwell 1985a).

#### 5.2.2.5 Resource Commitments

Resource commitments for the geologic disposal of all waste classes include energy, materials, and manpower. Estimated requirements for each waste class are presented in Appendix L (Table L.3); aggregated requirements for all six waste classes are summarized in Table 5.8. Resources related to predisposal activities are combined with those related to repository activities. Resources used during predisposal activities (retrieval, packaging, storage, and transportation) are taken from Rockwell (1985b). Resources used for repository activities (estimated in DOE 1980a,b) are prorated to that portion of the repository required for disposal of the particular waste class. Resource use would be expended over about 30 years.

**TABLE 5.8. Estimated Resource Requirements for Implementing the Geologic Disposal Alternative**

| Resource | HLW Onsite; TRU to WIPP | HLW Offsite; TRU to WIPP |
|---|---|---|
| Energy | | |
| Diesel fuel, $m^3$ | 120,000 | 120,000 |
| Propane, $m^3$ | 97,000 | 97,000 |
| Gasoline, $m^3$ | 14,000 | 15,000 |
| Electricity, GWh | 5,000 | 5,100 |
| Coal, t | 520,000 | 530,000 |
| Materials | | |
| Concrete, $m^3$ | 300,000 | 300,000 |
| Steel, t | 80,000 | 80,000 |
| Stainless Steel, t | 6,600 | 6,600 |
| Lumber, $m^3$ | 47,000 | 47,000 |
| Riprap, $m^3$ | 4,600,000 | 4,600,000 |
| Gravel, $m^3$ | 720,000 | 720,000 |
| Soil, $m^3$ | 1,800,000 | 1,800,000 |
| Manpower, man-yr | 57,000 | 58,000 |

#### 5.2.2.6 Costs

A summary of the costs associated with the geologic disposal of Hanford wastes is shown in Table 5.9. Cost breakdowns are given in Appendix L. Retrieval and processing cost components are taken from Rockwell (1987). Transportation costs are taken from Appendix I. For

**TABLE 5.9. Cost Summary for Geologic Disposal of All Waste Classes**

| | Millions of $1987[a] | |
|---|---|---|
| Waste Class | HLW Onsite; TRU to WIPP | HLW Offsite; TRU to WIPP |
| Existing Tank Waste | 12,700 | 13,200 |
| Future Tank Waste | 1,700 | 1,800 |
| Sr/Cs Capsules | 210 | 210 |
| Retrievably Stored and Newly Generated TRU | 180 | 180 |
| TRU-Contaminated Soil[b] | 470 | 470 |
| Pre-1970 Buried TRU Solid Waste[b] | 1,600 | 1,600 |
| Totals | 16,900 | 17,500 |

(a) Costs were revised from the draft EIS to reflect increased repository fees. Since the above costs were calculated, additional costs for repository fees have been proposed. These proposed costs further increase the geologic alternative by 20%. Additional changes in estimated repository fees can be expected in the future.
(b) Previously disposed-of wastes.

waste going to a repository in basalt or another crystalline rock, the repository cost component is developed using design and packaging concepts in Rockwell (1983) (see also Appendix J). This repository cost component represents the incremental cost associated with emplacing capsules and tank waste in a commercial repository. Costs are higher than in the draft EIS, primarily because of increased estimated cost of repository emplacement. For TRU wastes, a WIPP repository cost component is estimated based on recent preconceptual studies of salt repositories (Appendix J).

### 5.2.3 Socioeconomic Impacts

Possible socioeconomic impacts include both growth-related effects (e.g., demand for housing and schooling, traffic congestion) and social, cultural or psychological effects related to the hazardous nature of the materials or technology involved (e.g., apprehension about the nuclear industry in general, concern for the risks involved in safely managing nuclear materials, and stress resulting from perceived adverse consequences). The growth-related socioeconomic impacts are influenced primarily by the size and scheduling of the estimated manpower requirements. Time and manpower needs for construction and for operations to implement the geologic disposal alternative for each of the six waste classes are presented in Appendix K. Any growth in employment and population expected from implementing an alternative could potentially result in social and public service impacts. These impacts, which may be either positive or negative, are discussed in this section.

Socioeconomic impacts are assessed for the period between the proposed start of construction activities and the year 2015. Although some waste disposal activities will continue beyond then, most of the socioeconomic impacts, if there are any, will be experienced earlier.

In this EIS, socioeconomic considerations are limited to those that might be associated with implementing disposal alternatives at the Hanford Site and do not include the impact of developing geologic repositories. An EIS to address repository site selection is expected to discuss cumulative impacts, including socioeconomic impacts, of the repository program at all candidate sites, including Hanford.

Implementation of the geologic disposal alternative requires the largest work force among the alternatives analyzed in this EIS, and therefore would cause the largest growth-related socioeconomic impacts. From a radiological standpoint, occupational exposure from this alternative is expected to be several times greater than those of the other alternatives. However, the long-term radiological exposures calculated for this alternative are no greater than those of the other alternatives. Because the geologic disposal alternative isolates the wastes most completely from humans and the environment, perceived social and economic risks from this alternative are expected to be lowest.

#### 5.2.3.1 Manpower Requirements

Detailed manpower profiles from data provided by Rockwell (1985b) are presented in Appendix K. Between the years 1990 and 2015, the average number of workers required per year for the geologic disposal alternative is estimated to be about 1,920. The peak work force requirement is estimated at about 3,450 in the year 1993.

It is important to try to estimate the extent to which these work-force requirements are likely to induce additional population growth in the area and consequently cause pressure on social services and related indicators of socioeconomic conditions. The outcome depends largely on the availability of unemployed or underemployed workers already in the area who are qualified and available to work on these jobs. Also important is the timing of potentially concurrent major projects that also place demands on limited labor supply.

The main determinant of socioeconomic impacts can be traced to the match between the pressures a project places upon a community (demographic, fiscal, services, and social) and the ability of the community to meet those pressures in a planned, orderly, cost-effective way. For the geologic disposal alternative as for each of the other alternatives, the work-force requirements and likely population in-migration are small compared to recent Hanford Site experience, and these effects can be expected to be spread across several large communities in Benton, Franklin, and Yakima Counties. The projected manpower requirement for the geologic disposal alternative represents less than 10% of the projected bi-county employment.

Actual work-force requirements and patterns of in-migration would be monitored after implementation begins. Experience at other large sites indicates that preliminary manpower estimates tend to underestimate actual peak work-force needs, due mostly to scheduling problems during construction.

#### 5.2.3.2 Employment and Population Impacts

During the period of constructing Washington Public Power Supply System's nuclear power reactors from 1973 to 1981, employment in the Hanford area grew rapidly at an overall average rate of about 8.3% per year. After mid-1981, however, the sudden and unexpected curtailment of these major construction projects initiated significant losses of around 10,000 jobs within a few years. The area is beginning to recover with gradual increases in employment and population, but at a rate much lower than that experienced in the recent past.

Historical and projected baseline employment and population growth is presented in Appendix K. Employment includes both the direct primary employees working on the waste management activities and the indirect secondary workers in the community who provide services. The total population forecasts include both the workers and their dependents. The average employment for the geologic disposal alternative between the years 1990 and 2015 is about 4,220 workers per year. At the peak employment years almost 7,600 workers are expected. As a percent of the projected baseline employment, this is about 8% (10% during the two peak years). For comparison, the Washington Public Power Supply System total employment accounted for about one-third of the bi-county baseline employment in 1981.

The potential population impacts of manpower needs can be estimated similarly. It is reasonable to assume that some portion of the work force would be derived from the existing local labor pool (unemployed or underemployed workers). A likely population impact estimate can be based on the assumption that half of the needed work force comes from the local area and half from another region. This leads to the conclusion that population growth induced by the geologic disposal alternative will be less than 4% of the projected bi-county baseline population, which is also small when considered in historical perspective. Economically and demographically these activities can be expected to benefit the region.

#### 5.2.3.3 Community Services

The potential socioeconomic impacts of the employment and population growth expected are given in detail in Appendix K. New population moving into the bi-county area for employment in these activities will require housing and community services that include transportation, health care, schools, police and fire, water and sewer, and recreation facilities. Since the area will be recovering from the significant employment and population losses of the early 1980s at the time of the heaviest manpower requirements, most of these services should have excess capacity to meet these needs.

#### 5.2.3.4 Housing

Housing demand under a high baseline condition would require about 3,000 units during peak employment years (Appendix K). Given that housing construction is likely to pick up again as the local economy begins to recover, and that many of the jobs will be taken by local workers who already live in the area, adverse housing impacts would appear to be unlikely.

#### 5.2.3.5 Local Transportation

Traffic congestion is another major aspect of the Tri-Cities region that has been particularly sensitive to population increase and to the traffic volume associated with activities on the Hanford Site. The total amount of increased traffic to the Hanford Site expected will be substantially lower than that associated with the Washington Public Power Supply System's peak construction period. Recent and continuing highway improvements in the area will alleviate many of the past problems. Given the assumed moderate growth in baseline conditions, adverse local transportation impacts are unlikely.

#### 5.2.3.6 Education

There is currently sufficient capacity to absorb any growth in the student population likely to be caused by construction and operation associated with the geologic disposal alternative. The total excess capacity was estimated at around 4,700 student positions in these schools in 1982. No negative capital cost impacts are therefore anticipated.

#### 5.2.3.7 Utilities and Other Services

Given the largely unanticipated Washington Public Power Supply System cutbacks in 1981, community services capacity had expanded beyond residents' immediate needs. As the region undergoes the projected decline and recovery, all community services will be affected, including staffing levels and space utilization requirements of such services as health, social services, education, and public safety. However, given adequate lead time and notification regarding future development, the affected departments and agencies probably can adequately adjust to changing conditions resulting from waste management activities.

#### 5.2.3.8 Fiscal Conditions

In light of the Tri-Cities' fiscal adaptability, shown during the high growth of the 1970s, the less-steep growth curves projected for construction and operation of the geologic disposal alternative probably will create no serious problems in management or financing for the area. As was true in the high-growth period of the 1970s, the proposed waste disposal activities probably would fiscally benefit the local communities.

#### 5.2.3.9 Social Conditions

During the last decade, a highly skilled labor force, from construction workers to professionals, has settled around the Hanford Site in anticipation of continued growth and employment opportunity. The unexpected closure of two major Supply System construction projects in mid-1981 was a major impact. Offsetting the significant decline in employment and population is the recovery now under way, to which disposal management activities could contribute positively. Since the geologic disposal alternative results in the largest number of jobs, its positive impacts would be substantially greater than those from the other alternatives.

Social conditions refer to both individual and community well-being and, in the case of the Hanford Site, include the "cultural community" of neighboring Indian tribes. Because the implementation of any defense waste disposal alternative is projected to result in reduced long term impacts on the environment and somewhat reduced adverse health and safety consequences over the long term compared with the no disposal action alternative, adverse social impacts, if any, are also expected to be insignificant. See the section on social conditions (K.5) in Appendix K for further discussion.

### 5.2.4 Assessment of Long-Term Impacts

The primary performance objective of waste disposal systems is to provide reasonable assurance that radionuclides and inextricably intertwined chemicals in biologically significant concentrations are isolated and thus provide for long-term protection of public health and safety. The degree to which that objective would be expected to be met is presented in this section for the geologic disposal alternative. Impacts are examined where 1) present conditions remain unchanged, 2) disposal systems are disrupted by postulated natural events, and 3) disposal systems are disrupted by intruders.

The analysis in this section draws upon the description of wastes and geologic disposal alternative as provided in Chapter 3 and upon analyses of radiological consequences developed for appraisal of performance of the alternatives in Appendix R. Appendix R, in turn, is based on a protective barrier and marker system described in Appendices B and M; hydrologic modeling of the water pathway in Appendix O, description of modeling of source releases and inventories of radionuclides in Appendix P; information on hydrologic transport of chemicals in Appendix U; and probabilistic analysis in Appendix S.

Key findings disclosed in the analyses are as follows:

- The only important pathway for radionuclides and inextricably intertwined chemicals to the affected environment is via groundwater.
- For wastes disposed of near the surface on the Hanford Site, the consequences to the offsite population would be negligible compared with consequences from naturally occurring radiation sources.
- The conceptual protective barrier and marker system described in Appendix B, when operating as designed, would prevent translocation of nuclides by burrowing animals and plant roots, inhibit human disruption of waste sites, and provide backup assurance that no significant leaching of wastes and water movement of leached waste to groundwater would occur.
- With a protective barrier in place and 100% effective, the only reasonably postulated mechanism for movement of radionuclides to groundwater involves diffusion of the waste via soil pore water. This process would require several thousand years for nuclides to move to the edge of the barrier. Regional non-zero recharge to groundwater would also be required to transport nuclides on to the groundwater.

- Intruder scenarios, developed for the case where only passive institutional controls exist, predict significant and/or fatal consequences if intrusions were to take place.[a]

#### 5.2.4.1 Long-Term Impacts Where Present Conditions Remain Unchanged

This section discusses the long-term impacts associated with each disposal system where present conditions remain unchanged. The expected performance of the disposal systems is presented where those systems perform as designed under present climatic conditions, and without human-induced or other disruption. The disposal systems are the geologic repository and the near-surface burial grounds.

Some wastes (98% of activity) are disposed of in a geologic repository and some wastes, including the low-activity, high-volume fraction from processing tank contents, are disposed of on site and near surface in grout vaults. Inventories of key radionuclides and their location in the geologic disposal alternative are shown in Table 5.10.

**TABLE 5.10. Estimated Inventories[a] of Key Radionuclides** (Rockwell 1985) **Disposed of in the Geologic Disposal Alternative, Ci**

| Radionuclide | Total | In Geologic Repository | In Onsite Barriered Near-Surface Burial |
|---|---|---|---|
| $^{14}C$ | 5,300 | 5 | 5,300 |
| $^{79}Se$ | 1,100 | 4 | 1,100 |
| $^{90}Sr$ | 120,000,000 | 120,000,000 | 2,600,000 |
| $^{99}Tc$ | 35,000 | 34,000 | 1,300 |
| $^{129}I$ | 58 | 0 | 58 |
| $^{137}Cs$ | 130,000,000 | 120,000,000 | 2,300,000 |
| $^{151}Sm$ | 1,200,000 | 1,200,000 | 39,000 |
| $^{238}U$ | 580 | 510 | 65 |
| $^{239-240}Pu$ (b) | 120,000 | 120,000 | 1,800 |
| $^{241}Am$ (c) | 390,000 | 390,000 | 4,800 |

(a) Values have been rounded and therefore may not add.
(b) Includes about 39,000 Ci $^{239-240}Pu$ previously disposed of.
(c) Includes about 11,000 Ci $^{241}Am$ previously disposed of.

It is assumed that geologic repositories (either on site or off site) employed in the geologic disposal alternative would have been sited in accord with those applicable provisions of the Nuclear Waste Policy Act of 1982 (PL 97-425) and, as such, would meet limits prescribed for environmental protection in the EPA standard 40 CFR 191 (EPA 1985) with a

(a) Fatal doses to intruders might result from the unlikely event of drilling into encapsulated waste in a geologic repository.

reasonable degree of confidence. (See also Appendix S.) Conformance with NRC regulations as set forth in 10 CFR 60 (NRC 1985) would also be required. As a consequence of assumed conformance with EPA and NRC regulations and since the selection of a particular geologic repository is outside the scope of this EIS, no further analysis of long-term performance of geologic repositories is presented here. Impacts associated with geologic repositories in general are given in the final environmental impact statements for the management of commercially generated waste (DOE 1980a) and for the Waste Isolation Pilot Plant (DOE 1980b).

The residuals from processing of tank wastes for disposal in a repository would be grouted and disposed of in vaults on the Hanford Site. A protective barrier and marker system would be installed over each of the waste sites. Under present conditions and with protective barriers in place over the waste sites and working according to design, analysis showed that there is a diffusion-advection mechanism for migration of radionuclides through the unsaturated zone to groundwater and the Columbia River. This phenomenon is described in detail in Appendix O. A preliminary investigation has been made of the consequences of such a phenomenon; using best available values for parameters required for modeling (Appendix O), a cumulative total-body dose of about three man-rem over 10,000 years was projected for the population downstream from the Hanford Site.

Chemicals could similarly be transported to the river via similar diffusion-advection mechanisms as described in Appendix U. Using conservative and bounding values for parameters, the concentration of nitrate ion ($NO_3^-$) in the Columbia River amounted to only $10^{-8}$ of the EPA drinking water standard (EPA 1984) of 45 mg/L (based on nitrate).

Thus the environmental impacts on the general public from residual wastes (both radioactive and chemical) in the geologic disposal alternative under existing conditions with protective barriers in place are concluded to be insignificant. (See 5.2.4.3 for discussion of groundwater impacts.)

#### 5.2.4.2 Long-Term Impacts Following Postulated Disruptive Events

An analysis was made of postulated natural and man-induced events that might disrupt confinement of wastes in the geologic disposal alternative. Events identified as candidates for analysis as disruptive events and the determination of their importance in terms of public health and safety are provided in Appendix R. Although numerous postulated events were reviewed, only four were identified as having a reasonable expectation of occurring and likely to have some consequences for offsite population. These events were impact of large aircraft into a waste site, return of glaciation, a change to a wetter climate, and partial failure of a protective barrier.

**Impact of Aircraft**

Analysis of the impact of a large aircraft into the waste sites resulted in a maximum 70-year total-body dose to the offsite population of less than 0.3 man-rem for an impact into the waste site that would give rise to the largest dose (single-shell or double-shell tanks, as is, without barrier protection). Therefore, impacts of falling aircraft were not considered further. Other falling bodies such as meteorites were considered, but the low probability of a meteorite hitting a waste site and releasing some of its contents was felt to be too small to warrant further consideration as a reasonable disruptive scenario.

**Return of Ice Age**

A climate change scenario was examined that included the return of an ice age. In previous ice ages, ice dams on upper tributaries of the Columbia River have formed and, when broken through, have resulted in floods unimaginably large (about 2,000 $km^3$ within a few weeks compared to the river's present average annual flow of 100 $km^3$/yr). Such floods would probably either scour out all wastes not disposed of in a deep geologic repository and carry them to the ocean or would further isolate them with additional deposits of sediments. In any event, such floods would obliterate most evidence of civilization along the Columbia River. Studies initiated in support of this EIS effort suggest that recurrence of the advance and retreat of ice flows sufficient to result in catastrophic floods of this magnitude might arise 40,000 to 50,000 years from now. Because most of the high-level, tank and TRU wastes are disposed of in a geologic repository, beyond the effects of such a flood, no attempt was made to quantify impacts from this scenario for the geologic disposal alternative. See Section 5.3.4.2.

**Change in Climate**

The change to a wetter climate assumed for analysis in this EIS was one that resulted in an average recharge to groundwater of 5 cm/yr on the 200 Areas plateau. This is ten times the 0.5-cm/yr average recharge postulated for the current climate.

**Barrier Failure**

In order to assess the consequences if the protective barrier (Appendix M) should fail, two scenarios have been postulated in which partial failure of the protective barrier occurs in the year 2500 in conjunction with a climate change. In addition, DOE has determined that development and evaluation activities must be conducted to provide a final barrier design and to confirm the effectiveness of the barrier.

**Disruptive Failure Scenario**

The first scenario simulates a massive disruption of part of the barrier system. Several possible mechanisms for such a failure can be postulated, but the most plausible is that the barrier topsoil has been bladed off for use elsewhere.

The net effect of this disruptive failure is that enough soil is removed from over the barrier surface that it acts as a catchment rather than a barrier. Under high precipitation conditions (30 cm/yr) it is assumed that 15 cm/yr (50% of average annual precipitation) infiltrates through this disrupted area and that 10% of the barriered waste volume is so exposed to infiltration. This catchment effect is in contrast to the 5 cm/yr that would infiltrate through 200 Areas Plateau soil (with no barrier) under similar meteorological conditions.

### Functional Failure Scenario

In a second barrier failure scenario an attempt has been made to test a failure of a large barrier area. There are a number of phenomena that might cause such a degraded performance. The first of these could be wind erosion such that some of the cover soil is removed. Seismic events could conceivably disrupt the interface between the fines and the riprap such that some fines would percolate into the coarse material, thus degrading the barrier performance. Subsidence of the underlying wastes is another mechanism that could reduce barrier effectiveness. Also, the use of construction materials, particularly the topsoils, that are out of specifications might cause barriers to perform below standard.

The functional barrier failure is defined such that 50% of the waste is subject to infiltration of 0.1 cm/yr under precipitation conditions of 30 cm/yr.

In the geologic disposal alternative, those wastes placed in a geologic repository would not be expected to be significantly affected by a climate change, wherever the repository might be located.

In the case of diffusion and transport to groundwater and the Columbia River, the movement of radionuclides through the vadose zone would be hastened in comparison with the diffusion and transport postulated to occur at a recharge of 0.5 cm/yr. The initial analysis of the results of such transport calculations, again employing realistic parameters, indicated a dose of about 30 man-rem over 10,000 years to the downstream users of the Columbia River (Appendix O). No health effects would be projected for such a dose. It is concluded that impacts to the offsite population, even using highly conservative parameters, are quite small. A disruptive barrier failure scenario (see Appendix M) combined with a wetter climate would result in an additional cumulative total-body population dose to the downstream population of about 140 man-rem over 10,000 years. The functional barrier failure scenario combined with a wetter climate would result in an additional cumulative dose to the downstream population of about 50 man-rem. The combined dose for functional barriers and disruptive and functional failures would amount to about 220 man-rem. For comparison the cumulative dose from natural background to the same population over 10,000 years would be about 3 billion man-rem. Such a background exposure corresponds to 300,000 to 3,000,000 health effects (see Appendix N). Thus, by comparison, the combined scenarios do not constitute a significant impact.

Applying the diffusion scenario to single-shell tank waste assuming a recharge rate of 5 cm/yr, the movement of chemicals would also be enhanced over that at 0.5 cm/yr. Regardless, the large dilution by the Columbia River results in the concentration of chemicals being small fractions of the limits set by drinking water standards; e.g., the concentration of nitrate ion ($NO_3^-$) was calculated as about $2 \times 10^{-8}$ of the EPA drinking water standard of 45 mg/L (based on nitrate). As a consequence, for the offsite population, release of chemicals via this mechanism would be also insignificant.

#### 5.2.4.3 Impacts in the Long Term from Intrusion and Other Activities

In accord with EPA standards (EPA 1985) stipulating that active institutional controls are not to be relied upon for environmental protection for more than 100 years after disposal, this section presents consequences where disposal systems are disrupted by intruders. Thus, for this analysis, 100 years after disposal (for convenience, taken uniformly to be the year 2150 in this EIS), active institutional control is assumed to no longer exist on the Hanford Site. This leaves passive institutional controls, such as markers, monuments, and public records, as the only mechanisms to inhibit intrusion onto the Site and into waste sites. As is often stated in this EIS, federal ownership and presence on the Hanford Site is planned in perpetuity, and as long as active institutional control exists, the intrusion scenarios would be unrealistic.

There is little likelihood for the intruder scenarios to result in the exposure of offsite population to significant quantities of radiation. Rather, the dose is received by the intruder and in some cases the intruder's family. Repetitive intrusions could occur with long time periods between intrusions. Appendices M and S contain an analysis of the probabilities of such intrusions that might take place on the Site.

The intrusion scenarios analyzed in this EIS (Appendix R) included the following:

- Exploratory drilling that penetrates a waste site (maximum inventory sites for each waste class) and brings contaminated drilling mud to the surface, resulting in radiation exposure of the drilling crew.
- The preceding drilling scenario followed soon by individuals residing on or near the contaminated drilling mud and consuming garden produce raised in the contaminated soil.
- Biotic transport of nuclides to the surface by burrowing animals, followed in time by individuals residing on, and consuming produce from, a garden grown in the contaminated soil.

Other scenarios not requiring intrusion into the waste disposal sites included the following:

- Drilling a water well,[a] away from the disposal sites but still on the Hanford Site, that intercepts a contaminated aquifer; individuals residing near the well drink contaminated water and irrigate a garden with contaminated water and consume the garden produce.
- Resettlement of the west bank of the Columbia River in the northeastern part of the Hanford Site by farm families who drink contaminated groundwater and consume farm products produced by irrigation from contaminated wells.

(a) In accord with EPA Environmental Standards (EPA 1985), the location of the well is assumed to be 5 km from the waste disposal site. For all practical purposes, consequences determined at the 5-km well may be applied for other possible downgradient locations between that well and the river.

In the geologic disposal alternative, it is assumed that none of the above-mentioned scenarios would apply to wastes disposed of in deep geologic repositories. Intruder scenarios, however, were developed for analysis of long-time performance of generic deep geologic repositories (DOE 1980a). As might be anticipated, serious consequences were projected for a few individuals drilling into waste (substantially less likely at 1,000 m than at a few meters down) and to several dozen persons who might later reside nearby on soil contaminated with drilling mud.

All waste sites would be covered by a protective barrier and marker system (Appendix M). Moreover, ceramic hazard warning markers would have been distributed within the barrier itself. Thus reasonable attempts would have been made to dissuade an inadvertent intruder. The degree to which such passive institutional controls, including county land-use records and restrictions, would reduce inadvertent intrusion is subjective and judgmental. An attempt was made to rank the efficacy of the elements of the protective barrier and marker system; for example, it was estimated that drilling was twenty times more likely in the no disposal action/no institutional control case than where passive institutional controls exist (Appendix M). In the following text, however, the intrusions are assumed to take place and their consequences cited on a "what-if" basis.

Because of warning markers around and within the protective barrier, drilling through a protective barrier is believed unlikely; however, it is not precluded. In the case of near-surface disposal of tank residuals stabilized in grout or the residue (up to 5%) left in the single-shell tanks, drilling through a waste site was analyzed for consequences to the intruder. The analysis showed that in the geologic disposal alternative, the largest dose would result from drilling into an emptied single-shell tank and would amount to a maximum annual total-body dose of 0.02 rem. Such a dose is considerably less than the annual dose the intruder would have received from natural background and is concluded to be insignificant.

Where the drilling scenario is followed by residence on or near soils contaminated by drilling or excavation, the maximum annual total-body dose is determined to be 5 rem. The dose associated with intrusion involving tank residue was calculated for the tank with maximum inventory, one of 149 tanks of widely varying inventories. An annual dose of 5 rem is equivalent to present standards for dose to radiation workers.

In the geologic disposal alternatives, all sites would be covered with the protective barrier. The final barrier design would be expected to preclude movement of radionuclides to the affected environment by biota. Assuming (to represent current climatic conditions) a 0.5-cm/yr average annual recharge to groundwater and with a protective barrier in place, an individual drilling a well into the aquifer between the 200 Areas and the Columbia River in the year 7500 would receive a maximum 70-year total-body dose of about 0.2 rem. This assumes he uses the water for domestic purposes and irrigates a garden with it. The principal contributor to the dose is $^{129}I$ from grouted tank waste residuals. If the individual were to only drink water from the contaminated well, his potential maximum annual total-body dose would amount to $6 \times 10^{-5}$ rem. If the climate were to change corresponding to a 5-cm/yr average annual recharge, this full-garden scenario would yield to potential maximum 70-year total-body dose to the intruder of 0.06 rem. This dose would take place around the year 7200 and would result from $^{129}I$ in single-shell tank grout residuals. Again, if the individual were to only drink water from the contaminated well, his potential maximum annual total-body dose would amount to about $1 \times 10^{-5}$ rem.

It was determined that, based on chemical inventories in single-shell tanks (assumed to be in grouted waste) and an average annual recharge rate of 0.5 cm/yr, groundwater at the 5-km well could contain the following incremental concentrations of selected chemicals (Appendix U): $NO_3^-$ 1.0 mg/L, chromium $6.0 \times 10^{-3}$ mg/L, cadmium $8.6 \times 10^{-8}$ mg/L, mercury $5.6 \times 10^{-5}$ mg/L, and fluoride $4.2 \times 10^{-6}$ mg/L. At a recharge rate of 5 cm/yr, the following incremental concentrations are projected: $NO_3^-$ 0.38 mg/L, chromium $2.4 \times 10^{-3}$ mg/L, cadmium $4.4 \times 10^{-7}$ mg/L, mercury $2.2 \times 10^{-5}$ mg/L, and fluoride $2.5 \times 10^{-6}$ mg/L. These concentrations are all below EPA drinking water standards.

#### 5.2.4.4 Resettlement

Another scenario was considered wherein at some future time the area adjacent to the west bank of the Columbia River in the northeastern part of the Site is resettled and wells are dug that reach groundwater. The area in question was inhabited at the time the Hanford Site was established (towns of White Bluffs and Hanford). This scenario is restricted to the number of 2-ha small farms that could be supplied by the volume of contaminated water available. On this basis, the number of small farms was limited to 65. It was then assumed that 65 families composed of four individuals each resettled the land and drew drinking and food-crop irrigation water from wells. (In earlier times irrigation water was supplied to this area from the Hanford ditch that took its water supply from the Columbia River upstream of the communities.)

The integrated population dose to, and health effects among, occupants of these small farms was estimated for both an average annual recharge of 0.5 and 5 cm. For the geologic disposal alternative, the integrated population total-body dose was estimated to be 4,000 man-rem, which implies 0 to 4 health effects for the current climate and about 1,000 man-rem or 0 to 1 health effect for the wetter climate.[a] Thus it could be concluded that this area could be resettled in the future with minimal risk from the wastes disposed of according to the geologic disposal alternative described.

### 5.2.5 Irreversible and Irretrievable Commitment of Resources

The irreversible and irretrievable commitment of resources for the geologic disposal alternative includes commitments of energy, materials and manpower. Selected resource commitments are summarized in Table 5.11 (see Appendix L for details).

(a) Although waste would be expected to be leached out at a higher rate in the wetter climate, the larger dilutions more than compensate for the increased leaching. As a consequence the dose is smaller for the wetter climate.

**TABLE 5.11. Irreversible and Irretrievable Resource Commitments Necessary to Implement the Geologic Disposal Alternative**

| Resource | HLW Onsite; TRU to WIPP | HLW Offsite; TRU to WIPP |
|---|---|---|
| Energy | | |
| Diesel fuel, $m^3$ | 120,000 | 120,000 |
| Propane, $m^3$ | 97,000 | 97,000 |
| Gasoline, $m^3$ | 14,000 | 15,000 |
| Electricity, GWh | 5,000 | 5,100 |
| Coal, t | 520,000 | 530,000 |
| Materials | | |
| Concrete, $m^3$ | 300,000 | 300,000 |
| Steel,[a] t | 80,000 | 80,000 |
| Stainless Steel,[a] t | 6,600 | 6,600 |

(a) Partial recovery (as much as 25%) may be possible.

### 5.2.6 Unavoidable Adverse Impacts

Unavoidable adverse impacts on workers and public are summarized in Table 5.12. The radiological impacts associated with operational aspects of the disposal alternatives for workers are well within applicable standards, and doses to the public are insignificant in comparison to those from natural background.

**TABLE 5.12. Collective Radiation Doses from Implementing the Geologic Alternative[a]**

| Exposure Classification | Collective Total-Body Dose, man-rem |
|---|---|
| Occupational | 15,000 |
| Offsite Population[b] | 50 |
| Transportation | |
| TRU to WIPP; | |
| HLW Onsite | 45 |
| HLW Offsite | 85 |

(a) Onsite repository for all vitrified tank waste and capsules. WIPP for all retrievably stored and newly generated TRU waste.
(b) For comparison the same population would receive a dose from natural background of 2,500,000 man-rem.

### 5.2.7 Relationship to Land-Use Plans, Policies and Controls

The federal government preempted the Hanford Site in 1943 for activities in support of World War II and continued these activities for national defense during the "cold war" of the 1950s and thereafter. The Hanford Site remains dedicated to continued use for nuclear materials production, research and development and related activities. The disposal of the waste associated with these activities is inherent within, and a logical continuation of, the original preemption.

Implementation of the geologic disposal alternative will not conflict with any approved national, state, or local land-use policies as they currently exist. Implementation would not significantly alter the area already committed by previous waste processing and storage activities. In the case of an onsite repository, waste disposal use is consistent with current waste disposal policy, nuclear energy, defense and research and development activities of the Hanford Site.

Establishment of a National Environmental Research Park (NERP) at the Hanford Site has made available certain areas on the Site for arid lands ecological research consistent with DOE's nuclear energy and research and development activities. The operating and waste management areas on the Site are specifically excluded from the NERP areas, and all land on the Site remains available for nuclear-related activities.

No known archaeological sites on the Hanford Site would be affected by implementation of the geologic disposal alternative.

With regard to disposal of defense TRU waste at the WIPP site, the EIS for that site (DOE 1980b) presented a comparable discussion of the relationship of the proposed action to land-use plans, policies, and controls. It was concluded in that EIS that "... the activities of the WIPP project will comply with all applicable Federal, State, and local requirements for protecting the environment."

### 5.2.8 Relationship Between Near-Term Use of the Environment and Enhancement of Long-Term Productivity

The Hanford Site has a low biological productivity (see Chapter 4). The land occupied under any of the alternatives would occupy less than 0.5% of the total Site (about 200 ha) and would not significantly affect the biological productivity of the rest of the Site. No agriculture is practiced on the Site because of its exclusionary status and availability of other land better suited for growing crops and grazing livestock.

Future plans for the Hanford Site call for its continued use as an area dedicated primarily to energy and defense activities.

## 5.3 IN-PLACE STABILIZATION AND DISPOSAL

The disposal of Hanford defense high-level, transuranic and tank wastes by in-place stabilization and disposal involves stabilizing the wastes in place and covering all the disposal sites with protective barriers (see Appendices B and M) as mentioned in Section 5.2.

In addition to inhibiting biological intrusion, water infiltration, and human activities, the barrier is designed to maintain its integrity for thousands of years, reducing the probability of escape of significant quantities of radioactive wastes. Active institutional control of the site in perpetuity is assumed; however, in accord with EPA rules (EPA 1985) governing waste disposal, active institutional controls are assumed to exist for no more than 100 years. Since offsite disposal sites are not involved and construction efforts would not be as extensive, environmental consequences are not as varied as for geologic disposal. Section 5.3.2 summarizes the total of all consequences for all waste classes for this alternative.

The final stage for in-place stabilization and disposal would be covering each of the disposal sites with protective barrier and marker systems and recording the location of these sites in the Benton County, Washington State, and U.S. Government Archives and Records.

### 5.3.1 Waste Disposal Procedures

Representative procedures for disposing of the six waste classes for the in-place stabilization and disposal alternative are described in Chapter 3, Section 3.3.2 and Appendix B in detail.

### 5.3.2 Summary of Operational Impacts Associated with the In-Place Stabilization and Disposal Alternative

This section summarizes the operational impacts for the in-place stabilization and disposal alternative, including radiation doses to workers and to the public from normal operations and doses to the public from operational accidents; nonradiological emissions to the environment and resulting air-quality impacts; nonradiological accidents, ecological impacts, socioeconomic impacts, resource requirements, and costs.

#### 5.3.2.1 Radiological Consequences from Routine Operations

Implementation of the in-place stabilization and disposal alternative would require an estimated 4,800 man-years of radiation work, which would result in a total-body dose of about 2,400 man-rem to the work force. Implementation of the in-place stabilization and disposal alternative of most waste classes would also release minor amounts of radionuclides from the waste sites and surrounding potentially contaminated soil to the atmosphere that could result in radiation doses to members of the offsite general public. Exceptions are the TRU-contaminated soil sites and the pre-1970 buried TRU solid wastes, which are essentially undisturbed except for placement of a protective barrier and marker system. The calculated doses are summarized in Table 5.13. The calculated total-body dose commitment in any one year to a maximally exposed individual is $4 \times 10^{-7}$ and the calculated individual lifetime total-body dose is $1 \times 10^{-5}$ rem. The collective total-body dose to the population residing within 80 km in any one year is calculated to total 0.03 man-rem, and the calculated 70-year total dose from all operations is about 0.8 man-rem. At this level no health effects are projected. For comparison, the dose to the same population (420,000) over the same period from naturally occurring sources would be about 2,500,000 man-rem.

**TABLE 5.13.** **Estimated Total-Body Radiation Doses from Routine Operations for the In-Place Stabilization and Disposal Alternative**

| Waste Class | Occupational Doses, man-rem Operations | Maximum Off-Site Individual Dose Commitments, rem 1-yr Exposure | 70-yr Exposure[b] | Population Dose Commitments,[a] man-rem 1-yr Exposure | 70-yr Exposure[c] |
|---|---|---|---|---|---|
| Existing Tank Waste | 1,300 | $3 \times 10^{-8}$ | $1 \times 10^{-5}$ | $3 \times 10^{-3}$ | 0.7 |
| Future Tank Waste | 720 | $3 \times 10^{-7}$ | $2 \times 10^{-6}$ | 0.03 | 0.1 |
| Sr/Cs Capsules | 200 | $6 \times 10^{-10}$ | $9 \times 10^{-8}$ | $6 \times 10^{-5}$ | $6 \times 10^{-3}$ |
| Retrievably Stored and Newly Generated TRU | 60 | $2 \times 10^{-15}$ | $2 \times 10^{-14}$ | $2 \times 10^{-10}$ | $1 \times 10^{-9}$ |
| TRU-Contaminated Soil[c] | 40 | --[d] | -- | -- | -- |
| Pre-1970 Buried TRU Solid Wastes[c] | 80 | -- | -- | -- | -- |
| Totals | 2,400 | $4 \times 10^{-7}$ | $1 \times 10^{-5}$ | 0.03 | 0.8 |

(a) All dose commitment values have been rounded to one significant figure.
(b) "70-year exposure" implies a lifetime accumulated dose from all operations.
(c) Further stabilization is taken as an additional protective measure for these previously disposed-of wastes.
(d) Dashes indicate that these waste classes have no associated dose under this alternative.

#### 5.3.2.2 Radiological Consequences from Postulated Accidents

A range of postulated accidents was analyzed for operations in the in-place stabilization and disposal alternative for each waste class (see Appendix H). The postulated operational accidents that would result in the largest radiation doses to the public for each waste class and associated process are summarized in Table 5.14. The 70-year population dose from the most severe accident amounted to 7,000 man-rem. As previously noted, that same population would receive a dose of 2,500,000 man-rem from natural background in the same period.

#### 5.3.2.3 Nonradiological Consequences

Nonradiological consequences include generation of dust from site preparation and site stabilization; combustion products from operation of surface vehicles and equipment; and injuries and fatalities associated with waste stabilization. Details are presented in Appendices G, L and T.

Nonradiological emissions (dust and combustion products) resulting from in-place stabilization and disposal are summarized in Table 5.15.

Air-quality impacts are estimated in terms of maximum ground-level pollutant concentrations at the site boundary or at publicly accessible locations within the Hanford fenceline and are summarized in Table 5.16. Air-quality impacts beyond the site boundary would be less than those listed in Table 5.16. Pollutant concentrations are based on historical

**TABLE 5.14.** Summary of Upper-Bound Accidents and Calculated Total-Body Radiation Doses for the In-Place Stabilization and Disposal Alternative[a]

| Waste Class | Description of Upper-Bound Accident | Maximum Individual Dose Commitments, rem | | Population Dose Commitments, man-rem | |
|---|---|---|---|---|---|
| | | 1-yr Dose | 70-yr Dose Commitment | 1-yr Dose | 70-yr Dose Commitment[a] |
| Existing Tank Waste | Explosion of ferrocyanide precipitates in single-shell tank during waste stabilization operations. | 0.2 | 3 | 400 | 7,000 |
| Future Tank Waste | Pressurized release of liquid waste due to failure of a diversion box valve during hydraulic retrieval operations. | 0.09 | 0.9 | 300 | 2,000 |
| Sr/Cs Capsules | Shearing of a strontium capsule by improper handling during disposal operations. | $3 \times 10^{-4}$ | $4 \times 10^{-3}$ | 0.6 | 10 |
| Retrievably Stored and Newly Generated TRU Waste | Breach of waste container during package disposal operations. | $2 \times 10^{-3}$ | 0.04 | 5 | 80 |
| TRU-Contaminated Soil[b] | Collapse of voids at waste site during subsidence-control operations. | $2 \times 10^{-8}$ | $9 \times 10^{-7}$ | $5 \times 10^{-5}$ | $2 \times 10^{-3}$ |
| Pre-1970 Buried TRU Solid Waste[b] | Collapse of voids at waste site during subsidence-control operations. | $3 \times 10^{-7}$ | $7 \times 10^{-6}$ | $6 \times 10^{-4}$ | 0.02 |

(a) See Appendix H for details.
(b) Previously disposed-of wastes.

TABLE 5.15. **Summary of Nonradiological Emissions for the In-Place Stabilization and Disposal Alternative** (over a 20-year period)

| Pollutants | Emissions, t |
|---|---|
| Particulates | 22,000 |
| $SO_x$ | 790 |
| CO | 2,200 |
| HC | 260 |
| $NO_x$ | 1,200 |

TABLE 5.16. **Comparison of Estimated Concentrations of Nonradiological Pollutants in Air for the In-Place Stabilization and Disposal Alternative with Ambient Air-Quality Standards**[(a)]

| Pollutant | Concentration, μg/m³ | | | | |
|---|---|---|---|---|---|
| | 1 hr | 3 hr | 8 hr | 24 hr | Annual |
| CO | 460 (40,000) | --[(b)] | 140 (10,000) | -- | -- |
| $NO_x$ | -- | -- | -- | -- | 1.1 (100) |
| $SO_x$ | 630 (655) | 420 (1,300) | -- | 25 (260) | 2.1 (52) |
| Particulates[(c)] (including dust) | -- | -- | -- | 32 (120) | 1.3 (40) |

(a) Ambient air-quality standards are given in parentheses, see Appendix T.
(b) Dashes indicate that there is no applicable standard.
(c) Allowable concentration in excess of background.

meteorological data and expected maximum emissions and thus are only an indication of what conditions might be. The calculated values are compared to national standards.

For the in-place stabilization and disposal alternative, 110 occupational injuries and illnesses are estimated, resulting in lost work days but no fatalities. These figures are based on estimated manpower requirements and on accident statistics for similar activities conducted by DOE and its contractors.

#### 5.3.2.4 Ecological Impacts

Ecological impacts from in-place stabilization and disposal of all waste classes would be minimal since much of the area under consideration has already been disturbed as a result of radioactive defense waste management and other activities related to nuclear energy. The present locations of radioactive waste storage operations at Hanford have undergone some environmental modification, and additional impacts on plants and wildlife are expected to be minimal.

The construction requirement with the greatest ecological impact is the need for 9 million cubic meters of fill materials (soils, gravel and basalt) primarily for backfill and barrier construction. The soil material would probably be obtained from an area located west of 200 West Area; Gable Butte is the preferred location for the basalt quarry. Both locations are situated so as to create minimum interference with other activities and would also produce minimum offsite environmental impacts (Rockwell 1985a). Selection of the borrow area site for barrier construction soil will be conducted in accordance with procedures designed to comply with the requirements relating to protection of archaeological and native American religious sites. The borrow area will be rehabilitated, following removal of material, using state-of-the-art revegetation practices. These include site-specific soil cultural practices (e.g., tilling and inoculation) and seeding with native and other species of grasses. The major environmental impact is judged to be construction of about 3 miles of new road for the basalt quarry operation. Existing roads are adequate for hauling the soil. This construction would avoid disturbing all known archaeological sites referenced in Section 4.8.5.

#### 5.3.2.5 Resource Commitments

Resource commitments for the in-place stabilization and disposal alternative include energy, materials, and manpower. Estimated requirements are shown in Table 5.17 (details are in Appendix L). These resources would be expended over about 5 years.

**TABLE 5.17. Estimated Resource Requirements for Implementing the In-Place Stabilization and Disposal Alternative**

| Resource | Amount |
|---|---|
| Energy | |
| Diesel fuel, $m^3$ | 78,000 |
| Propane, $m^3$ | 3,100 |
| Gasoline, $m^3$ | 2,500 |
| Electricity, GWh | 1,500 |
| Coal, t | 73,000 |
| Materials | |
| Concrete, $m^3$ | 18,000 |
| Steel, t | 11,000 |
| Stainless steel, t | 30 |
| Lumber, $m^3$ | 4,500 |
| Riprap, $m^3$ | 6,800,000 |
| Gravel, $m^3$ | 850,000 |
| Soil, $m^3$ | 1,600,000 |
| Manpower, man-yr | 9,500 |

#### 5.3.2.6 Costs

Table 5.18 summarizes the costs associated with the in-place stabilization and disposal alternative (details are in Appendix L).

**TABLE 5.18. Cost Summary for In-Place Stabilization and Disposal of All Waste Classes**

| Waste Class | Millions of $1987 |
|---|---|
| Existing Tank Waste | 1,400 |
| Future Tank Waste | 500 |
| Sr/Cs Capsules | 210 |
| Retrievably Stored and Newly Generated TRU Waste | 68 |
| TRU-Contaminated Soils[a] | 68 |
| Pre-1970 Buried TRU Solid Waste[a] | 140 |
| Total | 2,400 |

(a) Further stabilization is taken as an additional protective measure for these previously disposed-of wastes.

### 5.3.3 Socioeconomic Impacts

As previously stated (Section 5.2.3), socioeconomic impacts are influenced by the size and scheduling of the estimated manpower requirements for each alternative and by public perception of the hazardous nature of radioactive materials. Time and manpower needs for construction and for operations to implement the in-place stabilization and disposal alternative for each of the six waste classes are presented in Appendix K.

#### 5.3.3.1 Manpower Requirements

Detailed manpower profiles, developed for each alternative from data provided by Rockwell (1985b), are presented in Appendix K. Manpower requirements for in-place stabilization and disposal are relatively low compared with those for the geologic disposal alternative. Between 1990 and 2015, the average number of workers required per year for the in-place stabilization and disposal alternative is estimated to be 270. The peak work force requirement would be about 600 workers, and it would occur in the year 1995.

The potential socioeconomic impacts created by the size of the work force would be much less than those created by the geologic disposal alternative.

#### 5.3.3.2 Employment and Population Impacts

Historical and projected baseline employment and population growth is presented in Appendix K. Employment includes both the direct primary employees working on the waste management activities and the indirect secondary workers in the community who provide services.

The total population forecasts include both the workers and their dependents. The average total employment expected for the in-place stabilization and disposal alternative between the years 1990 and 2015 is about 560 workers. At the peak employment years about 1,320 workers are expected.

#### 5.3.3.3 Community Services

Calculated socioeconomic impacts are small for this alternative. The potential socioeconomic impacts of the expected growth in employment and population are less than those expected for the geologic disposal alternative. Details are given in Appendix K.

#### 5.3.3.4 Housing

Housing demand under a high baseline condition, would be greatest for the geologic disposal alternative. For the in-place stabilization and disposal alternative it would be considerably less.

#### 5.3.3.5 Local Transportation

Traffic congestion is another major aspect of the Tri-Cities region that has been particularly sensitive to population increase and to the traffic volume associated with activities on the Hanford Site. The total amount of increased traffic to the Hanford Site expected with the in-place stabilization and disposal alternative will be substantially lower than that associated with the geologic disposal alternative.

#### 5.3.3.6 Education

No negative capital cost impacts are anticipated.

#### 5.3.3.7 Utilities and Other Services

Given adequate lead time and notification regarding future development, the affected community service departments and agencies probably can better adjust to changing conditions resulting from waste management activities associated with this alternative than with the geologic disposal alternative.

#### 5.3.3.8 Fiscal Conditions

As in the geologic disposal alternative, the proposed waste disposal activities probably would fiscally benefit the local communities. See Section 5.2.3.8 and Appendix K.

#### 5.3.3.9 Social Conditions

Since the geologic disposal alternative results in the largest number of jobs, positive impacts from the in-place stabilization and disposal alternative would be substantially less than those from that alternative. Even though the radiological consequences of in-place disposal are expected to be very small, there would likely be more public concern for disposal of wastes near surface than in a geologic repository.

### 5.3.4 Assessment of Long-Term Impacts

The primary performance objective of waste disposal systems was previously discussed (Section 5.2.4). This section includes examination of impacts of the in-place stabilization and disposal alternative where 1) present conditions remain unchanged, 2) disposal systems are disrupted by postulated natural events, and 3) disposal systems are disrupted by intruders.

As in the geologic disposal alternative, this analysis draws upon the description of wastes and disposal alternatives of Chapter 3 and upon analyses in Appendix R of radiological consequences developed for appraisal of performance of the alternatives. Appendix R, in turn, is based on a protective barrier and marker system described in Appendices B and M; hydrologic modeling of the water pathway in Appendix O, description of modeling of source releases and inventories of radionuclides in Appendix P; information on hydrologic transport of chemicals in Appendix U; and probabilistic analysis in Appendix S.

Key findings disclosed in the analyses are the same as those discussed for the geologic disposal alternative (Section 5.2.4) and are not repeated here. However small, the likelihood of intrusion into waste sites leading to fatal consequences is substantially greater in the in-place stabilization and disposal alternative than in the geologic alternative.

#### 5.3.4.1 Long-Term Impacts Where Present Conditions Remain Unchanged

This section discusses the long-term impacts where present conditions remain unchanged. The expected performance of the disposal system is presented where the system performs as designed under present climatic conditions and without human-induced or other disruption. The disposal system in the in-place stabilization and disposal alternative is all "near surface" (from about 1 to about 15 m below grade), but with the addition of a protective barrier over all waste sites and a marker system in place.

In the in-place stabilization and disposal alternative, all waste would be disposed of on site. Table 5.19 lists inventories of key nuclides disposed of according to this alternative.

All but one of the large number of waste sites disposed of in this alternative are located in the 200 Areas plateau, 40 to 70 m above the water table, about 10 km from the Columbia River. The exception, known as the 618-11 site, is located north of the 300 Area and about 3 km west of the Columbia River.

The diffusion and transport of waste through soils (described in Appendix O) was estimated to result in a dose of about 10 man-rem over 10,000 years for the population downstream from the Hanford Site. This dose resulted principally from $^{99}Tc$ in single-shell and double-shell tank wastes. This dose would not be expected to produce any health effects.

Chemicals could similarly be transported to the river via mechanisms described in Appendix U. Using conservative and bounding values of parameters, the concentration of nitrate ion ($NO_3^-$) amounted to only $10^{-8}$ of the drinking water standard of 45 mg/L (based on nitrate).

TABLE 5.19. **Inventory of Key Radionuclides** (Rockwell 1985b) **Disposed of in the In-Place Stabilization and Disposal Alternative**

| Radionuclide | Quantity, Ci |
|---|---|
| $^{14}C$ | 5,300 |
| $^{79}Se$ | 1,100 |
| $^{90}Sr$ | 120,000,000 |
| $^{99}Tc$ | 35,000 |
| $^{129}I$ | 58 |
| $^{137}Cs$ | 130,000,000 |
| $^{151}Sm$ | 1,200,000 |
| $^{238}U$ | 580 |
| $^{239-240}Pu$(a) | 120,000 |
| $^{241}Am$(b) | 390,000 |

(a) Includes about 22,000 Ci $^{239-240}Pu$ previously disposed of.
(b) Includes about 13,000 Ci $^{241}Am$ previously disposed of.

### 5.3.4.2 Long-Term Impacts Following Postulated Disruptive Events

As previously discussed (Section 5.2.4.2), an analysis was made of postulated natural and human-induced events that might disrupt confinement of wastes. Events identified as candidates for analysis as disruptive events were: impact of large aircraft into a waste site, return of glaciation, a change to a wetter climate, and partial failure of a protective barrier.

**Impact of Aircraft**

The consequences of an impact of a large aircraft are calculated to be a maximum 70-year total-body dose to the offsite population of 0.3 man-rem for an impact into a waste site (single-shell or double-shell tanks) without protective barriers, which would give rise to the largest dose. Any type of disposal action further reduces the consequence of this scenario. Therefore, impacts of falling aircraft were not considered further. As previously stated, other falling bodies such as meteorites were considered, but the low probability of a meteorite hitting a waste site and releasing some contents appeared too small to warrant further consideration as a disruptive scenario.

**Return of Ice Age**

In the 40,000-to-50,000-year time frame predicted for recurrence of glacial floods, the total inventory of waste included in the EIS will have decayed to a hazard index about one-fifth of the hazard index of the uranium from which the wastes were originally generated.

Although radioactive decay will have reduced the hazard from these wastes markedly by the time of the postulated glacial flood in the next 40,000 to 50,000 years, a study was initiated to determine whether the fate of the waste following such a flood could be estimated (Craig and Hanson 1985). Results of this study indicate that the first wave of such a flood could reasonably scour out the waste sites to a depth of several meters and then, as flood waters backed up at Wallula Gap, the water velocity would markedly decrease; and most of the sediments and wastes would probably be reworked and then redeposited within the Pasco Basin.

If all the $^{239}Pu$ (the radionuclide of principal interest at 40,000 years after disposal) in the scope of this EIS were entrained uniformly in just the upper 4 m of the sediments of the 6-km-by-13-km waste disposal area, the resulting concentration of $^{239}Pu$ would be about 0.05 nCi/g. The lifetime total-body dose that might be received by someone residing on such sediments once the water had receded would be about 0.3 rem; this can be compared to 7 rem the individual would have received from present-day background levels. If larger areas of scour and reworking of sediments were involved, as they reasonably might, this concentration would be further reduced. Because of the low concentrations of plutonium and other radionuclides at that time, radiological consequences of a glacial flood would appear minor compared to the flood itself whether the action on wastes was scouring, reworking, or depositional.

**Change in Climate**

The climate change assumed for this analysis is the same as that assumed in the geologic disposal alternative, i.e., a wetter climate represented by an average recharge to groundwater of 5 cm/yr on the 200 Areas plateau. Impacts are discussed in the next section.

**Barrier Failure**

Although it is reasonable to expect that the protective barrier as finally designed will remain effective, in order to assess the consequences if the barrier failed, two scenarios have been postulated in which partial failure of the protective barrier occurs in the year 2500 in conjunction with a climate change. These scenarios were discussed in more detail under the geologic disposal alternative, Section 5.2.4.2.

The diffusion and transport of waste through soils in a wetter climate (described in Appendix O) was calculated to result in a cumulative population total-body dose of 12 man-rem over 10,000 years to the downstream users of the Columbia River. No health effects would be predicted for such a dose. A disruptive failure of the barrier (Appendix M) could result in an additional dose to the downstream population of about 300 man-rem over 10,000 years. A functional failure of the barrier could result in an additional total-body dose to the downstream population of about 280 man-rem. Thus, at most, diffusion combined with barrier failures would result in a total-body dose of about 620 man-rem over 10,000 years. Again for comparison, the dose from natural background to the downstream population over 10,000 years would be about 3,000,000,000 man-rem. Thus, by comparison, the combined scenarios do not constitute a significant impact.

Applying the diffusion scenario to single-shell tank waste and a recharge rate of 5 cm/yr, the movement of chemicals would also be enhanced over that at 0.5 cm/yr. Regardless, the large dilution of the Columbia River results in the concentration of chemicals being small fractions of the drinking water standards; e.g., the concentration of nitrate ion ($NO_3^-$) was calculated as about $10^{-8}$ of the EPA drinking water standard (based on the nitrate standard, 45 mg/L). As a consequence, for the offsite population, release of chemicals via this mechanism would result in an insignificant impact.

#### 5.3.4.3 Impacts in the Long Term from Intrusion and Other Activities

The intruder scenarios analyzed for the in-place stabilization and disposal alternative are the same as those discussed briefly in Section 5.2.4.3 under geologic disposal. For convenience they are repeated here.

- Exploratory drilling that penetrates a waste site (maximum inventory sites for each waste class) and brings contaminated drilling mud to the surface, resulting in radiation exposure of the drilling crew.
- The preceding drilling scenario followed soon by individuals residing on or near the contaminated drilling mud and consuming garden produce raised in the contaminated soil.
- Biotic transport of nuclides to the surface by burrowing animals, followed in time by individuals residing on and consuming produce from a garden grown in the contaminated soil.

Scenarios not requiring intrusion into the waste disposal sites included the following:

- Drilling a water well near but not on the waste site that intercepts a contaminated aquifer; individuals residing near the well drink contaminated water and irrigate a garden with contaminated water and consume the garden produce.
- Resettlement of the west bank of the Columbia River in the northeastern part of the Hanford Site by farm families who drink contaminated groundwater and consume farm products produced by irrigation from contaminated wells.

As in the geologic disposal alternative, all waste sites would be covered by a protective barrier and marker system and the same type of warning markers would have been distributed within the barrier itself. Again, drilling through a protective barrier is not believed likely; however, it cannot be precluded. If it were to take place, the maximum dose would result from penetrating cesium capsules and bringing the drilling mud to the surface. The total-body dose calculated to the intruder for intrusion immediately after loss of active institutional control was high enough to be fatal (i.e., a total-body dose of 1,000 rem over a week or two). (See Appendix R.) By 400 years after disposal, the potential maximum annual dose to the intruder would be about 1 rem and no health effects among the intruders would be expected. Calculations indicated that drilling into any of the other waste sites would not have fatal consequences.

Where drilling had occurred, persons later might reside and grow gardens on the soil contaminated by drilling or excavation. With no consideration of probability of occurrence, drilling into strontium capsules promptly after loss of active institutional control could result in a potential maximum annual total-body dose to the subsequent intruding resident gardener of about 30,000 rem. Such a dose would be fatal to the intruder. By 400 years after disposal the potential maximum annual total-body dose to the intruder would be about 20 rem, and 1,000 years later would be $1 \times 10^{-5}$ rem. Thus, based on this scenario, one would expect fatalities to intruders early after disposal and marginally significant consequences after about 400 years.

Assuming a 0.5-cm/yr average annual recharge to groundwater (to represent current climatic conditions) and with a protective barrier in place, an individual drilling a well into the aquifer between the 200 Areas and the Columbia River in the year 7000 would receive a maximum 70-year total-body dose of about 0.1 rem. This assumes he uses the water for domestic purposes and irrigates a garden with it. The principal contributor to the dose is $^{99}Tc$ from double-shell tank grouted waste. If the individual were to only drink water from the contaminated well, his potential maximum annual total-body dose would amount to $1 \times 10^{-4}$ rem. If the climate were to change corresponding to a 5-cm/yr average annual recharge, this full-garden scenario would yield a potential maximum 70-year total-body dose to the intruder of 0.1 rem. This dose would take place around the year 6300 and would result from $^{99}Tc$ in single-shell tank grout residuals. Again, if the individual were to only drink water from the contaminated well, his potential maximum annual total-body dose would amount to $3 \times 10^{-5}$ rem.

Incremental groundwater concentrations at the 5-km well of $NO_3^-$, chromium, cadmium, fluoride and mercury are calculated to be the same as those calculated for the geologic alternative (they are disposed of in a roughly equivalent manner in both cases) and are all below limits established by EPA drinking water standards.

#### 5.3.4.4 Resettlement

The resettlement scenario discussed under the geologic disposal alternative (Section 5.2.4.4) was analyzed also for the in-place stabilization and disposal alternative. Estimates of the integrated population total-body dose to and health effects among farm occupants are 2,000 man-rem and 0 to 2 health effects for the current climate and 2,000 man-rem and 0 to 2 health effects for the wetter climate assumed in the analysis.

### 5.3.5 Irreversible and Irretrievable Commitment of Resources

The irreversible and irretrievable commitment of resources for the in-place stabilization and disposal alternative includes commitments of energy, materials, and manpower. Selected resource commitments are summarized in Table 5.20 (see Appendix L for details).

### 5.3.6 Unavoidable Adverse Impacts

Unavoidable adverse impacts on workers and the public are summarized in Table 5.21. The radiological impacts associated with operational aspects of the disposal alternatives for workers are well within applicable standards, and doses to the public are insignificant compared to those from natural background.

TABLE 5.20. Irreversible and Irretrievable Resource Commitments Necessary to Implement the In-Place Stabilization and Disposal Alternative

| Resource | Quantity |
|---|---|
| Energy | |
| Diesel fuel, $m^3$ | 3,000 |
| Propane, $m^3$ | 80,000 |
| Gasoline, $m^3$ | 2,000 |
| Electricity, GWh | 2,000 |
| Coal, t | 70,000 |
| Materials | |
| Concrete, $m^3$ | 18,000 |
| Steel,[a] t | 11,000 |
| Stainless Steel,[a] t | 30 |

(a) Partial recovery (as much as 25%) may be possible.

TABLE 5.21. Collective Radiation Doses from Implementing the In-Place Stabilization and Disposal Alternative

| Exposure Classification | Collective Total-Body Dose, man-rem |
|---|---|
| Occupational | 2,400 |
| Offsite Population[a] | 0.8 |
| Transportation | NA[b] |

(a) For comparison, the same population would receive a dose from natural background of 2,500,000 man-rem.
(b) NA--not applicable.

### 5.3.7 Relationship to Land-Use Plans, Policies and Controls

See Section 5.2.7 also.

The implementation of the in-place stabilization and disposal alternative will not conflict with any approved national, state, or local land-use policies as they currently exist. Implementation would not significantly alter the area already committed by previous waste processing and storage activities.

### 5.3.8 Relationship Between Near-Term Use of the Environment and Enhancement of Long-Term Productivity

See the previous discussion under geologic disposal, Section 5.2.8.

## 5.4 REFERENCE ALTERNATIVE (COMBINATION DISPOSAL)

As discussed in Chapter 3, Section 3.3.3, the reference alternative (combination disposal) combines disposal elements from the geologic disposal and the in-place stabilization and disposal alternatives. Waste disposal procedures are described in Chapter 3, Section 3.3.3, and operational impacts associated with the reference alternative are summarized in Section 5.4.2. Postdisposal performance of the reference alternative in terms of public health and safety is discussed in Section 5.4.4.

### 5.4.1 Waste Disposal Procedures

Representative procedures for disposing of the six waste classes for the reference alternative are described in Chapter 3, Section 3.3.3, and Appendix B in detail.

### 5.4.2 Summary of Operational Impacts Associated with Reference Disposal Alternative

Environmental impacts associated with implementing the reference disposal alternative for all six classes of waste considered in this EIS are presented in this section.

The operational impacts evaluated for the reference alternative include public and worker radiation doses from normal operations, public and occupational doses resulting from operational accidents, nonradiological emissions to the environment and resulting air quality impacts, nonradiological accidents, ecological impacts, socioeconomic impacts, resource commitments, and costs.

#### 5.4.2.1 Radiological Consequences from Routine Operations

Radiation doses calculated to result from implementation of the reference alternative for disposal of Hanford defense waste are summarized in Table 5.22. For all waste classes a total of 7,200 man-years of radiation work, including Transportable Grout Facility, Hanford Waste Vitrification Plant and Waste Receiving and Processing operations, is estimated to be required to dispose of all the waste classes. A total occupational total-body dose of about 3,600 man-rem could result from these activities. About 90% of the total occupational dose is incurred from disposing of existing and future tank waste, and less than 10% results from Transportable Grout Facility, Hanford Waste Vitrification Plant and Waste Receiving and Processing operations (Appendices C, D, and E). Repository emplacement and transportation of the waste not stabilized in place would add about 270 man-rem to the occupational dose total.

Operations to dispose of most waste classes would result in some minor releases to the atmosphere of radionuclides from the waste sites and surrounding potentially contaminated soil. No releases are anticipated from the previously disposed-of TRU-contaminated soil sites and the previously disposed-of pre-1970 buried TRU solid wastes, which remain essentially undisturbed. The total-body dose commitment in any one year to a maximally exposed offsite individual from these releases was calculated to be $6 \times 10^{-7}$ rem, and the individual lifetime total-body dose was calculated to be $1 \times 10^{-5}$ rem. The collective total-body dose to the population residing within 80 km in any one year is calculated to be about 0.05 man-rem, and the lifetime population dose from all operations is calculated to be about 1.0 man-rem. The major portion of the total-body doses to both the individual and the population is

**TABLE 5.22. Estimated Total-Body Radiation Doses from Routine Operations for the Reference Alternative**

| | Occupational Doses, man-rem | | Maximum Individual Dose Commitments, rem | | Population Dose Commitments,[a] man-rem | | |
|---|---|---|---|---|---|---|---|
| Waste Class | Operations | Repository Emplacement | 1-yr Exposure | 70-yr Exposure[b] | 1-yr Exposure | 70-yr Exposure[b] | Transportation, (offsite)[c] |
| Existing Tank Waste | 1,600 | 20 | $3 \times 10^{-8}$ | $1 \times 10^{-5}$ | $3 \times 10^{-3}$ | 0.6 | 0.8 |
| Future Tank Waste | 1,600 | 26 | $6 \times 10^{-7}$ | $2 \times 10^{-7}$ | 0.05 | 0.4 | 2 |
| Sr/Cs Capsules | 70 | 78 | $6 \times 10^{-10}$ | $4 \times 10^{-8}$ | $6 \times 10^{-5}$ | $2 \times 10^{-3}$ | 0.8 |
| Retrievably Stored and Newly Generated TRU Waste | 160 | 110 | $2 \times 10^{-10}$ | $1 \times 10^{-8}$ | $3 \times 10^{-6}$ | $1 \times 10^{-4}$ | 40 |
| TRU-Contaminated Soil[e] | 40 | --[d] | -- | -- | -- | -- | -- |
| Pre-1970 Buried TRU Solid Waste[e] | 150 | -- | -- | -- | -- | -- | -- |
| Totals | 3,600 | 230 | $6 \times 10^{-7}$ | $1 \times 10^{-5}$ | 0.05 | 1 | 40 |

(a) All dose commitment values have been rounded to one significant figure.
(b) "70-year Exposure" implies a lifetime accumulated dose from all operations.
(c) Transport of high-level wastes to alternative HLW repository up to 5,000 km from Hanford; TRU wastes to WIPP.
(d) Dashes indicate that the waste class has no associated dose under this alternative.
(e) Further stabilization is taken as an additional protective measure for these previously disposed-of wastes.

from releases during handling of existing and future tank waste. For comparison, the dose to the same population (420,000) over the same period from naturally occurring sources would be about 2,500,000 man-rem.

Disposal of retrievably stored and newly generated TRU waste requires offsite transport of the waste to the WIPP repository. This operation adds a dose of about 40 man-rem to the population, including the transportation work force.

#### 5.4.2.2 Radiological Consequences from Postulated Accidents

Implementation of the reference alternative (combination disposal) could result in accidents releasing radioactive materials to the environment. Accidents were postulated for disposal activities, and those accidents that resulted in the largest public doses for each waste class are summarized in Table 5.23. The largest population dose from these postulated accidents amounts to 7,000 man-rem. This dose is small compared to the dose of about 2,500,000 man-rem the same population (420,000) residing within 80 km would receive from natural background radiation over the operation period of 60 years. The largest 70-year dose commitment to any member of the public is calculated to be 3 rem (Appendix H).

#### 5.4.2.3 Nonradiological Consequences

Nonradiological consequences include generation of dust from waste retrieval, site preparation, site stabilization, and processing of mined material; combustion products from operation of surface vehicles and equipment, and transportation of waste; and injuries and fatalities associated with retrieval, stabilization, transportation, and disposal of the waste. Each impact (except air quality) represents a total that would actually be spread over a 20-to-30-year period. Details are represented in Appendices G, L, and T.

Nonradiological emissions (i.e., dust and combustion products) resulting from implementation of the reference alternative including Transportable Grout Facility, Hanford Waste Vitrification Plant and Waste Receiving and Processing operations are summarized in Table 5.24. The contributions from the latter three facilities are minimal (Appendices C, D, and E). The emissions are those generated on site during retrieval, packaging, storage and site stabilization. Transportation emissions result from shipping existing double-shell tank waste, capsules, and future tank waste to an onsite or offsite repository and from shipping retrievably stored and newly generated TRU waste to the WIPP repository. All emissions would be within applicable standards. The reader is referred to Appendix I for details about transportation.

Air-quality impacts are estimated in terms of maximum ground-level pollutant concentrations at the Site boundary or at publicly accessible locations within the Hanford fenceline and are summarized in Table 5.25.

Since these estimated pollutant concentrations are based on historical meteorological data and maximum expected releases of pollutants, they are only an indication of what conditions might be.

**TABLE 5.23. Summary of Upper-Bound Accidents and Calculated Total-Body Radiation Doses for the Reference Alternative[a]**

| Waste Class | Description of Upper-Bound Accident | Maximum Individual Dose, rem | | Population Dose Commitments, man-rem | |
|---|---|---|---|---|---|
| | | 1-yr Dose | 70-yr Dose Commitment | 1-yr Dose | 70-yr Dose Commitment[a] |
| Existing Tank Waste | Explosion of ferrocyanide precipitates in single-shell tank during waste stabilizing operations. | 0.2 | 3 | 400 | 7,000 |
| Future Tank Waste | Pressurized release of liquid waste due to failure of a diversion box valve during hydraulic retrieval operations. | 0.09 | 0.9 | 300 | 2,000 |
| Sr/Cs Capsules | Rupture of a strontium capsule by improper handling during retrieval operations. | $2 \times 10^{-7}$ | $3 \times 10^{-6}$ | $6 \times 10^{-4}$ | 0.01 |
| Retrievably Stored and Newly Generated TRU Waste | Pressurized release from waste drum rupture rupture due to buildup of radiolytic gases. | $2 \times 10^{-3}$ | 0.06 | 4 | 100 |
| TRU-Contaminated Soil[b] | Collapse of voids at waste site during subsidence-control operations. | $2 \times 10^{-8}$ | $9 \times 10^{-7}$ | $5 \times 10^{-5}$ | $2 \times 10^{-3}$ |
| Pre-1970 Buried TRU Solid Waste[b] | Collapse of voids at waste site during subsidence-control operations. | $3 \times 10^{-7}$ | $7 \times 10^{-6}$ | $6 \times 10^{-4}$ | 0.02 |

(a) See Appendix H for details.
(b) Previously disposed-of wastes.

**TABLE 5.24. Summary of Nonradiological Emissions for the Reference Alternative** (over a 20-year period)

| Pollutant | Emissions, t |
|---|---|
| Particulates | 19,000 |
| $SO_x$ | 1,500 |
| CO | 1,900 |
| HC | 210 |
| $NO_x$ | 900 |

**TABLE 5.25. Comparison of Estimated Concentrations of Nonradiological Pollutants in Air for the Reference Alternative with Ambient Air-Quality Standards[a]**

| Pollutant | Concentration, $\mu g/m^3$ 1 hr | 3 hr | 8 hr | 24 hr | Annual |
|---|---|---|---|---|---|
| CO | 490 (40,000) | --[b] | 150 (10,000) | -- | -- |
| $NO_x$ | -- | -- | -- | -- | 1.2 (100) |
| $SO_x$ | 310 (655) | 200 (1,300) | -- | 13 (260) | 1.0 (52) |
| Particulates[c] (including dust) | -- | -- | -- | 2.5 (120) | 1.6 (40) |

(a) Ambient air-quality standards are given in parentheses. See Appendix T.
(b) Dashes indicate there is no applicable standard.
(c) Allowable concentration in excess of background.

Nonradiological pollutant concentrations resulting from transportation of TRU waste to WIPP would be extremely small and well below applicable standards. Details on transportation-related air-quality impacts are provided in Appendix I.

The number of injuries, illnesses and fatalities determined to be associated with implementation of the reference alternative, including those associated with the Transportable Grout Facility, Hanford Waste Vitrification Plant, and Waste Receiving and Processing facility, is presented in Table 5.26. No fatalities are estimated for the construction or operation of the Transportable Grout Facility, Hanford Waste Vitrification Plant, and Waste Receiving and Processing facility. The number of injuries, illnesses and fatalities is based on accident statistics for similar activities (Appendix G) and on an estimate of manpower requirements. The disposal-related manpower requirements are the sum of manpower for retrieval, packaging, storage, and site stabilization (Rockwell 1985b) combined with manpower for repository activities as estimated for existing double-shell tank waste, strontium and cesium capsules, and future tank waste (DOE 1980a) and as estimated for retrievably stored and newly generated TRU waste (DOE 1980b). Repository manpower values are prorated to that portion of the repositories that the Hanford defense waste would occupy.

TABLE 5.26. **Summary of Estimated Nonradiological Injuries, Illnesses and Fatalities Associated with the Reference Alternative**

| Process | Injuries and Illnesses[(a)] | | Fatalities | |
|---|---|---|---|---|
| | HLW Onsite; TRU to WIPP | HLW Offsite; TRU to WIPP | HLW Onsite; TRU to WIPP | HLW Offsite; TRU to WIPP |
| Waste Retrieval and Processing | 140 | 140 | 0 | 0 |
| Repository Emplacement | 72 | 68 | 0 | 0 |
| Transportation | 10 | 10 | 1 | 1 |
| Other Operations | 5 | 0 | 0 | 0 |
| Total | 230 | 220 | 1 | 1 |

(a) Injuries and illnesses that result in lost work days.

#### 5.4.2.4 Ecological Impacts

Ecological impacts from implementing the reference alternative for all waste classes would be small since much of the area under consideration has already been disturbed as a result of radioactive waste management and other nuclear-energy-related activities. The construction requirement with the greatest ecological impact is the need for 6 million $m^3$ of fill materials (soils, gravel and basalt). Selection of the borrow area site for the barrier construction material will be conducted in accordance with procedures designed to comply with the requirements relating to protection of archaeological and native American religious sites. The borrow soil area will be rehabilitated, following removal of material, using state-of-the-art revegetation practices. These include site-specific soil cultural practices (e.g., tilling and inoculation) and seeding with native and other species of grasses.

#### 5.4.2.5 Resource Commitments

Resource commitments for the reference alternative include energy, materials and manpower. Estimated requirements including resource commitments for the Transportable Grout Facility, Hanford Waste Vitrification Plant and the Waste Receiving and Processing facility are summarized in Table 5.27 (see Appendix L for details). Resource commitments for the in-place stabilization and disposal elements of the alternative were provided by Rockwell (1985b). Resources for the geologic disposal elements of the alternative are estimated by combining resources related to predisposal activities with those related to repository activities. Resources used for repository activities (estimated in DOE 1980a,b) are prorated to that portion of the repository required for disposal of the particular waste class and type. These resources will be expended over a 20-to-30-year period.

#### 5.4.2.6 Costs

A summary of the costs associated with the reference alternative is shown in Table 5.28 (details in Appendices I and L). For each waste class, the retrieval, packaging, and onsite stabilization cost components were provided by Rockwell (1985a). In this alternative, the

TABLE 5.27. Estimated Resource Requirements for Implementing the Reference Alternative

| Resource | HLW Onsite; TRU to WIPP | HLW Offsite; TRU to WIPP |
|---|---|---|
| Energy | | |
| Diesel fuel, $m^3$ | 74,000 | 75,000 |
| Propane, $m^3$ | 14,000 | 14,000 |
| Gasoline, $m^3$ | 4,200 | 4,200 |
| Electricity, GWh | 3,800 | 3,800 |
| Coal, t | 46,000 | 47,000 |
| Materials | | |
| Concrete, $m^3$ | 65,000 | 65,000 |
| Steel, t | 14,000 | 14,000 |
| Stainless steel, t | 1,400 | 1,400 |
| Lumber, $m^3$ | 10,000 | 10,000 |
| Riprap, $m^3$ | 4,300,000 | 4,300,000 |
| Gravel, $m^3$ | 700,000 | 700,000 |
| Soil, $m^3$ | 960,000 | 960,000 |
| Manpower, man-yr | 16,000 | 16,000 |

TABLE 5.28. Cost Summary for Reference Alternative for All Waste Classes

| Waste Class | Millions of $1987[a] HLW Onsite; TRU to WIPP | HLW Offsite; TRU to WIPP |
|---|---|---|
| Existing Tank Waste | 2,000 | 2,000 |
| Future Tank Waste | 1,300 | 1,300 |
| Sr/Cs Capsules | 210 | 210 |
| Retrievably Stored and Newly Generated TRU Waste | 190 | 190 |
| TRU-Contaminated Soil[b] | 68 | 68 |
| Pre-1970 Buried TRU Solid Waste[c] | 170 | 170 |
| Totals | 3,900 | 3,900 |

(a) Costs were revised from the draft EIS to reflect increased repository fees. Since the above costs were calculated, additional costs for repository fees have been proposed. These proposed costs further increase the reference alternative by 5%. Additional changes in estimated repository fees can be expected in the future.
(b) Includes cost of Transportable Grout Facility and the Hanford Waste Vitrification Plant.
(c) Includes cost of the Waste Receiving and Processing facility.

volumes of existing and future tank waste that go to geologic disposal are about the same. The cost, however, of retrieving and processing existing double-shell tank waste is higher per unit volume than that for future tank waste. As a result, the total cost for disposing of existing tank waste is about twice as much as for future tank waste. The transportation costs are only about 1% of the total disposal costs for tank waste. Therefore, no significant difference exists between onsite and offsite disposal costs of those wastes in geologic repositories. For tank waste and capsules, the repository cost component is developed using design and packaging concepts conceived by Rockwell (1983) and for TRU waste cost-modeling techniques developed at PNL (Appendix J) were used. This repository cost component represents the incremental cost associated with emplacing existing double-shell tank waste, capsules, and future tank waste in a commercial repository and assumes overpacking of these wastes.

### 5.4.3 Socioeconomic Impacts

Appendix K presents the time and manpower needs for construction and operations to implement the reference disposal alternative for each of the six waste classes. Also, see Section 5.2.3.

#### 5.4.3.1 Manpower Requirements

Detailed manpower profiles, developed for each alternative from data provided by Rockwell (1985b), are presented in Appendix K. Manpower requirements for the reference alternative are relatively low compared with those for the geologic disposal alternative. Between the years 1990 and 2015, the average number of workers required per year for the reference disposal alternative is estimated to be about 360. The peak work force requirement would be about 740 workers and it would occur in 1993 and 1994.

The potential socioeconomic impact created by the size of the work force would be much less than that created by the geologic disposal alternative and only a little more than that created by the in-place stabilization and disposal alternative.

#### 5.4.3.2 Employment and Population Impacts

Historical and projected baseline employment and population growth are presented in Appendix K. Employment includes both the direct primary employees working on the waste management activities and the indirect secondary workers in the community who provide services. The total population forecasts include both the workers and their dependents. The average employment for the reference disposal alternative between the years 1990 and 2015 is about 690 workers per year. At the peak employment years about 1,600 workers are expected.

#### 5.4.3.3 Community Services

The potential socioeconomic impacts of the employment and population growth expected with the reference alternative are not expected to exceed the community's capacity for providing housing and community services that include transportation, health care, schools, police and fire, water and sewer, and recreation facilities. Details are provided in Appendix K.

#### 5.4.3.4 Housing

Housing demand under a high baseline condition would be significantly less for the reference alternative than for the geologic alternative (see Section 5.2.3.4). Given that housing construction is likely to pick up again as the local economy begins to recover, and that many of the jobs will be taken by local workers who already live in the area, housing impacts appear unlikely.

#### 5.4.3.5 Local Transportation

The total amount of increased traffic to the Hanford Site expected with the reference alternative will be substantially lower than that associated with the Washington Public Power Supply System's peak construction period. Recent and continuing highway improvements in the area are alleviating many of the past problems. Given the assumed moderate growth in baseline conditions, local transportation impacts are unlikely.

#### 5.4.3.6 Education

No negative capital cost impacts are anticipated.

#### 5.4.3.7 Utilities and Other Services

Given adequate lead time and notification regarding future development, the affected departments and agencies probably can adjust adequately to changing conditions resulting from waste management activities associated with the reference alternative.

#### 5.4.3.8 Fiscal Conditions

The proposed waste disposal activities probably would fiscally benefit the local communities. See Section 5.2.3.8 and Appendix K.

#### 5.4.3.9 Social Conditions

Little, if any, impact on social conditions is predicted for the reference alternative. As has been discussed in relation to social conditions in Appendix K and other sections of this EIS, none of the combinations of in-place stabilization with geologic disposal represented under the reference alternative is expected to cause adverse environmental or radiological impacts. Since social, economic and cultural impacts are linked to environmental and radiological effects, those consequences are expected to be insignificant also. A strong case has been made in the technical sections of this EIS to demonstrate that the implementation of any alternative other than no disposal action will represent a substantial improvement over current conditions in terms of environmental and health and safety consequences.

### 5.4.4 Assessment of Long-Term Impacts

The primary performance objective of waste disposal systems was previously discussed (Section 5.2.4).

This section includes examination of impacts of the reference alternative where 1) present conditions remain unchanged, 2) disposal systems are disrupted by postulated natural events, and 3) disposal systems are disrupted by intruders.

As in the geologic disposal alternative, this analysis draws upon the description of wastes and disposal alternatives of Chapter 3 and upon analyses in Appendix R of radiological consequences developed for appraisal of performance of the alternatives. Appendix R, in turn, is based on a protective barrier and marker system described in Appendices B and M; hydrologic modeling of the water pathway in Appendix O, description of modeling of source releases and inventories of radionuclides in Appendix P; information on hydrologic transport of chemicals in Appendix U; and probabilistic analysis in Appendix S.

Key findings disclosed in the analyses are the same as those discussed for the geologic disposal alternative (Section 5.2.4) and are not repeated here. However small, intrusion into near-surface waste sites would be more likely than if the wastes were disposed of in a geologic repository.

#### 5.4.4.1 Long-Term Impacts Where Present Conditions Remain Unchanged

This section discusses the long-term impacts associated with the reference disposal alternative where present conditions remain unchanged. The expected performance of the disposal systems is presented where those systems perform as designed under present climatic conditions and without human-induced or other disruption. The disposal systems are the geologic repository and, as in the case of the in-place stabilization and disposal alternative, the barrier-covered near-surface disposal system.

In the reference alternative, some wastes are disposed of in a geologic repository(ies) or by in-place stabilization and disposal. The residuals from processing of tank wastes for disposal in a repository would be grouted and disposed of in vaults on the Hanford Site. A protective barrier and marker system would be installed over each of the near-surface waste sites. Inventories of key radionuclides so disposed of are shown in Table 5.29.

As in the geologic disposal alternative, those wastes placed in a geologic repository would be expected to remain isolated from the biosphere and not be expected to produce any health effects over 10,000 years.

With the exception of the 618-11 site, those wastes stabilized and disposed of in place for the reference alternative would be expected to remain in place just as described for the in-place stabilization and disposal alternative. Thus there would be no expected environmental impacts from direct transport of these wastes to the accessible environment. The 618-11 site would be removed from its present location north of the 300 Area and removed to the 200 Area plateau for processing. The TRU wastes from the 618-11 site would be disposed of in a geologic repository (for calculation purposes assumed to be WIPP).

TABLE 5.29. **Estimated Inventories[a] of Key Radionuclides** (Rockwell 1985b) **Disposed of in the Reference Disposal Alternative, Ci**

| Radionuclide | Total | In Geologic Repository | In Onsite Barriered Near-Surface Burial |
|---|---|---|---|
| $^{14}C$ | 5,300 | 0 | 5,300 |
| $^{79}Se$ | 1,100 | 4 | 1,100 |
| $^{90}Sr$ | 120,000,000 | 79,000,000 | 44,000,000 |
| $^{99}Tc$ | 35,000 | 0 | 35,000 |
| $^{129}I$ | 58 | 0 | 58 |
| $^{137}Cs$ | 130,000,000 | 99,000,000 | 26,000,000 |
| $^{151}Sm$ | 1,200,000 | 530,000 | 680,000 |
| $^{238}U$ | 580 | 19 | 560 |
| $^{239-240}Pu$ (b) | 120,000 | 58,000 | 66,000 |
| $^{241}Am$ (c) | 390,000 | 340,000 | 56,000 |

(a) Values have been rounded and therefore may not add.
(b) Includes about 39,000 Ci $^{239-240}Pu$ previously disposed of.
(c) Includes about 11,000 Ci $^{241}Am$ previously disposed of.

Just as in the in-place stabilization and disposal alternative, diffusion might result in some movement of waste constituents stabilized and disposed of in place according to the reference alternative. However, as described previously, the impact analyses showed no health effects over 10,000 years. Similarly, potential movement of selected chemicals would also have no impact on downstream users of the Columbia River.

#### 5.4.4.2 Long-Term Impacts Following Postulated Disruptive Events

As previously discussed (Section 5.2.4.2), an analysis was made of postulated natural and human-induced events that might disrupt confinement of wastes. Events identified as candidates for analysis as disruptive events were impact of large aircraft into a waste site, return of glaciation, a change to a wetter climate, and partial failure of a protective barrier.

Since all of these events are the same as those previously discussed under the in-place stabilization and disposal alternative (Section 5.3.4.2), they are not repeated here.

The disruptive barrier failure was calculated to result in a cumulative population total-body 10,000-year dose to downstream Columbia River users of 270 man-rem, and the functional barrier failure results in a calculated population dose of 270 man-rem. Both of these doses are calculated for 5-cm/year recharge conditions.

#### 5.4.4.3 Long-Term Impacts from Intrusion

These events are the same as those described in the in-place stabilization and disposal alternative (Section 5.3.4.3) and so are not repeated here. At 100 years after disposal, the annual dose to an individual from the well-drilling scenario is 0.3 rem; the lifetime total-body dose from the post-drilling scenario is 100 rem; and the lifetime total-body dose from the full garden scenario is 0.2 rem.

#### 5.4.4.4 Resettlement

This is the same event discussed in the in-place stabilization and disposal alternative, is calculated to have the same impacts (Section 5.3.4.4), and is not repeated here.

### 5.4.5 Irreversible and Irretrievable Commitment of Resources

The irreversible and irretrievable commitment of resources for the reference disposal alternative includes commitments of energy, materials and manpower. Selected resource commitments are summarized in Table 5.30 (see Appendix L for details).

**TABLE 5.30. Irreversible and Irretrievable Resource Commitments Necessary to Implement the Reference Alternative**

| Resource | HLW Onsite; TRU to WIPP | HLW Offsite; TRU to WIPP |
|---|---|---|
| Energy | | |
| Diesel fuel, $m^3$ | 14,000 | 14,000 |
| Propane, $m^3$ | 74,000 | 75,000 |
| Gasoline, $m^3$ | 4,200 | 4,200 |
| Electricity, GWh | 3,800 | 3,800 |
| Coal, t | 46,000 | 47,000 |
| Materials | | |
| Concrete, $m^3$ | 65,000 | 65,000 |
| Steel,[a] t | 14,000 | 14,000 |
| Stainless steel,[a] t | 1,400 | 1,400 |

(a) Partial recovery (as much as 25%) may be possible.

Resource use for the reference alternative is generally bounded by the geologic disposal and in-place stabilization and disposal alternatives.

### 5.4.6 Unavoidable Adverse Impacts

Unavoidable adverse impacts on workers and public are summarized in Table 5.31. The radiological impacts associated with operational aspects of the disposal alternatives for workers are well within applicable standards, and doses to the public are insignificant compared to those from natural background.

TABLE 5.31. **Collective Radiation Doses from Implementing the Reference Alternative**

| Exposure Classification | Collective Total-Body Dose,[a] man-rem |
|---|---|
| Occupational | 3,800 |
| Offsite Population[b] | 1 |
| Transportation | |
| TRU to WIPP; | |
| HLW Onsite | 40 |
| HLW Offsite | 43 |

(a) Existing high-level fraction double-shell tank waste, high-level fraction future tank waste and capsules disposed of in geologic repository. Single-shell tank waste and disposed-of TRU waste stabilized on site, low-activity fraction grouted and disposed of on site. Retrievably stored and newly generated TRU waste disposed of in WIPP repository.

(b) For comparison, the same population would receive a dose from natural background of 2,500,000 man-rem over the same 60-year period.

### 5.4.7 Relationship to Land-Use Plans, Policies and Controls

The implementation of the reference disposal alternative will not conflict with any approved national, state, or local land-use policies as they currently exist. Implementation would not significantly alter the area already committed by previous waste processing and storage activities. See Section 5.2.7.

### 5.4.8 Relationship Between Near-Term Use of the Environment and Enhancement of Long-Term Productivity

See previous discussion under geologic disposal alternative, Section 5.2.8.

## 5.5 NO DISPOSAL ACTION (CONTINUED STORAGE)

No disposal action is represented by continued storage of wastes. It does not implement a long-term solution for permanent disposal of radioactive wastes. Wastes continue to be stored essentially as they are now for the indefinite future. To be consistent with other alternatives for calculation purposes, active institutional control over the stored wastes is assumed to be absent after 2150, leaving them without further protection. This is not an intended action, but it is evaluated as a no action alternative as required by Council on Environmental Quality regulations. This alternative serves primarily as a basis for comparison against permanent disposal alternatives. Section 5.5.2 provides a summary total of operational consequences for the six waste classes for no disposal action.

### 5.5.1 Waste Disposal Procedures

Waste disposal and waste management practices for handling the six waste classes for the no disposal action (continued storage) are described in Chapter 3, Section 3.3.4, and Appendix B in detail.

### 5.5.2 Summary of Operational Impacts Associated with No Disposal Action

The elements of the continued storage alternative are described in Chapter 3. The operational impacts are summarized in this section, including public and worker radiation doses from normal operations and from operational accidents; nonradiological emissions to the environment and air quality impacts; nonradiological accidents, ecological impacts, socioeconomic impacts, resource requirements, and costs.

#### 5.5.2.1 Radiological Consequences from Routine Operations

Radiation doses to workers and the public estimated from continued storage of Hanford defense waste per 100 years are summarized in Table 5.32. An estimated total of 3,800 man-years of radiation work per 100 years will be required for continued storage of all waste classes. A total occupational total-body dose of approximately 1,900 man-rem per 100 years would result. Existing tank waste accounts for over 60% of the occupational dose total.

**TABLE 5.32. Estimated Total-Body Radiation Doses from Routine Operations for No Disposal Action** (Continued Storage)

| Waste Class | Occupational Doses, man-rem | Maximum Offsite Individual Dose Commitments, rem | | Population Dose Commitments,[a] man-rem | |
|---|---|---|---|---|---|
| | Operations | 1-yr Exposure | 70-yr Exposure[b] | 1-yr Exposure | 70-yr Exposure[b] |
| Existing Tank Waste | 1,200 | $3 \times 10^{-9}$ | $2 \times 10^{-5}$ | $2 \times 10^{-3}$ | 1 |
| Future Tank Waste | 170 | $5 \times 10^{-8}$ | $9 \times 10^{-6}$ | $4 \times 10^{-3}$ | 0.5 |
| Sr/Cs Capsules | 420 | $6 \times 10^{-10}$ | $2 \times 10^{-7}$ | $6 \times 10^{-5}$ | 0.01 |
| Retrievably Stored and Newly Generated TRU Waste | 20 | --[c] | -- | -- | -- |
| TRU-Contaminated Soil[d] | 40 | -- | -- | -- | -- |
| Pre-1970 Buried TRU Solid Waste[d] | 20 | -- | -- | -- | -- |
| Totals | 1,900 | $5 \times 10^{-8}$ | $3 \times 10^{-5}$ | $6 \times 10^{-3}$ | 2 |

(a) Dose commitment values have been rounded to one significant figure.
(b) "70-year exposure" implies a lifetime accumulated total-body dose from all operations.
(c) Dashes indicate that these waste classes have no associated dose for this alternative.
(d) Previously disposed-of wastes.

Process operations would result in some minor releases of radionuclides from the waste sites and surrounding potentially contaminated soil to the atmosphere that could result in radiation doses to members of the general public at offsite locations. The calculated dose commitment in any one year to a maximally exposed individual is $5 \times 10^{-8}$ rem, and the calculated individual lifetime dose is $3 \times 10^{-5}$ rem. The collective dose in any one year to the population residing within 80 km is calculated to total $6 \times 10^{-3}$ man-rem, and the cumulative total-body dose from all operations is calculated to be about 2 man-rem. For comparison, the 70-year dose to the same population (420,000) would amount to about 3,000,000 man-rem.

#### 5.5.2.2 Radiological Consequences from Postulated Accidents

Table 5.33 summarizes the postulated accidents resulting in the largest public doses for operations in the no disposal action alternative (continued storage) for each waste class. As in the other alternatives, the most severe accident involved existing tank wastes. In this case, however, since an explosion of ferrocyanide precipitates is not credible, the most severe accident (failure of diversion box pipefitting) resulted in a 70-year population dose of 2,000 man-rem. For comparison, the dose to the same population for the same period from naturally occurring sources would amount to about 3,000,000 man-rem. Details of postulated accidents are in Appendix H.

#### 5.5.2.3 Nonradiological Consequences

Nonradiological consequences (Appendix L) include generation of dust from waste retrieval, site preparation, site stabilization, and construction; combustion products from operation of surface vehicles and equipment, and from transportation of waste (Appendix I); and injuries and fatalities associated with storage, remedial action and monitoring. Nonradiological consequences also include groundwater degradation due to contamination by chemicals (Appendix U). Nonradiological emissions (dust and combustion products) resulting from no disposal action (continued storage) are summarized in Table 5.34 for 100 years of continued storage. Air-quality impacts are estimated in terms of maximum ground-level pollutant concentrations at the Site boundary or at publicly accessible locations within the Hanford fenceline. The calculated values are summarized and are compared to the standards in Table 5.35.

With no disposal action, 130 injuries and illnesses that result in lost work days and no fatalities are estimated to occur. These numbers are based on accident statistics for similar activities and on manpower requirements estimated in Rockwell (1985b).

#### 5.5.2.4 Ecological Impacts

Ecological impacts from the no disposal action (continued storage) of all waste classes would essentially be unchanged from present conditions (ERDA 1975).

#### 5.5.2.5 Resource Commitments

Estimates of resource requirements for the first and subsequent centuries of storage are shown in Table 5.36. See Appendix L for details.

**TABLE 5.33. Summary of Upper-Bound Accidents and Calculated Total-Body Radiation Doses for No Disposal Action (Continued Storage)[a]**

| Waste Class | Description of Upper-Bound Accident | Maximum Individual Dose, rem | | Population Dose Commitments, man-rem | |
|---|---|---|---|---|---|
| | | 1-yr Dose | 70-yr Dose Commitment | 1-yr Dose | 70-yr Dose Commitment[a] |
| Existing Tank Waste | Pressurized release of liquid waste due to failure of a diversion box valve during hydraulic retrieval operations. | 0.06 | 0.9 | 100 | 2,000 |
| Future Tank Waste | Pressurized release of liquid waste due to failure of a diversion box valve during hydraulic retrieval operations. | 0.09 | 0.9 | 300 | 2,000 |
| Sr/Cs Capsules | Rupture of a strontium capsule by improper handling during retrieval operations. | $2 \times 10^{-7}$ | $3 \times 10^{-6}$ | $6 \times 10^{-4}$ | 0.01 |
| Retrievably Stored and Newly Generated TRU Waste | Collapse of voids at waste site during subsidence-control operations. | $5 \times 10^{-6}$ | $7 \times 10^{-5}$ | 0.01 | 0.2 |
| TRU-Contaminated Soil[a] | Collapse of voids in soil site during site-stabilization activities. | $2 \times 10^{-8}$ | $9 \times 10^{-7}$ | $5 \times 10^{-5}$ | $2 \times 10^{-3}$ |
| Pre-1970 Buried TRU Solid Waste[b] | Collapse of voids at waste site during subsidence-control operations. | $3 \times 10^{-7}$ | $7 \times 10^{-6}$ | $6 \times 10^{-4}$ | 0.02 |

(a) See Appendix H for details.
(b) Previously disposed-of wastes.

TABLE 5.34. **Summary of Nonradiological Emissions for No Disposal Action** (continued storage for 100 years)

| Pollutant | Emissions, t |
|---|---|
| Particulates | 100 |
| $SO_x$ | 330 |
| CO | 170 |
| HC | 120 |
| $NO_x$ | 18 |

TABLE 5.35. **Comparison of Estimated Concentrations of Nonradiological Pollutants in Air for the No Disposal Action with Ambient Air-Quality Standards**[a]

| | Concentration, $\mu g/m^3$ | | | | |
|---|---|---|---|---|---|
| Pollutant | 1 hr | 3 hr | 8 hr | 24 hr | Annual |
| CO | 62 (40,000) | --[b] | 20 (10,000) | -- | -- |
| $NO_x$ | -- | -- | -- | -- | 0.05 (100) |
| $SO_x$ | 45 (655) | 30 (1,300) | -- | 1.9 (260) | 0.14 (52) |
| Particulates[c] (including dust) | -- | -- | -- | 0.20 (120) | 0.01 (40) |

(a) Ambient air-quality standards are given in parentheses. See Appendix T.
(b) Dashes indicate there is no applicable standard.
(c) Allowable concentration in excess of background.

#### 5.5.2.6 Costs

Estimated costs for the first 100 years and each additional 100 years of continued storage are summarized in Table 5.37. Costs for the first 100 years are about $1.8 million and for each additional 100 years about $1.3 billion ($1987). See Appendix L.

### 5.5.3 Socioeconomic Impacts

Appendix K presents the time and manpower needs for construction and for operations to implement the no disposal action alternative for each of the six waste classes. Also, see Section 5.2.3.

#### 5.5.3.1 Manpower Requirements

Detailed manpower profiles, developed for each alternative from data provided by Rockwell (1985b), are presented in Appendix K. Manpower requirements for the no disposal action are low compared with those of any of the alternatives considered. Between the years 1990 and 2015, the average number of operational workers required per year is estimated to be about 120. The peak work force requirement of about 400 would occur in the time frame of 2010 to 2014.

TABLE 5.36. **Estimated Resource Requirements for Implementing No Disposal Action** (continued storage)

| Resource | Amount First 100 yr |
|---|---|
| Energy | |
| Diesel fuel, $m^3$ | 110 |
| Propane, $m^3$ | 17,000 |
| Gasoline, $m^3$ | 1,700 |
| Electricity, GWh | 300 |
| Coal, t | 110,000 |
| Materials | |
| Concrete, $m^3$ | 46,000 |
| Steel, t | 26,000 |
| Stainless steel, t | 43 |
| Lumber, $m^3$ | 8,000 |
| Soil, $m^3$ | 700,000 |
| Manpower, man-yr | 12,000 |

TABLE 5.37. **Cost Summary for No Disposal Action** (continued storage) **of All Waste Classes**

| Waste Class | Millions of $1987 First 100 yr | Millions of $1987 Each Additional 100 yr |
|---|---|---|
| Existing Tank Waste | 1,000 | 780 |
| Future Tank Waste | 450 | 430 |
| Sr/Cs Capsules | 300 | 64 |
| Retrievably Stored and Newly Generated TRU Waste | 9.4 | 9.4 |
| TRU-Contaminated Soils[a] | 11 | 11 |
| Pre-1970 Buried TRU Solid Waste[a] | 5.4 | 5.4 |
| Total | 1,800 | 1,300 |

(a) Previously disposed-of wastes.

The potential for socioeconomic impacts would hardly be detectable.

### 5.5.3.2 Employment and Population Impacts

Historical and projected baseline employment and population growth is presented in Appendix K. Employment includes both the direct primary employees working on the waste management activities and the indirect secondary workers in the community who provide services. The total population forecasts include both the workers and their dependents. As a percentage of the projected baseline employment, the average employment level created by the no disposal action is less than one.

#### 5.5.3.3 Community Services

The potential socioeconomic impacts of the employment and population growth expected are given in detail in Appendix K. The no disposal action would have no impact on community services.

#### 5.5.3.4 Housing

The no disposal action would have little, if any, impact on housing.

#### 5.5.3.5 Local Transportation

The no disposal action would have little, if any, impact on local transportation.

#### 5.5.3.6 Education

No negative capital cost impacts are anticipated.

#### 5.5.3.7 Utilities and Other Services

The no disposal action would have little, if any, impact on utilities and other services.

#### 5.5.3.8 Fiscal Conditions

The no disposal action would have little, if any, impact on local fiscal conditions.

#### 5.5.3.9 Social Conditions

The work force required to maintain the wastes in their current condition is relatively small, thereby resulting in insignificant growth-related socioeconomic impacts. However, public concerns for possible environmental contamination from no disposal action could result in loss of confidence in long-term management of the wastes.

### 5.5.4 Impacts in the Long Term of No Disposal Action (Continued Storage)

As noted earlier, consideration of the no disposal action (continued storage) alternative is mandated by Council on Environmental Quality regulations in implementing the NEPA (40 CFR 1500-1517). Continued storage in the long term is not a disposal action and is contrary to DOE policy and plans for management of defense wastes at Hanford. Nevertheless, a determination of long-term impacts of the no disposal action was made and is useful to contrast with the impacts of the disposal alternatives.

In the no disposal action alternative, wastes would continue to be managed much as they are today, except that strontium and cesium capsules would be removed from storage in water basins and placed in a near-surface drywell storage facility, and double-shell tank waste would be retanked at about 50-year intervals. Double-shell tank waste would remain in the liquid or semiliquid state.

For purposes of long-term analysis, active or passive institutional control is assumed to be absent from the Hanford Site beginning in the year 2150 without the DOE having provided for additional protection of the waste. Although the DOE has no intention of leaving the Hanford Site in such a manner, this assumption allows a parallel analysis to that performed for the disposal alternatives.

#### 5.5.4.1 **Impacts in the Long Term for No Disposal Action** (Continued Storage)--**Conditions Remain as at Present**

With conditions remaining as at present, there would be no significant impacts to the offsite population from continued storage until the loss of institutional control in the year 2150. The present population total-body dose rate of about 5 man-rem/yr, principally N Reactor operations, to the (1990) offsite populations (420,000 people) would be expected to continue, and in the event of any indication that waste was moving in significant quantities from its present location, corrective action would be taken.

Following the time when active institutional control of the Site is assumed to be absent, natural conditions could act upon the waste, causing nuclides to be leached from the various waste forms and be transported to groundwater and to the Columbia River. Impacts on the downstream population were calculated assuming the offsite population did not leave at the time the Site was vacated. Again, this is an unlikely occurrence (whatever caused the Site to be vacated would probably result in the region being vacated) but one that permits parallel analysis.

If the average annual recharge were 0.5 cm/yr (current climate), the cumulative total-body dose to downstream users of the Columbia River would amount to about 25,000 man-rem over 10,000 years. This dose would equate to between 2 and 25 health effects over 10,000 years, which can be compared to the 300,000 to 3,000,000 health effects to the downstream population from naturally occurring radioactive sources.

At 0.5-cm/yr recharge, some chemicals would be leached from waste sites and transported to groundwater and the Columbia River. The resulting Columbia River concentrations would be small fractions ($2 \times 10^{-5}$) of the limits established by EPA drinking-water standards.

#### 5.5.4.2 **Impacts in the Long Term, No Disposal Action--Waste Sites Without Long-Term Protection**

Where the waste sites are without long-term protection, a wetter climate could result in faster leaching of nuclides and transport to the Columbia River. Analysis of conditions assumed for a wetter climate (5-cm average annual groundwater recharge) shows that the cumulative total-body dose to the downstream population over 10,000 years would be about 4 million man-rem from which 400 to 4,000 health effects might be expected. This dose, dominated by $^{90}Sr$ leaching from double-shell tanks, would peak at about the year 2400. Again, this impact is small compared to that from natural background (300,000 to 3,000,000 health effects over the same time frame).

Chemicals in the waste would also be further subject to leaching under the 5-cm/yr recharge. Quantities reaching the river on an annual basis would be increased over what they were for a 0.5-cm/yr recharge condition. However, the large flow rate of the Columbia River reduces the concentrations to below the EPA drinking-water standards; e.g., $NO_3^-$ would be less than $10^{-3}$ of the limits established by EPA drinking-water standard (based on nitrate). Thus release even of these relatively large quantities of chemicals is not a significant impact to the offsite population. (See Appendix U.)

#### 5.5.4.3 Impacts from Disruption of Wastes by Intruders

Where wastes are in a continued storage mode but without any institutional control (active or passive), the probability of inadvertent intrusion is increased considerably (Appendix M). For wastes in continued storage, the same intrusion scenarios are analyzed as those for the disposal alternatives. The consequences are highly dependent on the class of waste into which intrusion is made. Only the incidents with the largest consequences are reported here; others (and details) may be found in Appendix R.

Drilling into a cesium capsule results in the highest total-body dose to the intruder. If drilling were to occur soon after loss of institutional control, the dose to the intruder would be fatal (about 1,000 rem in a week or two). By 400 years after disposal, the dose from drilling into a cesium capsule would be about one rem, less than that currently permitted for radiation workers. By 1,000 years, the radiation dose to drillers would be less than 0.01 rem/yr for all classes of waste considered in this EIS.

In the excavation scenario, maximum annual total-body doses to workers "in the hole" would amount to about 20,000 rem in the year 2150. Such doses to workers would be fatal. By the year 2450, maximum annual doses from this scenario would be about 20 rem/yr.

As noted earlier, where drilling or excavation had occurred, persons later might reside and grow gardens on the soil contaminated by drilling or excavation. With no consideration of probability of occurrence, drilling into strontium capsules promptly after loss of active institutional control could result in a potential maximum annual total-body dose to the subsequent intruding resident gardener of about 30,000 rem. Such a dose would be fatal to the intruder. By 400 years after disposal the potential maximum annual total-body dose to the intruder would be about 20 rem, and 1,000 years later would be $1 \times 10^{-5}$ rem. Thus, based on this scenario, one would expect fatalities to intruders early after disposal and marginally significant consequences after about 400 years.

Biota might invade waste sites and bring radioactive material to the surface, and later, in the absence of institutional control, persons might reside over the contaminated soil and consume produce grown in it. A maximum annual total-body dose to such persons of 0.3 rem is calculated to occur where intrusion takes place 10,000 years after loss of institutional control. Before that time, doses would be lower because of smaller amounts of material brought to the surface, and doses would slowly decrease after then due to radioactive decay.

A person might drill a well to water intercepting a contaminated aquifer and drink contaminated well water and consume produce irrigated with it. This scenario was examined in the case of 0.5-cm/yr average annual recharge and 5-cm/yr recharge as representative of a wetter climate.

For the 0.5-cm/yr recharge case, the maximum potential 70-year total-body radiation dose to such an individual was calculated to be 400 rem and was projected to occur in the year 2500. For the 5-cm/yr recharge case, the potential maximum 70-year total-body dose ($9 \times 10^6$ rem in the year 2500) was found to be far in excess of a lethal dose. If the individual only drank the water and did not consume garden produce irrigated with contaminated well water, his potential maximum annual total-body dose would be about 1,000 rem and his potential 70-year accumulated total-body dose would amount to about 70,000 rem, occurring at about the year 2500.

Chemicals reaching groundwater would also be available to an individual who drilled a well into the aquifer for his water supply. With the wetter climate and an average annual recharge of 5 cm/yr, incremental concentrations in water from the 5-km well would be projected to be $NO_3^-$ 6,000 mg/L, chromium 5.9 mg/L, cadmium $2 \times 10^{-4}$ mg/L, mercury 0.7 mg/L, and fluoride $3.8 \times 10^{-2}$ mg/L. These concentrations are up to about 1,000 times the EPA drinking-water standards.

#### 5.5.4.4 Resettlement

This scenario assumes that at some future time the area adjacent to the west bank of the Columbia River in the northeastern part of the Site is resettled and wells are dug that reach groundwater. That area was inhabited at the time the Hanford Site was established (towns of White Bluffs and Hanford). This scenario is restricted to the number of 2-ha small farms that could be supplied by the volume of contaminated water available. On this basis, the number of small farms was limited to 65. It was then assumed that 65 families composed of four individuals each resettled the land and drew drinking and food-crop irrigation water from wells. (In earlier times irrigation water was supplied to this area from the Hanford ditch that took its water supply from the Columbia River upstream of the communities.)

An estimate of the integrated population dose to, and health effects among, occupants of these small farms was made for both an average annual recharge of 0.5 cm/yr and 5 cm/yr. In the case of no disposal action and in the absence of active institutional control under the current climatic conditions, the consequences of resettlement are calculated to be 10 to 100 health effects over the next 10,000 years. The wetter-climate scenario would indicate fatal consequences for the entire exposed set (65 families of four individuals or about 300 total). These scenarios could be repeated several times over the 10,000-year period if knowledge of the problem were lost and as the intermittent arrival of high concentrations of radionuclides occurred.

#### 5.5.4.5 Summary of Impacts in the Long Term for No Disposal Action (Continued Storage)

As long as active institutional controls exist on the Hanford Site, monitoring and surveillance would detect movement of significant quantities of radionuclides or chemicals, appropriate corrective action would be taken, and there would be no expected long-term impacts to the offsite population. Moreover, there would be no intrusion into waste sites or interception of aquifers, whether contaminated or not. Where institutional control is assumed to be absent in the no disposal action case and with no protective barriers in place, mechanisms could move wastes to groundwater and the Columbia River. Also, if institutional control were absent, nothing would prevent various forms of intrusion into waste sites or groundwater. This analysis is conservative since even though no institutional controls are assumed to exist, the physical features of the waste sites and current land use records could be expected to warn an intruder. No credit has been taken, however, for such passive controls in this scenario.

Impacts on individuals varied from innocuous to fatal, depending upon the scenario investigated. However, most intrusions would probably not lead to fatal consequences. Although the offsite population would not be adversely affected by continued storage of waste where active institutional control is present at Hanford, it is concluded that in the absence of such control, the potential exists for adverse impacts on offsite populations and on those coming onto the Site.

### 5.5.5 Irreversible and Irretrievable Commitment of Resources

The irreversible and irretrievable commitment of resources for the no disposal action alternative includes commitments of energy, materials and manpower. Selected resource commitments are summarized in Table 5.38 (see Appendix L for details).

**TABLE 5.38. Irreversible and Irretrievable Resource Commitments Necessary to Implement the No Disposal Action Alternative**

| Resource | Quantity First 100 yr |
|---|---|
| Energy | |
| Diesel fuel, $m^3$ | 110 |
| Propane, $m^3$ | 17,000 |
| Gasoline, $m^3$ | 1,700 |
| Electricity, GWh | 300 |
| Coal, t | 110,000 |
| Materials | |
| Concrete, $m^3$ | 46,000 |
| Steel,[a] t | 26,000 |
| Stainless Steel,[a] t | 43 |

(a) Partial recovery (as much as 25%) may be possible.

### 5.5.6 Unavoidable Adverse Impacts

Unavoidable adverse impacts on workers and public are summarized in Table 5.39. The radiological impacts associated with operational aspects of the disposal alternatives for workers are well within applicable standards, and doses to the public are insignificant compared to those from natural background.

## 5.6 PREFERRED ALTERNATIVE

As discussed in Chapter 3, Section 3.3.5, the preferred alternative selects disposal elements from the reference disposal alternative for some waste classes and defers any disposal decision for the remaining classes of waste. Waste disposal procedures are described in Chapter 3, Section 3.3.5, and operational impacts associated with the preferred alternative are summarized in Section 5.6.2. Post-disposal performance of the preferred alternative in terms of public health and safety is discussed in Section 5.6.4.

**TABLE 5.39. Collective Total-Body Radiation Doses from Implementing the No Disposal Action Alternative**

| Exposure Classification | Collective Total-Body Dose[a] |
|---|---|
| Occupational | 1,900 |
| Offsite Population[b] | 1.6 |
| Transportation | NA[c] |

(a) For first 100 years and each century thereafter.
(b) For comparison, the same population would receive a dose from natural background of 4,000,000 man-rem over the same 100-year time period.
(c) Not Applicable.

### 5.6.1 Waste Disposal Procedures

Representative procedures for disposing of the three waste classes for the preferred alternative are described in Chapter 3, Section 3.3.3, and Appendix B in detail.

### 5.6.2 Summary of Operational Impacts Associated with Preferred Alternative

Environmental impacts associated with implementing the preferred disposal alternative are presented in this section. Discussions of the preferred alternative will center on the wastes for which a disposal preference has been identified; existing and future double-shell tank waste, retrievably stored and newly generated TRU solid waste, and strontium and cesium capsules. For the wastes for which the disposal preference decision is being deferred, existing single-shell tank waste, TRU contaminated soil sites and pre-1970 TRU buried solid waste, the potential impacts of the disposal alternatives are bounded by the reference alternative and by the geologic disposal alternative.

The operational impacts evaluated for the preferred alternative include public and worker radiation doses from normal operations, public and occupational doses resulting from operational accidents, nonradiological emissions to the environment and resulting air-quality impacts, nonradiological accidents, ecological impacts, socioeconomic impacts, resource commitments, and costs.

#### 5.6.2.1 Radiological Consequences from Routine Operations

Radiation doses calculated to result from implementation of the preferred alternative are summarized in Table 5.40. A total of 5,200 man-years of radiation work, including activities at the Transportable Grout Facility, Hanford Waste Vitrification Plant and Waste Receiving and Processing facility, are estimated to be required for the disposal of the waste classes considered in the preferred alternative. A total occupational total-body dose of about 2,600 man-rem could result from these activities. About 90% of the occupational dose total is incurred from disposing of existing double-shell and future tank waste; less than 10% results from the Transportable Grout Facility, Hanford Waste Vitrification Plant and Waste Receiving and Processing facility (Appendices C, D, and E). Repository emplacement and offsite transportation of geologically disposed of waste would add about 230 man-rem to the collective dose. Disposal of the deferred waste classes could result in an additional 990 to 12,000 man-rem depending upon whether these wastes are all disposed of in place or in a geologic repository. Operational impacts associated with continued storage of these three waste classes would be a small fraction of the current total ongoing site-wide operations impact shown in Table 5.1.

Operations to dispose of most waste classes would result in some minor atmospheric releases of radionuclides from the waste sites and surrounding potentially contaminated soil. The total-body dose commitment in any one year to a maximally exposed offsite individual from these releases was calculated to be $6 \times 10^{-7}$ rem, and the individual lifetime dose is $2 \times 10^{-5}$ rem. The collective annual and lifetime total-body dose to the population residing within 80 km in any one year is calculated to be about 0.05 and 1 man-rem, respectively. The major portion of the doses to both the individual and the population is from releases during recovery and processing of existing double-shell and future tank waste. The disposal method selected for the deferred waste classes could result in an additional $(5 \text{ to } 10) \times 10^{-6}$ rem to the lifetime total-body dose of an individual and 0.3 to 0.6 man-rem to the lifetime total-body dose of the surrounding population. For comparison, the dose to the same population (420,000) over the same period from naturally occurring sources would be about 2,500,000 man-rem.

Disposal of retrievably stored and newly generated TRU waste requires offsite transport of the waste to the WIPP repository. This operation contributes about 40 man-rem to the population dose, including the transportation work force. Transportation of the deferred waste classes to an offsite repository could result in an additional 30 man-rem.

**TABLE 5.40. Estimated Radiation Total-Body Doses from Routine Operations for the Preferred Alternative**

| Waste Class | Occupational Doses, man-rem: Operations | Occupational Doses, man-rem: Repository Emplacement | Maximum Individual Dose Commitments, rem: 1-yr Exposure | Maximum Individual Dose Commitments, rem: 70-yr Exposure[b] | Population Dose Commitments,[a] man-rem: 1-yr Exposure | Population Dose Commitments,[a] man-rem: 70-yr Exposure[b] | Population Dose Commitments,[a] man-rem: Transportation, (offsite)[c] |
|---|---|---|---|---|---|---|---|
| Existing Double-Shell Tank Waste | 800 | 20 | $5.3 \times 10^{-9}$ | $2.4 \times 10^{-7}$ | $4 \times 10^{-4}$ | 0.02 | 0.8 |
| Future Tank Waste | 1,600 | 26 | $5.7 \times 10^{-7}$ | $5.1 \times 10^{-6}$ | 0.05 | 0.4 | 2 |
| Sr/Cs Capsules | 70 | 78 | $6.3 \times 10^{-10}$ | $3.6 \times 10^{-8}$ | $6 \times 10^{-5}$ | $2 \times 10^{-3}$ | 0.8 |
| Retrievably Stored and Newly Generated TRU Waste | 160 | 110 | $1 \times 10^{-6}$ | $1 \times 10^{-4}$ | 0.09 | 9 | 40 |
| Subtotal | 2,600 | 230 | $2 \times 10^{-6}$ | $1 \times 10^{-4}$ | 0.1 | 9 | 40 |
| Existing Single-Shell Tank Waste[d] | 800-8,800 | 0-850 | $(2.6\text{-}2.7) \times 10^{-8}$ | $(4.5\text{-}9.5) \times 10^{-6}$ | $2 \times 10^{-3}$ | 0.3-0.6 | 0-30 |
| TRU-Contaminated Soil[d] | 40-750 | 0-52 | $0\text{-}2 \times 10^{-6}$ | $0\text{-}2 \times 10^{-4}$ | 0-0.1 | 0-10 | 0-2 |
| Pre-1970 Buried TRU Solid Waste[d] | 150-2,300 | 0-180 | $0\text{-}4 \times 10^{-4}$ | $0\text{-}5 \times 10^{-4}$ | 0-30 | 0-30 | 0-6 |
| Totals | 3,600-14,000 | 230-1,300 | $2 \times 10^{-6}$ to $4 \times 10^{-4}$ | $(1\text{-}7) \times 10^{-4}$ | 0.1-30 | 1-50 | 40-80 |

(a) All dose commitment values have been rounded to one significant figure.
(b) "70-year Exposure" implies a lifetime accumulated dose from all operations.
(c) Transport of high-level wastes to alternative HLW repository up to 5,000 km from Hanford; TRU wastes to WIPP.
(d) The decision regarding preferred disposal of this waste has been deferred. Values given represent a range depending upon whether waste is stabilized and disposed of in place or disposed of in geologic repository.

#### 5.6.2.2 Radiological Consequences from Postulated Accidents

As in the other alternatives, implementation of the preferred alternative could result in accidents releasing radioactive materials to the environment. Accidents were postulated for disposal activities, and those accidents that resulted in the largest potential public doses for each waste class to be disposed of in the preferred disposal alternative are summarized in Table 5.41. The largest potential lifetime population total-body dose from these postulated accidents amounts to 2,000 man-rem. This dose is small compared to the dose of 3,000,000 man-rem that the same population (420,000) residing within 80 km would receive from natural background radiation over the same period. The largest 70-year dose commitment to any member of the public is calculated to be about 0.9 rem (Appendix H).

Potential public doses resulting from postulated accidents for those waste classes whose disposal decision has been deferred are bounded by those resulting from accidents postulated for the geologic disposal and reference alternatives (Tables 5.4 and 5.23, respectively).

#### 5.6.2.3 Nonradiological Consequences

Nonradiological consequences include generation of dust from waste retrieval, site preparation, site stabilization, and processing of mined material; combustion products from operation of surface vehicles and equipment, and transportation of waste; and injuries and fatalities associated with retrieval, stabilization, transportation, and disposal of the waste. Each impact (except air quality) represents a total that would actually be spread over a period of 20 to 30 years. Details are presented in Appendices G, L, and T.

Nonradiological emissions (i.e., dust and combustion products) resulting from implementation of the preferred alternative, including the Transportable Grout Facility, Hanford Waste Vitrification Plant and Waste Receiving and Processing facility, are summarized in Table 5.42. The contributions from these three facilities are minimal (Appendices C, D, and E). The emissions are those generated on site during facility construction, retrieval, packaging, and storage. Transportation emissions result from shipping existing double-shell tank waste, strontium and cesium capsules, and future tank waste to an onsite or offsite repository and from shipping retrievably stored and newly generated TRU waste to the WIPP repository. All emissions would be within limits established by applicable standards. The reader is referred to Appendix I for details about transportation.

Air-quality impacts are estimated in terms of maximum ground-level pollutant concentrations at the Site boundary or at publicly accessible locations within the Hanford fenceline and are summarized in Table 5.43. Nonradiological pollutant concentrations resulting from transportation of TRU waste to WIPP would be extremely small and well below limits established by applicable standards (Appendix I).

These estimated pollutant concentrations are based on historical meteorological data and maximum expected releases of pollutants; they are a reasonable indication of possible future conditions.

**TABLE 5.41. Summary of Upper-Bound Accidents and Calculated Total-Body Radiation Doses for the Preferred Alternative[a]**

| | | Maximum Individual Dose, rem | | Population Dose Commitments, man-rem | |
|---|---|---|---|---|---|
| Waste Class | Description of Upper-Bound Accident | 1-yr Dose | 70-yr Dose Commitment | 1-yr Dose | 70-yr Dose Commitment |
| Existing Double-Shell[b] Tank Waste | Pressurized spray during hydraulic retrieval of residual liquids from a double-shell tank during waste processing operations. | 0.05 | 0.9 | 100 | 2,000 |
| Future Tank Waste | Pressurized release of liquid waste due to failure of a diversion box valve during hydraulic retrieval operations. | 0.09 | 0.9 | 300 | 2,000 |
| Sr/Cs Capsules | Rupture of a strontium capsule by improper handling during retrieval operations. | $2 \times 10^{-7}$ | $3 \times 10^{-6}$ | $6 \times 10^{-4}$ | 0.01 |
| Retrievably Stored and Newly Generated TRU Waste | Pressurized release from waste drum rupture due to buildup of radiolytic gases. | $2 \times 10^{-3}$ | 0.06 | 4 | 100 |
| Existing Tank Waste | Explosion of ferrocyanide or other organic precipitates during mechanical retrieval or stabilizing operations (geologic disposal or reference alternative) | 0.2 | 3 | 400 | 7,000 |
| TRU-Contaminated Soil Sites | Deflagration of contaminated material due to process malfunction in slagging pyrolysis incinerator (geologic disposal) | $5 \times 10^{-7}$ | $2 \times 10^{-5}$ | $1 \times 10^{-3}$ | $4 \times 10^{-2}$ |
| | Collapse of voids in soil site during subsidence-control operations (reference alternative) | $2 \times 10^{-8}$ | $9. \times 10^{-7}$ | $5 \times 10^{-5}$ | $2 \times 10^{-3}$ |
| Pre-1970 TRU Solid Waste | Deflagration of contaminated material due to process malfunction in slagging pyrolysis incinerator (geologic disposal) | $5 \times 10^{-6}$ | $1 \times 10^{-4}$ | $1 \times 10^{-2}$ | $3 \times 10^{-1}$ |
| | Collapse of void space at waste site during subsidence-control operations (reference alternative) | $3 \times 10^{-7}$ | $7 \times 10^{-6}$ | $6 \times 10^{-4}$ | $2 \times 10^{-2}$ |

(a) See Appendix H for details.
(b) Mishima et al. 1986.

**TABLE 5.42. Summary of Nonradiological Emissions in the Preferred Alternative** (over a 20-year period)[a]

| Pollutant | Emissions, t |
|---|---|
| Particulates | 19,000 - 58,000 |
| $SO_x$ | 1,500 - 3,800 |
| CO | 1,900 - 4,800 |
| HC | 210 - 590 |
| $NO_x$ | 900 - 3,400 |

(a) Emissions are bounded by the reference and geologic alternatives.

**TABLE 5.43. Comparison of Estimated Concentrations[a] of Nonradiological Pollutants in Air for the Preferred Alternative with Ambient Air-Quality Standards[b]**

| Pollutant | Concentration, g/$m^3$ 1 hr | 3 hr | 8 hr | 24 hr | Annual |
|---|---|---|---|---|---|
| CO | 490-560 (40,000) | --[c] | 150-170 (10,000) | -- | -- |
| $NO_x$ | -- | -- | -- | -- | 1.2-1.3 (100) |
| $SO_x$ | 310-390 (655) | 200-260 (1,300) | -- | 13-16 (260) | 1.0-1.3 (52) |
| Particulates[d] | -- | -- | -- | 2.5-6.9 (120) | 1.6-0.3 (40) |

(a) Concentrations are bounded by the reference and geologic alternatives.
(b) Ambient air-quality standards are given in parentheses. See Appendix T.
(c) Dashes indicate that there is no applicable standard.
(d) Allowable concentration in excess of background.

The number of injuries, illnesses and fatalities determined to be associated with implementation of the preferred alternative, is presented in Table 5.44. No fatalities are estimated to result from the construction or operation of the Transportable Grout Facility, Hanford Waste Vitrification Plant, and Waste Receiving and Processing facility. The number of injuries, illnesses and fatalities is based on accident statistics for similar activities (Appendix G) and on an estimate of manpower requirements. The disposal-related manpower requirements are the sum of manpower for repository activities as estimated for existing double-shell tank waste, strontium and cesium capsules, and future tank waste (DOE 1980a) and

TABLE 5.44. Summary of Estimated Nonradiological Injuries, Illnesses, and Fatalitites Associated with the Preferred Alternative[a]

| Process | Injuries and Illnesses[b] | | Fatalities | |
|---|---|---|---|---|
| | HLW Onsite; TRU to WIPP | HLW Offsite; TRU to WIPP | HLW Onsite; TRU to WIPP | HLW Offsite; TRU to WIPP |
| Waste Retrieval and Processing | 140 - 520 | 140 - 520 | 0 - 2 | 0 - 2 |
| Repository Emplacement | 72 - 380 | 68 - 340 | 0 - 2 | 0 - 2 |
| Transportation | 10 - 13 | 10 - 21 | 1 | 1 - 2 |
| Other Operations | 5 | 0 | 0 | 0 |
| Total | 230 - 910 | 220 - 880 | 1 - 5 | 1 - 6 |

(a) Impacts are bounded by the reference and geologic alternatives.
(b) Injuries and illnesses that result in lost work days.

as estimated for retrievably stored and newly generated TRU waste (DOE 1980b). Repository manpower values are prorated to that portion of the repositories that the Hanford defense waste would occupy.

#### 5.6.2.4 Ecological Impacts

Ecological impacts from implementing the preferred alternative for all waste classes would be small because much of the area under consideration has already been disturbed as a result of radioactive waste management and other nuclear-energy-related activities. The construction requirement with the greatest ecological impact is the need for 6 to 7 million cubic meters of fill materials (soils, gravel and basalt). Selection of the borrow area site for the barrier construction material will be conducted in accordance with the requirements relating to protection of archaeological and native American religious sites. The soil borrow area will be rehabilitated, following removal of materials, using state-of-the-art revegetation practices. These include site-specific soil cultural practices (e.g., tilling and inoculation) and seeding with native and other species of grasses.

#### 5.6.2.5 Resource Commitments

Resource commitments for the preferred alternative include energy, materials and manpower. Estimated requirements, including resource commitments for the Transportable Grout Facility (TGF), Hanford Waste Vitrification Plant (HWVP) and the Waste Receiving and Processing (WRAP) facility, are summarized in Table 5.45. Resources for the geologic repository disposal elements of this alternative are estimated by combining resources related to predisposal activities with those related to repository activities. Resources used for repository

**TABLE 5.45.** **Estimated Resource Requirements for Implementing the Preferred Alternative**[a]

| Resources | HLW Onsite; TRU to WIPP | HLW Offsite; TRU to WIPP |
|---|---|---|
| Energy | | |
| Diesel fuel, $m^3$ | 74,000 - 120,000 | 75,000 - 120,000 |
| Propane, $m^3$ | 14,000 - 97,000 | 14,000 - 97,000 |
| Gasoline, $m^3$ | 4,200 - 14,000 | 4,200 - 15,000 |
| Electricity, GWh | 3,800 - 5,000 | 3,800 - 5,100 |
| Coal, t | 46,000 - 520,000 | 46,000 - 530,000 |
| Materials | | |
| Concrete, $m^3$ | 65,000 - 300,000 | 65,000 - 300,000 |
| Steel, t | 14,000 - 80,000 | 14,000 - 80,000 |
| Stainless steel, t | 1,400 - 6,600 | 1,400 - 6,600 |
| Lumber, $m^3$ | 10,000 - 47,000 | 10,000 - 47,000 |
| Manpower, man-yr | 16,000 - 57,000 | 16,000 - 58,000 |

(a) Requirements are bounded by the reference and geologic alternatives.

activities (estimated in DOE 1980a,b) are prorated to that portion of the repository required for disposal of the particular waste class and type. These resources will be expended over a period of 20 to 30 years.

### 5.6.2.6 Costs

A summary of the costs associated with the preferred alternative is shown in Table 5.46. The existing and future double-shell tank waste, strontium/cesium capsules, and retrievably stored and newly generated TRU waste will be treated as discussed in the reference disposal alternative. The cost of implementing disposal of these wastes is approximately $3.0 billion (in 1987 dollars). No specific costs for single-shell tank waste, TRU-contaminated soil sites, and pre-1970 buried solid TRU waste may be delineated before a disposal decision is reached for those waste classes. However, the costs would be expected to range between $940 million (in-place disposal) and $13.4 billion (geologic disposal). The volumes of existing (double-shell) and future tank waste that go to geologic disposal are about the same. The cost, however, of retrieving and processing existing double-shell tank waste is higher per unit volume than that for future tank waste. As a result, the total cost for disposing of existing tank waste is about twice as much as for future tank waste. The transportation costs are only about 1% of the total disposal costs for tank waste. Therefore, no significant difference exists between onsite and offsite disposal costs of those wastes in

TABLE 5.46. Cost Summary for Preferred Alternative for All Waste Classes[a]

| Waste Class | Millions of $1987[b] Tasks Proposed To be Implemented | Delayed Tasks In-Place | Delayed Tasks Geologic |
|---|---|---|---|
| Existing Tank Waste | | | |
| SST | -- | 700 | 11,300 |
| DST[c] | 1,300 | -- | -- |
| Future Tank Waste[d] | 1,300 | -- | -- |
| Strontium and Cesium Capsules | 210 | -- | -- |
| TRU-Contaminated Soil Sites | -- | 68 | 470 |
| Pre-1970 Buried TRU Solid Waste | -- | 170 | 1,600 |
| Retrievably Stored and Newly Generated TRU Waste | 190 | -- | -- |
| | 3,000[e] | 940 | 13,400[e] |

(a) All costs are rounded to two significant figures.
(b) Costs were revised from the draft EIS to reflect increased repository fees. Since the above costs were calculated, additional costs for repository fees have been proposed. These proposed costs further increase the preferred alternative by 5 to 20%. Additional changes in estimated repository fees can be expected in the future.
(c) Includes cost of Transportable Grout Facility and the Hanford Waste Vitrification Plant.
(d) Includes cost of the Waste Receiving and Processing facility.
(e) HLW disposed of on site or off site and TRU waste sent to WIPP.

geologic repositories. For tank waste and capsules, the repository cost component is developed using present design and packaging concepts (Rockwell 1987). This repository cost component represents the incremental cost associated with emplacing existing double-shell tank waste, capsules, and future tank waste in a commercial repository and assumes overpacking of capsules.

### 5.6.3 Socioeconomic Impacts

Time and manpower needs for construction and operations to implement the disposal part of the preferred alternative for each of the waste classes have been estimated from the data previously presented for the geologic and reference alternatives.

#### 5.6.3.1 Manpower Requirements

Detailed manpower profiles, developed for each alternative from data provided by Rockwell (1985b) are presented in Appendix K. Manpower requirements for the preferred alternative (upper bound--geologic disposal) are relatively high compared with those for the reference alternative (lower bound). Between the years 1990 and 2015, the average number of workers required per year for the disposal part of the preferred alternative is estimated to be about 930. The peak work force requirement would be about 1,300 workers and would occur in six to seven years after the beginning of implementation of the disposal.

The potential socioeconomic impact created by the size of the work force would be bounded by the reference alternative and the geological disposal alternative.

#### 5.6.3.2 Employment and Population Impacts

Historical and projected baseline employment and population growth is presented in Appendix K (see also Section 5.2.3.2). Employment includes both the direct primary employees working on the waste management activities and the indirect secondary workers in the community who provide services. The total population forecasts include both the workers and their dependents. The average employment for the preferred alternative between the years 1990 and 2015 is about 1,800 workers per year. During the peak employment years about 2,800 workers are expected.

#### 5.6.3.3 Community Services

The potential socioeconomic impacts of the employment and population growth anticipated for the preferred alternative are not expected to exceed the community's capacity for providing housing and community services that include transportation, health care, schools, police and fire protection, water and sewer, and recreation facilities (see Section 5.2.3.3).

#### 5.6.3.4 Housing

Housing demand under a high baseline condition for the preferred alternative would not exceed that for the geologic alternative (see Section 5.2.3.4). Given that housing construction is likely to pick up again as the local economy begins to recover, and that many of the jobs will be taken by local workers who already live in the area, housing impacts appear unlikely.

#### 5.6.3.5 Local Transportation

The total amount of increased traffic to the Hanford Site expected with the preferred alternative will be substantially lower than that associated with the Washington Public Power Supply System's peak construction period. Recent highway improvements in the area have alleviated many of the past problems. Given the assumed moderate growth in baseline conditions, local transportation impacts are unlikely.

#### 5.6.3.6 Education

No capital cost impacts are anticipated.

#### 5.6.3.7 Utilities and Other Services

Given adequate lead time and notification regarding future development, the affected utilities and other services probably can be adjusted adequately to changing conditions resulting from waste management activities associated with the preferred alternative.

#### 5.6.3.8 Fiscal Conditions

The proposed waste disposal activities probably would fiscally benefit the local communities. See also Appendix K.

#### 5.6.3.9 Social Conditions

Impacts on social conditions from implementing the preferred alternative are expected to be positive. There has been strong public support for proceeding with disposal as in the preferred alternative. For those wastes for which a disposal preference has been deferred, public comment will again be sought before disposal decisions are made.

### 5.6.4 Assessment of Long-Term Impacts

The primary performance objective of waste disposal systems is to provide reasonable assurance that radionuclides and inextricably intertwined chemicals in biologically significant concentrations are isolated and thus provide for long-term protection of public health and safety.

This section includes examination of impacts of waste disposal in the preferred alternative where 1) present conditions remain unchanged, 2) disposal systems are disrupted by postulated natural events, and 3) disposal systems are disrupted by intruders. Long-term impacts of waste types for which a disposal decision has been deferred are bounded by the impacts resulting from the geologic and reference disposal alternatives as discussed in Sections 5.2.4 and 5.4.4, respectively, and will not be repeated here.

This analysis draws upon the description of wastes and disposal alternatives in Chapter 3 and upon analyses in Appendix R of radiological consequences developed for appraisal of performance of the alternatives. Appendix R, in turn, is based on a conceptual protective barrier and marker system described in Appendices B and M, hydrologic modeling of the water pathway in Appendix O, description of modeling of source releases and inventories of radionuclides in Appendix P, information on hydrologic transport of chemicals in Appendix U, and probabilistic analysis in Appendix S.

#### 5.6.4.1 Long-Term Impacts Associated with the Alternative Where Present Conditions Remain Unchanged

In the preferred alternative, existing and future double-shell tank wastes, retrievably stored and newly generated TRU wastes, strontium and cesium capsules and pre-1970 buried suspect TRU-contaminated solid waste from the 618-11 site would be disposed of in a geologic repository(ies) according to the reference alternative; a decision on the disposal of the remaining wastes would be deferred. The residuals from processing of tank wastes for disposal in a repository would be grouted and disposed of in vaults on the Hanford site. A protective barrier and marker system would be installed over each of the near-surface waste sites. Inventories of key radionuclides so disposed of are shown in Table 5.47. Long-term impacts from these wastes would range from those of the geologic disposal alternative to those of the reference alternative, depending on the ultimate disposal decision on all waste classes. Those wastes placed in a geologic repository would be expected to remain isolated from the biosphere and not be expected to produce any significant health effects over 10,000 years.

**TABLE 5.47. Estimated Inventories[a] of Key Radionuclides Disposed of in the Preferred Alternative, Ci**

| Radionuclide | Total | In Geologic Repository | Decision Deferred | Near Surface |
|---|---|---|---|---|
| $^{14}C$ | 5,300 | 4 | 3,000 | 2,300 |
| $^{79}Se$ | 1,100 | 4 | 800 | 260 |
| $^{90}Sr$ | 120,000,000 | 79,000,000 | 42,000,000 | 1,100,000 |
| $^{99}Tc$ | 35,000 | 0 | 16,000 | 19,000 |
| $^{129}I$ | 58 | 0 | 24 | 34 |
| $^{137}Cs$ | 120,000,000 | 100,000,000 | 11,000,000 | 13,000,000 |
| $^{151}Sm$ | 1,200,000 | 530,000 | 650,000 | 32,000 |
| $^{238}U$ | 560 | 19 | 520 | 20 |
| $^{239-240}Pu$ | 120,000 | 57,000 | 52,000 | 12,000 |
| $^{241}Am$ | 390,000 | 330,000 | 39,000 | 17,000 |

(a) Values have been rounded and therefore may not sum.

Impacts where conditions remain unchanged and barriers perform as designed were estimated for the preferred alternative to range as follows (depending on ultimate decisions for all waste classes, geologic disposal to reference alternative):

| | Current Climate | Wetter Climate |
|---|---|---|
| Integrated 10,000-year population dose, man-rem | 6-10 | 30-40 |
| Presumed health effects | 0 | 0 |

#### 5.6.4.2 Long-Term Impacts Following Postulated Disruptive Events

All high-level and TRU wastes from existing double-shell tanks, future tank waste, strontium and cesium capsules, and retrievably stored and newly generated TRU waste will be disposed of in a geologic repository; thus, no long-term impacts following postulated disruptive events are calculated for that portion of the preferred alternative. The low-activity fraction of tank waste will be grouted and disposed of near surface.

An analysis was made of postulated natural and human-induced events that might disrupt confinement of wastes for those waste types for which a disposal alternative has been deferred and for the grouted residuals disposed of near surface. The following events were identified as candidates for analysis as disruptive events: large aircraft crashing onto a waste site, return of glaciation, a change to a wetter climate, and partial failure of a protective barrier. The most significant of these in terms of radiological impact was that associated with a wetter climate and postulated barrier failures.

For the preferred alternative, impacts were estimated to range as follows (depending on ultimate decisions for disposal of all classes, geologic disposal to reference alternative):

| | Wetter Climate With Barrier Failures |
|---|---|
| Integrated 10,000-year population dose, man-rem | 320-580 |
| Presumed health effects | 0-1 |

#### 5.6.4.3 Long-Term Impacts from Intrusion

Doses resulting from these events are bounded by the doses resulting from those described in the geologic and reference disposal alternatives (Sections 5.2.4.3 and 5.4.4.3, respectively). The most significant of these events in terms of radiation dose was that associated with the post-drilling scenario.

Impacts associated with the post-drilling scenario were estimated for the preferred alternative to range (depending on ultimate decisions for disposal of all waste classes) from individual maximum annual total-body doses of 5 rem/yr (single-shell tank waste to geologic repository) to 100 rem/yr (single-shell tank waste disposed of in place) where the intrusion takes place 100 years after disposal. For intrusion 400 years after disposal, the maximum annual total-body dose associated with the post-drilling scenario would range from 0.005 to 0.1 rem.

#### 5.6.4.4 Resettlement

This is the same event discussed previously and is calculated to have impacts bounded by those given in Section 5.2.4.4 for the geologic disposal alternative and Section 5.3.4.4 for the in-place stabilization and reference alternatives.

Impacts in the resettlement scenario were estimated for the preferred alternative to range as follows (depending on ultimate decisions for disposal of all waste classes, geologic disposal to reference alternative):

| | Current Climate | Wetter Climate |
|---|---|---|
| Integrated 10,000-year population dose, man-rem | 2,000-4,000 | 1,000-2,000 |
| Presumed health effects | 0-4 | 0-2 |

### 5.6.5 Irreversible and Irretrievable Commitment of Resources

The irreversible and irretrievable commitment of resources for the preferred disposal alternative includes commitments of energy, materials and manpower. Selected resource commitments are summarized in Table 5.48 (see Appendix L for details).

**TABLE 5.48. Irreversible and Irretrievable Resource Commitments Necessary to Implement the Preferred Alternative** (Reference alternative to geologic disposal alternative)

| Resource | HLW Onsite; TRU to WIPP | HLW Offsite; TRU to WIPP |
|---|---|---|
| Energy | | |
| Diesel fuel, $m^3$ | 14,000 - 120,000 | 14,000 - 120,000 |
| Propane, $m^3$ | 74,000 - 97,000 | 75,000 - 97,000 |
| Gasoline, $m^3$ | 4,200 - 14,000 | 4,200 - 15,000 |
| Electricity, GWh | 3,800 - 5,000 | 3,800 - 5,000 |
| Coal, t | 46,000 - 52,000 | 47,000 - 530,000 |
| Materials | | |
| Concrete, $m^3$ | 65,000 - 300,000 | 65,000 - 300,000 |
| Steel, t[(a)] | 14,000 - 80,000 | 14,000 - 80,000 |
| Stainless steel, t[(a)] | 1,400 - 6,600 | 1,400 - 6,500 |

(a) Partial recovery (as much as 25%) may be possible.

Resource use for the preferred alternatives is generally bounded by the geologic disposal and in-place stabilization and disposal alternatives.

### 5.6.6 Unavoidable Adverse Impacts

Unavoidable adverse impacts on workers and the public are summarized in Table 5.49. The radiological impacts associated with operational aspects of the disposal alternatives for workers are well within applicable standards, and doses to the public are insignificant compared to those from natural background.

### 5.6.7 Relationship to Land-Use Plans, Policies and Controls

The federal government preempted the Hanford Site in 1943 for activites in support of World War II and continued these activities for national defense during the "cold war" of the 1950s and thereafter. The Hanford Site remains dedicated to continued use for nuclear materials production, research and development and related activities. The disposal of the waste associated with these activities is inherent within, and a logical continuation of, the original preemption.

Implementation of the disposal portion of the preferred alternative will not conflict with any approved national, state, or local land-use policies as they currently exist. Implementation would not significantly alter the area already committed by previous waste processing and storage activities. In the case of an onsite repository, waste disposal use is consistent with current waste disposal policy, nuclear energy, defense and research and development activities of the Hanford Site.

TABLE 5.49. **Collective Total-Body Radiation Doses from Implementing the Preferred Alternative**[a]

| Exposure Classification | Collective Dose, man-rem: Repository Disposal[b] | Disposal Decision Deferred[c] |
|---|---|---|
| Occupational | 3,000 | 1,000 - 10,000 |
| Repository Emplacement | 200 | 0 - 1,000 |
| Offsite Population[d] | 0.9 | 0.3 - 40 |
| Transportation | | |
| TRU to WIPP; | | |
| HLW Onsite | 40 | 0 - 8 |
| HLW Offsite | 40 | 0 - 40 |

(a) All collective dose numbers have been rounded to one significant figure.
(b) Existing high-level fraction double-shell tank waste, high-level fraction future tank waste and capsules disposed of in a geologic repository. Low-activity fraction disposed of near surface in grout vaults. Retrievably stored and newly generated TRU waste disposed of in WIPP repository.
(c) Range depending on reference or geologic disposal of deferred wastes.
(d) For comparison, the same population would receive a dose from natural background of 2,500,000 man-rem.

Establishment of a National Environmental Research Park (NERP) at the Hanford Site has made available certain areas on the Site for arid lands ecological research consistent with DOE's nuclear energy and research and development activities. The operating and waste management areas on the Site are specifically excluded from the NERP areas, and all land on the Site remains available for nuclear-related activities.

No known archaeological sites on the Hanford Site would be affected by implementation of the disposal portion of the preferred alternative.

With regard to disposal of defense TRU waste at the WIPP site, the EIS for that site (DOE 1980b) presented a comparable discussion of the relationship of the proposed action to land-use plans, policies, and controls. It was concluded in the EIS that "... the activities of the WIPP project will comply with all applicable Federal, State, and local requirements for protecting the environment."

### 5.6.8 Relationship Between Near-Term Use of the Environment and Enhancement of Long-Term Productivity

The Hanford Site has a low biological productivity (see Chaper 4). The land occupied under any of the alternatives would occupy less than 0.5% of the total Site (about 20 ha) and would not significantly affect the biological productivity of the rest of the Site. No agriculture is practiced on the Site because of its exclusionary status and availability of other land better suited for growing crops and grazing livestock. Future plans for the Site call for its continued use as an area dedicated primarily to energy and defense activities.

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# CHAPTER 6.0

## APPLICABLE REGULATIONS

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## 6.0 APPLICABLE REGULATIONS

This chapter lists currently identified federal and state permits, licenses, and other entitlements that would be required before waste disposal actions would be implemented at the Hanford Site. In addition, other major regulations that might govern implementation activities, depending on the strategy chosen and standards of performance for disposal systems, are briefly described. Waste disposal actions could occur over a period of many years, and thus various regulations and permitting requirements would also be addressed before each specific activity was undertaken.

The DOE exercises its responsibilities for protection of public health and safety and the environment through a series of Departmental Orders, incumbent on contractors operating DOE-owned facilities. On the basis of statutory obligations such as compliance with the National Environmental Policy Act, certain EPA standards, etc., DOE has established a general environmental protection policy. The "Environmental Policy Statement," DOE N 5400.1, issued by Secretary Herrington on January 8, 1986, and extended on January 7, 1987, describes the Department's commitment to national environmental protection goals by conducting operations "in an environmentally safe and sound manner...in compliance with the letter and spirit of applicable environmental statutes, regulations, and standards." This Environmental Policy Statement also contains a Departmental commitment to "good environmental management in all of its programs and at all of its facilities in order to correct existing environmental problems, to minimize risks to the environment or public health, and to anticipate and address potential environmental problems before they pose a threat to the quality of the environment or public welfare." Further, "it is DOE's policy that efforts to meet environmental obligations be carried out consistently across all operations and among all field organizations and programs."

### 6.1 RADIATION PROTECTION

In 1960, the Federal Radiation Council (FRC) issued basic radiation protection guidance for use by all federal agencies. This guidance was based on the recommendations of the U.S. National Council on Radiation Protection and Measurements (NCRP) and in accord with guidelines from the International Commission for Radiological Protection (ICRP). Federal standards for radiation protection are in the process of being changed from standards based on limiting radiation exposures to various parts (critical organs) of the body to a system based on an equivalent total risk of health effects. This system accounts for both the combined risk from simultaneous irradiation of various parts of the body and the continued irradiation from radionuclides persisting in the body on the basis of updated recommendations from the NCRP and ICRP.

#### 6.1.1 Radiation Dose Limits

Chapter XI of DOE Order 5480.1A established radiation protection standards and requirements for DOE and DOE contractor operations, and provided additional guidance on maintaining exposures to radiation at levels as low as reasonably achievable (ALARA). Although the Order has been reissued as DOE Order 5480.1B, the original provisions remain in effect until superseded by other new Orders or by interim requirements provided by Memorandum from DOE Headquarters to Field Offices. Table 6.1, standards for occupational exposures, is taken from Chapter XI of Order 5480.1A.

**TABLE 6.1. Radiation Protection Standards for Occupationally Related External and Internal Exposure** (Information from DOE Order 5480.1A)

| Type of Exposure | Exposure Period | Dose Equivalent (Dose or Dose Commitment),[a] rem |
|---|---|---|
| Whole body, head and trunk, gonads, lens of the eye,[b] red bone marrow, active blood-forming organs | Year<br>Calendar quarter | 5[c]<br>3 |
| Unlimited areas of the skin (except hands and forearms). Other organs, tissues, and organ systems (except bone) | Year<br>Calendar quarter | 15<br>5 |
| Bone | Year<br>Calendar quarter | 30<br>10 |
| Forearms[d] | Year<br>Calendar quarter | 30<br>10 |
| Hands[d] and feet | Year<br>Calendar quarter | 75<br>25 |

(a) To meet the above dose commitment standards, operations must be conducted in such a manner that it would be unlikely for an individual to assimilate in a critical organ, by inhalation, ingestion, or absorption, a quantity of a radionuclide or mixture of radionuclides that would commit the individual to an organ dose exceeding the limits specified in this table.

(b) A beta exposure below a maximum energy of 700 keV will not penetrate the lens of the eye; therefore, the applicable limit for these energies would be that for the skin (15 rem/yr).

(c) In special cases, with the approval of the Director, DOE Division of Operational and Environmental Safety (currently the Assistant Secretary for Environment, Safety and Health), a worker may exceed 5 rem/yr, provided his or her average exposure per year since age 18 will not exceed 5 rem/yr. This does not apply to emergency situations.

(d) All reasonable effort shall be made to keep exposures of forearms and hands to the general limit for the skin.

By Memorandum to Field Offices (Vaughan 1985; Sheppard 1985), the basic radiation standards of Chapter XI for protection of the public were replaced by those shown in Table 6.2, effective July 1, 1985. New radiation protection guidance to federal agencies was approved January 20, 1987, by President Reagan and published in the Federal Register (52 FR 2822). At the time facilities are constructed, draft DOE Order 5480.11 (to supercede Chapter XI, DOE Order 5480.1B) implementing the new federal guidance should be promulgated.

**TABLE 6.2. Radiation Standards for Protection of the Public in the Vicinity of DOE Facilities**

The effective dose equivalent for any member of the public from all routine DOE operations[(a)] (natural background and medical exposures excluded) shall not exceed the values given below:

| | Effective Dose Equivalent[(b)] | |
|---|---|---|
| | mrem/yr | (mSv/yr) |
| Occasional exposure[(c)] | 500 | (5) |
| Prolonged period of exposure[(c)] | 100 | (1) |

No individual organ shall receive an annual dose equivalent in excess of 5000 mrem/yr (50 mSv/yr).

(a) Routine DOE operations means normal planned operations and does not include actual or potential accidental or unplanned releases.
(b) Effective dose equivalent shall be expressed in rem (or mrem) with the corresponding value in sievert (or mSv) in parentheses. As used in this standard, effective dose equivalent includes both the effective dose equivalent from external radiation and the committed effective dose equivalent from ingestion and inhalation during the calendar year.
(c) For the purpose of these standards, a prolonged exposure shall be one that lasts, or is predicted to last, longer than 5 years.

### 6.1.2 Concentration Guides

Using standard assumptions for air and water consumption, and radiation doses equivalent to the prescribed annual dose limits, concentration guides for radionuclides can be derived. In Chapter XI of DOE Order 5480.1A, such Concentration Guides (CG) were included for both workers and members of the public, paralleling those provided by the NRC for its licensees.

Derived Concentration Guides (DCG) for protection of members of the public were provided to DOE Field Offices for interim use, based on the new public dose limits shown in Table 6.2. Although such concentration guides are frequently useful in simplifying procedures for controlling or evaluating releases of radioactive materials, the basic standards continue to be the annual dose equivalents or effective dose equivalents.

## 6.2 WATER QUALITY

### 6.2.1 Federal Water Pollution Control Act (33 USC 1251 et seq.)

This Act requires all branches of the federal government involved in activity that may result in a point source discharge or runoff of pollutants to waters of the United States, excluding source, special nuclear or byproduct materials regulated under the Atomic Energy Act of 1954, to comply with applicable federal, state, interstate, and local requirements, including obtaining permits if required. The objective of the Act is to restore and maintain the integrity of the nation's water. (See the final interpretive rule for byproduct materials, Section 6.6.) The EPA (Region X) is the permitting and enforcement agency for National Pollutant Discharge Elimination System (NPDES) permits issued to federal facilities within Washington State.

For the actions addressed by this EIS, no liquid point source discharge will be made to navigable waters, and no new NPDES permits are expected to be required.

### 6.2.2 **Safe Drinking Water Act** (SDWA) (42 USC 300f et. seq.), **as Amended by SDWA Amendments of 1986** (Public Law 99-339)

The purpose of the SDWA is to set primary drinking water standards for owners/operators of public water systems and to prevent underground injection that can contaminate drinking water sources.

National Primary Drinking Water Regulations, 40 CFR 141. These regulations apply to maximum contamination levels in public water systems. The regulations set maximum contaminant levels for radionuclides that may be contained in the water supplied to ultimate users by community water systems. The first such community water system downstream from the Hanford Site is the municipal water plant for Richland, Washington, that draws water from the Columbia River and therefore could be affected by radionuclides originating on the Hanford Site; there are no community water systems on the Hanford Site.

Excerpts from 40 CFR 141 that are applicable to public water systems are as follows:

**§ 141.11 Maximum contaminant levels for inorganic chemicals.**

(a) The MCL for nitrate is applicable to both community water systems and non-community water systems except as provided by in paragraph (d) of this section. The levels for the other inorganic chemicals apply only to community water systems. Compliance with MCLs for inorganic chemicals is calculated pursuant to § 141.23.

(b) The following are the maximum contaminant levels for inorganic chemicals other than fluoride:

| Contaminant | Level, milligrams per liter |
|---|---|
| Arsenic | 0.05 |
| Barium | 1 |
| Cadmium | 0.010 |
| Chromium | 0.05 |
| Lead | 0.05 |
| Mercury | 0.002 |
| Nitrate (as N) | 10 |
| Selenium | 0.01 |
| Silver | 0.05 |

(c) The Maximum Contaminant Level for fluoride is 4.0 mg/l. See 40 CFR 143.3, which establishes a Secondary Maximum Contaminant Level at 2.0 mg/l.

(d) At the discretion of the State, nitrate levels not to exceed 20 mg/l may be allowed in a non-community water system if the supplier of water demonstrates to the satisfaction of the State that:

(1) Such water will not be available to children under 6 months of age; and

(2) There will be continuous posting of the fact that nitrate levels exceed 10 mg/l and the potential health effects of exposure; and

(3) Local and State public health authorities will be notified annually of nitrate levels that exceed 10 mg/l; and

(4) No adverse health effects shall result.

[40 FR 59570, Dec. 24, 1975, as amended at 45 FR 57342, Aug. 27, 1980; 47 FR 10998, Mar. 12, 1982; 51 FR 11410, Apr. 2, 1986]

**§ 141.16 Maximum contaminant levels for beta particle and photon radioactivity from man-made radionuclides in community water systems.**

(a) The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year.

(b) Except for the radionuclides listed in Table A, the concentration of man-made radionuclides causing 4 mrem total body or organ dose equivalents shall be calculated on the basis of a 2 liter per day drinking water intake using the 168 hour data listed in *"Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure,"* NBS Handbook 69 as amended August 1963, U.S. Department of Commerce. If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 millirem/year.

TABLE A—AVERAGE ANNUAL CONCENTRATIONS ASSUMED TO PRODUCE A TOTAL BODY OR ORGAN DOSE OF 4 MREM/YR

| Radionuclide | Critical organ | pCi per liter |
|---|---|---|
| Tritium | Total body | 20,000 |
| Strontium-90 | Bone marrow | 8 |

[41 FR 28404, July 9, 1976]

The foregoing contaminant limits are substantially the same as those of the Washington State Board of Health regarding public water systems, WAC 248-54-175.

Underground Injection Control (UIC), 40 CFR 144,146. Under the SDWA, any planned disposal of fluids by well injection, with the potential to contaminate groundwater that is an actual or potential source of drinking water, requires a specific rule by EPA or a UIC permit. Disposal of waste in a geologic repository may require a UIC permit.[a] No waste disposal by well injection is planned as part of the activities described in this EIS.[a]

## 6.3 AIR QUALITY

Clean Air Act (42 USC 7401 et seq., as amended). This wide-ranging Act is intended to protect the public health and welfare, not only by establishing national ambient air-quality

(a) See discussion of 40 CFR 191 infra. The U.S. Court of Appeals recently (Natural Resources Defense Council et al. vs. EPA) (Civil Action 85-1915) indicated that disposal of high-level waste in a geologic repository may constitute well injection under the Safe Drinking Water Act.

standards, but also by abating existing air pollution and by preventing further deterioration of air quality. Primary implementation and enforcement is by state and local authorities. Each federal agency such as the DOE, with jurisdiction over any property or facility that may discharge air pollutants, must comply with applicable federal, state, interstate and local requirements to control and abate air pollution.

National Emission Standards for Hazardous Air Pollutants; Standards for Radionuclides (40 CFR 61): National Emission Standard for Radionuclide Emissions From Department of Energy (DOE) Facilities (Subpart H). This Subpart specifically addresses DOE activities and, along with emission standards, requires that the Department notify and obtain needed approvals before construction of a new source of radionuclide emissions. The Department must also provide notice of intended and actual startup dates for such facilities. The Department intends to provide the required notices and obtain the necessary approvals for any new facilities addressed by this EIS, such as the Hanford Waste Vitrification Plant. The salient emission standards are set forth in 40 CFR 61.92, shown here. Emissions from DOE's current Hanford Site activities are well below the levels that would cause the standards of paragraph 61.92 to be exceeded.

Excerpts for 40 CFR 61 regarding emission standards for hazardous air pollutants are as follows:

**§ 61.92 Emission standard.**

Emissions of radionuclides to air from DOE facilities shall not exceed those amounts that cause a dose equivalent of 25 mrem/y to the whole body or 75 mrem/y to the critical organ of any member of the public. Doses due to radon-220, radon-222, and their respective decay products are excluded from these limits.

**§ 61.93 Emission monitoring and compliance procedures.**

To determine compliance with the standard, radionuclide emissions shall be determined and dose equivalents to members of the public shall be calculated using EPA approved sampling procedures, EPA models AIRDOS-EPA and RADRISK, or other procedures, including those based on environmental measurements, that EPA has determined to be suitable. Compliance with this standard will be determined by calculating the dose to members of the public at the point of maximum annual air concentration in an unrestricted area where any member of the public resides or abides.

List of approved methods: [Reserved]

**§ 61.97 Alternative emission standards.**(a)

If a facility may exceed the values established in § 61.92, DOE may apply to EPA for an alternative emission standard. The Administrator will review such applications and will establish an appropriate alternative emission standard that will ensure that no member of the public being exposed to emissions from the facility will receive a continuous exposure of than 100 mrem/y effective dose equivalent and a noncontinuous exposure of more than 500 mrem/y effective dose equivalent from all sources, excluding natural background and medical procedures. The application shall include the following:

(a) An assessment of the additional effective dose equivalents to the individual receiving maximum exposure from the facility due to all other sources.

(b) The information required in § 61.94.

(c) The effective dose equivalent shall be calculated using the following weighting factors:

| Organ | Weighting factor |
|---|---|
| [Reserved] | [Reserved] |

Requests for alternative emission standards shall be sent to the Assistant Administrator for Air and Radiation (ANR-443), U.S. Environmental Protection Agency, 401 M Street, Washington, D.C. 20460.

(a) It may be noted that the alternative emission standards of paragraph 61.97 are the same as the DOE's own standards shown in Table 6.2.

Washington State Department of Ecology: Ambient Standards for Emission of Radionuclides (WAC 173-480). The standards provide that emissions of radionuclides to the air shall not cause a dose equivalent of more than 25 mrem/yr to the whole body or 75 mrem/yr to a critical organ of any member of the public, the same criteria as those in 40 CFR 61.92. Provisions for the permitting, monitoring, control, and reporting of such emissions are contained in the regulation of the Department of Social and Health Services, WAC 402-80-010, et. seq. The DOE will comply with applicable requirements of these regulations.

Air Pollution Control Authority Regulations (regional). Authority for establishing air quality standards and regulation of air emissions in southeastern Washington rests with the Environmental Protection Agency and with the Washington State Department of Ecology, which in turn has designated the Benton-Franklin-Walla Walla Air Pollution Control Authority as the cognizant level of air pollution control authority. The DOE will comply with General Regulation 80-7 of the Authority and will provide Notification of Construction of New Facilities in accordance with requirements of Regulation 80-7. While it is not expected that any emissions will exceed the thresholds requiring Prevention of Significant Deterioration (PSD) permits, DOE will evaluate activities associated with implementation of the selected disposal alternative and will apply for and obtain any necessary PSD permits.

Regional air quality standards applicable to Hanford emissions are listed below:

1. Sulfur dioxide:

| | | |
|---|---|---|
| Sulfur dioxide: | 1-hr average: | 0.4 ppm (not more than once a year) |
| | 1-hr twice per week: | 0.25 ppm |
| | 24-hr average: | 0.1 ppm |
| | Annual average: | 0.02 ppm |

   Reference: WAC 18-56

2. Nitrogen dioxide: Annual arithmetic mean 100 $\mu g/m^3$.

   Reference: 40 CFR 50

3. Suspended particulates: Annual mean concentration shall not exceed 60 $\mu g/m^3$. If the annual mean background concentration exceeds 20 $\mu g/m^3$ due to rural fugitive dust, the standard becomes 40 $\mu g/m^3$ plus the background concentration. Maximum 24-hr concentrations of 150 $\mu g/m^3$ of air are not to be exceeded more than once a year. If the background concentration exceeds 30 $\mu g/m^3$ due to rural fugitive dust, the standard becomes 120 $\mu g/m^3$ plus the background concentration.

   Reference: WAC 18-40

4. Carbon monoxide: Average concentrations over 8 hr shall not exceed 10 $mg/m^3$ more than once per year. Further, a concentration of 40 $mg/m^3$ averaging over a 1-hr period shall not be exceeded more than once per year.

   Reference: WAC 173-475

5. Ozone: 0.12 ppm (235 $\mu g/m^3$) where the expected number of days with maximum hourly average concentrations above 0.12 ppm is equal to or less than 1.

   Reference: WAC 173-475

## 6.4 NUCLEAR WASTE POLICY ACT (Public Law 94-425)

The Nuclear Waste Policy Act (NWPA) addresses disposal of high-level waste and spent fuel in geologic repositories. However, the NWPA does not require that all materials regarded as high-level waste be disposed of in a geologic repository. The NWPA directs DOE to continue and accelerate a program of research, development and investigation of alternative means and technologies for the permanent disposal of high-level waste (NWPA Section 2.22). Moreover, 40 CFR 191.17 provides that EPA may, by rule, substitute for any of the provisions of Subpart B alternative provisions after appropriate rulemaking. This alternative rulemaking provision used as an example the disposal of some defense wastes by stabilizing them in their current storage tanks. The NRC is also considering (52 FR 5992, February 27) redefinition of high-level waste. All of these regulatory standards will be considered, according to the preferred alternative, after completion of further development and evaluation efforts.

## 6.5 EPA STANDARDS FOR MANAGEMENT AND DISPOSAL OF HIGH-LEVEL AND TRU WASTES[a]

Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste (40 CFR 191, 50 FR 38066, September 19, 1985 and 50 FR 40003, October 1, 1985).

40 CFR 191 Subpart A provides that management and storage of spent nuclear fuel or high-level or transuranic radioactive wastes at all facilities for the disposal of such fuel or waste that are operated by the Department of Energy, and that are not regulated by the Nuclear Regulatory Commission or Agreement States, shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public in the general environment resulting from discharges of radioactive material and direct radiation from such management and storage shall not exceed 25 millirems to the whole body and 75 millirems to any critical organ.

The preamble to 40 CFR 191 explains that this provision applies to DOE waste disposal facilities covered by this rule but not regulated by NRC, such as the Waste Isolation Pilot Plant (WIPP).

The preamble further indicates that, for other DOE waste management and storage operations (such as the DOE Hanford Site) with a large number of facilities and with many other potential sources of radionuclide emissions, EPA intended that continued regulation under the broader scope of 40 CFR 61 rather than 40 CFR 191 Subpart A is to apply. As noted in the earlier discussion of the Clean Air Act, Hanford Site activities currently are well below the limits set by 40 CFR 61 and are expected to remain so under any of the alternatives evaluated in this EIS.

(a) The U.S. Court of Appeals (National Resource Defense Council et al. vs EPA) (Civil Action 85-1915) vacated and remanded Subpart B of 40 CFR 191 back to EPA for further consideration. Analysis and discussion of 40 CFR 191 requirements are based on the vacated regulation as promulgated September 19, 1985.

40 CFR 191 Subpart B establishes standards for disposal of existing and future tank waste, encapsulated strontium and cesium, and retrievably stored and newly generated transuranic (TRU) waste to the extent that these wastes are classified as high-level or TRU waste. The standard does not apply to TRU-contaminated soil sites or pre-1970 buried TRU solid wastes because those wastes had been disposed of before the standard became effective. The hazardous-chemical component of the tank and TRU wastes will also be managed in accordance with RCRA and CERCLA regulations as applicable (see Sections 6.6 and 6.7).

In Appendix S of this EIS, a preliminary analysis is made of the disposal alternatives and the no disposal action alternative with respect to Subpart B of the standard. Since no confirmed statistical basis is available for such key parameters as retardation coefficients, barrier performance, and average annual recharge rate, it is necessary to assume such values in order to perform the probabilistic analysis called for in 40 CFR 191.

The analysis performed in Appendix S assumes that all of the waste classes included in this EIS are subject to the release provisions of the standard. While such will not be the case because only future disposal of high-level, spent fuel and TRU waste are subject to the standard, this conservative approach permits comparison of the impacts of near-surface disposal activities of each of the alternatives. Until experimental data are available, such calculations as shown in Appendix S are useful for illustration of the relative features of each alternative. They are not intended, however, to be used to demonstrate compliance, or lack thereof, with the standard. Any disposal systems for materials regulated under Subpart B will not be finally selected and utilized unless and until the requirements of Subpart B, or such alternative requirements as EPA may establish under 40 CFR 191.17, are met.

The assurance requirements of 40 CFR 191.14 have the following implications for the disposal alternatives:

Except for in-place stabilization and disposal of retrievably stored and newly generated TRU wastes, and possibly single-shell tank waste in the in-place stabilization and disposal alternative and the reference alternatives, [with respect to 191.14 (d)] and double-shell tank waste in grout [with respect to 191.14 (f)], it appears that all of the assurance requirements would be met for all of the waste classes and all of the disposal alternatives. Additional engineered barriers might be needed for single-shell tank waste and retrievably stored and newly generated TRU waste to satisfy the assurance requirements if those wastes were to be disposed of according to the in-place stabilization and disposal alternative.

**191.14 (a) Active institutional controls over disposal sites should be maintained as long as practicable after disposal.**

Federal ownership and presence, and thus active institutional controls, on the Hanford Site are planned in perpetuity. The active institutional controls for the WIPP are similar and are described in DOE 1980. For a repository, at Hanford or elsewhere, description of institutional controls will be included in the license application. Planned presence of active institutional controls is invariant with alternatives analyzed in this EIS, and is as prescribed in 191.14 (a), thus satisfying this assurance requirement. Moreover, the nonreliance on active institutional controls called for in 191.14 (a) was treated uniformly in analysis of potential environmental impacts of each of the alternatives.

**191.14 (b) Disposal systems shall be monitored after disposal to detect substantial and detrimental deviations from expected performance.**

Ongoing environmental monitoring at the Hanford Site (Jaquish and Mitchell 1987) is also planned in perpetuity. Additional wells will be drilled at the grout disposal site and monitored following disposal. Monitoring for the WIPP is described in Appendix J of the final EIS for WIPP (DOE 1980). Monitoring at a geologic repository, at Hanford or elsewhere, would be conducted in accordance with the Performance Confirmation Program (10 CFR 60 Subpart F). Monitoring is either ongoing or planned in each of the alternatives, as a consequence, this assurance requirement would be satisfied.

**191.14 (c) Disposal sites shall be designated by the most permanent markers, records, and other passive institutional controls.**

The planned protective barrier and marker system for the 200 Areas is described in Appendix B. Passive controls at WIPP are described in Section 8.11.14 of the EIS for that facility (DOE 1980), and passive controls required for a commercial geologic repository are described in 10 CFR 60.51, "License Amendment of Permanent Closure." Provision has been made to satisfy this assurance requirement. Since the same system of passive controls, such as monuments, records, etc., would be employed regardless of disposal alternative selected for use on the Hanford Site, no distinction between alternatives on a basis of this assurance requirement is seen.

**191.14 (d) Disposal systems shall use different types of barriers, both engineered and natural, to isolate the wastes from the accessible environment.**

At geologic repositories, including the WIPP, the barriers are the waste form and its containers and overpacks, the geologic medium, and the geologic and hydrologic system in which the repositories are embedded. Thus, this assurance requirement would be met for all waste disposed of in geologic repositories.

Under the in-place stabilization and disposal alternative, the first barrier for tank wastes is the waste form (solidified from a liquid waste form that has been found to leak from some of the single-shell tanks). That waste form is covered with gravel or other substance to fill the tank and reduce the chance for subsidence. The second barrier is the steel shell(s), or primary container (tank). The steel shell(s) are further surrounded by a concrete shell. The tank structures are several meters below grade, some 60 m above groundwater, in relatively dry soils in an arid environment, and whole tank farms would be covered by an engineered protective barrier. While both natural and engineered barriers would be provided for tank wastes disposed of in the in-place stabilization and disposal alternative, the EPA has reserved judgment as to whether or not the protective barrier would be considered sufficient to meet the requirement of 40 CFR 191.14 (d) with respect to disposal in the in-place stabilization and disposal or reference alternatives.

If double-shell tank waste were processed into a grout and disposed of in vaults rather than reintroduced into double-shell tanks, so-called RCRA vaults for the grout would replace the double steel and concrete tanks as engineered barriers.

Strontium and cesium waste is doubly encapsulated and placed in handling containers that are placed within steel and concrete drywell structures below grade and covered by the protective barrier. Thus, both natural and engineered barriers are employed under the in-place stabilization and disposal alternative for encapsulated wastes.

Pre-1970 TRU-contaminated soil sites and pre-1970 buried suspect TRU-contaminated solid wastes were previously disposed of and are excluded from provisions of 40 CFR 191.

Post-1970 TRU waste was put in barrels and the barrels placed on asphalt pads for 20-year retrievable storage. As part of in-place stabilization and disposal, these wastes would be left in place or removed and buried if presently stored in buildings. The sites would be covered with the protective barrier. Since the engineered barriers associated with this waste class consist of only the container barrel and the protective barrier, this waste class might not meet this assurance requirement calling for multiple engineered barriers under the in-place stabilization and disposal alternative.

**191.14 (e) Places where there has been mining for resources or where there is a reasonable expectation of exploration for scarce or reasonably accessible resources or where there is a significant concentration of any material that is not widely available from other sources shall not be used for disposal of wastes.**

Although the presence of mineral or hydrocarbon resources cannot be ruled out, exploration to date has not produced evidence of unique and significant concentrations of any valuable mineral resource (DOE 1986) at the Hanford Site. Exploratory wells have been drilled in search of natural gas and oil in the vicinity of Hanford, however none of these were deemed to have commercial value by the exploring oil companies. The speculation that oil might exist in sediments beneath the area's basalt layers, which are thousands of feet thick, does not constitute reasonable expectation of scarce or reasonably accessible resources. With the exception of small gold placers along the Columbia River, there are no valuable metallic mineral resources known or believed likely on the Hanford Site. In the absence of reasonable expectation of unique and valuable resources, the Hanford Site would appear to meet this assurance requirement for any of the alternatives.

Mining considerations for the WIPP are discussed in the final EIS for that facility (DOE 1980).

**191.14 (f) Disposal systems shall be selected so that removal of most of the wastes is not precluded for a reasonable period of time after disposal.**

For materials disposed of in geologic repositories, retrievability is required by 10 CFR 60.111 (b) and thus the assurance requirement would be met. Except for double-shell tank waste, all wastes disposed of near surface in the in-place stabilization and disposal alternative would be retrievable, albeit with some difficulty and cost, thus meeting the assurance requirement. Double-shell tank waste, under the in-place stabilization and disposal alternative, is removed from the tanks, cesium is removed from future double-shell tank waste, and the remainder is made into grout for near-surface disposal. Since, in this case, it could be construed that this waste form contains "most" of the waste, retrieval for a reasonable period of time would have to be addressed.

Retrieval of TRU waste from WIPP would be possible even after the planned test and retrieval period (DOE 1980, Section 8.10).

Excerpts from 40 CFR 191 that bear in particular on this EIS are given below.

**§ 191.13 Containment requirements.**

(a) Disposal systems for spent nuclear fuel or high-level or transuranic radioactive wastes shall be designed to provide a reasonable expectation, based upon performance assessments, that the cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal from all significant processes and events that may affect the disposal system shall:

(1) Have a likelihood of less than one chance in 10 of exceeding the quantities calculated according to Table 1 (Appendix A); and

(2) Have a likelihood of less than one chance in 1,000 of exceeding ten times the quantities calculated according to Table 1 (Appendix A).

(b) Performance assessments need not provide complete assurance that the requirements of § 191.13(a) will be met. Because of the long time period involved and the nature of the events and processes of interest, there will inevitably be substantial uncertainties in projecting disposal system performance. Proof of the future performance of a disposal system is not to be had in the ordinary sense of the word in situations that deal with much shorter time frames. Instead, what is required is a reasonable expectation, on the basis of the record before the implementing agency, that compliance with § 191.13 (a) will be achieved.

**§ 191.14 Assurance requirements.**

To provide the confidence needed for long-term compliance with the requirements of § 191.13, disposal of spent nuclear fuel or high-level or transuranic wastes shall be conducted in accordance with the following provisions, except that these provisions do not apply to facilities regulated by the Commission (see 10 CFR Part 60 for comparable provisions applicable to facilities regulated by the Commission):

(a) Active institutional controls over disposal sites should be maintained for as long a period of time as is practicable after disposal; however, performance assessments that assess isolation of the wastes from the accessible environment shall not consider any contributions from active institutional controls for more than 100 years after disposal.

(b) Disposal systems shall be monitored after disposal to detect substantial and detrimental deviations from expected performance. This monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring.

(c) Disposal sites shall be designated by the most permanent markers, records, and other passive institutional controls practicable to indicate the dangers of the wastes and their location.

(d) Disposal systems shall use different types of barriers to isolate the wastes from the accessible environment. Both engineered and natural barriers shall be included.

(e) Places where there has been mining for resources, or where there is a reasonable expectation of exploration for scarce or easily accessible resources, or where there is a significant concentration of any material that is not widely available from other sources, should be avoided in selecting disposal sites. Resources to be considered shall include minerals, petroleum or natural gas, valuable geologic formations, and ground waters that are either irreplaceable because there is no reasonable alternative source of drinking water available for substantial populations or that are vital to the preservation of unique and sensitive ecosystems. Such places shall not be used for disposal of the wastes covered by this part unless the favorable characteristics of such places compensate for their greater likelihood of being disturbed in the future.

(f) Disposal systems shall be selected so that removal of most of the wastes is not precluded for a reasonable period of time after disposal.

**§ 191.15 Individual protection requirements.**

Disposal systems for spent nuclear fuel or high-level or transuranic radioactive wastes shall be designed to provide a reasonable expectation that, for 1,000 years after disposal, undisturbed performance of the disposal system shall not cause the annual dose equivalent from the disposal system to any member of the public in the accessible environment to exceed 25 millirems to the whole body or 75 millirems to any critical organ. All potential pathways (associated with undisturbed performance) from the disposal system to people shall be considered, including the assumption that individuals consume 2 liters per day of drinking water from any significant source of ground water outside of the controlled area.

**§ 191.16 Ground water protection requirements.** (a)

(a) Disposal systems for spent nuclear fuel or high-level or transuranic radioactive wastes shall be designed to provide a reasonable expectation that, for 1,000 years after disposal, undisturbed performance of the disposal system shall not cause the radionuclide concentrations averaged over any year in water withdrawn from any portion of a special source of ground water to exceed:

(1) 5 picocuries per liter of radium-226 and radium-228;

(2) 15 picocuries per liter of alpha-emitting radionuclides (including radium-226 and radium-228 but excluding radon); or

(3) The combined concentrations of radionuclides that emit either beta or gamma radiation that would produce an annual dose equivalent to the total body or any internal organ greater than 4 millirems per year if an individual consumed 2 liters per day of drinking water from such a source of ground water.

(b) If any of the average annual radionuclide concentrations existing in a special source of ground water before construction of the disposal system already exceed the limits in § 191.16(a), the disposal system shall be designed to provide a reasonable expectation that, for 1,000 years after disposal, undisturbed performance of the disposal system shall not increase the existing average annual radionuclide concentrations in water withdrawn from that special source of ground water by more than the limits established in § 191.16(a).

**§ 191.17 Alternative provisions for disposal.**

The Administrator may, by rule, substitute for any of the provisions of Subpart B alternative provisions chosen after:

(a) The alternative provisions have been proposed for public comment in the FEDERAL REGISTER together with information describing the costs, risks, and benefits of disposal in accordance with the alternative provisions and the reasons why compliance with the existing provisions of Subpart B appears inappropriate;

(b) A public comment period of at least 90 days has been completed, during which an opportunity for public hearings in affected areas of the country has been provided; and

(c) The public comments received have been fully considered in developing the final version of such alternative provisions.

**§ 191.18 Effective date.**

The standards in this subpart shall be effective on November 18, 1985.

[50 FR 38084, Sept. 19, 1985; 50 FR 40003, Oct. 1, 1985]

**APPENDIX A—TABLE FOR SUBPART B**

TABLE 1—RELEASE LIMITS FOR CONTAINMENT REQUIREMENTS

[Cumulative releases to the accessible environment for 10,000 years after disposal]

| Radionuclide | Release limit per 1,000 MTHM or other unit of waste (see notes) (curies) |
|---|---|
| Americium-241 or -243 | 100 |
| Carbon-14 | 100 |
| Cesium-135 or -137 | 1,000 |
| Iodine-129 | 100 |
| Neptunium-237 | 100 |
| Plutonium-238, -239, -240, or -242 | 100 |
| Radium-226 | 100 |
| Strontium-90 | 1,000 |
| Technetium-99 | 10,000 |
| Thorium-230 or -232 | 10 |
| Tin-126 | 1,000 |
| Uranium-233, -234, -235, -236, or -238 | 100 |
| Any other alpha-emitting radionuclide with a half-life greater than 20 years | 100 |
| Any other radionuclide with a half-life greater than 20 years that does not emit alpha particles | 1,000 |

**APPLICATION OF TABLE 1**

NOTE 1: *Units of Waste.* The Release Limits in Table 1 apply to the amount of wastes in any one of the following:

(a) An amount of spent nuclear fuel containing 1,000 metric tons of heavy metal (MTHM) exposed to a burnup between 25,000 megawatt-days per metric ton of heavy metal (MWd/MTHM) and 40,000 MWd/MTHM;

(b) The high-level radioactive wastes generated from reprocessing each 1,000 MTHM exposed to a burnup between 25,000 MWd/MTHM and 40,000 MWd/MTHM;

(c) Each 100,000,000 curies of gamma or beta-emitting radionuclides with half-lives greater than 20 years but less than 100 years (for use as discussed in Note 5 or with materials that are identified by the Commission as high-level radioactive waste in accordance with part B of the definition of high-level waste in the NWPA);

(d) Each 1,000,000 curies of other radionuclides (i.e., gamma or beta-emitters with half-lives greater than 100 years or any alpha-emitters with half-lives greater than 20 years) (for use as discussed in Note 5 or with materials that are identified by the Commission as high-level radioactive waste in accordance with part B of the definition of high-level waste in the NWPA); or

(a) According to definitions in this standard there are no special sources of groundwater at Hanford; hence Section 191.16 would not apply at Hanford.

(e) An amount of transuranic (TRU) wastes containing one million curies of alpha-emitting transuranic radionuclides with half-lives greater than 20 years.

NOTE 2: *Release Limits for Specific Disposal Systems.* To develop Release Limits for a particular disposal system, the quantities in Table 1 shall be adjusted for the amount of waste included in the disposal system compared to the various units of waste defined in Note 1. For example:

(a) If a particular disposal system contained the high-level wastes from 50,000 MTHM, the Release Limits for that system would be the quantities in Table 1 multiplied by 50 (50,000 MTHM divided by 1,000 MTHM).

(b) If a particular disposal system contained three million curies of alpha-emitting transuranic wastes, the Release Limits for that system would be the quantities in Table 1 multiplied by three (three million curies divided by one million curies).

(c) If a particular disposal system contained both the high-level wastes from 50,000 MTHM *and* 5 million curies of alpha-emitting transuranic wastes, the Release Limits for that system would be the quantities in Table 1 multiplied by 55:

$$\frac{50{,}000 \text{ MTHM}}{1{,}000 \text{ MTHM}} + \frac{5{,}000{,}000 \text{ curies TRU}}{1{,}000{,}000 \text{ curies TRU}} = 55$$

NOTE 3: *Adjustments for Reactor Fuels with Different Burnup.* For disposal systems containing reactor fuels (or the high-level wastes from reactor fuels) exposed to an average burnup of less than 25,000 MWd/MTHM or greater than 40,000 MWd/MTHM, the units of waste defined in (a) and (b) of Note 1 shall be adjusted. The unit shall be multiplied by the ratio of 30,000 MWd/MTHM divided by the fuel's actual average burnup, except that a value of 5,000 MWd/MTHM may be used when the average fuel burnup is below 5,000 MWd/MTHM and a value of 100,000 MWd/MTHM shall be used when the average fuel burnup is above 100,000 MWd/MTHM. This adjusted unit of waste shall then be used in determining the Release Limits for the disposal system.

For example, if a particular disposal system contained only high-level wastes with an average burnup of 3,000 MWd/MTHM, the unit of waste for that disposal system would be:

$$1{,}000 \text{ MTHM} \times \frac{(30{,}000)}{(5{,}000)} = 6{,}000 \text{ MTHM}$$

If that disposal system contained the high-level wastes from 60,000 MTHM (with an average burnup of 3,000 MWd/MTHM), then the Release Limits for that system would be the quantities in Table 1 multiplied by ten:

$$\frac{60{,}000 \text{ MTHM}}{6{,}000 \text{ MTHM}} = 10$$

which is the same as:

$$\frac{60{,}000 \text{ MTHM}}{1{,}000 \text{ MTHM}} \times \frac{(5{,}000 \text{ MWd/MTHM})}{(30{,}000 \text{ MWd/MTHM})} = 10$$

NOTE 4: *Treatment of Fractionated High-Level Wastes.* In some cases, a high-level waste stream from reprocessing spent nuclear fuel may have been (or will be) separated into two or more high-level waste components destined for different disposal systems. In such cases, the implementing agency may allocate the Release Limit multiplier (based upon the original MTHM and the average fuel burnup of the high-level waste stream) among the various disposal systems as it chooses, provided that the total Release Limit multiplier used for that waste stream at all of its disposal systems may not exceed the Release Limit multiplier that would be used if the entire waste stream were disposed of in one disposal system.

NOTE 5: *Treatment of Wastes with Poorly Known Burnups or Original MTHM.* In some cases, the records associated with particular high-level waste streams may not be adequate to accurately determine the original metric tons of heavy metal in the reactor fuel that created the waste, or to determine the average burnup that the fuel was exposed to. If the uncertainties are such that the original amount of heavy metal or the average fuel burnup for particular high-level waste streams cannot be quantified, the units of waste derived from (a) and (b) of Note 1 shall no longer be used. Instead, the units of waste defined in (c) and (d) of Note 1 shall be used for such high-level waste streams. If the uncertainties in such information allow a range of values to be associated with the original amount of heavy metal or the average fuel burnup, then the calculations described in previous Notes will be conducted using the values that result in the smallest Release Limits, except that the Release Limits need not be smaller than those that would be calculated using the units of waste defined in (c) and (d) of Note 1.

NOTE 6: *Uses of Release Limits to Determine Compliance with § 191.13* Once release limits for a particular disposal system have been determined in accordance with Notes 1 through 5, these release limits shall be used to determine compliance with the requirements of § 191.13 as follows. In cases where a mixture of radionuclides is projected to be released to the accessible environment, the limiting values shall be determined as follows: For each radionuclide in the mixture, determine the ratio between the cumulative release quantity projected over 10,000 years and the limit for that radionuclide as determined from Table 1 and Notes 1 through 5. The sum of such ratios for all the radionuclides in the mixture may not exceed one with regard to § 191.13(a)(1) and may not exceed ten with regard to § 191.13(a)(2).

For example, if radionuclides A, B, and C are projected to be released in amounts $Q_a$, $Q_b$, and $Q_c$, and if the applicable Release Limits are $RL_a$, $RL_b$, and $RL_c$, then the cumulative releases over 10,000 years shall be limited so that the following relationship exists:

$$\frac{Q_a}{RL_a} + \frac{Q_b}{RL_b} + \frac{Q_c}{RL_c} < 1$$

## 6.6 TRANSPORTATION REGULATIONS (see Appendix I for additional details)

Two types of packaged waste may be shipped from Hanford for offsite geologic disposal: Retrievable TRU waste will be shipped to the WIPP repository in New Mexico. HLW may be shipped to an offsite geologic repository if a repository is not constructed on the Hanford Site. Table 6.3 summarizes the applicable federal regulations for transportation of nuclear material. These will be complied with for offsite shipments of waste. In addition state transportation requirements applicable to transportation of radioactive waste from the Hanford Site (e.g., routing requirements) will be followed to the extent that such requirements are not inconsistent with federal regulations.

**TABLE 6.3. Summary of Major Federal Transportation Requirements**

| Government Agency | Code | Part No. | Title |
|---|---|---|---|
| NRC | 10 CFR | 71 | Packaging of radioactive material for transport and transportation of radioactive material under certain conditions |
| DOT | 49 CFR | 171 | General information, regulations, and definitions |
| DOT | 49 CFR | 172 | Hazardous materials tables and hazardous material communications regulations |
| DOT | 49 CFR | 173 | Shippers--general requirements for shipment and packaging |
| DOT | 49 CFR | 174 | Carriage by rail |
| DOT | 49 CFR | 177 | Carriage by public highway |
| DOT | 49 CFR | 178 | Shipping container specifications |

## 6.7 RESOURCE CONSERVATION AND RECOVERY ACT

Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976 and the Solid Waste Amendments of 1984 (42 USC 6901-6987).

The Resource Conservation and Recovery Act (RCRA) provides for protection of public health and the environment from activities associated with the management and disposal of solid and hazardous wastes. It sets forth requirements for generators and transporters of hazardous waste and also establishes a specific permit program for treatment, storage, and disposal of hazardous wastes. The statute is intended to place primary responsibility for control of solid waste activities on state and local governments. Under Section 6001 of RCRA, federal activities are subject to applicable federal, state, interstate, and local solid and hazardous waste requirements.

Source, special nuclear and byproduct materials are specifically exempted from the definition of a solid waste in Section 1004 of RCRA. Section 1006 of RCRA also provides that the provisions of the Act shall not apply to, nor authorize regulation of, any activity or substance which is subject to the Atomic Energy Act (AEA) of 1954, as amended, except to the extent that such an application or regulation is not inconsistent with requirements of that Act.

On May 1, 1987, the DOE issued (10 CFR 962), a final interpretative rule under Section 161p. of the Atomic Energy Act of 1954 (42 U.S.C. Paragraph 2011 et seq., hereinafter "the AEA") for the purpose of clarifying DOE's obligations under the Resource Conservation and Recovery Act (42 U.S.C. paragraph 6901 et seq., hereinafter "RCRA"). This final rule interprets the AEA definition of the term "byproduct material," set forth in Section 11e(1) of the Act [42 U.S.C. paragraph 2014(e)(1)], as it applies to DOE-owned or produced radioactive waste substances that are also "hazardous waste" within the meaning of RCRA. The effect of this rule is that all DOE radioactive waste that is also hazardous under RCRA will be subject to regulation under both RCRA and the AEA. This rule provides that only the actual radionuclides in DOE waste streams will be considered byproduct material. The non-radioactive components of those waste streams, under the final rule, will be subject to regulation under Subtitle C of RCRA to the extent that they contain hazardous components. However, the preamble to the final rule emphasizes the importance of Section 1006(a) in resolving any particular inconsistancies that may occur between the requirements of RCRA and those of the AEA. The DOE will comply with all applicable regulations promulgated pursuant to RCRA to the extent that such regulations are not inconsistent with AEA requirements.

The EPA has promulgated regulations to implement RCRA Subtitle C for treatment, storage and disposal (TSD) of hazardous waste requirements at 40 CFR 260-270. The hazardous waste regulations contain interim status standards that are applicable to TSD hazardous waste before a final permit is issued, and final status standards applicable after issuance of a final status permit. Corrective action is also required for releases of hazardous wastes or constituents from solid waste management units at a TSD facility. The State of Washington has promulgated hazardous waste regulations in WAC 173-303, pursuant to Chapter 70.105 of the Revised Code of Washington (RCW). The EPA has authorized the State of Washington to conduct the major portions of the RCRA hazardous waste interim status and final status permit program for hazardous wastes. The EPA has determined that wastes containing both hazardous waste and radioactive waste are subject to RCRA regulation (51 FR 24504, July 3, 1986). The State of Washington has not yet been authorized by EPA to implement the RCRA program for radioactive mixed wastes. However, on September 22, 1987 EPA published a rule notifying the public that Washington has applied for final RCRA authorization, which includes regulation of radioactive mixed wastes, and EPA intends to approve Washington's program. Final authorization is to be effective November 23, 1987 unless EPA withdraws its rulemaking. The EPA has retained authority to implement those sections of the hazardous waste program mandated by the 1984 amendments to RCRA. Regulated hazardous wastes generated by any of the disposal activities would be treated, stored and disposed of in accordance with applicable EPA and state requirements.

While the final delineation of specific radioactive waste streams subject to RCRA remains to be determined, facilities such as HWVP and WRAP, which may be constructed under the defense waste program evaluated in this EIS, would be designed, constructed, permitted and operated to treat or dispose of radioactive wastes with hazardous constituents in accordance with applicable RCRA requirements. Characterization studies pursuant to RCRA are being planned for those wastes currently in storage and those that will be generated by the HWVP and WRAP facilities. For example, preliminary analysis indicates that the low-activity constituent wastes (including residual waste from processing of double-shell tank wastes) will be classified as hazardous waste under RCRA. Therefore, the disposal of the low-activity constituent waste would utilize a disposal concept consistent with RCRA requirements (i.e., disposal as a cementitious grout in RCRA-type concrete vaults with appropriate monitoring and closure plans).

No final disposal or remedial action decision is being recommended in the preferred alternative for single-shell tank wastes, TRU-contaminated soil sites or pre-1970 suspect TRU buried solid waste sites, pending further development and evaluation.

The DOE intends to work closely with EPA and the State of Washington in addressing the potential RCRA issues associated with the disposal alternatives for these wastes. As noted in Section 6.8 of this EIS, DOE is working with the Environmental Protection Agency and the State of Washington to develop a comprehensive CERCLA/RCRA agreement for the Hanford Site. As noted by EPA in its comments on the draft HDW-EIS, these are novel issues associated with single-shell tank waste and other previously disposed-of waste classes at Hanford. Remediation under CERCLA or RCRA should be planned so as to facilitate ultimate disposal of radioactive wastes under the Energy Reorganization Act, Nuclear Waste Policy Act and other relevant statutes. The DOE plans to assure that future development and evaluation activities, and any future remedial or disposal actions, will reflect the regulatory program determined to be applicable to these wastes.

## 6.8 COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (42 USC Section 9601 et seq., as amended)

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) provides for liability, compensation, cleanup and emergency response for hazardous substances released into the environment and the cleanup of releases of hazardous substances as defined in CERCLA. For the private sector, it provides for a "superfund" source of funding to assure remedial action at certain qualifying hazardous waste sites. Funding is not provided under this Act for remedial action at federal operations.

The DOE implements CERCLA through DOE Order 5480.14 (April 26, 1985), which sets forth a policy and program to identify and evaluate potential problems associated with releases or potential for releases of hazardous substances from DOE facilities, to control the migration of hazardous substances from waste facilities, and to minimize the potential hazards to health, safety, and the environment that may result from those waste operations.

In October 1986, CERCLA was amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). Of particular importance is Section 120, which confirms and re-emphasizes that CERCLA is applicable to federal facilities and defines the process by which federal agencies are required to undertake remedial actions at their facilities. These amendments also affirm the applicability and the corrective action requirements of Section 3004(u) of RCRA. The responsibilities for implementation of the various provisions of CERCLA, as amended, are set forth in Executive Order 12580, dated January 23, 1987.

Hanford is presently completing Phase I and has initiated Phase II, site characterization, of the DOE program for compliance with CERCLA set forth in DOE Order 5480.14 (currently under revision). As part of this program, DOE, in August 1987, submitted to EPA the information needed to allow EPA to evaluate the waste sites for listing in the National Priority Listing. The current DOE program at Hanford is being revised and supplemented as appropriate to incorporate the requirements of the Superfund Amendments and Reauthorization Act (SARA).

The DOE is currently working with the Environmental Protection Agency and the State of Washington to develop a Federal Facilities Agreement addressing the program DOE will implement at Hanford to comply with the requirements of CERCLA. In recognition of the importance of addressing future waste management, disposal and remedial action in a unified and comprehensive manner, DOE has proposed that the agreement comprehensively address both CERCLA and RCRA activities at Hanford.

## 6.9 NOISE CONTROL ACT OF 1972 (42 USC 4901 et seq.)

Section 4 of the Federal Noise Control Act directs all federal agencies "to the fullest extent within their authority" to carry out programs within their jurisdiction in a manner that furthers a national policy of promoting an environment free from noise that jeopardizes public health or welfare. The DOE will comply with such requirements to the fullest extent possible.

## 6.10 CULTURAL AND NATURAL RESOURCES

While the majority of the disposal activities evaluated in this EIS are expected to occur in the 200 Areas of the Site (e.g., the construction of the HWVP), the following statutes may have relevance to some of these activities, particularly if they occur outside of the existing operational or previously utilized areas.

American Indian Religious Freedom Act (42 USC Section 1996, 43 CFR 7). The American Indian Religious Freedom Act provides the policy of the United States to protect and preserve, for American Indians, their right to believe, express and exercise tribal religious beliefs. While active institutional control exists on the Hanford Site, access to the Site will necessarily remain subject to some security restrictions. However, consultation and other appropriate actions regarding the American Indian Religious Freedom Act (Public Law 95-341) is planned as part of implementation of the disposal options finally chosen.

National Historic Preservation Act, 16 USC 470 et seq.; Executive Order 11593, Protection and Enhancement of the Cultural Environment; Archaeological and Historic Preservation Act, 16 USC 469-469c; and Historic Sites Act, 16 USC 461-467; 36 CFR 60, 36 CFR 63, and 36 CFR 800. Pursuant to these acts and Executive Order 11593, DOE must provide an opportunity as appropriate for comment and consultation with the Advisory Council on Historic Preservation, specifically the State Historic Preservation Officer (SHPO). The Section 106 process is detailed in 36 CFR 800, and has three phases (which are outlined in 36 CFR 800.4, 800.5, and 800.6 respectively):

1. Cultural resources that may be affected by disposal activities will be identified and evaluated for significance (i.e., possible listing in the National Register);
2. The effect of DOE's undertaking on historical resources listed in or eligible for listing in the National Register will be assessed;
3. The Advisory Council on Historic Preservation will have an opportunity to comment on the determination of effect.

DOE will comply with the requirements of these several Acts.

A Programmatic Memorandum of Agreement among the Advisory Council on Historic Preservation, the Washington State Historic Preservation Office, and the U.S. Department of Energy is being established to outline procedures that will be followed in the management and treatment of cultural resources encountered during Site activities. Letter number 223, State of Washington Nuclear Waste Board, contains a letter from the State of Washington Office of Archaeology and Historic Preservation (Vol 5, p 475). The state archaeologist recommends that professional archaeological resources surveys be conducted for proposed new construction and excavation. Subsequent contact with the SHPO is documented in Section 4.8.5.

Archaeological Resources Protection Act, 16 USC 470aa-47011 and 43 CFR 7, 36 CFR 296, 18 CFR 1312, 32 CFR 229; and the Antiquities Act, 16 USC 431-33 and 43 CFR 3. The ARPA is designed to protect archaeological resources on public and Native American lands by providing criminal and civil penalties for the unauthorized excavation and removal of these resources. The ARPA enlarges and further defines the requirements under the Antiquities Act and also requires consideration for the provisions of the American Indian Religious Freedom Act in promulgating regulations under ARPA.

The ARPA provides for the excavation and removal of archaeological resources which may be required during a cultural resources management plan and prior to disposal activities, and provides a process by which Native Americans can become involved in the consideration of tribal religious or cultural sites that may be impacted by archaeological investigations.

Permitting requirements are included in ARPA, with waiver provisions.

Under the Antiquities Act, DOE is responsible for the protection of paleontological resources as prehistoric properties.

Archaeology and Historic Preservation Laws: Archaeology and Historic Preservation, RCW 27.34; Indian Graves and Records, RCW 27.44. These state statutes generally provide for the protection of resources in similar manner to the federal statutes.

Endangered Species Act (16 USC Sections 1531-1543, 50 CFR 402, 43 FR 19957, June 3, 1986). The Endangered Species Act establishes a federal policy to conserve endangered or threatened species of fish, wildlife and plants. The DOE must determine whether any listed or proposed endangered or threatened species or their habitats will be affected by project activities. If a listed species or critical/proposed-critical habitat may be affected by the project, DOE must consult with the Regional Director, U.S. Fish and Wildlife Service and/or the National Marine Fisheries Service (NMFS) and follow the U.S. Fish and Wildlife Service Procedures.

The DOE will comply with this law by taking all necessary precautions to ensure that its proposed actions will not jeopardize the continued existence of any threatened or endangered species and/or their critical habitats. In accordance with requirements in 50 CFR 402 DOE initiated consultation with the U.S. Fish and Wildlife Service. Results of that consultation have been documented in Section 4.6.1.

Migratory Bird Treaty Act (16 USC 703-712, 50 CFR 10, 13, 21). The Migratory Bird Treaty Act affords protection to many species of migratory birds by prohibiting the pursuit, hunting, taking, capture, possession or killing of such species or their nests or eggs. It is possible that some migratory birds or their nests or eggs could be impacted by activities associated with disposal of Hanford defense waste. If this were the case, the DOE would informally discuss with the Fish and Wildlife Service measures to mitigate the effects of such activities on migratory birds.

Bald and Golden Eagle Protection Act (16 USC 668-668(d), 50 CFR 10, 13, 22. The Bald and Golden Eagle Protection Act affords protection to bald and golden eagles by establishing penalties for the unauthorized taking, possession, selling, purchase or transportation of eagles, their nests, or their eggs. The U.S. Fish and Wildlife Service has the authority to issue permits for the taking or disturbing of eagles or their nests or eggs for certain purposes. If defense waste activities will disturb bald or golden eagles, the DOE will initiate informal discussion with the U.S. Fish and Wildlife Service regarding mitigation measures. This process will also result in consultations with Washington State Department of Wildlife officials.

## 6.11 LICENSING BY THE NUCLEAR REGULATORY COMMISSION

The Nuclear Waste Policy Act of 1982 (Public Law 97-425) requires that any repository sited and constructed under the Act be licensed by the Nuclear Regulatory Commission (NRC).

Section 8(a)(3) of the Act requires that any repository for the disposal of high-level radioactive waste resulting from atomic energy defense activities only shall be subject to licensing by the Nuclear Regulatory Commission (Commission) under Section 202 of the Energy Reorganization Act of 1974 (42 USC 5842). Further, Section 202 of the Energy Reorganization Act requires Commission licensing of those DOE facilities authorized for the express purpose of long-term storage of high-level radioactive waste which are not used for, or are not a part of, research and development activities. Therefore, to the extent that any decision based on this final EIS requires defense high-level waste to be placed in a repository constructed under the Nuclear Waste Policy Act or a facility subject to licensing under Section 202 of the Energy Reorganization Act, such a repository or facility would be subject to licensing by the Commission.

## 6.12 REFERENCES


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Jaquish, K. E., and P. J. Mitchell. 1987. Environmental Monitoring at Hanford for 1986. PNL-6120, Pacific Northwest Laboratory, Richland, Washington.

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Sheppard, D. R., Acting Director, Office of Operational Safety. September 12, 1985. "Radiation Standards for Protection of the Public in the Vicinity of DOE Facilities." Memorandum for Distribution, U.S. Department of Energy, Washington, D.C.

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# CHAPTER 7.0

## PREPARERS AND REVIEWERS

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## 7.0 PREPARERS AND REVIEWERS

Those who prepared this final environmental impact statement on disposal of Hanford defense waste are identified in this chapter.

The overall effort was led by J. D. White, Director, Waste Management Division, with assistance from E. A. Bracken, Chief, Nuclear Waste Technology Branch at the Richland Operations Office, Department of Energy (DOE-RL). K. H. Rising, Program Manager, DOE-RL, had direct responsibility for development of the EIS. Reviews of the EIS draft materials were provided by staff from the Waste Management Division, Office of Chief Counsel, Environment, Safety and Health Division, Basalt Waste Isolation Division, Nuclear Energy/Waste Technology Division, and Site and Laboratory Management Division at DOE-RL; and staff from Office of Defense Waste and Transportation Management, Office of Environmental Guidance, Office of General Counsel for Environment, and Office of Geologic Repositories at DOE-Headquarters.

Assistance was provided to DOE-RL by the staff of Rockwell Hanford Operations, a subsidiary of Rockwell International (subsequently Westinghouse Hanford Company) under contract to the Department of Energy to provide waste management and other services at the Hanford Site. Staff of Rockwell Hanford Operations prepared detailed descriptions of waste classes, waste treatment, waste retrieval, and other aspects of waste disposal. This information was published in a document entitled Hanford Defense Waste Disposal Alternatives: Engineering Support Data for the HDW-EIS and in an Addendum. Staff contributing to those documents were:

| | |
|---|---|
| C. J. Geier<br>M. T. Jansky<br>R. T. Stordeur | Document Overview |
| B. A. Higley<br>D. E. Kurath | Existing Tank Waste |
| D. E. McKenney<br>F. M. Coony | Strontium and Cesium Capsules |
| R. A. Watrous<br>J. D. Kaser | Future Tank Waste |
| J. B. Anderson<br>D. L. Duncan<br>M. W. Gibson | Retrievably Stored and Newly Generated TRU Waste<br>TRU-Contaminated Soil Sites |
| C. C. Meinhardt<br>F. M. Coony | Pre-1970 Buried TRU Solid Waste Sites |
| R. J. Jensen | Radiological Releases |

Contributions were made also by M. R. Adams, D. E. Friar, C. DeFigh-Price, R. L. Koontz, and R. D. Wojtasek. Others providing technical review were H. E. McGuire, G. F. Boothe, R. E. Isaacson, R. D. Prosser, W. W. Schulz, K. M. Tominey, D. D. Wodrich, and D. E. Wood. Programmatic overview was provided by C. DeFigh-Price, R. D. Prosser, D. L. Merrick, and S. A. Wiegman.

Assistance was provided to DOE-RL also by staff of the Pacific Northwest Laboratory (PNL), operated for the Department of Energy by the Pacific Northwest Division of Battelle Memorial Institute. This assistance consisted chiefly of performing environmental analyses based largely on the above-mentioned resource document and preparing the EIS itself. The PNL Program Manager for preparation of the final EIS was P. E. Bramson, assisted by I. C. Nelson, and J. G. Stephan. PNL programmatic overview was provided by R. C. Liikala, and W. W. Laity. Editors for the final EIS were S. F. Liebetrau (lead), P. L. Gurwell and T. L. Gilbride. Pacific Northwest Laboratory staff contributing to the preparation of detailed aspects of the EIS are identified as follows:

| Volume 1 | Principals |
|---|---|
| Foreword | I. C. Nelson/J. B. Burnham |
| Executive Summary | J. B. Burnham/P. E. Bramson |
| Chapter 1. General Summary | J. A. Powell/I. C. Nelson |
| Chapter 2. Purpose and Need | I. C. Nelson |
| Chapter 3. Description and Comparison of Alternatives | H. H. Van Tuyl<br>J. G. Stephan<br>G. H. Sewart<br>I. C. Nelson |
| Chapter 4. Affected Environment | D. G. Watson<br>C. Cluett[(a)]<br>G. V. Last<br>W. H. Rickard<br>D. R. Sherwood |
| Chapter 5. Environmental Impacts | E. C. Watson<br>J. G. Stephan |
| Radiological Consequences | B. A. Napier<br>K. A. Hawley<br>R. L. Aaberg |
| Resource Use/Nonradiological Consequences | G. H. Sewart |
| Socioeconomics | C. Cluett |
| Hydrologic Aspects | C. T. Kincaid<br>A. E. Reisenauer<br>J. R. Raymond |
| Air Quality | C. S. Glantz<br>C. G. Lindsey |
| Transportation | P. M. Daling |
| Costs | L. L. Clark<br>A. T. Luksic<br>G. H. Sewart |

(a) Under contract at Battelle Human Affairs Research Centers, Seattle, Washington.

| Volume 1 | Principals |
|---|---|
| Assessment of Long-Term Impacts | B. A. Napier<br>I. C. Nelson<br>R. W. Wallace |
| Glacial Flooding | R. G. Craig[a] |
| Chapter 6. Applicable Regulations | J. P. Corley<br>P. E. Bramson<br>I. C. Nelson |
| Chapter 7. Preparers and Reviewers | J. A. Powell/S. F. Liebetrau |
| Chapter 8. Glossary | J. A. Powell/S. F. Liebetrau |
| **Volume 2 (Appendices A-L)** | |
| Analytical Methodology | J. B. Burnham |
| A. Waste Site Descriptions and Inventories | H. H. Van Tuyl |
| B. Description of Facilities and Processes | H. H. Van Tuyl |
| C. Hanford Waste Vitrification Plant | S. L. Stein |
| D. Transportable Grout Facility | S. L. Stein |
| E. Waste Receiving and Processing Facility | S. L. Stein |
| F. Method for Calculating Radiation Dose | B. A. Napier |
| G. Methods for Calculating Nonradiological Injuries and Illnesses and Nonradiological Fatalities | G. H. Sewart |
| H. Radiation Doses to the Public from Operational Accidents | K. A. Hawley<br>J. Mishima |
| I. Analysis of Impacts for Transportation of Hanford Defense Waste | P. M. Daling |
| J. Method for Calculating Repository Costs Used in the Hanford Defense Waste Environmental Impact Statement | L. L. Clark |
| K. Socioeconomic Impacts | C. Cluett |
| L. Nonradiological Impacts - Construction and Operational Period | G. H. Sewart |
| **Volume 3 (Appendices M-W)** | |
| M. Preliminary Analysis of the Performance of the Protective Barrier and Marker System | G. W. Gee<br>I. C. Nelson |
| N. Radiologically Related Health Effects | R. C. Thompson<br>E. S. Gilbert |

(a) Under contract at Kent State University, Kent, Ohio.

| Volume 3 | Principals |
|---|---|
| O. Status of Hydrologic and Geochemical Models Used to Simulate Contaminant Migration from Hanford Defense Wastes | C. T. Kincaid<br>J. R. Raymond |
| P. Release Models and Radionuclide Inventories for Subsurface Sources | C. T. Kincaid<br>J. R. Raymond |
| Q. Application of Geohydrologic Models to Postulated Release Scenarios for the Hanford Site | A. E. Reisenauer |
| R. Assessment of Long-Term Performance of Waste Disposal Systems | B. A. Napier |
| S. Probability and Consequence Analysis of Radionuclide Release and Transport After Disposal | M. G. Piepho |
| T. Method for Estimating Nonradiological Air-Quality Impacts | C. S. Glantz<br>C. G. Lindsey |
| U. Preliminary Analysis of the Future Groundwater Transport of Chemicals Released from Hanford Single-Shell Tanks | C. T. Kincaid<br>A. E. Reisenauer<br>J. R. Raymond |
| V. Site-Monitoring Experience | J. A. Stottlemyre<br>M. J. Graham |
| Index | P. L. Gurwell/S. F. Liebetrau |
| Volume 4 Responses to Public Comments | |
| Section 1: Introduction | S. L. Stein/J. G. Stephan |
| Section 2: Policy Issues and Responses | J. B. Brown, Jr.<br>I. C. Nelson<br>S. L. Stein<br>J. G. Stephan |
| Section 3: Technical Issues and Responses | P. E. Bramson<br>J. B. Brown, Jr.<br>I. C. Nelson<br>J. R. Raymond<br>D. R. Sherwood<br>J. G. Stephan |
| Section 4: Organization and Presentation Issues and Responses | S. L. Stein<br>J. B. Brown, Jr. |
| Volume 5 Public Comment Letters | J. B. Brown, Jr.<br>P. L. Gurwell |

Brief biographic sketches of preparers from PNL's research staff follow.

Rosanne L. Aaberg, Research Engineer, Geosciences Department, Earth & Environmental Sciences Center

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|---|---|---|
| B.S. | Chemical Engineering, University of Washington | 1976 |

Ms. Aaberg has worked in the areas of nuclear fuel cycle analysis, environmental impacts, and radiation dose calculations. Currently, in addition to dose pathways work, she is involved in RCRA Compliance Groundwater-monitoring projects on the Hanford Site.

Philip E. Bramson, Program Manager, Hanford Defense Waste Environmental Impact Statement, Office of Hanford Environment

| | | |
|---|---|---|
| A. B. | Engineering Physics, Northwest Nazarene College | 1959 |

Mr. Bramson has been involved in health and safety research, development and management for 28 years. Most recently he managed multidisciplinary staff involved in Hanford's major environmental monitoring programs. This work included sampling of all environmental media, program design, implementation and operation of monitoring programs for radioactive and hazardous wastes, and assessment of impacts of Hanford operations on the offsite environment and population. During his career he has made notable contributions to radiation dosimetry, in vivo counting and environmental monitoring technology.

John B. Brown, Jr. Staff Scientist, Waste Systems Department, Earth & Environmental Sciences Center

| | | |
|---|---|---|
| B.S. | Electrical Engineering, Iowa State University | 1959 |
| M.S. | Nuclear Engineering, Iowa State University | 1962 |
| M.S. | Nuclear Science, University of Michigan | 1965 |
| PhD. | Nuclear Engineering, Ohio State University | 1973 |

As a Staff Scientist at Battelle's Pacific Northwest Laboratory (PNL), Dr. Brown contributes to and manages projects that characterize health and safety risks and identifies and assesses methods to reduce, manage, or respond to these risks. Before managing the systems Risk Management Program, he was Manager of the Environmental and Risk Assessment Section at PNL. In this position, he was responsible for establishing a center of excellence in the environmental assessment sciences, and conducting projects focusing on environmental and risk assessment. Earlier, at Battelle's Columbus Laboratories, Dr. Brown was responsible for developing and conducting research programs in nuclear materials development and performance and the analysis of fuel cycle technology as they apply to fission energy systems.

John B. Burnham, Consultant

| | | |
|---|---|---|
| B.S. | Metallurgical Engineering, Stanford University | 1943 |
| M.S. | Metallurgical Engineering, Stanford University | 1947 |
| | Graduate Studies, Physics and Mathematics, Oregon State University | |

Mr. Burnham has been engaged in nuclear research for 37 years, during which time he has been concerned with development of nuclear fuels and fuel manufacturing processes, and research on fuel materials and on testing methods for quality control in fuels fabrication. He is presently engaged in engineering and economic analysis covering a broad range of interests, but centered on fuel cycle cost analysis and cost studies related to generation and transmission of power. Some of the programs in which he has been a major contributor include the environmental impact statement Management of Commercially Generated Radioactive Waste, Regional Assessment Program, Generic Environmental Statement on Mixed Oxide Fuels, and Waste Management Policy Study.

L. Lavelle Clark, Senior Research Scientist, Waste Systems Department, Waste Technology Center

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|---|---|
| B.S. | Chemistry, Brigham Young University |
| M.B.A. | Business Administration, Brigham Young University |

Mr. Clark is responsible for projects to develop cost estimating models and cost estimates for disposing of nuclear wastes in geologic repositories. He also is in charge of developing systems cost estimates for the entire waste management system, including waste treatment, transportation and disposal. Previously he developed the cost estimates for all of the waste treatment, transportation, storage and disposal alternatives in the environmental impact statement Management of Commercially Generated Radioactive Waste. He has been involved in various waste management and fuel cycle cost studies since 1972.

Christopher Cluett, Research Scientist, Social Change Study Center, Battelle Human Affairs Research Centers, Seattle

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|---|---|---|
| B.A. | English Literature, Williams College | 1963 |
| M.A. | Sociology, University of Washington | 1972 |
| Ph.D. | Sociology, with major emphasis in Demography and Urban Ecology, University of Washington | 1977 |

Dr. Cluett prepared the analysis of potential socioeconomic consequences of the proposed Basalt Waste Isolation Project on the Hanford Site for Rockwell Hanford Operations. This work included a socioeconomic impact forecast and a discussion of methods of analysis.

His work on previous EISs has included preparation of the socioeconomic and demographic impact analysis for the environmental impact statement Management of Commercially Generated Radioactive Waste. He was a member of an EIS Support Task Group to aid the DOE Assistant Secretary for Environmental Affairs, Office of Nuclear Waste Management, in the early involvement in environmental impact statements prepared for the Office of Nuclear Waste Management.

John P. Corley, Staff Engineer, Geosciences Department, Earth & Environmental Sciences Center

| | | |
|---|---|---|
| B.S. | Chemical Engineering, Carnegie Institute of Technology | 1942 |
| | Certified, American Board of Health Physics | 1965, 1981, 1985 |

Mr. Corley specializes in radiological surveillance and evaluation of the environment. His professional experience includes applied radiation protection work in nuclear fuels reprocessing and reactor plants, engineering studies for waste water disposal and water treatment, and research studies of Hanford Plant effects on Columbia River water quality. Mr. Corley currently provides technical assistance and serves as a primary reviewer of proposed standards and regulations for the U.S. Department of Energy's Offices of Nuclear Safety and Environmental Guidance, with special attention to environmental radiological matters.

Richard G. Craig, Associate Professor, Department of Geology, Kent State University, Kent, Ohio

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|---|---|
| B.A. | Sociology-Anthropology, Dickinson College |
| M.S. | Geology, The Pennsylvania State University |
| Ph.D. | Geology, The Pennsylvania State University |

Dr. Craig has 8 years' experience in simulation-modeling of geologic systems. Currently he is developing submodels of PNL's former Assessment of Effectiveness of Geologic Isolation Systems Program (AEGIS) Geologic Simulation Model (GSM) for the Columbia Plateau in support of the Hanford Defense Waste EIS. He has been peer reviewer for the AEGIS GSM and principal developer of a preliminary version of the GSM for the Nevada Test Site (Nevada Nuclear Waste Storage Investigations).

Philip M. Daling, Senior Research Engineer, Systems Analysis Section, Office of Technology Planning and Analysis

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|---|---|---|
| B.S | Physical Metallurgy, Washington State University | 1981 |

Mr. Daling has 6 years' experience in the area of radioactive and hazardous material transportation. He has been both project manager and technical contributor on numerous transportation-related projects, including analyses of commercial spent fuel transportation hardware requirements and costs; potential radiation dose reduction concepts for the commercial spent fuel transportation system (As Low As Reasonably Achievable analysis); licensing requirements for dry storage casks and casks for transporting forms of high-level waste. Mr. Daling is also an experienced risk and safety analyst and has contributed to risk and safety analyses of nuclear power plants, liquefied natural gas facilities, spent fuel storage facilities, geologic repositories, and others.

Glendon W. Gee, Staff Scientist, Geosciences Department, Earth & Environmental Sciences Center

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|---|---|---|
| B.S | Physics, Utah State University | 1961 |
| Ph.D. | Soil Physics, Washington State University | 1966 |

Dr. Gee has a wide range of research experience in the area of soil physics. He has been active in developing methodologies for improved measurements of various physical and hydrologic properties of soils, and has conducted research on water transport through soils in both arid and humid climates. He has been a technical leader in the hydrologic aspects of waste management, specifically transport analysis of the flow of contaminants through unsaturated sediments. His work has provided Pacific Northwest Laboratory with multidimensional modeling capabilities in assessing unsaturated transport of radionuclides and other contaminants.

Ethel S. Gilbert, Staff Scientist, Computational Sciences Department, Applied Physics Center

| | | |
|---|---|---|
| A.B. | Mathematics, Oberlin College | 1961 |
| M.A.T. | Teaching Program, Radcliffe College | 1962 |
| M.P.H. | Biostatistics Public Health, University of Michigan | 1964 |
| Ph.D. | Biostatistics, University of Michigan | 1966 |

Dr. Gilbert is experienced in epidemiological studies of health effects due to low-level exposures to occupational contaminants, particularly ionizing radiation. Since 1975, she has directed analysis of data for a study of mortality among Hanford workers. Dr. Gilbert was a member of the working group responsible for revising health effects in the NRC Reactor Safety Study. She provided a model for estimating cancer risks resulting from radiation exposure likely to be received by the general population from a nuclear reactor accident.

Clifford S. Glantz, Research Scientist, Atmospheric Sciences Department, Earth & Environmental Sciences Center

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|---|---|---|
| B.S. | Physics and Atmospheric Sciences, State University of New York | 1979 |
| M.S. | Atmospheric Sciences, University of Washington | 1982 |

Mr. Glantz has conducted research in air pollution meteorology, atmospheric transport and diffusion, cloud and aerosol physics, acid rain, and mesoscale meteorology. He contributed to the Basalt Waste Isolation Project (BWIP) Environmental Assessment, the BWIP Site Characterization Plan, the Process Facility Modifications Environmental Impact Study, and other Hanford environmental studies. He has been a major contributor in the development of the MESOI atmospheric dispersion model.

Michael J. Graham, Manager, Geosciences Department, Earth & Environmental Sciences Center

| | | |
|---|---|---|
| B.S. | Biology/Chemistry, Notre Dame | 1974 |
| M.S. | Geology (Hydrogeology), Indiana University | 1977 |
| Ph.D. | Geology (Hydrogeology), Indiana University | 1983 |

Dr. Graham has extensive experience in the analysis and evaluation of groundwater. As part of high-level defense waste performance assessment projects, he managed a comprehensive geohydrological and geochemical research program to evaluate the performance of various disposal options for high-level defense waste. The scope of this project included development of release models, development of advanced unsaturated and saturated flow and transport codes, and calibration and validation studies involving field data collection. He also managed a project to evaluate the migration of contaminates from commercial solidified low-level wastes in arid climates. Hydrologic and geochemical models are being developed in this long-term project to provide performance assessment capabilities for shallow-land disposal sites in arid climates.

Kathryn A. Hawley, Research Scientist, Geosciences Department, Earth & Environmental Sciences Center

| | | |
|---|---|---|
| B.A. | Chemistry, Reed College, Portland, Oregon | 1978 |

Ms. Hawley has recently developed exposure scenarios and performed radiological analyses for several Hanford projects; dose assessment for the proposed in situ vitrification of TRU liquid and solid disposal sites; and analysis of the radiological consequences from accidental releases from Z Plant as part of an Environmental Assessment. Ms. Hawley has also worked extensively in environmental radiological surveillance and has designed and evaluated radiological monitoring programs for nuclear power facilities.

Charles T. Kincaid, Senior Research Engineer, Geosciences Department, Earth & Environmental Sciences Center

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|---|---|---|
| B.S. | Civil Engineering, Humboldt State College | 1970 |
| Ph.D. | Engineering, Utah State University | 1979 |

Dr. Kincaid's primary emphasis since joining PNL in 1979 has been in the areas of water movement and solute migration through the vadose and saturated groundwater zones. He has participated in the Seasonal Thermal Energy Storage (STES) and Assessment of Effectiveness of Geologic Isolation Systems (AEGIS) programs and currently is involved in studies for industrial clients. Dr. Kincaid is a co-author of the Coupled Fluid, Energy, and Solute Transport (CFEST) code, which simulates groundwater movement and coupled energy and solute migration in confined aquifer systems. He has been involved in the study of uncertainty in groundwater potentiometric distributions caused by uncertainty in an aquifer's hydraulic conductivity and boundary condition data. His current research includes methods for coupling transport and geochemistry simulation capabilities.

George V. Last, Research Geologist, Geosciences Department, Earth & Environmental Sciences Center

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|---|---|---|
| B.S. | Geology, Washington State University | 1976 |

Mr. Last has a broad background in geology and hydrology. Since joining PNL in 1984, he has contributed to the understanding of the hydrologic systems of the Pasco Basin and the Hanford Site and to leaching studies of grout waste forms under simulated burial conditions. His professional experience on the Hanford Site also includes waste site characterization, drilling and sampling of contamination plumes, borehole geophysical logging, seismic monitoring, and groundwater geology.

Charles G. Lindsey, Research Scientist, Atmospheric Sciences Department, Earth & Environmental Sciences Center

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|---|---|---|
| B.A. | Political Economy, Colorado College | 1974 |
| M.S. | Environmental Sciences, University of Virginia | 1980 |

Mr. Lindsey is a research meteorologist specializing in studies of boundary layer transport, diffusion processes, and air pollution. He has recently completed a measurement program as part of at the CAPTEX regional-scale tracer diffusion study. He also has recently completed a study on mesoscale transport systems in coastal and complex terrain environments for the NRC. He has performed several air-quality impact studies, including the EIS for the Sayreville power plant (DOE/ERA) and the impacts resulting from emissions from coal-fired power plants operating at Hanford (DOE/RL).

A. T. Luksic, Research Scientist, Nuclear Systems and Concept Analysis Department, Reactor Technology Center

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|---|---|---|
| B.S. | Mathematics, State University of New York | 1973 |
| M.S. | Nuclear Engineering, Brooklyn Polytechnic Institute | 1976 |

Mr. Luksic has worked more than 10 years in the nuclear field, involved primarily with radiation transport and shielding design in both commercial and DOE facilities. He has worked extensively also in the licensing of a commercial nuclear plant. Presently he is involved in the economic assessment associated with geologic repositories for nuclear waste.

Jofu Mishima, Staff Scientist, Atmospheric Sciences Department, Earth & Environmental Sciences Center

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|---|---|---|
| B.S. | Chemistry, Wayne University | 1951 |

Mr. Mishima has been associated with Hanford for almost 30 years. His areas of expertise include the fractional airborne release of radionuclides as a consequence of non-nuclear initiated accidents, nuclear air-cleaning systems, particulate sampling of gaseous effluents from nuclear facilities, and research planning and organization.

Bruce A. Napier, Senior Research Scientist, Geosciences Department, Earth & Environmental Sciences Center

| | | |
|---|---|---|
| B.S. | Nuclear Engineering, Kansas State University | 1975 |
| M.S. | Nuclear Engineering, Kansas State University | 1977 |
| Diplomate | American Board of Health Physics | 1986 |

Mr. Napier has recently developed exposure scenarios and performed radiological analyses for a planned Hanford Nuclear Energy center; deep geologic waste repositories for the AEGIS program; studies for the NRC on decommissioning BWRs, low-level waste burial grounds, and non-fuel-cycle facilities; an analysis of EPA's proposed regulation 40 CFR 191 for the Office of Nuclear Waste Isolation; and a generic study on the environmental effects of proposed uranium mining in British Columbia. He also contributed to the EIS Management of Commercially Generated Radioactive Waste, the EIS for operation of PUREX, the EA on the Basalt Waste Isolation Project, and the FEIS on Double-Shell Tanks.

Iral C. Nelson, Staff Scientist, Geosciences Department, Earth & Environmental Sciences Center

| | | |
|---|---|---|
| B.S. | Mathematics, University of Oregon | 1951 |
| M.A. | Physics, University of Oregon | 1955 |
| Diplomate | American Board of Health Physics | 1962 |

Mr. Nelson became PNL program manager for preparation of the HDW-EIS in January 1983 and associate program manager in November 1984. He has been project manager for a number of NEPA-related efforts, including preparation of EISs for six nuclear power reactors and preparation of the Final EIS Management of Commercially Generated Radioactive Waste. Mr. Nelson has been involved in various aspects of radiation protection at Hanford since 1955.

Melvin G. Piepho, Senior Research Scientist, Energy Sciences Department, Applied Physics Center

| | | |
|---|---|---|
| B.S. | Mathematics and Physics, Butler University | 1968 |
| M.S. | Physics, Indiana University | 1970 |
| M.A. | Mathematics, Indiana University | 1971 |
| Ph.D. | Theoretical Physics, Indiana University | 1974 |

Dr. Piepho worked on the Probabilistic Risk Assessment (PRA) for the Clinch River Breeder Reactor Project. He has also worked on the mathematical modeling of reactor containment system responses, including source term, evacuation and dosimetry modeling. Recently, he has been involved with sensitivity/uncertainty methods for waste management, and hydrothermal modeling of water bodies.

Judith A. Powell, Communications Specialist, Process Technology Department, Waste Technology Center

| | | |
|---|---|---|
| B.A. | Comparative Literature, Indiana University | 1952 |
| M.A. | Comparative Literature, Indiana University | 1956 |
| Ph.D. | English, University of Utah | 1973 |

Dr. Powell writes and edits primarily in the area of nuclear waste technology, preparing or contributing to reports, journal articles, books, conference proceedings, proposals, bibliographies, presentations, and audiovisual materials. She regularly compiles technical progress reports covering numerous research and development programs. She has headed several large editing and publishing efforts, including multinational symposium proceedings, several interlaboratory multivolume documents, the draft EIS Management of Commercially Generated Radioactive Waste and other EISs. She also designed and conducted the first workshops in technical writing offered at Battelle-Northwest and for some years coordinated a laboratory-wide program of these workshops.

John R. Raymond, Staff Scientist, Geosciences Department, Earth & Environmental Sciences Center

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|---|---|---|
| B.S. | Geology, Washington State University | 1951 |

Mr. Raymond has over 30 years of technical and administrative experience in assessment and monitoring of groundwater and surface-water quality, disposal of wastes to the ground, energy storage in groundwater systems, and geohydrologic investigations. He presently is Staff Scientist for the Hanford Ground-Water Monitoring Program, where he provides consulting and support on radioactive waste disposal practices and advises on technology for monitoring and evaluating radioactive and chemical contaminants in the groundwater.

Andrew E. Reisenauer, Research Scientist, Geosciences Department, Earth & Environmental Sciences Center

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|---|---|---|
| B.S. | Bacteriology and Public Health, Washington State University | 1951 |

Mr. Reisenauer has been associated with Hanford since 1951. Since 1960 he has been associated with studies in hydrology. He has been a major contributor to mathematical modeling of saturated and unsaturated flow systems, including studies of salt water intrusion, long-term irrigation stress on aquifer systems, and effects of recharge and waste disposal of hazardous chemicals into aquifer systems. Additional modeling studies have included flow and transport from uranium mill tailings sites, salt dome and bedded salt repositories, and numerous studies on the Hanford unconfined aquifer. Mr. Reisenauer also contributed to the EIS Management of Commercially Generated Radioactive Waste, the FEIS for Hanford Waste Management Operations, and the PUREX EIS.

William H. Rickard, Staff Scientist, Environmental Sciences Department, Earth & Environmental Sciences Center

| | | |
|---|---|---|
| B.A. | Botany, University of Colorado | 1950 |
| M.A. | Botany, University of Colorado | 1953 |
| Ph.D. | Botany, Washington State Unviersity | 1957 |

Since joining Battelle in 1965, Dr. Rickard has conducted field and experimental research in terrestrial ecology. Research has centered around field sampling to measure primary productivity, soil-plant mineral relations, and man-imposed perturbations, especially cattle grazing, severe soil disturbances, and airborne chemical contaminants in the semiarid Columbia Basin Region of eastern Washington. He has conducted baseline ecology studies for commercial nuclear power stations and prepared environmental impact assessments for NRC and DOE, especially terrestrial ecology sections. Dr. Rickard is project manager for wildlife surveillance performed on the Hanford Site for the U.S. Department of Energy's Richland Operations Office.

Gretchen Sewart, Engineer, Geosciences Department, Earth & Environmental Sciences Center

| | | |
|---|---|---|
| B.S.E. | With Emphasis in Chemical Engineering, University of Washington | 1983 |

Mrs. Sewart has contributed to environmental documentation for the management of breeder reactor fuel and of commercially generated spent fuel. Mrs. Sewart has investigated nuclear material safeguards as related to high-density storage of spent fuel. She also helped develop a gasification process which converts agricultural waste to usable fuel gases.

Douglas R. Sherwood, Research Scientist, Environmental Sciences Department, Earth & Environmental Sciences Center

| | | |
|---|---|---|
| B.A. | Chemistry-Environmental Studies, Whitman College | 1977 |

Since joining Battelle in 1979, Mr. Sherwood has been involved in a wide range of geochemical investigations into radioactive and hazardous chemical wastes. His work has included contaminant transport investigations of uranium mill tailings, field sampling and analysis of mine and process wastes as well as geochemical modeling of chemical processes influencing contaminant mobility. At present, Mr. Sherwood leads tasks on two major Hanford environmental programs. He serves as waste site characterization task leader for the CERCLA program at Hanford. Mr. Sherwood also leads the data and methods task of the Hanford Site Ground-Water Monitoring Program.

Steven L. Stein, Research Scientist, Human Systems Research Center, Battelle Human Affairs Research Centers, Seattle

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| B.S. | Geology, Washington State University | 1978 |

Since joining PNL in 1979, Mr. Stein has been involved in the evaluation of impacts associated with defense and commercial radioactive waste management and disposal programs. Mr. Stein was contributor to both the environmental impact statement Management of Commercially Generated Radioactive Waste and the Environmental Impact Statement Operation of PUREX and Uranium Oxide Plant Facilities, Hanford Site, Richland, Washington.

Joachim G. Stephan, Senior Research Scientist, Health Physics Department, Life Sciences Center

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| B.S. | Geodetic Science, Ohio State University | 1962 |
| Graduate Studies | Radiological Sciences through the Joint Center for Graduate Study, University of Washington, Richland, Washington | 1980-present |

Mr. Stephan has been deputy project manager on the Hanford Defense Waste Program since September 1980. He has also served in management and contributor functions for DOE-sponsored waste isolation and fuels conversion programs. Since joining Battelle in 1965, he has been active in safety programs required for underground nuclear testing.

James A. Stottlemyre, Deputy Manager, Earth & Environmental Sciences Center

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| B.S. | Physics, University of Washington | 1970 |
| M.S. | Geophysics, University of Washington | 1973 |
| Ph.D. | Geophysics, University of Washington | 1981 |

As a scientist and project manager at Battelle, Dr. Stottlemyre has specialized in the physics and chemistry of geomedia under conditions of moderate temperatures and pressures. and on the subsurface transport of contaminants associated with the disposal of nuclear, fossil energy and chemical wastes. Dr. Stottlemyre's experience includes studies in thermal energy storage; impact analysis of the reinjection of geothermal spent fluids; characterization and modeling of the migration of contaminants in subsurface environments; and the identification and quantification of geological, geophysical, and hydrological phenomena that could conceivably lead to radionuclide migration from a waste disposal facility.

Roy C. Thompson, Senior Staff Scientist, Biology and Chemistry Department, Life Sciences Center

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|---|---|---|
| B.A. | Chemistry, University of Texas | 1940 |
| M.A. | Biochemistry, University of Texas | 1942 |
| Ph.D. | Bio-Organic Chemistry, University of Texas | 1944 |

Dr. Thompson has been engaged in various aspects of radiation biology research at the Hanford Site since 1950. He has been concerned with the distribution and biological effects of internally deposited radionuclides, in particular plutonium and other actinides, strontium-90, and tritium, as deduced from studies with experimental animals. He is a member of the National Council on Radiation Protection and Measurements, and was for 16 years a member of Committee 2 on Secondary Limits of the International Commission on Radiological Protection.

Harold H. Van Tuyl, Manager, Critical Mass Laboratory

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|---|---|---|
| B.S. | Chemistry, Texas A&M | 1948 |
| Several graduate courses, University of Washington Center for Graduate Study, Richland, Washington | | 1948-1960 |

Mr. Van Tuyl is currently manager of the Critical Mass Laboratory at PNL. He has had 17 years' experience as a research chemist for General Electric (1948-1965) and six years as a research chemist for PNL (1965 to 1970). For 15 years he was manager of Nuclear Fuel Cycle Chemistry Section, comprising about twelve chemists engaged in basic and applied chemical research. In his 35 years at Hanford, Mr. Van Tuyl has worked with many aspects of the chemistry of radioactive materials and has contributed to the preparation of several environmental impact statements.

Richard W. Wallace, Research Scientist, Geosciences Department, Earth & Environmental Sciences Center

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|---|---|---|
| B.S. | Geology, Iowa State University | 1959 |
| M.S. | Geology, Iowa State University | 1961 |
| Ph.D. | Hydrogeology, University of Idaho | 1972 |

Dr. Wallace has worked with proposed radioactive-waste disposal techniques, methods and systems for the past 8 years. His work has included description and characterization of various geologic media and settings, development of release scenarios (both from natural events and from human activity), and analysis of scenarios for waste released as source terms for dose and consequence analyses.

Donald G. Watson, Staff Scientist, Geosciences Department, Earth & Environmental Sciences Center

| | | |
|---|---|---|
| B.S. | Fisheries, University of Washington | 1948 |

Mr. Watson is experienced in aquatic ecology, radiation ecology, and environmental impact assessment. He has participated in preparing EISs for eight nuclear power plants and in the environmental assessment of non-nuclear thermal electrical power plants, uranium mill tailings, and commercially generated radioactive wastes. Mr. Watson has also conducted research on the biological effects of radiation and on the distribution and food web transfer of worldwide fallout. He has been employed in various aspects of aquatic ecology at the Hanford Site since 1949.

Edwin C. Watson, Staff Scientist, Geosciences Department, Earth & Environmental Sciences Center (deceased)

| | | |
|---|---|---|
| A.B. | Physics, William Jewell College | 1947 |
| | Graduate Studies in Physics and Mathematics, University of Kansas | 1949 |
| | Continuing Education, University of Washington, University of California, and Harvard University | |
| Diplomate | American Board of Health Physics | 1962 |

Mr. Watson was associated with radiation protection, health physics and environmental assessment programs at Hanford since 1949 and was a forerunner in the development of mathematical models for calculating population dose resulting from surface and airborne radioactive contaminants.

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# CHAPTER 8.0

## GLOSSARY

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## 8.0 GLOSSARY

This explanation of terms used in the Hanford Defense Waste Environmental Impact Statement and its support documents was prepared based on general usage of the Hanford Site. The information is arranged alphabetically, including terms that are constructed by joining words. For example, "salt cake" is listed under s and "low-level waste" under l.

In addition to definitions of terms, this section includes acronyms, abbreviations and symbols (8.2), the elements and their symbols (8.3), and selected conversion factors (8.4).

### 8.1 DEFINITION OF TERMS

absorbed dose - the quantity of energy imparted to unit mass of material exposed to radiation, expressed in rads (100 erg/gram); SI units gray (Gy)

absorption - the process by which radiation imparts some or all of its energy to any material through which it passes; the taking up of a substance by another substance

acceptable corrosion rate - permissible rate of surface layer removal, based on back calculations from a vessel design life, original thickness, and minimal thickness for strength and integrity

accessible environment - the atmosphere, land surface, surface waters, oceans, and all of the lithosphere (the solid part of the earth below the surface, including any groundwater contained in it) that is beyond the controlled area (see 40 CFR 191)

accountability - material balance usually of a valuable material (e.g., Pu and U) encompassing all significant incoming and outgoing amounts of the valuable material

actinides - elements with atomic numbers above 88; common actinides for Hanford waste management include Th, U, Np, Pu, Am and Cm

activation - the induction of radioactivity in material by irradiation with neutrons or other particles

activation products - radionuclides formed through bombardment with neutrons or other particles; nuclides such as $^{3}H$, $^{63}Ni$, $^{14}C$, and $^{60}Co$ are typically considered activation products, TRU nuclides such as $^{240}Pu$ also included by strict definition

active institutional control - in this document, active institutional control means continued federal control of the Hanford Site along with maintenance and surveillance of facilities and waste sites

active subsidence control - engineering techniques such as tank dome filling, pile driving, dropping weights, and grout injection intended to minimize future subsidence (see also subsidence and subsidence-accommodating barrier)

activity - the number of spontaneous nuclear transformations per unit time of a radioactive material

acute - happening over a short time period, usually referring to accidents

adsorption - adhesion of atoms, ions, or molecules to the surface of liquids or solid bodies they contact

advective flow - movement of water as represented by average velocity

aging waste - term usually reserved for high-activity and/or high-heat waste from fuel reprocessing that is stored until it decays sufficiently to simplify processing and/or disposal airborne radioactive material - radioactive aerosols, particles, mists, fumes, and/or gases transported by air

alluvial fan - rock deposit laid down by streams flowing from mountains into lowland regions

alluvium - the detrital materials eroded, transported, and deposited by streams; an important constituent of shelf deposits

alpha decay - radioactive decay in which an alpha particle is emitted from the nucleus of an atom

alpha particle - a positively charged particle made up of two neutrons and two protons (nucleus of helium atom) emitted by certain radioactive materials

anadromous - of a fish, such as the salmon and shad, that ascends fresh-water streams from the sea to spawn

anastomosing channels - branching or interlacing channels forming an interconnecting system

anticline - an up-arched fold in which the rock strata dip away from the fold's axis; opposite of syncline

antithetic - as applied to faults, indicates faults with dips in the opposite direction from the dip of the enclosing rocks

aquifer - a subsurface formation containing sufficient saturated permeable material to yield significant quantities of water

asphalt pad - abbreviated description of a standard design for a 20-year retrievable storage trench, pertaining to the blacktop paving upon which waste is stacked (see also retrievably stored)

atmosphere, control of - in this document, term refers to engineered regulation of the environment within a facility and usually consists of a maintained negative pressure and/or an inert gas blanket

atomic number(Z) - the number of protons (positive charges) in the nucleus of each chemical element

B Plant - old Hanford Pu recovery and separations facility converted for waste fractionation (see also bismuth phosphate process)

background radiation - that level of radioactivity from naturally occurring sources; principally radiation from cosmogenic and primordial radionuclides

barrier - (see engineered barrier)

basalt - a dark, fine-grained, extrusive igneous rock

benthic organisms (benthos) - those organisms dwelling on the bottoms of bodies of water

beta radiation - essentially weightless charged particles (electrons or positrons) emitted from the nucleus of atoms undergoing nuclear transformation

bioconcentration (bioaccumulation) - the process whereby an organic system selectively removes an element from its environment and accumulates that element in a higher concentration

biological oxygen demand (BOD) - a measure of the organic pollution of water, determined by the extent to which bacteria and other contained organisms in a water sample will use dissolved oxygen in a given time; therefore, a measure of the residual oxygen in the water for use by other organisms such as fish biomass - the total mass of living and dead organisms present in an area, volume, or ecological system

biosphere - the portions of the earth, atmosphere, lithosphere and hydrosphere that support plant and animal life, that is, the life zone

biota - the plant and animal life of a region

biotic - caused by living organisms

bismuth phosphate process - one of the earliest separation techniques used at Hanford to separate Pu from irradiated U fuels; replaced by the more efficient processes REDOX and PUREX (see also extraction)

body burden - the amount of a specified radioactive material or the summation of the amounts of various radioactive materials present in an animal or human body at the time of interest

boiling waste - radioactive waste containing radionuclides (principally $^{90}Sr$ and $^{137}Cs$) in quantity to provide sufficient decay heat to be near the liquid's boiling point; usually requires supplemental means of cooling (see also aging waste)

borrow area - area from which material is removed for use somewhere else, e.g., a gravel pit

bottoms (tank) - concentrated material remaining in waste tanks after most of the contents have been pumped out for solidification or transfer to other storage tanks; refers also to specific tanks used to collect such bottoms waste from several other tanks

buffer zone - the portion of a DOE site that surrounds the storage/disposal site and is not used for storage/disposal, but where public access is restricted

burial ground - land area specifically designated to receive contaminated waste packages and equipment, usually in trenches covered with overburden (see also trench, overburden, vault, caisson, "vee" trench)

byproduct material - waste produced by extraction or concentration of uranium or thorium from any ore processed primarily for its source material content, including discrete surface waste resulting from uranium solution extraction processes; excludes fission products and other radioactive material covered in 10 CFR Part 20.3(3) (from DOE 5820.2) (see, however, waste byproducts)

caisson - underground structure used to store high-level wastes; typical designs include corrugated metal or concrete cylinders about 2.5 m in diameter, 55-gal drums welded end-to-end, and vertical steel pipes below grade

calcine - to heat a substance to a high temperature, but below its melting point, causing loss of volatile constituents such as moisture; refers also to the material produced by this process

caliche - an accumulation of calcareous material formed in soil or sediments in arid regions

canister - container for high-level waste such as Sr or Cs capsules or vitrified wastes

canyon facility - at sites handling radioactive material, a heavily shielded, partially below-grade concrete structure used for remote chemical processing of fuels or wastes

capable (fault) - said of a fault if there is evidence of a movement at or near the ground surface during the last 35,000 years or of two or more movements during the last 500,000 years

capillary action - the force that holds a fluid in small void spaces or pores as that held between solid particles in sludge capsule - as used here, a stainless-steel cylinder used for containment of strontium and cesium recovered from radioactive wastes

cask - a container designed for transporting radioactive materials; design usually includes special shielding, handling, and sealing features to provide positive containment and to minimize personnel exposure

centrifugation - a solids/liquids phase separation technique utilizing the force inherent in rotating bodies which impels material outward from the center

certification plan - a plan prepared by a waste generator and approved by the Waste Acceptance Criteria Certification Committee, describing methods for processing and packaging TRU waste before shipment to WIPP

certified waste - waste that has been confirmed to comply with disposal-site waste acceptance criteria

characterization - identification of components in a waste or contaminated material; usually includes measurement of quantities, mapping of locations and other similar data

chemical oxygen demand (COD) - a measure of the extent to which all chemicals contained in a water sample use dissolved oxygen in a given time; thus a measure of residual dissolved oxygen in the water available for use by organisms such as fish

chemical processing - chemical treatment of materials to separate specific usable constituents; at Hanford, the separation by chemical means of plutonium from uranium and fission products resulting from the irradiation of uranium in a nuclear reactor

chronic - occurring over a long time period, or continuous, as opposed to acute

cladding - the outer jacket of nuclear fuel elements used to prevent corrosion of the fuel and release of fission products into reactor coolants

Code of Federal Regulations (CFR) - a documentation of the regulations of federal executive departments and agencies; divided into 50 titles representing broad areas subject to federal regulation; each title is divided into chapters, which are further subdivided into parts

coliform (count, number) - a measure of the bacterial content of water; a high coliform count indicates potential contamination of a water supply by human waste

colluvium - loose, incoherent deposits at the foot of a slope or cliff, brought there principally by gravity

commercial reactor equivalent - metric tons of defense nuclear fuel adjusted for the burn-up ratio of the defense fuel to 30,000 MWd/t

commercial repository - a deep geologic repository developed pursuant to the Nuclear Waste Policy Act for disposal of commercial and defense high-level waste and/or spent fuel

complexants - chemicals, usually organic, which assist in chelating (a type of chemical bonding) metallic atoms; examples include citrates, EDTA, HEDTA

concentrated complexant - (or complex concentrate) material containing high concentrations of complexants and stored in double-shell tanks; usually resulting from strontium recovery

concentration guide - the average concentration of a radionuclide in air or water to which a worker or member of the general population may be continuously exposed without exceeding applicable radiation dose standards

confined aquifer - a subsurface water-bearing region having defined, relatively impermeable upper and lower boundaries and whose pressure is significantly greater than atmospheric throughout conservative - conservative choices of parameters or assumptions are those that would tend to overestimate rather than underestimate impacts

contact-handled transuranic waste (CH-TRU) - waste, usually packaged in some form, which emits low enough radiation levels (less than 200 mR/hr) to permit close and unshielded manipulation by workers

contamination (contaminated material) - the deposition, solvation, or infiltration of radionuclides on or into an object, material, or area; the presence of unwanted radioactive materials or their deposition, particularly where it might be harmful

controlled area - any specific region of the Hanford Site into which entry by personnel is regulated by physical barrier and/or procedure

controlled exposure - the limiting, administratively, of ionizing radiation exposures to workers

corrosion testing - controlled experiments to determine the resistance of a metal to chemical attack (see also acceptable corrosion rate)

counts per minute (cpm) - the number of events per unit time recorded by an instrument designed to detect radioactive particles; especially used to indicate the relative amount of radioactive contamination

crib - an underground structure designed to receive liquid waste which can percolate into the soil directly and/or after traveling to a connected tile field

criteria - often used in conjunction with standards; criteria are general guidelines or principles from which more quantitative or definitive standards are prepared to regulate activities

critical - a condition wherein an element or compound is capable of sustaining a nuclear chain reaction

criticality - state of being critical; refers to a self-sustaining nuclear chain reaction in which there is an exact balance between production and loss of neutrons in the absence of extraneous sources

criticality safety - procedures and understandings necessary to the handling of fissile materials that will prevent their reaching a critical condition

curie (Ci) - a unit of radioactivity defined as the amount of a radioactive material that has an activity of $3.7 \times 10^{10}$ disintegrations per second (d/s); millicurie (mCi) = $10^{-3}$ curie; microcurie (μCi) = $10^{-6}$ curie; nanocurie (nCi) = $10^{-9}$ curie; picocurie (pCi) = $10^{-12}$ curie; femtocurie (fCi) = $10^{-15}$ curie; megacurie (MCi) = $10^{6}$ curie

current climate - in this document, describes climatic conditions that result in a recharge rate range represented by 0.5 cm/yr under certain vegetative cover conditions; from currently available data, 0.5 cm/yr appears to represent current climate conditions

customer waste - waste generated outside the 200 Areas; usually LLW

daughter products - the nuclides formed by the radioactive disintegration of a radionuclide (parent)

deactivated - condition of a facility or disposal site where steps have been taken to preclude further operation or further addition of waste

decay chain - the sequence of radioactive disintegrations in succession from one nuclide to another until a stable nuclide is formed

decay heat - thermal energy produced in a material by its own radioactive disintegrations decay product - the resulting nuclide following radioactive decay of a nuclide, also called daughter

decay, radioactive - a spontaneous nuclear transformation of one nuclide into a different nuclide or into a different energy state of the same nuclide by emission of particles and/or photons

decommissioning - actions taken to reduce the potential health and safety impacts of surplus facilities, including activities to stabilize, reduce, or remove radioactive contamination

decontamination - the removal of radioactive contamination from facilities, soils, or equipment by washing, chemical action, mechanical cleaning, or other techniques

decontamination factor (DF) - the factor by which the concentration of radioactive contaminants is reduced; the ratio of the radioactivity initially present to that subsequently present

defense waste - radioactive waste from any activity performed in whole or in part in support of DOE atomic energy defense activities; term excludes waste under purview of the NRC or generated by the commercial nuclear power industry

definitive design - detailed design stage of a process or facility from which construction or implementation can ensue

Department of Energy radioactive waste - radioactive waste generated directly by activities of the Department (or its predecessors) and its contractors or subcontractors or other radioactive waste for which the Department is responsible; may be referred to as DOE waste

design basis accident - a postulated accident believed to have the most severe expected impacts on a facility; used as the basis for safety analysis and protection by structural design

diastrophism - the process by which the earth's crust is deformed, producing mountains, faults, etc.

dielthermal region - that portion of a body of water whose temperature varies with the daily fluctuating light cycles

dip-slip fault - a fault in which one wall has moved up or down the face of the fault relative to the other wall

disintegration, nuclear - transformation of the nucleus of an atom from one state to another, characterized by the emission of particles and/or electromagnetic radiation

disintegrations per minute (dpm) - the number of radioactive decay events occurring per unit time in a given amount of material

dismantlement - those actions required to disassemble and remove sufficient radioactive or contaminated materials from the facility and site in order to permit release of the property to unrestricted use

dispersion - phenomenon by which a material placed in a flowing medium gradually spreads and occupies an ever-increasing portion of the flow domain

disposal - emplacement of waste so as to ensure isolation from the biosphere without maintenance and with no intent of retrieval and requiring deliberate action to gain access after emplacement

disposal site - the area dedicated to waste disposal and related activities

distribution coefficient (or $K_d$) - the ratio of the concentration of a solute sorbed by ion-exchange substances to the concentration of solute remaining in solution ditch - a small open trench used for conducting liquid waste streams from facilities usually to ponds (see also ponds)

dome fill - material for backfilling (dome filling) the open space above wastes in single- and double-shell tanks

dose commitment - the integrated dose which results from an intake of radioactive material when the dose is evaluated from the beginning of intake to a later time (usually 50 to 70 years); also used for the long-term integrated dose to which people are considered committed because radioactive material has been released to the environment

dose equivalent - the product of absorbed dose, quality factor, distribution factor, and other modifying factors necessary to evaluate the effects of irradiation received by exposed persons, so that the different characteristics of the exposure are taken into account; commonly expressed in rems

dose rate - the radiation dose delivered per unit time

dosimeter - a device, such as film, thermoluminescent material, or pocket ionization chamber, that measures radiation dose over a given period

double-shell slurry (DSS) - a mixture of fine solids, primarily sodium nitrate, suspended in a viscous liquid medium and stored in double-shell tanks

double-shell tank (DST) - a reinforced concrete underground vessel with two inner steel liners to provide containment and backup containment of liquid wastes; annulus is instrumented to permit detection of leaks from inner liner

drainable liquor - liquid in waste storage tanks which can migrate by gravity through the salt cake or sludge such that it could leak from the tank if it were breached below the liquid level

drum - a metal or composition cylindrical container used for the transportation, storage, and disposal of waste materials

drum counter - an assay tool for measuring radioactive contents of waste packaged in barrels (drums)

drywell - a drainage receptacle constructed by digging a hole and refilling with coarse gravel; also a watertight well casing used for inserting monitoring equipment

ecology - that branch of biological science which deals with the study of relationships between organisms and their environment

ecosystem - an assemblage of biota (community) and habitat

encapsulated waste - CsCl doubly encapsulated in stainless steel inner and outer capsules and $SrF_2$ doubly encapsulated in a Hastelloy inner capsule and stainless steel outer capsule in WESF water basins (see also WESF, Hastelloy®, fractionation)

engineered barrier - a manmade addition to a disposal site that is designed to retard or preclude radionuclide transport and/or to preserve the integrity of the disposal site

environmental surveillance - a program to monitor the effects on the surrounding region of the discharges from industrial operations

ephemeral - lasting briefly

epiclastic - pertaining to the texture of mechanically deposited sediments consisting of detrital material from preexistent rocks

evaporator/crystallizer - Hanford facilities to reduce the moisture content in tank waste to minimize potential leaks from tank liner failures and reduce storage space needs (see also waste concentration) evapotranspiration - the combined loss of water from soil by evaporation and from the surfaces of plant structures

excursion - a sudden rapid increase of power produced when a reactor or other system of fissile material undergoes a sudden increase in reactivity

exposure - the condition of being made subject to the action of radiation; a measure, in roentgens, of the ionization produced in air by x-ray or gamma radiation (see roentgen)

extraction - the mass transfer of an element or compound between two immiscible phases (see also bismuth phosphate, PUREX and REDOX)

facies - part of a rock body that is differentiated from other parts by appearance or composition

fallout - those radioactive materials deposited on the earth's surface and in the atmosphere following the detonation of nuclear weapons

fast flux (fast neutron) - a stream of neutrons having energies (velocities) near that imparted to them by a fission event; when applied to nuclear reactors, refers to those using high-velocity neutrons to cause successive fission events

fault - a break in the continuity of a rock formation, caused by a shifting or dislodging of the earth's crust, in which adjacent surfaces are differentially displaced parallel to the plane of fracture

feral - existing in a natural state

fertile isotope - a nuclide particularly capable of being transmuted into a fissile isotope (especially $^{238}U$, which is transmuted in production reactors to $^{239}Pu$)

fissile - describes material capable of undergoing fission by slow neutrons

fission (nuclear) - the division of a nucleus into two (and infrequently three) nuclides of lower mass, usually accompanied by the expulsion of gamma rays and neutrons

fission products - the lighter atomic nuclides (fission fragments) formed by the fission of heavy atoms; refers also to the nuclides formed by the fission fragments' radioactive decay

fissionable - material capable of undergoing fission by any process

fixation - the binding or adsorption of certain radionuclides on soil particles

fixative - a substance (such as paint, asphalt, or grout) used to stabilize loose contamination

fluoride removal - a process yet to be developed for removing free fluoride from NCRW, required if studies show fluoride inhibits setting of grout

food chain - a linear sequence of successive utilizations of nutrient energy by a series of species

food web - the concept of nutrient energy transfers (including decomposition) between species in an ecosystem

fractionation - as used here, refers to nuclide separation process

French drain - a rock-filled encasement with an open bottom to allow seepage of liquid waste into the ground

frit - chemical additives mixed with waste which create a glass upon heating; examples include fusible ceramic oxides and silicates (see also vitrification)

FRP box - a package commonly used for burying LLW, a plywood box reinforced with fiberglass-plastic; formerly used to store some TRU waste

fuel (nuclear, reactor) - fissionable material used as the source of power when placed in a critical arrangement in a nuclear reactor

fuel separation (fuel reprocessing) - processing of irradiated (spent) nuclear reactor fuel to recover useful materials as separate products, usually separation into plutonium, uranium, and fission products

future waste - for purposes of this document, future wastes are those on and offsite-generated wastes projected for November 1983 and beyond (The term "future" used in combination with double-shell tank inventories, i.e., liquid, grout, slurry, etc., is meant to imply inventories generated in the future during the current PUREX campaign. It should not be misinterpreted to mean double-shell tanks to be constructed in the future. Thus, the term "future double-shell tank" appearing in all the tables cited implies the inclusion of all wastes being generated and disposed to double-shell tanks during the current PUREX campaign. Use of the term "future" is independent of the schedule for tank farm construction.)

gamma radiation - electromagnetic energy emitted in the process of a nuclear transition

gamma scan - process of measuring the energy spectrum of the gamma rays emitted by a material in order to determine its constituent nuclides

gastrointestinal (GI) dose - the dose to the stomach and lower digestive tract of humans and animals via external exposure or via internal transport of radioactive material

genetic effects - radiation-induced effects (primarily mutations) that affect the descendants of the exposed individual; also called "hereditary" effects

geologic repository - a deep (on the order of 600 m or more), underground mined array of tunnels used for disposal of radioactive waste

glaciofluvial - pertaining to streams flowing from glaciers, or the deposits made from such streams

greater confinement - a technique for disposal of waste that uses natural and/or engineered barriers which provide a degree of isolation greater than that of shallow-land burial but possibly less than that of a geologic repository

greenhouse - in radiation protection, a temporary structure, frequently of wood and plastic film, used as a confinement barrier between a radioactive work area and a nonradioactive area to prevent spread of contamination

groundwater - water that exists or flows below the surface (within the zones of saturation)

grout - a fluid mixture of cementitious materials and liquid waste that sets up as a solid mass and is used for waste fixation and immobilization

grout plant - facility designed to combine liquid wastes with a grout binder for placement in near-surface disposal units

habitat - the abiotic characteristics of the place where biota live (see also community)

half-life - the time required for a radionuclide's activity to decay to half its value, used as a measure of the persistence of radioactive materials; each radionuclide has a characteristic constant half-life

half-life, biological - the time required for an organism to eliminate by biological processes half the amount of a substance that it has absorbed

half-life, effective - the time required for an organism to reduce its radioactive content by half as a combined result of radioactive decay and biological elimination halogenated hydrocarbons - organic compounds containing halogen atoms such as chlorine, fluorine, iodine, or bromine

Hanford facility waste - radioactive waste, other than fuel reprocessing waste, that is generated by Hanford contractors other than Rockwell (formerly called customer waste)

Hastelloy® - a trade name for a nickel-based alloy with corrosion-resistant properties and used at Hanford for encapsulating strontium fluoride. It is manufactured by Cabot Wrought Products Division, Cabot Corporation, Kokomo, Indiana.

hazardous waste - at Hanford this term usually means nonradioactive chemical toxins or otherwise potentially dangerous materials such as sodium, heavy metals, beryllium, and some organics

health effects - presumed radiation-induced fatal cancers and genetic effects

helium leak check - a method used during encapsulation at WESF to ensure the integrity of weld seals on capsules

HEPA filters - high-efficiency particulate air filters; material (usually a paper or fiber sheet pleated to increase surface area) which captures entrained particles from an air stream, usually with efficiencies of 99.95% and above

high-activity waste - any waste is above NRC Class C (10 CFR 61.55) waste

high-density concrete - a more effective shielding material produced by replacing some of the aggregate and sand in concrete with a denser material such as iron along with a higher Portland cement content

high-heat waste - liquid radioactive waste which generates sufficient fission product decay heat to cause self-boiling and self concentration (see also self-boiling waste)

high-level waste (HLW) - the highly radioactive waste material that results from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid waste derived from the liquid, that contains a combination of TRU waste and fission products in concentrations as to require permanent isolation (DOE Order 5820.2)

hind cast - estimated for past periods of time by means of more recent information

hood - a canopy and exhaust duct used to confine hazardous materials in order to reduce the exposure of industrial workers

hot cell - well-shielded enclosure for remote operations (see also canyon facility)

hot semiworks - a surplus facility formerly used to test processes on a semiproduction basis, scheduled for decontamination and decommissioning in the near future; also called Strontium Semiworks

hull waste - a type of cladding removal waste, usually refers to solid waste from FFTF fuel decladding

hydraulic conductivity - the parameter relating the volumetric flux to the driving force in flow through a porous medium (particularly water through soil); a function of both the porous medium and the properties of the fluid

hydraulic potential - a measure of the force present to cause groundwater flow; related to the height of the column of water above the point relative to mean sea level

hydraulic sluicing - a method for removing slurry from double-shell tanks by dissolving/suspending in water and pumping out (see also mechanical recovery) hydrostatic equilibrium - the state of a fluid where no relative motion occurs between fluid elements and the pressure at any point is equal to the weight of a unit cross-section of a column of fluid above that point

hygroscopic - absorption and retention of atmospheric moisture

immobilization - a process such as grouting or vitrification designed to inhibit mobility of waste

inadvertent intrusion - human activity such as home excavation, resource mining, and well-digging, which accidentally breaches a waste site

institutional control - continued control over the Hanford Site by legal ownership and management by the federal government

interstitial liquor - liquid in a waste matrix accommodated in the pore spaces; some is capable of gravity drainage while the rest is held by capillary forces

intruder - a person who ignores site and marker boundaries

inversion - a condition in which temperature increases with height in the atmosphere

ion exchange - process for selectively removing a constituent from a waste stream by reversibly transferring ions between an insoluble solid and the waste stream; the exchange medium (usually a column of resin or soil) can then be washed to collect the waste or taken directly to disposal; for example, a water softener operates by ion exchange

irradiation - exposure to radiation by being placed near a radioactive source; usually in the case of fuel materials, being placed in an operating nuclear reactor

isokinetic - a line in a given surface connecting points with equal wind speed

isopleth - in meteorology, a line connecting all points of equal air concentration

isotherm - a line joining points having the same temperature

isotope - nuclides with the same atomic number (i.e., the same chemical element) but with different atomic masses; although chemical properties are the same, radioactive and nuclear properties may be quite different for each isotope of an element

jet pumping - a technique for removing interstitial liquor from single-shell tanks (see also interstitial liquor and salt well)

joule heating - method of applying energy to a crucible of solid material to achieve melting, and involving placement of electrodes into the material and applying electrical potential resulting in a current flow and heating (see also vitrification)

$K_d$ - see distribution coefficient

knuckle - point where the side wall and the bottom curved surface of the tank meet

lag storage - space required to hold materials temporarily so that processes are not upset by throughput variations

leach - to dissolve out the soluble components of a solid by contact with water or other solvent

leachate - the solution or product obtained from leaching

leaching trench - an excavation used for the disposal of liquids so that the soil will remove contaminants while allowing water and other solvents to pass through

liquid-waste disposal site - facilities used for discharge of contaminated liquids to the ground (see also crib, pond, ditch, sump, reverse well, French drain) lithologic - pertaining to the characteristics and study of rocks

loess - a homogeneous, nonstratified, unindurated sediment, largely silt, mainly wind-deposited

low-activity waste - for purposes of fractionation analyses of tank wastes in this EIS, low-activity waste means any waste whose concentrations of radionuclides do not exceed those given in the NRC criteria for near surface waste disposal, Subpart (5)(i) and (4)(ii) of 10 CFR 61.55, for Class C waste

low-level waste (LLW) - radioactive waste not classified as high-level waste, TRU waste, spent nuclear fuel, or byproduct material (as defined by DOE Order 5820.2)

lysimeter - an instrument for measuring the water percolating through soils and determining the materials dissolved by the water

magmatic - pertaining to rock derived from magma

manipulator - mechanical hands or some other device for performing work behind a barrier or in a shielded cave

man-rem - the product of the dose equivalent in rem and the number of people receiving that dose, a collective population dose

marker - a surface or subsurface monument or plaque of durable material containing a warning and/or information message designed to inhibit intrusion

mass number (A) - the number of nucleons (protons and neutrons) in the nucleus of an atom

maximum (or maximally) exposed individual - a hypothetical member of the public whose habits tend to maximize radiation dose to a given organ; for the case where exposures from airborne radionuclides result in the highest contribution to dose, this individual is assumed to reside continuously at the location of highest airborne radionuclide concentration and to eat food grown there

mechanical recovery - a means of removing waste from an underground storage tank without using water; often conceptualized as a mining technique using a clam-shell scoop (see also hydraulic sluicing)

mesic - of or pertaining to a habitat characterized by a moderate amount of water

meteoric water - groundwater that originates in the atmosphere and reaches the zone of saturation by infiltration and percolation

metric ton (tonne, t) - 1000 kilograms, equivalent to 2,205 pounds

monitoring wells - holes sunk in the ground to various depths where instruments are lowered or water samples are taken to determine presence of radioactivity

natural barrier - physical, chemical, and hydrologic characteristics of the geologic environment at the disposal site that act, individually and collectively, to retard or preclude transport of radioactivity

near surface - a location designation for waste disposed of within the first 30 m of the earth's surface

neutralization - the reaction of acidic waste with an alkali (such as NaOH, $Ca(OH)_2$, KOH) to reduce corrosion and thereby increase the life of waste containers

neutron - a particle existing in or emitted from the atomic nucleus; it is electrically neutral and has a mass about equal to that of a stable hydrogen atom

neutron activation - the process of irradiating a material with neutrons so that the material itself is transformed into a radioactive nuclide nitrogen oxides ($NO_x$) - a mixture of nitrogen-oxygen containing compounds primarily formed as gaseous waste effluents in the combustion of most fossil fuels

nondestructive assay - analytical technique which can determine the presence and quantity of an element(s) without altering the matrix material

normal operating conditions - operation, including startup, shutdown, and maintenance of systems within the normal range of facility operating parameters

nuclear fission - see fission

nuclear radiation - particles and electromagnetic energy given off by transformations occurring in the nucleus of an atom

nuclear reactor - a device constructed of fissionable material such that a chain of fission events can be maintained and controlled to meet a particular purpose

nucleus - the positively charged center of an atom

nuclide - a species of atom having a specific mass, atomic number, and nuclear energy state

off-gas treatment - generic name for equipment designed to clean up vent gases from processes; may be adsorbers, sand beds, gas flares, HEPA filters, etc.

off site - any place outside the Hanford Site boundary

on site - any place within the Hanford Site boundary

out-year - budget term referring to estimates beyond the centrally identified period of concern

overburden - soil used to backfill an excavation containing solid waste or a liquid waste disposal structure

ozonization - a process for oxidizing (or destroying) complexants in recovered complexed concentrate from double-shell tank slurry (see also complexants) by reaction with ozone

packaging - assembly of radioactive material in one or more containers

paleoslope - the direction of initial dip of a former land surface, such as an ancient continental slope

particulate - generally refers to particles in an aerosol stream; usually can be removed by filtration

partitioning - process of separating liquid waste into two or more fractional solutions

pathway analysis - the study of the movement of radioactive materials from the source to locations of interest; may involve computer simulation

penetrating radiation - forms of radiation capable of passing through significant thicknesses of solid material; usually include gamma rays, x-rays and neutrons, also specifically, radiation capable of penetrating human skin and exposing internal organs

percolation - gravity flow of groundwater through the pore spaces in rock or soil

periphyton - organisms that live attached to underwater surfaces

permeability - capacity of a medium for transmitting a fluid

phytoplankton - microscopic plants that live drifting in a body of water

ponds - surface depressions (sometimes called swamps) used to contain low-level contaminated solutions (see also liquid waste disposal site) population dose (population exposure) - summation of individual radiation doses received by all those exposed to the source or event being considered

porosity - the ratio of the aggregate volume of small spaces or pores in a rock soil to its total volume

precertified - solid TRU waste packaged (see WRAP) to meet requirements of WIPP-WAC (see also certification plan)

precipitation - in solution chemistry, solids separating out of solution and usually settling by gravity; otherwise rain, snow, etc.

preconceptual - in early, prototype stages, usually with reference to a design

present worth - the amount of money that would need to be invested on a certain date at a fixed rate of interest to provide the required funding to accomplish a planned action; at the end of the action, the balance of invested money has been reduced to zero and the amount invested plus the interest on it equals the total expenditure to accomplish the action

production reactor - a nuclear reactor designed for transforming one nuclide into another, usually natural uranium into plutonium

programmatic - generic or broad-based; not specific to a site or facility; basic policy

psychrometric data - temperature and humidity data collected for tank ventilation air, used to estimate heat content or thermal load of waste

PUREX - Plutonium URanium EXtraction, latest in a line of separation technologies, preceded by bismuth phosphate and REDOX (see also extraction)

quality assurance - the systematic actions necessary to provide adequate confidence that a material, component, system, process, or facility performs satisfactorily, or as planned in service

quality control - the quality assurance actions that control the attributes of a material, process, component, system, or facility in accordance with predetermined quality requirements

rad - a special unit of measure for the absorbed dose of radiation; one rad equals 100 ergs absorbed per gram of material

radiation (ionizing) - particles and electromagnetic energy emitted by nuclear transformations that are capable of producing ions when interacting with matter

radiation monitoring - a term covering application of a field of knowledge including determination of dose rates, surveys of personnel and equipment for contamination control, air sampling, exposure control, etc.

radiation survey - evaluation of an area or object with instruments in order to detect, identify and quantify radioactive materials and radiation fields present

radiation zone - area containing radioactive materials in quantities significant enough to require control of personnel entry to the area

radioactive (decay) - the undergoing of spontaneous nuclear transformation in which nuclear particles or electromagnetic energy are emitted

radioactive waste - solid, liquid, or gaseous material of negligible economic value that contains radionuclides in excess of threshold quantities except for radioactive material from post-weapons-test activities radioactive waste management - the planning, coordination, and control of those functions related to handling, treatment, storage, transportation, and disposal of radioactive waste, as well as associated surveillance and maintenance activities

radioactivity - the property of certain nuclides of emitting particles or electromagnetic radiation while undergoing nuclear transformations

radiofrequency drying - similar to microwave heating, a laboratory-tested process for in-place drying of moist waste

radiolytic decomposition - the breaking up of a compound by radiation

radionuclide - a nuclide that is radioactive

radiosonde - instrumentation for simultaneous measurement and transmission of meteorological data

radiotoxicity - a material's ability to adversely affect biological organisms through nuclear radiation

radwaste - radioactive waste materials

raffinate - that portion of a treated liquid mixture that is not dissolved and not removed by a selective solvent

raptor - bird of prey

reactivity - a measure of a system's capability to maintain criticality; systems with high reactivity are capable of undergoing rapid excursions of increasing power while those with low reactivity will undergo slower excursions and systems with negative reactivity will not become critical

reactor - see nuclear reactor

recharge - the net process of water percolating downward through the soil profile resulting from the individual processes of precipitation, surface runoff and evapotranspiration

recharge rate - the net rate of downward water movement resulting from recharge; units - volume per unit time per unit area ($cm^3/cm^2$-yr = cm/yr): the equivalent depth of water hypothetically placed at the land surface that becomes recharged each year

redd - the spawning grounds or nests of salmon

REDOX - a facility and/or process for separating plutonium from irradiated reactor fuels by using successive steps of chemical REDuction/OXidation together with solvent extraction

redundancy - a policy of including backup safeguards in design, e.g., stable waste form, container, overpack, burial, engineered barriers and markers

regolith - rock "waste" or surface mantle of unconsolidated rock debris; in the Pasco Basin, the basin-fill sediments that are the parent materials of the local "soils"

release factor - ratio of amount of a substance released from a process as waste to the total amount present

release limit (release guide) - the maximum concentration or amount of radioactive material that may be released to the environment; usually derived from the limiting dose that may be received by persons in the environment from such releases

rem - the special unit of the dose equivalent; the radiation dose equivalent in rems is numerically equal to the absorbed dose in rads at the point of interest in tissues, multiplied by a quality factor, distribution factors, and all other modifying factors; one rem approximately equals one rad for X, gamma, or beta radiation remedial action - activities conducted to reduce potential radiation exposure to people and potential harm to the environment from radioactive contamination in the environment

remote-handled transuranic waste (RH-TRU) - waste having a surface dose rate greater than 200 mR/hr and requiring shielding from and distance between it and human manipulators

remote sensing - monitoring at a distance as opposed to bringing sample and detector in direct contact

reprocessing - chemical processing of irradiated nuclear reactor fuels to remove desired constituents

residual waste - that waste that remains after a major processing step. For example, the waste in single shell tanks is removed from the tanks and processed in the geologic disposal alternative to remove Sr, Cs, Tc and TRU and other nuclides; that not recovered from the tanks and that remaining after such removal are forms of residual waste

retention basin - an excavated and lined area used to hold fluids until radioactive decay reduces activities to levels permissible for release or until sampling verifies that the fluid is at a level permissible for release

retention time - the time that waste stream components are held up in a zone; a function of flow rate and chamber size

retired facility - a facility that has been shut down with no intention of restarting and has had appropriate controls and safeguards placed on it

retrievably stored - interim stored waste retrievable with minimal risk and cost for further processing and/or disposal (see also double-shell tank, asphalt pad, tunnel)

reverse well - an early Hanford liquid disposal waste structure consisting of a well (sometimes drilled into water table) into which waste solutions were pumped

riparian - living or located on a riverbank

riprap - an assemblage of broken stones often used to protect against water erosion

Rockwell - abbreviated form of Rockwell Hanford Operations

roentgen - a unit of measure of ionizing electromagnetic radiation (exposure) (x and gamma rays); one roentgen corresponds to the release by ionization of 83.8 ergs of energy per gram of air

rupture - a breach of the metal cladding of production reactor fuel elements, releasing radioactive materials to reactor cooling streams

salt cake - crystallized nitrate and other salts deposited in waste tanks, usually after active measures are taken to remove moisture

salt well - a hole drilled or sluiced into a salt cake and lined with a cylindrical screen to permit drainage and jet pumping of interstitial liquor

sanitary landfill - a burial operation for disposing of nonradioactive waste or garbage

sanitary sewage - human waste and other nonradioactive material for disposal to preserve public health

saturated zone - the subsurface zone in which all interconnecting voids or pores are filled with water

seepage pond - an artificial body of surface water formed by discharge from Hanford process operations

seismicity - the tendency for earthquakes to occur self-boiling waste - high-level liquid radioactive waste whose constituent radionuclides contribute sufficient decay heat to cause the solution to boil and/or self-concentrate

shallow-land burial - disposal of waste in near-surface excavations that are covered with a protective overburden

shielding - bulkheads, walls, or other constructions used to absorb radiation in order to protect personnel or equipment

Shippingport reactor - the Shippingport atomic power station was a pressurized water reactor (PWR) built in the mid-1950s to demonstrate PWR technology and generate electricity; the reactor portion of this facility is scheduled for decommissioning, and the fuel is under DOE control and may be reprocessed at PUREX

single-shell tank (SST) - older style Hanford HLW underground tank composed of a single carbon steel liner surrounded by concrete

slagging pyrolysis incinerator (SPI) - a facility to combine retrieved waste with contaminated soil or overburden to form a chemically inert, physically stable, basalt-like slag

sludge - primarily insoluble metal hydroxides and oxides precipitated from neutralized waste

sludge washing - sludge cleanup with water to remove soluble "impurities" that would increase the glass volume if the sludge were vitrified

slurry growth - a change in volume of double-shell tank waste which results from a chemical reaction of the organic components

soil plume - the trail of contaminated soil left behind due to adsorption from a liquid waste discharge

solid waste (radioactive) - either solid radioactive material or solid objects that contain radioactive material or bear radioactive surface contamination

solid waste burial site - a land area specifically designated to receive contaminated solid waste materials for burial (see also burial ground trench, caisson, vee trench, vault)

somatic effects - radiation-induced effects that become manifest in the exposed individual; at low doses and dose rates, these are statistically predicted delayed cancers

sorption - a general term used to encompass the processes of absorption, adsorption, ion exchange, ion retardation, chemisorption, and dialysis

sorptive capacity - the measure of a material's ability to sorb specific constituents from a liquid as it passes through the material

source material - uranium or thorium or any ores that contain at least 0.05% of uranium or thorium

source term - the quantity of radioactive material, released by an accident or operation, which causes exposure after transmission or deposition

special nuclear material (SNM) - plutonium, $^{233}U$, $^{235}U$, or uranium enriched to a higher percentage of the 233 or 235 isotopes than normal

spent nuclear fuel - fuel that has been withdrawn from a nuclear reactor following irradiation, whose constituent elements have not been separated by reprocessing

stability (atmospheric) - a description of the atmospheric forces on a parcel of air following vertical displacement in an atmosphere otherwise in hydrostatic equilibrium; if the forces tend to return the parcel to its original level, the atmosphere is stable; if they tend to move the parcel further in the direction of displacement, the atmosphere is unstable; if the air parcel tends to remain at its new level, the atmosphere has neutral stability stabilization - treatment of waste or a waste site to protect the biosphere from contamination (see also isolation, immobilization, active subsidence control, engineered barrier)

stabilize - as applied to wastes for disposal in place at Hanford, the application of processes or actions that, if needed, will increase their resistance to chemical change or physical disintegration

standby - the condition in which a facility or burial ground, etc., is placed in a nonoperating condition but is maintained ready for subsequent operation

storage - retention of waste in a retrievable manner that requires surveillance and institutional control

storage basin - a water-filled facility for holding irradiated reactor fuels or encapsulated radioactive strontium or cesium; water acts as a shield and coolant

storage site - area dedicated to waste storage and related activities

strike-slip fault - a fault in which the movement (offset) of one wall with respect to the other wall has been parallel to the fault's strike

subsidence - gradual or sudden sinking of the ground surface below natural grade level due to slow decay and compression of material or collapse of a large void space

subsidence accommodating barrier - barrier designed thick and rugged enough to withstand and self-heal as the waste below compacts or decays; sometimes called a slump-and-fill barrier

sulfur oxides ($SO_2$, $SO_3$) - compounds formed as waste effluents in the burning of some fossil fuels

sump - a collection point (depression or tank) for liquids prior to their transfer

supernatant liquors - usually refers to a distinct liquid phase resting atop a solid layer

suprabasalt - rocks overlying basalt

surplus facility - any facility or site (including equipment) that has no identified programmatic use and may or may not be radioactively contaminated to levels that require controlled access

surveillance - those activities that ensure the site waste remains safe (including inspection and monitoring of the site, maintenance of access barriers to radioactive materials left on the site, and prevention of activities on the site that might impair these barriers)

survey - an evaluation of the radiation hazards incidental to the production, use, release, disposal, or presence of radioactive materials or other sources of radiation under a specific set of conditions

syncline - a low, troughlike area in bedrock, in which rocks incline together from opposite sides

tank - a large steel-lined concrete container located underground for storage of liquid waste

tank farm - an installation of interconnected underground tanks for storing waste

tectonic - pertaining to or designating the rock structures resulting from deformation of the earth's crust

terrane - any rock formation or series of formations (also terrain)

tholeiitic - pertaining to a group of basalts composed principally of plagioclase, pyroxene, and iron oxide minerals as phenocrysts in a glassy groundmass thoria process (and campaign) - a special PUREX flowsheet designed for two limited process campaigns of aluminum-clad thorium dioxide ($ThO_2$) fuel; significant in that these campaigns contributed considerable $^{233}U$ to the Hanford waste inventory (see also PUREX)

threshold quantity - quantity or concentration of radioactivity above which the waste must be managed according to the requirements of the DOE Order and below which the waste may be disposed of as nonradioactive waste at an approved sanitary landfill

tiering - a method (see 40 CFR 1508.28) for preparing a network of environmental documents branching off from a generic, broad EIS to optimize use of support documentation

tracer - radionuclide(s) or chemical introduced in minute quantities to a system or process for using detection techniques to follow the behavior of the process or system

transmissivity - a coefficient relating the volumetric flow through a unit width of groundwater to the driving force (hydraulic potential); a function of the porous medium, fluid properties, and saturated thickness of the aquifer

transmutation - process whereby one nuclide changes (or is changed) into another; usually by addition of nuclear particles

transuranic waste - without regard to source or form, radioactive waste that at the end of institutional control periods is contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years and concentrations greater than 100 nCi/g

transuranium radionuclide - any radionuclide having an atomic number greater than 92

trench - a large structure usually filled with solid radioactive wastes and buried

trophic levels - pertains to groupings of organisms according to characteristics of their intake of nutrients

tunnel - a large underground storage structure for large pieces of equipment, often on railroad cars; PUREX storage tunnels

turbidity - a measure of the degree to which sediments and other foreign matter are suspended in water (cloudiness)

200 Areas plateau - highest portion (aside from Rattlesnake and Gable Mountains) on Hanford Site, containing most of the waste processing and storage facilities

224-T - a building currently used to store plutonium on the Hanford 200 Areas plateau

unconfined aquifer - an aquifer that has a water table or surface at atmospheric pressure

unplanned release - unplanned discharge of contaminated liquid or particulate onto the ground

unsegregated solid waste - waste buried before 1970 which was not separated according to TRU content, combustibility, or other criteria

vadose zone - the unsaturated region of soil between the ground surface and the water table

vault - another type of solid waste storage structure similar to a caisson

"vee" trench - a specific type of trench (see solid waste burial site) named for its characteristic shape (cross sectional), constructed as a prototype CH-TRU waste storage and abandonded in favor of asphalt pads

vermiculite - a micaceous mineral that is a hydrous silicate, used as a packaging material or as an absorbent for liquid waste

vitrification - a method of immobilizing radioactive waste for eventual disposal in a geologic repository; involves adding frit and waste to a joule-heated vessel and melting it into a glass that is then poured into a canister void space - air space either above waste in a caisson, burial trench, or tank and/or within pores or interstices of a bulk material such as gravel or random barrels

volcanoclastic - volcanically derived sediments that have been redeposited by water

waste byproducts - material, other than special nuclear material that, if separated and recovered from nuclear fuel cycle waste streams can be used for safe, environmentally acceptable, and cost-effective applications (DOE 5820.2)

waste concentration - removal of excess water from liquid waste or slurries (see evaporator/crystallizer)

waste container - a containment vessel for radioactive waste, including any liner or shielding material intended for disposal

waste form - the form in which a waste exists at the time of interest

waste package - the radioactive waste, waste container, and absorber that are intended for storage or disposal as a unit; in the case of contaminated, damaged, leaking, or breached waste packages, any overpack shall be considered the container, and the original package shall be considered part of the waste

water basin - stainless steel-lined concrete pool with water circulation and treatment for storing and cooling strontium and cesium capsules

water table - upper boundary of an unconfined aquifer surface below which soil saturated with groundwater occurs; defined by the levels at which water stands in wells that barely penetrate the aquifer

wind rose - a diagram designed to show the distribution of wind directions at a given location; one variation includes wind speed groupings by direction

WYE Burial Ground (300-Y) - an old waste burial ground off the 200 Areas plateau near the site of the present WPPSS No. 2 Reactor; also designated as 618-11

X-rays - a penetrating form of electromagnetic radiation emitted when the inner orbital electrons of an excited atom return to their normal state; always non-nuclear in origin, x-rays originate external to the nucleus of the atom

Zircaloy - a type of reactor fuel cladding composed of zirconium alloy (zirconium alloyed with tin and iron)

Zirflex - a process for chemically decladding Zircaloy-clad fuel elements, using an ammonium fluoride, ammonium nitrate solution

zooplankton - microscopic animals that live drifting in a body of water

## 8.2 ACRONYMS, ABBREVIATIONS AND SYMBOLS

$\alpha$ - alpha radiation

AEC - Atomic Energy Commission

AECM - Atomic Energy Commission Manual

AED - Aerodynamic Equivalent Diameter

ALARA - as low as reasonably achievable

ALE - Arid Lands Ecology, a research reserve on the Hanford Site operated for DOE by Battelle, Pacific Northwest Laboratories

atm - atmosphere

$\beta$ - beta radiation, also bulk soil density

BNW - Pacific Northwest Laboratories of Battelle Memorial Institute, commonly referred to as Battelle-Northwest

Btu - British thermal unit

BWIP - Basalt Waste Isolation Project

CAW - current acid waste

CCDF - complementary cumulative distribution function

CDR - Conceptual Design Report

CEQ - Council on Environmental Quality

CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act of 1980

CF - concentration factor

CFR - Code of Federal Regulations

CG - concentration guide

$CG_W$ - concentration guide for water

CH - contact-handled

Ci - curie

cm - centimeter

$cm^3$ - cubic centimeter

CPF - Capsule Packaging Facility

CRW - cladding removal waste

D&D - decontamination and decommissioning

DEIS - Draft Environmental Impact Statement

DF - decontamination factor

DMRHF - dry materials receiving and handling facility

DNW - direct neutralized waste (see neutralization)

DOE - Department of Energy

DOT - Department of Transportation

dpm - disintegrations per minute

DST - double-shell tank

DSTS - double-shell tank slurry

DWSF - drywell storage facility

EDTA - ethylenediaminetetraacetic acid

EIS - Environmental Impact Statement

EPA - Environmental Protection Agency

E/Q - normalized time-integrated air concentration, Ci-sec per $m^3$ per Ci released (Ci-sec/Ci-$m^3$); also written sec/$m^3$

ERDA - Energy Research and Development Administration

ERDAM - Energy Research and Development Administration Manual

erg - a unit of energy, dyne-centimeter or gram-$cm^2$/$sec^2$

FDC - Functional Design Criteria

FEIS - Final Environmental Impact Statement

FFTF - Fast Flux Test Facility

FP - fission products

FRP - fiberglass-reinforced plastic or plywood box

FSAR - Final Safety Analysis Report

g - gram (seismology, g = acceleration due to gravity)

gal - gallon(s)

GI - gastrointestinal

Gy - gray, unit of absorbed dose

$\gamma$ gamma radiation

ha - hectare = 10,000 $m^2$, equivalent to 2.47 acres

HDW - Hanford Defense Waste

HEDL - Hanford Engineering Development Laboratory (operated by Westinghouse Hanford Company)

HEDTA - Hydroxyethylethylene-diaminetetraacetic acid

HEHF - Hanford Environmental Health Foundation

HEPA - high-efficiency particulate air (filter)

HFW - Hanford Facilities Waste

HLW - high-level waste

HMS - Hanford Meteorological Station

HWVP - Hanford Waste Vitrification Plant

IAEA - International Atomic Energy Agency

ICRP - International Commission on Radiological Protection

INEL - Idaho National Engineering Laboratory

INTE - Intera Environmental Consultants, Inc.

ISD - in-place stabilization and disposal

$K_d$ - see distribution coefficient

kV - kilovolt

kW - kilowatt

kWh - kilowatt-hour

L - liter

LANL - Los Alamos National Laboratory

LLI - lower large intestine

LLW - low-level waste

$m^2$ - square meter

$m^3$ - cubic meter

mb - millibars

MCi - megacurie ($1 \times 10^6$ Ci)

mCi - millicurie ($1 \times 10^{-3}$ Ci)

$\mu$Ci - microcurie ($1 \times 10^{-6}$ Ci)

MeV - million electron volts

mg - milligram

MIBK - methyl isobutyl ketone (hexone)

min - minute

mL - milliliter

MPC - maximum permissible concentration

$MPC_W$ - maximum permissible concentration for water

mR - milli-Roentgen

mrad - millirad

mrem - millirem

MSL - mean sea level

MTHM - metric ton of heavy metal

MTM - metric ton of metal

MW - megawatt

MWDt/t - megawatt days-thermal per ton

MWe - megawatts, electric

MWt - megawatts, thermal

NCAW - neutralized current acid waste

nCi - nanocurie (1 x $10^{-9}$ Ci)

NCRP - National Council on Radiation Protection and Measurements

NCRW - neutralized cladding removal waste (see neutralization)

NDE - nondestructive examination

NEPA - National Environmental Policy Act of 1969

NERP - National Environmental Research Park

No. - number

NPDES - National Pollutant Discharge Elimination System

NPH - normal paraffin hydrocarbons

NRC - Nuclear Regulatory Commission

NSC - National Safety Council

NTS - Nevada Test Site

NWPA - Nuclear Waste Policy Act of 1982

ONWI - Office of Nuclear Waste Isolation

ORNL - Oak Ridge National Laboratory

OSHA - Occupational Safety and Health Administration

OWI - Office of Waste Isolation

OWW - organic wash waste

PANRG - Performance Assessment National Review Group

pCi - picocurie (1 x $10^{-12}$ Ci)

PFMP - Process Facility Modifications Project

PFP - Plutonium Finishing Plant (Z Plant) pH - a measure of acidity and alkalinity

PMF - probable maximum flood

PNL - Pacific Northwest Laboratory

ppb - parts per billion

ppm - parts per million

ppt - parts per thousand

PRA - probabilistic risk assessment

PUREX - Plutonium URanium EXtraction

% - percent

Q - release quantity of radioactive materials, Ci

Q' - release rate of radioactive material, Ci/sec

RADTRAN III - computer code (developed at Sandia National Laboratories) that calculates the risk of transporting radioactive material

RCRA - Resource Conservation and Recovery Act of 1976

REDOX - REDuction OXidation

RH - remote-handled

SI - Systeme Internationale

SNL - Sandia National Laboratories

SNM - Special Nuclear Material

SPI - slagging pyrolysis incinerator

SRP - Savannah River Plant

SS - stainless steel

SST - single-shell tank

SWIMS - Solid Waste Information Management System

T - standard ton

t - tonne (metric ton)

TBP - tri-n-butyl phosphate

TGE - transportable grout equipment

TGF - Transportable Grout Facility

tonne - metric ton = 1000 kg = ~2200 lb

Tri-Cities - area including cities of Richland, Pasco and Kennewick, Washington

TRU - see transuranic waste (in 8.1)

TRUSAF - TRU Storage and Assay Facility

UNH - uranyl nitrate hexahydrate

WAC - Waste Acceptance Criteria

WESF - Waste Encapsulation and Storage Facility

WHC - Westinghouse Hanford Company

WIPP - Waste Isolation Pilot Plant

WIPP-WAC - Waste Isolation Pilot Plant Waste Acceptance Criteria

WISAP - Waste Isolation Safety Assessment Program

wk - week

WNP-2 - Washington Nuclear Plant (Number 2)

WPPSS - Washington Public Power Supply System; the utilities company which operates WNP and the Hanford Generating Plant

WRAP - Waste Receiving and Processing

wt - weight

$\chi$ - chi, concentration, $Ci/m^3$

$\bar{\chi}/Q'$ - chi-bar/Q prime, normalized annual average air concentration ($Ci/m^3$ per Ci/sec released, also written $sec/m^3$); also called the annual average atmospheric dispersion factor

## 8.3 ALPHABETICAL LIST OF ELEMENTS AND SYMBOLS

| Element | Symbol | Element | Symbol | Element | Symbol |
|---|---|---|---|---|---|
| Actinium | Ac | Hafnium | Hf | Praseodymium | Pr |
| Aluminum | Al | Helium | He | Promethium | Pm |
| Americium | Am | Holmium | Ho | Protactinium | Pa |
| Antimony | Sb | Hydrogen | H | Radium | Ra |
| Argon | Ar | Indium | In | Radon | Rn |
| Arsenic | As | Iodine | I | Rhenium | Re |
| Astatine | At | Iridium | Ir | Rhodium | Rh |
| Barium | Ba | Iron | Fe | Rubidium | Rb |
| Berkelium | Bk | Krypton | Kr | Ruthenium | Ru |
| Beryllium | Be | Lanthanum | La | Samarium | Sm |
| Bismuth | Bi | Lawrencium | Lr | Scandium | Sc |
| Boron | B | Lead | Pb | Selenium | Se |
| Bromine | Br | Lithium | Li | Silicon | Si |
| Cadmium | Cd | Lutetium | Lu | Silver | Ag |
| Calcium | Ca | Magnesium | Mg | Sodium | Na |
| Californium | Cf | Manganese | Mn | Strontium | Sr |
| Carbon | C | Mendelevium | Md | Sulfur | S |
| Cerium | Ce | Mercury | Hg | Tantalum | Ta |
| Cesium | Cs | Molybdenum | Mo | Technetium | Tc |
| Chlorine | Cl | Neodymium | Nd | Tellurium | Te |
| Chromium | Cr | Neon | Ne | Terbium | Tb |
| Cobalt | Co | Neptunium | Np | Thallium | Tl |
| Copper | Cu | Nickel | Ni | Thorium | Th |
| Curium | Cm | Niobium | Nb | Thulium | Tm |
| Dysprosium | Dy | Nitrogen | N | Tin | Sn |
| Einsteinium | Es | Nobelium | No | Titanium | Ti |
| Erbium | Er | Osmium | Os | Tungsten | W |
| Europium | Eu | Oxygen | O | Uranium | U |
| Fermium | Fm | Palladium | Pd | Vanadium | V |
| Fluorine | F | Phosphorus | P | Xenon | Xe |
| Francium | Fr | Platinum | Pt | Ytterbium | Yb |
| Gadolinium | Gd | Plutonium | Pu | Yttrium | Y |
| Gallium | Ga | Polonium | Po | Zinc | Zn |
| Germanium | Ge | Potassium | K | Zirconium | Zr |
| Gold | Au | | | | |

## 8.4 CONVERSION FACTORS

| | | | |
|---|---|---|---|
| **Length** | | **Mass** | |
| 1 millimeter | = 0.0394 inch | 1 gram | = 0.035 ounce |
| 1 meter | = 3.281 feet | 1 kilogram | = 2.2 pounds |
| 1 kilometer | = 0.6215 mile | 1 megagram | = 2,200 pounds |
| **Area** | | **Energy** | |
| 1 sq cm | = 0.155 sq inch | 1 QUAD | = $10^{15}$ Btu |
| 1 sq meter | = 10.76 sq feet | | = $3 \times 10^{11}$ kWh |
| 1 sq kilometer | = 0.386 sq mile | | = 33 GWe-yr |
| | = 247 acres | 1 therm | = $10^5$ Btu |
| | | 1 kilocalorie | = 3.96 Btu |
| **Volume** | | 1 kWh | = 859 kilocalories |
| 1 cu meter | = 1,000 liters | 1 GWe-yr | = $8.76 \times 10^9$ kWh |
| | = $10^6$ $cm^3$ | | |
| | = 35.31 cu ft | | |
| | = 264 gallons | | |

| Multiplier | Prefix | Symbol | Equivalent |
|---|---|---|---|
| $10^{12}$ | tera | T | trillion |
| $10^9$ | giga | G | billion |
| $10^6$ | mega | M | million |
| $10^3$ | kilo | k | thousand |
| $10^2$ | hecto | h | hundred |
| $10^1$ | deka | da | ten |
| $10^{-1}$ | deci | d | a tenth part |
| $10^{-2}$ | centi | c | a hundredth |
| $10^{-3}$ | milli | m | a thousandth |
| $10^{-6}$ | micro | μ | a millionth |
| $10^{-9}$ | nano | n | a billionth |
| $10^{-12}$ | pico | p | a trillionth |
| $10^{-15}$ | femto | f | one thousandth of a millionth of a millionth |
| $10^{-18}$ | atto | a | one millionth of a millionth of a millionth |

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waste site inventories — K.1, Appendix A, Intro to Apps

water quality standards — 6.2

water/sewage services — See community

windstorms — 4.5.1

West Valley Demonstration Project (WVDP) — C.1, C.4

Yakima River — 4.4.1, Q.4

Z Plant — D.2

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Act Program

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Nuclear Waste Project*
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Hanford Oversight Committee*
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High-Level Nuclear Waste Office

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President, League of Women Voters of the
United States

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Salem Fellowship of Reconciliation

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Seattle Women Act for Peace**
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Sierra Club
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Snake River Alliance

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Tacoma Audubon Society

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Washington Public Interest
Research Group
ATTN: Susan Krala

Washington Public Interest
Research Group
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Washington Public Interest**
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