APPENDIX B

ACCIDENT ANALYSIS

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

List of Tables

APPENDIX B. ACCIDENT ANALYSIS

This Appendix provides detailed information on potential accident scenarios associated with various alternatives for salt processing at the Department of Energy's (DOE) Savannah River Site (SRS). The Appendix provides estimates of the quantity and composition of hazardous materials that could be released in an accident, as well as the consequences to workers and the public. Estimates are given in terms of dose and latent cancer fatalities for radiological releases and of concentration levels for chemical releases.

The primary source of information for the accident analyses is an engineering calculation prepared specifically to document the accident sequences, frequencies, and source terms for the various alternatives. Unless specifically noted, all references in this Appendix are to Cappucci et al. (2000).

B.1 General Accident Information

An accident, as discussed in this Appendix, is an inadvertent release of radiological or chemical hazardous materials as a result of a sequence of one or more probable events. The sequence usually begins with an initiating event, such as a human error, equipment failure, or earthquake, followed by a succession of other events (which could be either dependent on or independent of the initial event), that dictate the accident's progression and the extent of materials released. Initiating events fall into three categories:

- *Internal initiators* – normally originate in and around the facility, but are always a result of facility operations. Examples include equipment or structural failures and human errors.

- *External initiators* – independent of facility operations and normally originate outside the facility. Some external initiators affect the ability of the facility to maintain its confinement of hazardous materials because of potential structural damage. Examples include helicopter, aircraft, or vehicle crashes, nearby explosions, and toxic chemical releases at nearby facilities that affect worker performance.

- *Natural phenomena initiators* – natural occurrences that are independent of facility operations and occurrences at nearby facilities or operations. Examples include earthquakes, high winds, floods, lightning, and snow. Although natural phenomena initiators are independent of external facilities, their occurrence can involve those facilities and compound the progression of the accident.

The likelihood of an accident occurring and its consequences usually depend on the initiator, the sequence of events, and their frequencies or probabilities. Accidents can be grouped into four categories—anticipated, unlikely, extremely unlikely, and beyond extremely unlikely, as listed in Table B-1. DOE based the frequencies of accidents on safety analyses and historical data about event occurrences.

B.2 Accident Analysis Methods

For the salt processing alternatives, potential accident scenarios that could involve release of both radiological and nonradiological hazardous materials were identified. Section B.2.1 provides information about the various alternatives. Sections B.2.2 and B.2.3 provide details about the specific analysis methods used in this Appendix.

The accident sequences analyzed in this SEIS would occur at frequencies generally greater than once in 1,000,000 years. However, the analysis considered accident sequences with smaller frequencies, if their impacts could provide information important to decision making.

Table B-1. Accident frequency categories.

Accident frequency category	Frequency range	Description
Anticipated	Less than once in 10 years but greater than once in 100 years	Accidents that might occur several times during a facility lifetime
Unlikely	Less than once in 100 years but greater than once in 10,000 years	Accidents that are not likely to occur during a facility lifetime; natural phenomena include Uniform Building Code-level earthquake, maximum wind gust, etc.
Extremely unlikely	Less than once in 10,000 years but greater than once in 1,000,000 years	Accidents that probably will not occur during a facility life cycle; this includes the design-basis accidents.
Beyond extremely unlikely	Less than once in 1,000,000 years	All other accidents.

Source: DOE (1994).

The methods of accident analysis are consistent with the guidance provided by DOE's Office of National Environmental Policy Act (NEPA) Policy and Assistance in *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements* (DOE 1993). In addition to the specific guidance on accident analyses, DOE has applied the recommendation to base analysis on realistic, rather than overly conservative, exposure conditions. DOE has also applied the recommendation to use a *sliding scale* approach, which means to provide a level of detail in the analysis of specific issues and their impacts in proportion to their significance.

Recently the Office of NEPA Policy and Assistance issued draft guidance entitled *Analyzing Accidents Under NEPA* (DOE 2000a). It clarifies and supplements the information in the 1993 guidance. DOE has used the guidance's clarifications on the use of the sliding-scale approach, range of accident scenarios, avoidance of compounding conservatisms, frequency, and risk. However, this Appendix does not include the suggestion in the guidance to present direct and indirect effects of post-accident activities. Such analysis would require the development of methodology to measure these impacts in a consistent basis, followed by the integration of this methodology into the specific salt processing accidents analyzed in this Appendix. In light of these circumstances and judicious application of the sliding-scale approach, DOE Savannah River Office (SR) considers the evaluation of post-accident cleanup impacts to be both inefficient and minor in comparison to the customary evaluation of human health impacts of potential accidents.

B.2.1 SALT PROCESSING ALTERNATIVES

The accident data in this Appendix are organized by alternative. The accident impacts in Chapter 4 are also organized by alternative to reflect potential accident occurrences for the associated alternative.

DOE proposes to select a technology and design, construct, and operate the required facilities to replace the In-Tank Precipitation (ITP) process to separate the highly radioactive components of high-level waste (HLW) salt solutions from the low-activity components of the salt solution. The new process would be compatible with existing facilities and processes for HLW storage and vitrification and for disposal of low-level waste at the SRS. The alternatives being considered in this SEIS are:

- No Action
- Small Tank Tetraphenylborate Precipitation
- Crystalline Silicotitanate Ion Exchange
- Caustic Side Solvent Extraction

- Direct Disposal in Grout

Each alternative is discussed in detail in Chapter 2 and Appendix A; however, a brief description of each alternative is included here.

No Action Alternative

Under the No Action alternative, DOE would continue current HLW management activities, including tank space management and tank closure, without a process to separate the high-activity and low-activity salt fractions. The Defense Waste Processing Facility (DWPF) would vitrify only sludge from the HLW tanks. Saltcake and supernatant would remain in the HLW tanks, and monitoring activities would continue. Current tank space management projections indicate that, after 2010, additional tank space would be needed to support continued operations and meet tank closure commitments under the No Action alternative.

As soon as DOE determined that a salt processing facility would not be available by 2010, decisions about additional tank space would have to be made. The course of action that DOE would follow cannot be predicted at this time, but available options may include the following, either individually or in combination.

1. Identify additional ways to optimize tank farm operations
2. Reuse tanks scheduled to be closed by 2019
3. Build tanks permitted under wastewater treatment regulations
4. Build tanks permitted under RCRA regulations
5. Suspend operations at DWPF.

Because the No Action alternative is the basis from which each of the proposed alternatives progresses, the hazards associated with each action alternative are supplemental to those of the No Action alternative. However, through the processing of salt solution, hazards associated with continued storage would decrease over time. Therefore, since the No Action alternative includes only current tank space management operations, which have been evaluated under the NEPA process and in approved safety analysis reports and the activities DOE would pursue during the post tank space management phase have not been determined, this Appendix does not analyze accidents associated with No Action failure of a salt solution hold tank is analyzed in the *High-Level Waste Tank Closure Draft Environmental Impact Statement* (DOE 2000b). The radiological and nonradiological hazards associated with the four action alternatives are evaluated in this Appendix.

Small Tank Precipitation

DOE would construct a new shielded facility to house process equipment to implement this alternative. The Small Tank Precipitation alternative would use the same chemical process as the ITP process to remove high-activity radionuclides from the salt solution. However, radioactive HLW would be processed through the facility in a manner that would control the high benzene generation rates that led DOE to develop an alternative salt processing technology.

Soluble radioactive metal ions (cesium, strontium, uranium, and plutonium) in the salt solution and concentrated supernatant would be precipitated with tetraphenylborate (TPB) or sorbed on monosodium titanate (MST) to form insoluble solids. The resulting solids would be concentrated by filtration and the product slurry treated to yield a non-flammable stream for transfer to DWPF for vitrification. The decontaminated salt solution, containing primarily sodium hydroxide, nitrate, and nitrite would be transferred to the Saltstone Manufacturing and Disposal Facility for disposal as grout.

Ion Exchange

DOE would construct a new shielded facility to house chemical processing equipment (tanks, pumps, filter systems, ion exchange columns) to implement this alternative. The Ion Exchange process would use crystalline silicotitanate (CST) resin in ion exchange columns to remove cesium from the salt solution. Strontium, plutonium, and uranium would first be removed by adsorption on MST, and the resulting solids would then be transferred to DWPF for vitrification. The cesium-loaded resin would also be transferred to DWPF for vitrification. The low-activity salt solution would be transferred to the Saltstone Manufacturing and Disposal Facility for disposal as grout.

Solvent Extraction

DOE would construct a new shielded facility to house chemical processing equipment (tanks, pumps, filter systems, contactors). The Solvent Extraction process would employ a highly specific organic extractant in a diluent solvent to remove cesium from the caustic salt solution, using centrifugal contactors to provide high surface area interactions between the organic solvent and aqueous solution. The separated cesium would be extracted into an acidic aqueous stream to be transferred as an all-liquid phase to DWPF for vitrification. Prior treatment with MST would remove strontium, uranium, and plutonium from the salt solution for transfer to DWPF. The low-activity salt solution would be transferred to the Saltstone Manufacturing and Disposal Facility for disposal as grout.

Direct Disposal in Grout

DOE would construct a new shielded facility to immobilize the HLW salt solution in grout, without separation of radioactive cesium. Prior treatment with MST would remove strontium, uranium, and plutonium from the salt solution for transfer to DWPF. The cesium-containing solution would be mixed with cement, flyash, and slag for disposal as grout in shielded saltstone vaults in Z Area.

The saltstone waste form generated in this alternative would be required to meet U.S. Nuclear Regulatory Commission (NRC) Class C low-level waste disposal requirements for near surface disposal.

B.2.2 RADIOLOGICAL HAZARDS

The accidents identified for the salt processing alternatives are described in Section B.3. These descriptions include an approximation of the material at risk (MAR) that would potentially be involved in a given type of accident. Depending on the particular scenario, release fractions have been applied to the MAR to determine the amount of material that could be released to the environment via the air. This amount is referred to as the source term. Source terms are provided as curies of fission products and transuranics. The fission product source term is significantly dominated by radioactive cesium, while plutonium-239 has one of the highest dose factors of the common alpha-emitters found in SRS radiological effluents. Therefore, the analysis used radioactive cesium to represent the fission product source term and plutonium-239 to represent the transuranic source term.

The source terms were calculated by spreadsheet using Microsoft Excel. The Source Term and the Resuspension Source Term were determined using the following formulas.

Source Term: $ST = MAR \times DR \times ARF \times RF \times LPF$, where:

DR = Damage Ratio: fraction of MAR actually impacted by the accident

ARF = Airborne Release Fraction: the coefficient used to estimate the amount of radioactive material suspended in air as an aerosol and thus available for airborne transport due to physical stress from a given accident

LPF = Leak Path Factor: fraction of radionuclides or chemicals in the air transported through some confinement or filtration mechanism.

Resuspension Source Term: $ST_r = MAR \times ARR \times RF$, where:

MAR = Material at Risk: amount of radioactive materials or chemicals available to be acted upon by an event

ARR = Airborne Release Rate: the coefficient used to estimate the amount of material that can be suspended in air and made available for airborne transport under a specific set of induced physical stresses as a function of time.

RF = Respirable Fraction: fraction of airborne radionuclides or chemicals as particles that can be transported through the air and inhaled into the respiratory system

The analysis of airborne releases used the computer code AXAIRQ, which models accidental atmospheric radioactive releases from SRS that are of relatively short duration. AXAIRQ determines the concentration of radiological releases to the atmosphere in every direction around the release location. The code considers the height of the release and wind speed and direction changes in the calculation. AXAIRQ strictly follows the guidance in Regulatory Guide 1.145 (NRC 1982) on accidental releases, and has been verified and validated (Simpkins 1995a and 1995b). Because all considered accidents would occur at either ground level or from a 46-meter stack, the releases for both heights were evaluated using AXAIRQ. In accordance with the regulatory guide, the code considers plume meander and fumigation under certain conditions. Plume rise due to buoyancy or momentum is not available. The program uses a 5-year meteorological database for the SRS, and determines the shortest distance to the Site boundary in each of the 16 compass direction sectors by determining the distance to one of 875 locations along the boundary. The impacts derived from this code used the average, or 50 percent meteorology. The code uses the shortest distance in each sector to calculate the concentration for that sector.

DOE used the computer code PRIMUS, which was developed by the Oak Ridge National Laboratory, to consider decay and daughter in-growth. PRIMUS determines radionculide in-growth matrices from user specified sources. In-growth must be considered for radionculides that are generated from the decay of more than one isotopic chain and their own decay.

Simpkins (1999) provided unit dose conversion factors for the applicable radionuclides for release locations in S and Z Areas. These factors were applied to the airborne source terms from the previously described excel spreadsheet to calculate the doses to various receptors.

For population dose calculations, age-specific breathing rates were applied, but adult dose conversion factors were used. Radiation doses were calculated to the maximally exposed offsite individual (MEI), to the population within 50 miles of the facility, to a noninvolved worker assumed to be 2,100 feet (640 meters) downwind of the facility, to an involved worker assumed to be 328 feet (100 meters) downwind of the facility, and to the onsite population. All doses are committed effective dose equivalents.

After DOE calculated the total radiation dose to the public, it used dose-to-risk conversion factors established by the National Council on Radiation Protection and Measurements (NCRP) to estimate the number of latent cancer fatalities (LCFs) that could result from the calculated exposure. There is inconclusive data that small radiation doses cause cancer; however, to be conservative the NCRP assumes that any amount of radiation has some risk of inducing cancer. DOE has adopted the NCRP factors of 0.0005 LCF for each person-rem of radiation exposure to the general public and 0.0004 LCF for each person-rem of radiation exposure to radiation workers for doses less than 20 rem. For larger doses, when the rate of exposure would be greater than 10 rads per hour, the increased likelihood of LCF is doubled, assuming the body's diminished capability to repair radiation damage (NCRP 1993).

B.2.3 CHEMICAL HAZARDS

For chemically toxic materials, the long-term health consequences of human exposure to hazardous materials are not as well understood as those related to radiation exposure. A determination of potential health effects from exposures to chemically hazardous materials, compared to radiation, is more subjective. Therefore, the consequences from accidents involving hazardous materials are expressed in terms of airborne concentrations at various distances from the accident location, rather than in terms of specific health effects.

To determine potential health effects to workers and the public that could result from accidents involving hazardous materials, the airborne concentrations of such materials released during an accident at varying distances from the point of release were compared to the Emergency Response Planning Guideline (ERPG) values (AIHA 1991). The American Industrial Hygiene Association established these values, which depend on the chemical substance, for the following general severity levels to ensure that necessary emergency actions occur to minimize exposures to humans.

- ERPG-1 Values – Exposure to airborne concentrations greater than ERPG-1 values for a period greater than one hour results in an unacceptable likelihood that a person would experience mild transient adverse health effects (i.e., rash, nausea, headache) or the perception of a clearly defined objectionable odor.

- ERPG-2 Values – Exposure to airborne concentrations greater than ERPG-2 values for a period greater than one hour results in an unacceptable likelihood that a person would experience or develop irreversible or other serious health effects (i.e., organ damage, seizures, pneumonitis) or symptoms that could impair a person's ability to take protective action (i.e., dizziness, confusion, impaired vision).

- ERPG-3 Values – Exposure to airborne concentrations greater than ERPG-3 values for a period greater than one hour results in an unacceptable likelihood that a person would experience or develop life-threatening health effects (i.e., loss of consciousness, cardiac arrest, respiratory arrest).

B.3 Postulated Accident Scenarios Involving Radioactive Materials

These sections describe the potential accident scenarios associated with each alternative that could involve the release of radioactive materials. The impacts of these scenarios are described in Section B.4.

Several of the accidents identified for a particular alternative are also common to other alternatives. However, they will be discussed individually for each alternative.

B.3.1 SMALL TANK PRECIPITATION

The accidents identified for the Small Tank TPB Precipitation process that result in the release of radiological materials to the environment include:

- Loss of confinement in a process cell
- Beyond design-basis earthquake
- Fire in a process cell
- Benzene explosion in the Precipitate Hydrolysis Cell (PHC)
- Helicopter or aircraft crash
- Benzene explosion in Precipitate Hydrolysis Aqueous (PHA) Surge Tank

B.3.1.1 Loss of Confinement in a Process Cell

Scenario: Mechanical failure or an external event, such as a dropped cell cover or crane mishap, could cause a failure of the primary confinement for a tank or its associated piping. A failure of primary confinement would release material into the process cell. For this event, the entire tank contents at maximum capacity would be released through the rupture. It was assumed that the release would not be cleaned up for 168 hours (7 days).

The tanks of concern would be the Precipitate Reactor and the PHA Surge Tank. A failure of the Precipitate Reactor or associated piping would release material to the PHC, while a failure of the PHA Surge Tank or associated piping would release material to the PHA Surge Tank process cell. Flammable benzene vapors and hydrogen generated by leaking slurry from the PHA Surge Tank could cause an explosion, if they were allowed to reach flammable concentrations in the presence of an ignition source. A benzene explosion following a PHA Surge Tank loss of confinement event is in the beyond-extremely-unlikely category and is bounded by the benzene explosion in the PHA Surge Tank event discussed in Section B.3.1.6. The precipitate slurry would also be somewhat flammable and, if allowed to reach a combustible state, a large enough ignition source could cause a precipitate fire in the process cell. For this scenario, however, it is assumed that no explosion or fire occurs.

A leak detection system would mitigate the consequences of releases from process tanks and associated piping. This system would be designed to detect the leak and terminate the process, thus minimizing the amount of material that would leak from the system. A shielded secondary confinement system would protect onsite workers from radiological consequences of the leaks.

Probability: The initiating event for the loss of primary confinement of a process tank could be mechanical failure or an external event. External events could cause leaks from tanks or piping. Impacts during cell cover and crane movement are assumed to cause spills from a rupture in the tank or associated piping. It was assumed that there would be 50 feet of piping associated with each tank. The annual frequency of a loss of primary confinement for a process tank was calculated to be 3.4×10^{-2}. Therefore, a loss of confinement accident would be expected once in 30 years.

Source Term: A dropped cell cover or crane mishap was assumed to damage the affected tank significantly enough to release the entire contents of the tank to the cell. Good engineering practices would be used during design of the process facility to ensure that high-efficiency particulate air (HEPA) filters would be located in a remote part of the facility away from process cells (e.g., event location). DOE would perform regular in-place testing to ensure that installed HEPA filters would have a particle removal efficiency of greater than 99.9 percent. Therefore, the HEPA filters and ventilation system were assumed to be operating due to the physical distance between the filter location and event location, reducing the amount of radioactivity released from the process cell within 99 percent efficiency. The radiological source terms associated with this accident are provided in Table B-2. In addition, a loss of primary confinement for the PHA Surge Tank would release benzene in an uncontrolled manner to the process cell ventilation system. The source terms associated with nonradiological chemical releases are addressed in Section B.5. All releases were postulated to occur from the 46-meter stack.

Table B-2. Source terms for loss of confinement in a process cell of the Small Tank Precipitation facility.

	Source term (Ci)	
	Fission products	Transuranics
Precipitate Reactor	1.1	3.1×10^{-3}
PHA Surge Tank	4.2	0.012

B.3.1.2 <u>Beyond Design-Basis Earthquake</u>

Scenario: The structures for the Small Tank Precipitation process would be designed to withstand Performance Category-3 (PC-3) earthquakes, straight winds, and tornadoes. The PC-3 earthquake is considered to be the bounding Natural Phenomena Hazards (NPH) event. The process vessels, piping, and structures that house the hardware would be designed to withstand such an earthquake. For the beyond design-basis event, an earthquake slightly stronger than the design-basis earthquake is postulated to occur. This earthquake would cause the primary and secondary confinement to fail, releasing the entire facility inventory into the building. The ventilation system and HEPA filters are also postulated to collapse, resulting in some airborne releases of both transuranic and fission product inventories.

Probability: The structure, primary confinement, and secondary confinement were conservatively assumed to fail due to an earthquake only slightly stronger than the design-basis earthquake of 0.16 g. The annual probability of exceeding a 0.16 g earthquake is 5.0×10^{-4}. Therefore, structural failure of the facility would be expected to occur less than once in 2,000 years.

Source Term: A release of the full inventory from the facility was postulated from collapse of the structure and of the primary and secondary confinement. The airborne source term associated with this accident would consist of 700 curies (Ci) of fission products and 2.0 Ci of transuranics. The release was postulated as a ground-level release.

B.3.1.3 Fire in a Process Cell

Scenario: A fire in any of the process cells could release radiological materials contained in the process vessels. The process would not introduce any combustible materials into the process cells; however, equipment or material that might be left behind during maintenance activities could lead to the initiation of this event. Good engineering practices would be used during design of the processing facility to ensure that HEPA filters would be located in a remote part of the facility away from process cells (e.g., event location). DOE would perform regular in-place testing to ensure that installed HEPA filters would have a particle removal efficiency of greater than 99.9 percent. The fire was assumed to challenge the ventilation system and process equipment; however, the HEPA filters would be expected to maintain their function due to the physical distance between the filter location and event location and would minimize releases to the environment within 99 percent efficiency. The entire cell inventory was assumed to be at risk. A leak was expected to occur from the fire.

In this scenario, the benzene releases are negligible compared to releases from fires/explosions elsewhere (i.e. Precipitate Hydrolysis Cell) due to the small amount of benzene in the PHA Surge Tank.

Probability: A fire in a process cell was assumed to be limited by the combustible control program, the fire barriers, and the fire department. The annual probability of a fire occurring in a process cell was calculated to be 1.0×10^{-4}. Therefore, a fire in a process cell would be expected to occur once in 10,000 years.

Source Term: The fire was assumed to damage the process vessel enough to cause a leak. The damage was assumed to be equivalent to a 0.5-inch-diameter opening. The leak was assumed to be stopped within 24 hours, allowing the fire department to put out the fire, a response plan to be developed, and implementation of the response plan to control the consequences of the leak. The worst-case scenario would be a fire in the process cell containing the PHA Surge Tank, because this cell has the greatest amount of material. The airborne source term associated with this accident would consist of 37 Ci of fission products and 0.11 Ci of transuranics. Any release was postulated to occur from the 46-meter stack.

B.3.1.4 Benzene Explosion in the PHC

Scenario: Benzene could be introduced into the cell if one of the benzene-containing vessels or piping within the cell developed a leak. An ignition source could then cause a deflagration in the PHC, over-pressurizing the cell and dislodging the cell covers. The cell covers could then fall back into the PHC, striking the Organic Evaporator, Organic Evaporator Condensate Tank, Organic Evaporator Condenser, Organic

Evaporator Decanter, and Salt Cell Vent Condenser and spilling liquid benzene onto the cell floor. Benzene vapors evolving from this spilled inventory could lead to a second PHC deflagration, damaging and releasing the contents of the Precipitate Reactor. This accident assumes that the remaining liquid benzene on the PHC floor would ignite and burn.

The PHC design would incorporate a ventilation system to maintain airflow through the cell and minimize the possibility that benzene could leak into the cell and reach explosive concentrations.

Probability: A benzene explosion in the PHC that damages the cell would have the potential to damage and release the contents of multiple tanks that contain benzene and the Precipitate Reactor. For an explosion to occur, a large explosive benzene vapor cloud must form in the PHC and an ignition source must be present. For an explosive benzene cloud to form, the ventilation system was assumed to fail, eliminating airflow to the PHC, and forcing benzene from the PHC vessels. The annual probability that an explosion would occur in the PHC with damage to the cell was calculated to be 1.01×10^{-5}. Therefore, a benzene explosion would be expected to occur once in 99,000 years.

Source Term: An explosion in the PHC that would damage the cell was assumed to spill the entire contents of multiple tanks that contain benzene, as well as the Precipitate Reactor, which contains radiological material, into the cell. An ensuing fire would consume the benzene, so the accident would only involve radiological releases. HEPA filters are assumed to be damaged, failing to mitigate the release. The airborne source term associated with this accident would consist of 1,800 Ci of fission products and 5.3 Ci of transuranics. The release was postulated to occur from the 46-meter stack.

B.3.1.5 Helicopter or Aircraft Crash

Scenario: External events that could impact the facility include helicopter, aircraft, or vehicle impacts and external fire. According to Cappucci (2000), an unmitigated aircraft impact has the potential to release the entire facility inventory. A vehicle impact would be postulated to only release the contents of the vessel impacted and is therefore no different than the loss of confinement events addressed earlier. The building structure would be a PC-3 structure. Therefore, the building would mitigate the consequences from the postulated vehicle crash by protecting the inventory in primary and secondary confinement within the structure. Additionally, segmentation of the process cells would further mitigate the consequences of this external event. However, the PC-3 structure was assumed to experience local structural failure (collapse) from a helicopter crash and full structural failure (collapse) from an aircraft crash. The helicopter crash was assumed to release the inventory in one cell and the aircraft crash was assumed to release the entire building inventory. Both structural failures were assumed to be coincident with fires from ignition of the helicopter or aircraft fuel. The fires would compound the radiological release inventories.

Probability: The most likely causes of releases from the Small Tank Precipitation facility from external events would be impacts from helicopter or aircraft crashes. The frequency of a helicopter crash onto the Small Tank Precipitation facility was calculated to be 4.8×10^{-7} per year, while the frequency of an aircraft impact was calculated to be 3.7×10^{-7} per year. Therefore, a helicopter crash would be expected once in 2,100,000 years and an aircraft impact would be expected once in 2,700,000 years.

Source Term: The Small Tank Precipitation facility would be a PC-3 structure with primary and secondary confinement. The building structure would be expected to withstand vehicle crashes. Benzene and radiological releases would be expected to occur from helicopter or aircraft crashes. However, benzene would be consumed by the ensuing fire, so airborne releases would only include radiological material.

HEPA filters are assumed to be damaged, failing to mitigate the release. The airborne source terms calculated for the various accident scenarios are shown in Table B-3. These releases were postulated as ground-level releases.

Table B-3. Source terms for helicopter or aircraft crashes into the Small Tank Precipitation facility.

	Source term (Ci)	
	Fission Products	Transuranics
Helicopter Crash[a]		
Fresh Waste Day Tank Cell	160	0.32
Precipitation Tank Cell	190	0.38
Concentrate Tank Cell	760	2.2
Filtrate Hold Tank Cell	8.8	0.025
Wash Tank Cell	940	2.2
PHA Surge Tank	7,400	22
PHC	2,800	8.3
Aircraft Crash	12,000	35

a. Cappucci 2000.

B.3.1.6 Benzene Explosion in PHA Surge Tank

Scenario: Degradation of TPB produces benzene that would be released to the vapor space of the PHA Surge Tank. Hydrogen and oxygen are produced from the radiolysis (decomposition) of water, forming a flammable mixture. Because the consequences of such an event are unsatisfactory, the PHA Surge Tank would be equipped with a safety-class nitrogen inerting system. In this scenario, both the primary and backup nitrogen systems are assumed to fail and the failure to go undetected. An ignition source could then cause an explosion (detonation or deflagration) in the vapor space and a subsequent fire. (In a deflagration, the shock wave travels at less than the speed of sound; in a detonation, the shock wave travels faster than the speed of sound.) The tanks and piping would maintain their integrity during a deflagration, but not during a detonation; therefore, the event was conservatively assumed to be a detonation. It was also conservatively assumed that the detonation in the process tanks or piping would release the entire tank contents. The HEPA filters and ventilation were assumed to be damaged and bypassed, failing to mitigate the release. An explosion in the PHA Surge Tank, because of the amount of material at risk, would bound explosions in all other process tanks.

Probability: A benzene explosion in the PHA Surge Tank has the potential to damage the tank and release the entire tank contents. For an explosion to occur, an ignition source and an explosive gas mixture in the tank vapor space must be present. Failure of a safety-class system further increases the probability of occurrence. The annual probability that an explosion would occur in the PHA Surge Tank was calculated to be 1.84×10^{-8}. Therefore, an explosion in the PHA Surge Tank would be expected to occur once in 54,000,000 years and is not a credible event. Since the likelihood of this event is below the credibility threshold of once in 10,000,000 years, it is not evaluated further in this Appendix.

B.3.2 ION EXCHANGE

The accidents identified for the Ion Exchange process that would result in the release of radiological materials to the environment include:

- Loss of confinement in a process cell
- Beyond design-basis earthquake
- Loss of cooling to the Loaded Resin Hold Tanks (LRHTs)
- Fire in a process cell
- Helicopter or aircraft crash
- Hydrogen explosion in a process cell

B.3.2.1 Loss of Confinement in a Process Cell

Scenario: The tanks of concern are the Alpha Sorption Tank (AST), the LRHTs, and tanks in the Alpha Filter Cell (Washwater Hold Tank, Sludge Solids Receipt Tank, and Cleaning Solution Dump Tank [CSDT]). Because the material inventory in the CSDT would be small compared to the other vessels in the alpha filter cell, a release from the CSDT would be bounded by releases from the other tanks in the cell. See Section B.3.1.1 for a description of the scenario.

Probability: See Section B.3.1.1 for a discussion of the probability of the event occurring.

Source Term: A dropped cell cover or crane mishap was assumed to damage the affected tank significantly enough to release the entire contents of the tank to the cell. Good engineering practices would be used during design of the process facility to ensure that HEPA filters would be located in a remote part of the facility away from process cells (e.g., event location). DOE would perform regular in-place testing to ensure that installed HEPA filters would have a particle removal efficiency of greater than 99.9 percent. The HEPA filters and ventilation system were assumed to be operating due to the physical distance between the filter location and event location, reducing the amount of radioactivity released from the process cell within 99 percent efficiency. The airborne source terms associated with this accident are shown in Table B-4. The release was postulated to occur from the 46-meter stack.

Table B-4. Source terms for loss of confinement in a process cell of the Ion Exchange facility.

	Source term (Ci)	
	Fission products	Transuranics
AST	0.37	7.2×10^{-4}
Washwater Hold Tank	0.023	4.5×10^{-7}
Sludge Solids Receipt Tank	0.041	0.0064
LRHT	2.3	1.1×10^{-6}

B.3.2.2 Beyond Design-Basis Earthquake

Scenario: The structures for the Ion Exchange process would be designed to withstand PC-3 earthquakes, straight winds, and tornadoes. See Section B.3.1.2 for a description of the scenario.

Probability: See Section B.3.1.2 for a discussion of the probability of the event occurring.

Source Term: A release of the full inventory from the facility was postulated from collapse of the structure and of the primary and secondary confinement. HEPA filters are assumed to be damaged, failing to mitigate the release. The airborne source term associated with this accident would consist of 1,100 Ci of fission products and 0.72 Ci of transuranics. The release was postulated as a ground-level release.

B.3.2.3 Loss of Cooling to the LRHTs

Scenario: A loss of cooling water to the LRHTs would allow the decay heat of the fission products to raise the temperature of the liquid phase in the involved tanks enough to boil. It was assumed that the liquid would boil for eight hours. Vapors from the boiling liquid would be vented and filtered through HEPA filters operating with an efficiency of 99 percent. It was assumed that the cooling water coils would be designed so that leakage of radionuclides into the cooling water system would not be credible, thereby eliminating direct releases to the aquatic environment.

Probability: The equipment in this scenario was assumed to be similar to vessels in DWPF. Therefore, frequencies and probabilities for DWPF were used as a basis for evaluation. The initiating events that could lead to loss of cooling would be power failure, human error, or equipment failure. In order for a loss of cooling event to result in damage to the vessel, the loss of cooling was coupled with the failure of pressure and temperature indicators. The frequency was estimated to be 1.9×10^{-4} per year. Therefore, a loss of cooling water to the LRHTs would be expected once in 5,300 years.

Source Term: The source term for this scenario was based on the assumption that 65 gallons of the LRHT inventory and 100 gallons of the first CST column (liquid) inventory would be involved. This assumption was based on an estimation of the liquid mass evaporated by the decay heat of the fission products in eight hours. The airborne source terms associated with this accident are shown in Table B-5. The releases were postulated to occur from the 46-meter stack.

Table B-5. Source terms for loss of cooling event in Ion Exchange facility.

	Source term (Ci)	
	Fission products	Transuranics
LRHTs	0.11	5.3×10^{-8}
CST Column	0.0041	8.1×10^{-8}

B.3.2.4 Fire in a Process Cell

Scenario: See Section B.3.1.3 for a description of the scenario.

Probability: See Section B.3.1.3 for a discussion of probability.

Source Term: The fire was assumed to damage the process vessel sufficiently to cause a leak. The damage was assumed to be equivalent to a 0.5-inch-diameter opening. The leak was assumed to be stopped within 24 hours, allowing for the fire department to put out the fire, a response plan to be developed, and implementation of the response plan to control the leak. The process cells that would bound this accident for Ion Exchange would be the AST Cell, the Alpha Filter Cell, and the CST Columns Cell. The airborne source terms associated with a fire in each of these process cells are provided in Table B-6. Any release was postulated to occur from the 46-meter stack.

Table B-6. Source terms for process cell fires in the Ion Exchange facility.

	Source term (Ci)	
	Fission products	Transuranics
AST Cell	1.6	0.0031
Alpha Filter Cell	0.72	0.072
CST Columns Cell	55	3.6×10^{-5}

B.3.2.5 Helicopter or Aircraft Crash

Scenario: See Section B.3.1.5 for a description of the scenario.

Probability: The most likely causes of releases from the Ion Exchange Facility from external events would be impacts from helicopter or aircraft crashes. See Section B.3.1.5 for a discussion of the probability of either event occurring.

Source Term: The Ion Exchange facility would be a PC-3 structure with primary and secondary confinement. The building structure would be expected to withstand vehicle crashes. Releases would be expected to occur from helicopter or aircraft crashes. HEPA filters are assumed to be damaged, failing to mitigate the release. The source terms calculated for the various accident scenarios are shown in Table B-7. These releases were postulated as ground-level releases.

Table B-7. Source terms for helicopter or aircraft crashes into the Ion Exchange facility.

	Source Term (Ci)	
	Fission Products	Transuranics
Helicopter Crash[a]		
AST Cell	5,700	11
Alpha Filter Cell	980	99
CST Columns Cell	75,000	0.050
Aircraft Crash	87,000	110

a. Cappucci 2000.

B.3.2.6 Hydrogen Explosion in a Process Cell

Scenario: The decomposition of water as a result of radiolysis leads to the production of hydrogen and oxygen. These flammable gases could accumulate in the vapor space of process vessels and, if left unchecked, could eventually reach the lower flammability limit (LFL) required for an explosion. Failure of the purge system to remove flammable gases, coupled with the presence of an ignition source, could initiate a hydrogen explosion (deflagration or detonation). The tanks of concern include the

AST, the tanks in the Alpha Filter Cell (Sludge Solids Receipt Tank, Washwater Hold Tank, and CSDT), and the tanks in the CST columns cell (LRHTs, the CST Columns, and the Product Holdup Tank). The tanks and piping would maintain their integrity during a deflagration, but not during a detonation; therefore, the event was conservatively assumed to be a detonation. An explosion in a process cell was conservatively assumed to release the contents of all vessels within that cell. Significant damage to the HEPA filters and ventilation system was assumed, allowing for an unmitigated radioactive release from the process cell.

Probability: The process equipment was assumed to be similar to process equipment in DWPF. Therefore, frequencies and probabilities for DWPF were used as a basis for this evaluation. The initiating events for a hydrogen explosion in the tank would be the presence of an ignition source and the presence of the explosive gas mixture. The presence of the explosive gas mixture would be due to the loss of purge to the tank that goes undetected and uncorrected. The annual probability that a hydrogen explosion would occur was calculated to be 4.7×10^{-8}. Therefore, a hydrogen explosion in a process cell would be expected to occur once in 21,000,000 years and is not a credible event. Since the likelihood of this event is below the credibility threshold of once in 10,000,000 years, it is not evaluated further in this Appendix.

B.3.3 SOLVENT EXTRACTION

The accidents identified for the Solvent Extraction alternative that would result in the release of radiological materials to the environment include:

- Loss of confinement in a process cell
- Beyond design-basis earthquake
- Fire in a process cell
- Hydrogen explosion in the Extraction Cell
- Helicopter or aircraft crash
- Hydrogen explosion in a process cell

B.3.3.1 Loss of Confinement in a Process Cell

Scenario: Mechanical failure or an external event, such as a dropped cell cover or crane mishap, could cause a loss of the primary confinement for a tank or its associated piping. A loss of primary confinement would release material into the process cell. The tanks of concern are the AST, the tanks in the Alpha Filter Cell (Washwater Hold Tank, Sludge Solids Receipt Tank, CSDT), the Salt Solution Feed Tank, tanks in the Extraction Cell, and the DWPF Salt Feed Tank. Because the material inventory in the CSDT would be small compared to the other vessels in the Alpha Filter Cell, a release from the CSDT would be bounded by releases from the other tanks in the cell. The Strip Effluent Stilling Tank was assumed to contain the bounding inventory in the Extraction Cell. For this event, the entire contents of the bounding tank at maximum capacity would be released through a leak from the tank or associated piping. It was assumed that the release would not be cleaned up for 168 hours (7 days).

A leak detection system would mitigate the consequences of releases from process tanks and associated piping. This system would be designed to detect the leak and terminate the process, thus minimizing the amount of material that would leak from the system. A shielded secondary confinement system would protect onsite workers from radiological consequences of the leaks.

Probability: The initiating event for the loss of primary confinement of a process tank could be mechanical failure or an external event. External events could cause leaks from tanks or from piping. Impacts during cell cover and crane movement are assumed to cause spills from a rupture in the tank or associated piping. It was assumed there would be 50 feet of piping associated with each tank. The annual frequency of a loss of primary confinement for a process tank was calculated to be 3.4×10^{-2}. Therefore, a loss of confinement accident would be expected once in 30 years.

Source Term: A dropped cell cover or crane mishap was assumed to damage the affected tank significantly enough to release the entire contents of the tank to the cell. Good engineering practices would be used during design of the process facility to ensure that HEPA filters would be located in a remote part of the facility away from process cells (e.g., event location). DOE would perform regular in-place testing to ensure that installed HEPA filters would have a particle removal efficiency of greater than 99.9 percent. The HEPA filters and ventilation system were assumed to be operating due to the physical distance between the filter location and the event location, reducing the amount of radioactivity released from the process cell within 99 percent efficiency. The airborne source terms associated with this accident are shown in Table B-8. The release was postulated to occur from the 46-meter stack.

B.3.3.2 Beyond Design-Basis Earthquake

Scenario: The structures for the Solvent Extraction process would be designed to withstand PC-3 earthquakes, straight winds, and tornadoes. See Section B.3.1.2 for a description of the scenario.

Table B-8. Source terms for loss of confinement in a process cell of the Solvent Extraction facility.

	Source term (Ci)	
	Fission products	Transuranics
AST	0.46	9.1×10^{-4}
Washwater Hold Tank	0.023	4.5×10^{-7}
Sludge Solids Receipt Tank	0.041	0.0064
Salt Solution Feed Tank	0.46	9.0×10^{-6}
Extraction Cell	0.024	1.8×10^{-9}
DWPF Salt Feed Tank	4.8	3.6×10^{-7}

Probability: See Section B.3.1.2 for a discussion of the probability of the event occurring.

Source Term: A release of the full inventory from the facility was postulated from collapse of the structure and of the primary and secondary confinement. The airborne source term associated with this accident would consist of 580 Ci of fission products and 0.74 Ci of transuranics.

The release was postulated as a ground-level release.

B.3.3.3 Fire in a Process Cell

Scenario: See Section B.3.1.3 for a description of the scenario.

Probability: See Section B.3.1.3 for a discussion of the probability.

Source Term: The fire was assumed to damage the process vessel sufficiently to cause a leak. The damage was assumed to be equivalent to a 0.5-inch-diameter opening. The leak was assumed to be stopped within 24 hours, allowing the fire department to put out the fire, a response plan to be developed, and implementation of the response plan to control the leak. The process cells that would bound this accident for the Solvent Extraction process would be the AST Cell, the Alpha Filter Cell, the Extraction Cell, the DWPF Salt Feed Tank Cell, the Salt Solution Feed Tank Cell, and the Decontaminated Salt Solution (DSS) Hold Tank Cell. The airborne source terms associated with a process cell fire in any of these cells are provided in Table B-9. The releases were postulated to occur from the 46-meter stack.

Scenario: The decomposition of water as a result of radiolysis leads to the production of hydrogen and oxygen. These flammable gases could accumulate in the vapor space of process vessels and, if left unchecked, could eventually reach the LFL required for an explosion. Failure of the purge system and the presence of an ignition source could initiate a hydrogen explosion (deflagration or detonation). The vessels of concern would include the Stripping Effluent

Table B-9. Source terms for process cell fires in the Solvent Extraction facility.

	Source term (Ci)	
	Fission products	Transuranics
AST Cell	1.6	0.0031
Alpha Filter Cell	0.46	0.072
Extraction Cell	0.27	2.0×10^{-8}
DWPF Salt Feed Tank Cell	21	1.6×10^{-6}
Salt Solution Feed Tank Cell	1.6	3.1×10^{-5}
DSS Hold Tank Cell	0.011	3.1×10^{-5}

B.3.3.4 Hydrogen Explosion in the Extraction Cell

Stilling Tank, the Aqueous Raffinate Stilling Tank, and six centrifugal contactors. The vessels were assumed to contain a deflagration, but not a detonation. In a deflagration, the process HEPA filters were assumed to be severely damaged, causing a release from the stack. A detonation would be expected to damage the vessel of concern and release its entire inventory. A hydrogen detonation of any of the vessels would be expected to impact other vessels, due to their co-location in the process cell. To prevent this event, a tank purge or inerting system was assumed to be present. The secondary confinement was assumed to mitigate this event.

Probability: A hydrogen explosion in the process vessels would have the potential to damage the vessels and release all the contents. For this explosion to occur, ignition sources and an explosive gas mixture would have to be present. For explosive gases to be present, the nitrogen purge system was assumed to fail and the failure to be undetected. The detonation in this cell was assumed to release the inventories of all 16 vessels containing radionuclides within that process cell. This would result in an overall hydrogen detonation frequency of 7.6×10^{-7} per year. Therefore, a hydrogen explosion in the Extraction Cell would be expected once in 1,300,000 years.

Source Term: The hydrogen explosion was assumed to release the entire contents of the Stripping Effluent Stilling Tank, the Aqueous Raffinate Stilling Tank, and six centrifugal contactors within the cell. The HEPA filters and the ventilation system were assumed to be damaged and bypassed, failing to mitigate the release from the process cell. The airborne source term associated with this accident would consist of 357 Ci of fission products and 0.00057 Ci of transuranics. The releases were postulated to occur from the 46-meter stack.

B.3.3.5 Helicopter or Aircraft Crash

Scenario: See Section B.3.1.5 for a discussion of the scenario.

Probability: The most likely causes of releases from the Solvent Extraction facility from external events would be impacts from helicopter or aircraft crashes. See Section B.3.1.5 for a discussion of the probability of such events occurring.

Source Term: The Solvent Extraction facility would be a PC-3 structure with primary and secondary confinement. The building structure would be expected to withstand vehicle crashes. Releases would be expected to occur from helicopter or aircraft crashes. HEPA filters are assumed to be damaged, failing to mitigate the release. The source terms calculated for the various accident scenarios are shown in Table B-10. These releases were postulated as ground-level releases.

B.3.3.6 Hydrogen Explosion in a Process Cell

Scenario: The tanks of concern include the AST, the tanks in the Alpha Filter Cell (Sludge Solids Receipt Tank, Washwater Hold Tank, and CSDT), the Salt Solution Feed Tank, and the DWPF Salt Feed Tank. See Section B.3.2.6 for a description of the scenario.

Table B-10. Source Terms for Helicopter or Aircraft Crashes into the Solvent Extraction facility.

	Source term (Ci)	
	Fission products	Transuranics
Helicopter Crash[a]		
AST Cell	810	1.6
Alpha Filter Cell	110	28
Extraction Cell	62	0.00088
Salt Solution Feed Tank Cell	810	0.016
DSS Hold Tank Cell	4.4	0.013
DWPF Salt Feed Tank Cell	8,350	0.00063
Aircraft Crash	10,000	13

a. Cappucci 2000.

Probability: See Section B.3.2.6 for a discussion of the probability.

B.3.4 DIRECT DISPOSAL IN GROUT

The accidents identified for the Direct Disposal in Grout alternative which could result in the release of radiological materials to the environment include:

- Loss of confinement in a process cell
- Beyond design-basis earthquake
- Fire in a process cell
- Helicopter or aircraft crash
- Hydrogen explosion in a process cell

B.3.4.1 Loss of Confinement in a Process Cell

Scenario: Mechanical failure or an external event, such as a dropped cell cover or crane mishap, could cause a loss of primary confinement for a tank or its associated piping. A loss of primary confinement would release material into the process cell. The tanks of concern are the AST, the Sludge Solids Receipt Tank, the CSDT, the Salt Solution Hold Tank, and the Saltstone Hold Tank. For this event, the entire tank contents at maximum capacity would be released through a leak from the tank or associated piping. It was assumed that the release would not be cleaned up for 168 hours (7 days).

With the exception of the Saltstone Hold Tank, a leak detection system would mitigate the consequences of releases from process tanks and associated piping. This system would be designed to detect the leak and terminate the process, thus minimizing the amount of material that would leak from the system. Because of the viscous nature of the saltstone grout mixture, a leak detection system might not detect a leak from the Saltstone Hold Tank or piping. However, radiation monitors would be available to detect leakage. The monitors were assumed to be properly positioned and calibrated to ensure detection of a grout mixture leak. A shielded secondary confinement system would protect onsite workers from radiological consequences of leaks from tanks and associated piping. No credit was taken for the leak detection system in the analysis of this event.

Probability: See Section B.3.1.1 for a discussion of the probability of the event occurring.

Source Term: A dropped cell cover or crane mishap was assumed to damage the affected tank significantly enough to release entire inventory to the cell. Good engineering practices would be used during design of the process facility to ensure that HEPA filters would be located in a remote part of the facility away from process cells (e.g., event location). DOE would perform regular in-place testing to ensure that installed HEPA filters would have a particle reoval efficiency of greater than 99.9 percent. The HEPA filters and ventilation system were assumed to be operating due to the physical distance between the filter location and event location, reducing the amount released from the process cell within 99 percent efficiency. The airborne source terms associated with this accident are shown in Table B-11. The release was postulated to occur from the 46-meter stack.

Table B-11. Source terms for loss of confinement in a process cell of the Direct Disposal in Grout facility.

	Source term (Ci)	
	Fission products	Transuranics
AST	0.37	7.2×10^{-4}
Sludge Solids Receipt Tank	0.038	0.0020
CSDT	3.8×10^{-5}	2.0×10^{-6}
Salt Solution Hold Tank	0.37	7.2
Saltstone Hold Tank	0.0018	3.6×10^{-8}

B.3.4.2 Beyond Design-Basis Earthquake

Scenario: The structures for the Direct Disposal in Grout process would be designed to withstand PC-3 earthquakes, straight winds, and tornadoes. See Section B.3.1.2 for a description of the scenario.

Probability: See Section B.3.1.2 for a discussion of the probability of the event occurring.

Source Term: A release of the full inventory from the facility was postulated from collapse of the structure and of the primary and secondary confinement. The airborne source term associated with this accident would consist of 77 Ci of fission products and 0.28 Ci of transuranics. The release was postulated as a ground-level release.

B.3.4.3 Fire in a Process Cell

Scenario: See Section B.3.1.3 for a description of the scenario.

Probability: See Section B.3.1.3 for a discussion of the probability of the event occurring.

Source Term: The fire was assumed to damage the process vessel sufficiently to cause a leak. The damage was assumed to be equivalent to a 0.5-inch-diameter opening. The leak was assumed to be stopped within 24 hours, allowing the fire department to put out the fire, a response plan to be developed, and implementation of the response plan to control the leak. The process cells that would bound this accident for the Direct Disposal in Grout process would be the AST Cell, the Sludge Solids Receipt Tank Cell, and the Salt Solution Hold Tank Cell. Good engineering practices would be used during design of the process facility to ensure that HEPA filters would be located in a remote part of the facility away from process cells (e.g., event location). DOE would perform regular in-place testing to ensure that installed HEPA filters would have a particle removal efficiency of greater than 99.9 percent. HEPA filters would be expected to maintain their function due to the physical distance between the filter location the event location, and would minimize releases to the environment 99 percent efficiency. The airborne source terms associated with a process cell fire in any of these cells are provided in Table B-12. The releases were postulated to occur from the 46-meter stack.

Table B-12. Source terms for process cell fires in the Direct Disposal in Grout facility.

	Source term (Ci)	
	Fission products	Transuranics
AST Cell	1.5	0.0029
Sludge Solids Receipt Tank Cell	0.43	0.023
Salt Solution Hold Tank Cell	1.5	2.9×10^{-5}
Saltstone Hold Tank Cell	0.021	4.0×10^{-7}

B.3.4.4 Helicopter or Aircraft Crash

Scenario: See Section B.3.1.5 for a description of the scenario.

Probability: The most likely causes of releases from the Direct Disposal in Grout facility from external events would be impacts from helicopter or aircraft crashes. See Section B.3.1.5 for a discussion of the probability of the event occurring.

Source Term: The Direct Disposal in Grout facility would be a PC-3 structure with primary and secondary confinement. The building structure would be expected to withstand vehicle crashes. Releases would be expected to occur from helicopter or aircraft crashes. HEPA filters are assumed to be damaged, failing to mitigate the release. The source terms calculated for the various accident scenarios are shown in Table B-13. These releases were postulated as ground-level releases.

Table B-13. Source Terms for helicopter or aircraft crashes into the Direct Disposal in Grout facility.

	Source Term (Ci)	
	Fission Products	Transuranics
Helicopter Crash[a]		
AST Cell	5,700	11
Sludge Solids Receipt Tank Cell	590	31
CSDT Cell	0.067	0.0036
Salt Solution Hold Tank Cell	5,700	0.11
Saltstone Hold Tank Cell	3.9	7.6×10^{-5}
Aircraft Crash	1,400	4.8

a. Cappucci 2000.

B.3.4.5 Hydrogen Explosion in a Process Cell

Scenario: The tanks of concern include the AST, the Sludge Solids Receipt Tank, the CSDT, the Salt Solution Hold Tank, and the Saltstone Hold Tank. See Section B.3.2.6 for a description of the scenario.

Probability: See Section B.3.2.6 for a discussion of the probability of the event occurring.

B.4 Accident Impacts Involving Radioactive Materials

This section presents the potential impacts, including LCFs, expected from offsite impacts associated with accident scenarios involving the release of radioactive materials identified in Section B.3.

B.4.1 SMALL TANK PRECIPITATION

Table B-14 provides the radiological impacts to onsite and offsite receptors from the accidents described in Section B.3.1. The accidents are ordered by decreasing frequency.

B.4.2 ION EXCHANGE

Table B-15 provides radiological impacts to onsite and offsite receptors from the accidents described in Section B.3.2. The accidents are ordered by decreasing frequency.

B.4.3 SOLVENT EXTRACTION

Table B-16 provides radiological impacts to onsite and offsite receptors from the accidents described in Section B.3.3. The accidents are ordered by decreasing frequency.

B.4.4 DIRECT DISPOSAL IN GROUT

Table B-17 provides radiological impacts to onsite and offsite receptors from the accidents described in Section B.3.4. The accidents are ordered by decreasing frequency.

B.5 Postulated Accidents Involving Nonradioactive Hazardous Materials

This section summarizes the potential accident scenarios involving nonradioactive hazardous chemicals for the various processes.

B.5.1 SMALL TANK PRECIPITATION

The accidents identified for the Small Tank Precipitation process that result in the release of non-radioactive hazardous materials to the environment include:

- Caustic Tank loss of confinement
- TPB Storage Tank spill
- Organic Evaporator loss of confinement
- PHA Surge Tank loss of confinement

Table B-14. Accident impacts for the Small Tank Precipitation process.

Accident	Annual frequency (frequency category)	Maximally exposed individual (rem)[a]	Maximally exposed individual LCF	Offsite population (person-rem)[a]	Offsite population LCF	Noninvolved worker (rem)[a]	Noninvolved worker LCF	Involved worker (rem)[a]	Involved worker LCF	Onsite population (person-rem)[a]	Onsite population LCF
Loss of confinement	3.4×10^{-2} (Anticipated)										
PHA Surge Tank		0.0016	8.2×10^{-7}	88	0.044	0.024	9.5×10^{-6}	3.2×10^{-6}	1.3×10^{-9}	39	0.016
Precipitate Reactor		4.1×10^{-4}	2.0×10^{-7}	22	0.011	0.0060	2.4×10^{-6}	8.0×10^{-7}	3.2×10^{-10}	9.7	0.0039
Beyond design-basis earthquake	$<5.0\times10^{-4}$ (Unlikely)	0.31	1.5×10^{-4}	16,000	8.0	9.6	0.0038	310	0.12	9,000	3.6
Fire in a process cell	1.0×10^{-4} (Unlikely)	0.014	7.2×10^{-6}	780	0.39	0.21	8.5×10^{-5}	2.8×10^{-5}	1.1×10^{-8}	340	0.14
Benzene explosion in the PHC	1.0×10^{-5} (Extremely Unlikely)	0.70	3.5×10^{-4}	38,000	19	10	0.0041	0.0014	5.5×10^{-7}	17,000	6.7
Helicopter Crash	4.8×10^{-7} (Beyond Extremely Unlikely)										
Fresh Waste Day Tank Cell		0.049	2.5×10^{-5}	2,600	1.3	1.5	6.2×10^{-4}	49	0.020	1,400	0.58
Precipitation Tank Cell		0.059	2.9×10^{-5}	3,100	1.6	1.8	7.4×10^{-4}	59	0.024	1,700	0.69
Concentrate Tank Cell		0.34	1.7×10^{-4}	18,000	9.0	11	0.0043	340	0.14	10,000	4.0
Filtrate Hold Tank Cell		0.0039	1.9×10^{-6}	200	0.10	0.12	4.9×10^{-5}	3.9	0.0016	110	0.046
Wash Tank Cell		0.34	1.7×10^{-4}	18,000	9.1	11	0.0043	350	0.14	10,000	4.0
PHA Surge Tank Cell		3.3	0.0016	170,000	87	100	0.041	3,300	1.3	97,000	39
PHC		1.3	6.3×10^{-4}	67,000	33	40	0.016	1,300	0.51	37,000	15
Aircraft Crash	3.7×10^{-7} (Beyond Extremely Unlikely)	5.4	0.0027	280,000	140	170	0.067	5,400	2.1	160,000	63

a. Refer to the Glossary for the definition of rem and person-rem.
LCF = latent cancer fatality.
PHA = Precipitate Hydrolysis Aqueous.
PHC = Precipitate Hydrolysis Cell.

Table B-15. Accident impacts for the Ion Exchange process.

Accident	Annual frequency (frequency category)	Maximally exposed individual (rem)[a]	Maximally exposed individual LCF	Offsite population (person-rem)[a]	Offsite population LCF	Noninvolved worker (rem)[a]	Noninvolved worker LCF	Involved worker (rem)[a]	Involved worker LCF	Onsite population (person-rem)[a]	Onsite population LCF
Loss of confinement	3.4×10^{-2} (Anticipated)										
AST		9.7×10^{-5}	4.9×10^{-8}	5.2	0.0026	0.0014	5.7×10^{-7}	2.8×10^{-7}	1.1×10^{-10}	2.3	9.3×10^{-4}
Sludge Solids Receipt Tank		8.3×10^{-4}	4.2×10^{-7}	45	0.022	0.012	4.9×10^{-6}	6.4×10^{-8}	2.6×10^{-11}	20	0.0080
Washwater Hold Tank		2.4×10^{-7}	1.2×10^{-10}	0.0013	6.6×10^{-6}	3.6×10^{-6}	1.4×10^{-9}	1.7×10^{-8}	6.9×10^{-12}	0.0057	2.3×10^{-6}
LRHT		1.8×10^{-5}	9.2×10^{-9}	1.0	5.1×10^{-4}	2.8×10^{-4}	1.1×10^{-7}	1.7×10^{-6}	7.0×10^{-10}	0.44	1.8×10^{-4}
Beyond design-basis earthquake	$<5.0\times10^{-4}$ (Unlikely)	0.12	5.9×10^{-5}	6,200	3.1	3.7	0.0015	120	0.047	3,500	1.4
Loss of cooling to the LRHTs[b]	1.9×10^{-4} (Unlikely)	9.4×10^{-7}	4.7×10^{-10}	0.052	2.6×10^{-5}	1.4×10^{-5}	5.7×10^{-9}	8.8×10^{-8}	3.5×10^{-11}	0.023	9.0×10^{-6}
Fire in a process cell	1.0×10^{-4} (Unlikely)										
AST cell		4.2×10^{-4}	2.1×10^{-7}	23	0.011	0.0062	2.5×10^{-6}	1.2×10^{-6}	4.8×10^{-10}	10	0.0040
Alpha Filter Cell		0.0094	4.7×10^{-6}	500	0.25	0.14	5.5×10^{-5}	9.1×10^{-7}	3.6×10^{-10}	220	0.089
CST Process Cell		4.4×10^{-4}	2.2×10^{-7}	25	0.012	0.0067	2.7×10^{-6}	4.1×10^{-5}	1.7×10^{-8}	11	0.0043
Helicopter Crash	4.8×10^{-7} (Beyond extremely unlikely)										
AST		0.20	9.8×10^{-5}	10,000	5.2	6.2	0.0025	200	0.079	5,800	2.3
Alpha Filter Cell		1.7	8.5×10^{-4}	89,000	45	53	0.021	1,700	0.68	50,000	20
CST Columns Cell		0.11	5.5×10^{-5}	5,800	2.9	3.5	0.0014	110	0.045	3,300	1.3
Aircraft Crash	3.7×10^{-7} (Beyond extremely unlikely)	2.0	0.0010	110,000	53	63	0.025	2,000	0.81	59,000	24

a. Refer to the Glossary for the definition of rem and person-rem.
b. Combined source terms from the LRHTs and the CST Column were used to determine impacts from the loss of cooling event.
LCF = latent cancer fatality; LRHT = Loaded Resin Hold Tank; AST = Alpha Sorption Tank.

Table B-16. Accident impacts for the Solvent Extraction process.

Accident	Annual frequency (frequency category)	Maximally exposed individual (rem)[a]	Maximally exposed individual LCF	Offsite population (person-rem)[a]	Offsite population LCF	Noninvolved worker (rem)[a]	Noninvolved worker LCF	Involved worker (rem)[a]	Involved worker LCF	Onsite population (person-rem)[a]	Onsite population LCF
Loss of confinement	3.4×10^{-2} (Anticipated)										
AST		1.2×10^{-4}	6.1×10^{-8}	6.5	0.0033	0.0018	7.1×10^{-7}	3.5×10^{-7}	1.4×10^{-10}	2.9	0.0012
Wash Water Hold Tank		2.4×10^{-7}	1.2×10^{-10}	0.013	6.6×10^{-6}	3.6×10^{-6}	1.4×10^{-9}	1.7×10^{-8}	6.9×10^{-12}	0.0057	2.3×10^{-6}
Sludge Solids Receipt Tank		8.3×10^{-4}	4.2×10^{-7}	45	0.22	0.012	4.9×10^{-6}	6.4×10^{-8}	2.6×10^{-11}	20	0.0080
Salt Solution Feed Tank		4.8×10^{-6}	2.4×10^{-9}	0.26	1.3×10^{-4}	7.2×10^{-5}	2.9×10^{-8}	3.4×10^{-7}	1.4×10^{-10}	0.11	4.6×10^{-5}
Extraction Cell		1.9×10^{-7}	9.4×10^{-11}	0.010	5.2×10^{-6}	2.9×10^{-6}	1.1×10^{-9}	1.8×10^{-8}	7.1×10^{-12}	0.0045	1.8×10^{-6}
DWPF Salt Feed Tank		3.8×10^{-5}	1.9×10^{-8}	2.1	0.0010	5.7×10^{-4}	2.3×10^{-7}	3.6×10^{-6}	1.4×10^{-9}	0.91	3.6×10^{-4}
Beyond design-basis earthquake	$<5.0\times10^{-4}$ (Unlikely)	0.12	5.8×10^{-5}	6,100	3.0	3.6	0.0015	120	0.046	3,400	1.4
Fire in a process cell	1.0×10^{-4} (Unlikely)										
AST Cell		4.2×10^{-4}	2.1×10^{-7}	23	0.011	0.0062	2.5×10^{-6}	1.2×10^{-6}	4.8×10^{-10}	10	0.0040
Alpha Filter Cell		0.0094	4.7×10^{-6}	500	0.25	0.14	5.5×10^{-5}	7.2×10^{-7}	2.9×10^{-10}	220	0.089
Extraction Cell		2.1×10^{-6}	1.1×10^{-9}	0.012	5.9×10^{-5}	3.2×10^{-5}	1.3×10^{-8}	2.0×10^{-7}	8.0×10^{-11}	0.051	2.0×10^{-5}
Salt Solution Feed Tank Cell		1.7×10^{-5}	8.3×10^{-9}	0.92	4.6×10^{-4}	2.5×10^{-4}	1.0×10^{-7}	1.2×10^{-6}	4.8×10^{-10}	0.40	1.6×10^{-4}
DSS Hold Tank Cell		4.2×10^{-6}	2.1×10^{-9}	0.22	1.1×10^{-4}	6.1×10^{-5}	2.4×10^{-8}	8.3×10^{-9}	3.3×10^{-12}	0.099	4.0×10^{-5}
DWPF Salt Feed Tank Cell		1.6×10^{-4}	8.1×10^{-8}	9.1	0.0045	0.0025	9.9×10^{-7}	1.5×10^{-5}	6.2×10^{-9}	3.9	0.0016
Hydrogen Explosion in the Extraction Cell	7.6×10^{-7} (Beyond extremely unlikely)	0.0029	1.4×10^{-6}	160	0.081	0.044	1.8×10^{-5}	2.7×10^{-4}	1.1×10^{-7}	70	0.028
Helicopter Crash	4.8×10^{-7} (Beyond extremely unlikely)										
AST Cell		0.25	1.2×10^{-4}	13,000	6.5	7.7	0.0031	250	0.099	7,200	2.9
Alpha Filter Cell		1.7	8.5×10^{-4}	89,000	45	53	0.021	1,700	0.68	50,000	20
Extraction Cell		7.2×10^{-4}	3.6×10^{-7}	38	0.019	0.023	9.1×10^{-6}	0.74	2.9×10^{-4}	21	0.0085
Salt Solution Feed Tank Cell		0.0099	5.0×10^{-6}	530	0.26	0.32	1.3×10^{-4}	10	0.0041	290	0.12
DSS Hold Tank Cell		0.0019	9.7×10^{-7}	100	0.051	0.061	2.4×10^{-5}	1.9	7.8×10^{-4}	57	0.023
DWPF Salt Feed Tank Cell		0.079	3.9×10^{-5}	4,200	2.1	2.5	0.0010	81	0.032	2,300	0.94
Aircraft Crash	3.7×10^{-7} (Beyond extremely unlikely)	2.0	0.0010	110,000	54	64	0.026	2,000	0.81	60,000	24

a. Refer to the Glossary for the definition of rem and person-rem.
LCF = latent cancer fatality, AST = Alpha Sorption Tank, DSS = Decontaminated salt solution.

Table B-17. Accident impacts for the Direct Disposal in Grout process.

Accident	Annual frequency (frequency category)	Maximally exposed individual (rem)[a]	Maximally exposed individual LCF	Offsite population (person-rem)[a]	Offsite population LCF	Involved worker (rem)[a]	Involved worker LCF	Noninvolved worker (rem)[a]	Noninvolved worker LCF	Onsite population (person-rem)[a]	Onsite population LCF
Loss of confinement	3.4×10^{-2} (Anticipated)										
AST		9.0×10^{-5}	4.5×10^{-8}	5.3	0.0027	0.0013	5.4×10^{-7}	6.6×10^{-7}	2.6×10^{-10}	1.6	6.3×10^{-4}
Sludge Solids Receipt Tank		2.4×10^{-4}	1.2×10^{-7}	14	0.0072	0.0036	1.5×10^{-6}	7.3×10^{-8}	2.9×10^{-11}	4.2	0.0017
CSDT		2.4×10^{-7}	1.2×10^{-10}	0.014	7.2×10^{-6}	3.6×10^{-6}	1.5×10^{-9}	7.3×10^{-11}	2.9×10^{-14}	0.0042	1.7×10^{-6}
Salt Solution Hold Tank		3.7×10^{-6}	1.9×10^{-9}	0.22	1.1×10^{-4}	5.3×10^{-5}	2.1×10^{-8}	6.6×10^{-7}	2.6×10^{-10}	0.063	2.5×10^{-5}
Saltstone Hold Tank		1.9×10^{-8}	9.3×10^{-12}	0.0011	5.4×10^{-7}	2.7×10^{-7}	1.1×10^{-10}	3.3×10^{-9}	1.3×10^{-12}	3.1×10^{-4}	1.3×10^{-7}
Beyond design-basis earthquake	$<5.0\times10^{-4}$ (Unlikely)	0.042	2.1×10^{-5}	2300	1.1	1.3	5.3×10^{-4}	42	0.017	1000	0.41
Fire in a process cell	1.0×10^{-4} (Unlikely)										
AST Cell		3.6×10^{-4}	1.8×10^{-7}	21	0.011	0.0054	2.2×10^{-6}	2.7×10^{-6}	1.1×10^{-9}	6.3	0.0025
Sludge Solids Receipt Tank Cell		0.0027	1.4×10^{-6}	160	0.081	0.041	1.6×10^{-5}	8.2×10^{-7}	3.3×10^{-10}	48	0.019
Salt Solution Hold Tank Cell		1.5×10^{-5}	7.5×10^{-9}	0.87	4.4×10^{-4}	2.2×10^{-4}	8.6×10^{-8}	2.7×10^{-6}	1.1×10^{-9}	0.25	1.0×10^{-4}
Saltstone Hold Tank Cell		2.1×10^{-7}	1.0×10^{-10}	0.012	6.1×10^{-6}	3.0×10^{-6}	1.2×10^{-9}	3.7×10^{-8}	1.5×10^{-11}	0.0035	1.4×10^{-6}
Helicopter Crash	4.8×10^{-7} (Beyond extremely unlikely)										
AST Cell		0.20	9.8×10^{-5}	11,000	5.3	6.2	0.0025	200	0.079	4800	1.9
Sludge Solids Receipt Tank Cell		0.53	2.7×10^{-4}	29,000	14	17	0.0067	530	0.21	13,000	5.3
CSDT Cell		0.0081	4.0×10^{-6}	430	0.22	0.25	1.0×10^{-4}	8.2	0.0033	200	0.078
Salt Solution Hold Tank Cell		4.8×10^{-5}	2.4×10^{-8}	2.6	0.0013	0.0015	6.1×10^{-7}	0.049	2.0×10^{-5}	1.2	4.7×10^{-4}
Saltstone Hold Tank Cell		5.3×10^{-4}	2.7×10^{-7}	29	0.014	0.017	6.7×10^{-6}	0.53	2.1×10^{-4}	13	0.0053
Aircraft Crash	3.7×10^{-7} (Beyond extremely unlikely)	0.74	3.7×10^{-4}	40000	20	23	0.0093	740	0.30	18,000	7.3

a. Refer to the Glossary for the definition of rem and person-rem.
LCF = latent cancer fatality.
AST = Alpha Sorption Tank.
CSDT = Cleaning Solution Dump Tank.

- Beyond design-basis earthquake
- Organic Waste Storage Tank (OWST) loss of confinement
- Loss of cooling
- Benzene explosion in the OWST

B.5.1.1 Caustic Tank Loss of Confinement

Scenario: The Small Tank Precipitation facility would have 5,000 gallons of 50-percent sodium hydroxide in the Caustic Storage Tank and 500 gallons in the Caustic Feed Tank (CFT). The limiting event considered was the spill of the entire inventory of the 5,000-gallon Caustic Storage Tank.

Probability: A leak or rupture of the tank would have the potential to release the tank contents. Spilling of the tank contents could occur from a leak or rupture of the tank or piping. The overall frequency of a spill from a leak or rupture was estimated to be 3.4×10^{-2} per year, or once in 30 years.

Source Term: The source term was estimated by assuming the sodium hydroxide tank would be full and the entire inventory would be released to a diked area outside the facility. The release rate of 1,030 milligrams per second was assumed be at ground level.

B.5.1.2 TPB Storage Tank Spill

Scenario: TPB contains a small amount of benzene (up to 650 parts per million). The TPB Storage Tank would be a 20,000-gallon tank located in the Cold Feeds Area, outside the process areas. A spill from the TPB Storage Tank was assumed to occur, which would cause a benzene release. Some typical causes of accidental spills of chemicals would be overflows, transfer errors, and leaks. The most likely initiator would be a valve or flange leak.

There would be a sump and a dike around the TPB Storage Tank large enough to contain the entire contents of the tank, to prevent it from reaching the environment or process areas in case of a leak.

Probability: The frequency of a spill from the TPB Storage Tank was estimated to be 3.4×10^{-2} per year, or once in 30 years.

Source Term: The following assumptions were made in calculating the benzene source term resulting from a spill from the TPB Storage Tank:

- The concentration of benzene in TPB would be 650 parts per million.
- The spill would result in all of the TPB (20,000 gallons) being released to the Cold Feeds Area dike. At 650 parts per million, the total amount of benzene spilled would be 112 pounds (51.0 kilograms).

The benzene release rate from the spill was calculated to be 110,000 milligrams per second. Release of benzene would occur for 7.5 minutes. The release was assumed to occur at ground level.

B.5.1.3 Organic Evaporator Loss of Confinement

Scenario: A failure of the Organic Evaporator or its associated piping would cause a release of benzene into the PHC. For this event, the entire contents of the evaporator were assumed to be released. A number of initiating events could cause a loss of primary confinement of the evaporator (i.e., leaks, ruptures, crane or cell cover impacts).

Probability: The initiating event frequency is similar to all other loss of confinement events evaluated in this Appendix with a frequency of 3.4×10^{-2} per year, or once in 30 years.

Source Term: The hazardous material source term calculated for this event was a release of 7.8×10^{5} milligrams per second of benzene.

B.5.1.4 PHA Surge Tank Loss of Confinement

Scenario: A failure of the PHA Surge Tank or its associated piping would cause a release of benzene into the PHA Surge Tank process cell. For this event, the entire contents of the tank were assumed to be released. A number of initiating events could cause a loss of primary confinement of the evaporator (i.e., leaks, ruptures, crane or cell cover impacts).

Probability: The initiating event frequency is similar to all other loss of confinement events evaluated in this Appendix with a frequency of 3.4×10^{-2} per year, or once in 30 years.

Source Term: The hazardous material source term calculated for this event was a release of 0.0013 milligrams per second of benzene.

B.5.1.5 Beyond Design-Basis Earthquake

Scenario: The structures for the Small Tank Precipitation process would be designed to withstand PC-3 earthquakes, straight winds, and tornadoes. The PC-3 earthquake is considered to be the bounding NPH event. The process vessels, piping, and structures that house the hardware would be designed to withstand such an earthquake. For the beyond design-basis event, an earthquake slightly stronger than the design-basis earthquake is postulated to occur. This earthquake would cause the primary and secondary confinement to fail, releasing the entire facility inventory into the building. The ventilation system and HEPA filters are also postulated to collapse, resulting in some airborne releases of benzene.

Probability: The initiating event frequency is similar to all beyond design basis earthquake events evaluated in this Appendix with a frequency of 5.0×10^{-4} per year, or once in 2,000 years.

Source Term: The hazardous material source term calculated for this event was a release of 4,600 milligrams per second of benzene.

B.5.1.6 OWST Loss of Confinement

Scenario: The OWST would be a 40,000-gallon tank located outside the process areas. Leak detection would be provided within the secondary tank to alert operators to leakage from the primary tank. The secondary tank would contain any leakage from the primary tank; however, failure of the secondary tank would allow benzene to be released to the ground outside the tank. This scenario would be considered incredible; however, a more likely release scenario would be the failure of the 2-inch process line during benzene transfers from the PHC to the OWST.

Probability: The frequency of concurrent failures of the primary and secondary tanks was calculated to be 7.4×10^{-8}. Failure of the 2-inch process line, however, was deemed to be credible. Assuming that 700 feet of piping would be associated with the tank, and that the transfer operation would be performed 100 hours per year, the frequency of a large spill from the transfer line was calculated to be 7.0×10^{-6} per year, or once in 140,000 years.

Source Term: A rupture of the transfer line from the PHC to the OWST was assumed to release benzene during the transfer operation. The source term calculated for this release of benzene was 5.6×10^{6} milligrams per second.

B.5.1.7 Loss of Cooling

A loss of cooling to the Precipitation, Concentrate, or Wash Tanks would increase the temperature of the liquid phase of the contents of each tank. Benzene generation and releases, due to the radiolytic and catalytic decomposition of TPB, would accelerate. The enhanced benzene evolution would result in a higher benzene concentration in the effluent gas released from these tanks. The effects of a loss of cooling on the Recycle Wash Hold or Filtrate Hold Tanks would be minimal, due to the lack of solids in the liquid phase.

Even with a loss of cooling, the nitrogen flow through the tanks would still maintain the tanks in an inerted condition and would prevent explosions and fires from occurring in the tanks.

The low decay heat rate (approximately 0.005 watts per curie) of the tank contents would mitigate the effects of a loss-of-cooling event. A significant period of time would be required to sufficiently raise the temperature of the tanks to increase benzene generation rates, which would allow operating personnel time to minimize the effects of the accident. In addition, the height of the process stack through which benzene would be released is designed to prevent high concentrations of benzene from reaching onsite workers.

Probability: The frequency of a failure of the cooling water system that would last long enough for process vessels to overheat, resulting in increased benzene emissions, is 6.0×10^{-6} per year, or once in 170,000 years.

Source Term: The following assumptions were made when calculating the benzene source term resulting from a loss of cooling:

- The Small Tank Precipitation facility building stack was assumed to be 46 meters above grade.
- Average exit velocity from the stack would be 10 to 40 meters per second.
- Effluent temperature would be the temperature of the material in the process tanks (45°C).
- The benzene generation per hour would be 50 milligrams per liter of material in the tank.
- Tanks would be at maximum capacity (Precipitation Tanks #1 and #2 – 15,000 gallons each; Concentrate Tank – 10,000 gallons; Wash Tank – 10,000 gallons).

The resulting benzene source term was calculated as 2,600 milligrams per second.

B.5.1.8 <u>Benzene Explosion in OWST</u>

Scenario: Benzene and other organic compounds would normally be present in the OWST. The primary tank would be equipped with a floating roof to restrict organic waste evaporation and to reduce benzene emissions. The primary stainless steel tank would be within a secondary carbon steel tank. To prevent the vapor space from becoming flammable, the OWST would be pressurized with a safety-class nitrogen inerting system. However, the vapor space could become explosive if positive pressure was lost and air leaked into the vessel. With the presence of an ignition source, a deflagration could occur in the tank vapor space and cause the vessel to fail, spilling the liquid benzene inventory into the secondary tank. For this scenario, the secondary tank was also assumed to leak from the force of the explosion.

The OWST would be equipped with a nitrogen purge system and a seismically qualified liquid nitrogen vessel and vaporizer.

Probability: A benzene explosion in the OWST would have the potential to damage and release the entire inventory of benzene. The frequency that an explosion in the tank would occur was calculated to be 1.3×10^{-6} per year, or once in 770,000 years.

Source Term: An explosion of the OWST was assumed to release the entire contents of the primary tank into the secondary tank. The secondary tank was assumed to leak from the force of the primary tank explosion, releasing the entire contents outside the tank. The hazardous material source term was calculated to be 5.2×10^{7} milligrams per second of benzene. The release was assumed to occur at ground level.

B.5.2 ION EXCHANGE AND DIRECT DISPOSAL IN GROUT

One bounding chemical accident was evaluated, a CFT loss of confinement that would be common to both the Ion Exchange and the Direct Disposal in Grout processes.

Scenario: The Ion Exchange facility would have 5,000 gallons of 50-percent sodium hydroxide in the CFT and the Direct Disposal in Grout facility would have 500 gallons of the 50-percent sodium hydroxide solution. Therefore, the limiting event was assumed to be a spill of the entire inventory of the sodium hydroxide tank (5,000 gallons).

Probability: A leak or rupture of the CFT could release the tank contents. The overall frequency of a spill from a leak or rupture was estimated to be 3.4×10^{-2} per year, or once in 30 years.

Source Term: The source term was estimated by conservatively assuming the sodium hydroxide tank would be full and the entire inventory would be released into a diked area outside the building. The release rate of sodium hydroxide was estimated to be 1,030 milligrams per second.

B.5.3 SOLVENT EXTRACTION

The accidents identified for the Solvent Extraction process that result in the release of non-radioactive hazardous materials to the environment include:

- Caustic Tank release
- Caustic Dilution Feed Tank release
- Nitric Acid Feed Tank loss of confinement

B.5.3.1 Caustic Storage Tank Release

Scenario: The Solvent Extraction facility would have sodium hydroxide in the CFT, Filter Cleaning Caustic Tank, Caustic Dilution Feed Tank, Caustic Storage Tank, Caustic Make-up Tank, and Solvent Wash Solution Make-up Tank. The limiting event considered was the spill of the entire inventory of the 5,000-gallon, 50-percent sodium hydroxide Caustic Storage Tank.

Probability: See Section B.5.2 for a discussion of the probability of the event occurring.

Source Term: See Section B.5.2 for a discussion of the source term.

B.5.3.2 Caustic Dilution Feed Tank Loss of Confinement

Scenario: The Solvent Extraction facility would have 15,000 gallons of 2-molar sodium hydroxide in the Caustic Dilution Feed Tank, which would be located in the operating area corridor. For conservatism, the postulated event was assumed to be a spill of the entire inventory, which would be contained in a diked area.

Probability: A leak or rupture of the tank would have the potential for releasing the tank contents. Spilling of the tank contents could occur because of a leak from the tank or piping, or rupture of the tank or piping. The overall frequency of a spill from a leak or rupture was estimated to be 3.4×10^{-2} per year, or once in 30 years.

Source Term: The release of the sodium hydroxide was assumed to be at ground level. The release rate was calculated to be 5,500 milligrams per second.

B.5.3.3 Nitric Acid Feed Tank Loss of Confinement

Scenario: The Solvent Extraction facility would have 1,000 gallons of 50-percent nitric acid in the Nitric Acid Feed Tank located in the Cold Feeds Area outside the main building. For conservatism, the postulated event was assumed to be a spill of the entire inventory, which would be contained in a diked area.

Probability: A leak or rupture of the tank would have the potential for releasing the tank contents. Spilling of the tank contents could occur because of a leak from the tank or piping, or rupture of the tank or piping. The overall frequency of a spill from a leak or rupture was estimated to be 3.4×10^{-2} per year, or once in 30 years.

Source Term: The release of the nitric acid was assumed to be at ground level. The release rate was calculated to be 160 milligrams per second.

B.6 Accident Impacts Involving Nonradioactive Hazardous Materials

As Section B.4 provided for the radiological consequences of identified accidents, this Section provides the potential impacts associated with the release of nonradioactive hazardous materials from the various accident scenarios.

B.6.1 SMALL TANK PRECIPITATION

The accidents described in Section B.5.1 would release hazardous chemicals (sodium hydroxide and benzene). Table B-18 provides atmospheric dispersion factors for two individual receptors: the noninvolved worker and the MEI (Hope 1999). By applying these factors, the maximum concentrations at those receptor locations were calculated. These concentrations are also presented in Table B-18.

The ERPG-1 value (described in Section B.2.3) is 0.5 milligrams per cubic meter (mg/m^3) for sodium hydroxide and 160 mg/m^3 for benzene; therefore, no significant impacts would occur to offsite receptors due to a loss-of-cooling accident or spills from the CFT, the TPB tank, or the Organic Evaporator. By definition, individuals exposed to airborne concentrations below EPRG-1 threshold concentrations would not experience even mild transient adverse health effects or the perception of a clearly defined objectionable odor.

Three of the accidents were shown to exceed the ERPG-2 value of 480 mg/m^3 for benzene concentrations to noninvolved workers. Airborne concentrations from two of these accidents, an explosion in the PHC and OWST loss of confinement, would be below the ERPG-3 value of 3,190 mg/m^3. By definition, individuals exposed to airborne concentrations above the ERPG-2 threshold could experience or develop irreversible or other serious health effects or symptoms that may impair their ability to take protective action. Airborne concentrations from the third accident, an explosion in the OWST, would exceed the ERPG-3 value. By definition, individuals exposed to airborne concentrations above the ERPG-3 threshold could experience or develop life-threatening health effects. All three of these accidents are in the extremely unlikely category.

B.6.2 ION EXCHANGE AND DIRECT DISPOSAL IN GROUT

The CFT accident described in Section B.5.2 would release sodium hydroxide at a release rate of 1,030 milligrams per second. Table B-19 provides atmospheric dispersion factors for two individual receptors, the noninvolved worker and the MEI (Hope 1999). By applying these factors, the maximum concentrations at those receptor locations were calculated. These concentrations are also presented in Table B-19.

The ERPG-1 value described in Section B.2.3 is 0.5 mg/m^3 for sodium hydroxide; therefore, no significant impacts would occur to onsite or offsite receptors from this accident. Refer to the discussions in Section B.6.1 on the effects of concentrations below EPRG-1 thresholds.

B.6.3 SOLVENT EXTRACTION

The accidents described in Section B.5.3 would release hazardous chemicals (sodium hydroxide and nitric acid). Table B-20 provides atmospheric dispersion factors for two individual receptors, the noninvolved worker and the MEI (Hope 1999). By applying these factors, the maximum concentrations at those receptor locations were calculated. These concentrations are also presented in Table B-20.

The ERPG-1 value (described in Section B.2.3) is 0.5 mg/m^3 for sodium hydroxide and 2.6 mg/m^3 for nitric acid; therefore, no significant impacts would occur to offsite receptors from these accidents. By definition, individuals exposed to airborne concentrations below

Table B-18. Chemical release concentrations from Small Tank Precipitation process.

Scenario	Frequency (frequency category)	Evaporation release rate (mg/s)	Atmospheric dispersion factor (sec/m^3) Noninvolved worker	MEI	Resultant concentration (mg/m^3)[a,b,c,d] Noninvolved worker	MEI	Total atmospheric release (mg)
Sodium hydroxide							
CFT Loss of Confinement	3.4×10^{-2} (Anticipated)	1,030	1.7×10^{-4}	5.7×10^{-7}	0.18	5.9×10^{-4}	770
Benzene							
TPB tank spill	3.4×10^{-2} (Anticipated)	110,000	1.7×10^{-4}	5.7×10^{-7}	18.7	0.06	5.1×10^{7}
Organic Evaporator Loss of Confinement	3.4×10^{-2} (Anticipated)	780,000	1.7×10^{-4}	5.7×10^{-7}	130	0.45	5.7×10^{9}
PHA Surge Tank Loss of Confinement	3.4×10^{-2} (Anticipated)	0.0013	1.7×10^{-4}	5.7×10^{-7}	2.2×10^{-8}	7.41×10^{-10}	800
Beyond Design-Basis Earthquake	5.0×10^{-4} (Unlikely)	4,600	1.7×10^{-4}	5.7×10^{-7}	0.78	0.0026	1.4×10^{7}
OWST Loss of Confinement	7.0×10^{-6} (Extremely unlikely)	5,600,000	1.7×10^{-4}	5.7×10^{-7}	950	3.2	3.3×10^{9}
Loss of cooling accident	6.0×10^{-6} (Extremely unlikely)	2,600	1.7×10^{-4}	5.7×10^{-7}	0.44	0.0015	7.6×10^{7}
OWST explosion	1.3×10^{-6} (Extremely unlikely)	52,000,000	1.7×10^{-4}	5.7×10^{-7}	8,840	30	9.3×10^{9}

Source: WSMS 2000.
a. ERPG-1 value (sodium hydroxide) = 0.5 mg/m^3.
b. ERPG-1 value (benzene) = 160 mg/m^3.
c. ERPG-2 value (benzene) = 480 mg/m^3.
d. ERPG-3 value (benzene) = 3190 mg/m^3.
mg/s = milligrams per second.
sec/m^3 = seconds per cubic meter.
mg/m^3 = milligrams per cubic meter.
CFT = Caustic Feed Tank, PHA = Precipitate Hydrolysis Aqueous, OWST = Organic Waste Storage Tank.

EPRG-1 threshold concentrations would not experience even mild transient adverse health effects or the perception of a clearly defined objectionable odor. The Caustic Dilution Feed Tank accident would result in concentrations of sodium hydroxide to the noninvolved worker slightly higher than the ERPG-1 values. By definition, individuals exposed to airborne concentrations above the ERPG-1 threshold may experience mild transient health effects.

B.7 Environmental Justice

In the event of an accidental release of radioactive or hazardous chemical substances, the dispersion of such substances would depend on meteorological conditions, such as wind direction, at the time. Given the variability of meteorological conditions and the low probability and risk of accidents, an accident would be unlikely to occur that would result in disproportionately high or adverse human health and environmental impacts to minorities or low-income populations.

Table B-19. Sodium hydroxide release concentrations from Ion Exchange and Direct Disposal in Grout processes.

Scenario	(frequency category	Evaporation release rate (mg/s)	Atmospheric dispersion factor (sec/m^3) Noninvolved worker	MEI	Resultant concentration (mg/m^3)[a] Noninvolved worker	MEI	Total atmospheric release (mg)
CFT Loss of Confinement	3.4×10^{-2} (Anticipated)	1,030	1.7×10^{-4}	5.7×10^{-7}	0.18	5.9×10^{-4}	770

Source: WSMS 2000.
a. ERPG-1 value = 0.5 mg/m^3.
mg/s = milligrams per second.
sec/m^3 = seconds per cubic meter.
mg/m^3 = milligrams per cubic meter.

Table B-20. Chemical release concentrations from Solvent Extraction process.

Scenario	Frequency (frequency category)	Evaporation release rate (mg/s)	Atmospheric dispersion factor (sec/m^3) Noninvolved worker	MEI	Resultant concentration (mg/m^3)[a,b,c] Noninvolved worker	MEI	Total atmospheric release (mg)
Sodium hydroxide							
CFT Loss of Confinement	3.4×10^{-2} (Anticipated)	1,030	1.7×10^{-4}	5.7×10^{-7}	0.18	5.9×10^{-4}	770
Caustic Dilution Feed Tank Loss of Confinement	3.4×10^{-2} (Anticipated)	5,470	1.7×10^{-4}	5.7×10^{-7}	0.93	0.0031	5.5×10^{3}
Nitric acid							
Nitric Acid Feed Tank Loss of Confinement	3.4×10^{-2} (Anticipated)	155	1.7×10^{-4}	5.7×10^{-7}	0.026	8.8×10^{-5}	95

Source: WSMS 2000.
a. ERPG-1 value (sodium hydroxide) = 0.5 mg/m^3.
b. ERPG-2 value (sodium hydroxide) = 5.0 mg/m^3.
c. ERPG-1 value (nitric acid) = 2.6 mg/m^3.
mg/s = milligrams per second.
sec/m^3 = seconds per cubic meter.
mg/m^3 = milligrams per cubic meter.

References

AIHA (American Industrial Hygiene Association), 1991, *Emergency Response Planning Guideline*, Emergency Response Planning Guidelines Committee, Akron, Ohio.

Cappucci, A. J., Jr., M. L. Baker, D. E. Welliver, 2000, *Determination of Accident Sequence, Frequency, and Source Term Selection for the Salt Disposition Supplemental Environmental Impact Statement*, S-CLC-G-00187, Rev. 2, Westinghouse Safety Management Solutions, Aiken, South Carolina.

Cappucci, A. J., Jr., (Westinghouse Safety Management Solutions), 2000, "Corrected Table," electronic message to B. Bradford, Tetra Tech NUS, Aiken, South Carolina, September 19.

DOE (U.S. Department of Energy), 1993*, Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements*, Office of Environment, Safety, and Health (EH-25), Washington, D.C.

DOE (U.S. Department of Energy), 1994, *Preparation Guide for U.S. DOE Non-reactor Nuclear Facility Safety Analysis Reports*, DOE-STD-3009-94, Washington, D.C.

DOE (U.S. Department of Energy), 2000a, *Analyzing Accidents under NEPA – Draft*, Office of NEPA Policy and Assistance, Washington, D.C.

DOE (U.S. Department of Energy), 2000b, *High-Level Waste Tank Closure Draft Environmental Impact Statement*, DOE/EIS-0303D, Savannah River Operations Office, Aiken, South Carolina.

Hope, E. P., 1999, *Parametric Dispersion Calculations for H-Area Releases*, S-CLC-H-00693, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina.

NCRP (National Council on Radiation Protection and Measurements), 1993, *Limitation of Exposure to Ionizing Radiation*, Report No. 116, Bethesda, Maryland.

NRC (U.S. Nuclear Regulatory Commission), 1982, *Regulatory Guide 1.145: Atmospheric Dispersion Models for Potential Accidental Consequence Assessments at Nuclear Power Plants*, Rev. 1, Washington, D.C.

Simpkins, A. A., 1995a, *Verification of AXAIRQ*, WSRC-RP-95-708, Savannah River Technology Center, Aiken, South Carolina.

Simpkins, A. A., 1995b, *AXAIRQ User Manual*, WSRC-RP-95-709, Savannah River Technology Center, Aiken, South Carolina.

Simpkins, A. A., (Westinghouse Savannah River Company), 1999, "Salt Disposition Facility EIS Accidental Release Environmental Dosimetry Calculations," SRT-EST-99-316, Interoffice memorandum to C. B. Shedrow, Westinghouse Savannah River Company, Aiken, South Carolina, July 22.

WSMS (Westinghouse Safety Management Solutions), 2000, *ERPGs and TEELs for Chemicals of Concern:* WSMS-SAE-00-0001, Rev. 16, Aiken, South Carolina.