Appendix C.9

Facility Disposition Modeling

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Appendix C.9

Facility Disposition Modeling

This appendix analyzes the long-term consequences (generally over a 10,000-year analysis period) of leaving contamination in major Idaho Nuclear Technology and Engineering Center (INTEC) facilities that would be closed as part of the waste processing and facility disposition alternatives described in this Environmental Impact Statement (EIS). The U.S. Department of Energy (DOE) acknowledges that impact projections that extend 10,000 years into the future are not likely to be exact. However, these projections of impacts presented in this appendix are useful in that they employ the same methodology, thus permitting comparisons of alternatives.

DOE has revised waste inventory data and has modified certain model assumptions and parameters from those used in the Draft EIS. Therefore, this appendix provides the methodology and revised impacts for all facility disposition alternatives analyzed in this EIS. A Calculation Package (TtNUS 2001) is the major sources of technical information used to support this appendix. The appendix provides a descriptive interface between the facility disposition impacts reported in this EIS and the Calculation Package.

Section 5.3 of this EIS presents the impacts from the facility disposition alternatives. In most cases, these impacts are the immediate, short-term impacts from the activities associated with disposition. Facility disposition could leave some residual contamination that could result in long-term consequences. The Clean Closure Alternative could leave residuals that would be indistinguishable from background concentrations. Under the alternatives that dispose of contaminated grout on the Idaho National Engineering and Environmental Laboratory (INEEL) or leave stored materials in the facilities indefinitely, quantities of contamination would remain in perpetuity.

C.9.1 INTRODUCTION

C.9.1.1 Problem Statement

When high-level waste (HLW) facilities have completed their missions, good environmental stewardship and Federal law require that the facilities be closed in a systematic fashion that addresses future risk to the environment and to people who could be impacted by any remaining contamination. Two of the ways of addressing these risks are to remove as much of the contaminated material as is feasible and to stabilize that which remains. Radiological contamination left in the facilities can impact humans by direct radiation, and radiological and hazardous contaminants can migrate from the facilities through the environment such that air, soil, groundwater, and surface water could become contaminated. Once these media are contaminated, drinking water or eating foods that have taken up the contamination can result in adverse health effects. This appendix presents the analytical results of modeling potential contaminant contributions from these existing facilities and the low-level waste disposal options, so that relative comparison can be made between impacts of various facility disposition alternatives.

As discussed in Chapter 3, DOE considered multiple conditions in which the facilities could be readied for ultimate disposition. Some of these alternatives would result in residual radioactivity and nonradiological constituents that would remain in the facilities after disposition and could be transported to the environment at some point in the future. DOE identified six alternatives that could be implemented for disposition of some or all of the existing INTEC facilities. These alternatives are summarized here; more detailed descriptions can be found in Section 3.2.1.

No Action - Under the No Action Alternative, the calcine in the bin sets and the liquid mixed transuranic waste/sodium-bearing waste (referred to as mixed transuranic waste/SBW) in the Tank Farm would not be treated and would remain in existing storage facilities. During the period of active institutional control through 2095, surveillance and maintenance necessary to protect the environment and safety and health of workers would be performed in the normal course of INTEC operations. Beyond the period of institutional control, storage facilities could deteriorate and fail, allowing contaminants to migrate into the environment. (The Continued Current Operations Alternative described in Section 3.1.2 would calcine all remaining mixed transuranic waste/SBW and store the calcine in the bin sets indefinitely. As a result, the bin set source terms would be somewhat increased from those evaluated for the No Action Alternative. Although this alternative was not specifically analyzed in this appendix, the impact of the increased source term is discussed qualitatively in Section C.9.6.)

Clean Closure - Under this alternative, facilities would have the hazardous wastes and radiological contaminants, including contaminated equipment, removed from the site or treated so that the hazardous and radiological contaminants would be indistinguishable from background concentrations. Clean Closure could require total dismantlement and removal of facilities. Use of the facilities (or the facility sites) after Clean Closure would present immeasurably small risk to workers or the public from contaminants from previous activities.

Performance-Based Closure - Closure methods would be dictated on a case-by-case basis depending on the risk associated with radiological and chemical hazards. The facilities would be decontaminated such that residual waste and contaminants no longer pose an unacceptable exposure or risk to workers or to the public. For the Tank Farm and bin sets, DOE anticipates using a specially engineered grout mixture to be placed in these facilities as a waste stabilization method. The grout would be specially engineered to provide favorable characteristics that would provide long-term structural support and that would bind any residual contaminants to reduce leaching to groundwater. The specially engineered grout produces reducing conditions and is commonly referred to as reducing grout.

Closure to Landfill Standards - The facility would be closed in accordance with the state and Federal requirements for closure of landfills. Closure to landfill standards is intended to protect the health and safety of the workers and the public from potential releases of contaminants from the facility. This could be accomplished by installing an engineered cap, establishing a groundwater monitoring system, and providing post-closure monitoring and care of the waste containment system, depending on the type of contaminants. As with the Performance-Based Closure, DOE anticipates using a specially engineered (reducing) grout mixture to be placed in these facilities as a stabilization method for the Tank Farm and bin sets. The reducing grout would be designed to provide favorable characteristics that would provide long-term structural support and that would bind contaminants to reduce leaching to groundwater.

Performance-Based Closure with Class A Grout Disposal - As discussed in Section 3.1, some of the Separations Alternative options remove sufficient quantities of transuranics and highly radioactive nuclides such that the remaining fraction could be stabilized with grout and categorized as Class A-type low-level waste. In such cases, this grouted waste could be disposed in (1) a near-surface disposal facility on or off the INEEL or (2) the Tank Farm and bin sets. Under this facility disposition alternative, the Tank Farm and bin sets would be closed as described for the Performance-Based Closure Alternative. Following completion of these closures, the Class A-type low-level waste grout would be placed in the underground tanks and bin sets. The grout would be designed to provide favorable characteristics that would provide long-term structural support and bind contaminants to reduce leaching to groundwater.

Performance-Based Closure with Class C Grout Disposal - As discussed above for Performance-Based Closure with Class A Grout Disposal, radionuclide separations could result in a low-level waste fraction that would be suitable for disposal in the underground tanks and bin sets at INTEC. If the separations process is designed to leave higher concentrations of some radionuclides in the low-level waste fraction, that fraction could be stabilized with grout and categorized as Class C-type low-level waste. Under this facility disposition alternative, the Tank Farm and bin sets would be closed as described above for the Performance-Based Closure Alternative. Following completion of these closures, the Class C-type low-level waste grout would be placed in the underground tanks and bin sets. The grout would be designed to provide favorable characteristics that would provide long-term structural support and bind contaminants to reduce leaching to groundwater.

The Class A or Class C-type low-level waste grout could also be disposed in a near surface disposal facility on or off the INEEL. If the disposal option selected for the grouted Class A or Class C-type low-level waste fraction is an offsite near-surface landfill, the waste would be prepared for transport and shipped accordingly. If the onsite near-surface landfill option is selected, DOE would construct the new Low-Activity Waste Disposal Facility on the INEEL. For purposes of analysis in this EIS, this facility would be built in the vicinity of INTEC and would be designed in accordance with applicable regulations. In addition to the six alternatives for disposition of existing facilities, this appendix analyzes the long-term impacts associated with the new Low-Activity Waste Disposal Facility.

C.9.1.2 Long-Term Impact Analysis for Facility Disposition Alternatives

For purposes of long-term impacts analysis in this EIS, DOE determined that the Clean Closure Alternative removes residual contamination to be indistinguishable from background levels so there is no long-term impact. In addition, DOE estimated that the residual inventories under the Performance-Based Closure Alternative and the Closure to Landfill Standards Alternative are so similar that a single analysis can accommodate both alternatives. Finally, with regard to offsite low-level waste disposal options, DOE assumed that such facilities would have undergone all the necessary environmental review and permitting in accordance with applicable regulation. Therefore, this appendix analyzes long-term impacts for only the following alternatives:

- No Action
- Performance-Based Closure/Closure to Landfill Standards
- Performance-Based Closure With Class A Grout Disposal
- Performance-Based Closure With Class C Grout Disposal
- Class A Grout Disposal in a New Low-Activity Waste Disposal Facility
- Class C Grout Disposal in a New Low-Activity Waste Disposal Facility

Table 3-3 identifies the many facilities at INTEC that are subject to facility disposition and the facility disposition alternatives applicable to each.

For long-term impacts analysis, the facility list was narrowed because DOE determined that just five facilities contain, by far, most of contamination that could contribute to long-term impacts. These facilities are identified in Table C.9-1, along with the applicable facility disposition alternative and the general type of contamination remaining in the closed facility.

C.9.1.3 General Analytical Method

The approach DOE used to calculate long-term impacts is outlined in Figure C.9-1. The steps and activities associated with facility disposition modeling are very complex and this appendix provides an overview of the process. Details of the approach are available in the supporting Calculation Package (TtNUS 2001).

Develop Conceptual Models - Conceptual models are simplified representations of real-world conditions. For long-term impact modeling, the conceptual model includes identification or specification of the geometry of the contamination, the nature and geometry of the engineered containment, the timing of the failure of engineered containment, the natural mechanisms that can release the contamination to various media, the methods by which people can be exposed, the types of people that would be exposed, and the parameters that will be reported as final results. As an example, for Performance-Based Closure of a HLW tank, the contamination could be modeled as a pancake of contamination at the bottom of the tank, with grout and soil above and concrete and soil below. The conceptual model could choose to ignore the stainless steel tank. Infiltration of water through the soil, grout, and

Table C.9-1. Facilities selected for long-term closure analysis.

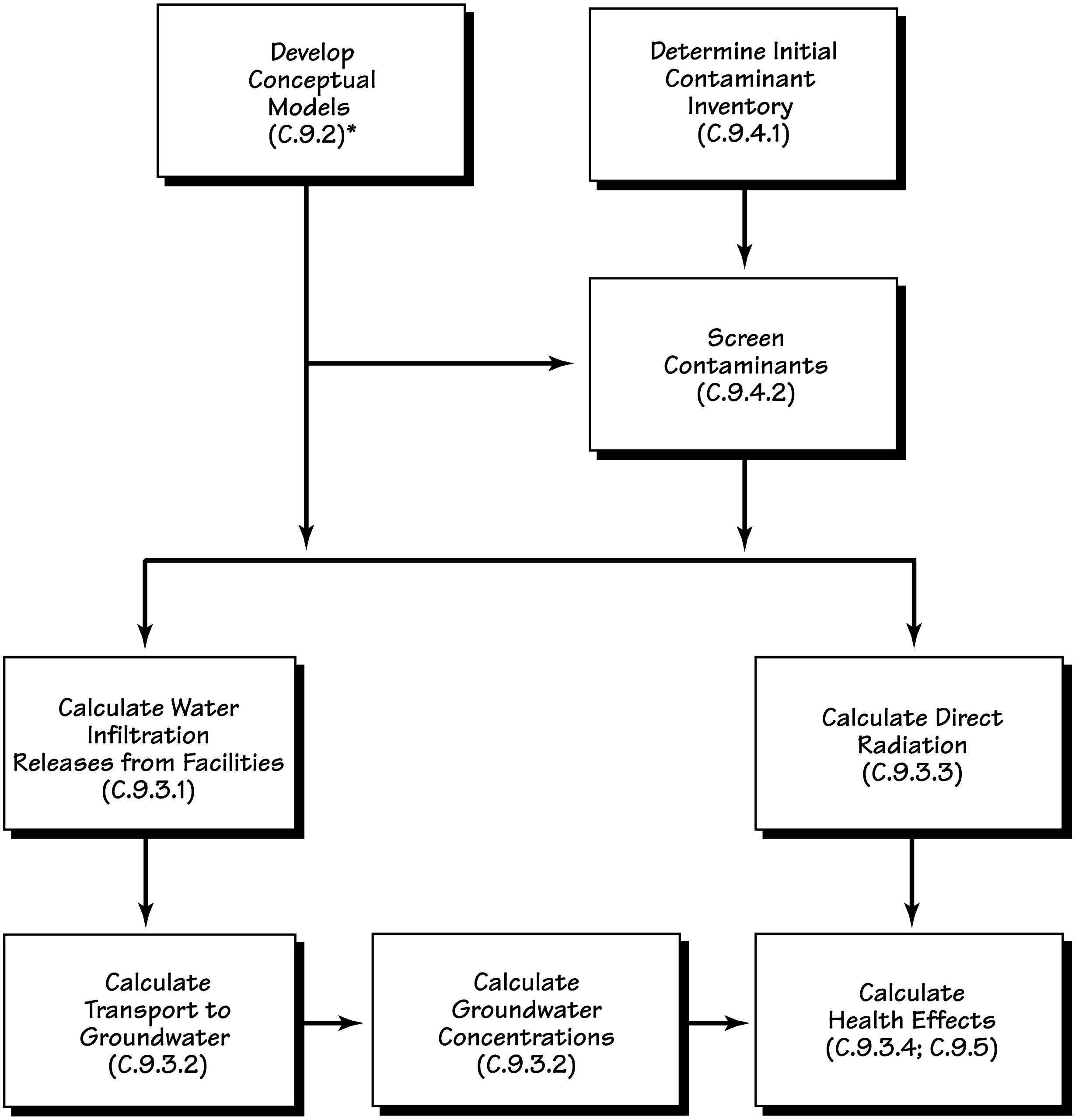
Facility	Applicable alternative	Contaminant description
Tank Farm	No Action	Stored SBW
	Performance-based Closure/Closure to Landfill Standards	Residual contamination
	Class A or Class C Grout Disposal	Residual plus Class A or Class C-type grout
Bin sets	No Action	Stored calcine
	Performance-based Closure/Closure to Landfill Standards	Residual contamination
	Class A or Class C Grout Disposal	Residual plus Class A or Class C-type grout
Process Equipment Waste Evaporator	Performance-based Closure/Closure to Landfill Standards	Residual contamination
New Waste Calcining Facility	Performance-based Closure/Closure to Landfill Standards	Residual contamination
Low-Activity Waste Disposal Facility	Class A or Class C Grout Disposal	Class A or Class C-type grout

contamination could then release the constituents of the contamination to move downward through the concrete, soil, and eventually into the groundwater. Containment failure at 500 years would accelerate the release process. Following assumed loss of institutional control in 2095, a future resident could drill a well into the aquifer below INTEC and drink the water, resulting in radiation exposure expressed in terms of lifetime dose in millirem. The conceptual models DOE used (see Section C.9.2) are consistent with this example but have more elements and are more detailed. Separate conceptual models were developed for each combination of disposition alternative and facility.

Determine Initial Contaminant Inventory - DOE used engineering studies to determine a best estimate of the contents of the tanks, bin sets, and other facilities selected for closure under the various alternatives. These studies were based on records of what materials went into the facilities, an accounting of changes that have occurred since the materials were placed into the facilities, and direct measurements of existing volumes and contaminant concentrations. The initial inventories are described in Section C.9.4.1.

Screen Contaminants - Since only a limited number of contaminants contribute appreciably to long-term impacts, DOE developed and applied a method (referred to here as "screening") to identify those contaminants of potential concern that warrant detailed quantitative analysis. The multi-step screening process, which is described more fully in Section C.9.4.2, results in the identification of a few constituents that would produce the greatest long-term impacts. The screening process is dependent on the conceptual models, as indicated in Figure C.9-1. For example, a constituent that is very insoluble in water, and thus potentially insignificant in a water pathway, might prove to be a key constituent in a direct radiation pathway. The screening process for direct radiation is different than screening for a groundwater release pathway. As described in Section C.9.2, the conceptual model development resulted in only two major exposure modes being analyzed: groundwater and direct radiation.

Calculate Water Infiltration Releases from Facilities - Transport of contaminants to the groundwater requires infiltration of water through the facilities. DOE used a computer program (MEPAS) to estimate release rates of



*Nomenclature in parentheses refer to section numbers in this appendix.

FIGURE C.9-1.
General Analytical Method.

constituents that would result from infiltration of water through the closed facilities.[1] The computer program was configured to represent the conceptual models (Section C.9.2) and the input parameters were tailored for the conditions in the facilities and their environs. The resulting release rates were presented as a function of time over the analysis period of 10,000 years. Section C.9.3.1 describes the computer program and explains how this analysis was performed.

Calculate Transport to Groundwater - DOE used another computer program (TETRAD) that incorporates the constituent release rates from the facilities as inputs and calculates contaminant transport through the unsaturated soil to the groundwater. The TETRAD model was configured for a reasonable representation of the subsurface conditions known to exist under INTEC. The result of this calculation is groundwater concentrations, as a function of time, in the Snake River Plain Aquifer underneath INTEC. Section C.9.3.2 provides more information on calculation of contaminant transport to the groundwater.

Calculate Groundwater Concentrations - Groundwater concentrations are important endpoints because they are used as inputs to the human health impact analysis and because the concentrations can be compared to Federal drinking water regulations. These concentrations were calculated using the TETRAD computer program described in the previous step. Section C.9.3.2 provides more information on calculating groundwater concentrations.

Calculate Direct Radiation - Based on the contaminant screening results described in Section C.9.4.2 and the geometries of the conceptual models (Section C.9.2), it is possible to calculate radiation dose rate from radiologically contaminated soils and closed facilities. The conceptual models also identify the assumptions governing receptors which lead to direct exposure to radiation so that radiation dose to these receptors can be calculated. Section C.9.3.3 describes how the direct radiation doses were calculated.

Calculate Health Effects - Once direct radiation fields and groundwater concentrations are known, this information, combined with the living habits of the receptors (Section C.9.2.2), can be used to calculate contaminant intake (mainly by ingestion and inhalation) and direct radiation exposure of human receptors. This allows the determination of human health impacts in terms of the analytical endpoints described in C.9.2.4. Section C.9.3.4 describes these calculations of impacts to human receptors. The results are summarized in Section C.9.5.

C.9.2 CONCEPTUAL MODELS

C.9.2.1 Release and Exposure Modes

DOE has identified three general mechanisms by which individuals could be impacted by residual contamination as follows:

- Contaminants could be transported to the aquifer under the facilities and eventually reach wells allowing humans to access the contaminated water for drinking, irrigation, and other purposes. (Surface water exposure scenarios were not considered credible events for the setting and time frames analyzed.)
- Contaminants in closed facilities could emit gamma radiation which could directly irradiate humans in the vicinity.
- Contaminants could be released to the environment through airborne pathways due to degradation and weathering of the bin sets under the No Action Alternative.

Except for the scenario of the bin sets under No Action identified in the third bullet above, and airborne pathways resulting from groundwater pumped to the surface, DOE does not believe that there are other credible ways in which con-

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[1] The term "closed" is used in the Resource Conservation and Recovery Act (RCRA) sense of the word - that is, approved closure plans would be prepared and implemented for the underground tanks, bin sets, and new Low-Activity Waste Disposal Facility in accordance with applicable hazardous waste regulations.

taminants could be introduced to the air after closure of the underground tanks, bin sets, or new Low-Activity Waste Disposal Facility. More specifically, where approved closure plans have been implemented for these facilities, it is assumed that water infiltration will eventually move contaminants down to the groundwater as waste containment structures gradually lose integrity, and that this will occur before weather erodes the surface exposing contaminants for air transport.

The airborne pathways associated with the bin set - No Action scenario are addressed as facility accidents in Section 5.2.14 and Appendix C.4. The abnormal event accident described in Table C.4-2 provides the bounding long-term air release analysis for bin set failure. This accident involves the degradation and ultimate failure of one of the bin sets after the end of the institutional control period at 2095. Since the air impacts due to bin set accidents are addressed in Appendix C.4, the remaining subsections in this appendix only describe the conceptual models for groundwater and direct radiation exposures.

C.9.2.1.1 Groundwater Release and Exposure

Figure C.9-2 illustrates the conceptual model used by DOE in evaluating the impacts to individuals from groundwater releases following facility closure. As shown in the figure, the transport of contaminants would be accomplished via infiltration of rainwater, which would eventually leach contaminants from the facilities and transport them down through the unsaturated zone to the aquifer. DOE's conceptual model for infiltration begins with the rainfall in the INTEC area and deducts run-off and evapotranspiration typical of the INTEC area. The permeability of the overlaying soil, engineered structures, and contaminate layer all influence the flux of water through and from the facility. The chemical properties of the water after passing through the engineered structures and the tenacity (known as a distribution coefficient) of the concrete, soil, and contaminant medium to retain radioactive or hazardous constituents determine the concentration of contaminants in the water.

The conceptual model also accounts for methods by which people could be exposed to groundwater. These methods include the following exposure pathways, which all rely on the water being pumped from the Snake River Plain Aquifer to the surface:

- Drinking contaminated groundwater
- Using groundwater to irrigate food crops and to water animals used for food
- Inadvertent ingestion of soil contaminated by groundwater irrigation
- Breathing air containing contaminated soil particles
- Absorption through skin contact with contaminated soil or water

DOE conservatively assumed that the well water is withdrawn from the location of peak aquifer concentration for each contaminant, even if the peak concentration for different contaminants occur at different points within the aquifer. Similarly, cumulative dose and risk are determined assuming that peak aquifer concentrations for each contaminant overlap in time. The method used for estimating intakes of contaminants from ingestion of contaminated groundwater or crops grown on contaminated site soils or irrigated with groundwater is based on the methodology developed for baseline risk assessments previously performed for INTEC (DOE 1994, Rodriguez et al. 1997). DOE evaluated these exposure routes by assuming that the contaminants in soil and groundwater (irrigation water) are transferred to various food crops by means of deposition (from overhead irrigation) and root uptake. The soil concentrations used for root uptake (as well as inadvertent soil ingestion) were calculated under the assumption that the only significant pathway for soil contamination was through irrigation with contaminated groundwater.

The major assumptions that DOE made in its assessment of groundwater release impacts are as follows:

- To be conservative, any residual contaminants left in the tanks and bin sets after flushing and/or final cleaning would be assumed to reside on the floor of the facility, thereby creating a higher

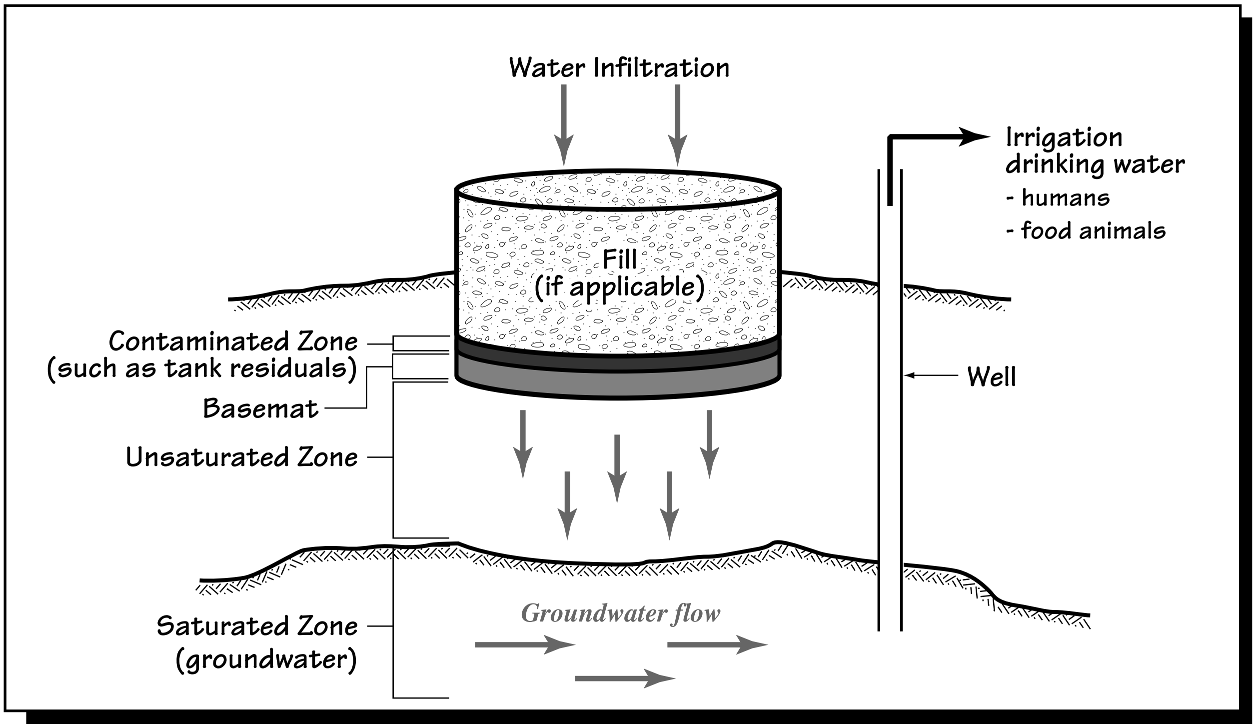

FIGURE C.9-2.
Generalized conceptual model for groundwater release.

concentration layer. Contaminants in the Class A and Class C-type grout are assumed to be uniformly distributed throughout the grout.

- At 500 years, the concrete and grout in the tanks and bin sets assumes the same hydrogeologic transport characteristics as the surrounding soil; however, chemical properties of grout and concrete are assumed to remain unchanged.
- The present environmental conditions including meteorology, infiltration rates, and geologic conditions would remain constant throughout the entire 10,000-year period of analysis. (The sensitivity studies discussed in Section C.9.6 explore the impacts of changing precipitation.)

Assumptions for specific receptors are provided in Section C.9.2.2. Conceptual assumptions specific to alternatives or facilities are provided in Section C.9.2.3.

C.9.2.1.2 *Direct Radiation*

The assessment of direct radiation exposure scenarios includes cases where future receptors are exposed to direct radiation from (a) radionuclides in contaminated soil and (b) residual radioactivity in closed facilities including the Tank Farm, bin sets, New Waste Calcining Facility, Process Equipment Waste Evaporator, and (c) Class A or Class C-type grout in the Tank Farm, bin sets, or a new Low-Activity Waste Disposal Facility. DOE developed exposure scenarios for contaminated soil and closed facilities for which some of the assumptions are described below. Separate discussions are provided for soil and closed facility contamination assessments since there are major differences in the methodology between the two.

Direct Radiation from Contaminated Soil

The conceptual model for direct radiation from soil is based on soil that has been contaminated by irrigation from contaminated groundwater. As a result, the radioactive contaminants in groundwater are the only ones assumed to be found in the soil. These radionuclides are further assumed to be evenly distributed in the top 6 inches of soil; the contaminated land extends infinitely in all directions. The concentration of contaminants in the soil has been calculated based on equations presented in Section 3.6 of the Calculation Package. The dose rate at 1 foot above the surface is used to calculate total lifetime dose for the various receptors.

Direct Radiation from Dispositioned Facilities

The approach for modeling external radiation dose from radionuclides in dispositioned facilities begins with the development of a conceptual model which defines the source geometry, dimensions, and shielding materials for each source facility. For some existing facilities, this model is closely patterned after the actual construction of the facility under evaluation, while for others simplifying assumptions were necessary. For example, the source geometry and construction materials used for the Tank Farm model closely approximate those of existing storage tanks, whereas a simplified geometry is used to approximate the more complex array of calcine storage bins within a bin set. DOE then made conservative estimates for the average distance between receptor and source for each category of receptor and source facility. The radionuclide inventories in the closed facilities are based on estimates for the year 2016 (Staiger and Millet 2000; Demmer and Archibald 1995; Barnes 2000) and then decay-corrected to apply to the time frame of the specific cases assessed. More details on these conceptual models are found in Section 5.2.2 of the Calculation Package.

C.9.2.2 Receptor Identification

In its consideration of disposition activities, DOE recognized that certain types of receptors are the most likely to be impacted by the closure scenarios. To identify the specific receptors for which analyses would be performed, DOE considered real receptors (known individuals and populations) that could be impacted in the present or near-term time frame, as well as hypothetical receptors that could be exposed under bounding conditions at any time throughout the 10,000-year period of analysis. In postulating these receptors, DOE assumed that certain activities, such as construction of residences or industrial complexes, could occur on or near the land where the dispositioned facilities are located.

DOE evaluated impacts to eight receptors. Two of these receptors, the INEEL Worker and the Unauthorized Intruder, had exposures before the end of institutional control and were thus not truly representative of long-term impacts. One receptor, Average Resident, was similar in nature and bounded by the Maximally Exposed Resident. The Indoor Worker was similar in nature and bounded by the Construction Worker. Therefore, the analysis in this EIS is simplified to cover the following four receptors, which represent several potential future uses of the land.

- **Maximally Exposed Resident -** a resident farmer who lives in a dwelling constructed at the INTEC site after the period of institutional control and who uses the land for subsistence. This receptor would obtain all of his domestic and agricultural water supply from a well drilled into the aquifer, which is assumed to be affected by contaminant releases from compromised dispositioned facilities. The maximally exposed resident is assumed to be exposed for a duration of 30 years.

- **Future Industrial Worker -** an adult who would have access to the site after the period of institutional control but who is considered to be a member of the public for compliance purposes. The future worker is assumed to be exposed for a duration of 25 years.

- **Future Intruder -** a person who gains access to the site after the period of institutional control and engages in activities (such as digging around buried radiation sources) that exacerbate the radiation exposure hazard. For Tank Farm scenarios, it is assumed that the intruder unknowingly excavates to the top level of a HLW tank, eliminating the shielding afforded by the soil overburden. This assumption results in higher projected impacts from the Tank Farm scenarios than from the equivalent scenarios for the bin sets. By design, the Tank Farm relies on soil overburden for shielding. The intruder would remove that soil overburden, causing a substantial rise in dose rate. The 1 1/2 feet thickness of concrete on top of the tanks is ignored in calculating impacts to the intruder. In contrast, the bin sets have thick shielding built into their design (because they are not completely under ground), which result in lower impacts for the intruder. Although the intruder was assessed primarily for exposure to external radiation sources, exposure to soil contaminated with radionuclides was also considered. The intruder was not analyzed for nonradiological risk since the contaminant intake potential is very much lower than for other receptor categories. The intruder is assumed to be exposed for a duration of 1 day.

- **Recreational User** - a person who routinely would visit the affected area after the period of institutional control and use the area for recreational activities, including camping, hiking, and hunting. The recreational user is assumed to be exposed for a duration of 2 weeks per year for 24 years.

Table C.9-2 identifies which exposure pathways apply to each of the four receptors and provides the defining characteristics of each receptor.

C.9.2.3 Analyzed Scenarios

A scenario is a specific combination of a facility closure alternative and a facility. DOE has identified 12 separate combinations of alternatives and facilities, each of which has been analyzed for all the selected receptors. Table C.9-3 identifies these scenarios. For example, the first scenario (facility-alternative combination) identified in the table is Tank Farm - No Action.

Some of the assumptions that apply to the scenarios generally are as follows:

- The impact area in question is the general vicinity of the current INTEC. Institutional control would be maintained over this area until the year 2095. After that time, it is assumed for purposes of analysis that this area would not be controlled, and could be used for residential, agricultural, industrial, or recreational purposes for a period of roughly 10,000 years.

- For alternatives other than the No Action Alternative and Performance-based Closure with Class A or Class C Grout Disposal, DOE assumed that a clean grout material would be used to fill the Tank Farm and bin sets to provide long-term structural stability. DOE also assumed that this would be a reducing grout in order to provide favorable characteristics that would inhibit the leaching of some contaminants to the aquifer.

- Except for the case of No Action for the bin sets, there would be no credible scenario under which significant amounts of radionuclides from closed facilities would be released to air.

- Surface water exposure scenarios were not considered credible events for the setting and time frames analyzed.

Assumptions related to specific alternatives or scenarios are described below.

No Action Alternative

As discussed in Chapter 3, under the No-Action waste processing alternative, waste would remain in the Tank Farm and bin sets. Because the Tank Farm and bin sets under No Action contain the great majority of contaminants among all the HLW facilities, only these two scenarios are analyzed as part of No Action. In its evalua-

Table C.9-2. Exposure pathways for each receptor.

Receptor	Primary exposure sources	Exposure pathways
Maximally exposed resident	groundwater	- drinking water - soil ingestion - dermal contact with soil and groundwater - eating food from irrigated garden a. vegetables and fruits b. grains - eating food from watered animals a. meat b. poultry c. milk and milk products d. eggs - inhalation of soil particles suspended in air
	facility sources	- direct radiation from contaminated soils - direct radiation from dispositioned facilities
Future industrial worker	groundwater	- drinking water - soil ingestion - dermal contact with soil and groundwater - inhalation of soil particles suspended in air
	facility sources	- direct radiation from contaminated soils - direct radiation from dispositioned facilities
Future intruder	groundwater	- soil ingestion - inhalation of soil particles suspended in air
	facility sources	- direct radiation from contaminated soils - direct radiation from dispositioned facilities
Recreational user	groundwater	- drinking water - soil ingestion - dermal contact with soil and groundwater - eating meat of game animals - inhalation of soil particles suspended in air
	facility sources	- direct radiation from contaminated soils - direct radiation from dispositioned facilities

tion of impacts, DOE has assumed that no fill material is placed in the facilities. Section 2.3 of the Calculation Package provides more detail on the No Action scenarios.

Under the Tank Farm - No Action scenario, which is represented in Figure C.9-3, a composite tank is assumed which contains all of the contents of the tanks (five full tanks of mixed transuranic waste/SBW and six tanks emptied to their heels and containing residual contamination). The contents of the composite tank are assumed to leach through the basemat and into the soil beneath the composite tank as described in Section C.9.2.1.1. Water infiltration would continue to wash contaminants out of the tank. For direct radiation, the receptor is assumed to stand immediately above the tanks, which would be shielded by 10 feet of soil, except for the intruder, which gets no benefit of shielding. In addition, DOE analyzed the impacts of a direct release of contaminants from the five full mixed transuranic waste/SBW tanks to the soil. Section C.9.6 provides further description of this scenario.

Table C.9-3. Analyzed scenarios.

Alternative	Applicable Facilities
No Action	Tank Farm (stored mixed transuranic waste/SBW) bin sets (stored calcine)
Performance-Based Closure and Closure to Landfill Standards	Tank Farm (residual) bin sets (residual) New Waste Calcining Facility (residual) Process Equipment Waste Evaporator (residual)
Performance-Based Closure with Class A and Class C Grout Disposal	Tank Farm (residual plus Class A-type grout) Tank Farm (residual plus Class C-type grout) bin sets (residual plus Class A-type grout) bin sets (residual plus Class C-type grout)
Disposal of Class A or Class C Grout in a New Low-Activity Waste Disposal Facility	Low-Activity Waste Disposal Facility (Class A-type Grout) Low-Activity Waste Disposal Facility (Class C-type Grout)

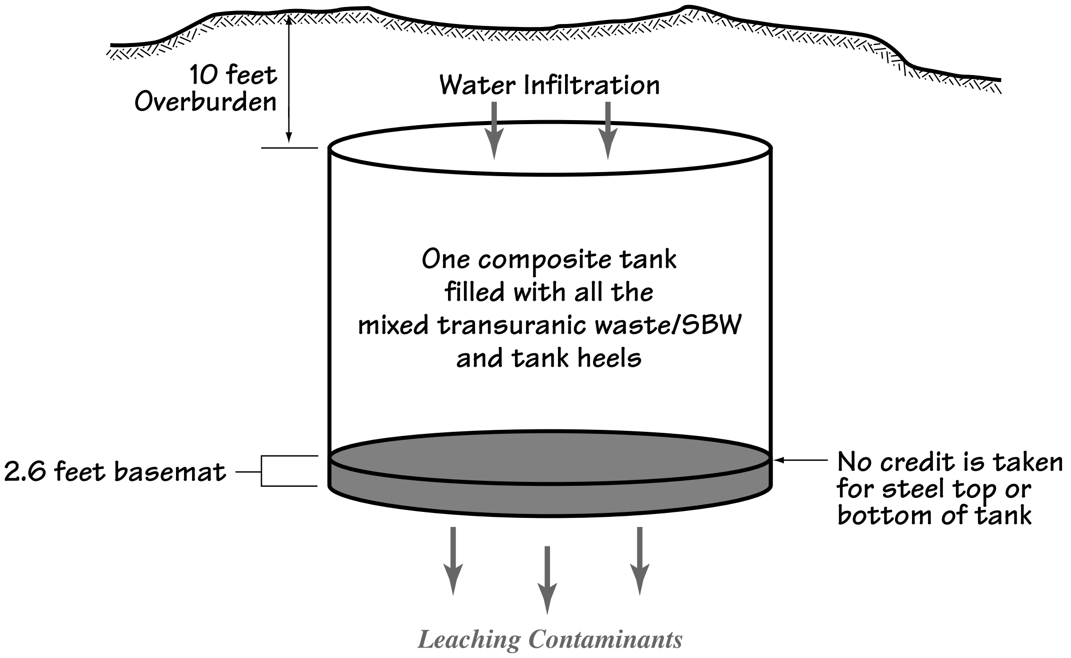

FIGURE C.9-3.
Conceptual diagram of the Tank Farm - No Action scenario.

Under the bin sets - No Action scenario, which is represented in Figure C.9-4, water is allowed to infiltrate through a partially buried composite bin set containing all the calcine of the six currently used bin sets. The constituents in the calcine are then leached through the basemat and eventually reach groundwater. Also, the degraded bin set can release calcine to the air. The impact of the degraded bin sets is analyzed as a facility accident and the results are presented in Section 5.2.14 and Appendix C.4. For direct radiation, dose rates are calculated at 3 feet and 10 feet from the outer surface of a bin set (a nominal distance that a person might normally be expected to stand or walk in the presence of a very large structure), which provides 5.3 feet of concrete shielding.

DOE has selected dimensions of the composite Tank Farm tanks and composite bin sets, which are representative of all tanks and bin sets considered in the analysis. Dimensional difference of these facilities is discussed in the sensitivity analysis section (C.9.6).

Performance-Based Closure or Closure to Landfill Standards

Under these alternatives, the Tank Farm, bin sets, New Waste Calcining Facility, and Process Equipment Waste Evaporator would be closed to meet performance-based objectives. For all four scenarios associated with these alternatives, a clean grout material would be used to fill the volume of these facilities. Although studies have shown that cementitious materials (such as grout or concrete) can be engineered to last for extended periods of time approaching 1,000 years or more (Poe 1998), the uncertainties of unpredictable natural and man-made events this far into the future requires a more conservative approach. Hence, DOE assumes that the grout and concrete structure of the bin sets and tanks will instantaneously become more permeable at 500 years post-closure. The grout is assumed to completely cover the contaminants, which were assumed to reside on the floor of the facilities. Figures C.9-5, C.9-6, and C.9-7 depict these scenarios for contaminant releases. In these figures,

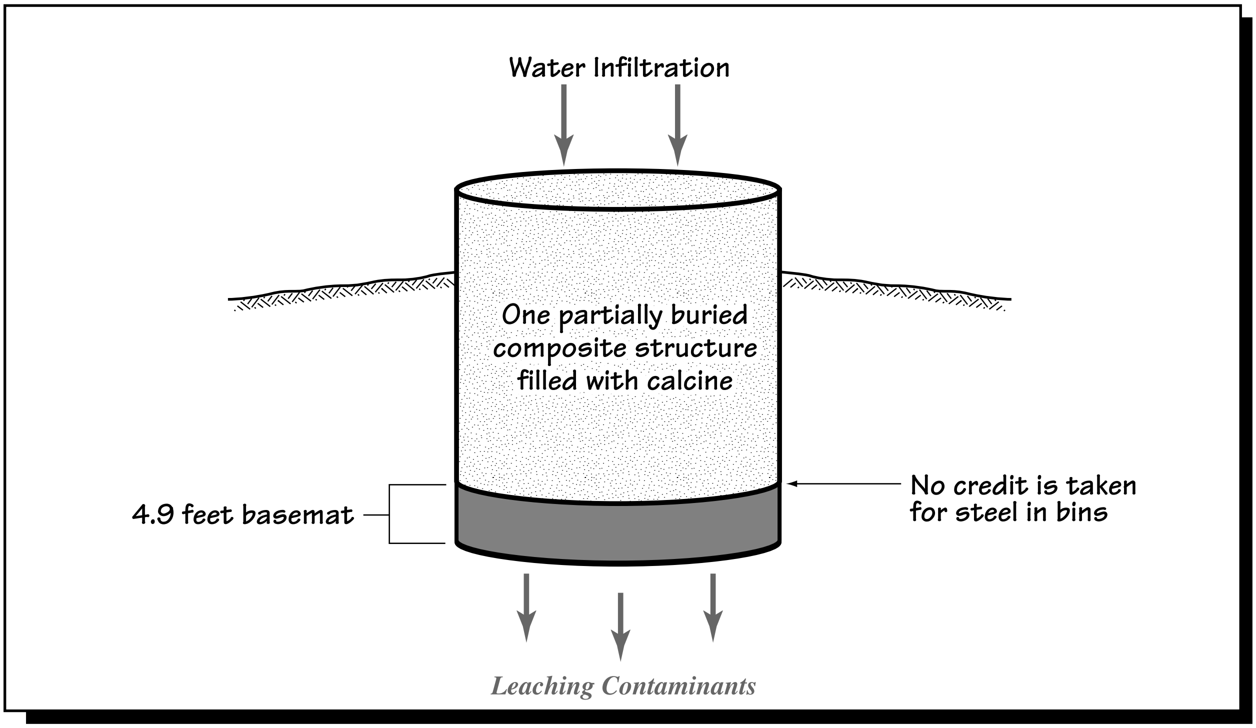

FIGURE C.9-4.
Conceptual diagram of the bin sets - No Action scenario.

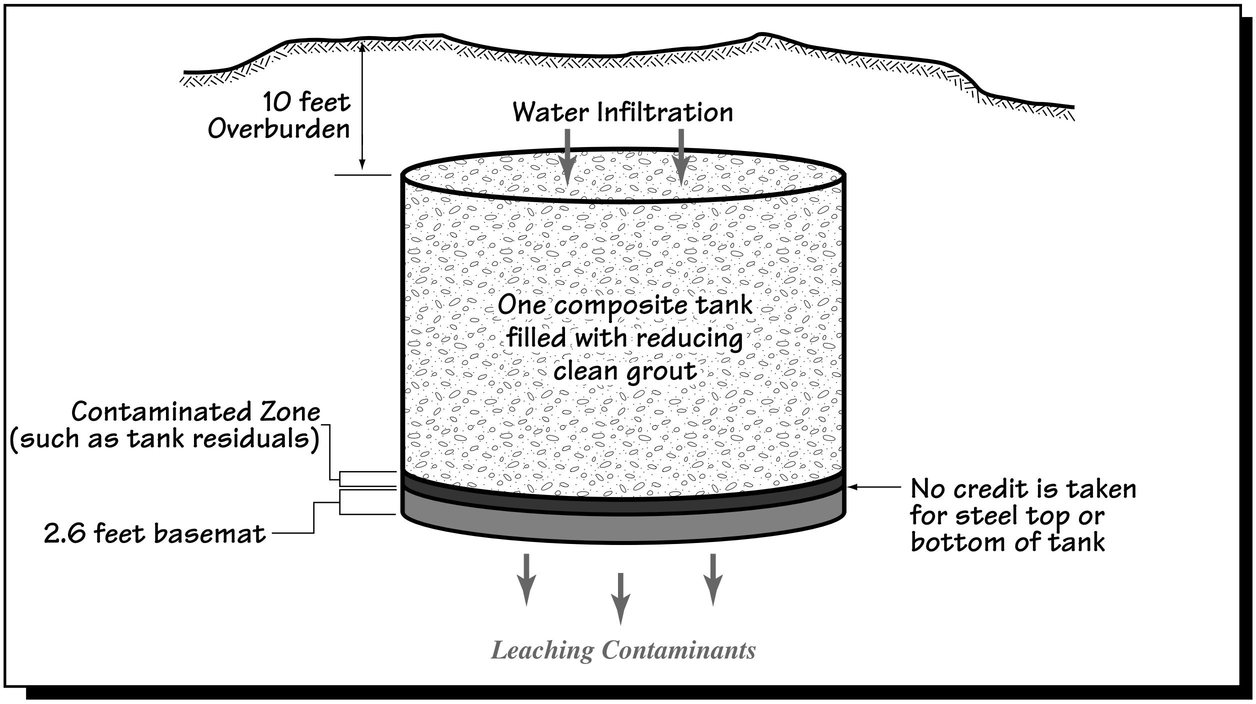

FIGURE C.9-5.
Conceptual diagram of the Tank Farm - Performance-Based Closure or Closure to Landfill Standards scenario.

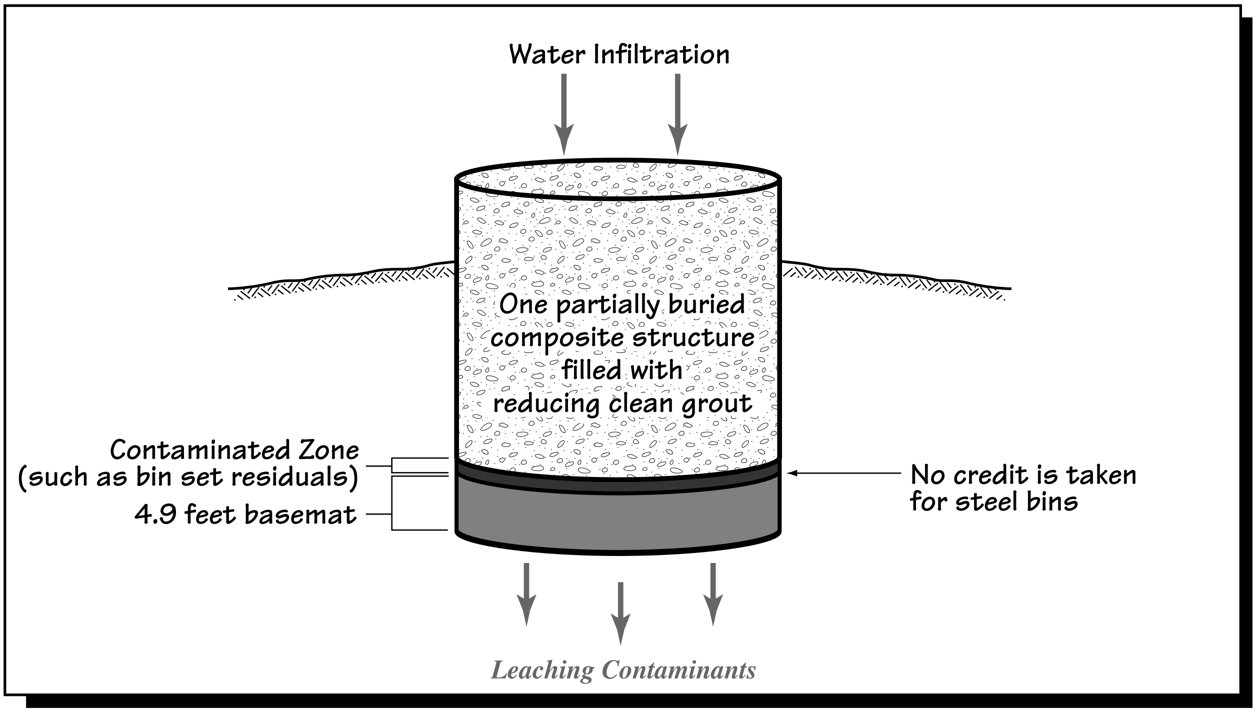

FIGURE C.9-6.
Conceptual diagram of the bin sets - Performance-Based Closure or Closure to Landfill Standards scenario.

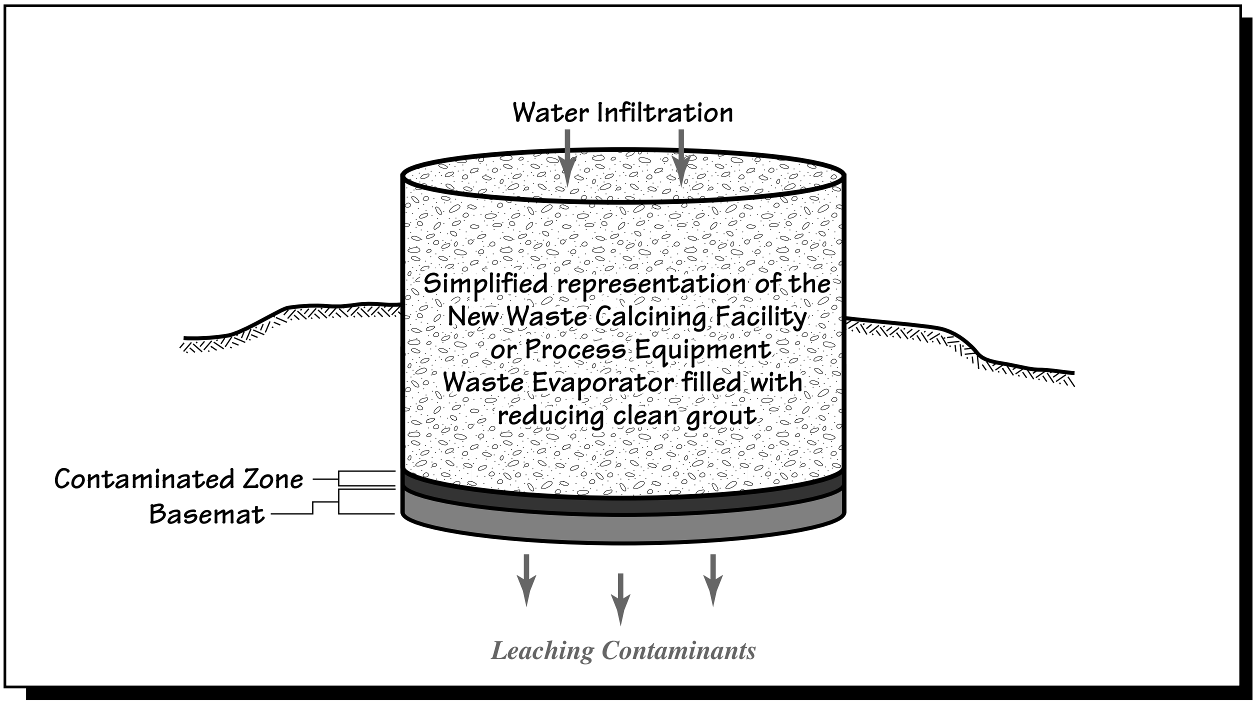

FIGURE C.9-7.
Conceptual diagram of the New Waste Calcining Facility and Process Equipment Waste Evaporator - Performance-Based Closure or Closure to Landfill Standards scenario.

the contaminated zone refers to a layer of contaminated material that cannot be readily removed from the bottom of the tanks or bin sets. This layer of contaminated material in the tanks is conservatively estimated, on the average, to be about 4 inches thick. In actual practice, most of the contaminant layer is expected to be removed during tank closure operations.

As described in Section C.9.2.1, a major mechanism for contaminant transport out of these facilities would be leaching by water. Because the facilities are above the aquifers underlying INTEC, the primary source of water for leaching would be precipitation that moves vertically through the facilities and transports contaminants to the aquifer system. Precipitation in the region of INTEC averages approximately 9 inches per year. However, due to evaporation and runoff, the actual infiltration rate into soils in this area is about 1.6 inches per year (Rodriguez et al. 1997).

During the 500 years prior to the assumed failure of the grout and concrete structure, a minimal amount of leaching was assumed to occur, and DOE took no credit for the presence of steel liners in the Tank Farm or bin sets. The hydraulic conductivity of the grout and the concrete in the facilities would limit the actual amount of water that can move through the facilities. However, after the assumed failure at 500 years occurs, the cementitious materials were assumed to have a much higher hydraulic conductivity, allowing more water to pass through the facilities and leach contaminants to the aquifer system. The chemical characteristics of the grout, however, are expected to persist long after the analysis period of 10,000 years (DOE 1998). Therefore, DOE believes that the chemical characteristics of the water passing through the grout would continue to inhibit the amount of leaching that would occur after failure.

Direct radiation is also another exposure mode and would be modeled in a manner similar to that for the No Action scenarios for Tank Farm and bin sets (except for different inventories and shielding). For the New Waste Calcining Facility and the Process Equipment Waste

Evaporator, the receptor is assumed to stand on top of the entombed facility. Section 2.4 of the Calculation Package provides additional details.

Performance-Based Closure with Class A and Class C Grout Disposal

As discussed earlier, a Class A or Class C-type grout mixture would be generated as a result of some potential waste processing alternatives involving separations that are described in Chapter 3. DOE assumes for purposes of analysis that this grout would be similar in chemical composition to that described above for the Performance-Based Closure Alternative, except that the grout in this alternative would also carry contaminants as a result of implementing the waste processing alternatives.

This grout would be used to fill the Tank Farm and bin sets, resulting in two scenarios. The grout contains contaminants in addition to those that would be present in the facilities to be closed. Therefore, there would be two sources of contaminants in the Tank Farm and bin sets: the residual contamination following cleaning activities and the contamination in the Class A or Class C-type grout to be poured into the facilities. Figures C.9-8 and C.9-9 represent the two scenarios. Direct radiation would be modeled in a manner similar to that done for the Performance-Based Closure Alternative (except for a different contaminant inventory). Section 2.4 of the Calculation Package provides more details.

Disposal of Class A or Class C Grout in a New Low-Activity Waste Disposal Facility

The Class A or Class C-type grout could be disposed in a new Low-Activity Waste Disposal Facility specially constructed to minimize leaching. Under this alternative, the grout is assumed to remain intact for 500 years, after which time the grout would fail in a similar fashion as that described for the Performance-Based Closure Alternative. The increased hydraulic conductivity would allow more water to flow through the grout, but the chemical properties of the reducing grout are assumed to remain unchanged over the period of analysis. Figure C.9-10 depicts the conceptual model of the two scenarios associated with this alternative. Direct radiation would be modeled with the receptor standing on top of the facility, which would be covered by 7 feet of soil and 3.5 feet of concrete. Section 2.4 of the Calculation Package provides more details on the conceptual model for this alternative.

The analysis of the Low-Activity Waste Disposal Facility in this appendix is based on the preliminary design prepared for the EIS (Kiser et al. 1998).[2] If the onsite near surface landfill option is selected, DOE would develop a detailed design for the Low-Activity Waste Disposal Facility in accordance with applicable regulations. The final design could include features that would influence the long-term performance of this facility. DOE would conduct supplemental National Environmental Policy Act evaluation, if necessary, and prepare a radiological performance assessment as required by DOE Order 435.1 prior to finalizing the design for a near-surface disposal facility. Additional review would also occur during the permitting process for such a facility.

C.9.2.4 Analytical Endpoints

Future human receptors who work at or near the closed INTEC facilities may be exposed to radionuclides and to carcinogenic and noncarcinogenic chemical contaminants. For radionuclide exposures, commonly used endpoints to report comparative analyses results are lifetime dose and lifetime latent cancer risk. Specifically, the term "lifetime dose" means total effective dose equivalent that results from a given expo-

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[2] The reference design used to analyze impacts for this appendix does not include some of the features normally associated with RCRA disposal facilities (such as clay liners, leachate collection and contaminant collection systems, etc.), some of which provide retardation of contaminants to the soil column. Thus, the environmental impacts analyzed for disposal of Class A or Class C-type grout in this appendix are extremely conservative.

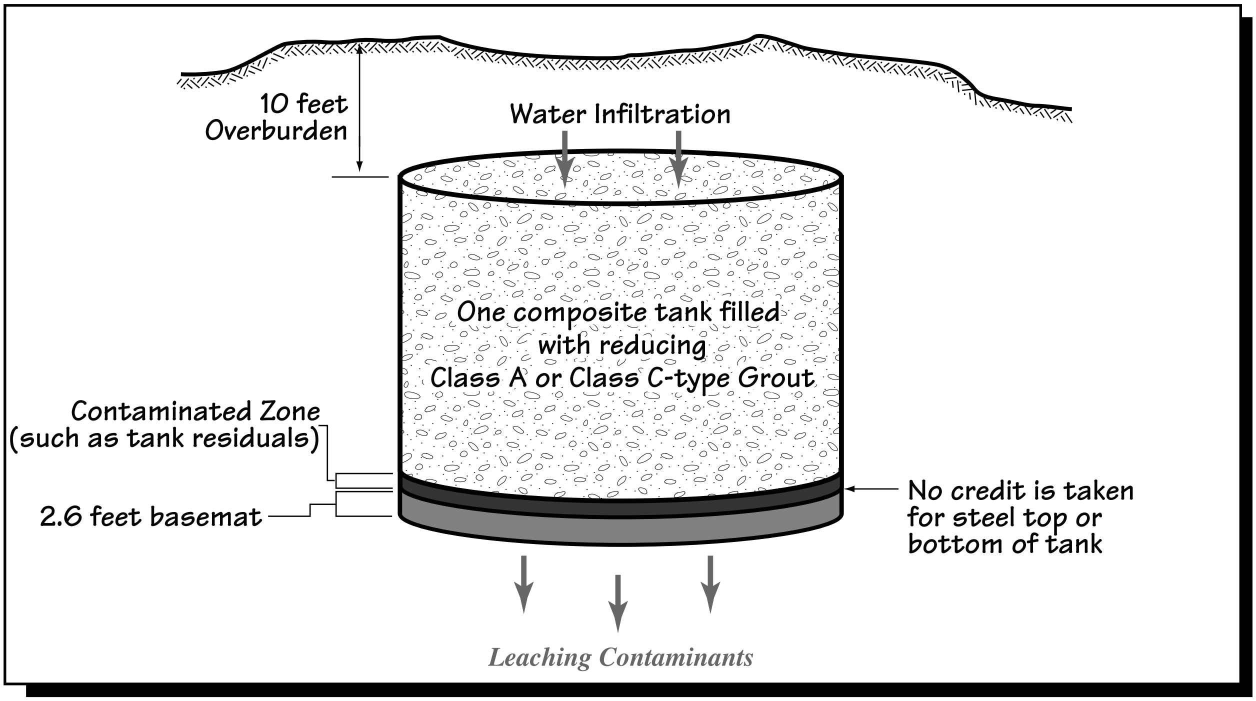

FIGURE C.9-8.
Conceptual diagram of the Tank Farm - Performance-Based Closure with Class A or Class C Grout Disposal scenarios.

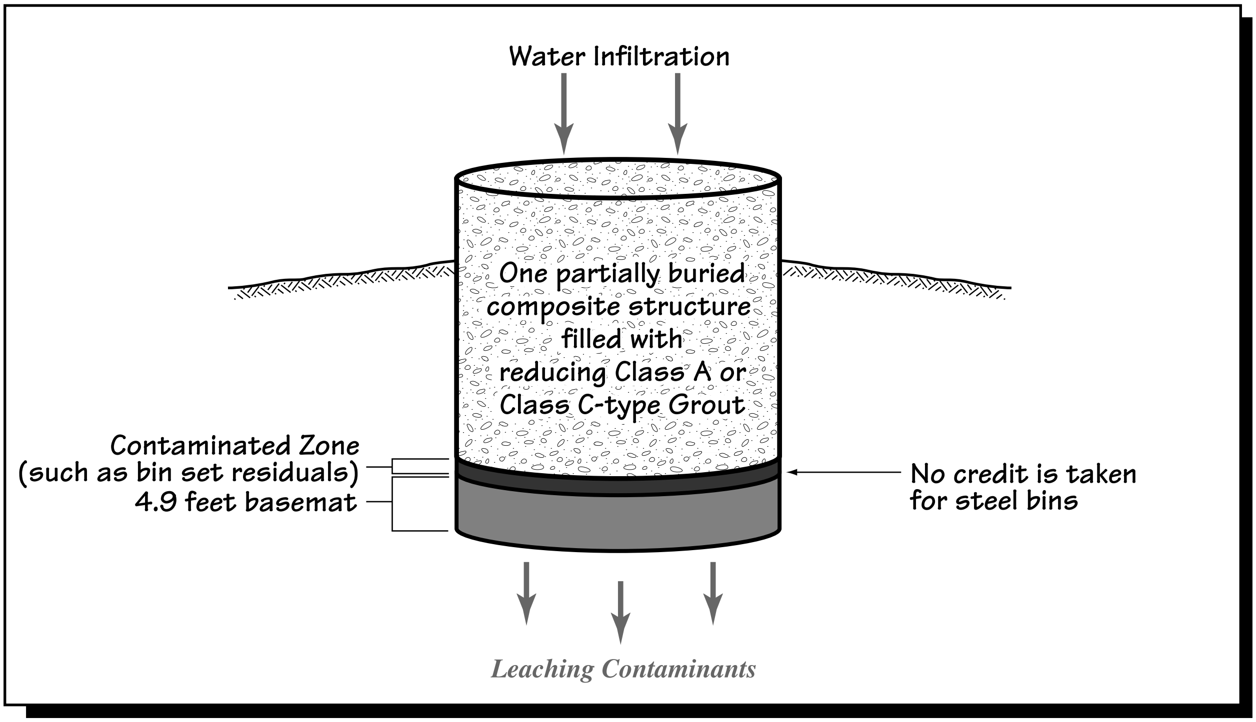

FIGURE C.9-9.
Conceptual diagram of the bin sets - Performance-Based Closure with Class A or Class C Grout Disposal scenarios.

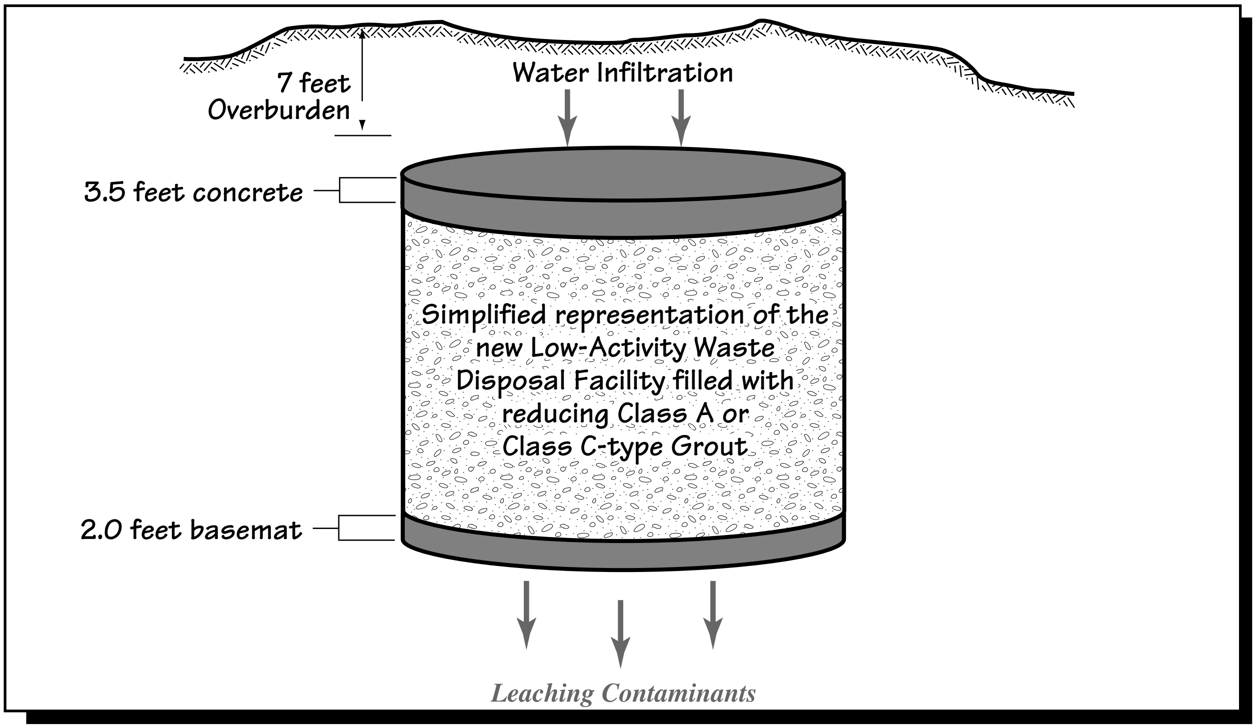

FIGURE C.9-10.
Conceptual diagram of Class A or Class C grout disposal in new Low-Activity Waste Disposal Facility.

sure scenario. This term includes the external dose received during the exposure period as well as the committed effective dose equivalent that results from the intake of radionuclides over the exposure period. Since contaminant concentrations in the environment vary with time, doses are calculated for periods when the overall dose rate would be highest. For nonradiological constituents, human health hazard quotients are used as a measure of the ratio of the chronic intake rate to the U.S. Environmental Protection Agency (EPA) reference dose. Since it is not appropriate to sum hazard quotients for contaminants with different toxicological endpoints, these are reported separately for each contaminant. Hazard quotients are also calculated at the time of maximum environmental concentration. Another basic endpoint is the lifetime cancer risk from exposure to carcinogenic chemicals, calculated for the period of peak environmental concentrations. Finally, groundwater concentrations of the individual contaminants during the peak year are presented for comparison to regulatory standards. Drinking water standards (40 CFR 141) are based on intake of radionuclides and are calculated using specified methodology and assumptions to derive radionuclide-specific concentration limits. All these endpoints apply to all receptors and are reported in Section C.9.5 by scenario.

In addition to these basic endpoints, there are several intermediate results that could be reported. These include individual pathway results for each receptor and individual constituent, reported by scenario. These intermediate results are not provided in this appendix but appear in the Calculation Package.

In summary, Section C.9.5 reports the following analytical endpoints:

- peak contaminant groundwater concentrations for comparison to drinking water standards
- total lifetime radiation dose by receptor, facility and scenario

- excess radiogenic cancer probabilities by receptor, facility and scenario
- human health hazard quotients by contaminant, receptor, facility and scenario
- nonradiological cancer probability (summary description only)

C.9.3 EXPOSURE AND TRANSPORT MODELING DESCRIPTION

C.9.3.1 Releases From Closed Facilities

C.9.3.1.1 *Model Description*

The leaching of contaminants out of the closed facilities[3] to the unsaturated zone would be primarily one-dimensional movement in the downward direction. Therefore, DOE used the MEPAS (Buck et al. 1995) code developed at Pacific Northwest National Laboratories (PNNL) to calculate the flux of contaminants from the facilities. The calculational methodology for MEPAS was developed by PNNL in the 1980s and is based on active transport in one dimension with dispersion allowed in three dimensions. MEPAS uses analytical solutions incorporating partitioning coefficients expressed as distribution coefficients, the porosity and hydraulic conductivity of the media, the water infiltration rate, and a dispersivity coefficient to calculate the amount of leaching that occurs in the source zone and ultimately the flux from the facility.

C.9.3.1.2 *Conceptual Model Configuration*

Due to the one-dimensional nature of MEPAS, the solutions are based on the assumption that precipitation will move through the residual contaminants based on the infiltration rate and hydraulic conductivity of the layers between the residual contaminants and the ground surface, leach material as determined by the partitioning coefficient, and move the contaminants downward to the soil beneath the tanks. Because MEPAS was used only for flux calculations from the facilities, the groundwater modeling portions of this code were not used, and the flux results were coupled with results from TETRAD to determine the groundwater concentrations.

DOE calculated the fluxes assuming that the facilities would remain intact until structural failure (physical degradation of the concrete and grout) is assumed to occur at 500 years post-closure. Therefore, the flux from the facilities is expected to leach a negligible small amount of contaminants prior to the assumed failure time. After 500 years, the grout and concrete are assumed to instantly become more permeable, with the structural failure allowing an increased flow of water through the facilities and providing greater volumes of leachate to the vadose zone. Section 5.1 of the Calculation Package presents further details on the methodology for calculating contaminant releases from closed HLW facilities.

Because the driving force for contaminant migration out of closed HLW facilities has been assumed to consist of infiltration of water through the closed facility, the most important parameters in modeling the leaching of contaminants are distribution coefficient (K_d), hydraulic conductivity, infiltration rate, and porosity. To support the selection of parameter values, DOE conducted a literature search of published parameter values considered to be reasonable for INEEL conditions (Kimmel 2000a). Based on this review and an understanding of the chemical and physical conditions related to the closed HLW facilities, a set of parameter values were selected for the facility release modeling. Section 5.1 of the Calculation Package presents further description of the source, identity, and use of these input parameter values.

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[3] Closed facilities analyzed for leaching of contaminants include: (1) the tanks and bin sets, closed with clean or Class A or Class C-type grout; (2) the new Low-Activity Waste Disposal Facility; and (3) the Process Equipment Waste Evaporator and New Waste Calcining Facility, facilities that could have a significant inventory of radioactive materials after closure.

C.9.3.2 Vadose Zone and Aquifer Transport Modeling

In order to model contaminant transport from the closed facilities through the vadose zone, and eventually through the aquifer, DOE used two conceptual models that have been used successfully in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process at INTEC for the Waste Area Group 3 (WAG 3) Remedial Investigation/Feasibility Study (RI/FS) (Rodriguez et al. 1997). The first of these two models was used to model the infiltration of water and the subsequent transport of contaminants through the vadose zone. The vadose zone was modeled with contaminants originating primarily near ground surface and allowed to infiltrate vertically as well as to spread laterally. DOE updated and simplified this approach (Schafer 1998) for the modeling performed at INTEC. This updated methodology was checked against previous model runs for various fluxes and found to be in close agreement with the model predictions (Schafer 1998).

Water and contaminant mass flow through the bottom layer of the vadose zone model were then used as the upper boundary condition for the aquifer simulation domain. The overall model was optimized to predict contaminant concentrations for a typical contaminant with specific characteristics (e.g., half-life, distribution coefficient).

The overall model was adjusted for hydrogeologic conditions at INTEC (Rodriguez et al. 1997) and the simplified approach was used to assess the specific disposition scenarios. In general, representative locations were selected and, for each of the locations, full three-dimensional vadose and aquifer models were simulated to inject a "unit" mass of a contaminant. Mass flux to the aquifer resulting from the unit mass of contaminant was computed and used to estimate contaminant concentrations in the aquifer. These concentrations were used for subsequent risk calculations (see Section C.9.3.4).

C.9.3.2.1 Model Description

In the WAG 3 RI/FS (Rodriguez et al. 1997), the vadose zone-aquifer system at INTEC was simulated using a three-dimensional transient program called TETRAD. This model was successfully used and gained the approval of regulators. The TETRAD program allows incorporation of the heterogeneous physical properties necessary to solve the vadose zone infiltration problem with the large areal and point source influxes of water and contaminants. During the WAG 3 RI/FS modeling, the simulation was divided into a vadose zone conceptual domain and an aquifer conceptual domain. The bulk of the computational time was expended solving the vadose zone transport equations mainly due to the nonlinearity introduced through the dependence of permeability on pressure and saturation. However, in a steady state flow system, the permeability becomes a constant in time, and the system of equations become linear. The linearity is achieved by allowing the vadose zone to reach steady state conditions, which implies that contaminants released at a particular surface location follow the same flow path regardless of when the release occurs. Using a steady-state approach, an updated methodology was developed (Schafer 1998) to estimate the mass flux to the aquifer by scaling from a previous computer simulation. Mass flux estimates were prepared using this methodology and were compared with the TETRAD model results and found to be in good agreement. This methodology provides an estimate of the cumulative mass flux to the aquifer. A similar approach was used for the HLW facility disposition modeling.

During the TETRAD simulation, the contaminant mass flux through the bottom plane of the vadose zone model was the output throughout the vadose zone modeling time frame. These mass fluxes were then used as input as source terms for the top plane of the aquifer model. During the WAG 3 RI/FS, the sensitivity of predicted contaminant migration to the parameters used to implement the conceptual model was obtained. The base-case conceptualization of the flow and hydraulic transport domain was representative, rather than overly conservative. The TETRAD model was calibrated using concentration distributions of known contaminants from known releases. As a result, predicted concentrations in the WAG 3 RI/FS were based on the best information available, within acceptable accuracy. The use and utility of TETRAD and its specific attributes have been well documented in the following references: Shook (1995), Shook and Faulder (1991), Magnuson (1995), and Vinsome and Shook (1993).

The updated methodology using previously calibrated TETRAD model results involved the following.

- Representative locations were selected and for each of the facilities, full three dimensional vadose and aquifer models were used to inject a "unit" mass of a contaminant.
- Mass flux to the aquifer resulting from the unit mass of contaminant was computed and used to estimate contaminant concentrations in the aquifer.
- These concentrations were used for subsequent risk calculations.

C.9.3.2.2 *Model Configuration*

The physical and hydrogeologic setting of INTEC is highly complex, consisting of layered basalt and sediment units. Perched water zones exist within the vadose zone and several large water sources at the surface currently contribute to them. As INTEC facilities are dispositioned, these water sources will also be closed except for local precipitation and flow in the Big Lost River as discussed in Section 4.8.1. Therefore, most water sources would cease to contribute to the perched water during the 10,000-year period of analysis. In order to account for the complex nature of the subsurface at INTEC, three-dimensional modeling (using TETRAD) was used.

Simulation Domains

The domains were similar to the ones considered during the WAG 3 RI/FS. The vadose zone model extends 2,000 meters in the east-west directions and 3,000 meters in the north-south direction. This area extends approximately 800 meters beyond the INTEC boundaries in the north-south direction and 600 meters in the east-west direction (Rodriguez et al. 1997).

Simulation of Source Area Locations

Based on the facility disposition scenario, contaminant sources were defined and incorporated into the simulation model at a grid block or a set of grid blocks. Similar methodology has been successfully used during the WAG 3 RI/FS (Rodriguez et al. 1997). In the numerical simulation model, the horizontal grid block locations for all sources were defined by overlaying the numerical grid on a map of the INTEC area. Each contaminant source was identified by a grid block and source input parameters were applied for the corresponding block. Using the surface source term information on a unit basis, the updated methodology (Schafer 1988) was used to simulate the transport of a contaminant through the vadose zone and a mass flux curve was computed for a facility. Cumulative mass flux to the aquifer was then calculated. The mass flux was then used to simulate the transport of contaminants in the aquifer and to estimate the resulting concentrations. These concentrations were used for subsequent risk calculations.

Scope of the Model

The horizontal extent of the vadose zone model was defined by the INTEC footprint. Contaminant transport was first simulated through the vadose zone model and the mass flux out the bottom of the vadose model is used as an input to the aquifer model. Model predictions were made to estimate the magnitude and time of peak concentrations within the domain. The simulations were focused on obtaining future groundwater concentrations to support the 10,000-year risk evaluation.

C.9.3.2.3 *Modeling Assumptions and Uncertainties*

Several assumptions were made during the simulation of TETRAD for the WAG 3 RI/FS. As the same model is projected to be used for closure modeling, previous assumptions and approximations (made during the RI/FS) for parameters/methods to estimate some properties are applicable. A key assumption for this approach was that the steady-state vadose zone model adequately describes the flux to the aquifer.

Uncertainties associated with model predictions include the degree to which the conceptual model represents unsaturated and saturated zone flow and transport processes at the INTEC, the choice of contaminant-specific distribution coefficients, and the accuracy of the estimated source term. However, during the RI/FS, the model was calibrated with collected data and was found to predict the contaminant movement effectively.

C.9.3.3 Direct Radiation Exposure

The assessment of exposure scenarios includes cases where future receptors are exposed to direct radiation from either (a) radionuclides in contaminated soil; (b) residual radioactivity in closed facilities; or (c) facilities used for radioactive waste disposal. The latter include the Tank Farm, bin sets, and other facilities that could have a significant inventory of radioactive materials after closure. External dose rates were developed for soil and facilities using the IDF code, which is part of the GENII package (Napier et al. 1988). The conceptual models used to facilitate these assessments are described in Section C.9.2.1. A summary of general assumptions and considerations used in the external dose assessment is provided below. For additional detail, the reader is referred to Sections 3.4 and 3.6 of the Calculation Package.

Exposure to direct radiation from soil results from irrigation of land using groundwater contaminated with radionuclides. During the contaminant screening process described in Section C.9.4.2, only Tc-99 and I-129 remained for groundwater pathway analysis. These radionuclides were assumed to be pumped from the groundwater to the surface for irrigation and to be evenly distributed in a 6 inch-thick soil layer which is modeled as an infinite slab. The dose is evaluated at a point 1 foot above the slab. The soil exposure pathway is only credible in the distant future, since considerable time would be required for these radionuclides to leach from closed facilities (which are assumed to remain intact for 500 years), migrate through the vadose zone and reach the aquifer. Exposure to radionuclides in soil is assumed to coincide in time with radionuclide intakes from other groundwater-derived exposure modes (ingestion of water, soil, food products, etc.). Therefore, doses from these exposures are additive.

For radiation emanating from closed facilities, DOE calculated dose rates based on available radionuclide inventory ("source term") data in conjunction with a conceptual model (geometry, shielding materials and thicknesses, etc.) that approximated the system under evaluation. The source term for the reference HLW tank or bin set was based on the individual tank or bin set with the highest projected inventory for each closure scenario. The estimated radionuclide inventory (in curies) was converted into units of activity per unit volume or area, depending on the system being modeled, for use as input to the IDF model. (See Section 5.4 of the Calculation Package for facility-specific source terms.) The radionuclide inventory was evaluated at 2095, and dose rates were calculated for all radionuclides with significant penetrating emissions (not just Tc-99 and I-129 as in the soil case). These dose rates were then summed to determine a total dose rate. For below-grade (buried) sources, substantial shielding is provided by the soil overburden. This shielding is assumed to remain intact in all cases except intruder scenarios, which assume that an individual unknowingly removes soil shielding by excavating around a buried source. In contrast to the soil exposure case, which is driven by contaminated groundwater, exposure to direct radiation from closed facilities is only important for a few hundred years after the period of institutional control. This is because the dose rate is driven by relatively short-lived radionuclides (primarily Cs-137/Ba-137m) that will undergo considerable decay by the time groundwater-derived pathways become credible.

C.9.3.4 Calculation of Impacts to Receptors

The general methods and data that DOE used to calculate impacts to receptors are consistent with those used in previous baseline risk assessments performed at the INTEC. The process involves the use of conceptual models, equations and data to calculate the transfer of contaminants to media that serve as intake or exposure sources for the postulated receptors. Various constants are used to account for individual habits of these postulated receptors. These constants may be either generic, or they may be specific to receptors, scenarios or contaminants. Body weight of an adult receptor is an example of generic data, whereas parameters such as exposure duration, food or water intake rates, etc. use receptor-specific data. Dose factors and toxicological data are examples of contaminant-specific constants. The data and equations used are detailed in the supporting Calculation Package, while a general overview of the method is presented below.

The impact calculation process can be broadly divided into radiological and nonradiological assessments. The primary goal of the radiological assessment is to estimate radionuclide intakes, internal and external dose, and associated radiogenic cancer risk for specific receptors under various facility closure scenarios. Radionuclide intake and internal dose are calculated only for the groundwater pathway, including all significant ways that radionuclides in groundwater could reach human receptors. The exposure pathways are identified in Table C.9-2.

The radionuclide intake (in units of picocuries) was calculated and then multiplied by the appropriate ingestion or inhalation dose factor (with units of millirem per picocurie) to determine effective dose equivalent in millirem. Dose from external radiation exposure was calculated simply as the product of the dose rate (in millirem per hour) and the total exposure period (hours). As previously mentioned, concurrent internal (from groundwater) and external (from closed facilities) doses are not credible. For this analysis, the maximum of the two is used to represent peak dose. Radiogenic cancer risk from internal exposure was estimated by multiplying the internal dose (millirem) by the appropriate cancer slope factor (risk per millirem). Cancer risk from external exposure was estimated using cancer risk factors (risk per millirem) for workers or the general population, as applicable, recommended by the International Commission on Radiological Protection. The radiogenic cancer risk value can be loosely interpreted as the increased probability that the individual will develop a fatal or nonfatal cancer over his or her lifetime as a result of receiving the specified dose.

The method used to calculate nonradiological contaminant intake closely parallels the method used for radionuclides. Contaminant intake rates [milligrams (of contaminant) per kilogram (of body weight)-day] were calculated for each pathway, and these were then converted to health hazard quotients by dividing by the corresponding EPA reference dose (which has the same units of milligrams per kilogram-day). Of the nonradiological contaminants assessed, only cadmium is considered a human carcinogen, and cancer risk is only quantifiable for this substance via the inhalation mode of intake. The cancer risk was calculated as the product of inhalation intake (milligrams per kilogram-day) and slope factor (risk per milligrams per kilogram-day). For the scenarios considered here, intake rates from inhalation of contaminated soil are very low, resulting in risk values of less than 10^{-12}, or one in a trillion. Thus, scenario-specific nonradiological cancer risk values are not presented.

For both radiological and nonradiological contaminants, DOE developed "summary intake factors" to facilitate the calculation of intake by each receptor category and exposure mode. These summary intake factors provide a simple but effective means of calculating contaminant intake from media concentration by incorporating all applicable constants into a single expression. These are then multiplied by appropriate media concentrations to determine contaminant intake. For example, the summary intake factor for radionuclides via groundwater ingestion by the maximally exposed resident has a value of 2.1×10^{4} in units of liters. Multiplying this value by the groundwater concentration in picocuries per liter yields the estimated intake of the radionuclide, in picocuries, by this receptor. Summary intake factors were derived and entered into Microsoft Excel™ workbooks to execute the calculations and organize the results.

C.9.4 CONTAMINANT SOURCES

This section describes the methodology and assumptions used by DOE to estimate the amount of material remaining in INTEC HLW facilities after closure for each of the facility disposition scenarios described in Section C.9.2. The amount of contaminants within the facility affects the quantity that could ultimately be transferred to the aquifer. Larger initial amounts would lead to greater fluxes to the aquifer while lower initial amounts would cause lower fluxes and hence lower concentrations of contaminants in the aquifer. DOE performed the following activities to identify the source term values for use in this analysis:

- Estimate the amount of contaminants that could be left in facilities following disposition
- Perform screening to identify those contaminants that warrant detailed quantitative analysis
- Identify the final list of contaminants for further detailed analysis

Each of these activities is described in further details in the following sections. Section 4 of the Calculation Package presents further technical details on the screening process methods used to determine the source term values.

C.9.4.1 Inventory Identification

DOE performed engineering studies to estimate the amount of contaminants that could be left in facilities following disposition. Section 4.1 of the Calculation Package lists these values for radiological and nonradiological constituents by facility and scenario. As discussed in Section C.9.1, for purposes of analysis, DOE assumed that the amount and character of the residual inventory would be the same for both Performance-Based Closure and Closure to Landfill Standards (for those facilities for which both facility disposition alternatives are applicable).

For all pathways except external irradiation, the source inventories provided in the Calculation Package were used because the entire inventories were available to be released to the ecosystem. The radionuclide source term was decayed to a constant year to provide a consistent basis for analysis. For external irradiation, however, DOE postulated that the receptor would be closer to a particular facility (i.e., the one that would result in the highest radiation dose) than the others. Consequently, the receptor would not be exposed to all the contaminants in all the facilities to the same degree.

C.9.4.1.1 *No Action Alternative*

Tank Farm

DOE developed Tank Farm inventory and source terms for the No Action Alternative (Staiger and Millet 2000) using the following assumptions:

- The liquid waste from the pillar and panel tanks would be transferred out and concentrated in the evaporators.
- The concentrate would be stored in five of the monolithically vaulted tanks.
- These five monolithically vaulted tanks would be subsequently filled to capacity with the existing mixed transuranic waste/SBW and with newly generated liquid waste. The newly generated liquid waste, which is defined in Section 3.1, would be lower in radioactivity relative to existing waste.
- Contributions from the concentration of existing Tank Farm liquid waste and New Waste Calcining Facility decontamination effluents are considered to be internal recycle and would not be "new" source material.
- The emptied pillar and panel tanks would be flushed with 40,000 gallons of water and pumped to their heel volumes and the liquid evaporated.

Based on these assumptions, DOE estimated the contents of each of the five 300,000-gallon storage tanks and the eventual date they would be filled. These results were then used to generate an estimated source term. The source terms are listed in the Calculation Package.

Bin Sets

Since December 1963, fluid-bed calcining has been used at INTEC to convert aqueous wastes to granular solids. The wastes were processed in a heated fluidized-bed calciner to metallic oxides or fluorides, water vapor, and nitrogen oxides. The solids are transported to stainless steel bins for interim storage. Detailed operational chronologies for the various calcination campaigns are presented by Staiger (1999).

Source term estimates for the calcine in the bin sets under the No Action Alternative are described in Staiger and Millet (2000) and listed in the Calculation Package. These source term estimates employ the most conservative information on isotopic ratios and are conservatively based on liquid fed to the calciners and assume no recycle.

Iodine, mercury, and tritiated water are volatile at calcination temperatures. Therefore, their retention in the calcine is reduced. Only 13 percent of the iodine in the waste feed is estimated to remain with the calcine (Staiger and Millet 2000). Mercury retention in the calcine is calculated to be 70 percent for calciner operation at 400 degrees Celsius and 1 percent when operation was 500 degrees Celsius and above (Staiger and Millet 2000). Water (tritium) accumulation in the calcine is expected to be very low. Retention in the calcine is conservatively estimated at 0.1 percent of that processed (Staiger and Millet 2000).

C.9.4.1.2 Performance-Based Closure or Closure to Landfill Standards

Tank Farm

The residual source terms remaining in the Tank Farm after closure (for Performance-Based Closure or Closure to Landfill Standards) were based on the assumption that all the tanks would be emptied to heel volume and that the heel would be flushed with one 40,000-gallon flush of water, which would be pumped out to heel volume with installed equipment. All solids are assumed to remain in the tank after flushing. The flush solutions would not remove any radioactivity from the solids. Source term estimates for the residual material remaining in the tanks are further described in Staiger and Millet (2000) and listed in the Calculation Package.

Bin Sets

The volume of the solids in the emptied bin set vessels is assumed to be 0.5 percent of the filled volume (Staiger 1998). The concentrations of radiological and chemical constituents in the emptied vessels is assumed to be the same as for the filled bin sets under the No Action Alternative, described above. The residual activity in the bin sets after closure is listed in the Calculation Package.

Other Facilities

Other existing INTEC HLW facilities evaluated in this appendix are the Process Equipment Waste Evaporator (CPP-604) and the New Waste Calcining Facility (CPP-659). DOE previously estimated (Beck 1998) that the residual inventory in these facilities after closure would be less than the amount remaining in the Waste Calcining Facility (CPP-633) after it was closed. Therefore, for this analysis, DOE conservatively assumed that the residual inventory in the Process Equipment Waste Evaporator and New Waste Calcining Facility would be equal to that in the Waste Calcining Facility. The characteristics of the residual remaining in the Waste Calcining Facility are described by Demmer and Archibald (1995). The residual activity in the Process Equipment Waste Evaporator and New Waste Calcining Facility after closure is listed in the Calculation Package.

C.9.4.1.3 Class A or Class C Grout Disposal in a New Low-Activity Waste Disposal Facility

As described in Chapter 3, approximately 27,000 cubic meters of Class A-type grout would be produced under the Full Separations Option and approximately 22,700 cubic meters of Class C-type grout would be produced under the Transuranic Separations Option. One method evaluated for disposal of this grout is disposal in a new Low-Activity Waste Disposal Facility, an engineered near-surface disposal facility. The characteristics of the radioactive and chemical constituents in this Class A or Class C-type grout are described by Barnes (2000) and are listed in the Calculation Package.

C.9.4.1.4 Performance-Based Closure with Class A or Class C Grout Disposal

In addition to disposal in a new Low-Activity Waste Disposal Facility, as described in Section C.9.2.3, DOE evaluated a second onsite method for disposal of the Class A or Class C-type grout produced under the Full Separations and Transuranic Separations Options. This second onsite disposal method is disposal in the Tank Farm and bin sets, after these facilities have undergone performance-based closure. The Class A or Class C-type grout would serve to bind residual contaminants remaining in these facilities and provide structural stability in the closed facilities.

DOE assumed that the Class A or Class C-type grout would be emplaced in both the Tank Farm and bin sets. DOE assumes that 22,000 cubic meters of grout would be emplaced in the bin sets and the remainder (5,000 cubic meters of Class A-type grout and 700 cubic meters of Class C-type grout) would be emplaced in the Tank Farm (Kimmel 2000b). The Class A or Class C-type grout would be in addition to the residual contamination remaining in the Tank Farm and bin sets after performance-based closure (as discussed above). The Calculation Package lists the characteristics of the radioactive and chemical constituents in Tank Farm and bin sets under the Performance-Based Closure with Class A Grout Disposal and the Performance-Based Closure with Class C Grout Disposal scenarios.

C.9.4.2 Contaminant Screening

C.9.4.2.1 Groundwater Pathway Screening

The original list of contaminants present in HLW facilities to be closed included a long list of radiological and chemical constituents. For example, the initial Tank Farm inventory data included 143 radionuclides and 20 chemical constituents (plus numerous other chemicals present in only trace amounts). Therefore, DOE developed and applied a screening method to identify those contaminants of potential concern that warrant detailed quantitative analysis. Section 5.3 of the Calculation Package presents the entire initial list of radiological and chemical constituents present in HLW facilities to be closed.

The screening method described in this section was specifically developed for the Tank Farm and bin set closure scenarios. Contaminants that were identified as significant for closure of these facilities were also analyzed for the closure of other INTEC facilities (the New Waste Calcining Facility and the Process Equipment Waste Evaporator), as well as alternative concepts for the disposal of Class A or C-type grout (in the Tank Farm or bin sets, or in a new Low-Activity Waste Disposal Facility).

Radionuclide Screening

An illustration of the general process used for radionuclide screening is presented in Figure C.9-11. The screening of both the Tank Farm and bin sets contaminants started with total decay-corrected residual inventories for the years 2095 and 2516 (Staiger and Millet 2000). DOE performed the following steps in the radionuclide screening process. Section 5.3 of the Calculation Package presents further details on each of these steps.

1. The first step screened out all radionuclides that either (a) had half-lives less than 10 years, or (b) were present in very small amounts. No specific numerical criteria were used for the latter, although a nominal value of one-billionth (1×10^{-9}) of the total activity in the Tank Farm or bin set inventory was used as a guideline. The short half-life criterion was used since previous analysis has shown that for even the most mobile species the migration time through the tank or bin structures (tanks, vaults, etc.) and the underlying vadose (unsaturated) zone to the aquifer is on the order of hundreds of years.

2. The next step was to apply a more quantitative screening factor. The parameter used for this purpose is the radionuclide-specific "ground-burial screening factor" from the National Council on Radiation Protection and Measurements

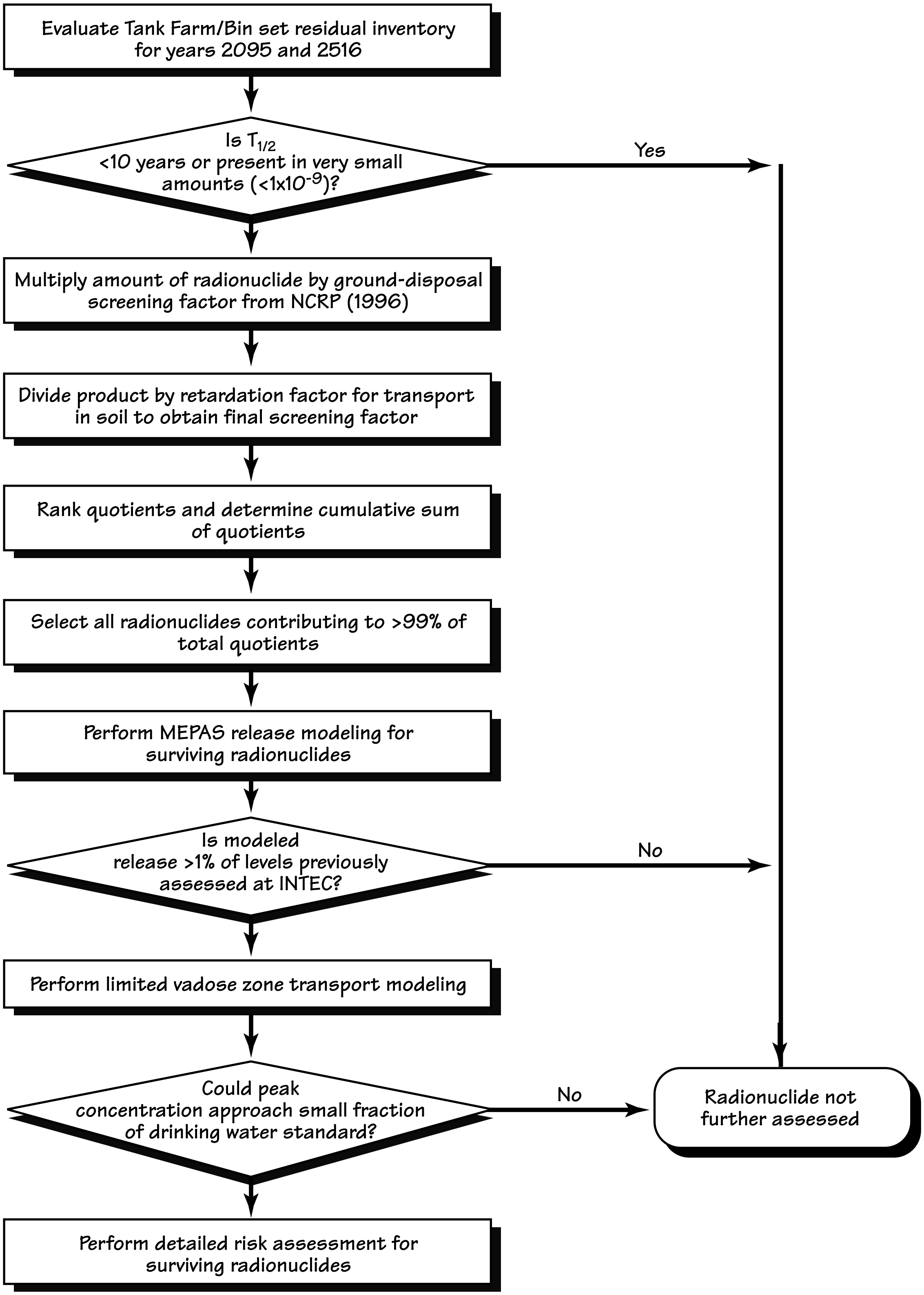

FIGURE C.9-11.
General process used for radionuclide screening for groundwater pathway assessment.

Report No. 123, *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground* (NCRP 1996). This screening factor is well suited for this purpose, in that it considers a range of factors, including half-life, leach rate and release delay time, and potential dose to receptors by inhalation, ingestion and external exposure modes. DOE performed this screening step by multiplying the amount of each radionuclide remaining in the inventory by the total screening factor for the groundwater pathway to obtain a "screening factor product." Since the National Council on Radiation Protection and Measurements method does not specifically address the migration rate of radionuclides in the unsaturated zone beneath the waste layer, DOE applied an additional screening step to modify the screening factor product by a soil retardation factor. The resulting quotients were then summed, and the radionuclides that collectively accounted for greater than 99 percent of the total radionuclide inventory were selected for further analysis.

3. DOE then performed release modeling using the MEPAS code and compared the results to those of other modeling evaluations previously performed for INTEC activities. Specifically, in order for the radionuclide to be further evaluated, the estimated total activity released to the vadose zone under any facility disposition scenario (including landfill scenarios) must be greater than one percent of the release evaluated for that same radionuclide in the WAG 3 RI/FS (Rodriguez et al. 1997). That study established the health risk to future human receptors for releases which are generally much larger than those projected under the facility disposition scenarios. The WAG 3 RI/FS results enabled DOE to apply this comparison step to screen out those radionuclides that previous analyses have clearly shown will not pose a significant additional risk via the groundwater pathway at the projected level of release.

4. The final screening step involved vadose zone modeling to estimate radionuclide concentrations in the vadose zone at the aquifer interface. This process is described in Section C.9.3.2 and Section 3 of the Calculation Package. Radionuclides projected to be below the 40 CFR 141 maximum contaminant level (MCL) in the pore water of the vadose zone-aquifer interface were eliminated, since dilution in the upper aquifer would quickly dilute contaminant levels to small fractions of the MCL.

As a result of this process, two radionuclides passed the screening and qualified for detailed quantitative analysis: Tc-99 and I-129. The dose and heath risk impacts associated with these long-lived radionuclides were then quantitatively assessed for all facility disposition scenarios (not just those which met the one percent release criterion).

Nonradiological Contaminant Screening

The approach used in identifying chemical contaminants of potential concern warranting further analysis was based primarily on inventory estimates, toxicity, and results of previous evaluations. DOE used the Tank Farm and bin sets inventory data from Staiger and Millet (2000), which contained estimates of bulk chemicals as well as elements formed by fission product decay and neutron activation. The bulk species inventory does not depend on time, but the inventory of some fission and activation species can increase with time. Therefore, the fission and activation species inventory is conservatively based on Year 2516. DOE performed the following steps in the nonradiological contaminant screening process. Section 5.3 of the Calculation Package presents further details on each of these steps.

1. The first step was to identify all chemicals that are both (a) potentially toxic or carcinogenic, and (b) present in the inventory in greater than trace quantities. For the latter, a nominal value of one kilogram was used as a threshold for

human carcinogens, while a 10-kilogram threshold was used for other chemicals (out of a total inventory of hundreds of thousands of kilograms). A noncarcinogenic chemical is considered potentially toxic if an oral reference dose has been established in the EPA's Integrated Risk Information System database (EPA 1998). If an oral reference dose was not available, the contaminant was not selected for further evaluation since ingestion is by far the most important exposure mode for the groundwater pathway. Similarly, a chemical was considered potentially carcinogenic if it is classified within EPA's database as either a human carcinogen or probable human carcinogen.

2. All potential human carcinogens meeting the inventory-based screening criteria were selected for further evaluation by release and vadose zone transport modeling. For noncarcinogenic substances, DOE developed a screening parameter based on inventory and potential toxicity. The screening parameter is the inverse of the product of the inventory and the reference dose. An adjustment to this step was required to account for the effect of lead. No reference dose is established for lead in EPA's database because all levels of intake are considered toxic, and no safe threshold can be assumed. For screening purposes, lead was included in the list of chemicals warranting further evaluation. The screening products for chemicals excluding lead were then ranked, and the chemicals that individually accounted for one percent or more of the total screening product were retained for further evaluation by release and vadose zone transport modeling.

   For bulk species, fluoride, mercury and nitrate accounted for over 99 percent of the screening product total and were selected for further evaluation. Lead and the potential carcinogens cadmium, chromium and nickel were also selected. The screening process conservatively assumes that all of the chromium in the inventory consists of the carcinogenic hexavalent form. The fission and activation species that passed the screening process included uranium, barium, and molybdenum, along with lead and the potential carcinogens arsenic, beryllium and cadmium. For both the Tank Farm and bin set scenarios, the combined total dose for the selected species (excluding lead and carcinogens) would be about 99 percent of the total screening product.

3. The final steps were the same as those used in the radionuclide screening, namely, a comparison of release rates to those previously analyzed in the baseline risk assessment (Rodriguez et al. 1997), and release and transport modeling to estimate contaminant levels at the vadose zone-aquifer interface.

C.9.4.2.2 *Direct Radiation Pathway Screening*

The initial source term for each facility is the estimated radionuclide contents decay-corrected to the Year 2016. For the Tank Farm and bin set modeling, the single tank or bin set with the highest inventory was selected as the source facility to be used for the residual contamination and No Action scenarios. For cases in which the tank or bin sets are filled with Class A or C-type grout, the dose from both residual activity and radionuclides in the waste materials are included. From the original list of contaminants present in HLW facilities to be closed, DOE identified those radionuclides that account for more than 99 percent of the external dose rate over the period of evaluation. The radionuclide inventory was decay-corrected to 2095, which is assumed to be the earliest date at which institutional control could be lost.

C.9.4.3 Contaminant Source Development for Modeling

As a result of the screening analysis described above, DOE has selected the final list of contaminants shown in Table C.9-4 for both the groundwater and direct radiation pathways.

Table C.9-4. Final list of contaminants after screening that were analyzed for facility disposition impacts.

Groundwater Pathway	Direct Radiation Pathway	
Technetium-99	Americium-241	Plutonium-241
Iodine-129	Barium-137m	Radium-225
Cadmium	Cobalt-60	Radium-226
Fluoride	Cesium-137	Samarium-151
Nitrate	Europium-154	Strontium-90
	Iodine-129	Technetium-99
	Neptunium-237	Thorium-229
	Protactinium-233	Thorium -230
	Plutonium-238	Uranium-233
	Plutonium-239	Uranium-234
	Plutonium-240	Yttrium-90

C.9.5 RESULTS OF IMPACT ANALYSIS

This section describes the potential human health risk posed by contaminants released to groundwater from INTEC HLW facilities over the long term (10,000 years) following ultimate disposition of those facilities. The basis for these evaluations are projected long-term peak groundwater concentrations, which have been reassessed (Schafer 2001) since the issuance of the Draft EIS. Summary results are presented for each of the facility disposition scenarios, and are listed by receptor category, individual facility and closure method. Peak groundwater concentrations and comparison to drinking water standards are also presented. Radiological dose and risk results are presented first, followed by non-radiological health hazard quotients and risks. Results of a more detailed nature are presented in the supporting Calculation Package.

C.9.5.1 Radiological Dose and Risk

As described in Section C.9.4.2, the radionuclides that remained after screening for the groundwater pathway and were subsequently evaluated in detail are Tc-99 and I-129. Table C.9-5 compares the calculated peak groundwater concentrations (in the aquifer beneath INTEC) against the MCLs specified for drinking water by 40 CFR 141. The year when the peak groundwater concentration would occur is also shown. With the exception of Tc-99 in the bin sets - No Action scenario, all radionuclide concentrations are well below their MCLs.

In addition, DOE assessed the external dose to receptors from other radionuclides in dispositioned facilities. The radiation doses resulting from these evaluations are presented in Table C.9-6. The results represent doses over the entire period of exposure for each receptor that would occur during peak years of exposure (peak groundwater concentration or highest external dose rates, depending on receptor). The resultant cancer risk associated with these doses is presented in Table C.9-7. These values represent the probability of developing an excess cancer (fatal and non-fatal) in a receptor receiving the specified dose.

For the maximally exposed resident, doses are highest under the bin sets - No Action scenario (Table C.9-6). The dose of 490 millirem (equivalent to about 16 millirem per year) is dominated by Tc-99 intake via groundwater and food product ingestion. A dose of 84 millirem to the maximally exposed resident is estimated for the Tank Farm - No Action scenario.

Much higher doses are calculated for Tank Farm intruder scenarios than for other facility cases. This disparity is a direct result of the scenario conditions underlying the calculation. The HLW tanks were designed to rely heavily on the soil overburden for radiation shielding, and this soil (as well as a 6-inch concrete layer) is assumed to be removed by the intruder, leaving only the

Table C.9-5. Projected long-term peak groundwater concentrations for contaminants associated with the facility disposition scenarios.

Contaminant	Contaminant concentration (picocuries per liter or milligrams per liter)		Concentration as a percent of MCL	Time (years after closure) of peak concentration
	Calculated peak groundwater concentration	Reference MCL[a]		
Tank Farm - No Action				
Technetium-99	440	900	49	600
Iodine-129	0.19	1.0	19	700
Cadmium	5.2×10^{-4}	5.0×10^{-3}	10	3,200
Fluoride	1.2×10^{-4}	4.0	< 1	2,800
Nitrate	0.62	44 [b]	1.4	600
Bin Sets - No Action				
Technetium-99	2.6×10^{3}	900	290	600
Iodine-129	0.51	1.0	51	800
Cadmium	0.011	5.0×10^{-3}	210	6,500
Fluoride	5.1×10^{-3}	4.0	< 1	10,000[c]
Nitrate	0.048	44	< 1	600
Tank Farm - Performance-Based Closure or Closure to Landfill Standards				
Technetium-99	15	900	1.7	700
Iodine-129	0.13	1.0	13	600
Cadmium	6.8×10^{-5}	5.0×10^{-3}	1.4	3,000
Fluoride	8.1×10^{-7}	4.0	< 1	3,000
Nitrate	2.6×10^{-3}	44	< 1	600
Bin Sets - Performance-Based Closure or Closure to Landfill Standards				
Technetium-99	7.1	900	0.79	900
Iodine-129	2.8×10^{-3}	1.0	0.28	700
Cadmium	7.9×10^{-5}	5.0×10^{-3}	1.6	4,700
Fluoride	4.3×10^{-5}	4.0	< 1	5,000
Nitrate	7.4×10^{-4}	44	< 1	600
New Waste Calcining Facility - Performance-Based Closure or Closure to Landfill Standards				
Technetium-99	0.18	900	< 1	900
Iodine-129	-[d]	1.0	-	-
Cadmium	-	5.0×10^{-3}	-	-
Fluoride	2.8×10^{-6}	4.0	< 1	5,400
Nitrate	1.2×10^{-5}	44	< 1	700
Process Equipment Waste Evaporator - Performance-Based Closure or Closure to Landfill Standards				
Technetium-99	0.19	900	< 1	900
Iodine-129	-	1.0	-	-
Cadmium	-	5.0×10^{-3}	-	-
Fluoride	8.1×10^{-6}	4.0	< 1	1,400
Nitrate	1.2×10^{-5}	44	< 1	700

Table C.9-5. Projected long-term peak groundwater concentrations for contaminants associated with the facility disposition scenarios (continued).

Contaminant	Contaminant concentration (picocuries per liter or milligrams per liter)		Concentration as a percent of MCL	Time (years after closure) of peak concentration
	Calculated peak groundwater concentration	Reference MCL[a]		
Tank Farm - Performance-Based Closure with Class A Grout Disposal				
Technetium-99	15	900	< 1	700
Iodine-129	0.18	1.0	24	700
Cadmium	1.1×10^{-3}	5.0×10^{-3}	22	6,300
Fluoride	5.2×10^{-4}	4.0	< 1	10,000
Nitrate	0.092	44	< 1	600
Bin Sets - Performance-Based Closure with Class A Grout Disposal				
Technetium-99	7.2	900	< 1	800
Iodine-129	0.071	1.0	7.1	1,200
Cadmium	1.5×10^{-3}	5.0×10^{-3}	30	10,000
Fluoride	7.4×10^{-4}	4.0	< 1	10,000
Nitrate	0.47	44	1.1	600
Tank Farm - Performance-Based Closure with Class C Grout Disposal				
Technetium-99	15	900	< 1	700
Iodine-129	0.14	1.0	14	700
Cadmium	5.2×10^{-4}	5.0×10^{-3}	90	3,200
Fluoride	2.8×10^{-4}	4.0	< 1	3,500
Nitrate	0.013	44	< 1	600
Bin Sets - Performance-Based Closure with Class C Grout Disposal				
Technetium-99	7.7	900	< 1	800
Iodine-129	0.053	1.0	5.3	1,200
Cadmium	1.8×10^{-3}	5.0×10^{-3}	36	10,000
Fluoride	9.0×10^{-4}	4.0	< 1	10,000
Nitrate	0.37	44	< 1	600
Disposal of Class A Grout in a New Low-Activity Waste Disposal Facility				
Technetium-99	0.90	900	< 1	1,000
Iodine-129	0.55	1.0	55	900
Cadmium	0.012	5.0×10^{-3}	250	6,500
Fluoride	6.5×10^{-3}	4.0	< 1	9,300
Nitrate	0.13	44	< 1	700
Disposal of Class C Grout in a New Low-Activity Waste Disposal Facility				
Technetium-99	5.7	900	< 1	1,000
Iodine-129	0.39	1.0	39	900
Cadmium	0.014	5.0×10^{-3}	280	6,000
Fluoride	7.9×10^{-3}	4.0	< 1	8,000
Nitrate	0.037	44	< 1	700

a. Maximum contaminant levels are drinking water standards specified in 40 CFR 141.

b. The MCL for nitrate in 40 CFR 141 is 10 milligrams per liter for the nitrogen component, which equates to approximately 44 milligrams per liter of nitrate.

c. Peak concentration occurs near or after 10,000 years. For those contaminants that have peak concentrations occurring after 10,000 years, the analysis indicates that the concentrations would not approach MCLs (Schafer 2001).

d. A dashed line indicates that there is no significant release.

Table C.9-6. Lifetime radiation dose (millirem) for Tc-99 and I-129 by receptor and facility disposition scenario.

Facility	Maximally exposed resident	Future industrial worker	Future intruder	Recreational user
No Action				
Tank Farm	84	4.4	5.1×10^{4}	0.64
Bin sets	490	25	2.3×10^{-4}	3.7
Performance-Based Closure or Closure to Landfill Standards				
Tank Farm	4.4	0.36	1.9×10^{4}	0.057
Bin sets	1.3	0.070	6.6×10^{-9}	0.010
New Waste Calcining Facility	0.034	1.7×10^{-3}	9.1×10^{-11}[a]	2.4×10^{-4}
Process Equipment Waste Evaporator	0.036	1.8×10^{-3}	9.6×10^{-11}[a]	2.6×10^{-4}
Performance-Based Closure with Class A Grout Disposal				
Tank Farm[b]	5.0	0.44	2.0×10^{4}	0.070
Bin sets[b]	2.2	0.19	6.7×10^{-9}	0.030
Performance-Based Closure with Class C Grout Disposal				
Tank Farm[c]	4.6	0.38	2.5×10^{5}	0.061
Bin sets[c]	2.1	0.16	2.4×10^{-7}	0.025
Class A or C Grout Disposal in a New Low-Activity Waste Disposal Facility				
Class A disposal facility	6.9	0.95	2.8×10^{-6}	0.16
Class C disposal facility	5.8	0.72	4.4×10^{-3}	0.12

a. Direct radiation dose to intruder from exposure to residual activity in closed New Waste Calcining Facility and Process Equipment Waste Evaporator was not assessed. Doses shown for these facilities are from groundwater pathway, which includes soil ingestion and inhalation of soil particles as shown in Table C.9-2.

b. Includes residual contamination plus Class A-type grout.

c. Includes residual contamination plus Class C-type grout.

steel shell of the tank between source and receptor. Alternatively, substantial radiation shielding is provided by structural elements of the bin sets and Low-Activity Waste Disposal Facility, and this shielding is assumed to remain intact during the intrusion scenario for those facilities.

C.9.5.2 Nonradiological Dose and Risk

Nonradiological risk is incurred from intake of cadmium, fluorides and nitrates via ingestion of groundwater, soil and food products, inhalation of dust, and dermal absorption. These intake scenarios are only credible over distant timeframes, well beyond the period of institutional control. Table C.9-5 shows peak aquifer concentrations while Table C.9-8 summarizes noncancer risks associated with intakes in terms of a health hazard quotient, which is the ratio of contaminant intake to the applicable inhalation or oral reference dose. The results represent hazard quotients that would occur during peak years of exposure (peak groundwater concentration). A hazard quotient greater than one indicates that the intake is higher than the reference value. The highest values result from cadmium intake by the maximally exposed resident under the bin sets - No Action scenario and the scenarios involving disposal of Class A or C-type grout in a Low-Activity Waste Disposal Facility. The health hazard quotient is slightly below one for the bin sets - No Action and Class A Grout Disposal in a new Low-Activity Waste Disposal Facility scenarios (0.81 and 0.96, respectively), and slightly above one (1.1) for the Class C Grout Disposal in a new Low-Activity Waste Disposal Facility scenario. Table C.9-5 also compares the peak, long-term groundwater concentrations for nonradionuclides to the MCLs specified in 40 CFR 141. With the exception of cadmium, all concentrations are within currently specified limits. Cadmium concentrations could exceed the MCL under the bin sets - No Action scenario and the scenarios involving disposal of Class A or C-type grout in a Low-Activity Waste Disposal Facility.

Table C.9-7. Lifetime excess radiogenic cancer risk for facility disposition scenarios.

Facility	Maximally exposed resident	Future industrial worker	Future intruder	Recreational user
No Action				
Tank Farm	8.0×10^{-5}	4.1×10^{-6}	0.031	6.0×10^{-7}
Bin sets	4.7×10^{-4}	2.4×10^{-5}	1.4×10^{-10}	3.5×10^{-6}
Performance-Based Closure or Closure to Landfill Standards				
Tank Farm	3.8×10^{-6}	2.8×10^{-7}	0.012	4.4×10^{-8}
Bin sets	1.3×10^{-6}	6.5×10^{-8}	4.0×10^{-15}	9.6×10^{-9}
NWCF	3.2×10^{-8}	1.6×10^{-9}	2.3×10^{-10}[a]	2.3×10^{-10}
PEW Evaporator	3.4×10^{-8}	1.7×10^{-9}	2.5×10^{-10}[a]	2.5×10^{-10}
Performance-Based Closure with Class A Grout Disposal				
Tank Farm[b]	4.1×10^{-6}	3.3×10^{-7}	0.012	5.3×10^{-8}
Bin sets[b]	1.9×10^{-6}	1.4×10^{-7}	4.0×10^{-15}	2.3×10^{-8}
Performance-Based Closure with Class C Grout Disposal				
Tank Farm[c]	3.9×10^{-6}	3.0×10^{-7}	0.15	4.7×10^{-8}
Bin sets[c]	1.8×10^{-6}	1.3×10^{-7}	1.5×10^{-13}	2.0×10^{-8}
Class A or C Grout Disposal in a New Low-Activity Waste Disposal Facility				
Class A disposal facility	4.6×10^{-6}	6.4×10^{-7}	1.7×10^{-12}	1.1×10^{-7}
Class C disposal facility	4.2×10^{-6}	4.9×10^{-7}	2.6×10^{-9}	8.1×10^{-8}

a. Direct radiation dose to intruder from exposure to residual activity in closed New Waste Calcining Facility and Process Equipment Waste Evaporator was not assessed. Doses shown for these facilities are from groundwater pathway, which includes soil ingestion and inhalation of soil particles as shown in Table C.9-2.

b. Includes residual contamination plus Class A-type grout.

c. Includes residual contamination plus Class C-type grout.

For the cases assessed here, quantifiable cancer risk is associated only with inhalation of cadmium entrained in fugitive dust. These cancer risks were assessed and found to be exceedingly low (less than 1×10^{-10} in all cases), and are therefore not presented in table form.

C.9.5.3 Conclusion

The long-term human health risk associated with various facility disposition scenarios has been assessed using conservative assumptions and refined modeling. For all scenarios other than No Action, all projected radiological doses and risks to residents and workers are very low and meet current regulatory criteria. Protection against intrusion would be required to preclude potentially high doses under some intrusion scenarios. For nonradiological contaminants, current regulatory criteria would be met for all scenarios other than cadmium under the bin set - No Action scenario and Class A or C Grout Disposal in a new Low-Activity Waste Disposal Facility scenarios. Although conservative assumptions have been applied to these analyses, the only projected adverse health effect would be noncancer effects from cadmium intakes that could exceed the reference dose under the Class C Grout Disposal in a new Low-Activity Waste Disposal Facility scenario.

C.9.6 SENSITIVITY ANALYSIS

In additional to the baseline calculations described above, DOE performed a quantitative sensitivity analysis to assess the impact of parameter variability on the contaminant flux to groundwater. Sensitivity analyses were performed by varying the values of a number of parameters used to model the contaminant flux from the closed facilities into the vadose zone. The following sections describe the parameters and the methodology used to implement the sensitivity analysis.

Table C.9-8. Noncarcinogenic health hazard quotients.

Contaminant	Cadmium			Fluoride			Nitrate		
Facility	Maximally exposed resident	Future industrial worker	Recreational user	Maximally exposed resident	Future industrial worker	Recreational user	Maximally exposed resident	Future industrial worker	Recreational user
				No Action					
Tank Farm	0.040	8.5×10^{-3}	9.7×10^{-4}	1.6×10^{-4}	1.9×10^{-5}	3.8×10^{-6}	0.047	3.8×10^{-3}	6.5×10^{-4}
Bin sets	0.81	0.17	0.020	7.1×10^{-3}	8.3×10^{-4}	1.7×10^{-4}	3.6×10^{-3}	2.9×10^{-4}	5.0×10^{-5}
				Performance-Based Closure or Closure To Landfill Standards					
Tank Farm	5.3×10^{-3}	1.0×10^{-3}	1.2×10^{-4}	1.1×10^{-6}	1.3×10^{-7}	2.7×10^{-8}	1.7×10^{-4}	1.4×10^{-5}	2.4×10^{-6}
Bin sets	6.1×10^{-3}	1.3×10^{-3}	2.8×10^{-3}	6.0×10^{-5}	7.1×10^{-6}	1.4×10^{-6}	5.6×10^{-5}	4.6×10^{-6}	7.8×10^{-7}
NWCF	- [a]	-	-	3.8×10^{-6}	4.5×10^{-7}	9.2×10^{-8}	8.9×10^{-7}	7.2×10^{-8}	1.2×10^{-8}
PEW Evaporator	-	-	-	1.1×10^{-5}	1.3×10^{-6}	2.7×10^{-7}	9.2×10^{-7}	7.5×10^{-8}	1.3×10^{-8}
				Performance-Based Closure with Class A Grout Disposal					
Tank Farm[b]	0.088	0.019	2.1×10^{-3}	7.2×10^{-4}	8.5×10^{-5}	1.7×10^{-5}	6.9×10^{-3}	5.6×10^{-4}	9.6×10^{-5}
Bin sets[b]	0.12	0.026	5.5×10^{-3}	1.0×10^{-3}	1.2×10^{-4}	2.5×10^{-5}	0.035	2.9×10^{-3}	4.9×10^{-4}
				Performance-Based Closure with Class C Grout Disposal					
Tank Farm[c]	0.040	8.4×10^{-3}	9.6×10^{-4}	3.8×10^{-4}	4.5×10^{-5}	9.3×10^{-6}	9.1×10^{-4}	7.5×10^{-5}	1.3×10^{-5}
Bin sets[c]	0.14	0.031	6.1×10^{-3}	1.2×10^{-3}	1.5×10^{-4}	3.0×10^{-5}	0.028	2.3×10^{-3}	1.4×10^{-4}
				Class A or C Grout Disposal In a New Low-Activity Waste Disposal Facility					
Class A disposal facility	0.96	0.20	0.023	9.1×10^{-3}	1.1×10^{-3}	2.2×10^{-4}	9.8×10^{-3}	8.0×10^{-4}	1.4×10^{-4}
Class C disposal facility	1.1	0.23	0.026	0.011	1.3×10^{-3}	2.6×10^{-4}	2.8×10^{-3}	2.3×10^{-4}	3.9×10^{-5}

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a. A dash indicates that there is no quantifiable exposure to this toxicant.
b. Includes residual contamination plus Class A-type grout.
c. Includes residual contamination plus Class C-type grout.
NWCF = New Waste Calcining Facility; PEW = Process Equipment Waste.

C.9.6.1 Methodology

In this EIS, DOE has made assumptions on numerical parameters that affect the calculated impacts. There is some uncertainty associated with the values of these parameter due to unavailable data and current state of knowledge about closure processes and long-term behavior of materials. The purpose of this section is to discuss the primary sources of uncertainty in the prediction of the mass flux of contaminants leaching from storage containment and being released to the vadose zone. This leaching rate, which is subsequently used as the source term for vadose zone and aquifer concentrations, requires estimation of several parameters, including the following:

- **Inventory:** The amount of material in the closed tanks and facilities directly, linearly affects the concentrations at any given location. The inventories have been estimated as described in Section C.9.4.

  The Continued Current Operations Alternative described in Section 3.1.2 would calcine all remaining mixed transuranic waste/SBW and store the calcine in the bin sets indefinitely. As a result, the volume of calcine stored in the bin sets would be increased by about 20 percent from that evaluated for the No Action Alternative. The amount of radioactivity (total curies) remaining in the bin sets would be increased by about 5 percent. The long-term impacts associated with the bin sets under the Continued Current Operations Alternative would be slightly larger than those presented for the bin set - No Action Scenario. Conversely the long-term impacts associated with the Tank Farm - No Action Scenario would decrease because the liquid mixed transuranic waste/SBW would have been removed from the Tank Farm tanks and calcined.

- **Facility Dimensions:** The physical dimensions of the facilities are important parameters in modeling contaminant releases from closed HLW facilities. DOE made several simplifying assumptions related to facility dimensions in modeling the contaminant transport for this EIS. The Tank Farm and bin sets were each modeled as a single "composite" tank or bin having the characteristics of the individual tanks and bin sets. The surface area of the composite tank/bin set was modeled as the sum of the surface areas of the individual tanks and bin sets. For example, the surface area of the bottoms of the 11 HLW tanks is 1,963.5 square feet each (Spaulding et al. 1998). The total surface area of the composite tank is thus 21,598.5 square feet. Similarly, the basemat thickness was modeled as an average of the basemat thicknesses of the individual tanks and bin sets. For example, the basemat thickness of Tanks WM-180 and WM-181 is 3.0 feet and the basemat thickness of Tanks WM-182 to WM-190 is 2.5 feet (Spaulding et al. 1998). The average basemat thickness is therefore 2.59 feet. Since the basemat thickness is an important parameter, the results would be sensitive to changes in assumed basemat thickness. If the basemat thickness of an individual tank or bin set was smaller that the average basemat thickness of the composite tank/bin, the results for that tank/bin could be higher than that tank or bin set's portion of the composite tank/bin set. Using an average basemat thickness for the composite analysis is a reasonable model simplification.

- **Infiltration Rate:** The driving force for contaminant migration has been assumed to consist of infiltration through the closed facility, which is assumed to remain constant over the entire 10,000-year period of analysis. The infiltration rates through the closed facilities would be less than the annual precipitation rate of 9 inches per year (assuming no localized ponding occurs on top of the closed facilities). Previous INEEL Studies (Rodriguez et al. 1997) have indicated that average infiltration through sediments at the INEEL is on the order of 1.6 inches per year, which is equal to the precipitation rate minus evaporation and plant transpiration. In the area of each of the closed facilities, evaporation would continue as a natural process, reducing the infiltration from the precipitation rate of 9 inches per year. However, it is unlikely that plant transpiration would occur as a result of vegetation growth on top of the closed facilities. This lack of vegetation would probably be offset by run-off from these facilities to lower elevation areas, offsetting the loss of infiltration due to lack of transpiration. Given these competing factors, the MEPAS simulations were performed assuming the site average infiltration rate of 1.6 inches per year.

DOE performed a quantitative sensitivity analysis of the effect of changes in assumed infiltration rate on the resulting groundwater concentrations discussed in Section C.9.5. The effect of increasing or decreasing this value by a factor of 10 was investigated for the contaminant/scenario combinations listed in Table C.9-9.

- **Time of Assumed Grout Failure -** Studies have shown that cementitious materials (such as grout or concrete) can be expected to last for extended periods of time approaching 1,000 years or more (Poe 1998). Therefore, it is likely that the grout would retain its original hydraulic properties for much longer than the 500 years assumed in this analysis. However, the modeling assumes that at 500 years, the concrete and grout in the tanks and facilities would assume the same hydrogeologic transport characteristics as the surrounding soil; however, chemical properties of grout and concrete would remain unchanged. DOE performed a quantitative sensitivity analysis of the effect of changes in assumed time of grout failure. This time of grout failure was varied from the baseline value by assuming that failure occurred earlier (100 years) or later (1,000 years). The effect of an earlier or later time to failure was investigated for the contaminant/scenario combinations listed in Table C.9-9.

- **Distribution Coefficient -** The distribution coefficient (K_d) affects the rate at which contaminates move through strata. Large K_d values retard contaminant movement. Although the reducing grout is assumed to lose hydraulic containment at 500 years, the reducing grout would retain its chemical composition. As a result, the grout would still retard the migration of reactive (adsorbing) chemicals and radioactive constituents. The actual K_d values used in this analysis were selected based on laboratory work performed for reducing cementitious environments (Kimmel 2000a). Sensitivity analyses were performed on the K_d values for the same contaminants that had passed the initial screening and for which MEPAS baseline analyses were performed (Section C.9.3.1) for several of the analyzed scenarios. Table C.9-9 shows the K_d values that were assumed for the contaminant/scenario combinations for which a sensitivity analysis run was performed. These sensitivity analysis runs also serve as an indicator of the effects of different chemical properties of the residual waste or facility basemat layers (i.e., if the residual waste has an oxidizing rather than a reducing environment).

- **Tank Failure:** In the No Action scenario, the 5 tanks in the monolithic tank vaults are assumed to be filled to capacity and the other 6 tanks have residual heels. After being filled to capacity it was conservatively assumed that the tanks degrade and would fail simultaneously at 500 years. For the base case analysis reported in Section C.9.5, some retardation credit was taken for the facility structure. However, there is uncertainty concerning the capability of the structure to retard the liquid once the tanks are assumed to fail. The worst-case event would assume that there is a direct path from the liquid to the soil column.

  Additional analysis was conducted to determine the impact on groundwater from the degradation and simultaneous failure of 5 full mixed transuranic waste/SBW tanks at Year 2516. This

Table C.9-9. Description of sensitivity analysis runs.

Contaminant	Run	K_d (basemat/heel)	Infiltration rate (in/yr)	Fail time (yrs)
Infiltration rate sensitivity runs				
Tank Farm – Performance-Based Closure or Closure to Landfill Standards				
I-129	Base case	2/2	1.6	500
	#17	2/2	0.16	500
	#18	2/2	16	500
Sr-90	Base case	1/8	1.6	500
	#19	1/8	0.16	500
	#20	1/8	16	500
Tc-99	Base case	1/500	1.6	500
	#21	1/500	0.16	500
	#22	1/500	16	500
Time of assumed grout failure sensitivity runs				
Tank Farm - Performance-Based Closure or Closure to Landfill Standards				
I-129	Base case	2/2	1.6	500
	#11	2/2	1.6	100
	#12	2/2	1.6	1000
Sr-90	Base case	1/8	1.6	500
	#13	1/8	1.6	100
	#14	1/8	1.6	1000
Tc-99	Base case	1/500	1.6	500
	#15	1/500	1.6	100
	#16	1/500	1.6	1000
Distribution coefficient sensitivity runs				
Tank Farm - Performance-Based Closure or Closure to Landfill Standards				
I-129	Base case	2/2	1.6	500
	#1	0.2/0.2	1.6	500
	#2	20/20	1.6	500
Tc-99	Base case	1/500	1.6	500
	#3	0.1/50	1.6	500
	#4	10/5000	1.6	500
	#24	0.1/0.1	1.6	500
Sr-90	Base case	1/8	1.6	500
	#5	0.1/0.8	1.6	500
	#6	10/80	1.6	500
Hg	Base case	100/60	1.6	500
	#7	10/6	1.6	500
	#8	1000/600	1.6	500

Table C.9-9. Description of sensitivity analysis runs (continued).

Contaminant	Run	K_d (basemat/heel)	Infiltration rate (in/yr)	Fail time (yrs)
Distribution coefficient sensitivity runs (continued)				
Tank Farm - Performance-Based Closure or Closure to Landfill Standards (continued)				
Cd	Base case	40/23	1.6	500
	#9	4/2.3	1.6	500
	#10	400/230	1.6	500
Pu-239	Base case	5000/2800	1.6	500
	#23	500/280	1.6	500
Np-237	Base case	5000/5000	1.6	500
	#25	5/100	1.6	500
F	Base case	87/44	1.6	500
	#27	0/0	1.6	500
Cr	Base case	360/7.9	1.6	500
	#28	36/0.8	1.6	500
Mo	Base case	280/0	1.6	500
	#29	28/0	1.6	500
Ba	Base case	16,000/16,000	1.6	500
	#30	50/50	1.6	500
Tank Farm - Performance-Based Closure with Class A Grout Disposal				
Np-237	Base case	5000/5000	1.6	500
	#31	5/100	1.6	500
Tc-99	Base case	1/500	1.6	500
	#32	0.1/0.1	1.6	500
F	Base case	87/87	1.6	500
	#33	0/0	1.6	500
Cr	Base case	360/7.9	1.6	500
	#34	36/0.8	1.6	500
Mo	Base case	280/0	1.6	500
	#35	28/0	1.6	500
Ba	Base case	16,000/16,000	1.6	500
	#36	50/50	1.6	500
Tank Farm - Performance-Based Closure with Class C Grout Disposal				
Np-237	Base case	5000/5000	1.6	500
	#37	5/100	1.6	500
Tc-99	Base case	1/500	1.6	500
	#38	0.1/0.1	1.6	500
F	Base case	87/87	1.6	500
	#39	0/0	1.6	500

Table C.9-9. Description of sensitivity analysis runs (continued).

Contaminant	Run	K_d (basemat/heel)	Infiltration rate (in/yr)	Fail time (yrs)
Distribution coefficient sensitivity runs (continued)				
Tank Farm - Performance-Based Closure with Class C Grout Disposal (continued)				
Cr	Base case	360/7.9	1.6	500
	#40	36/0.8	1.6	500
Mo	Base case	280/0	1.6	500
	#41	28/0	1.6	500
Ba	Base case	16,000/16,000	1.6	500
	#42	50/50	1.6	500
Bin Sets - No Action				
Pu-239	Base case	5000/2800	1.6	500
	#26	500/280	1.6	500
Bin Sets - Performance-Based Closure or Closure to Landfill Standards				
Np-237	Base case	5000/5000	1.6	500
	#43	5/100	1.6	500
Tc-99	Base case	1/500	1.6	500
	#44	0.1/0.1	1.6	500
F	Base case	87/44	1.6	500
	#45	0/0	1.6	500
Cr	Base case	360/7.9	1.6	500
	#46	36/0.8	1.6	500
Mo	Base case	280/0	1.6	500
	#47	28/0	1.6	500
Ba	Base case	16,000/16,000	1.6	500
	#48	50/50	1.6	500
Bin Sets – Performance-Based Closure with Class A Grout Disposal				
Np-237	Base case	5000/5000	1.6	500
	#49	5/100	1.6	500
Tc-99	Base case	1/500	1.6	500
	#50	0.1/0.1	1.6	500
F	Base case	87/87	1.6	500
	#51	0/0	1.6	500
Cr	Base case	360/7.9	1.6	500
	#52	36/0.8	1.6	500
Mo	Base case	280/0	1.6	500
	#53	28/0	1.6	500
Ba	Base case	16,000/16,000	1.6	500
	#54	50/50	1.6	500

Table C.9-9. Description of sensitivity analysis runs (continued).

Contaminant	Run	K_d (basemat/heel)	Infiltration rate (in/yr)	Fail time (yrs)
Distribution coefficient sensitivity runs (continued)				
Bin Sets - Performance-Based Closure with Class C Grout Disposal				
Np-237	Base case	5000/5000	1.6	500
	#55	5/100	1.6	500
Tc-99	Base case	1/500	1.6	500
	#56	0.1/0.1	1.6	500
F	Base case	87/87	1.6	500
	#57	0/0	1.6	500
Cr	Base case	360/7.9	1.6	500
	#58	36/0.8	1.6	500
Mo	Base case	280/0	1.6	500
	#59	28/0	1.6	500
Ba	Base case	16,000/16,000	1.6	500
	#60	50/50	1.6	500
Class A Grout Disposal in a New Low-Activity Waste Disposal Facility				
Np-237	Base case	5000/5000	1.6	500
	#61	5/100	1.6	500
Tc-99	Base case	1/500	1.6	500
	#62	0.1/0.1	1.6	500
F	Base case	87/87	1.6	500
	#63	0/0	1.6	500
Cr	Base case	360/7.9	1.6	500
	#64	36/0.8	1.6	500
Mo	Base case	280/0	1.6	500
	#65	28/0	1.6	500
Ba	Base case	16,000/16,000	1.6	500
	#66	50/50	1.6	500
Class C Grout Disposal in a New Low-Activity Waste Disposal Facility				
Np-237	Base case	5000/5000	1.6	500
	#67	5/100	1.6	500
Tc-99	Base case	1/500	1.6	500
	#68	0.1/0.1	1.6	500
F	Base case	87/87	1.6	500
	#69	0/0	1.6	500
Cr	Base case	360/7.9	1.6	500
	#70	36/0.8	1.6	500
Mo	Base case	280/0	1.6	500
	#71	28/0	1.6	500
Ba	Base case	16,000/16,000	1.6	500
	#72	50/50	1.6	500

assessment was made for four key radionuclides using similar modeling methods as those used in the WAG 3 RI/FS (Rodriguez et al. 1997). The results indicate that groundwater concentrations could reach approximately 42 percent of the drinking water standards for Tc-99, 47 percent for I-129, 2.3 percent for Np-237, and 57 percent for plutonium isotopes. This event is treated as an accident and the associated impacts are analyzed and reported in Appendix C.4 and Section 5.2.14.

Analysis was also conducted to determine the impact on groundwater from the degradation and failure of a single full mixed transuranic waste/SBW tank at year 2001. This assessment was made for the same four key radionuclides again using the WAG 3 RI/FS modeling methodology. The results indicate that groundwater concentrations could reach approximately 13 percent of the drinking water standards for I-129, 11 percent for Tc-99, 2.0 percent for Np-137, and 7.3 percent for plutonium isotopes. This event is also treated as an accident and the associated impacts are analyzed and reported in Appendix C.4 and Section 5.2.14.

For tank failures analyzed as accidents, if different modeling assumptions than those considered in the WAG 3 RI/FS were used, calculated groundwater impacts could be much larger. These modeling assumptions are discussed in Appendix C.4 and Section 5.2.14.

- **Interbed continuity and thickness:** In the vadose zone and aquifer transport modeling performed for the WAG 3 RI/FS (Rodriguez et al. 1997), which is the basis for the simplified modeling described in Section C.9.3.2, DOE grouped the sediment interbeds into four relatively thick and continuous interbeds. However, actual observations indicate that the interbeds have a thin and discontinuous nature. Also, more recent interpretation of the INTEC subsurface suggests that sediments comprise about 5 percent of the subsurface rather than the 23 percent assumed for the vadose zone and aquifer modeling. An assumption of thin, discontinuous interbeds would result in faster travel times through the vadose zone and higher peak aquifer concentrations. Reducing the sediment proportion would result in a further reduction in the travel time through the vadose zone.

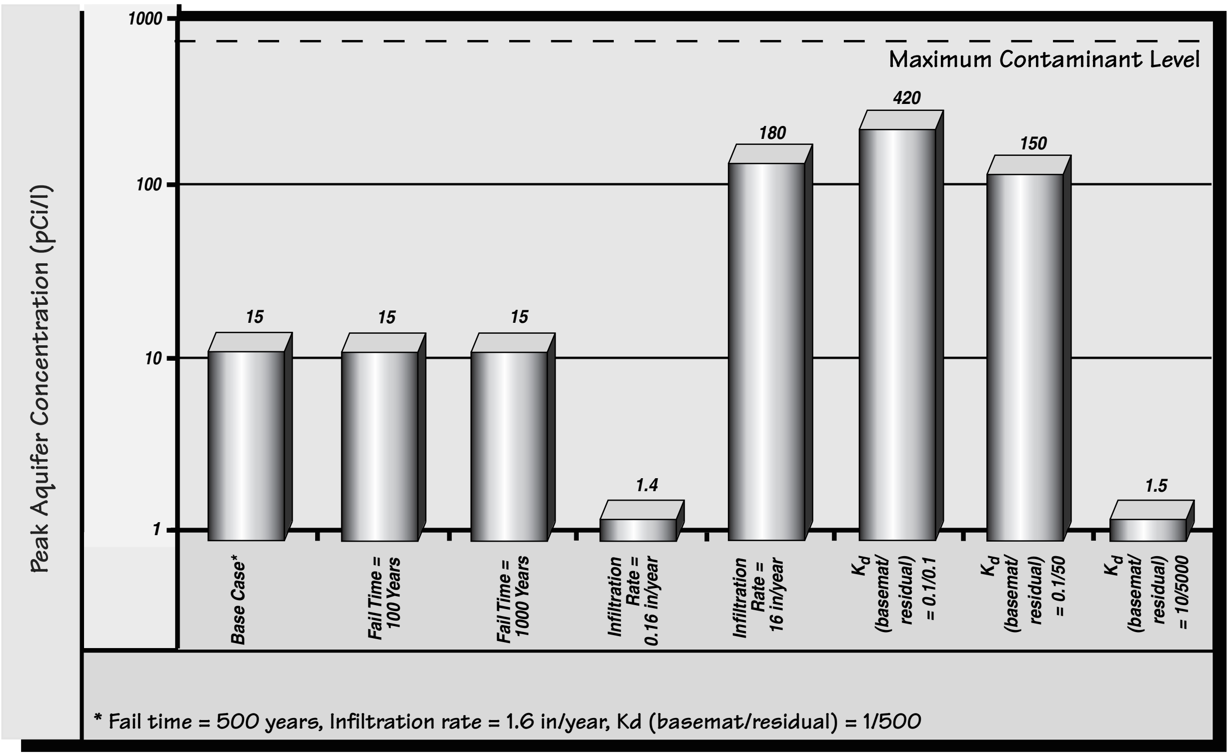
The period of analysis for this modeling was 10,000 years. For constituents that have not reached a peak concentration within 10,000 years (e.g., plutonium), additional sensitivity analysis runs were performed to determine when these constituents reach a peak concentration in the aquifer and at what level. The results of these sensitivity analyses are presented in the Calculation Package.

After selection of these properties and processes, MEPAS simulations were used to predict the flux rate to the soil under the facilities. This mass flux was then used as input into the vadose zone and subsequently into the aquifer. At this point, the analytical approach used in this Appendix is equivalent to that used for the WAG 3 RI/FS (Rodriguez et al. 1997), which provides a discussion of the uncertainties related to the vadose zone and aquifer modeling.

C.9.6.2 Results and Conclusions

DOE performed quantitative sensitivity analyses for the contaminant/scenario combinations listed in Table C.9-9. The results of these analyses are presented in the Calculation Package. To graphically illustrate the sensitivity analysis results, this appendix presents the results of the Tc-99 and I-129 (which constitute the majority of the dose for the base case) Tank Farm - Performance-Based Closure or Closure to Landfill Standards scenario sensitivity analyses. These results are shown in Figures C.9-12 through C.9-15.

Changes in the time of assumed grout failure do not appreciably change the magnitude of the predicted peak groundwater concentrations. In reality, it is expected that failure of the fill material and facility basemat in the individual tanks would occur randomly over time, rather than simultaneously as assumed in this appendix.



* Fail time = 500 years, Infiltration rate = 1.6 in/year, Kd (basemat/residual) = 1/500

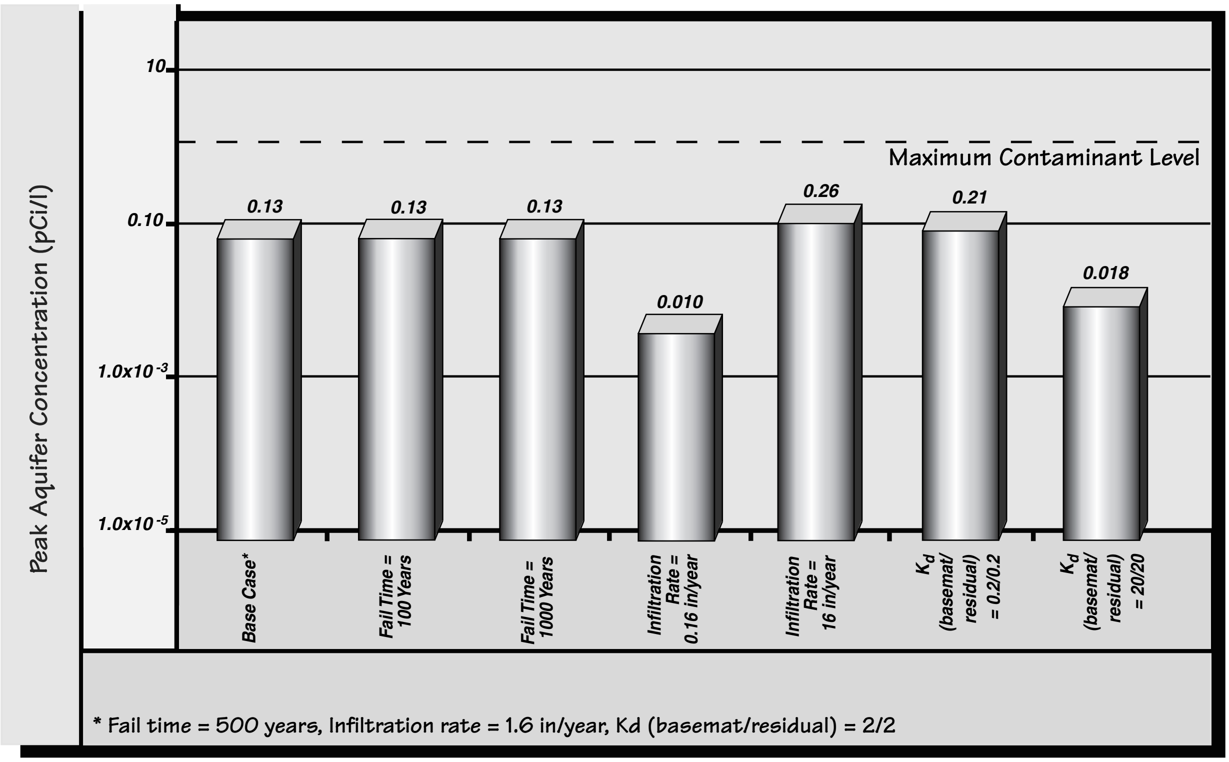
FIGURE C.9-12.
Sensitivity Analysis Results (peak aquifer concentration) for Tc-99: Tank Farm Performance-Based Closure or Closure to Landfill Standards.

Therefore, the assumed time of grout failure has the conservative impact of overestimating the actual transport of contaminants into the environment.

Changes in assumed infiltration rate result in substantial changes in the magnitude of the predicted peak groundwater concentrations. Increasing the infiltration rate results in an increase in predicted peak groundwater concentration. Because the assumed infiltration rate was based on previous INEEL studies (Rodriguez et al. 1997), DOE believes that this value is reasonable for the analyses presented in the appendix.

The distribution coefficient is the most sensitive parameter in estimating the initial leaching of contaminants from the source material (residual contamination or Class A/C-type grout) into the infiltrating water. Therefore, as expected, for all contaminants, decreasing the distribution coefficient results in large increases in the predicted peak groundwater concentrations. As discussed in Section C.9.3.1.2, DOE conducted a literature search of published values for distribution coefficients considered to be reasonable for INEEL conditions (Kimmel 2000a). Based on this review and an understanding of the chemical and physical conditions related to the closed HLW facilities, DOE believes that the set of distribution coefficients values selected for use in the modeling are reasonable for the analyses presented in this appendix.

As described in this appendix, a number of conservative assumptions were included as part of this modeling effort. This has the effect of providing dose/concentration estimates that may be greater than values that might actually be measured. The relative lack of sensitivity of the magnitude of the results to many of the parameters listed above, however, suggests that the estimates depend on a limited few key parameters, such as source term, distribution coefficient, and infiltration rate. DOE recognizes that over the period of analysis in this EIS, there is uncertainty in the structural behavior of materials and the



* Fail time = 500 years, Infiltration rate = 1.6 in/year, Kd (basemat/residual) = 2/2

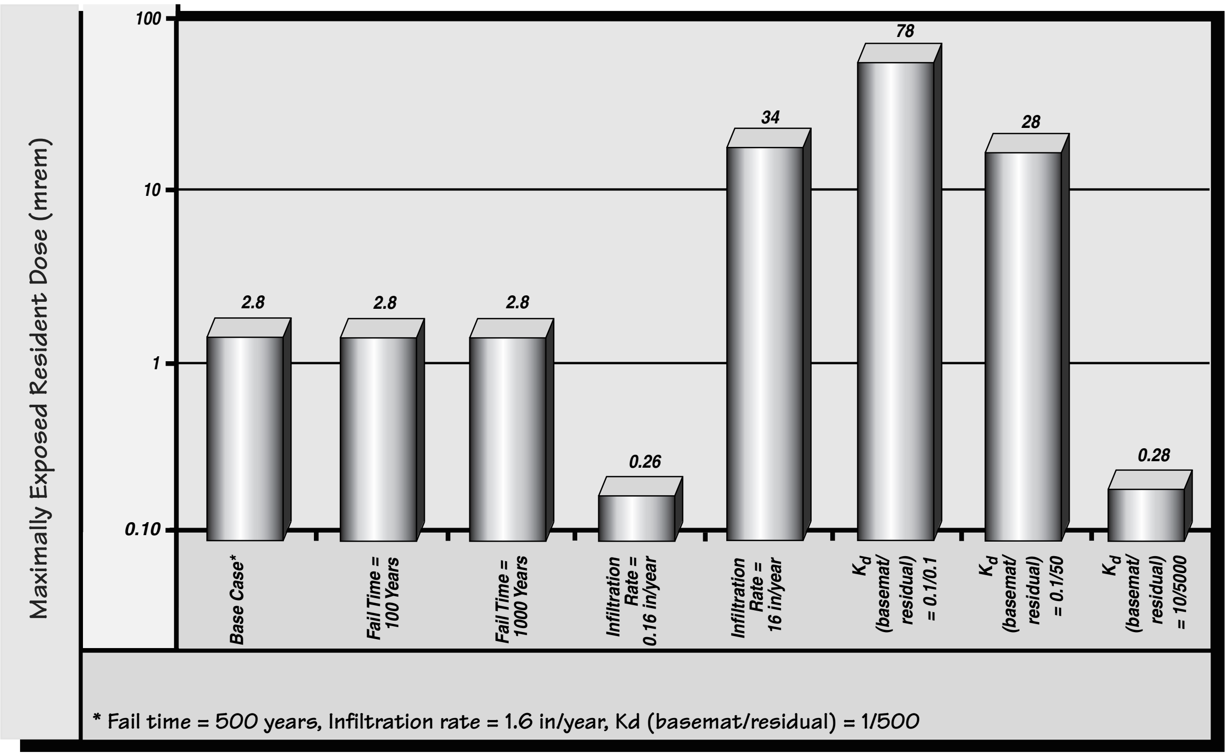
FIGURE C.9-13.
Sensitivity Analysis Results (peak aquifer concentration) for I-129: Tank Farm Performance-Based Closure or Closure to Landfill Standards.

geologic and hydrogeologic setting of the INTEC. DOE realizes that overly conservative assumptions can be used to bound the estimates of impacts; however, DOE believes that this approach could result in masking of differences of impacts among facility disposition alternatives. Therefore, DOE has attempted to use assumptions in its modeling analysis that are reasonable based on current knowledge so that meaningful comparisons among scenarios can be made.

C.9.7 UNCERTAINTY ANALYSIS

A number of conservative assumptions were included as part of this modeling effort. This has the effect of providing dose/concentration estimates that may be greater than values that might actually be measured. The relative lack of sensitivity of the magnitude of the results to many of the parameters listed above, however, suggests that the estimates depend on a limited few key parameters, such as source term, distribution coefficient, and infiltration rate. It is recognized that over the period of analysis in this EIS, there is uncertainty in the structural behavior of materials and the geologic and hydrogeologic setting of the INTEC. Overly conservative assumptions can be used to bound the estimates of impacts; however, it is believed that this approach could result in masking of differences in impacts among facility disposition alternatives. Therefore, the assumptions used in its modeling analysis, which are reasonable based on current knowledge, allow for meaningful comparisons among scenarios to be made.

The ability of the modeling described in Sections C.9.1 through C.9.5 to represent, or adequately predict, contaminant transport through closed HLW facilities and the subsurface of the INTEC is inherently uncertain. The uncertainties associated with these prediction are primarily functions of (1) the degree to which the conceptual model represents actual contaminant flow and transport processes, (2) the choice of the contaminant specific K_d values and other parame-



* Fail time = 500 years, Infiltration rate = 1.6 in/year, Kd (basemat/residual) = 1/500

FIGURE C.9-14.
Sensitivity Analysis Results (maximally exposed resident dose) for Tc-99: Tank Farm Performance-Based Closure or Closure to Landfill Standards.

ters, and (3) the accuracy of the estimated source term. The uncertainties related to physical parameters (including the conceptual model and K_d values) are summarized in Section C.9.7.1, and the accuracy of the source term is addressed in Section C.9.7.2.

C.9.7.1 Discussion of Physical Parameter Uncertainty

Conceptual Models

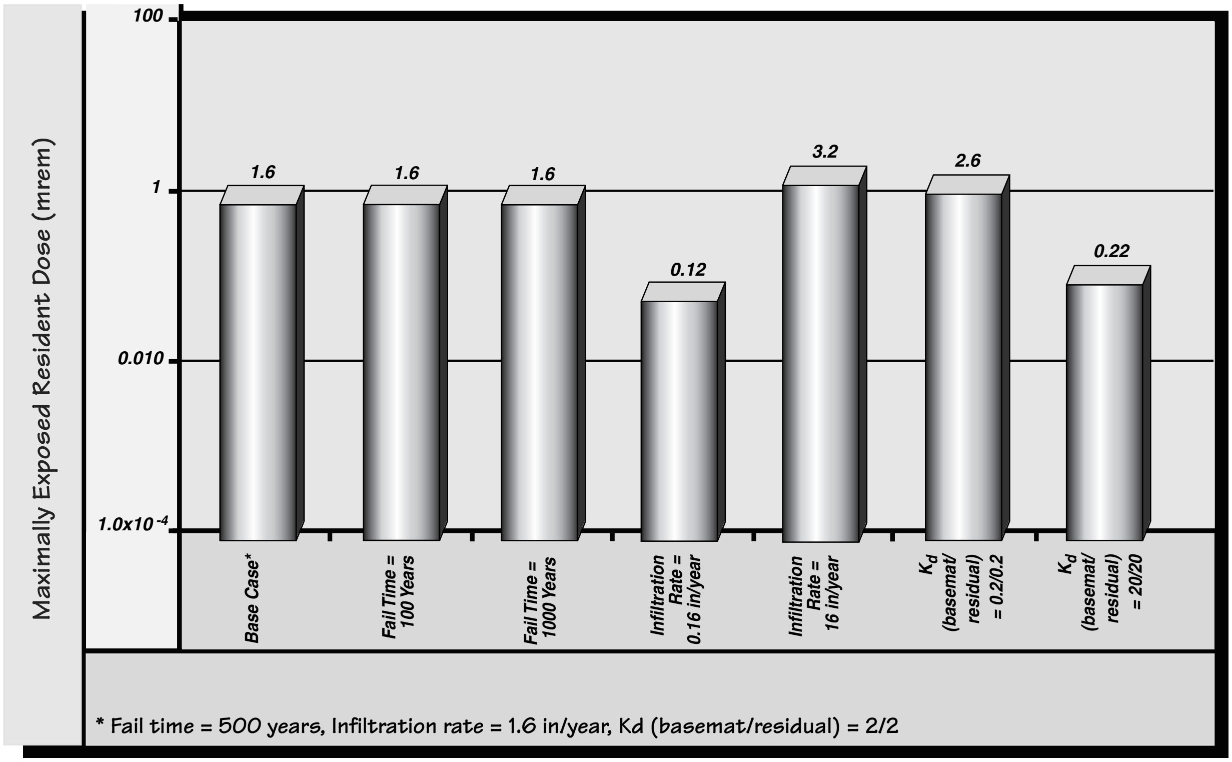
As described in Section C.9.2, the conceptual model includes three general mechanisms by which individuals could be impacted by residual contamination as follows:

- Contaminants could be transported to the aquifer under the facilities and eventually reach wells allowing humans to access the contaminated water for drinking, irrigation, and other purposes.
- Contaminants in closed facilities could emit gamma radiation which could directly irradiate humans in the vicinity.
- Contaminants could be released to the environment through airborne pathways due to degradation and weathering of the bin sets under the No Action Alternative.

Uncertainties associated with the vadose zone and aquifer modeling were addressed in Sections 9, 10, and 11 of Appendix F of Rodriguez et al. (1997). The discussions and conclusions in those sections also apply to the updated and simplified approach used in this modeling, as described in Section C.9.3.2.

Uncertainties associated with the conceptual model for the facility basemat modeling include:

- The analysis is based on the assumption that any residual contaminants left in the tanks and bin sets after flushing and/or



* Fail time = 500 years, Infiltration rate = 1.6 in/year, Kd (basemat/residual) = 2/2

FIGURE C.9-15.
Sensitivity Analysis Results (maximally exposed resident dose) for I-129: Tank Farm Performance-Based Closure or Closure to Landfill Standards.

final cleaning would reside on the floor of the facility, thereby creating a higher concentration layer. If residual contaminants were to actually reside on locations other than the floor (i.e., tank walls), this could have the effect of decreasing the predicted contaminant flux out of the facility basemat (by spreading the contaminants through a larger thickness of grout), or it could have the effect of increasing the predicted contaminant flux out of the facility basemat (if the contamination was in an area that was subject to greater water infiltration, such as a void space between the tank walls and the fill material.

- The analysis is based on the assumption that the concrete and grout in all of the tanks and bin sets simultaneously assumes the same hydrogeologic transport characteristics as the surrounding soil at 500 years. In reality, failure of the facility basemat and fill materials would occur randomly over time, which would lead to lower total contaminant flux out of the facility basemat.

- The analysis is based on the assumption that the present environmental conditions including meteorology, infiltration rates, and geologic conditions would remain constant throughout the entire 10,000-year period of analysis. This modeling is dependent on parameter values, such as the infiltration rate, that correspond to these environmental conditions. As discussed in Section C.9.6 the infiltration rate is a sensitive parameter in the facility basemat modeling. Changes in assumed infiltration rate result in substantial changes in the magnitude of the predicted peak groundwater concentrations. Increasing the infiltration rate results in an increase in predicted peak groundwater concentration. Because the assumed infiltration rate was based on previous INEEL studies (Rodriguez et al. 1997), DOE believes that this value is reasonable for this analyses.

Distribution Coefficients (K_ds)

There is considerable range of K_d values for the various contaminants of concern in this modeling. In addition to these different K_d values, there are several different materials through which the contamination would be transported, including calcine, ungrouted Tank Farm residuals, sand pads, facility basemats, reducing grout (Class A or Class C-type grout), and grouted residual waste.

The assumption that the chemical characteristics of the grout are expected to persist long after the analysis period of 10,000 years, and therefore, that the chemical characteristics of the water passing through the grout would continue to inhibit the amount of leaching that would occur after failure also has a significant impact on the calculated contaminant transport. If this assumption were to not occur and the assumed reducing conditions did not exist, the contaminants would migrate into the infiltrating water at a higher rate (i.e., the K_d value would be lower) than was predicted for the reducing environment.

As shown above in Section C.9.6, the K_d value is the most sensitive parameter in estimating the initial leaching of contaminants from the source material (residual contamination or Class A/C-type grout) into the infiltrating water. Therefore, differences in assumed K_d value result in large changes in the predicted peak groundwater concentrations. For these reasons, DOE conducted a literature search of published values for distribution coefficients considered to be reasonable for INEEL conditions (Kimmel 2000a). Kimmel (2000a) presents the rationale for the selected K_d values for each transport layer. Based on this review and an understanding of the chemical and physical conditions related to the closed HLW facilities, it is believed that the set of distribution coefficients values selected for use in the modeling are reasonable for the analyses.

Facility Disposition Alternatives

As described in Section C.9.2, the EIS considered multiple conditions in which the facilities could be readied for ultimate disposition. Some of these alternatives would result in residual radioactivity and nonradiological contaminants that would remain in the facilities after disposition and could be transported to the environment at some point in the future. DOE identified six alternatives that could be implemented for disposition of some or all of the existing INTEC HLW management facilities. These facility disposition alternatives were defined based on the current regulatory requirements for closure of HLW management facilities and do not define *a priori*, what is an acceptable level of residual contamination in each HLW management facility. Therefore, there is uncertainty regarding the exact method in which a facility disposition alternative would be applied to a given HLW management facility.

For existing HLW management facilities, the Preferred Alternative, as described in Section 3.4.2, was to apply performance-based closure methods on a case-by-case basis. These methods would provide a systematic reduction of risks due to residual wastes and contaminants. Closure would be performed to levels economically, practically, and technically feasible such that satisfactory protection of the environment and the public is achieved. Given that these levels depend on a full and accurate characterization of the residual material remaining in the facilities prior to closure, they would not be fully defined until the facilities reach the closure stage. A discussion of uncertainties associated with the contaminant and source term estimates is provided in Section C.9.7.2.

Exposure Receptor Assumptions

As described in Section C.9.2.2, since the nature of land use after the period of institutional control cannot be accurately predicted, a spectrum of potential receptors was identified, and for each of these, a set of exposure-related conditions was developed based on applicable reference sources or reasonable assumptions. (In the context used here, the term receptor refers to categories of persons that may be impacted, after the period of institutional control, by the disposition of HLW management facilities at INTEC.) There is uncertainty related to the definition of these receptors and their habits, and thus potential exposure pathways.

One assumption made in this analysis was that for the impact area in question (the general vicinity of the current INTEC), institutional control would be maintained over this area until the year 2095. After that time, it is assumed for purposes of analysis that this area would not be controlled, and could be used for residential, agricultural, industrial, or recreational purposes for a period of roughly 10,000 years. This assumption would tend to lead to conservative results, since receptors having agricultural habits (including consumption and other use of potentially contaminated groundwater) tend to have the highest intake of contaminants. If this assumption regarding institutional control was to prove to be incorrect and institutional controls over the impact area were to remain in effect, the calculated impacts to these receptors would be less than those reported in this analysis.

C.9.7.2 Uncertainty in the Contaminants and Source Term Estimates

As described in Section C.9.4, engineering studies were performed to estimate the amount of contaminants that could be left in facilities following disposition. These engineering studies relied primarily on process knowledge, supported by limited sampling data. For example, the radionuclide quantities in the solids assumed to be present in the Tank Farm residual were based on analysis of the Tank WM-188 residual solids. However, the I-129 content of the Tank WM-188 solids was below the analytical method detection limit. Therefore, the process knowledge values for I-129 were used in the Tank Farm inventory.

Visual inspections also form the basis for estimating Tank Farm heel solids. In early 1999, a video inspection of Tank WM-188 resulted in an estimate of the residual solids estimate accumulation of one inch (actually ¼ to ½ inch, but conservatively assumed to be one inch). Recent video inspections have subsequently revealed greater accumulations in tanks WM-182 and WM-183, which are estimated to have accumulations of four inches and eight inches, respectively. For the bin sets, the source term estimates were based on measured values, to the extent that these values exist, supplemented by calculated radionuclide ratios to fill in any gaps. These Tank Farm and bin set values subsequently formed the basis for the Class A and Class C-type grout source terms.

DOE expects the residual inventory in the Process Equipment Waste Evaporator (CPP-604) and the New Waste Calcining Facility (CPP-659) after closure would be less than the amount remaining in the Waste Calcining Facility (CPP-633) after it was closed. For this analysis, it was conservatively assumed that the residual inventory in each of the Process Equipment Waste Evaporator and New Waste Calcining Facility would be equal to that in the Waste Calcining Facility. Since residual contamination in these facilities has not been fully characterized (as neither facility has begun waste removal or closure activities), the actual characteristics of the residual have not been measured or otherwise quantified. Therefore, there is substantial uncertainty regarding the residual contaminant source term in these facilities.

It is expected that the source term values for all of the facilities addressed in this modeling represent conservative estimates and that the actual inventories remaining in closed HLW management facilities would be lower than these estimates. As described above in Section C.9.6, the amount of material in the closed tanks and facilities directly, linearly affects the concentrations at any given location. Therefore, any changes in the actual residual source term values from those used in this analysis would strongly influence the final calculated result. Before facilities at INTEC would be closed, the residual contamination would be characterized to quantify the amount of residual material and its concentrations of radioactive and nonradioactive contaminants.

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